EVALUATE LIVE CAPTURE SELECTIVE HARVEST METHODS

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ABSTRACT

Selective fishing is the ability of a fishing operation to avoid non-target species or stocks, or when encountered, to capture and release them in a manner that minimizes mortality. Two gears, the tangle net and a floating trap net were tested on the lower Columbia River to selectively harvest adult spring chinook salmon (*Oncorhynchus tschawytscha*) and coho salmon (O. *kisutch*). Experienced gill netters simultaneously fished tangle nets (3.5” and 4.5” mesh size) and conventional gill nets (8” mesh size) on the Columbia River to evaluate their effectiveness for live release of non-target stocks of spring chinook salmon. Live fish were tagged and released for recovery in sport fisheries, commercial fisheries, at hatchery racks and traps, and during spawning ground surveys. Control fish that had not been captured in the test gears were tagged and released from an adult trap in Bonneville Dam, just upstream of the fishing area. The 4.5” tangle net was as effective for capturing spring chinook salmon as the conventional gill net, but the 3.5” net caught significantly fewer spring chinook salmon than the 8” gill net. Fish were generally captured in good condition. The immediate survival (from capture to release from the boat) of adult spring chinook salmon captured in the 8” gill net was 99%, compared to 96% from the 3.5” tangle net, and 97% from the 4.5” tangle net. However, spring chinook salmon released from the tangle nets were recovered at about 91% of the rate of controls, while spring chinook salmon released from the conventional gill net were recovered at about 50% of the rate of the controls. These tests showed that using conventional gear with short soaks and careful fish handling is not enough to ensure the survival of released spring chinook salmon. However, switching to the 4.5” or 3.5” tangle net, coupled with short soaks and appropriate fish handling is a viable selective harvest gear for the commercial gill net fleet fishing for spring chinook salmon on the Lower Columbia River because the post-release mortality on non-target stocks can be greatly reduced compared to a conventional gill net, without sacrificing catch efficiency.

We fished a 5” gill net in tandem with the 8” gill net on four occasions on the lower Columbia River near Camas, Washington to evaluate its potential for selective harvest of spring chinook salmon. During this short test, the immediate mortality of adult spring chinook salmon rose to 10%, compared to 0% in the 8” gill net during the same period. This increased mortality was likely caused by an increase in capture by mouth clamping in the 5” gill net rather than by tangling or by the body as in the 8” gill net.

In fall, 2001, we evaluated the feasibility of using the tangle net to capture marked coho salmon while releasing unmarked coho salmon near the mouth of the Columbia River. A variety of tangle net configurations were used and showed that this fishing method warrants further consideration if the mark rate is high. Immediate mortality of unmarked coho salmon was 17% but because 84% of the coho salmon were marked, relatively few unmarked coho salmon were killed.

In spring and fall, 2001, we tested the feasibility of using a floating trap net near the mouth of the Columbia River to capture marked salmon live and allow the release of non-target species and stocks. The trap net was ineffective at capturing fish.

INTRODUCTION

The Columbia River is one of the largest chinook salmon (*Oncorhynchus tschawytscha*) producing rivers in the world, and has supported fisheries since long before Europeans came to the area. However, like many other rivers in the Pacific Northwest, it has not been spared from declines in salmon populations; several stocks of spring, summer and fall chinook salmon are listed as threatened or endangered under the federal Endangered Species Act. The remaining non-treaty commercial salmon harvest on the Columbia River is done by gill net fleets that are managed using time, area, and gear restrictions to minimize catch of listed fish because there is little opportunity to release fish live and unharmed using conventional gears and fishing practices. Although there have been no non-treaty commercial fisheries for spring chinook since 1977 because of the small runs, the flesh quality and high fat content make it the most prized of all the Columbia River salmon. The process of reopening these fisheries began in spring 2001 with the largest recorded return of spring chinook salmon to the Columbia River.

Selective harvest technologies and practices allow a continued harvest, while protecting weak stocks. "Selective fishing", more accurately described as “live capture, selective harvest”, is the ability of a fishing operation to avoid non-target species or stocks, or when encountered, to capture and release those animals in a manner that results in minimal mortality. Successful selective fishing requires that two objectives be met. First, a conservation goal must be achieved for the species or stock of concern, and second, a harvest goal must be met to make the fishery economically viable. Weak stocks of spring chinook salmon return to the Columbia River intermingled with healthy stocks returning to hatcheries and lower river spawning sites. Harvesting salmon with gill nets in these mixed stock fisheries is a problem because fishers inadvertently catch weaker species and stocks while targeting salmon from stronger runs. Because successful live release of salmon from a gill net is difficult, the only practical way these traditional gears can be more selective for the target species is by time and area closures. While these restrictions can be very efficient at reducing by-catch and meeting the conservation goal for the fishery, they necessarily reduce fishing opportunity for the target species and do not meet the harvest goals.

In 2001, protecting weak salmon stocks required significant restrictions in commercial harvest even though fish from the healthy stocks were numerous. We therefore began working with the commercial fishing industry to develop acceptable live capture gears that will provide more fishing opportunity while continuing to protect weak stocks. Simultaneous with the development of selective fishing methods, large portions of the hatchery production of spring chinook salmon are being identified by the excision of the adipose fin before release as juveniles. When these fish return as adults, fishers can distinguish them from naturally produced fish that do not have the adipose fin excised.

The tangle net is a possible substitute for gill nets that may meet the criteria for selective fishing. Tangle nets look similar to a gill net with a small mesh size (3.5”-4.5” compared to 8” in a conventional spring chinook salmon net). Tangle nets are made from multifilament web while gill nets are typically made from monofilament web. Both gears are fished in the same method and locations, but the similarities stop there. Unlike a gill net, which captures an adult salmon around the gills or body, the mesh size of the tangle net prevents adult fish from entering the net that far. Instead, the fish is caught by the maxillary or teeth, which allows it to continue respiring in the net so it can be released live. External and associated internal injuries are also reduced using this capture method. Modifications in fishing practices, including the use of fish revival boxes, short soak times, and careful fish handling, are as important as the gear in ensuring that fish are released live and unharmed.

The untested premise of live capture, selective harvest is that the released fish survive to contribute to rebuilding their stock. It is assumed that fish released in good condition will survive, but there have been no published studies looking at the long-term survival of fish that have been captured and released from commercial gill nets. Studies evaluating the survival of fish captured in sport fisheries indicate that mortality of released fish is variable and likely depends on the species captured, the skill of the fisher in releasing the fish, the water temperature, and the fishing method. Survival of lake trout captured in gill nets in Lake Superior and held in tanks for 48 hours varied seasonally from 68% to 77% (Gallinat et al. 1997) and studies evaluating coho salmon released from commercial fishing gears in British Columbia have shown that mortality of fish held in net pens for 24 hours was less than 3% (Farrell et al. 2001). However, evaluations of post-release survival of salmonids held in net pens are unlikely to reflect the post-release survival of free-swimming fish, because the fish in net pens are not subject to predation, currents, or encounters with obstacles to migration (e.g. dams, shallow parts of rivers, etc.) which a severely stressed fish, such as those captured in gears (Farrell et al. 2000) must contend with. Many tagging studies evaluating migration and population sizes suggest that fish can be captured and released with some success, but these types of studies were not specifically directed at looking at the effects of the capture gears on survival.

The main goal of this study was to test the fundamental assumption of selective fishing – that the released fish we are trying to protect really do survive at acceptable levels to contribute to rebuilding the weak stocks they are part of – by estimating the post-release mortality of spring chinook salmon released from tangle nets and conventional gill nets on the Columbia River. We also estimated and compared the immediate mortality and catch efficiency of the two gears and evaluated characteristics of fish caught in each gear. Gear changes may result in encounters with different non-target species (by-catch), and this is expected with the tangle net as many small fish species that dwell in the Columbia River can pass through the large mesh gill nets without incident, but would be captured in the smaller-meshed tangle net. Because it is undesirable to shift the impacts from one species to another, we also compared the capture of species other than spring chinook salmon in each gear. In fall 2001 we evaluated the tangle net for capturing marked coho salmon but requiring release of unmarked coho salmon. Our second objective was to examine the feasibility of using a floating trap net to capture spring chinook salmon and coho salmon in the lower Columbia River.

PART 1 SURVIVAL OF SPRING CHINOOK SALMON CAPTURED AND RELEASED FROM TANGLE NETS AND CONVENTIONAL GILL NETS

METHODS

The Columbia River is the second largest river in the United States, draining an area of 258,000 square miles. From its source in British Columbia to its mouth at the Pacific Ocean, the Columbia River flows 1,270 miles. Spring chinook salmon returning to the Columbia River encounter Bonneville Dam, the first mainstem hydroelectric dam, at river mile (RM) 146, and fish going further upstream will encounter nine more mainstem hydroelectric dams before they reach the impassable Grande Coulee Dam at RM 597. Fish venturing up the Snake River, the largest tributary to the Columbia River, encounter seven more dams. Spawning grounds for spring chinook salmon are dispersed throughout the Columbia River basin, as are a number of hatcheries that produce spring chinook salmon for supplementation and harvest. Consequently, spring chinook salmon returning to the Columbia River belong to a number of stocks that also disperse as they move upstream.

We fished for returning adult spring chinook salmon at the following locations downstream of Bonneville Dam: between Ainsworth and Benson State Park (RM 139); near Sheperds Dell State Park, above Bridal Veil (RM 134); across from Rooster Rock State Park (RM 130); near Crown Point State Park (RM 127); and near Cottonwood Point, on the western end of Reed Island (RM 126).

We contracted four local fishers to fish nets that were 75 fathoms of tangle net (1.5 mm x 4 strands, 3.5" or 4.5" mesh size hung at a ratio of 3:1 and 2:1, respectively) shackled to 75 fathoms of conventional gill net commonly used in their areas for the target species (monofilament, 8" mesh size, hung at a ratio of 2:1). The hang ratio describes the number of fathoms of mesh per fathom of cork line. Both gear types were hung to the same depth, and the depth of the nets was suitable to each area being fished. The net colors were based on availability from the manufacturer - most were a shade of light green and one panel of 4.5” tangle net was pink. Because we fished mainly at night to avoid conflicts with anglers, the color of the net did not affect catch efficiency. A diver net, which sinks and follows the bottom contours, as opposed to the other floating nets that remain at the surface, was used on two vessels. Each vessel was equipped with a hydraulic reel mounted in the bow that was used to deploy and retrieve the nets. Fishers contracted for this project had many years of experience gillnetting for salmon in the study area and were asked to mimic the fishery pertaining to the location and as to how nets were laid out.

When possible we alternated the end of the net that was closest to shore on subsequent sets so that the fishing effort of each net type was as similar as possible for each area fished. The nets were set by reeling them across the river (typically in a curved pattern) and allowing both ends to drift freely. Observers selected the appropriate set time for each set. The set time was defined as the time from when the first cork went into the water until the last cork was removed from the water.

All vessels were equipped with a recovery box made from ¾” plywood painted black. The recovery boxes were built with two compartments for holding fish. Each compartment was about 42” long, 16” high and 7.5” wide. The compartments of the recovery box were wide enough to allow a salmon to fit with its head facing the fresh water flow but narrow enough to prevent the fish from turning around. A 12 V, 3800 gallon/h submersible bilge pump was connected to a 1.5” discharge hose which supplied fresh water through pipes located at the bottom of the box. Overflow outlets were located at the opposite end of the recovery box.

Two observers were on board each vessel. One observer primarily recorded data, while the other observer handled fish. For each set observers recorded the time when the first part of the net was placed in the water, the time the first part of the net was removed from the water, the time the shackle between the two nets was removed from the water, the time the end of the net was brought on board, the longitude and the latitude for the set (using a Magellan handheld GPS unit), which net type was put in the water first and which net type was removed from the water first. Observers also recorded the date, skipper’s name, boat name, observer names, set number, weather conditions, water and surface temperatures, presence of seals and any other observations pertaining to each particular set.

Observers informed fishers when to start picking up nets. Fishers were instructed on proper fish handling as they removed fish from the net, particularly to avoid touching the gill area or holding fish by its caudal peduncle. As possible, fishers also looked over the bow as the net was pulled up so they could lift fish over the roller. Fish were placed immediately into a tank of freshwater located near the bow. Any unusual observations about fish handling from net to tank were recorded.

For each spring chinook salmon caught, the observer noted the net type where it was captured (tangle or gill), the type of capture, whether the adipose fin was missing, the condition of fish at capture, and the sex. The observer then measured the fork length and tagged the fish with a numbered jaw tag covered with a plastic sheath and printed with a number. The plastic sheaths were colored to correspond to the net type where the fish was captured. We characterized the type of capture as tangled by teeth or mouth, rolled in net, gilled (net around the gills), wedged (web around body further than gills) or mouth clamped (net wrapped around mouth, clamping it closed). A fish was initially ranked as condition 1 if it was lively and not bleeding, condition 2 if it was lively but bleeding, condition 3 if it was lethargic but not bleeding, condition 4 if it was lethargic and bleeding, and condition 5 if it showed no visible movement or ventilation. Fish ranked condition 1 or 2 were tagged and released overboard immediately. Fish in conditions 3 to 5 were held in the recovery boxes until they either recovered to condition 1 or 2, and could be released, or they died. The time was recorded when fish were placed into the recovery box and at release or when resuscitation failed and fish was determined to be dead. Loss of scales, damaged fins and other visible injuries were recorded. Non-target species encountered were counted according to the net type where captured.

A control group of spring chinook salmon was collected and tagged with a colored jaw tag at the adult fish trap located in the fish ladder at Bonneville Dam on the Washington shore of the Columbia River. These fish had passed through all the same predatory pressures as the fish caught in the gears as well as similar fishing pressures, but had not been captured in our test gears. Because the fish had also passed through one additional popular sport fishing area and had successfully located the fish ladder, they may have an advantage compared to the spring chinook salmon released from the test gear that would be reflected as a higher post-release survival rate. In the trap, fish pass through a series of diverters and chutes and into a holding tank. Clove oil was added to the holding tank to temporarily anesthetize the fish. Each spring chinook salmon in the control group was then measured (fork length) and tagged, and the sampler noted whether it was missing its adipose fin and had other visible injuries. Fish were then transferred to fresh water until they revived back into lively condition and were released into a chute and diverted back to the fish ladder to continue their migration. Trapping occurred throughout the test fishery to ensure the same populations of migrating fish were tagged in each group.

To evaluate the survival of released fish, we monitored the number of tagged spring chinook salmon passing up fish ladders of three dams, contacted hatcheries and spawning ground surveyors for jaw tag recovery and informed the fishing public about where to return jaw tags. Bonneville, John Day and The Dalles dams are each equipped with two viewing windows located at the fish ladders. Technicians stationed at the viewing windows reported a daily total of the different colored jaw tagged fish as they passed through the ladders. Posters were produced requesting the following information: date of harvest, location of harvest, tag color and tag number. They were posted at various locations to target both treaty and non-treaty anglers. Hatchery crews and stream surveyors returned the same information.

For each day we were able to fish both nets equally, we compared the catch per hour of adult spring chinook salmon in the 3.5" and 4.5" tangle nets to the 8" gill net. While jack spring chinook salmon are captured in the tangle nets, they are not as important either for marketing or for stock management and were omitted from this analysis. The fishing time included only the time the nets were actually fishing and not time spent preparing for the next set. Because we recorded only the time the first cork went in the water, and not when the shackle went in, we designated the time to set the first net as 3 minutes in every case. The total fishing time for each net was then calculated as the time from when the first cork of that net was placed in the water to the time when the last cork of that same net type was removed from the water.

The frequency distributions of spring chinook salmon by condition at capture were compared using a chi-square analysis ($P=0.05$). Set times, total soak times, fish lengths, and the numbers of non-salmonids in sets with and without dead fish were compared using t-tests ($P=0.05$). We chose a conservative approach for comparing the post-release survival of spring chinook salmon released from each net and used the Z-statistic as described in Zar (1984) for comparing two proportions. To eliminate bias in how catch efficiency may be related to fish abundance, the catch efficiencies of each net type were compared using a sign test. Where appropriate, we combined the results for both tangle net types (3.5" and 4.5" mesh sizes) for comparison to the 8" gill net, and data were pooled among skippers and across fishing days to represent a more balanced picture of a fishing season.

RESULTS

IMMEDIATE SURVIVAL AND CONDITION

Test fishing with the tangle nets and conventional gill nets began on April 4, 2001 and we fished 61 boat days between that day and May 24, 2001. We captured 1,372 adult (including 20 recaptures) and 182 jack spring chinook salmon (including 1 recapture; here defined as fish that are 60 cm fork length or less) in the 3.5", 4.5" and 8" nets. Of those, 25 adults (1.8%) and 13 jacks (7.2%) could not be revived after capture for release (Table 1). All live adults and 18 jacks were tagged before release, so that 814 chinook salmon captured in the 8" gill net were tagged and released, and 528 chinook salmon captured in the 3.5" and 4.5" tangle nets were tagged and released (**Figure 1**). Most jacks were released untagged because their jaw was too small for correct application of the tag. We tagged 1,206 spring chinook salmon in the control group at Bonneville Dam throughout the test fishing period. None died during handling.

Table 1. Immediate survival (%) of adult and jack spring chinook captured during test fishing in each net type on the Columbia River. N is the number of spring chinook encountered.

Mesh Size	Adults			Jacks		
	% Survival	N	95% Confidence Interval	% Survival	N	95% Confidence Interval
3.5"	95.7	188	91.8-97.8	95.1	41	83.9-98.7
4.5"	97.4	348	95.2-98.6	91.8	134	85.9-95.4
8.0"	99.0	836	98.1-99.5	100.0	7	64.6-100

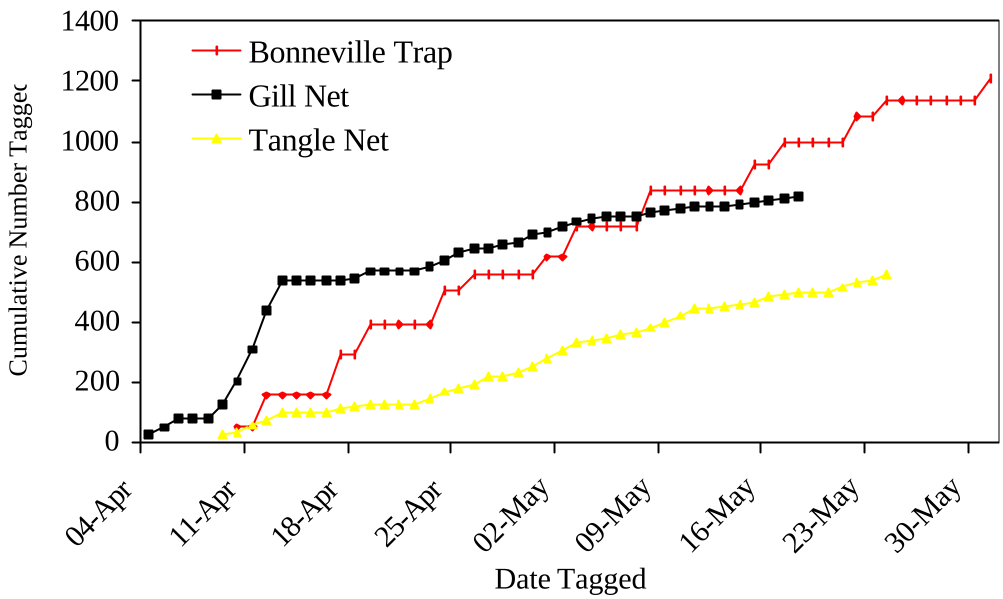

Figure 1. Cumulative number of spring chinook salmon tagged and released during test fishing below Bonneville Dam using the 8" gill net and the 3.5" and 4.5" tangle nets, and at the adult trapping facility in Bonneville Dam.

Twenty-one spring chinook salmon that we tagged and released were recaptured during the test fishery, with 14 being recaptured in the 8" gill net. The time between the initial and the second capture ranged from 50 minutes (a subsequent set on the same day) to 433.3 hours (about 18 days). All fish survived the second capture and were released in good condition. This low frequency of recaptures (1.5% of adults encountered) suggests that the potentially cumulative effects of multiple recaptures on survival may be minimal. However, if many boats are fishing close to one another, the rate could increase so care should be taken to release fish away from other fishers.

The initial condition of each fish was scored as the fish was brought on board. The distribution of adult spring chinook salmon in each category was significantly different between the tangle nets (3.5" and 4.5" combined) and the gill nets (chi-square = 59.5, df=4, P<0.0001), with the tangle nets having larger proportions of fish captured in conditions 3 and 5 than the gill net, and the gill net having a larger proportion of fish captured in condition 2 than the tangle net.

Table 2. Adult spring chinook salmon (including recaptured fish) scored in each condition at capture category that were released (Rel'd) or died for the tangle nets (3.5" and 4.5" combined) and the 8" gill net.

Mesh Size	Condition At Capture									
	1 Lively		2 Lively, bleeding		3 Lethargic		4 Lethargic, bleeding		5 No visible movement or ventilation	
	Rel'd	Died	Rel'd	Died	Rel'd	Died	Rel'd	Died	Rel'd	Died
3.5"	166	0	3	0	6	3	2	0	3	5
4.5"	293	0	5	0	28	2	0	0	13	7
8"	724	0	68	0	30	1	6	0	0	7
Total	1183	0	76	0	64	6	8	0	16	19

Fish captured in conditions 3 and 5 in the tangle net were typically captured by tangling or mouth clamping, methods that rarely occur when using the 8" gill net (Table 3). Capturing fish around the gills frequently caused bleeding, and the fish were then classified as condition 2 at capture. This capture type is common with conventional gill nets, but rare with the tangle net. Capture around the gills occurred in the tangle net when meshes were torn, such that the effective mesh size was larger than the original constructed mesh size, or when small fish were encountered.

Table 3. Capture types of adult spring chinook salmon (includes recaptures) that were released (Rel'd) or died.

Capture Type	Mesh Size					
	3.5"		4.5"		8.0"	
	Rel'd	Died	Rel'd	Died	Rel'd	Died
Gilled	3	0	1	0	73	3
Mouth Clamped	6	2	44	8	0	0
Tangled	171	6	290	1	23	0
Wedged	0	0	4	0	732	5
Total	180	8	339	9	828	8

Virtually every adult chinook salmon captured in the gill net had net marks around the body in front of the dorsal fin or around the gills, and virtually every adult captured in the tangle net had net marks around the snout. Net marks on the body tended to be severe – scales were dislodged and missing, and the underlying skin was often abraded and red. While not visible, a loss of the protective slime layer would be associated with this injury. Net marks from the tangle net tended to be less severe as the snout does not have easily dislodged scales. The marks tended to be dark lines where the net pressed on the skin, and tended to be on the lower snout and jaw. The slime layer on some of these fish may have been disturbed if they rubbed against the net, or if the fish rolled itself into the net. Other injuries included damaged fins, hook wounds and seal wounds. We noted seal wounds on 15% of the fish captured, and these ranged from scars to open wounds with substantial tissue trauma. While seals occurred in the areas we fished, they were infrequent visitors to the nets, so most recent wounds likely occurred during the upriver migration. Seals and sea lions are common near the mouth of the Columbia River.

Fish in conditions 1 or 2 were tagged and released overboard with minimal holding. We attempted to recover fish in conditions 3, 4 or 5 to condition 1or 2 for release. Holding times in the recovery box ranged from 2 to 81 minutes, with most fish showing a quick improvement in condition. We successfully recovered and released 78% of adult spring chinook captured in conditions 3, 4 or 5. No fish captured in condition 5 in the gill net could be recovered, while 57% of those captured in condition 5 in the tangle nets were revived.

During the test fishery, 25 adults died before they could be released overboard. The mean fork length of dead adults (76.1 cm, N=24) was not significantly different from the mean fork length of live adults (75.4 cm, N=1,285; t=1.71, df=23, P=0.34). These fish were captured in sets that were significantly longer than average (t=1.73, df=19, P=0.002). The total set time, the time from when the first cork goes in the water until the last cork comes out, for sets with dead fish varied from 38 minutes to 135 minutes, with an average set time of 68.5 minutes (N=19 sets). The total set time for all sets varied from 20 minutes to 135 minutes with an average of 50.1 minutes (N=241 sets). The average soak time (the time from when the first cork is put into the water until the first cork is pulled back out) for all sets was 20.2 minutes (N=24 sets), significantly shorter than the average soak time for sets with dead adults (22.3 minutes, N=19 sets, t=1.65, df= 258, P=0.03). The occurrence of dead fish was related to the total number of non-salmonids captured in a set, which itself affects the total set time, as more non-salmonids will take longer to remove from the net. Sets with dead adult spring chinook had significantly more non-salmonids (72.2 per set, N=19 sets) than all sets (38.9 per set, N=224 sets; t=1.70, df=31, P=0.047).

The relationship between the increased number of non-salmonids and increased immediate mortality may be an important factor in a tangle net fishery. The tangle net captured many more non-target species than the gill net (Table 4). The actual numbers of non-salmonids are likely underreported because this was not the primary goal for the observers. Sturgeon were generally released in good condition, while the condition of the other species was variable. Twenty-two steelhead salmon were encountered during test fishing, and all were released in excellent condition.

Table 4. Catch of non-target species in the tangle nets (3.5" and 4.5" combined) and the 8" gill net during test fishing on the Columbia River. "Other" includes walleye, flounder, carp, bass, etc. for which 10 or fewer animals were encountered.

Species	Tangle Nets	Gill Net
Shad	7022	10
Northern Pike Minnow	311	2
Steelhead	20	2
Sturgeon	1608	441
Suckers	438	1
Other	51	9
Total	9450	465

Surface temperatures during fishing ranged from 8°C in early April to 15°C in mid-May. The mean surface temperature of the 19 sets with dead fish was 11.6°C, not significantly higher than the mean surface temperature for all sets (11.0°C, N=241, t=1.17, df=258, P=0.12). Therefore, within the ranges we observed, temperature did not affect immediate survival.

Among all adults captured, 42.6% were unmarked, but among the dead fish, 56% were unmarked. Unmarked fish represent a mix of hatchery and wild origin fish. Scales were collected from the dead fish, and of those that could be assigned to either hatchery or wild, 10 were wild and 1 was hatchery. This suggests that there may be some differential mortality associated with capture for wild and hatchery fish, but it is difficult to explain why there would be such a difference, and it may simply be a result of the small sample size.

Post-release survival

We tagged and released 814 spring chinook salmon from the 8" gill net (including 2 jacks) and 528 from the 3.5" and 4.5" tangle nets (including 16 jacks). Tags were recovered throughout the Columbia River in sport fisheries, commercial fisheries, at hatcheries and on spawning grounds (Figure 2). The first tag was recovered on 12 Apr 2001 and the last was recovered on 11 Sep 2001. Not all of the tag colors were reported, and some of the tag numbers were illegible, such that some tags could not be assigned to the original net they were captured in, or to other subcategories identified at the time of capture (capture type, jack or adult, condition at capture, etc.).

Most recovered fish were reported in good condition. Recoveries were clumped in areas with popular sport fisheries and at hatcheries. These are the areas with the most intensive sampling, but do not indicate that tagged fish didn't return to other areas. We assumed that fish tagged in each net type were from the same populations, and therefore their tags were equally likely to be recovered, so that observed differences in tag recovery rates were due to survival differences. Figure 2 shows that tagged fish from each group were represented in each of the recovery areas, and that our assumption is therefore valid.

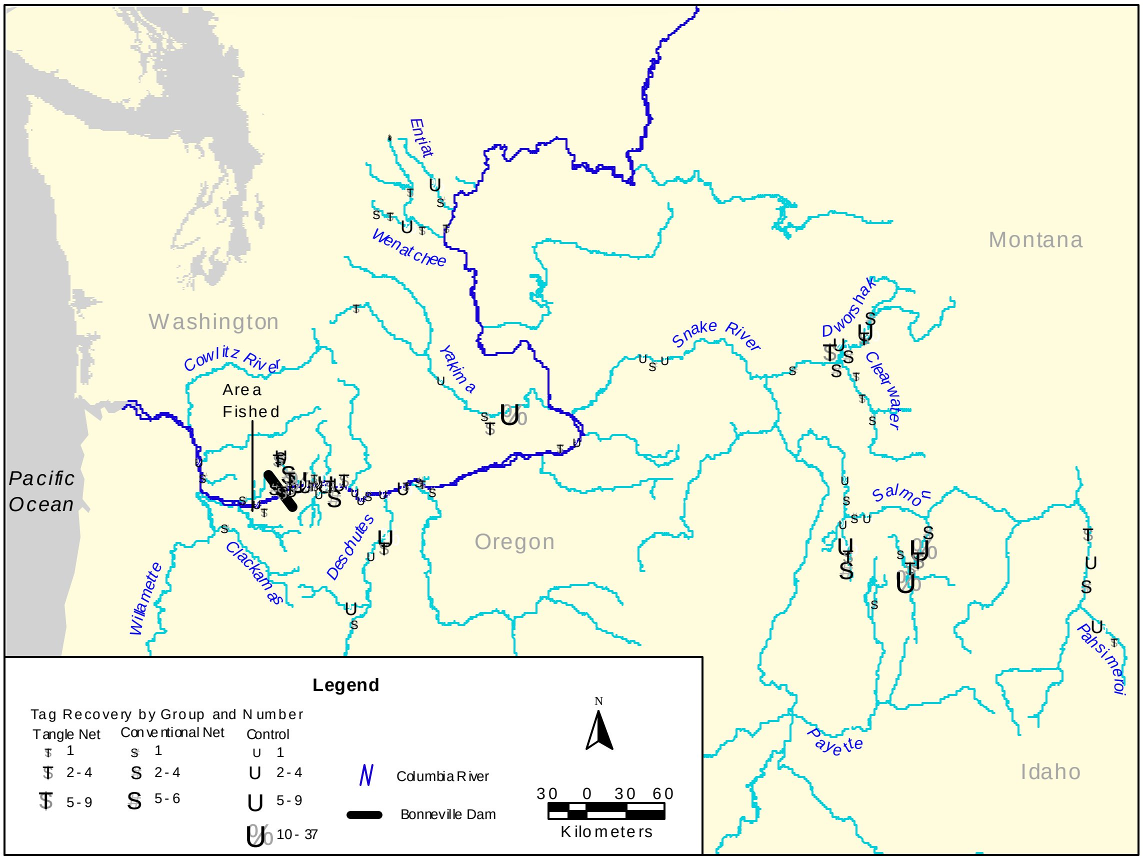

Figure 2. Recovery locations of spring chinook salmon captured and released from 3.5” and 4.5” tangle nets, 8” conventional gill nets and from the adult trapping facility at Bonneville Dam (controls). The “area fished” denotes the location where the test nets were fished and tagged fish were released.

Significantly more spring chinook salmon that were captured and released from the tangle nets were recovered than those captured and released from the gill nets (Table 5; $Z=3.77$, $P<0.001$). The control group of fish was assumed to be subject to all the same natural mortality as the test groups, except to the effects of capture in the nets. Therefore, relative to the survival of the control group, we estimated that 92.0% of the fish released from the tangle net survived to be recovered, while 49.7% of those released from the gill net survived. Spring chinook released from the 3.5” and 4.5” tangle nets were all tagged with yellow tags. Because the numbers printed on the tags were not always readable or reported when recovered, the survival from each net cannot be correctly assigned, and can only be underestimated. With this in mind, using only tags that could be assigned definitively to one net or the other, we calculated that about 80.9% and 88.4% of the spring chinook salmon released from the 3.5” and 4.5” tangle nets survived to be recovered, respectively.

Table 5. Recovery of tags from hatcheries, fisheries and spawning grounds.

Group	Number Tagged	Number Recovered	Percent Recovered	95% Confidence Interval
Bonneville Controls	1,206	149	12.4%	10.7%-14.7%
Gill Net	814	50	6.1%	4.6% - 8.0%
Tangle Nets	528	60	11.4%	8.9%-14.2%
Total	2,548	259	10.2%	

Using our calculated estimates of survival to demonstrate the effects of this difference, we expect that for every 1000 spring chinook salmon caught in the 8” gill net that must be released, 10 would die immediately (1%), and another 498 (50.3%) would die after release, for a total kill of 508 fish. However, using the tangle nets, for 1000 spring chinook salmon captured that must be released, we would expect 32 (3.2% combined for both tangle net types) to die immediately, and another 78 (8.0%) to die after release, for a total kill of 110 fish. Therefore, about 6.5 times as many spring chinook salmon could be handled and released from the tangle nets for the same mortality caused by the gill net. These rates would only be expected with the combination of the gears and the careful handling techniques we used.

Fish tagged in each of the three main test fishing areas were subsequently recovered somewhere in the Columbia River Basin, with the recovery rate improving for fish captured nearer Bonneville Dam compared to those captured further downstream (Figure 3). Fish released closer to Bonneville Dam may have been more likely to pass over the dam and be recaptured in our focused search areas. The tag recovery rate varied among skippers and among areas they fished.

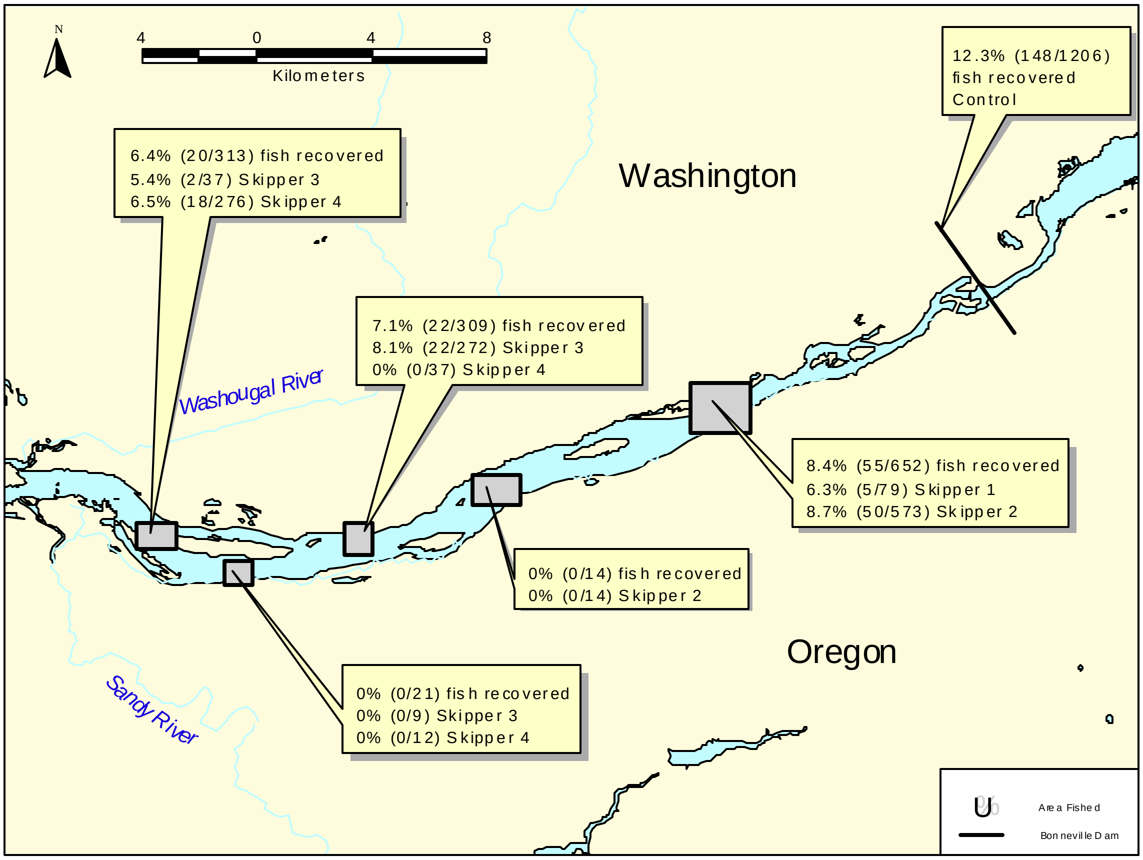

Figure 3. Percentages of tagged fish from each fishing area that were subsequently recovered, by skipper.

We recovered tags from spring chinook salmon captured in each condition category, but those captured in condition 1 were disproportionately represented in the recovered tags. At capture, 86.2% of the fish were in condition 1, while 91.4% of the recovered tags were from fish that had initially been captured in condition 1. This suggests that although fish captured in other conditions can recover to a state where they appear to be in condition 1 at release, physiologically, they have not fully recovered. Longer holding in the recovery box before release could improve survival.

Fish initially captured by wedging were underrepresented in the recovered tags (54% of tags released, 41% of tags recovered). All other capture methods were represented in higher proportions the recovered than the released tags, with fish caught by tangling showing the highest increase (35.8% at release, 43.8% at recovery). Capture methods are confounded with mesh size. There was no significant difference between the mean fork length of fish that were recovered (75.08 cm, N=102) and fish that were not recovered (75.05 cm, N=1,208).

CATCH EFFICIENCY

Each time we had paired sets with the 3.5" tangle net and the 8" gill net, the 8" gill net caught more fish than the 3.5" tangle net (Figure 4) and overall was significantly more effective than the 3.5" tangle net (Wilcoxon signed rank test; T=0, t=0, P<0.05). However, there was no significant difference between the number of fish caught in the 4.5" tangle net and the 8" gill net (Wilcoxon sign test, T=10, t=5, P>0.05).

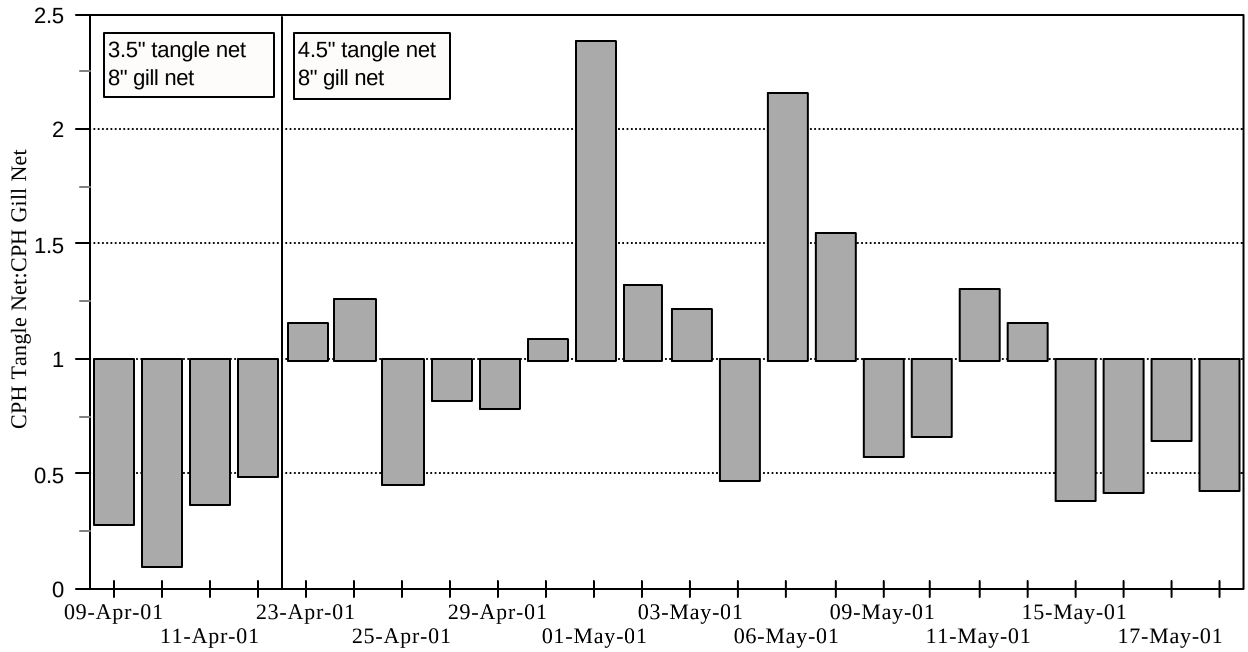

Figure 4. Relative catch of adult spring chinook salmon per hour (CPH) for the 3.5" net compared to the 8" gill net (bars to the left of the vertical line) and for the 4.5" tangle net compared to the 8" gill net (bars to the right of the vertical line). Values at 1 indicate equal catch efficiency, while those below 1 indicate the 8" gill net was more effective than the tangle net, and those above 1 indicate the tangle net was more effective than the 8" gill net. Paired sets were pooled by day across skippers.

The catch per hour was highest during the early part of the test fishery and dropped off in mid-April (Table 6). The highest numbers of spring chinook passed over Bonneville Dam during the weeks of April 8 and April 15, 2001 (Figure 5). Allowing for a few days of travel time, the highest densities of fish were likely available to us between April 6 and April 12. During this time, only the 3.5" net was available from the manufacturer, so we were unable to evaluate the catch efficiency of the 4.5" tangle net compared to the 8" gill net during the highest density of fish. However, based on the numbers of fish passing Bonneville Dam during the weeks of April 22 and 29, 2001, good numbers of fish were present when we did have the 4.5" tangle net available, so the catch efficiency of the 4.5" tangle net relative to the 8" gill net likely represents what would be expected if fish densities were higher. In contrast, the 3.5" net was deployed when the highest densities of fish were available, but not when densities declined.

Table 6. Capture of adult spring chinook salmon per hour (CPH) during comparable sets for each net type.

Mesh Size	Min CPH	Max CPH	Average CPH
Period 1 (Early to mid-April)			
3.5”	2.1	5.6	3.7
8.0”	8.0	20.5	13.5
Period 2 (Mid-April to mid-May)			
4.5”	0.95	5.9	3.0
8.0”	0.96	8.5	3.4

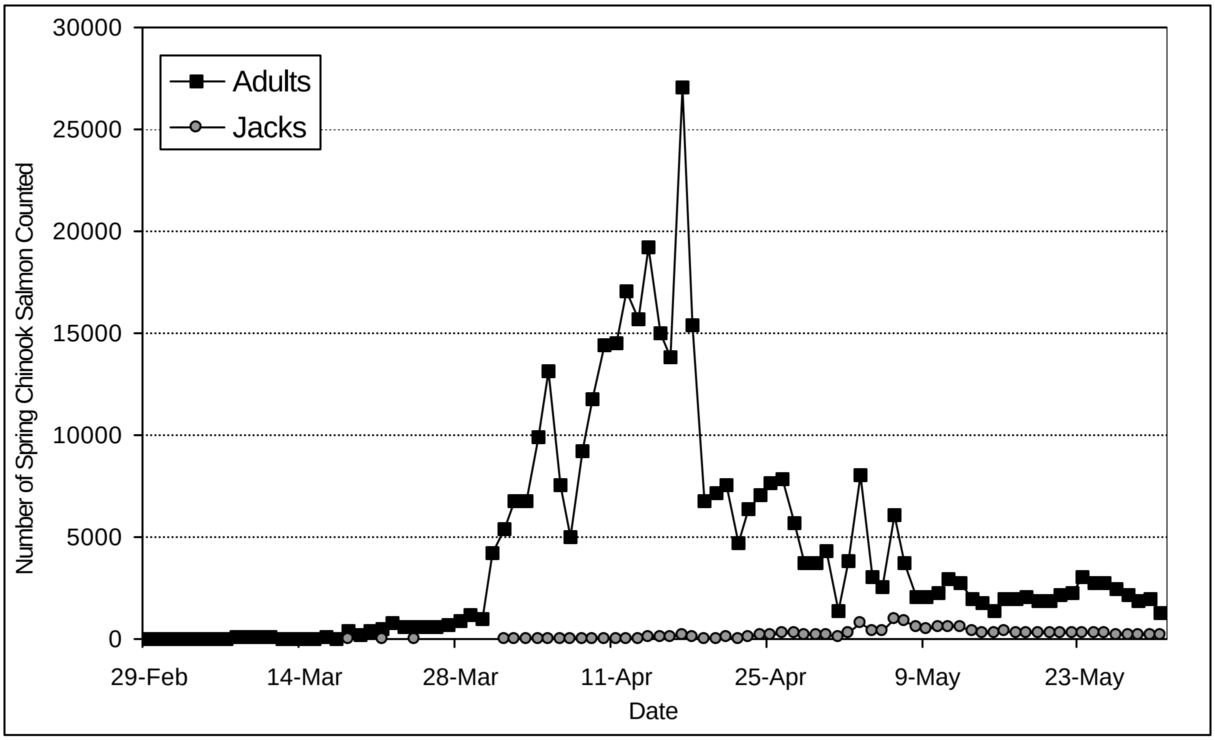

Figure 5. Number of adult and jack spring chinook salmon counted at the counting windows in Bonneville Dam, 2001. Data source is the US Army Corps of Engineers.

SIZE OF ADULTS CAPTURED

We found no significant difference between the fork lengths of adult spring chinook salmon captured in the 4.5” and 3.5” tangle nets (74.9 and 74.9 cm, respectively, t=1.96, df=531, P=0.84), so these data were pooled for comparison with the 8” gill net. A small, but statistically significant difference existed between the average fork lengths of adult spring chinook salmon captured in the tangle nets (74.9 cm, N=533) and those captured in the gill net (75.7 cm, N=776, t=1.96, df=531, P=0.002).

JACK SPRING CHINOOK SALMON

We captured 182 jacks (here defined as small or immature chinook salmon 60 cm fork length or less) during the test fishery. Of those, 22.5% were captured in the 3.5" tangle net, 73.6% were captured in the 4.5" tangle net, and 3.9% were captured in the 8" gill net. Immediate survival was 92.5%. Jacks captured in the 3.5" net (N=41) were mainly captured by wedging (56.1%) or gilling (34.4%). Jacks captured in the 4.5" tangle net (N=134) were mainly captured by gilling or wedging (33.6% each) in the net. The increased number of jacks captured in the 4.5" tangle net compared to the 3.5" tangle net is likely due to the increasing numbers of jacks present during the time we fished the 4.5" tangle net, as well as the fact that we fished the 4.5" tangle net for many more days. Only seven jacks were captured in the 8" gill net as most are small enough to pass through. Compared to adults, a relatively low 71.4% of the jacks were brought on board in condition 1, with the rest mostly in conditions 3 and 5. However, we were able to revive all of the jacks captured in conditions 2 through 4 to condition 1, but only 38% (N=8) of those captured in condition 5. Many jacks were severely descaled as a result of capture.

PASSAGE OVER BONNEVILLE, THE DALLES AND JOHN DAY DAMS

The first tags were observed passing Bonneville Dam during the week of April 8, 2001, and were counted daily until July 31 at Bonneville, The Dalles and John Day dams (Figure 6, Figure 7, and Figure 8). It was clear that the technicians counting the fish were unable to distinguish yellow tags from white tags at The Dalles and John Day dams (they counted only white tags), but that at least some technicians were able to distinguish the tag colors at Bonneville Dam. However, because of the identification errors at The Dalles and John Day dams, we assumed that there was also some unknown identification error at Bonneville Dam, and therefore were forced to combine the counts of yellow and white tags (for tangle and gill nets). Future studies that evaluate passage through the dams must use more contrasting tag colors.

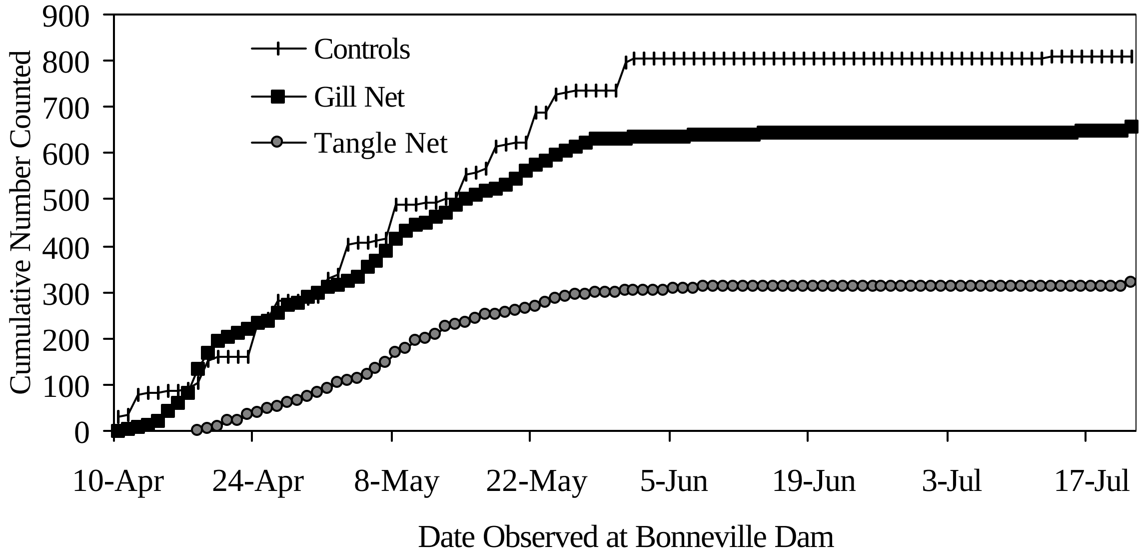

Figure 6. Cumulative number of jaw tagged spring chinook salmon observed passing the counting windows at Bonneville Dam in 2001. While the technicians were able to distinguish some yellow (tangle net) and white (gill net) tags, the identification error is unknown, and the two groups are not discreet.

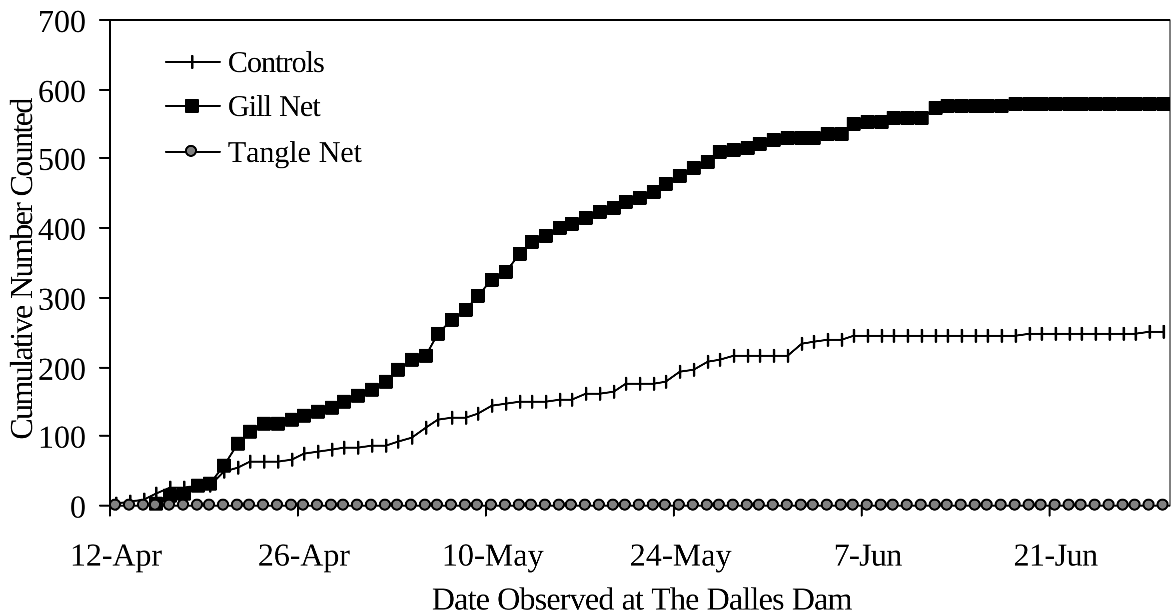

Figure 7. Cumulative number of jaw tagged spring chinook salmon observed passing the counting windows at The Dalles Dam in 2001. Because no yellow tags (tangle net) were counted, the technicians were clearly unable to distinguish yellow and white tags (gill net), thus the gill net counts represent combined tangle net and gill net tags.

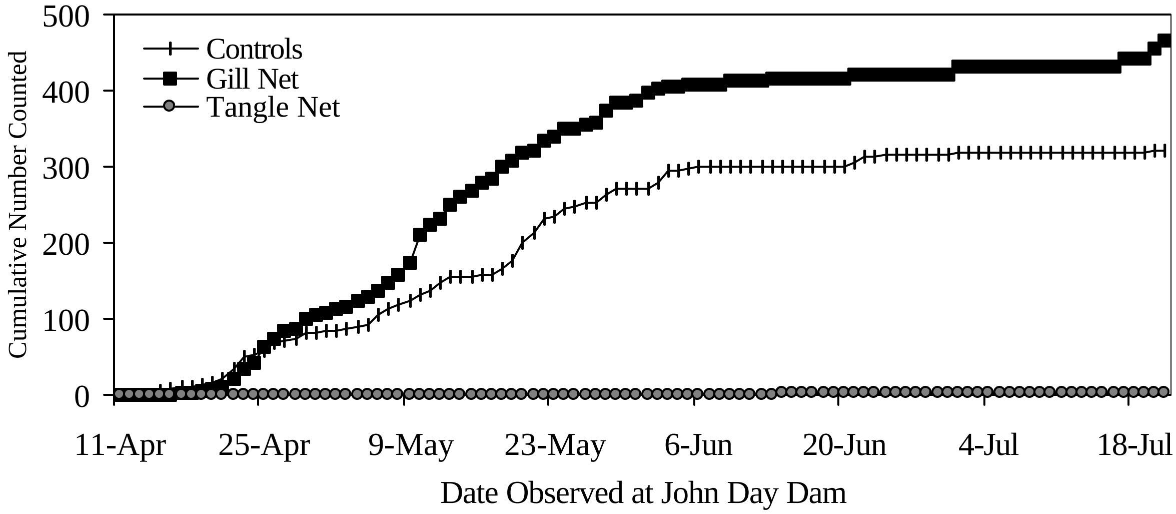

Figure 8. Cumulative number of jaw tagged spring chinook salmon observed passing the counting windows at John Day Dam in 2001. Because no yellow tags (tangle net) were counted, the technicians were clearly unable to distinguish yellow and white tags (gill net), thus the gill net counts represent combined tangle net and gill net tags.

Because we had to combine the tags from the gill net and the tangle net, the meaning of the passage results is unclear. We observed better passage over all three dams for fish captured and released from our gears than for the controls (Table 7) even though the controls were returned to the ladder just downstream of the counting window at Bonneville Dam. This estimated passage from the adult trap in Bonneville Dam is lower than observed for radio-tagged fish. Another anomaly in the data was the lower percentage of tags from the control fish observed at the Dalles Dam compared to John Day Dam, even though the fish must pass the window at the Dalles Dam before they reach John Day Dam. These observations indicate that the red tags used for the control fish were also difficult for the technicians to detect. While the numbers of tags counted over each dam cannot be interpreted, the temporal distribution of the counts supports our assumption that the fish tagged in the control group represented the same population as the fish in the two treatment groups.

Table 7. Total counts of tags released and counted at the upstream dams for the spring chinook salmon tagged in the trap at Bonneville Dam and captured in tangle nets and gill nets downstream of the dam.

	Controls		Gill Net/Tangle Net	
	Num Counted	% of Tagged	Num Counted	% of Tagged
WDFW Tagged and Released	1,206		1,371	
Counted at Bonneville Dam	811	67.3%	978	71.3%
Counted at The Dalles Dam	251	20.8%	580	42.3%
Counted at John Day Dam	321	26.6%	468	34.1%

DISCUSSION

Our results indicate that tangle nets could be used for selectively harvesting marked spring chinook salmon in a commercial fishery on the Columbia River. Tangle nets are as efficient at capturing adult spring chinook salmon as the conventional gill net, it has an acceptably low immediate mortality for fish brought on board, and we were able to show that the post-release mortality of spring chinook salmon released from the tangle net is about 1/6 that of fish released from the gill net. In addition, because they don't have net marks on their bodies (or the associated internal injuries), spring chinook salmon captured in a tangle net may realize higher market prices than fish captured in the gill net.

We see two possible reasons why the fish released from the tangle net survived better than the fish released from the gill net, given that the method of capture was the only difference between the two groups. First, unlike those caught in the tangle net, fish captured in the gill net sustain considerable external injury in the way of scale loss, skin abrasion and loss of the protective slime layer when they are captured in the body. We suspect that some of these injuries impair the fishes' ability to fight off disease, particularly the ubiquitous *Saphrolegnia* spp. fungus (spring chinook salmon migrating to the Columbia River generally enter the river about 4-5 months before spawning), osmoregulate, and successfully navigate the river.

Second, while removing chinook salmon from the nets, we observed that fish released from the gill net tended to be lively, difficult to hold, and generally fighting to get out of the holding tanks. Spring chinook salmon released from the tangle net were noticeably calmer, and seemed even to be in a slight stupor. We hypothesize that this behavior carries over from when they were in the net - spring chinook salmon captured around the body fight the net the entire time they are captured, and that those captured around the face tend to remain calm while in the net. If this is true, then spring chinook salmon coming on board from the gill net would be nearing physiological exhaustion even though they appear lively and able to swim at release. Farrell et al. (2001) showed that coho salmon captured in commercial gill nets were physiologically exhausted and stressed as a result of capture. In contrast, spring chinook salmon coming on board from the tangle net would be in much better physiological condition at release, and better able to avoid predators, navigate barriers, and adapt to changing currents than tired fish. This hypothesis could be tested by using underwater cameras to observe the behavior of the fish captured in the nets, and by analysis of stress hormones and lactic acid in blood samples from spring chinook salmon brought on board from each gear.

While we showed that tangle nets reduce post-release mortality of spring chinook salmon, it is still important to understand how the stress related to this capture method may affect reproduction and gamete quality. The stress response can be maladaptive to reproductive fitness (Shreck 2000), so while spring chinook salmon survived capture and release, their ability to reproduce may have been impaired, countering the potential conservation benefits of increased survival. However, spring chinook salmon spawn about 4 months after the fishery occurs, which could give them time to recover and resume the reproductive process. We recommend experiments examining the physiological responses of spring chinook salmon to capture and the resulting effects on reproduction.

Several studies have found minimal mortality after a short holding period in net pens. Farrell et al. (2001a) found that 2.3% of coho salmon captured in gill nets and held for 24 hours died. Farrell et al (2001b) found no post-capture delayed mortality after 24 hours of holding coho salmon captured by troll fishing in net pens. Gallinat et al. (1997) found mortality of lake trout captured and released from gill nets varied seasonally between 23% and 32% after 48 hours of holding. Holding spring chinook salmon in net pens on the Columbia River for 72 h after captured in gill nets showed 7% mortality while 3% of those captured in tangle nets died (P. Frazier, Oregon Department of Fish and Wildlife, personal communication 2001). These short-term observations of mortality are often used to represent the post-release mortality of free-swimming fish, because it was thought that most fish die within a short time of capture. There is a clear discrepancy with our estimates of post-release mortality. Either the assumption that holding fish in net pens is indicative of their free-swimming mortality during the observation period is invalid, or the assumption that most of the post-release mortality occurs within a few days of capture is invalid. Certainly, our results suggest that the holding mortality should not be used to estimate post-release mortality.

We expect the post-release mortality to vary between species, and with changing environmental conditions. Different species are known to have different responses to the same stressors (Schreck et al. 2001), and so may not respond to the nets in the same ways. A given species may also display a different response in a more stressful environment than a less stressful environment. In our study, the environment was likely favorable to capture and release because the water was relatively clear and cool during the spring chinook salmon migration. Fishing in poorer conditions (e.g. higher, warmer, or more turbid water, more predators present) would most likely increase mortality, although we don't know the magnitude of the difference.

The two-chambered recovery boxes used for lethargic fish were effective for recovering spring chinook salmon. Farrell et al. (2001a) found these types of recovery boxes effective for recovering coho salmon, although we were unable to achieve the 93.5% recovery of fish captured in gill nets in condition 5 (no visible movement or ventilation) that they observed. The reason for this difference is unclear, but may be a species difference, or because of the capture method. We also found that although a fish was observed to recover to a lively condition in the box, this did not necessarily mean the fish would survive after release, likely because a true physiological recovery requires much longer than the time for which we held fish, and much longer than would be practical in a competitive fishery. Post-release survival could probably be improved by holding fish for as long as possible, especially if the fish was brought on board in very poor condition, or by holding the fish in a cage alongside the vessel to promote active swimming during recovery (Farrell et al. 2001b).

The tangle net has shortcomings. As expected, it captured many more non-target species than the conventional gill net. As with any selective fishing operation, fishers using the tangle net must learn and use careful handling techniques to maximize survival of released fish. These include significant changes to fishing practices, and successful implementation requires concurrent redesign of the fishery by managers to encourage a high-priced market for a steady, but lower volume, supply of fish. Enforcing these types of behavioral changes is at best difficult, and a large investment in fishery observers will likely be necessary. Finally, there is a capital investment that is required by each fisher to purchase new nets, recovery boxes and other related equipment, as well as additional time needed to develop markets.

This experiment represents the first study we know of that evaluated the post-release survival of free-swimming fish released from commercial fishing nets and showed that the method of capture is critical to their survival. We observed more than a 6-fold decrease in post-release mortality of spring chinook released from the tangle nets compared to the 8” gill net. The tangle net therefore warrants consideration for selectively harvesting spring chinook salmon on the Columbia River while still protecting wild stocks. Achieving this potential requires that we continue solving the problems with the tangle net and refine handling techniques to maximize post-release survival.

PART 2 - A SHORT TEST OF 5" GILL NET FOR LIVE CAPTURE OF SPRING CHINOOK SALMON

METHODS

While waiting for tangle nets to arrive from the manufacturer, we fished a 5" gill net (3-strand) in place of the tangle net on April 18, 19, 24 and 25, 2001. The net was hung with trammels to match the 8" gill net, and fished in the same areas, and as described for the tangle nets. Observers collected the same set information and details about each fish brought on board as for the tangle nets.

RESULTS

We made 16 sets to capture 39 adult and 4 jack spring chinook salmon in the 5" tangle net and 58 adult and 2 jack spring chinook salmon in the 8" gill net. On average, the 5" gill net captured 4.2 adults per hour, compared to 5.7 adults per hour in the 8" gill net, but these were not significantly different ($T=6$, $t=3$, $P>0.05$). Adults captured in the 8" gill net were captured in better condition than those captured in the 5" gill net (Table 8). The immediate survival reflected this, with 10.3% of fish captured in the 5" gill net dying before release while none of those captured in the 8" gill net died before release.

Adults captured in the 5" gill net were captured by tangling (46%), mouth clamp (44%), gilling (5%) and wedging in the net (5%). Three of the four adults that died in the 5" gill net were captured with their mouths clamped shut, and the fourth was tangled in the gear. Adults captured in the 8" gill net were captured mainly by wedging in the net (83% of captures), with some gilled (7%) and the remainder tangled (10%).

Table 8. Initial condition of spring chinook salmon captured in the 5" and 8" gill nets. Immediate mortality is the number of spring chinook salmon that could not be revived for release.

Mesh Size		Condition at Capture 1 Lively	2 Lively, bleeding	3 Lethargic	4 Lethargic, bleeding	5 No visible movement or ventilation	Total	Immediate Mortality (%)
5"	Jacks	1	1	1	0	1	4	25.0
	Adults	20	0	9	0	10	39	10.3
8"	Jacks	1	0	1	0	0	2	0
	Adults	50	7	1	0	0	58	0

Both nets encountered shad, sturgeon, suckers and flounder. The only species captured in quantity was sturgeon, these were mainly juveniles, and the 5" gill net proved more effective than the 8" gill net (1,411 and 218 captured, respectively). No steelhead salmon were encountered during this part of the test fishery.

DISCUSSION

We were able to take advantage of a short opportunity to test the 5" gill net in tandem with the 8" gill net. While the 5" gill net was effective at capturing spring chinook salmon, we were concerned with the high initial mortality. During test fishing, the soak times were short, the fish from each net were handled in the same careful manner, and any fish needing revival was placed into a recovery box. It is therefore logical that the capture method is the likely cause of the increased mortality in the 5" gill net compared to the 8" gill net and the 3.5" and 4.5" tangle nets. This particular net was hung with trammels on both parts, with the idea that the trammels would increase the catch efficiency. Because both parts of the net had trammels, the increased mortality in the 5" gill net is not explained by this feature. After observing the capture of several thousand spring chinook salmon, we believe that the method of capture is very important to the long term survival.

Comparing the percentages in each category for each net shows how the increasing mesh size from 3.5" to 4.5" to 5.0" results in a larger proportion of the fish being captured by mouth clamping (Table 9), and a general trend towards more fish being captured by gilling and wedging. Mouth clamping proved detrimental to the immediate survival of the spring chinook salmon – of the 29 adults killed during the test fishery, 13 (45%) had been captured by mouth clamping. Our results also showed that capture by gilling and wedging (i.e. the methods of the 8" gill net), while not detrimental to immediate survival, were detrimental to the long-term survival.

Table 9. Percentage of fish captured by each method for each size mesh. N is the total number of fish captured in each net type.

Capture Type	3.5" net	4.5" net	5.0" Net	8.0" Net
Gilled	1.6%	0.3%	5%	9.1%
Mouth Clamped	4.3%	14.9%	43.6%	0%
Rolled	6.4%	2.6%	0%	0.2%
Tangled	87.8%	81.0%	46.2%	2.5%
Wedged	0%	1.2%	5%	88.2%
N	188	348	39	836

The web of our 5" gill net stretched to 5.25" (it is typical for gill net web to stretch, particularly when wet), and we suspect that this may be crossing the threshold between nets that truly function as tangle nets and nets that function as gill nets (hence the low rate of tangling in the 5" gill net). While our sample was small, it was clear from our test that the 5" gill net did not capture fish in the same manner as the 3.5" and 4.5" tangle nets, so the post-release survival rates from those nets should not be applied to the 5" or larger meshed nets. It is likely that the post-release survival rate for these mid-sized nets lies somewhere between the rates estimated for the tangle net and for the gill nets. Based on these observations, if the objective is to maximize the survival of unmarked spring chinook salmon, we recommend a maximum mesh size of 4.5".

PART 3 - FEASIBILITY OF USING A FLOATING TRAP FOR LIVE CAPTURE OF SPRING CHINOOK SALMON AND COHO SALMON

METHODS

The trap net we tested on the Columbia River was originally designed to capture coho salmon (*Oncorhynchus kisutch*) on the Naselle River. It consisted of a mouth formed by two 150= long vertical wings designed to funnel fish toward the middle section, or the "heart" of the net. The heart was formed from side and bottom panels equipped with three center baffles to entrap fish and encourage their movement toward the cod end of the trap-net. The cod end was constructed with 2.5@ coated nylon knotless web and measured 10= wide, 17= long, and 10= deep. The remainder of the net was constructed with 3.5@ nylon web, except for the wings which were 8" nylon web. The entire net was suspended from a polypropylene float line and weighted with a 50 lbs/100= lead line. The overall length of the net was 309= and its maximum depth was 15=.

For this test, the trap net was modified with: (1) a baffle that could be closed to prohibit fish from exiting the cod end; (2) a floor in the cod end that could be lifted to crowd captured fish for easier removal; (3) a welded aluminum frame attached to the cod end float line to maintain its shape and to prevent it from collapsing while being towed; (4) jiggers at the base of the wings to further encourage fish movement toward the cod end; and (5) an additional 150= extension for each wing. The wing extensions were too cumbersome and were removed after two days of fishing.

A single boat was used to deploy the trap net. The cod end was launched by hand from the deck while the wings were fed over the rail from deck-mounted hydraulic gill net spools. Two boats were used to tow the trap net and to keep the mouth open. Each wing was attached to a boat by a line. In most instances, the net was towed just fast enough to maintain shape its shape against the current. At the conclusion of the set, bringing the boats together closed the mouth and the net was spooled onto one boat until the cod end was reached. The fisher in the second boat used a dip net to remove fish from the cod end. The trap net was deployed during all tidal phases, with the mouth facing seaward to maximize encounters with fish moving upstream. Species, condition at capture, sex, and presence or absence of an adipose fin were recorded for each salmon before release.

We contracted two local fishers to fish the floating trap net on the lower Columbia River between river miles 31 and 47 in the spring and between river miles 14 and 23 in the fall of 2001 (Figure 1). It was fished on 6 days in the spring between May 7^{th} and May 14^{th}, targeting spring chinook salmon and 5 days in the fall between September 4^{th} and September 12^{th}, targeting coho salmon, averaging three sets per day. Fishing occurred between 0700 h and 1900 h. Set lengths, defined as the elapsed time between when the first part of the trap net went into the water and when the last part was retrieved, ranged from 29 to 156 minutes with the average set length being about 82 minutes. Deployment generally took fewer than 5 minutes.

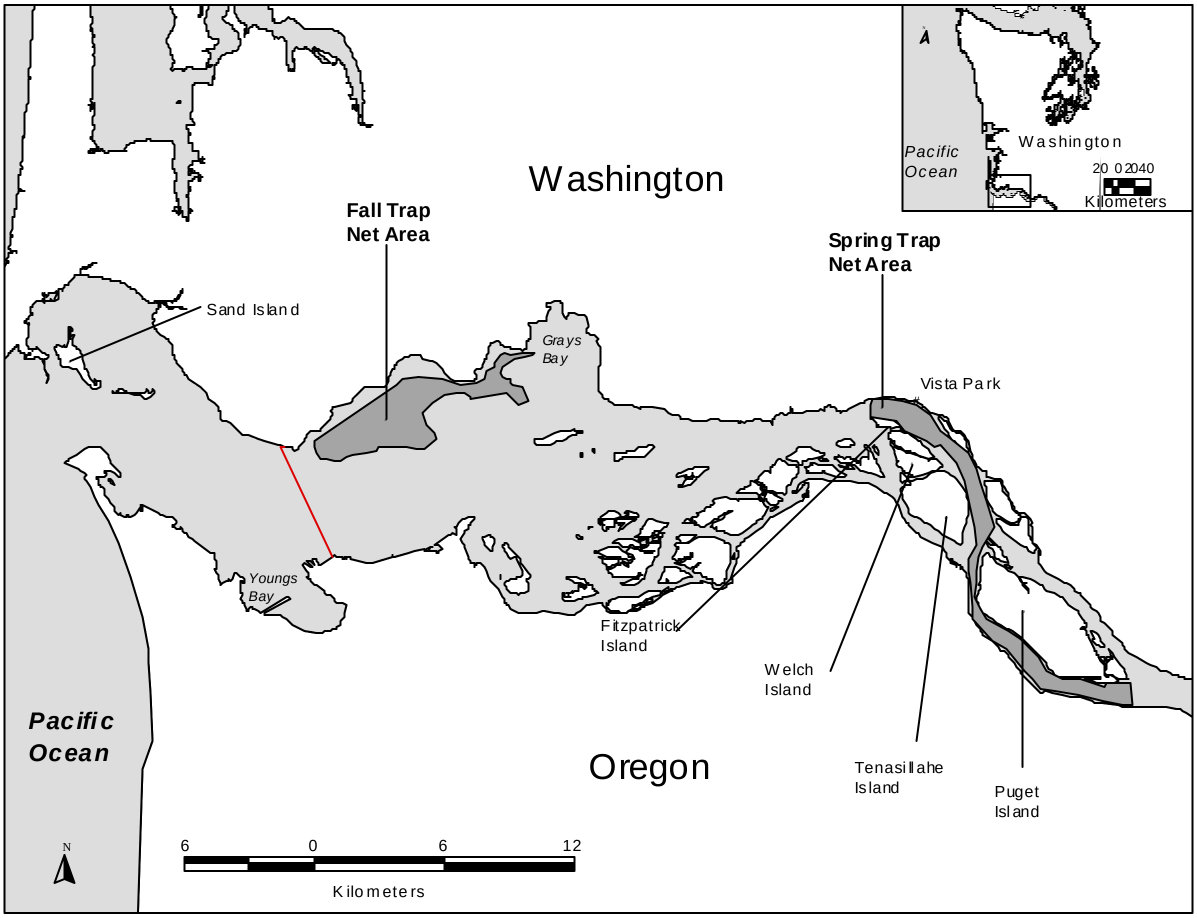

Figure 9. Test fishing locations for the floating trap net in spring and fall 2001.

We fished the trap net under a wide variety of conditions ranging from shallow nearshore sites with fast moving water, to deep offshore sites with weak current. Throughout both the spring and fall, water clarity was high, possibly due to drought related low flows. We fished only during daylight hours and when no commercial harvests were occurring within the test fishing areas.

RESULTS

No fish were captured in the spring. Historic run times, fish counts at Bonneville Dam (Figure 5), and the relative success of concurrent sport and test fisheries at up- and downriver sites suggest that most of the salmon had already transited the test fishing area by the second week of May. Repairs and modifications to the trap-net took longer than expected. Thus, we were unable to fish during peak run time in the spring.

During the fall test fishing period, we captured 11 coho salmon and 1 chinook salmon. Of the coho salmon captured, all were adipose fin clipped (hatchery origin), 7 were male and 1 was female (sex data from 3 fish were not obtained). The chinook salmon was of unknown origin. All were in excellent condition at time of capture and released immediately, unharmed. Coho salmon were known to be abundant in and adjacent to the test fishing area based on high capture rates in the sport fishery and frequently observed jumpers. Both coho salmon and sturgeon were seen jumping in the mouth of the trap-net during sets when no fish were captured. One observer estimated over 300 sturgeon jumps in the fishing area and inside the mouth of the trap-net during a single set; however, no fish were captured. Non-target species (white sturgeon, *Acipenser transmontanus* and starry flounder, *Platichthys stellatus*) were captured in low numbers and also released unharmed.

DISCUSSION

Low abundance of salmon in the test fishing area during the spring trial precluded an evaluation of trap net effectiveness in that fishery. However, low capture rates in the fall, during a time when salmon were abundant in the test fishing area, suggests that the trap net is largely ineffective for that fishery. Similar trap net designs have been fished in Canada and have been marginally successful with pink salmon, but have had difficulty harvesting other species of Pacific salmon. Efforts to improve the efficiency of these nets have focused on closing the mouth of the trap net quickly to prevent escape, reducing the visibility of the net material near the cod end, and reducing the weight (drag) of material used in construction. All of these modifications are aimed at reducing the ability of the fish to detect the net.

Thus far, all fishing has occurred during daylight. Future trap net experiments should include fishing at night. If avoidance reactions are visually cued, then greater efficiency may be achieved by fishing after dark. Further, towing too hard often results in a distortion to the intended shape of the trap net. Design modifications that permit greater tow speeds without compromising shape or structural integrity may improve encounter rates. Success of the floating trap net in harvesting Pacific salmon has yet to be achieved. Conceivably, additional time and resources dedicated to design improvements could increase encounter rates and improve efficiency.

PART 4 - FEASIBILITY OF USING TANGLE NETS FOR LIVE CAPTURE OF COHO SALMON

In this study we explore the feasibility of using a tangle net to harvest coho salmon selectively on the Columbia River. Fishers were paid by the sale of target stocks that they harvested. Catch efficiency and immediate mortality were examined to determine if economic feasibility and live capture and release of non-target stocks could coexist in this particular fishery.

METHODS

Six fishers participated in a test fishery using small mesh gear (3.5@ to 4.5@). Net lengths were restricted to 900' and were not allowed to soak for longer than 30 min per set. Soak time was defined as the time from when the first float entered the water to the time the first float was removed from the water. Total soak time, as listed in Table 1, was defined as the time from when the first float entered the water until the last float was removed at the end of the set. Eleven nets, designated A through K, were used. The nets varied in overall dimension, color, mesh size, web type and hang ratio (hang ratio = total length of stretch mesh: total length of float line). Two of the nets were fished after sundown by one fisher, otherwise, all fishing occurred during daylight between 6 Sep and 19 Oct 2001. Observers from WDFW were on board each fishing vessel to collect environmental and biological data. Each fisher had good local knowledge of the test fishing areas and was restricted to 8 h of fishing.

Fisher 1 fished during the late evening and early morning of 6 and 7 Sep in area I (Figure 10) with two nets. Both nets were 450' long, 28' deep, with green mesh. One was constructed from 3.5" multi-filament web hung at a ratio of 3:1 (Net A) and the other, which was originally used to capture sockeye, was constructed from 4.5" two-strand web hung at 2:1 (Net B). This fisher had a market for a limited volume of very high quality fish. As a result, he kept only the best fish, and returned some fish to the water that could legally have been retained. Fisher 2 fished on 7 Sep in area II and used a net that was 900' long, 17' deep, and was constructed from 4" green multi-strand web hung at 2:1 (Net C). Fisher 3 fished on 13 Sep in area I using two nets. Both were 28' deep and hung at a ratio of 3:1. Net D was 510' in length and constructed from 3.5" green multi-strand web. Net E was 390' long and constructed from 4.5" pink multi-strand. Fisher 4 fished on 14 Sep in area III using two nets. Both were 450' long, 28' deep, and hung at 2:1. Net F was constructed from 3.5" green multi-strand that was strung top to bottom approximately every 12' (at every other float). Net G was constructed from 4.5" blue-grey multi-strand strung top to bottom approximately every 6' (at every float). Fisher 5 fished on 13 Oct in area IV with nets F (see previous description) and H. Net H was constructed from 4.5" monofilament web, strung top to bottom approximately every 25', and was otherwise the same as net F. Fisher 6 fished on 19 Oct in area IV with three nets. Each net was 300' long and 28' deep. Nets I and J were constructed from 3.5" green and 4.5" blue-grey multi-strand, respectively, and were hung at 3:1. Net K was constructed from 4.5" green monofilament hung at 2.4:1.

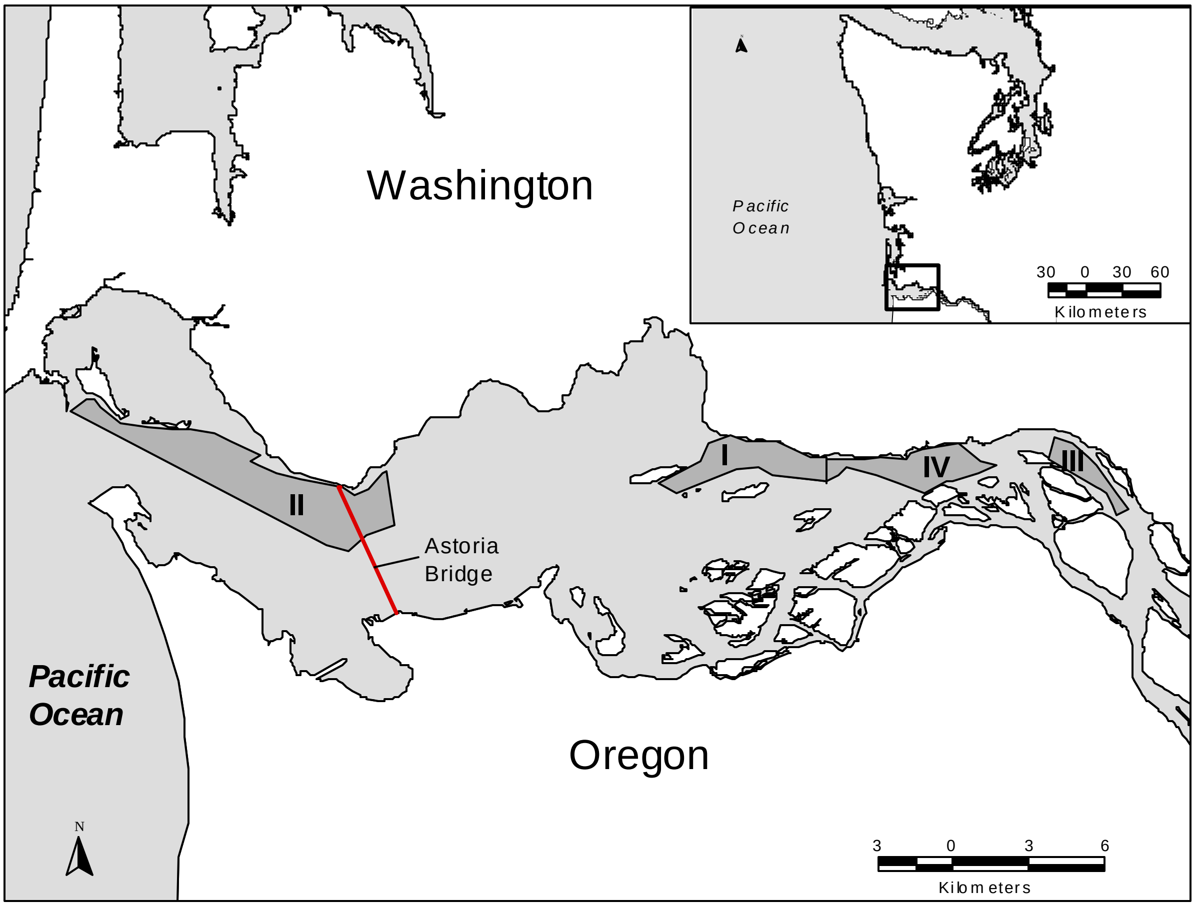

Figure 10. Fishing areas for evaluating tangle nets for live capture of coho salmon in fall, 2001.

Fishers were allowed to retain and sell all chinook salmon and marked coho salmon, identified by the absence of the adipose fin. All sturgeon, steelhead, and unmarked coho salmon were returned to the water. Steelhead and unmarked coho salmon received condition scores at time of capture as follows: 1 (vigorous and not bleeding); 2 (vigorous and bleeding); 3 (lethargic and not bleeding); 4 (lethargic and bleeding); or 5 (no movement or apparent ventilation). All steelhead and unmarked coho salmon receiving scores of 1 or 2 were immediately released into the water. A working recovery box was required on board each vessel. Steelhead and unmarked coho salmon receiving scores of 3 or higher were held in the box until their condition improved or they died. All dead fish were returned to the water.

RESULTS

A total of 892 coho salmon were captured over the course of six fishing periods (Table 10). Of these, 84% (748) were marked. Twenty-four (17%) of the unmarked coho salmon died before release. Also captured were chinook salmon, steelhead salmon and sturgeon. Bright chinook salmon were identified by their nickel bright color, the presence of loosely attached scales, and little apparent sexual dimorphism. Tule chinook salmon, on the other hand, had a brassy hue with firmly attached scales and clearly distinguished sexes with well-developed gonads. Jacks are small (less than 56 cm.) male chinook salmon that mature and return to spawn at age two. Twenty-one steelhead were captured and all were returned to the water in excellent condition. The sturgeon were also released in excellent condition.

Table 10. Number of fish captured and total soak time for each net configuration (see text for description of each net).

Species captured	Net Configuration											Total
	A	B	C	D	E	F	G	H	I	J	K	
Coho, marked	70	49	61	231	23	100	33	85	16	33	47	748
Coho, live, unmarked	15	7	11	49	7	7	5	8	2	4	5	120
Coho, dead, unmarked	1	3	3	11	0	2	0	1	1	1	1	24
Chinook, bright	7	3	1	11	2	0	0	0	0	0	0	24
Chinook, tule	14	8	1	7	1	4	0	0	0	0	0	35
Chinook, jack	10	3	3	2	0	3	1	0	0	0	0	22
Steelhead, marked	2	0	3	5	0	4	1	0	0	0	0	15
Steelhead, unmarked	1	0	1	1	1	0	1	0	0	1	0	6
Total soak time (min)	333	355	290	413	340	741	334	271	170	204	263	

DISCUSSION

Current full fleet fisheries on lower Columbia River targeting fall-run coho salmon allow the sale of all coho salmon, including those of non-hatchery origin. Although the fishery is temporally adjusted to avoid wild coho salmon, there remains a substantial overlap between wild and hatchery origin runs. Our results suggest that a mark-selective coho fishery using tangle nets could be feasible if the mark rate remains high, and deserves further exploration where particular runs require protection.

Live capture techniques have other advantages unrelated to conservation. For instance, fisher 1 sorted his catch for a specific, high quality market. If fish are captured live, the unmarketable or unprofitable fish can be returned to the water unharmed rather than sold at a loss or killed. Individual fishers have also expressed interest in developing a high profit market for live Pacific salmon, which could be realized using the tangle net.

REFERENCES

Farrell, A.P., P.E. Gallaugher, J. Fraser, D. Pike, P. Bowering, A.K.M. Hadwin, W. Parkhouse and R. Routledge. 2001(a). Successful recovery of the physiological status of coho salmon on board a commercial gillnet vessel by means of a newly designed box. Canadian Journal of Fisheries and Aquatic Science 58:1932-1946.

Farrell, A.P., P.E. Gallaugher, and R. Routledge. 2001(b). Rapid recovery of exhausted adult coho salmon after commercial capture by troll fishing. Canadian Journal of Fisheries and Aquatic Science 58:2319-2324.

Farrell, A.P., P. Gallaugher, C. Clarke, N. DeLury, H. Kreiberg, W. Parkhouse and R. Routledge. 2000. Physiological status of coho salmon (*Oncorhynchus kisutch*) captured in commercial non-retention fisheries. Canadian Journal of Fisheries and Aquatic Science 57:1668-1678.

Gallinat, M.P., H.H. Ngu and J.D. Shively. 1997. Short-term survival of lake trout released from commercial gill nets in Lake Superior. North American Journal of Fisheries Management 17:136-140.

Schreck, C.B. 2000. Accumulation and long-term effects of stress. In: Moberg, G.P., Mench, J.A. (Eds.). The Biology of Animal Stress: Assessment and Implications for Welfare. CAB International, Wallingford.

Schreck, C.B., W. Contreras-Sanchez and M.P. Fitzpatrick. 2001. Effects of stress on fish reproduction, gamete quality and progeny. Aquaculture 197:3-24.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall, Inc. New Jersey.