Tangle Nets

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Background and Objectives

Background

Tangle net (or tooth net) research first came about in the U.S. Pacific Northwest and Canada as a way to evaluate whether a conservation goal could be achieved for a salmon species or stock of concern. Specifically, researchers wanted to determine the survival rates of nontarget salmon captured and released from tangle nets. This knowledge—whether the survival rate is acceptable—enables fish managers to allow commercial "selective fishing" while protecting weak stocks. Commercial selective fishing is deemed successful if conservation goals are achieved for the species or stock of concern and if a harvest goal is met to make the fishery economically viable.

Work done by Vander Haegen et al. (2002, 2004) compared tangle nets with traditional gill nets and showed that the use of a tangle net, with careful handling techniques, can reduce spring chinook salmon *Oncorhynchus tshawytscha* mortality. The handling techniques included an abbreviated soak time, a shorter net, and meticulous removal of fish from the net. They also included the use of a revival box, which Farrell et al. (2001a) showed could reduce the physiologic stress on coho following their capture in a gill net. Research by Ashbrook et al. (2004a, 2004b) has provided further information for estimating survival of bycatch following their release from tangle nets. Consequently, Columbia River fishery managers have instituted selective tangle net fisheries for upriver spring chinook salmon. In addition to their use in selective fishing studies, applications for tangle nets include capturing fish to apply tags, and for broodstock and biosample collection.

Rationale

Selective capture and subsequent release of nontarget bycatch is possible because the tangle net can efficiently capture salmonids in large rivers and estuaries in short time periods with low immediate mortality rates and relatively low postrelease mortality rates (Vander Haegen et al. 2002 and 2004; Ashbrook et al. 2004). Experienced gill-net fishermen can transition easily to tangle nets, which operate similarly. Tangle nets are visually comparable to gill nets (see Figure 1), and the two gears are fished in the same manner; however, the mesh of the tangle net is smaller than that of a conventional gill net, which results in the fish being caught by the snout or teeth. Ideally, the smaller mesh size increases the chance for fish to continue respiring in the net so they can be released live.

Although different species can be easily sorted, stock-selective fisheries in the U.S. Pacific Northwest and Canada rely on a physical mark—in most cases, adipose fin excision—that allows fishers to distinguish easily between stocks of hatchery-origin fish (which can be retained) and unmarked naturally spawning stocks (which must be released).

FIGURE 1. — A gill net (left) alongside a tangle net.

Objectives

Tangle nets enable practitioners to capture a representative sample of fish to assess survival, to tag, or to collect biological data. Regardless of the goal of tangle net fishing, it is important for fishers to release captured fish in a manner that allows for a high postrelease survival rate. The use of tangle nets also gives scientists a sampling of the percentage of hatchery versus wild-origin fish as they are entering the river system or are in its lower reaches.

Sampling Design

Site selection

Tangle net fishing may be conducted in any area where gill-net fishing is suitable, and in a variety of habitats. Timing depends on the species, life stage, and population(s) that are targeted. In general, the environment is most favorable to tangle net capture and release when water temperatures are relatively cool. Fishing in poorer conditions (e.g., among predators, in waters with relatively high velocity or warm temperatures) is expected to increase postrelease mortality. Water flow and depth as well as snags on the river bottom may affect the use of a tangle net. Adult salmonids may be captured in habitats adjacent to and along migratory routes to spawning grounds. Populations sampled may include visually marked and unmarked populations of the same species as well as other fish species (including salmonids). As fish size varies, a tangle net for one species may act as a gill net for another species, and therefore, practitioners must choose the mesh size carefully.

Sampling frequency

Depending on the purpose of tangle-net fishing and the target species, fishing can occur at or below spawning areas. To capture fish for biological samples or to assess abundance or diversity, one or many sets may be employed, either on one day or throughout a longer period, and this could occur over a wide range of habitats or areas. In most instances, fish should be captured and evaluated in

proportion to their abundance. For salmon, this would mean fishing with the same effort throughout the time-frame of their spawning run. The number of sampling sites will vary depending on the question the researcher is trying to answer. For example, to evaluate selective fishing ideally, practitioners should fish in typical fishing areas and during typical fishing seasons to capture the targeted adults. To evaluate the use of a tangle net and estimate survival with jaw tags, approximately 1,000 fish need to be captured per treatment group each year. In our project, the jaw tag recovery rate (which allowed estimation of postrelease survival) ranged from 10% to 20%. If a tag that has greater detection (e.g., a passive integrated transponder [PIT] tag) or recovery can be used, fewer fish will need to be tagged. To calculate survival estimates with the tangle net, sampling over multiple years is most useful because it incorporates year-to-year variation.

Field/Office Methods

Setup

Permits

Permitting requirements may take a few years if a research permit is not already in place. In the event that a research permit has been acquired for an existing study, it is more efficient to add the tangle-net study onto the existing research permit. In the United States, if there is a possibility that species listed under the Endangered Species Act (ESA) may be captured, setup preparations will require obtaining a research take permit under the ESA.

Contracting fishers and setting up nets

Contracting local gill-net fishers who have years of experience fishing for the target species is ideal because these fishers know the most effective manner, location, and times for fishing. Furthermore, in the case of a selective fishing study, the fishers can be asked to mimic the fishery both in manner and location fished. It is recommended that researchers initiate a competitive bid process, which takes into consideration fees and fishing experience. Setting up a contract can take several months. The process includes the following steps: publicize and send out a request for bids, evaluate the bids based on amount as well as the extent to which applicants meet the minimum qualifications for experience and insurance, and contact the fishers and have them send in a signed contract and proof of insurance.

When the fishing contracts are in place, researchers can make arrangements for the fishing sites and meeting locations. Discussions with the fishers will be helpful in choosing the appropriate mesh and net sizes. Finally, regarding net acquisition and preparation, often it is more efficient and less expensive to have the fishers order the nets and hang them on the cork line (hanging the net with floats and weights) than to do this in a separate process.

- For capturing adult spring chinook salmon and releasing those without clipped adipose fins, we recommend using an 11.4-cm (4.5-in), four-strand, 1.5-mm multifilament mesh net that is hung at a ratio of 2:1. The hang ratio describes the length of mesh relative to the length of cork line. This compares to the conventional spring chinook salmon gill net of 20.3-

cm (8-in), monofilament single-strand mesh hung at a ratio of 2:1. We used a net with a total length of 275 m (150 fathoms).

- For capturing coho salmon and releasing unmarked coho salmon and chinook salmon, we recommend a 9-cm (3.5-in), four-strand, 1.5-mm multifilament mesh that is hung at a ratio of 3:1. This compares to the conventional coho salmon gill net of 14.6-cm (5.75-in), monofilament single-strand mesh hung at a ratio of 2:1. We used a net with a total length of 295 m (160 fathoms).

Diver nets, which sink and follow the bottom contours, may be used in addition or as an alternative to floating nets, which remain at the surface. For comparing two nets, the nets may be shackled together to form a complete panel that is 275 m in length. Gear types should be of similar depth. For example, for capturing coho salmon, we used a tangle net that was 74 meshes deep shackled to a gill net that was 45 meshes deep to ensure that both nets fished at the same depth. The depth and color of the nets should be suitable to the area fished.

Preparations for using a control

Preseason preparations can vary if a control is used and depending on the control. If a fish trap that is located within a dam is used (e.g., the adult fish facility in the Bonneville Dam, Columbia River), a request will need to be made to the facility managers. This can entail filling out forms, obtaining signatures, fulfilling safety courses, getting passes and keys for each employee, learning how to operate the trap, and coordinating research schedules with the other research that is taking place at the trap site. If another net type such as a beach or purse seine is used, fishers contracted must be competent with this gear.

If the control fish need to be released near the fish captured in the tangle net, researchers need to consider obtaining an oxygenated fish transport tank, a vehicle to pull the tank, oxygen tanks, and a means of filling the tank with water and hiring additional staff.

Field office

If the fishing location is more than 2 h away from the office, setting up a field station may be necessary; this process takes around 2 d. A field station provides a place to communicate with the headquarters, enter data, and store gear. It can also serve as a place to sleep and make meals if the project duration is too short to rent accommodations or if hotel arrangements are not possible. Among the elements to include are a computer with e-mail capability, a phone, a desk, and office supplies. A dry-erase board can be used to list out the sampling schedule and indicate changes that occur on a daily basis. The field station may also house an area for preparing tagging equipment and drying out rain gear.

Hiring staff

For each boat, one to three researchers will be needed to collect data and tag fish. For studies in which two or more boats fish simultaneously, temporary staff is warranted. Advertising for temporary staff, interviews, hiring, and training can take a few months. Furthermore, each staff member will require safety and first-aid training as well as rain gear.

Tags and biosamples

If fish are to be tagged, the appropriate tag needs to be identified and ordered. Each tagging process has strengths and weaknesses; choosing the tag that best suits the study is an important decision. Some tags, such as telemetry tags, require that receivers (which pick up the signal) be placed along the banks of the river. Use of these tags also necessitates coordinating with other researchers who are using telemetry in the area. If PIT tags are used, detection areas and handheld detectors are required.

Other tags, such as jaw and Floy tags, are less labor-intensive and less costly. Jaw tags, which consist of a piece of copper wire with a colored plastic sheath and individual alphabet-number combination, enable the researcher to connect the recovered tag back to the individual fish. Furthermore, different sheath colors can be used to differentiate study groups or treatment and control groups. If the study depends on tag recovery from recreational fishers, we recommend creating and putting up posters that request recovery information, provide a toll-free telephone number, and offer a lottery-drawn cash prize as incentive.

When collecting biosamples such as tissue, blood, or scales, we recommend developing and rehearsing a quick and efficient method before the study begins. Consider in advance the fact that inclement weather can frustrate tagging and biosampling efforts on the boat.

Database and gear preparation

Prior to the field season, a database and data sheets should be created using a program such as Microsoft Access. The datasheets can be printed onto waterproof paper and multiple copies made. (See the appendices for examples.)

For each vessel used, a sampling tote can be prepared that includes a first-aid kit, a global positioning system (GPS), batteries, headlamps for night fishing, pencils, data sheets, a clipboard, and a thermometer. Each vessel also requires a revival box. For a multiple-year study, the revival box made in the first year can be used during the successive years.

Events sequence

The night before or on the morning of each field day, researchers prepare a sampling tote that includes a first aid kit, GPS unit, thermometer, data sheets, tags and tagging equipment, pencils, and plastic bags. The researchers meet the fisherman at a designated location. One researcher primarily handles the fish while the other primarily collects and records information on the data sheets. If multiple tags are applied—such as a jaw tag, a PIT tag, and a telemetry tag—a total of three researchers may be needed. The fisher drives to the fishing site and deploys the net. As this occurs, the data researcher collects the GPS reading and notes on the data sheet the time the net was deployed, GPS information, date, time, presence or absence of pinnipeds, temperature, first net out (if more than one net is deployed), and weather condition and the fisher's name, boat name, and names of researchers for that day. A large plastic tote is filled with water. Just prior to bringing in the net, the pump that operates the revival box is started.

The fishing vessel is equipped with a hydraulic reel mounted in the bow that deploys and retrieves the net(s). The nets are set by reeling them across the river in a curved pattern and allowing both ends to drift freely. Initially, as they remove fish from the net, fishers are instructed on proper fish handling, particularly to avoid

touching the gill area or holding a fish by its caudal peduncle. When possible, fishers look over the bow as the net is pulled up so that they can lift fish over the roller. If two nets are shackled together, the fisher—if at all feasible—alternates the end of the net that is closest to the shore on subsequent sets so that the fishing effort of each net type is similar.

Depending on the species, fishing location, and safety conditions, fishing may take place during the day or night. In an estuarine area, fishing typically occurs during daylight and at optimal tides for catching fish. Vessels may also be fished simultaneously and proximately to mimic a commercial fishery. In a fishery that captures fish live, the amount of time the tangle nets are left to drift is less than it is in a traditional gill-net fishery. For example, a tangle net fishery deploys nets for a number of minutes where a traditional gill-net fishery deploys nets for a number of hours. During our studies, the time the first cork is deployed until the last cork is pulled in ranged from about 20 min to an hour, depending on the number of fish captured and their condition. If fish are to be released, fish must be carefully handled and revived.

To further ensure fish survival following release, all vessels are to be equipped with a revival box similar to that described by Farrell et al. (2001a). The boxes can be made from 2-cm thick plywood painted black or from stainless steel (see Figure 2) and contain two compartments for holding fish. Each compartment is about 107 cm long, 41 cm high, and 19 cm wide. The compartments of the revival box are wide enough to allow a chinook salmon to fit with its head facing the fresh water flow but narrow enough to prevent the fish from turning around. A 12 V, 240 L/min submersible bilge pump or a 5-cm gas-powered Honda water pump is connected to a discharge hose that supplies fresh water through pipes located at the front and near the bottom of the box. The front panels of the box where the tubes are attached for water flow are constructed to slide vertically. Lifting the panels provides a water slide so that fish can be released in a stream of water into the river. Overflow outlets are located at the opposite end of the revival box.

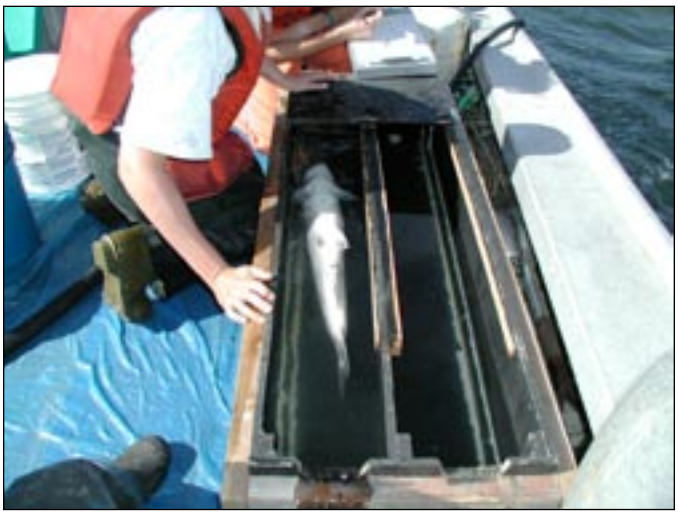

FIGURE 2. — Adult salmon in revival box.

Fish captured by tangle net

As fish are brought in, the fisher extracts them from the net (see Figure 3) and places them into a large plastic tote box (see Figure 4). Data collection then takes

place (see pages 348–349). The researcher handling the fish then returns the fish to the water, taking care to release the fish so that it is not recaptured by the net. Any fish that die are checked for a coded wire tag with a detection wand and donated to a public food bank.

Fish captured as a control to the tangle net (i.e., for evaluating survival)
Fish may be collected by a trap or purse or beach seine. They are placed individually into a tank and their condition is evaluated, length and distinguishing marks are recorded, and tags are applied as described above. Depending on the study design, control fish are either returned to the water from where they were captured or transported to a release site near the fishing location. (See Appendices A–B for field forms.)

FIGURE 3. — Deployed tangle net with fisher retrieving net. The fisher occasionally looks over the bow for additional fish.

FIGURE 4. — After the fisher extracts the fish from the tangle net, he places it in a tote of water. The researcher evaluates the condition of the fish while carefully holding it with both hands.

Data collection

This section describes the data collection technique used to evaluate survival (see Appendices A–B for field forms). For other studies, some of these steps may not be pertinent. A series of mark–recapture experiments is used to estimate the survival of adult salmon captured and released from tangle nets. To compare different sized nets, the following elements are examined: (a) immediate survival; (b) catch-per-unit-effort; (c) species composition; and, when possible, (d) long-term survival. To obtain this information two research personnel are on board each vessel during test fishing; one person primarily records data while the other monitors, handles, and tags fish. For each set (one deployment and retrieval of the net), personnel record the time when the first part of the net is placed in and removed from the water, the time the end of the net is brought on board, and the longitude and the latitude for the set (using a handheld GPS unit). If two nets are shackled together, observers also record the time the shackle between the two nets is removed from the water, which net type is put in the water first, and which net type is removed from the water first. Personnel also record the date, skipper's name, boat name, personnel names, set number, weather conditions, water and surface temperatures, presence of pinnipeds, and any other observations pertaining to a particular set. Researchers inform fishers when to start picking up nets to ensure short soak times (the time from when the first cork goes in the water until the last cork is removed from the water).

As they remove fish from the net, fishers are instructed on proper fish handling, particularly to avoid touching the gill area or holding fish by its caudal peduncle. Fishers remove each fish from the net and either place it in a holding tank of fresh water located in the bow or release it overboard, as directed by the researcher. Any unusual observations about fish handling are recorded. For each salmon caught, the data collector notes the net type where it was captured, the type of capture, whether the adipose fin was missing, and the condition of fish at capture.

The researcher who is handling the fish calls out to the data researcher the manner of capture (e.g., tangled by teeth or mouth, gilled [net around the gills], wedged [web around body posterior to the gills], or mouth clamped [net wrapped around mouth, clamping it closed]).

A numerical rating of the condition of the fish is then recorded:

- 1 = Vigorous
- 2 = Vigorous and bleeding as a result of capture
- 3 = Lethargic
- 4 = Lethargic and bleeding as a result of capture
- 5 = No signs of ventilation
- 6 = Dead from being torn into pieces as from pinniped predation

The length and tags or other distinguishing marks, including scratches or wounds from pinnipeds, lamprey marks, descaling, and Floy tags, are then recorded.

If PIT tags are to be applied, a PIT-tag detector is run over the fish at this point. If the fish is less than vigorous (i.e., worse than condition 2), it is placed into the revival box until it recovers to condition 1 or 2 or dies. A tag can be applied or a biosample collected at this point. The person handling the fish measures the fork

length and tags the fish. We typically attach a plastic colored jaw tag printed with a number and a color corresponding to the net type where the fish was captured.

The data researcher records whether fish are placed into the recovery box as well as the condition at release or when resuscitation fails and a fish is determined to be dead. Loss of scales, damaged fins, and other visible injuries are also recorded. Nontarget species encountered are counted, and the net mesh size where they are captured is noted. (Another option for every nontarget bycatch encountered is to collect the same information as for the targeted fish; this decision will depend on the goal of the study.) If a fish with a numbered tag is brought on board, its condition at capture, tag number, and whether the fish was caught in the top, middle, or bottom third of the net is recorded. Salmon are released when they are judged to be in good condition. Once dead salmon are scanned for coded wire tags, they are donated to a public food bank.

Control fish counted at dams

At dams, observers record any visible injuries and whether a captured fish is missing its adipose fin. Fish are then transferred to a holding tank with fresh water until they revive in lively condition; at that point, they are either released into a chute and diverted back to the fish ladder to continue migration or are transported to a site near where the tangle net is being fished. Trapping occurs throughout the test fishery to ensure that the same populations of migrating fish are tagged.

Data Handling, Analysis and Reporting

See the appendix for metadata collection procedures (including descriptions of fields and sizes), sample collection information, site description, and quality assurance procedures.

Database design

We created a simple series of flat tables to accommodate our field data—four tables that hold all our field collections and one table that houses our tag recovery information. All the data collected during the release of fish from our fishery are entered into three of the tables (*FinalSetInformation, *Finalsalmonids, and *FinalBycatch). The tables are joined via a three-field key. A separate table (Bonn-Trap) was created to house the control fish releases from the Bonneville Dam. Recovery information was housed in the *FinalTagRecoveryInfo table. This table was connected via a cross-table query to both test fishery and control release groups. Relationships among tables can include date, set number, boat skipper, fish number, and net type.

Data entry

Following field review and verification of field data sheets, the data is entered into the database. Prior to analysis, the data sheets are checked against the database again to ensure accuracy. Data sheets are photocopied and brought to the headquarters each week. The database is backed up weekly on compact discs.

Data summaries

Estimating survival

Survival is estimated as described in Ashbrook et al. (in press). The protocol enables estimation of immediate, postrelease, and total survival. Immediate survival was estimated as the binomial proportion

$$\hat{S}_I = \frac{a}{n} \quad \text{(eq 1)}$$

where
n = total number of fish captured with the tangle net, and
a = number of fish retrieved from the tangle net that lived.

The sample error for immediate survival was estimated by

$$\sqrt{\hat{Var}(\hat{S}_I)} = \sqrt{\frac{\hat{S}_I(1-\hat{S}_I)}{n}} \quad \text{(eq 2)}$$

with confidence intervals estimated by the normal approximation (Zar 1984). Postrelease survival was estimated using the Ricker relative recovery model, where

$$\hat{S}_P = \frac{\left(\frac{t}{T}\right)}{\left(\frac{c}{C}\right)} \quad \text{(eq 3)}$$

where
T = number of tangle net fish released,
t = number of tags recovered from tangle net fish,
C = number of control fish released, and
c = number of tags recovered for control fish.

The variance of was estimated by the delta method, where

$$\hat{Var}(\hat{S}_P) = \hat{S}_P^2 \left[\frac{1}{c} - \frac{1}{C} + \frac{1}{t} - \frac{1}{T}\right] \quad \text{(eq 4)}$$

Total survival was calculated as the product of the immediate and postrelease survival estimates, where

$$\hat{S}_T = \hat{S}_I \bullet \hat{S}_P \quad \text{(eq 5)}$$

with approximate variance estimator

$$\hat{Var}(\hat{S}_T) = \hat{S}_I^2 \bullet \hat{Var}(\hat{S}_P) + \hat{S}_P^2 \bullet \hat{Var}(\hat{S}_I) - \hat{Var}(\hat{S}_I) \bullet \hat{Var}(\hat{S}_P) \quad \text{(eq 6)}$$

Summarized tangle net data are reported to managers and researchers in the format shown in Table 1.

TABLE 1. — Format for reporting summary tangle net data to managers and other researchers.

Study year	Study group	Spring chinook adult catch	Immediate adult mortality (%)	Total tagged and released adults	Jaw tag recoveries (n)	Relative long-term adult mortality (%) (95% conf. int.)	Total mortality due to treatment (%)
2004	Tangle net						
	Gill net						
	Controls						
2005	Tangle net						
	Gill net						
	Control						

Report format

Most often the key data analyses can be broken into two categories: immediate and postrelease. The immediate category includes number of target fish captured in the tangle net, their immediate survival, recapture history, visible injuries, species composition or bycatch, temperature, and catch efficiency. The postrelease category includes postrelease and long-term survival, percentage of fish recovered by skipper, and location fished. If a control is used, similar information is collected.

Immediate

The immediate category includes number of fish captured in the tangle net, immediate survival, condition at capture and at release, recaptured fish, catch-per-unit-effort (CPUE), and species composition.

We list the dates fishing began and ended and list the total number of boat days (defined as an individual boat-date combination). We state the total number of captured and recaptured target adults and provide the same information for juvenile fish. Immediate survival is calculated as shown in the "Estimating Survival" section, and the results are shown in a table. The cumulative number of fish captured is shown in a histogram figure. We then list the number of fish that were given tags before release from the tangle net.

TABLE 2. — Immediate survival (%) of adult and juvenile fish captured including recaptures during test fishing in each net type. *N* is the number of target fish encountered.

	Adults		Jacks	
Net type	Survival (%)	*N*	Survival (%)	*N*
Tangle				
Gill				

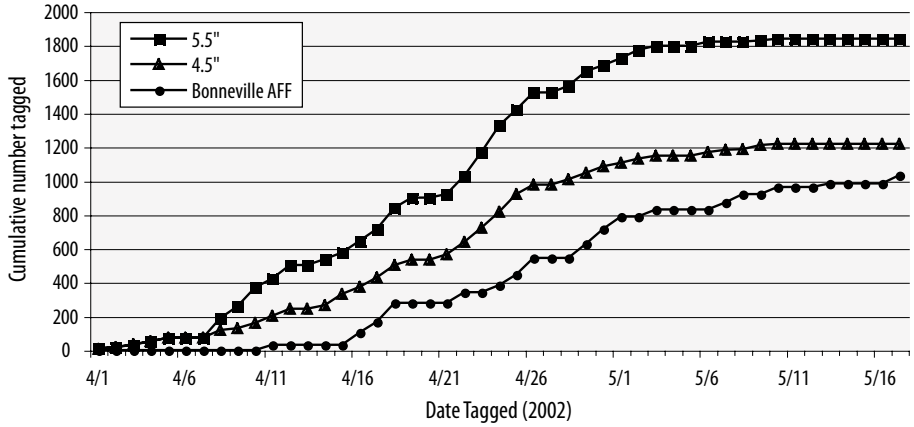

FIGURE 5. — Cumulative number of adult target fish tagged and released during test fishery and at the adult trapping facility with 11.4-cm (4.5-in) and 14.0-cm (5.5-in) mesh nets.

Recaptured fish

The number of recaptured fish are listed and the recaptured percentage is tallied. We also record the number and percent of recaptured fish that survive and are released in good condition.

Condition at capture

We provide a table that lists the number of fish by their initial condition as they are brought aboard the boat; if more than one net is used, a chi-square test is conducted to show if the distribution of the condition of targeted fish in each category is significantly different.

TABLE 3. — Adult fish (including recaptured fish) scored in each condition at capture category that were released (Rel'd) or died for each net

	Condition at capture									
	1		2		3		4		5	
	Lively		Lively, bleeding		Lethargic		Lethargic, bleeding		No visible movement or ventilation	
Net type	Rel'd	Died	Rel'd	Died	Rel'd	Died	Rel'd	Died	Rel'd	Died
Tangle										
Gill										
Total										

Next, we test whether the proportions of fish caught by the different capture types are significantly different between the two net types using a chi-square test.

TABLE 4. — Capture types of adult spring chinook salmon (includes recaptures) that were released (Rel'd) or died.

	Net type			
	Tangle		Gill	
Capture type	Rel'd (%)	Died	Rel'd (%)	Died
Gilled				
Mouth clamped				
Tangled				
Wedged				
Total				

Visible injuries

Visible injuries from net capture or marine mammal wounds are recorded. If more than one net type is used, they can be compared with a chi-square test.

TABLE 5. — Occurrence of visible injuries (%) on fish captured in each net type. The other category contains low occurrences of torn gills, torn operculum, and hook wounds.

Net type	De-scaling (%)	Net marks - body (%)	Net marks - head (%)	Marine mammal wounds (%)	Torn fins (%)	Other (%)
Tangle						
Gill						

Fork length

The range and average fork length for fish captured in the tangle net is provided. The mean fork lengths for fish that died before release and for recovered fish are provided. The soak times of the net for sets with dead fish can be compared to the average soak time for all sets using a *t*-test.

Species composition or bycatch

The number of nontarget species captured in the tangle net can be provided. Often, the actual numbers of nontarget fish may be underreported if this is not the primary goal of the study. We also mention the condition of the bycatch at release.

TABLE 6. — Count of nontarget species in the tangle net caught during the test fishery. ("Other fishes" includes walleye, flounder, carp, bass, and so forth, for which only a small number were encountered.)

Species	Tangle net
Shad	
Northern pike minnow	
Sturgeon	
Sucker	
Other fishes	
Total	

Temperature

The range and average for surface and water temperatures during test fishing are provided. The mean surface temperature for sets including fish mortalities is compared to the average temperatures for all sites and tested with a *t*-test to learn if temperature affects immediate survival.

Catch efficiency

For each day we are able to fish both nets equally, we can compare the catch per hour of targeted fish in each net. For adult-focused research, juvenile animals are omitted from the analysis. The fishing time includes only the time the nets are actually fishing and not the time spent preparing for the next set. Because we record only the time the first cork goes into the water (not when the shackle goes in), we designate the time to set the first net as 3 min in every case. The total fishing time for each net can then be calculated as the time from when the first cork of that net is placed in the water to the time when the last cork of that same net type is removed from the water. We calculate the total number of targeted fish for each net for each set. The total numbers of fish are summed with the set time for each net type by skippers for each day fished. The catch efficiencies of each net type can be compared using a paired t test or, for non parametric data, a Wilcoxon signed rank test.

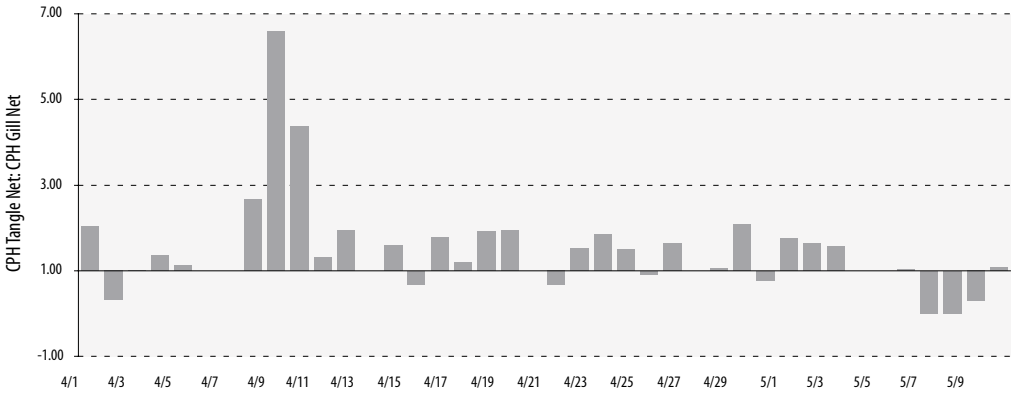

FIGURE 6. — Relative catch of adult spring chinook salmon per hour (CPH) for the tangle net compared to the gill net. Values at 1 indicate equal efficiency, those below 1 indicate when the tangle net was more efficient, and those above 1 indicate when the gill net was more effective. Paired sets were pooled by day across boat skippers.

TABLE 7. — Example of targeted fish per hour (CPH) capture rates during comparable sets for each net type.

Net type	Min. CPH	Max. CPH	Avg. CPH
Tangle	1.6	14.1	6.2
Gill	0.0	22.6	9.2

Postrelease

Postrelease analysis includes how recovery information is collected, the number of fish released from tangle nets, the number of fish recovered following their release from tangle nets, estimation of postrelease survival, comparison of recovery rates by boat skipper and location fished, and fish passage through detection centers.

We evaluate long-term survival of released fish by their returns to hatcheries, sport and treaty harvest, and at spawning ground surveys. Posters are produced that request the following information: date of harvest, location of harvest, tag color, and tag number. They are posted at various locations to target fishers. In addition, hatchery crews and stream surveyors are contacted and asked to return the same information. See Estimating Survival section for a description of how survival is estimated.

We record the number of fish that were given tags and released from the tangle net(s). Tags are recovered throughout sport and commercial fisheries, at hatcheries, and on the spawning grounds (Figures 8 and 9). We record when the first and last tags were recovered and provide a figure that shows the breakdown of jaw tag recoveries by fishery and the size of the estimated return to the natal stream over time. We subsequently report on the number of tags recovered.

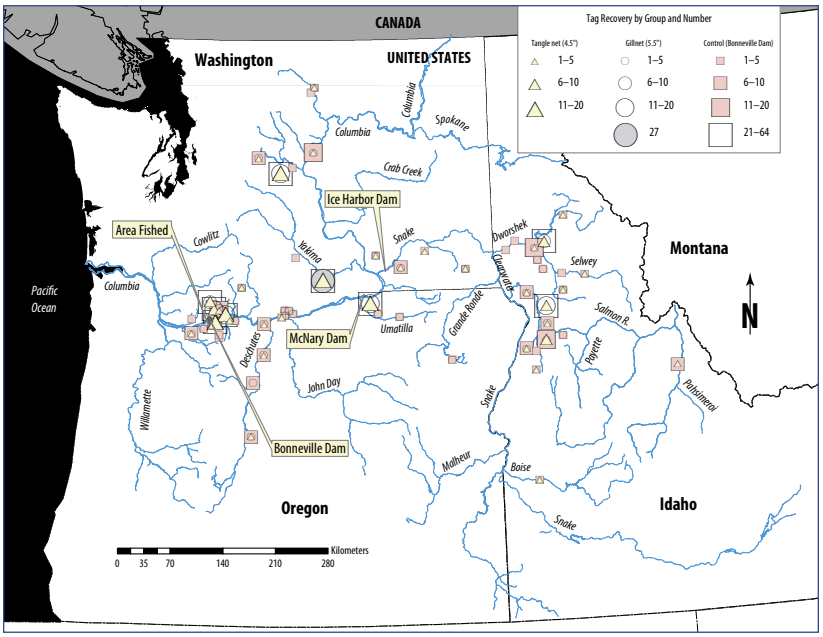

FIGURE 7. — Example of recovery locations of target fish captured and released from tangle nets and from the control fish trap. The area fished denotes the location where the test nets were fished and tagged fish were released from the test nets. The geographic area is the Columbia and Snake rivers.

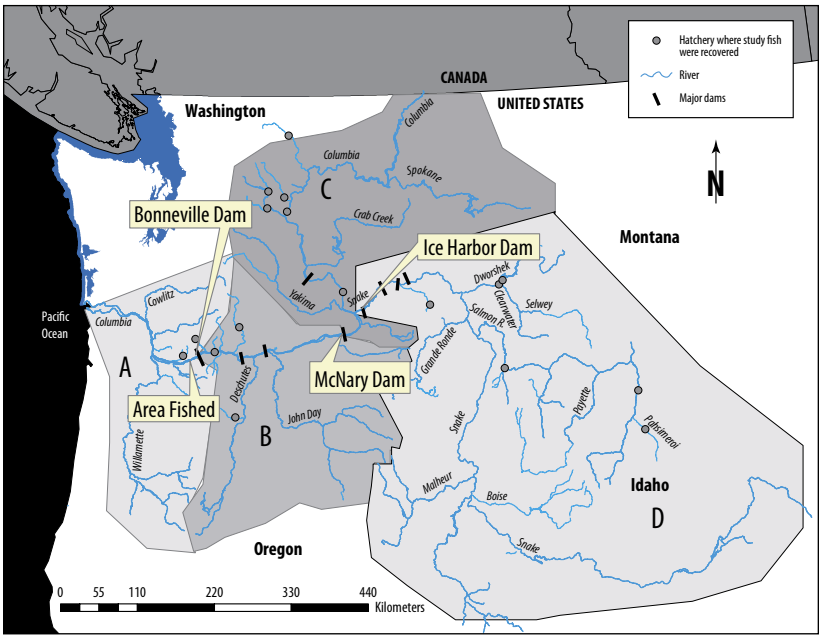

FIGURE 8. — Geographic areas where fish were recovered on the Columbia and Snake rivers: (A) Below Bonneville Dam, (B) between Bonneville and McNary dams, (C) Upper Columbia above McNary Dam, and (D) Snake River above Ice Harbor Dam.

TABLE 8. — Target adult fish released and number recovered by geographic area and chi-square test results.

Both nets	Control	Total	Chi-square test results
P > 0.05			
Number of fish released			
Recoveries: below Bonneville Dam			
Recoveries: Bonneville Dam to McNary Dam			
Recoveries: Snake R. above Ice Harbor Dam			
Recoveries: Columbia R. above McNary Dam			
Total			

The *Z*-statistic as described in Zar (1984) can be used to compare the two proportions and assess whether net size has a significant effect on postrelease survival.

TABLE 9. — Recovery of tag groups from hatcheries, fisheries, and spawning grounds.

Group	Number tagged	Number recovered	Percent recovered	Relative survival rate	95% confidence interval
Control				100%	N/A
Gill net					
Tangle net					

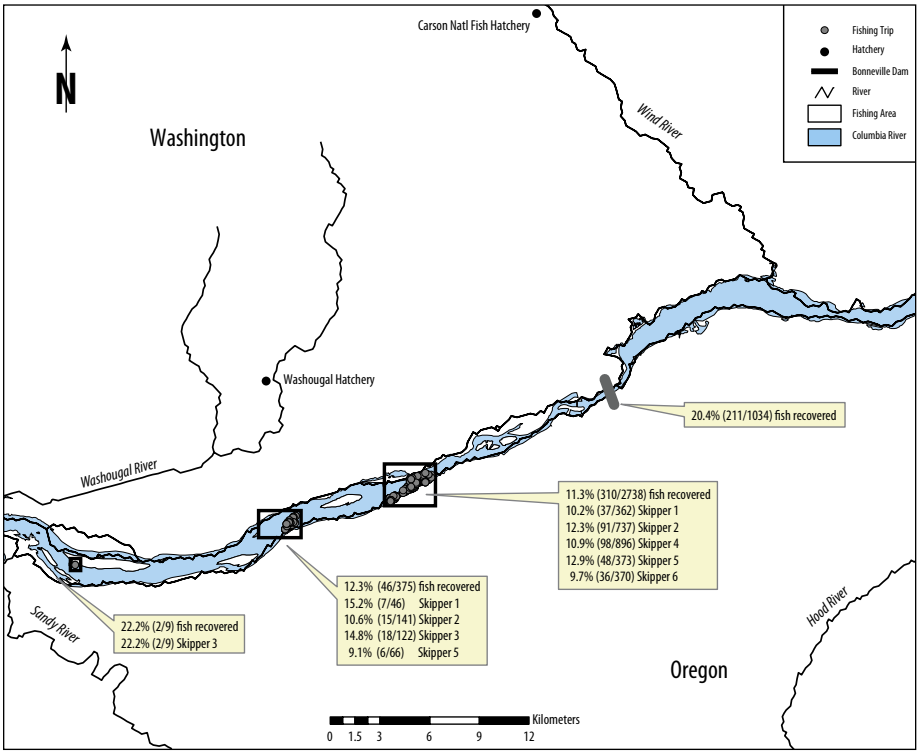

FIGURE 9. — Percentages of tagged fish from each fishing area that were subsequently recovered by boat skipper.

Passage over dams

This evaluation can occur if PIT or telemetry tags are used and if there is suitable placement and a suitable number of PIT detection centers or telemetry receivers. We give the range of passage days and dates for the first and last targeted fish detected at the first and last detection center.

Control fish

To evaluate survival for tangle net captured fish, a control is needed. With the exception of being captured in the tangle net, ideal control fish will have passed through all the same predatory and fishing pressures as the fish caught in the tangle net.

Archival procedures

Hard-copy data are archived in folder files by year. Electronic data are archived on computers, an external hard drive, and CD-ROMs.

Personnel Requirements and Training

Roles and responsibilities

The contracted fisher or fishers are responsible for driving the boat, deploying and retrieving the net, and ensuring that all applicable safety regulations are met. The researchers should not handle any of the boat operations. The contracted fisher is responsible for repairing the net. The fisher extracts the fish from the net and then hands the fish to the researchers. The researchers are responsible for data collection, sample processing, and tagging. These roles and responsibilities should be stipulated in the fisher's contract and made clear to the research staff.

Qualifications

All crew members must be able to handle, lift, and collect samples from fish. For spring chinook salmon, this means being able to lift, hold, tag, and release overboard fish that weigh as much as 30 lbs continuously for each set. Each set is about 45 min. Crew members need to stand for hours at a time, lift water totes and gear onto and off of the vessel, and repetitively tag fish, often in inclement weather. Furthermore, crew members should not be prone to seasickness. All crew members must wear life jackets and should be willing and able to work quickly and efficiently, and have excellent data collection and data entry skills.

Training

All crew members need to be trained in first aid, fish handling, species identification and basic biology, and tag application. Safe handling of the fish is a critically important part of this work: fish should be held with two hands—one hand around the caudal peduncle and the other hand holding the head. Holding the salmon in the tote with its belly up usually makes collecting length measurement and tag application easier.

Operational Requirements

Workload and Field Schedule

The employees needed for tangle-net monitoring include a research scientist, field leader, database lead, and research technicians. One to three research personnel are needed on each boat per boat day. In a recent research project targeting spring chinook or coho salmon, each boat day comprised 6–10 sets. A field leader schedules the research crew, arranges fishing days with the contract fishers, ensures that data are being entered accurately into the database, queries the database weekly, and sends a report to the research scientist in charge of the project. A database lead sets up the database for data entry, queries the database, and makes final correction checks. The database lead may also download portions of the database into a geographic information system and create appropriate maps of fishing and recovery site locations. The research scientist, field leader, and database lead write up final reports. Experimental design and any in-season changes are the responsibility of the research scientist.

The length and timing of the field season depend on the targeted species and stocks. For example, for spring chinook adult salmon returning to the Columbia River, the field season could begin in March and continue through mid-June. Tag recovery would likely occur from March through December. Data entry, data review, and results and report writeup would begin in March and be finalized by the following June.

Tangle-net fishing can occur at any time and in any area where gill-net fishing is suitable. In the case of targeting migrating fish, as fish capture tapers off, the research personnel are assigned to other activities associated with the study.

Equipment Needs

- Tangle net(s) suitable for capturing target fish
- Lead line and floats for the tangle net
- Plastic tote box to hold fish for measurement and sampling
- Dip nets
- Rain gear
- Life jackets
- Marking, tagging, and sampling supplies, data sheets, and pencils
- GPS units
- Tags and tagging equipment
- Computer for data entry and analysis
- Field office

For postrelease survival estimates, a suitable control is needed. This could be an adult trap or another fishing method such as a beach or purse seine. If a purse seine is used, the contracted fisher can provide all required equipment, including a net, skiff, and crew for deploying and retrieving the net. If the control fish need to be transported, a fish hauling tank and vehicle to haul the tank are needed.

Budget Considerations

- Cost to hire contract fishers (fishers supply boat and fuel and show proof of valid insurance)
- Cost for personnel
- Net, cork line, and recovery box costs (net may need to be replaced each year); cost to have net hung onto cork line
- Field equipment (e.g., life jackets, boots, rain gear, GPS units, thermometers, rainproof paper for data collection, computer, software)

Acknowledgments

Geraldine Vander Haegen contributed many of the experimental design and data analysis techniques that are now standard for tangle net research efforts.

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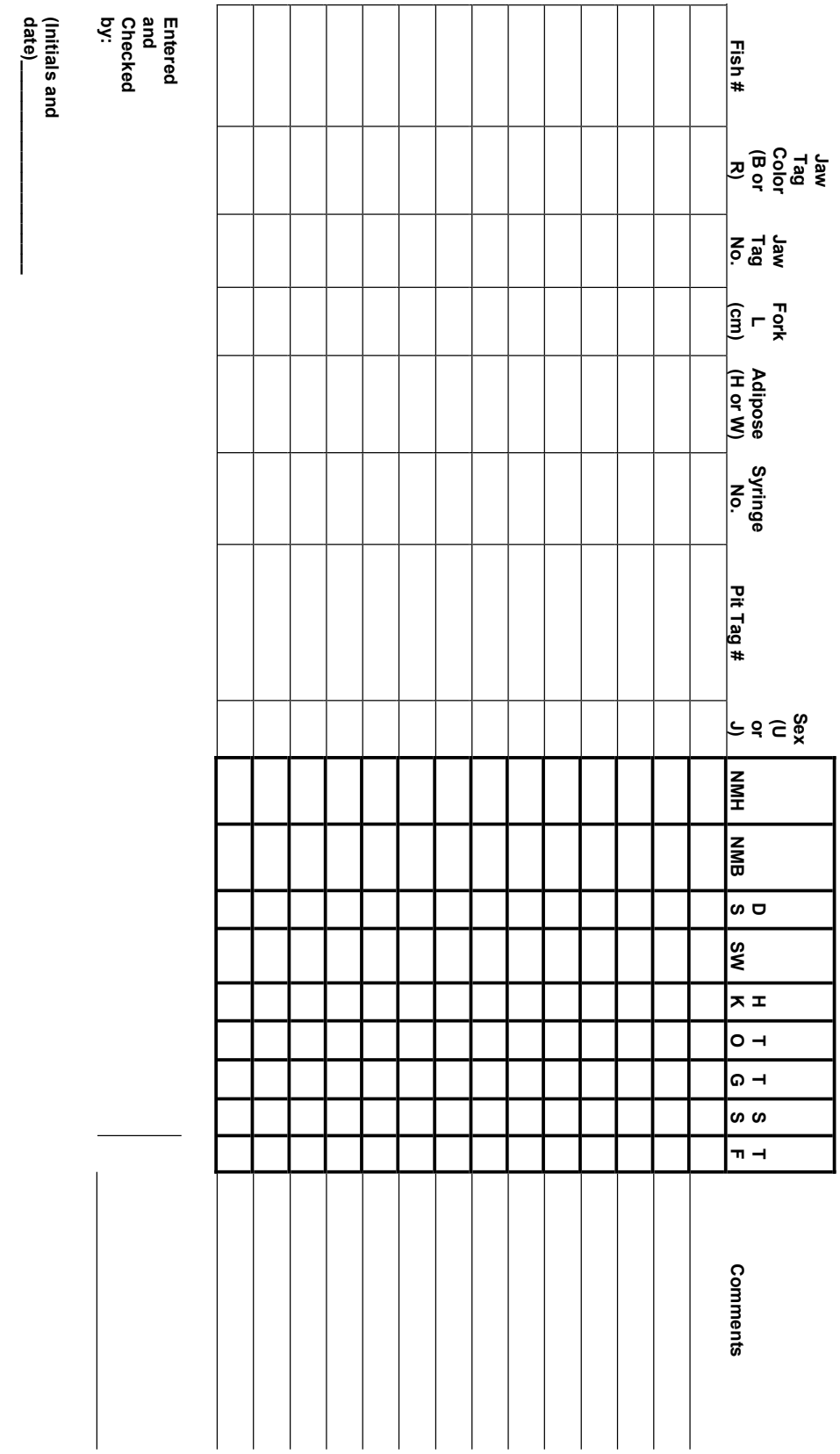
Appendix A: Tangle Nets Data Sheet



Appendix B: Tangle Nets Data Sheet

Idaho Cooperative Fish and Wildlife Research Unit & WDFW
Adult Tag Form: Lower Columbia- 2003
Date ____________________

Skipper___________
__

Boat ____________
Sampler ________________________
Recorder _______________________
LAT: __ __ . __ __ __ __ N
LON: __ __ __ . __ __ __ __ W

GPS unit:__________
Waypoint:__________

(circle one)
net IN water first: 4.25 4.5
net OUT of water first: 4.25 4.5

Set#_____of_____

Time 1st float In:

Time 1st float Out:
Time Shackle Out:
Time Last Float Out:

Fish #	Sp p.	Mesh Size	Capt. Type	Cond. at Capture	Sex: M/F/U/J	Adipose (H or W)	Fork L (cm)	Jaw Tag Color	Jaw Tag #	Syringe	Pit Tag #	Recovery Box Y/N	Sthd Tag Time	Release Cond.	SS	NMH	NMB	DS	SW (Visible In)	HK (Visible In)
													____:____		____:____					
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Date entered into:
(file name)___________________

Entered and Checked by:
(Initials and date)_____________________

Capture Types: T=Tangled, G=Gilled, MC=Mouth Clamp, W=Wedged

Condition Codes: 1=Vigorous, not bleeding, 2=Vigorous, bleeding, 3=Lethargic, not bleeding, 4=Lethargic, bleeding, 5=No movement or ventilation