Carcass Counts

Bruce Crawford, Thaddeus R. Mosey, and David H. Johnson

Background and Objectives

Background

Most adult anadromous salmon die shortly after returning from the sea to spawn in their natal streams. Their bodies contribute significantly to the nutrients needed by the next generation of salmonids (Wipfli et al. 2003), a wide array of wildlife species (Cederholm et al. 2001), and the larger watershed ecosystems in which they play an integral part (Wipfli et al. 1999; Bilby et al. 2001; Stockner 2003) (see Figure 1). This protocol deals with the counting and biological sampling of recently spawned anadromous salmonid carcasses. We have drawn heavily from Heindl (1989) in the development of this protocol.

Salmon carcasses provide important information to scientists, including scales, tissue samples, length measurements, and population sex composition data. Scales and otoliths are used to determine age and offer insights into the population's age characteristics. Fish lengths (i.e., length from postorbital to hypural plate—POHL) provide length–frequency information. Although snout to fork (fork length) is one measurement option, POHL is more useful because the tails of spawners, especially females, are frequently so worn that the fork is difficult or impossible to locate. It is also important to use POHL to avoid length distortion caused by jaw development (kype). Some scientists have taken postorbital to fork length, which we consider less useful because of the need for subsequent conversion to either POHL or fork length (S. Young, Washington Department of Fish and Wildlife, personal communication). Marks (fin clips and/or tags) provide key information on the fish's origins. A clipped adipose fin indicates a hatchery-origin fish, which many also have coded wire tags (CWT) implanted in their snouts. In the field, a coded wire wand or detector can be used to determine the presence of a CWT in the snout of the fish; without field detection, it is recommended to cut off the snout to assess the CWT information at a later point. Other types of markers and tags as well as radio telemetry units may be collected from carcasses where specific studies are involved. In addition to scales, tissue samples from hard body parts (e.g., fin rays, vertebrae, otoliths) may be collected for age determination. Soft tissue samples (e.g., liver, heart, eyes) may be collected for genetic analysis. Field staff use both foot and boat surveys to locate carcasses.

Combined with redd counts and live fish counts, carcass counts can be used to assess escapement as well as carcass-derived nutrient contributions to the ecosystem. Although data from this protocol can be used to support other assessments, this document does not focus on counts of salmonids that have undergone mass die-offs due to other causes (e.g., water temperature or oxygen level issues, strandings, poisons).

FIGURE 1.—Chinook salmon *Oncorhynchus tshawytscha* carcass. The marine-derived nutrients accumulated in salmon play an integral part in a healthy ecosystem. (Photo by Todd N. Pearsons, Washington Department of Fish and Wildlife.)

Rationale

Salmon carcasses are a source of biological samples (e.g., scales, other tissues) and crucial demographic measurements (e.g., body size, sex ratios, age). With marked fish, carcass recoveries offer a mechanism to support mark–recapture population assessments. Carcasses are also a means to assess the relative number of wild versus hatchery-based fish in the system. By estimating the numbers of spawning fish in a total redd count, one may determine the number of carcasses that need to be recovered (sampled) to evaluate key demographic and genetic aspects of hatchery and supplementation programs.

The ocean-derived nutrients salmon bring to spawning grounds are significant and play a substantial role in the functioning of a healthy ecosystem. Carcasses of adult hatchery fish are often placed in the upper reaches of the watershed for the nutrients they provide (Stockton 2003; Sanderson et al. 2004). Specific guidance for distributing salmonid carcasses has been developed in British Columbia (<www.bccf.com/steelhead/pdf/Carcass 2002 Final.pdf>) and Washington (<http://wdfw.wa.gov/hab/ahg/shrg_t11.pdf>). Carcass counts are often done in conjunction with foot-based visual counts of spawning fish and with redd counts.

Objectives

- Determine the length, sex, age, phenotypes, and genotypes of spawning fish by collecting a representative sample of the target species' carcasses.
- Determine ratios of hatchery origin and wild fish contributing to spawning populations.
- Recover carcasses in support of mark–recapture and other demographic studies.
- Determine contribution of nutrient amounts to ecosystem.

Sampling Design

Site Selection

Site selection for carcass surveys is based on the timing and spawning locations of adult anadromous salmonids. Streams should be divided into survey reaches prior to sampling; typically these are the same survey reaches that are used for redd counts. This can be done either through a randomized sampling protocol or through previous surveys that identify where the target salmon are known to spawn.

Sampling Frequency and Replication

Replication of carcass counts is necessary to estimate the total or relative number of spawners over the spawning season. Carcass counts are often done in conjunction with redd counts and/or counts of live spawning fish. As such, the expected spawning season should be identified for each survey. Surveys should be scheduled to begin before the first spawning takes place and to continue until after the last spawner completes the spawning process. Such counts are generally conducted every 7–10 days throughout the spawning season for the focal species.

Sample size for a given objective will be determined based on precision goal. For CWT analysis, the generally accepted sample size is 20% of the population of interest. Determination of estimates for proportion of gender, length, and age composition of a given population is dependent upon the precision requirements for those estimates. Estimates of the age composition of each gender of natural spawners and the overall proportion of each gender should be made so that all the estimated fractions are within ±5 percentage points of their true values 95% of the time. To estimate age composition using scales, the number of scale samples collected needs to be sufficient to estimate the mean length of major age classes (comprising >5% of the runs) so that all estimates are within ±10 mm of their true values 95% of the time.

We offer the following example, using chinook salmon. For age and gender, proportions from carcass sampling data, minimum sample sizes are as follows: the estimated escapement was approximately 4,000 females, 6,000 males ≥ age 3, and 1,500 males of age 2. Estimates based on redd count methodologies were lower than the estimates but would lead to smaller recommended sample sizes due to finite population correction. According to multinomial sampling guidelines in Thompson (1987), with an infinite population a sample size of 510 or greater will be adequate to ensure that proportions are within ±5 percentage points of the true values 95% of the time. We then applied the correction for finite population of $m=n/[1+(n-1)/N]$ where n is the initial sample size, m is the adjusted sample size, and N is the approximate population size (Zar 1984). Because not all collected chinook scales are readable (due to regeneration, etc.), we need to further adjust the sample size. Assuming >80% readable we then divide the sample size by 0.80 to get the final recommendation. Table 1 shows the target sample size of scale samples to be collected.

TABLE 1.—Sample sizes for achieving stated precision objectives for carcass and live fish recovery (either ±5 or ±10 percentage points at 95%). The starting points are 510 and 128, respectively, and are adjusted for finite population size and then for readable scales; ±10% is the stated goal.

Chinook	Pop. size	Corrected for			
		finite population		readable = 80%	
		±5%	±10%	±5%	±10%
Females	4,110	454	124	568	156
Males (over 50 cm, ≥age 3)	6,127	471	126	589	157

TABLE 2.—Numbers of fish to examine (*C*) to derive Petersen mark–recapture estimates with 95% confidence intervals of 10%, 25%, and 50% (100p*) of *N* across a range of population abundance (Robson and Regier 1964). A *p* value of 0.25 will yield 95% confidence intervals such that the point estimate is within ±25% of the true values 95% of the time.**

Estimated number in population (*N*)	Total number marked (*M*)	Percent marked	Number of fish to examine (*C*)		
			p=0.50	*p*=0.25	*p* =0.10
5,000	100	2	965	2,017	3,967
5,000	200	4	524	1,244	3,265
5,000	300	6	355	889	2,756
5,000	400	8	266	685	2,371
5,000	500	10	210	552	2,069
5,000	600	12	173	460	1,825
10,000	100	1	1,946	4,059	7,951
10,000	200	2	1,068	2,527	6,577
10,000	300	3	731	1,824	5,590
10,000	400	4	553	1,421	4,848
10,000	500	5	443	1,159	4,269
10,000	600	6	368	976	3,805
10,000	800	8	273	735	3,107
10,000	1,000	10	215	585	2,608
10,000	1,200	12	176	482	2,233
20,000	200	1	2,155	5,092	13,198
20,000	400	2	1,128	2,892	9,798
20,000	600	3	759	2,007	7,758
20,000	800	4	569	1,529	6,398
20,000	1,000	5	453	1,230	5,427
20,000	1,200	6	375	1,026	4,699
20,000	1,600	8	277	763	3,679
20,000	2,000	10	217	602	2,999
20,000	2,400	12	177	494	2,514

Source: Chinook Funding Proposal. "Assessment of Chinook Salmon Spawning Escapement in the Green River via Mark–recapture and Redd Surveys, 2002." ("New Project": One Year Study, July 1, 2002 through June 30, 2003; Mark–recapture Studies Funded in 2000, 2001; Redd Assessments Funded in 1999, 2000, 2001.) Submitted May 9, 2002, by Tom Cropp, Steve Foley, Pat Hanratty, Peter Hahn, Biometrician, Washington Department of Fish and Wildlife. Submitted to U.S. Section Office, Northwest Region, National Marine Fisheries Service. Table 1, page 14.

It is important to be aware that there are differential recovery rates of carcasses that may bias sampling (e.g., females tend to end up closer to the redds, and

lighter males may wash farther outstream [Zhou 2002]). Additionally, small fish may be underrepresented using carcass sampling because they are more easily scavenged and harder to see (Cropp et al. 2002).

Field/Office Methods

Setup

Prior to Arrival

Before a survey is undertaken, the surveyor must be well aware of what reach to survey, when the spawning season begins and ends, the time interval for the survey, what data are needed, and what equipment is required. The basis for the sampling design, including the source of information on spawning location, should be clearly and thoroughly documented in the project description metadata.

Equipment

The foot surveyor should be equipped with hip boots or waders, dark clothing or raingear to minimize disturbance to spawners, polarized sunglasses, appropriate carcass survey forms, maps, biological sampling forms, snout ID tabs and bags, and a handheld global positioning system (GPS) device. In some situations it is valuable for the surveyor to carry a CWT detection wand. Additional equipment for boat or canoe access includes life vests, dry bags, survival kit (containing matches, food, whistle, emergency blanket, etc.), helmets, and a throw line. See the equipment list on p. 68 for a full inventory.

Events/Sequence

Survey Description

Carcass surveys are usually undertaken at the same time that live fish or redd surveys are conducted. Be aware that carcasses can display evidence of numerous factors that affect the population being surveyed. Carcasses may be discovered at virtually any location in the stream and on the streambank. While they are most often located in slack water areas below spawning riffles, depending on the stream or river system, they may be distributed widely across bars, islands, and floodplain areas. When sampling a carcass, first examine it for marks, fin clips, operculum punches, tags, or telemetry units, and record each one noted. Next, measure the POHL (Figure 2) and record the result. The hypural plate forms the last and largest vertebra in the spinal column and is located in the caudal peduncle. The obvious flex point of the tail at the posterior edge of the hypural plate is the point to which measurements are made. Finally, open the abdominal cavity to determine the fish's sex and to ascertain the extent to which it spawned. If the carcass is a female, presence of only a few (<50 or so) loose eggs in the body cavity indicates a completely spawned fish. Larger numbers of retained eggs probably indicate incomplete spawning; in such cases, it will be necessary to estimate the percent of the eggs remaining and the percent of eggs deposited in the stream.

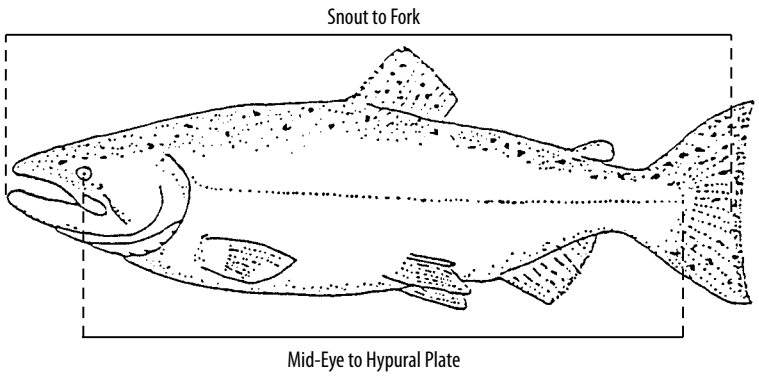

FIGURE 2.—Fish length measurements (from Heindl 1989). Note: The hypural plate forms the last and largest vertebra in the spinal column and is located in the caudal peduncle. The obvious flexpoint of the tail at the posterior edge of the hypural plate is the point to which measurements are made.

Other desired samples (e.g., scales, tissue) can then be removed and their collection noted on the applicable data forms. Scale sampling techniques are described in the following section. If the carcass carries a CWT (as detected by a CWT reader), remove its snout by cutting across the head, straight down behind the eyes, until reaching a point even with the line of the mouth. Next, place the knife in the fish's mouth and cut back toward the first incision until the snout is cut free. Finally, place the snout in a plastic bag with a numbered tag that identifies its source and enter the tag number on the data form. When sampling has been completed, cut the tail from the carcass to identify it as having been previously counted and sampled, and discard it.

In summary, the following steps are undertaken when conducting carcass counts:

1. Determine the species and whether it is a target species of the survey.
2. Assign the carcass a sample number and record the number on the data card.
3. Examine the surface of the fish for visible marks or tags. A missing fin will usually indicate a mark. The most common missing fin will be the adipose fin because it is used to indicate a hatchery-origin fish. A fish with a clipped adipose fin may also be tagged with a CWT in the snout. Record whether a mark has been observed on the appropriate form. A tag indicates that the fish is involved in a mark–recapture project to estimate overall population size.
4. Measure the carcass standard length to the nearest millimeter (postorbital to hypural plate).
5. Cut open the carcass and observe the gonads to determine the sex and record the information on the form.
6. If it is a female, evaluate the amount of eggs retained in the body cavity and estimate the egg retention percentage. This will require some previous training and familiarity with the fecundity of the target species. Record the percentage on the form.
7. Pass the CWT detection wand over the fish to determine if there is a CWT embedded in the snout. If a tag is detected, cut the forward end of the head (snout) off and place in a plastic bag. Number the snout sample with the same number as the carcass number.

8. Upon completing the process, cut the caudal (tail) fin off of the carcass to indicate that the carcass has been processed.
9. Repeat steps 1–8 for each carcass encountered or according to the established subsampling protocol.

Scale Sampling

Scale samples are collected to gain insight into the age and origin of the fish involved. Hatchery fish may be thermal-marked, a technique involving changes in water temperature at the hatchery that are reflected in the differential growth ring patterns shown in the otoliths. The scales most useful for analytical purposes (i.e., those containing complete growth records) are located along the sides of the fish, within the preferred area (Figure 3) (Clutter and Whitesel 1956; INPFC 1963). (The preferred area lies on either side of the fish, two to three scale rows above the lateral line and within six scale columns on either side of a diagonal line running from the posterior base of the dorsal fin to the anterior base of the anal fin.) Using a forceps or a small hemostat, remove six scales—three per side—from each fish sampled. If scales are missing from one side, take all samples from the other (and note this in the comments section of the data form).

If no acceptable scales can be found, do not collect any. Note that a good scale appears oval and well formed and, when held up to the light, shows a distinct central focal point with obvious concentric markings. Because they adhere tightly to their scale pockets, scales are frequently difficult to remove from carcasses. As a result, care must be exercised to collect only the scale and not other tissue parts. Examine each extracted scale for damage or regeneration (a consequence of previous scale damage).

Before mounting any scales, identify the scale card by labeling it with the sampling location, date, and card number. Put the fish's left-side scales *above* the cell number and its right-side scales below (see Figure 3). When mounting scales, it is important to orient each one similarly to facilitate subsequent reading and measuring in the lab. Also, place scales on the card in the manner they grew on the fish (with their exterior surfaces facing up). If in doubt whether the scale has been properly mounted, test it with a pencil point: a scale's rough outer surface will accept a pencil mark.

* About the size of this block

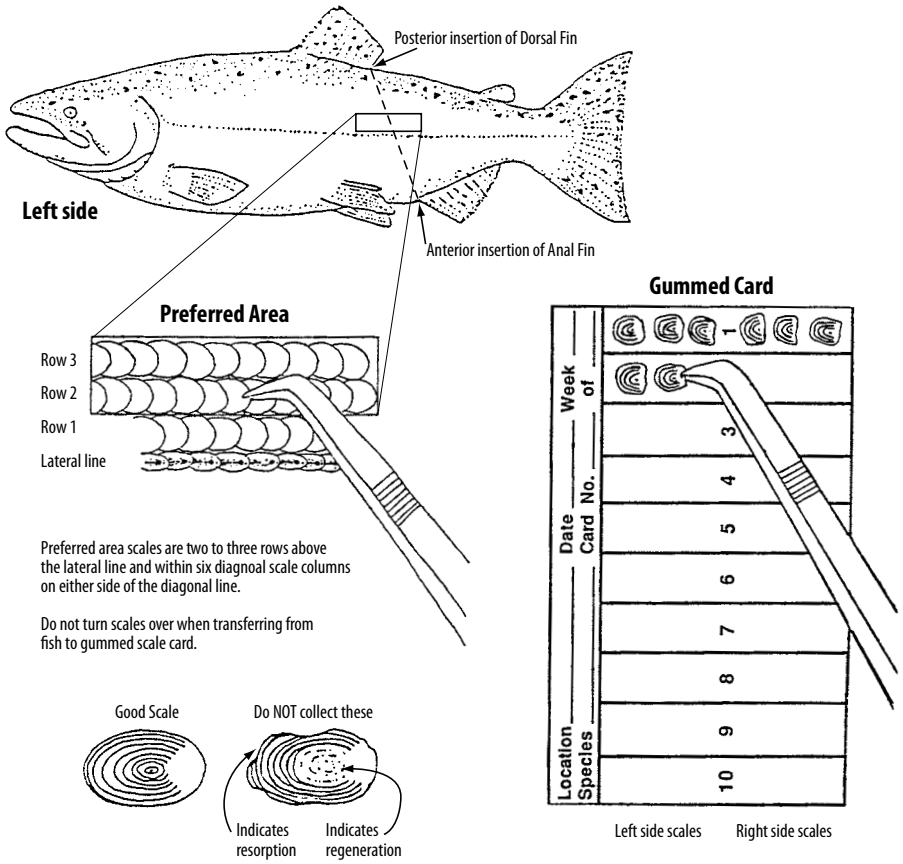

FIGURE 3.—Scale sampling procedure (from Heindl 1989).

Tissue Samples for DNA Analysis

From the U.S. Geological Survey lab, Anchorage, Alaska (<www.absc.usgs.gov/research/genetics/sampling.doc>).

- Ensure that your collection kit contains numbered microtubes (i.e., 1–100), a sample collection form, and a permanent marker.
- Record data associated with the respective sample (e.g., species, sample ID number, collection location, collection date, sex and age if known, name of the collector). Additional data may be required, depending upon study.
- Label the outside of the box (i.e., species, collection location, collection dates, collector name, and contact telephone number).

Fin Tissues

Tissue/1 vial/ethanol/room temperature

At least 50 fin samples for population genetic analysis and 3 or 4 reference samples (whole fish) for phylogenetic analysis need to be collected from each location. There are two methods for sample collection: dry or in vials with 100% ethanol (EtOH). The preferred method of collection is to store the tissue in a vial with 100% EtOH. If this is not possible, the following dry method can be used.

Tissue/1 container/dry/room temperature

Use clean scissors or a clean scalpel blade to cut a small piece of tissue from one of the fins of the live fish. Tissue size should be approximately 5 mm^2 *; a wedge from the upper or lower lobe of the tail fin works well. Although some DNA can be extracted from adipose fins, they are not easy targets because the tissue contains a lot of complex lipids. Eroded fins from dead salmon carcasses are highly degraded, and DNA is usually not readily extracted from such tissue. A well-dried 5-cm^2 piece of skin tissue works best under these conditions.

The date of collection, fish species and stock, type of collection method, and fish length, sex, and age (young of the year, juvenile, adult will suffice) should be collected with each fin where possible.

If samples are to be sent through the mail, ethanol should be drained from the samples immediately prior to mailing; the samples will be rehydrated upon receipt at the lab.

Dry Sample Collection (Alternative)

For the dry method, Whirl-Pack bags, Cryo-Tubes, or scale envelopes lined with high-quality filter paper work well. Either in the field after collection or in the office immediately upon return from the field, samples should be air-dried on filter paper or paper towels until all mucus and moisture in the fin have evaporated and the fin feels dry to the touch. Sun drying in the field works best and can be done quickly. Drying fins inside usually takes 18–24 hours at room temperature. Fungus and bacteria immediately invade the fins upon collection; these factors break down the cell walls of the tissue, and the DNA exudes into the surrounding medium, making DNA extraction in the lab difficult if not impossible. If drying is to be delayed for more than 4 hours, samples do best when packed on ice. DNA from moist-stored fins can often be all right for 6–8 hours, depending on the original condition and size of the fin clip.

Dried fin clips should be repackaged separately (make sure the baggy or envelope is also dry) and attached to field notes for shipment. Dry samples can be sent via surface mail without special packaging.

Hard tissue (bone or teeth/1 envelope/dry/room temperature)

Hard tissue samples such as bone or teeth should be kept as dry as possible. Because DNA is extracted from tooth pulp, the whole tooth is preferred. These can be stored in containers or envelopes.

Muscle (tissue/1 vial/tissue preservation buffer/room temperature)

Muscle tissue samples are the preferred samples for work that includes mtDNA analyses along with nuclear DNA analyses, particularly for birds. Among muscle tissue samples, heart is the most preferred, since the mtDNA yield is very high relative to nuclear yield. DNA can also be extracted from skin, teeth, and bone. Soft tissue samples can be stored at room temperature in the field in the tissue preservation buffer. Any muscle or skin tissue will work and can be stored in this buffer solution. It is important to ensure that the storage buffer completely covers the tissue sample. Also, make sure to clean instruments between sampling (to prevent cross-contamination) using a 10% bleach solution followed by a water rinse. A sample about the size of a pencil eraser is all that is needed, but make sure the sample is entirely submersed in the buffer.

Tags and Markers

Mark–recapture studies often employ various markers and tags (Guy et al. 1996). Floy ("spaghetti") tags are thin, colored pieces of plastic implanted into the body of the fish just beneath the dorsal fin. All tagged fish typically receive two tags of like color at the time of their trapping. Typical tag colors are blue, yellow, orange, grey, and brown. Jaw tags are another example of colored plastic tags; they are attached through the mouth region of the fish.

One technique of marking live fish for mark–recapture studies involves capturing fish and punching a small hole through their operculum (ODFW 2005), the bony flap covering the gills on both sides of the fish's head. Punches are typically made with a wide-gap paper punch and may be made in the left operculum, the right operculum, or both. For each side, there are three possible punch locations: above center, below center, and center; there are five possible hole shapes: square, round, rectangle, crescent, and triangle. Marks are stratified by Julian week and identified by the side of fish and area of operculum punched. The second capture event consists of recovering fish on the spawning grounds. All fish will be sampled for length, scales, and sex and checked for marks. Careful attention should be directed towards identifying opercula punches. Carcasses may fungus up, or the punch may skin over, making it difficult to see the mark. The gill cover may erode into the punch, changing the round hole to a crescent-shaped mark. Any remnant of an opercula punch will be recorded as a marked fish. Each fish will be sampled once and the tail removed.

Analytical Methods for Mark–recapture Data

The Chapman modification of the Petersen estimator can be used to estimate the population size of adult fish in each stream or river as long as all assumptions are met. From Seber (1982) the population size is estimated by

$$\hat{N} = \frac{(\hat{n}_1 = 1)\,(n_2 + 1)}{(m_2 + 1)} - 1 \qquad \text{(eq 1)}$$

$\hat{n}_1$ = estimated number of marked fish on the spawning grounds,
n_2 = the number of fish inspected for marks on the spawning grounds,
m_2 = the number of marked fish recaptured on the spawning grounds,

where

$$\hat{n}_1 = n_1 - mort - h - f \qquad \text{(eq 2)}$$

n_1 = the total number of fish marked at the seining or trapping site
mort = the number of tagged fish that were found dead within a few days of tagging
h = the number of tagged fish recovered
f = the number of tagged fish found (or extrapolated from radio tagging) downstream of the tagging sites or out of basin.

The assumptions for use of the Petersen estimator (Seber 1982, restated) are

1. all fish have an equal probability of being caught and marked at the first-capture site; *or*
2. all fish have an equal probability of later being inspected for marks (i.e., the second sample is a simple random sample); *or*
3. marked fish mix completely with unmarked fish in the population between events;

and

4. there is no recruitment to the population between capture events (population is closed);
5. there is not trap-induced behavior;
6. fish do not lose their marks and all marks are recognizable (and reported on recovery in the second sample);
7. survival is equal for marked and unmarked fish.

Data Handling, Analysis, and Reporting

Data from carcass counts should be entered into a database for data management. Separate counts for redds, live spawners, or carcasses should be maintained separately in the database. Table 3 provides metadata for variables that should be collected during the carcass surveys. Examples of field data forms for carcass count data are shown in ODFW 2005 and for the collection of genetic tissue samples in Appendix 1.

TABLE 3.—Sample parameters of adult anadromous salmonid carcass count data.

Description	Metric	Format	Comments
Species	Text	Text	Note the species sampled
River	Text	Text	Record the stream name and section being surveyed
Reach length	Meters	XXXX.X	Record the total distance of the survey reach
Dead	#	XXXX.	Number of carcasses observed
Days sampled	#	XXXX.	Record the total number of days sampled
Sample number	Text	XXXX.	Assign a number to the carcass sample. This number will correlate with the scale number and the snout number so that age and CWT information can be tied to the correct carcass
Carcass length	Cm	XXX.X	Record carcass length (POHL)
Sex	M/F	X	Record carcass sex
Carcass tag/mark	None, AD, CWT, RP, LP, D, RV, LV, AN, JT, ST	1–4	Record whether carcass had a mark or contained a coded wire tag. CWT = coded wire tag. AD = adipose clip, RP = right pectoral clip, LP = left pectoral clip, D = dorsal fin clip, RV = right ventral clip, LV = left ventral clip, AN = anal fin clip, JT = jaw tag, ST = spaghetti tag, None = no tag or mark
Scale sample	#	XXXX.	Record the scale envelope/card number
Egg retention	%	XX.X	Record the percentage of eggs retained in the carcass postspawning
CWT snout collection	Bag #	XXXX.	Record the bag number
Reach	Text	Text	Record the reach description and reach code
Scale position	Text	Text	Record the location where the scales were taken.
Date	Date		Record the date of the survey
Samplers	Text		Record the last name of the samplers
Start latitude	D, M, S	XX,XX,XX	Record the latitude (or universal transverse mercator [UTM] and zone) of the beginning survey point
Start longitude	D, M, S	XX,XX,XX	Record the longitude (or UTM and zone) of the beginning survey point

Description	Metric	Format	Comments
End latitude	D, M, S	XX,XX,XX	Record the latitude (or UTM and zone) of the end survey point
End longitude	D, M, S	XX,XX,XX	Record the longitude (or UTM and zone) of the end survey point
Temp	Degrees C	XX.X	Record the stream temperature at the time of the survey
Time	Time	Time	Record the time the survey began
Conditions	Text	Text	Record the water conditions and weather at the time of the survey
Other	Text	Text	Describe other samples taken and remarks

Data analysis procedures will vary with the objectives of the survey. Generally, however, data are evaluated with respect to the abundance or relative abundance of spawners throughout the spawning season. Other methods, such as area-under-the-curve (English et al. 1992), may be used to extrapolate the total number of spawners/redds/carcasses from the survey data.

Analytical Methods for Age and Gender Composition

We offer the following example, using chinook salmon:

The proportion of the spawning population composed of a given age within the single size group ≥ 50 cm in length is estimated as a binomial variable from fish sampled from each of the stock components, (a) hatchery fish and (b) natural spawner groups (equation 3). (The natural spawner group may be split into upper and lower river and into males and females.) Those less than 50 cm in length are usually 100% age 2 "jack" males (often very low sample size), whereas those ≥ 50 cm in length are age 3 and older.

$$\hat{p}_j = \frac{n_j}{n} \qquad \text{(eq 3)}$$

where $\hat{p}_j$ is the estimated proportion of the population of age *j;* n_j is the number of chinook salmon of age *j;* and *n* is the number of chinook salmon ≥50 cm in length taken on the spawning grounds.

Sample variance is calculated as

$$v(\hat{p}_j) = \frac{p_j(1 - \hat{p}_j)}{\mathrm{n} - 1} \qquad \text{(eq 4)}$$

Numbers of spawning fish by age are estimated as the summation of products of estimated age composition and estimated abundance within size categories *i*

$$\hat{N}_j = \hat{p}_j\hat{N} \qquad \text{(eq 5)}$$

with a sample variance calculated according to procedures in Goodman (1960)

$$v(\hat{N}_j) = v(\hat{p}_j)\hat{N}^2 + v(\hat{N})\hat{p}_j^{\,2} - v(\hat{p}_j)v(\hat{N}) \qquad \text{(eq 6)}$$

Sex composition and age-sex composition for the entire spawning population and its associated variances are also estimated with the equations above by first redefining the binomial variables in samples to produce estimated proportions by sex $\hat{p}_K$, where *k* denotes gender (male or female) such that $\sum_k \hat{p}_j = 1$, and by age-sex $\hat{p}_{jk}$, such that $\sum_{jk} \hat{p}_{jk} = 1$.

Personnel Requirements and Training

Responsibilities

A crew of two carcass count surveyors should be used. They can split up part of the survey area if necessary, but two persons should be employed for safety reasons. The project leader supervises the crew and must ensure that each surveyor or team carries all necessary maps and equipment.

Qualifications

The staff conducting a spawning survey should have been properly trained by an experienced field biologist and should have 1 year of experience in sampling fish. Volunteers can be used when carefully trained and evaluated.

Training

Crews should be trained in the classroom first with illustrations of sampling techniques, equipment needed, process for location of survey reaches, and so forth. This should be followed up with at least one survey with an experienced instructor who can assist the student in the field sampling techniques of carcass counts and scale/tissue sampling.

Operational Requirements

Field Schedule

The field schedule for carcass counts is determined by the spawning season of the target species.

Equipment List

Item	Comments	Cost
Data forms and backing	e.g., clipboard, digital data device	
Pencils		
GPS handheld device	Used to record survey latitude and longitude or UTM	
Cell phone and/or Motorola FM 2-way TalkAbout radios	Useful for emergencies and for maintaining contact with other crews	
Polarized glasses		
Wading gear with belt	Not recommended if rafting	
Metric measuring tape		
Forceps or hemostat	For taking scale samples	
Scale cards/envelopes	For collecting scales	
Rubber bands	For holding cards/envelopes together	
Knife and sharpener		
Machete		
Water thermometer		
Scalpel	For removing soft tissue	
Small saw or wire cutters	For cutting off snouts	
Collectors permits	State and/or federal as needed	

Item	Comments	Cost
Tissue sample containers	Glass or plastic vials with caps	
Labels	To identify tissue samples	
Plastic bags	For carrying snouts, etc.	
Small ice chest and dry ice	If gonadosomatic index samples are collected	
First-aid kit		
Colored flagging or spray paint	For marking multiple survey reaches	
Indelible markers	For marking flagging	
Day pack	For carrying supplies, lunch, etc.	
Extra clothing	Jacket, raingear, hat	
Rubber raft	If floating on a river	
Air pump		
Spare oar or paddle		
Spare oarlock		
Tool kit	Pliers, crescent wrench, wire, heavy tape, bolts, nuts, washers, etc.	
Rope		
Waterproof bag		
Flotation vest		
Wet suit		

Budget

The following guidelines can be used to calculate budget.

Activity/item	Cost
Equipment	variable
Staff time for two biologists to walk the stream reach.	3 hours
Travel time	variable
Preparation time	1 hour
Training	1 hour
Lab workup	2 hours
Data analysis	8 hours

Literature Cited

Bilby, R. E., B. R. Fransen, J. K. Walter, C. J. Cederholm, and W. J. Scarlett. 2001. Preliminary evaluation of the use of stable isotope ratios to establish escapement levels for Pacific salmon. Fisheries 26:6–14.

Cederholm, C. J., D. H. Johnson, R. Bilby, L. Dominguez, A. Garrett, W. Graeber, E. L. Greda, M. Kunze, J. Palmisano, R. Plotnikoff, B. Pearcy, C. Simenstad, and P. Trotter. 2001. Pacific salmon and wildlife -ecological contexts, relationships, and implications for management. In D. H. Johnson and T. A. O'Neil, managing directors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission Bulletin 9.

Cropp T., S. Foley, P. Hanratty, and P. Hahn. Chinook Funding Proposal. "Assessment of Chinook Salmon Spawning Escapement in the Green River via Mark–recapture and Redd Surveys, 2002." ("New Project": One Year Study, July 1, 2002 through June 30, 2003; Mark–recapture Studies Funded in 2000, 2001; Redd Assessments Funded in 1999, 2000, 2001.) Submitted May 9, 2002, by Tom Cropp, Steve Foley, Pat Hanratty, Peter Hahn, Biometrician, Washington Department of Fish and Wildlife. Submitted to U.S. Section Office, Northwest Region, National Marine Fisheries Service.

English, K. K., R. C. Bocking, and J. R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Science 49:1982–1989.

Goodman, L. A. 1960. On the exact variance of products. Journal of American Statistical Association 55:708–713.

Guy, C. S., H. L. Blankenship, and L. A. Nielsen. 1996. Tagging and marking. Pages 353–383 in B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Heindl, A. L. 1989. Columbia River chinook salmon stock monitoring project for stocks originating above Bonneville Dam, field operations guide. Columbia River Inter-Tribal Fish Commission, Technical Report 87-2 (revised), Portland, Oregon.

INPFC (International North Pacific Fisheries Commission). 1963. International North Pacific Fisheries Commission Annual Report–1961. International North Pacific Fisheries Commission, Seattle.

ODFW (Oregon Department of Fish and Wildlife). 2005. Coastal salmon spawning survey procedures manual 2005. Oregon Department of Fish and Wildlife, Corvallis.

Robson, D. S. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215–226.

Sanderson, B., P. Kiffney, C. Tran, K. Macneale, and H. Coe. 2004. Assessment of three alternative methods of nutrient enhancement (salmon carcass analogs, nutrient pellets, and carcasses) on biological communities in Columbia River tributaries. 2003–2004 Annual Report, Project No. 200105500. Bonneville Power Administration, BPA Report DOE/BP-00007621-1, Portland, Oregon.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, 2nd edition. MacMillan and Company, New York.

Stockner, J. 2003. Nutrients in salmonid ecosystems: sustaining production and biodiversity. American Fisheries Society, Symposium 34, Bethesda, Maryland.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41(1):42–46.

Wipfli, M. S., J. P. Hudson, D. T. Chaloner, and J. P. Caouette. 1999. Influence of salmon spawner densities on stream productivity in southeast Alaska. Canadian Jounal of Aquatic Science 56:1600–1611.

Wipfli, M. S., J. P. Hudson, J. P. Caouette, and D. T. Chaloner. 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase growth rates of stream-resident salmonids. Transactions of the American Fisheries Society 132:371–381.

Zar, J. H. 1984. Biostatistical analysis. 2nd edition. Prentice Hall, Englewood Cliffs, New Jersey.

Zhou, S. 2002. Size-dependent recovery of chinook salmon in carcass surveys. Transactions of the American Fisheries Society 131:1194–1202.

Appendix A

Personal communication from Sewall Young, WDFW, April 3, 1999: Fork length estimates based on postorbit to hypural plate length.

Fork length estimates based on post-orbital to hypural plate length

POHL

Group	slope	intercept	45	50	55	60	65	70	75	80	85	90	95	100	105	110
Hatchery Spawners																
All females	1.19	3.55	57	63	69	75	81	87	93	99	105	111	117	123	129	134
Green River remales	1.2	2.91	57	63	69	75	81	87	93	99	105	111	117	123	129	135
WA coast females	1.13	8.45	59	65	71	76	82	88	93	99	105	110	116	121	127	133
Columbia River females	1.2	2.82	57	63	69	75	81	87	93	99	105	111	117	123	129	135
All males	1.29	-0.6	57	64	70	77	83	90	96	103	109	116	122	128	135	141
Green River males	1.3	-0.58	58	64	71	77	84	90	97	103	110	116	123	129	136	142
WA coast males	1.2	5.12	59	65	71	77	83	89	95	101	107	113	119	125	131	137
Columbia River males	1.31	-1.82	57	64	70	77	83	90	96	103	110	116	123	129	136	142
Natural Spawners																
All females	1.13	7.26	58	64	69	75	81	86	92	98	103	109	115	120	126	132
WA coast females	1.07	12.37	61	66	71	77	82	87	93	98	103	109	114	119	125	130
Columbia River females	1.11	8.77	59	64	70	75	81	86	92	98	103	109	114	120	125	131
All males	1.23	3.41	59	65	71	77	83	90	96	102	108	114	120	126	133	139
WA coast males	1.17	7.21	60	65	72	77	83	89	95	101	107	113	118	124	130	136
Columbia River males	1.25	2.59	59	65	71	78	84	90	96	103	109	115	121	128	134	140

From personal communication with Sewall Young (Washington Department of Fish and Wildlife, April 3, 1999).

Appendix B

Coastal Salmon Spawning Survey Procedures Manual 2005, Oregon Adult Salmonid Inventory and Sampling Project (OASIS), Oregon Department of Fish and Wildlife, pp. 14 and 28–42.

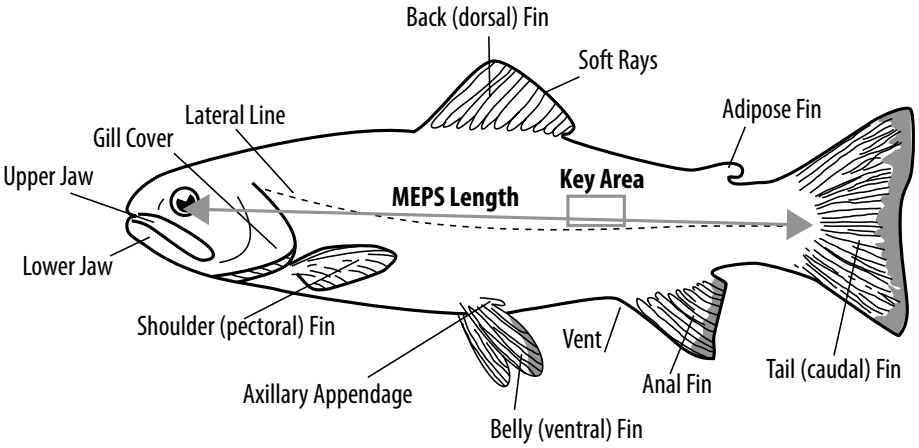

FIGURE 1. — This diagram of a generic salmon identifies fin names, the Key Area for collecting scale samples, and guideposts for measuring the mid-eye-to-posterior-scale (MEPS) length.

SPAWNING SURVEY FIELD FORMS

There are four forms used for recording spawning survey data.
They are:

1. Spawning Fish Survey Field book (*used in field*)
2. 2005 Spawner Survey Form *(stays in office)*
3. Biological Sampling Form 2005 *(used in field)*
4. Survey Evaluation Form *(stays in office)*

The function and directions for use of each of these forms is as follows:

Spawning Survey Field Book

- Pocket-sized books with 40 forms per book.
- Used for recording survey conditions, tallying fish and redd counts and recording comments (see below).
- Data are transcribed to ***2005 SPAWNER SURVEY FORM*** at end of each day.
- Completed forms are kept at your workstation and turned in to crew leaders at end of season.
- Codes and abbreviations can be found on the front and back cover of the field books.

SPAWNING SURVEY FIELD BOOK:

Survey: _____ **Date:** _____
W: ____ **F:** ____ **V:** ____ **Fish Activity: CH** ___ **CO** ___ **CM** ___

	Live				Dead					
	unMk	Mk	Unk.	Jack	Male	Fem	Jack	Unk	PHA	PHJ
Redds										

(Use reverse side for comments and gravel counts)

2005 SPAWNER SURVEY FORM

REACH ID: _____ *SEGMENT:* ____

DISTRICT: _____ **SURVEY:** _____ (___)MILE **TARGET SPECIES:** _____

BASIN: _____ **UTM COORDINATES:**

SUBBASIN: _____ **UP-E** **UP-N** **DOWN-E** **DOWN-N** **SURVEY TYPE:** _____

_____ _____ _____ _____

LOCATION: _____

_____

_____

_____

Date	Surveyor ID	Survey Conditions			Live Fish Activity			Comments		REDDS	CHINOOK							COHO										CHUM				STLHD
											Live		Dead					Live				Dead							Live	Dead			
mm/dd		W	F	V	CH	CO	CM	C1	C2		A	J	M	F	J	U	PHA	UnMA	MkA	UnKA	J	M	F	J	U	PHA	PHJ	A	M	F	U	

Send copies of this sheet to the Corvallis Research office on the 1st and 15th of every month. *Return original datasheet to Corvallis at the end of the season.*

2005 SPAWNER SURVEY DATA FORM INSTRUCTIONS

This data form is used to record tallied counts and activities of spawning salmon and other associated aspects of the survey.

- Forms are kept in the office and data are transcribed to this form daily.
- Copies of forms must be **received** by the Corvallis Research Lab (attention: LaNoah Babcock) by the **1st and the 15th of each month** for data entry.
- Original forms are sent to Corvallis at end of season.
- Remember to **highlight** any changes on both originals and copies

Header

NOTE: Survey location, survey description, survey type and target species are preprinted on forms for all established surveys. All fields in the header will need to be filled in for new survey areas.

Reach ID and Segment: (preprinted on form)

Used to uniquely identify each survey area. Supplied by Corvallis OASIS.

District: (preprinted on form)

1 - North Coast
2 - Tillamook
3 - Lincoln
4 - Siuslaw
5 - Umpqua
6 - Coos/Coquille/Tenmile
7 - Lower Rogue/South Coast
8 - Upper Rogue
20 - Columbia River Management
21 - Lower Willamette

BASIN, SUBBASIN: (preprinted on form)

Major basin and sub basin where survey area is located as defined by Corvallis OASIS.

UTM COORDINATES: (preprinted on form)

UTM coordinates for downstream and upstream boundaries of survey segment.

- Check to see if the coordinates are correct whenever possible. If incorrect, update directly onto spawner survey form and highlight. Make sure to use the Averaging function on your GPS unit when obtaining coordinates.

START COORD: (preprinted on form)

Township, Range and Segment at downstream boundary of survey segment.

LOCATION: (preprinted on form)

Survey description. Check and revise if necessary. Pay close attention to any instructions for landowner notification/compliance and routes for exiting survey segment.

TARGET SPECIES (preprinted on form)

Species that is the focus of the survey:

1 - Fall Chinook
2 - Coho
3 - Chum
4 - Steelhead
5 - Summer Chinook

SURVEY TYPE (preprinted on form)

1 - Standard index survey
2 - Supplemental survey
3 - Spot-check
4 - Random
5 - Lake (coho only, Tenmile, Siltcoos and Tahkenitch Lakes)
6 - Volunteer
7 - (NWHF) National Wildlife Heritage Foundation
8 - BLM

Body

DATE

Date of the survey: Enter the month and day the survey took place (e.g. 01/22).

SURVEYOR ID

Surveyor ID number

Used to identify the person conducting the survey. If a survey is divided between surveyors, the surveyor filling out the survey form should use his/her ID number. **Also make sure when splitting the survey to get ALL of the information from your partner and write it on your survey form.**

W (WEATHER)

Describe the weather as:

C - Clear
O - Overcast
F - Foggy
R - Rain
S - Snow
P - Partly Cloudy

F (FLOW)

Describe the stream flow as:

L - Low or Dry ***stream covers less than 50% of the active channel width***
M - Moderate ***stream covers 50% to 75% of the active channel width***
H - High ***stream width covers > 75% of the active channel width and stream height approaches bankful***
F - Flooding ***stream is out of its banks***

V (VISIBILITY)

Describe stream visibility as:
1 - Can see bottom of riffles and pools
2 - Can see bottom of riffles
3 - Cannot see bottom of riffles or pools (check several areas before making this determination – see page 56)

LIVE FISH ACTIVITY

Live fish activity of each species observed must be recorded.

13 Most fish spawned out

14 Most fish holding in pools (prior to spawning)

15 Most fish migrating through survey area

16 Most fish actively spawning (as demonstrated by courtship behavior, excavation of redds, competition for mates, and guarding of redds)

Comments

Use comment codes from the following list. There is room for two comments per survey. Prioritize comments on the Salmon Spawning Survey Form according to the priority of the categories listed below. If further comments would be useful, record the date and comment code on the reverse side of the Spawning Survey Evaluation Form.

Comment Codes

Marks and Tags (Priority I, Highest Priority*)*

This category must be represented in the comment section when appropriate

50 Adipose (CWT) fish observed
51 Adipose (CWT) fish observed, snout recovered
52 Live tagged fish observed
53 Dead tagged fish observed
54 Dead tagged fish observed, tag recovered
55 Fin clipped (other than adipose fin) fish observed

Redds (Priority I, Highest Priority*)*

71 Number of redds estimated because of high density

Area Surveyed (Priority II Mid Priority)

01 Includes tributary to survey *(Used when fish are encountered in tributary of parent survey. See page 57 for details*)
02 Holes not surveyed *(Used when water is too high to survey holes)*
03 Survey boundary description change

Factors Affecting Fish Abundance (Priority II, Mid Priority)

40 Poaching
42 Stream low
43 Stream dry
44 Instream habitat improvement in or near survey section
45 Habitat damage in or near survey section
46 Passage barriers below survey area
47 No survey conducted due to drought conditions
66 Actual number probably substantially higher than observed
97 Placed coho carcasses

Viewing Conditions (Priority II, Mid Priority)

20 Dark (pertains to the light source, not the water clarity)
21 Dark in pools (pertains to water quality, often tannins)
22 High glare
23 Partly frozen
24 Not surveyable (stream too high and/or turbid, counts will be disqualified)

Comments (continued)

Survey Timing (pertains to TARGET SPECIES) (Priority III, Lowest Priority)

NOTE: These codes need only be used when two or more surveys during the season are separated by more than ten days. **These codes are used in cases where the stream segment is not surveyed over the course of the spawning season (typically due to extreme stream flows).** They are an indication of whether the surveyor feels the peak run was sampled or the survey was ended too early or too late.

10 Peak survey
11 Survey too early--before peak
12 Survey too late--after peak

Stream Conditions within the Survey Area (Priority III, Lowest Priority)

31 Impassable logjam
32 Passable logjam
33 Impassable beaver dam
34 Passable beaver dam
35 Impassable culvert
36 Evidence of scouring of streambed
37 Severe stream bank erosion
38 Passable culvert

Miscellaneous (Priority III, Lowest Priority)

60 Most carcasses washed out
61 Heavy silt deposition in streambed
62 Count in holes estimated
64 Exposed redds due to low flow
65 Redds obliterated due to high flow
67 No new spawning fish observed
88 Road closed or impassable/ inaccessible
39 Octopus at milepost 12

REDDS

Number of spawning redds observed

A redd is defined as the single excavated depression dug by a female. Individual redds may overlap,. and form clusters. A redd may be identified by a hollow in the gravel and the adjacent downstream plume of excavated gravel. The gravel from a recently dug redd will usually appear lighter colored and less uniformly oriented than the undisturbed gravel. Care should be taken not to confuse redds with general stream scouring or scouring associated with wood, rootwads, or larger rocks.

When it is not possible to distinguish individual redds because of high redd density estimate count and include comment 71 under comments.

CHINOOK

LIVE

A -Number of live adults
J -Number of live jacks

DEAD

M -Number of dead males
F -Number of dead females
J -Number of dead jacks
U -Number of dead unknown sex
PHA -Number of previously handled dead adults (tails removed)

A chinook jack is defined as a male measuring 510 mm (20 inches) or less in MEPS length or 600 mm (24 inches) or less in fork length.

MEPS length is the "mid-eye to posterior most scale" (anterior edge of tail) measurement.

COHO

LIVE

UnMA -Number of live adults with intact adipose fin
MkA -Number of live adults with adipose fin removed
UnKA -Number of live adults, presence of adipose fin undetermined
J -Number of live jacks

DEAD

M -Number of dead males
F -Number of dead females
J -Number of dead jacks
U -Number of dead unknown sex or unknown finclip
PHA -Number of previously handled dead adults (tails removed)
PHJ -Number of previously handled dead jacks (tails removed)

A coho jack is defined as a male measuring 430 mm (17 inches) or less in MEPS length, or 500 mm (20 inches) or less in fork length.

CHUM

LIVE

A -Number of live adults

DEAD

M -Number of dead males
F -Number of dead females
U -Number of dead unknown sex

STLHD Number of steelhead (total count of live and dead).

Biological Sampling Form

Surveyor ID_____ **Year_____** **Page ___ of ___**

Line #	Date mm/dd	Reach ID	Segment	Species	Sex	Length (MEPS)	Clip	Carcass Condition	Scale #	DNA #	Snout #	Mark-Recapture coho and/or chinook			Opercule chinook only		Comments		
												Color	Carcass Tagged **Tag 1**	Carcass Tag Recov. **Tag 2**	Left	Right	C1	C2	C3
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

Appendix C: Genetic Sample Collection Form

Collection box type:	Short-term storage:
Species:	Collection location:
Dates of collection:	Contact name and telephone number:

Tube #	Species	Collection location	Collection date	Sex	Age	Notes/ comments
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						

Place a copy of the DNA Sample Collection Form in the sample box.

Label the outside of the box with collection information (i.e., species, collection location, dates of collection, contact telephone).