COLUMBIA RIVER CHINOOK SALMON STOCK MONITORING PROJECT FOR STOCKS ORIGINATING ABOVE BONNEVILLE DAM

FIELD OPERATIONS GUIDE

Technical Report 87-2 (Revised)

Alex L. Heindl

25 May 1989

YAKIMA NEZ PERCE WARM SPRINGS UMATILLA

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
975 S.E. Sandy, #202, Portland, OR 97214, (503) 238-0667

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CONTENTS

I. PROJECT DESCRIPTION

The United States - Canada Pacific Salmon Treaty is designed to conserve and rebuild salmon stocks through ocean fishery regulation. To monitor the impacts of Treaty-imposed ocean harvest controls, the Treaty established research programs to identify, categorize, and determine population sizes of many Pacific Northwest salmon stocks.

The Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes will conduct fieldwork to help implement Pacific Salmon Treaty monitoring programs. The research will consist of two separate but related projects: Stock monitoring and stock identification. This manual applies to stock monitoring and describes rationales and methodologies for assessing spawning escapement of "indicator" chinook stocks -- stocks that federal, state, and tribal biologists believe are likely to reflect the effects of Treaty-imposed regulations through changes in escapements from the offshore fisheries. A separate manual (Schwartzberg 1987) has been created to describe the associated stock identification research. The purpose of both is to ensure standardization in the various sampling and field data collection aspects of the monitoring programs.

Stock Monitoring

From the perspective of the United States, a primary reason for negotiating the US-Canada Treaty was the need to rebuild the Pacific Northwest's naturally spawning chinook stocks. Of

particular concern were stocks originating in the Columbia River, historically North America's most productive system.

Under the Treaty, the United States and Canada must regulate their offshore fisheries to the degree necessary to allow Columbia River chinook stocks to be rebuilt by 1998. Compliance with Treaty objectives is measured in terms of increased escapement to the spawning grounds. Seven Columbia River spring chinook stocks (Middle Fork Salmon and Selway in Idaho; Wenatchee and Yakima in Washington; and Grande Ronde, Imnaha, and John Day in Oregon) have been chosen as the initial "indicators." Each is being monitored to determine the success or failure of the rebuilding program. Although some escapement data on these stocks has been previously collected, concerns about its consistency, comparability among different stocks, and statistical reliability have led the Pacific Salmon Commission to require an expanded and improved spawning escapement information base for the Columbia River Basin.

During US-Canada-funded spawning ground surveys, redds (spawning nests), live salmon, and dead salmon (carcasses) are located, counted, and -- in the case of carcasses -- sampled for various information that will help to assess stock health. Redd counts are used to develop indices of spawning escapement and success. Live fish numbers provide an indication of spawn-timing. Carcasses are a source of biologic samples (scales and other tissues), and also provide measurements for describing the population's growth parameters, sex ratios, and spawning success.

II. DATA COLLECTION

TYPES OF DATA AND SAMPLES COLLECTED

a. Redd numbers indicate the extent of stream use by spawning fish, the time of spawning, and also provide an estimate of deposited egg numbers.

b. Live fish counts provide insight into the potential for and timing of spawning activity within a stream.

c. Carcasses supply scales, tissue samples, length measurements, and population sex composition information.

d. Scales are used to determine age. Collecting sufficient numbers of scales from different individual fish provides an opportunity to estimate a population's age characteristics.

e. Lengths (mid-eye to hypural plate and snout to fork) provide length-frequency information. The mid-eye to hypural length is the more useful of the two measurements because tails of spawners, especially of females, are frequently so eroded that the fork is difficult or impossible to locate.

f. Marks (fin clips and/or tags) are noted to preserve information valuable to other researchers (i.e., those who applied the marks). If the carcass' adipose fin is clipped, the snout will be collected so that the coded-wire tag within it can be deciphered.

g. Tissue samples from hard body parts (e.g., fin rays, vertebrae, or otoliths) may be collected (in addition to scales) for age determination. Soft tissue samples (e.g., liver, heart, and eye) may be collected for GSI (Genetic Stock Identification) analysis.

SAMPLE COLLECTION METHODS

Pre-Survey Preparation

Streams to be surveyed should be divided into reaches that facilitate reasonable ease in survey completion. Reach boundaries should be readily recognizable to prevent collection of incomplete or excessive data. It may be advisable to further divide reaches into sub-units of one to five kilometers in length to provide more detailed data analysis capability and easier recognition of changes in spatial distribution of spawners. Before a survey is undertaken, surveyors must be well aware of what reach they are to survey, what data are needed, and what equipment is required in order to collect it. Familiarity with the data form is also essential.

Pre-survey training in redd identification, fish recognition (more than one species may be present), and carcass sampling techniques is necessary in order to prevent confusion and inconsistent data collection by inexperienced personnel. Exposure to such training is the best means to acquire initial familiarity with data needs and collection methods -- and thus facilitate reliable surveys. If inexperienced personnel have not

been provided thorough pre-survey training, they should not be permitted to perform surveys alone.

Prior to initiating a survey, the project leader must be sure that all necessary equipment is carried by each surveyor or surveying team (see Appendix A, FIELD EQUIPMENT LIST). The specific items required will depend somewhat on particular data needs. Surveying without essential equipment must be avoided because it can result in incomplete data collection, which reduces the value of the survey record.

Survey Description

To facilitate ease of movement, conduct surveys from upstream to downstream points. At the survey's start, enter the reach location (identified by beginning and end point), surveyor's name(s), and the date on the data form (see Section IV, DATA FORMS). Also note incidental informational items such as weather conditions, water temperature (measured at start and finish of survey), turbidity, and flow conditions. Then begin moving in a manner that allows all stream areas to be inspected, with redds, live fish, and carcasses noted as they are seen. If the reach has been sub-divided note the specific section to which the data pertain. All side channels deemed accessible to fish must be thoroughly reconnoitered. (Note: Prior knowledge of basic stream morphology is valuable in delineating survey reaches and planning surveys. Inspection of extremely braided channel sections can be much more difficult and time consuming for a lone

surveyor than for a team. Conversely, singular channel reaches might be readily surveyable by one person.)

When multiple surveys are conducted on a particular stream reach, it is important to maintain uniform survey and data collection methods. This is most easily achieved if the same surveyor(s) does all surveys on that reach. Also, when a stream is scheduled for multiple surveys, it will be necessary to **mark** redds as they are found so as to prevent their being recounted. A redd can be quickly marked by placing a brightly painted stone at its upstream end or by attaching colored vinyl flagging to nearby vegetation. On the flagging, record the date the redd is first located and its specific position in the stream (useful if multiple redds are immediately present nearby or additional redds are subsequently found.) To distinguish results of separate surveys use differently colored marks.

Redd Identification and Counting

Spring chinook typically build redds where gravels of about seven to fifteen centimeters in diameter predominate (Burner 1951). Most construction occurs in water of moderate velocity and at depths of about ten to seventy five centimeters, but redds may be found at any site where appropriately sized gravels accumulate in the absence of much fine sediment. Where high water velocities promote a predominance of boulders or large cobble as substrate, or where low velocities permit fines to freely precipitate, the likelihood of discovering redds is

reduced. One commonly used redd construction site is at the head of riffles, where the suddenly increased stream gradient causes water to move down through as well as over the gravel and thus assures a constant supply of oxygen to embryos or fry developing within.

At first glance, a redd may look like nothing more than a disturbed area in the streambed -- which is exactly what it is. Gravel comprising the redd will probably appear noticeably cleaner than the surrounding substrate because much of the normally present fine sediments will have been washed away during the redd construction process. Because these fines are lacking, and also because the newly piled gravel has not completely settled, the redd will be somewhat more loosely arranged than the adjacent, undisturbed streambed.

Spring chinook redds are highly variable in shape and size, but with a little practice a surveyor can learn to quickly recognize them. They typically appear roughly tear-drop in shape, with the wider end upstream, and range from about one to four meters in length and from one-half to one and one-half meters in width (see Figure 1, REDD PROFILE). Viewed in cross-section from upstream to downstream, a typical redd begins as an excavated depression or pocket in the streambed. From this depression emerges a mound, created from the excavated material, that slopes gradually up to its maximum height at about two thirds of the way down the length of the redd. The mound then tapers in both height and width to the redd's downstream terminus

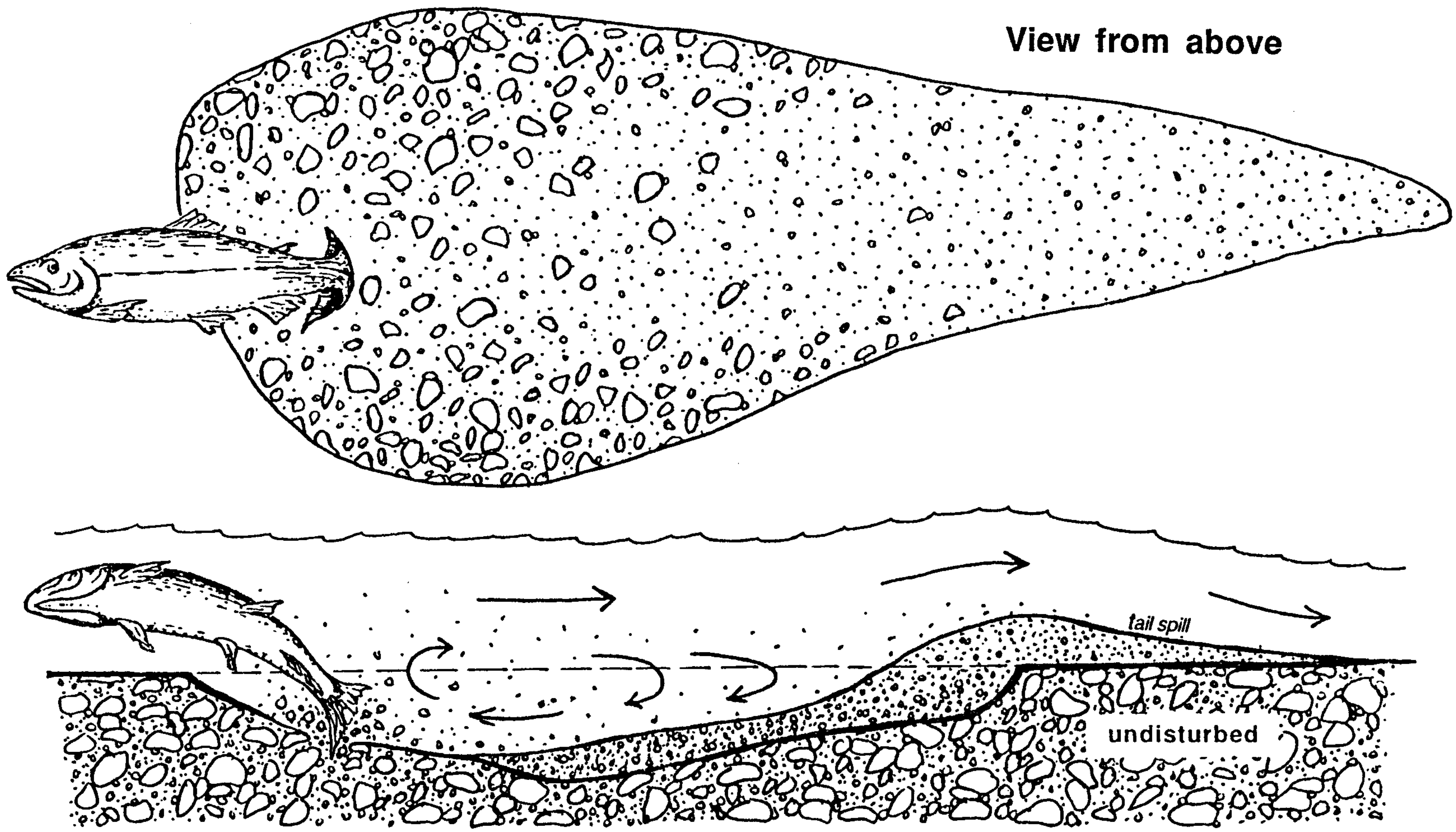


Figure 1. Redd Profile

or "tail-out." The top of the mound is usually not more (and is often considerably less) than about 25 to 35 centimeters higher than the head of the slope. The tail-out is normally somewhat pointed and often displays surface deposits of substrate fines and sand, precipitated because water velocities behind the mound are reduced by its presence.

The surface of some redds will appear almost rippled, with two or more indistinct mounds arranged like waves. Other redds may be constructed "normal to" (across) rather than parallel to the streamflow. In such cases, the redd will be wider than long, and the mound may appear as a narrow hump running perpendicular to the stream.

Redds may be found singly or in multiples. As a result, a little patience and practice is necessary to accurately count the number present at a given location. Multiple, in-line redds may initially appear as a long, individual one because the tail-out of the upstream redd may obscure the upstream pocket(s) of a redd just downstream. If what first appears to be one redd is considerably larger or longer than what is typical for that reach, a closer inspection is advised. If more than one mound is visible, or partially obscured pockets can be located, then more than one redd is probably present. A careful examination will usually allow the observer to distinguish where one ends and another begins.

When closely clustered redds are encountered or suspected a good approach to deriving an accurate count is to first identify

the obvious ones, and to then try to locate additional, nearby pockets and/or mounds that might evidence efforts to complete other, less immediately obvious redds. Close examination of the excavated areas may help determine if the volume of gravel removed from each is large or small in proportion to what would probably have been required to complete a redd. Judgment must be applied, however, because the entire "pocket" created by a female fish covering her final egg deposit will not always be a single, uniform excavation. To further complicate matters, excavations associated with different redds may intrude on one another -- or into an adjacent redd. They may even be located at oblique angles to their associated mounds. And mounds, too, may overlap or be closely spaced, thus making clear definition difficult. When in doubt, look carefully at the streambed and try to visualize it from the fish's perspective. Try to determine why an excavated area or mound appears as it does. The presence within the spawning gravel of, for example, cobble or boulders too large for a fish to move may have forced it to search around or between them for suitable gravel with which to complete its redd. A large rock protruding from a redd may also give the impression that two separate redds are being viewed. Unraveling the picture may not be easy, but once the location of one redd has been established, the positions of others adjacent to it can usually be determined as well.

In areas where very dense spawning occurs, or in good habitat exposed to a protracted spawning period, redds may be

superimposed to the extent that they defy individual definition. Because the impacts (original redd obliteration, egg dislodgment, etc.) of this are hard to assess, the best approach is to count the number of visible redds and note on the data form that superimposition was apparent or suspected at that location.

It is also not uncommon to find numerous small "test redds" or "test digs" during a survey. Noticeably smaller (generally less than one meter across at any point) and usually lacking the shape characteristic of a completed, egg-bearing redd, test redds probably represent the initial efforts of female fish to find suitable gravel in which to spawn. Redds of other fall-spawning salmonids (e.g., bull or brook trout) may likewise be encountered. These, too, will likely be smaller than actual chinook redds and will probably be constructed in smaller-sized gravels. Neither test redds nor redds of other species should be counted in the survey.

Avoid stepping on redds, especially the mounded area. There are one or more pockets of eggs beneath the gravel (the larger the redd the more pockets), and they are easily shocked or crushed.

In summary: Redds, although basically similar, will vary considerably in size and shape depending on their location in the stream channel, the size and flow characteristics of their host stream, average size and availability of gravel, and spawner size. No two situations will ever be identical, but careful interpretation of what is seen in the stream will allow a useful

count to be made. And regardless of what is encountered, a consistent assessment methodology must be maintained. The surveyor must be prepared to think.

Live Fish Counting

Because live fish are wary, mobile, and easily camouflaged, numbers observed in a stream will rarely reflect actual numbers present. Live-fish counts are used as an aid to determine whether spawning activity is just beginning or nearing completion. For spring chinook this typically occurs between late July and early November and may vary considerably from stream to stream. Live counts are most useful when contrasted with redd and, to a lesser degree, carcass numbers. Comparatively high live-fish and low redd and carcass numbers, for example, may indicate that spawning is just beginning. The opposite (low live fish and high redd and carcass numbers) can indicate spawning in that particular stream is nearly completed for the year.

Live fish may be encountered practically anywhere in a stream. Prior to spawning they may concentrate in deep pools, along undercut banks, around log jams, or any other location affording good hiding cover. As spawning begins and progresses, they are more often observed on or near the spawning riffles. When startled, live fish often move quickly away to avoid the oncoming disturbance, and then may suddenly dart back to the area where they were initially disturbed. The surveyor must take care

to avoid double-counting.

It is not unusual to find live spawned-out fish in slack water below spawning riffles. Females are often easily distinguishable because of wear on their caudal and ventral fins. After spawning, both sexes may become considerably less wary than unspawned fish, and are often so lethargic that they can be easily approached and even handled. These "live carcasses" (especially the females) usually appear slack-sided because their gametes have been expended. If included in the live fish count, note that these fish have already spawned.

Carcass Sampling

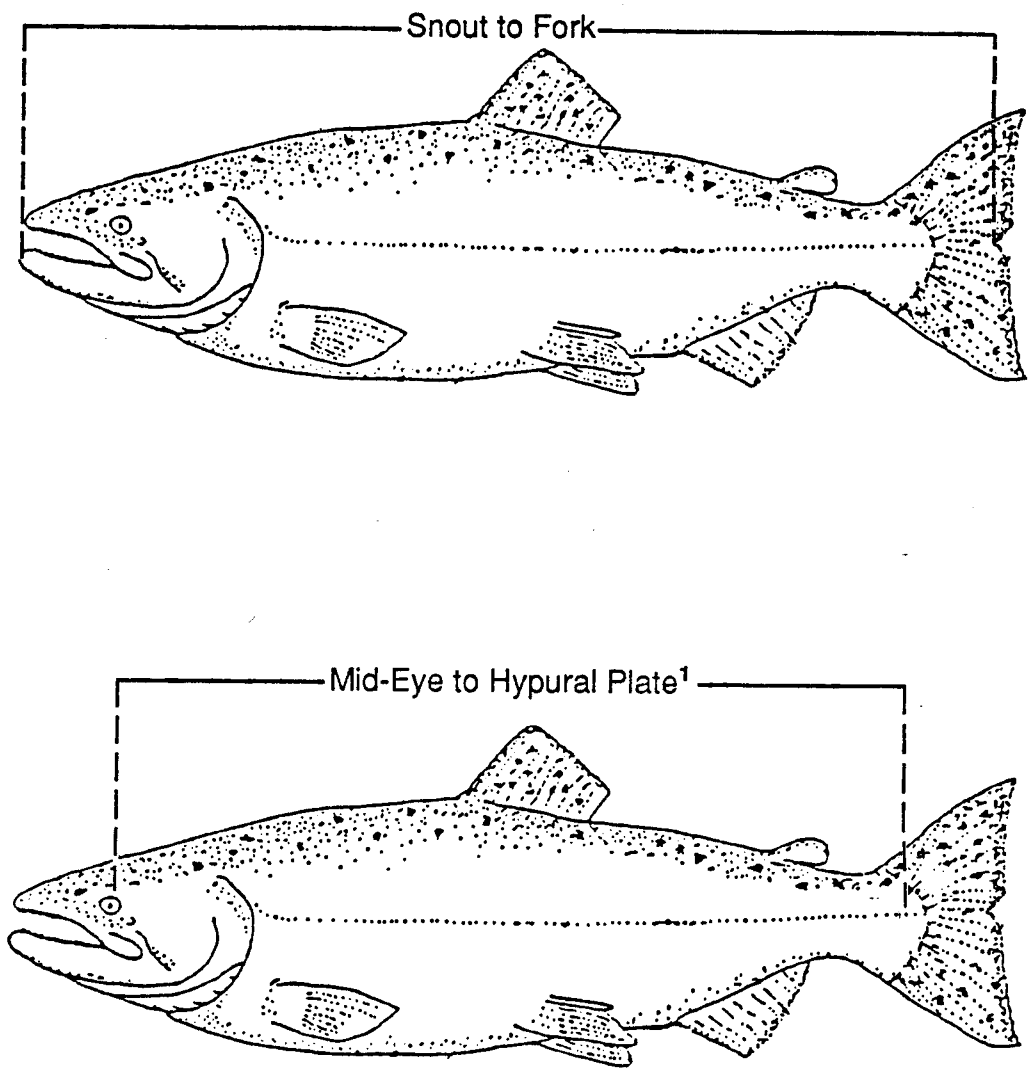
During routine sampling, be aware that carcasses can display evidence of numerous factors affecting the population being surveyed. Unspawned or incompletely spawned carcasses, for example, may reflect predator activity, or may be an artifact of some population members failing to find mates in a large habitat base. But if the phenomenon is proportionally widespread in fish of one sex, it may be signaling an imbalance in the population's spawner sex ratio, which may bear further looking into. Evidence of disease or injury may also be apparent. Seen in only one fish this may not be important, but as a chronic condition it may be significant. In short, it is worthwhile to note anything unusual about a carcass or carcasses observed during the survey. It will take just a short time to jot a remark or two on the data form, and the information may prove valuable at some later date.

Carcasses may be discovered at virtually any location in the stream, but they are most often located in slack water areas below spawning riffles. When sampling a carcass, first examine it for marks, fin clips, and tags, and record each one noted. Next, measure it for mid-eye to hypural plate length and record the result. If desired, fork length may also be recorded (see Figure 2, FISH LENGTH MEASUREMENTS). Finally, open the abdominal cavity to determine the fish's sex and to ascertain the extent to which it spawned.

If the carcass is of 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 and it will be necessary to estimate what percent of the eggs remain and what percent were deposited in the stream. Enter the percent deposited on the data form. Use the same process for determining and recording male spawning success.

Other desired samples (scales, tissue, etc.) can then be removed and their collection noted on the data form. Scale sampling techniques are described in Section III. If the carcass carries a coded-wire tag (indicated by a clipped adipose fin), 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 at the appropriate location on

Figure 2. Fish Length Measurements



1. 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.

the data form for cross referencing. When sampling is completed, cut the tail from the carcass to identify it as having been previously counted and/or sampled, and discard it.

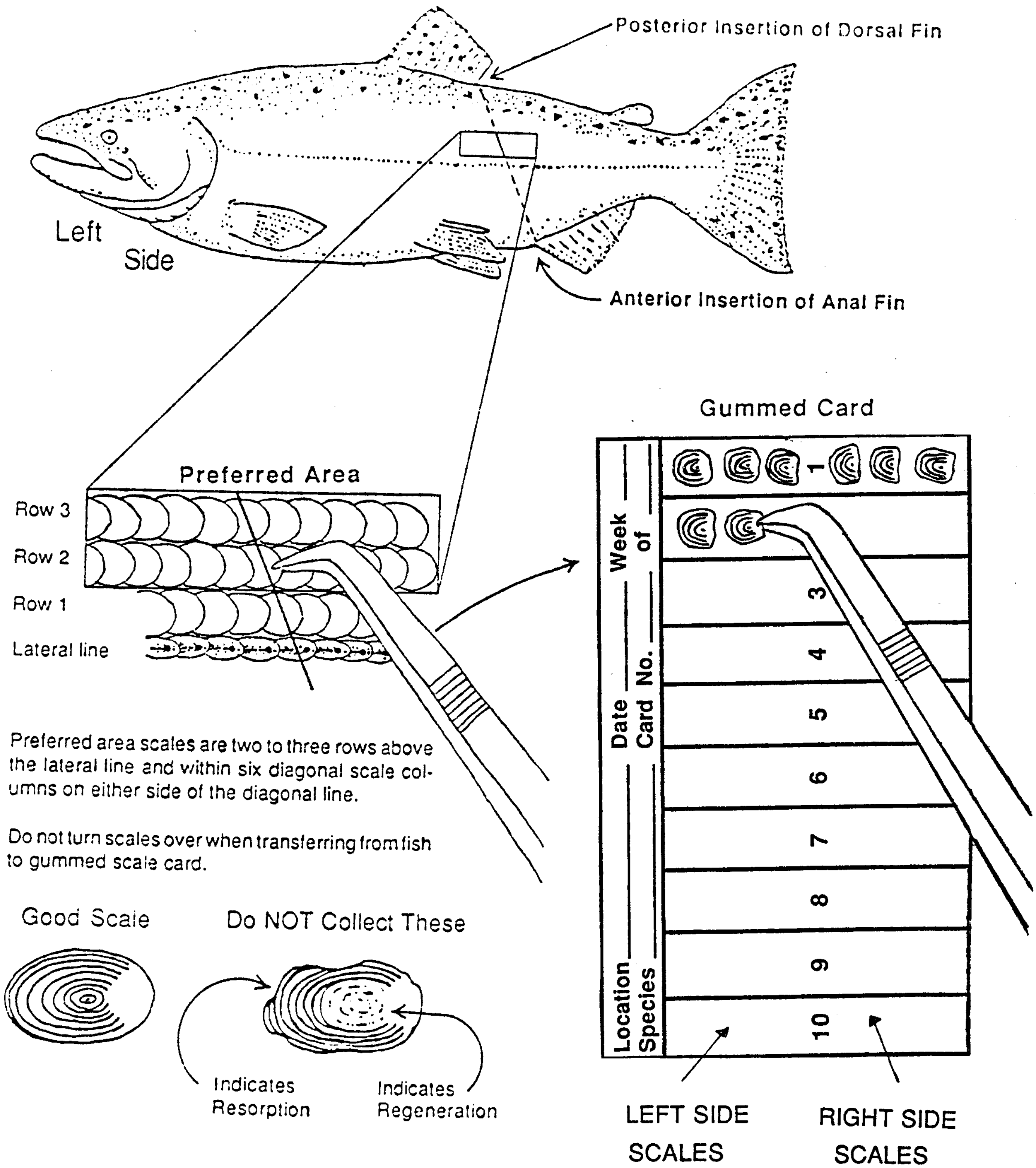
III.SCALE SAMPLING

Because scale growth corresponds to overall fish growth it is possible to establish a record of an individual fish's life history by interpreting its scales. And because a fish's age may also be determined from scale growth patterns, it is possible to identify a run's age classes through scale analysis. Similarly, differing natal stream conditions are reflected in the freshwater growth zones of scales from anadromous salmonids. Differences in the freshwater growth of hatchery and wild fish may likewise be detected. It may thus be possible to determine the racial composition of aggregate fish runs through scale-pattern analysis.

Collection

Scales most useful for analytical purposes, i.e. those containing complete growth records, are usually located in the fish's "preferred" areas (Clutter and Whitesel 1956, INPFC 1963)(See also Figure 3, SCALE SAMPLING PROCEDURE). 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 forceps or a small hemostat, remove six scales -- three per side -- from each fish sampled. If scales are missing from one side take all sample scales from the other. When this occurs note it in the sampling form's "Remarks" column. If no acceptable scales

Figure 3. Scale Sampling Procedure



can be found, do not collect any.

Because they adhere tightly to their scale pockets, it is frequently difficult to remove scales 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 damage to that or nearby scales). 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.

Mounting

Before mounting any scales, identify the scale card (see Figure 3) by labeling its back side with the sampling location, date, and card number. Do not label the card's front (gummed) side. Affix the scales by placing them in the appropriate cell on the front of the card and pressing with a dry cloth or fingertip. Put the fish's left-side scales above the cell number and its right-side scales below it. If possible, do not cover the cell numbers.

When mounting scales, it is important to orient each one similarly to facilitate subsequent reading and measuring in the laboratory. Also, place scales on the card in the manner they grew on the fish -- with their exterior surfaces facing up. If in doubt as to whether the scale has been properly mounted, test it with a pencil point. A scale's rough, outer surface will accept a pencil mark. If the scale cannot be so marked, remove

and wash it thoroughly. Excess glue will make reading it difficult or impossible. After cleaning, replace the scale on the card with the proper side up.

Keep the scale card dry to preserve its glue base and prevent it from curling. Finally, store the card between plastic sheets (or other rigid, smooth-sided material) held together with rubber bands.

IV. DATA FORMS

RIVER ______________ SPECIES ______________ SAMPLERS ______

REACH ______________ WATER TEMP. ____ to ____ PAGE ____ of ____

DATE ______________ SURVEY CONDITIONS ______________

	Fish Counts			Scale Cd			Length					
Redds	Live	Dead	Samp. No.	Number	Position	Marks	Fork	Mid-Eye to Hypural	Sex	% Spawned	Other Samp.	Remarks
Total	Total	Total										

FIGURE 4. Tributary Sampling Form (reduced 25%)

EXPLANATION OF DATA FIELDS

a. River and Reach

Record the stream name and section (reach) being surveyed. Include the reach code, if available.

b. Date

Record the survey date.

c. Species

Note the species being sampled.

d. Water Temperature

Record water temperature at the beginning and end of the survey.

e. Survey Conditions

Describe general weather conditions (visibility, wind, etc.) encountered that could affect survey results.

f. Samplers

Note the samplers' names.

g. Page __ of __

Record as 1 of 1, 2 of 3, etc.

h. Redds

Record as noted. Total after completing survey.

i. Fish Counts - Live and Dead

Record as noted. Total after completing survey.

j. Sample Number

Reference each carcass sampled during a survey. Begin at number 1 as each new survey is initiated. Tag all tissue samples collected, noting survey location, date, and carcass sample number for cross-referencing with the data form.

k. Scale Card Number and Position

Reference the scale card number and the sample position (cell) on which corresponding scales are placed. If no scales are collected, leave these columns blank.

l. Marks

Record all fin clips, jaw tags, and body tags observed on a sampled carcass. If more space is required, use the "Remarks" column. Use the following codes to identify marks and tags:

RP, LP	-	right, left pectoral fin
D	-	dorsal fin
RV, LV	-	right, left ventral fin
AD	-	adipose fin (indicates coded-wire tag in snout; in "Remarks" column note whether snout was collected or not).
AN	-	anal fin
Jaw Tag	-	enter identifying number; note right or left jaw in "Remarks" column.
Spaghetti Tag	-	enter identifying source and number; note color in "Remarks" column.

m. <u>Length (Fork)</u>

To the nearest 0.5 centimeter, measure carcass from tip of snout to fork of tail (see Figure 2, FISH LENGTH MEASUREMENTS).

n. <u>Length (Mid-Eye to Hypural)</u>

To the nearest 0.5 centimeter, measure the carcass from mid-eye to the hypural plate (see Figure 2, FISH LENGTH MEASUREMENTS).

o. <u>Sex</u>

Determine the fish's sex and record as M or F.

p. <u>% Spawned</u>

Estimate to the nearest 5% the amount of sex products expended.

q. <u>Other Samples</u>

Use this column to indicate whether other bio-samples (e.g., otoliths or GSI tissue samples) are collected. On the label(s) accompanying the sample(s) note the survey location, date, and carcass (sample) number.

r. <u>Remarks</u>

Record additional information pertinent to individual fish samples here.

V. REPORTING REQUIREMENTS

A report of US-Canada activities is expected by federal contracting authorities in December of each year. In order to promote good scientific practices, and to meet federal contractual requirements, data are to be tabulated and draft reports written and submitted to CRITFC within six weeks after field operations cease. Some guidelines that will help to facilitate routine report-writing are offered below:

1. Use either "Word Perfect" or "Word Star" for text;

2. Use "Lotus" or a similar spreadsheet program to tabulate original data and generate tables. Verify that the table format corresponds directly with field data sheets so that clerical persons can make actual data transfers from collection form to spreadsheet. This will help limit subsequent report-writing duties to proofreading and modifying previous year's text to reflect current results.

3. Follow "Transactions of the American Fisheries Society" style: Introduction, Description of Study Area, Methods (use this manual), Results, Discussion, and References.

VI. REFERENCES

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APPENDIX A: FIELD EQUIPMENT LIST

Surveyors will encounter varied terrain and weather conditions during the spawning season, so a little forethought will reduce the potential of accident or discomfort during field work. It is certainly advisable to be at least somewhat familiar with the country to be surveyed and to carry any extra items that might be needed. If a survey reach lies within, for instance, steep-sided canyons or other sunlight limiting landforms, a light jacket might be worth its extra weight. And while surveys should not be attempted if rain is likely, if rain unexpectedly occurs, having rainclothes can be the difference between having a comfortable and miserable survey. A basic first-aid kit is always a worthwhile addition as is, if the country suggests, a snake-bite kit.

If the survey is by raft, a good repair kit is a must. Likewise, an extra oar and oarlock or a paddle may prove invaluable. Generally speaking, a little consideration and planning for situations that might arise can help make the survey a pleasant effort.

A suggested equipment list follows. Aside from the basics, each surveyor must be aware of his personal needs and prepare accordingly. Although each item on the list may not be necessary on every survey, it remains the surveyor's responsibility to determine what is needed and to be certain that those items are on hand. In the list below, the most basic items -- those that will always be necessary -- are marked with an asterisk.

DATA FORMS* and BACKING (e.g., clip board)
PENCILS*
<u>POLARIZED</u> GLASSES* (to enhance visibility through water)
WADING GEAR (not recommended if rafting)
METRIC MEASURING TAPE*
FORCEPS or HEMOSTAT*
SCALE CARDS* (with covers)
RUBBER BANDS (to contain scale cards and covers)
KNIFE* and SHARPENER
WATER THERMOMETER*
SCALPEL (for removing soft tissue samples)
SMALL SAW or WIRE CUTTERS (for removing hard tissue samples)
TISSUE SAMPLE CONTAINERS (glass or plastic vials with caps)
LABELS* (to identify tissue samples, snouts, etc.)
PLASTIC BAGS* (for carrying snouts with coded-wire tags)
SMALL ICE CHEST and DRY ICE (if GSI samples are collected)
COLORED FLAGGING or SPRAY PAINT* (multiple-survey reaches)
INDELIBLE MARKERS (for writing on flagging)
DAYPACK (for carrying supplies, lunch, etc.)
EXTRA CLOTHING (jacket, rainclothes, hat, etc.)

Field Equipment List (concluded):

The following items may be useful when surveying by raft:

RAFT REPAIR KIT
AIR PUMP
SPARE OAR or PADDLE
SPARE OARLOCK
TOOL KIT (pliers, crescent wrench, wire, heavy tape, bolts, nuts, washers, etc.)
ROPE
WATERPROOF RIVER BAG
FLOTATION VEST
WETSUIT

APPENDIX B: SYNOPSIS OF SOME OTHER TECHNIQUES POTENTIALLY APPLICABLE TO CENSUSING PSC INDICATOR STOCKS

INTRODUCTION

The underlying objective of the PSC stock monitoring project is to collect data from which the effects of US-Canada Treaty-imposed management decisions can be assessed. The sought-after data are counts or estimates of either adult (spawner) escapement or juvenile (smolt) production, or both. Only adult enumeration techniques are discussed here. Smolt production estimates can be derived from spawner escapement figures if an escaping population's male/female ratios, the average number of eggs/female, and the egg-to-smolt survival rate are known.

Because the potentially affected fish stocks are too numerous to readily allow their being individually monitored, only a relatively few, "indicator" stocks serve as actual data sources. This approach is founded on the assumption that Treaty-induced changes observed in the indicator stocks also sufficiently reflect changes being experienced by the larger aggregate of unmonitored stocks. Thus, assuming the indicators are well chosen, rational judgments about the probable effects of US-Canada management decisions on stocks throughout the Columbia River Basin can be made based upon data collected from a small but representative sample of those stocks.

ADULT ESCAPEMENT COUNTING

Adult escapement counts or estimates can be developed through a number of means, with varying degrees of accuracy and precision (Cousens et al. 1982, Symons and Waldichuk 1984). These counts are used to contrast a stock's annual returns on a year-to-year basis, as well as, once a sufficient number of years' data are available, the average values of multi-year returns. Knowledge of short and long term changes in population strength may inform managers monitoring Treaty implementation whether a given stock or group of stocks is remaining stable, rebuilding, or declining under a given management scenario. Further, knowledge of how existing management affects a stock may also suggest how alternative strategies might differently affect it and thus promote its rebuilding, which is the overall objective of the Pacific Salmon Treaty. A brief description of some population estimation techniques, other than redd counting, that are potentially applicable to the stock monitoring program follows, together with general comments about some strengths and weaknesses of each.

Fence Counts

In situations where all fish entering an area can be counted at a particular location, fence counting is generally regarded as the most accurate technique available (Cousens et al. 1982). To use this method, a permanent or temporary barrier, e.g., a fence, weir, or dam, is placed in the stream to deflect all migrating fish past a point where counting, trapping, or both may occur. Counting may be done manually by observers or electronically with, for example, video tape. If passage is to be continuous and uninterrupted, then counting must occur at all hours. When this cannot be done, but a complete record of passage is desired, the fence must be closed during non-counting periods. Associated passage delays may cause mortalities, and can also result in a redistribution of adults on the spawning areas from that which would have occurred had passage not been intermittent.

The strength of this method lies in its ability to produce complete counts rather than estimates of a total run. Its drawbacks include high initial construction costs and, if counting is done manually, costs associated with a labor intensive operation.

Tower Counts

With this method, counts of all fish passing a given point in a stream are made by the observer, whether human or electronic, from a position sufficiently above the stream to allow unobstructed viewing of the migratory path. It may be necessary to anchor neutrally colored background panels to the streambed at the counting point to provide sufficient contrast to allow the observer to easily view the fish. Upstream turbulence interfering with visibility may also require modification. If counting is done at night, some form of floodlighting will be necessary.

Tower counting has been used extensively in Alaska, and has seen limited use in Washington and British Columbia. It is considered most effective when used to provide escapement estimates of bank oriented salmon species (primarily pink and sockeye) migrating in waters of good clarity (Cousens et al. 1982). In situations where escapement estimates will be generated from counts made during specific sample periods, the technique may be applicable to other species provided that their migration pattern displays a relatively even temporal and spatial distribution. Caution is advised if chinook (or any other mid-channel migrator) are to be counted using this method. In such situations the tower must be located so as to allow clear observation of mid-channel areas. If the stream being surveyed is wide, this requirement may present difficulties.

Good visibility is crucial to obtaining accurate tower counts. Overcast skies, turbid or turbulent water, and glare (whether from natural or artificial light) can all hamper visibility. The likelihood of encountering such conditions must be considered if tower counting is being appraised as a census method. This technique may not be a good choice in areas with mixed-species migrations, unless discrimination between the species is relatively easy to achieve.

When used under suitable conditions, counting from towers can provide relatively accurate escapement estimates. In Alaska, tower counts have been used as a standard against which the accuracy of test fishing results and aerial and side-scan sonar counts have been compared (Various authors as cited in Cousens et al. 1982).

Foot Surveys

Counting live and/or dead salmon while walking along a stream is one of the oldest and simplest methods of estimating escapement. Because of spawner "turnover" and carcass loss, it can also be one of the least precise, typically producing serious underestimates of total escapement. Counts made during foot surveys are generally considered to provide, at best, only escapement indices. Without some form of adjustment, typical accuracy may be no better than about 50% (Cousens et al. 1982).

The precision of foot survey counts can be heightened by repeating them at intervals approximately equal to the stream residence time of spawners, and then the summing counts of live fish to establish an estimate of total spawners (escapement). Obviously, any variation in run timing, survey timing, and stream residence time will affect accuracy of the counts.

Some reduction of error associated with spawner turnover can also be achieved by counting only carcasses. If this method is chosen, it will require frequent, perhaps even daily, surveys to minimize problems connected with carcass loss. It will also necessitate either removing or marking of carcasses to prevent their being recounted.

Considerable experience in locating and counting fish in a stream is necessary to prevent underestimates, a common occurrence resulting from counts by inexperienced personnel. Good visibility is important, and any factor that reduces it may adversely affect the count. Foot survey techniques, as with most other visual-dependent methods, are probably best suited for use in shallow, clear headwater streams.

This is one of the most labor intensive, and thereby potentially expensive, survey methods available. And although it is still widely used, the questionable accuracy of counts obtained through foot surveys should be seriously considered before deciding to exclusively employ it as a population estimation technique.

Snorkel Counts

This method has been used with some success to locate cryptically colored species, particularly steelhead, in deep pools or under cover along stream banks. It may be the only practical method of visually counting adults in canyon topography. Even so, snorkel counts are entirely visually dependent, and contain all the weaknesses incumbent in foot survey counts. Various research indicates that underwater census techniques tend to underestimate fish populations (Northcote and Wilkie 1963, Slaney and Martin 1987).

Mark-Recapture

This method of enumerating a population is based on the principle that a total population size can be reasonably estimated by capturing, marking, and releasing a known number of individuals (M) within the population, allowing them to randomly redistribute through it, then capturing a second sample (C), and -noting the number of recaptures (R) of individuals marked as part of the first sample. An estimate of the total population (N) can then be calculated using the formula: $N = MC/R$.

Ricker (1975) has shown that this basic formula tends to overestimate the total population if sample sizes of either M or C are small, but some compensatory modifications can be applied as a result. In situations where mixing of tagged individuals is incomplete, and some stratification of the populations exists, other modifications may be called for.

Accuracy of a mark-recapture derived estimate may depend on the extent to which marked individuals evenly distribute within the larger population, and whether or not the number of initially marked individuals, and/or the total number of individuals captured during the recovery effort, are representative samples of the entire population. To increase the probability that these conditions are met and, thereby, to reduce bias adversely affecting results, both the marking and recovery efforts should be designed to sample as much of the run as is possible.

A well designed mark-recapture study will be both time consuming and labor intensive and, because of this, expensive. Nevertheless, if assumptions inherent in mark-recapture strategies are understood and met, the method is capable of producing relatively accurate results. A good analysis of theory and application of mark-recapture techniques is available in Symons and Waldichuk (1984).

Electronic and Acoustic Counting Systems

Numerous electronically based counting methods exist (Cousens et al. 1982). Two general categories are potentially applicable to typical stock monitoring projects, and they are discussed in some detail here. For a good introduction into the basic science and variations of acoustic counting technologies, see Nielsen and Johnson (1983) and Gaudet (1984).

1. Pulsar Conductivity Tunnel Counts

Typically, Pulsar conductivity counts are attempted only at weirs or fishways. The usual arrangement is a bank of four tunnels positioned so that all migrating fish must pass through them. In addition, a "control" tunnel, which is not open to fish passage, is included to provide a constant measure of normal water conductivity -- the "background" count against which all other tunnels are constantly compared. When a fish enters an open tunnel the conductivity between electrodes in the tunnel wall increases, and this change from the background level is registered as a count. Upstream and downstream fish movement are distinguishable.

The Pulsar counter, and other tunnel based systems, are best suited for use in counting single species migrations. Some flow and debris control upstream of the counting point is often desirable to minimize interference with passage through the tunnels. Periodic visual checks on counting accuracy are advised, as is periodic cleaning to prevent fouling. Maintenance frequency will depend on individual stream conditions. When properly calibrated, Pulsar counters usually provide reliably accurate estimates, although at extremely high hourly passage rates (e.g., 5000 - 7000 fish/hour) their accuracy may be considerably reduced (Cousens et al. 1982). Initial acquisition and installation costs may be high, but normal operating costs are relatively low. This method is not widely used in the Pacific Northwest.

2. Bendix Side-Scan Sonar

The side-scan sonar was developed for use in enumerating large, bank-oriented (primarily sockeye and pink salmon) migrations in glacially occluded, Alaskan river systems. The technology works equally well in clear water systems. A side-scan sonar unit consists, generally, of a single transducer mounted on the inshore end of a submersible 20 m x 20 cm aluminum pipe "substrate", which is connected to a signal analysis/recorder unit. Power is typically supplied by batteries recharged via solar panels. When in use, the substrate is positioned in the stream perpendicular to its flow, flooded, and anchored. The recording equipment remains on the adjacent shore. Fish are counted acoustically as they swim through conical sound beams emanating from the substrate. Discrimination between fish and debris occurs based on the number of echoes returned from each target.

Under suitable conditions, side-scan sonar counts have shown high, positive correlations with results from other (e.g., tower counts, test fishing, etc.) escapement estimation techniques. But aside from high initial investment associated with establishing a sonar counting station, two major concerns must be dealt with when considering the technology for use in the stock monitoring program. Proper site selection is extremely important (Symons and Waldichuk 1984). Also -- and in light of present indicator stock conditions this may be a more crucial consideration -- because sonar unit calibration is difficult to maintain in the face of low fish densities, accuracy of side-scan sonar counts is dubious when passage rates fall below about 3,000 fish/day (Cousens et al. 1982).

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