Beach Seining

Peter K. J. Hahn, Richard E. Bailey, and Annalissa Ritchie

Background and Objectives

Background

Seining is a fishing technique traditionally done in areas with large schools or groups of fish. The earliest form of seining was dragnetting (also called beach seining). There is evidence of seine nets used in artisanal fisheries several thousands of years ago and on every continent (von Brandt 1984), including North America, where native peoples used them to catch salmon in the Columbia River (Craig and Hacker 1940) (see Appendix B) and elsewhere. Nets ranged in size from very small, single-person "stick seines" to seines in New Zealand that measured more than 1,600 m long and employed hundreds of people to retrieve.

The typical modern seine net has weights on the bottom (lead line) and buoys on the top (float or cork line) to keep the net vertical when pulled through the water to entrap fish. Some seine nets are designed to sink or to float, but most remain in constant contact with both the bottom and the surface and thus are best suited for shallow waters. A beach seine is often set from shore to encircle a school of fish and is then closed off to trap them against the shore. One variation is to set a seine net parallel to and some distance from shore and then pull it to the beach. Another variation is to encircle fish some distance from shore but still in shallow water and pull the net onto boats. This latter method evolved into the purse seine, which has rings along the lead line through which a rope is pulled to "purse" or tighten the bottom of the net together before the net is gathered to the side of a boat; purse seines, however, are not limited to shallow waters for their effectiveness. Between a beach and purse seine is the lampara net, which is fished at the surface in deep water. It has a lead line much shorter than the float line, which shapes the seine much like a dust pan and prevents epipelagic fish from diving and escaping (von Brandt 1984; Hayes et al 1996). Some seines are even fished through holes cut in ice-covered lakes to capture semitorpid aggregations of fish.

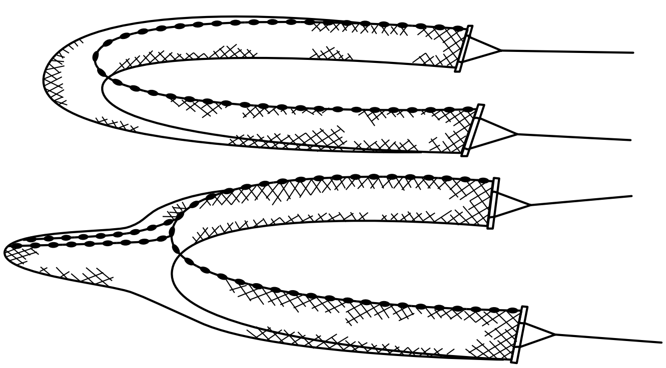


FIGURE 1. — Beach seine diagrams (FAO technical paper). The lower net has a "bag" in the "bunt" (middle) section in order to hold more fish and to prevent fish from escaping. Bunt mesh size is usually smaller than for "wing" sections. Typically "tow lines" are attached to each end to allow pulling the net in from a distance.

In the early years of the nonnative commercial salmon fisheries, beginning before 1880 in the Columbia River (Craig and Hacker 1940), beach seines were set from large rowboats and the nets would be hauled in by hand or with horses. The fishermen rowed their boats to the fishing grounds or hitched a tow from a steam-powered cannery tender. Gradually, the fisheries became more mechanized, utilizing power boats and motor winches. By 1908, some seine nets were nearly 800 m long (see Appendix B) and highly effective. In 1917, purse seining and again in 1934–1935, beach seining, trap nets, and fish wheels were outlawed on the Columbia River.

Today, beach seining is generally not permitted for commercial purposes in any North American rivers, except in some areas of the far north; however, research seines can be employed in wadable and nonwadable systems across a variety of habitat types to capture both juvenile and adult salmonids. In these habitats, seines can be deployed by wading or from drift boats or powerboats. Hayes et al. (1996) described generic applications of seining for fish capture. Specific seine applications include capturing fish to estimate total abundance (usually by mark–recapture studies), estimate relative abundance over time and space, describe fish population diversity and distribution, capture broodstock, monitor effectiveness of habitat alterations, and mark fish and collect biosamples (Dawley et al. 1981; Farwell et al. 1998; Brandes and McLain 2001; Rawding and Hillson 2002; Fryer 2003; Hahn et al. 2003; Kagley et al. 2005).

Rationale

Beach and pole seining is an efficient method to capture salmonids and some nonsalmonid fishes in a wide variety of habitats (see Appendix B), including rivers, estuarine, and nearshore lake, reservoir, and marine habitats (Pierce et al. 1990). It is most effective when used in relatively shallow water with few obstructions, where fish are in high concentrations, and for species that are less likely to outswim the net; however, in some circumstances seining can capture highly mobile species such as adult salmon. Seining permits the sampling of relatively large areas in short periods of time as well as the capture and release of fish without significant stress or harm, as long as the bunt of the seine is kept in water and the fish are not too crowded (or fish are quickly moved to a holding container). Cost of gear, boats, and personnel range from relatively inexpensive to modest, depending on the scope and frequency of sampling. Purse and lampara net seining can also be effectively conducted in deeper water. These two techniques often require larger boats and nets (and thus greater financial investment) and are mentioned only briefly in this chapter.

Seining is a useful technique for objectives such as collecting fish for biological samples, sampling fish diversity within a given habitat (low-precision requirements), and estimating relative abundance (with modest precision) or population abundance with high accuracy and precision (via mark–recapture). Seining is frequently used for capturing small juvenile salmonids, where a measure of relative abundance or catch-per-unit-effort (CPUE, as fish/set, fish/area, or fish/volume sampled) is needed. By using standardized nets and deployment methods, scientists have attempted to characterize abundance over time and space, either within or across years. Other capture methods, such as midwater trawls, can contribute results with similar units (Brandes and McLain 2001). Beach seines allow the selective capture and subsequent release of a wide range of salmonid fish sizes. This characteristic makes beach seining a useful capture method for many mark–recapture based salmonid assessments, in which marking more fish allows for greater precision of the population estimate.

Objectives

Selecting seines as a method of fish capture should depend on requirements for data and specific study objectives. It should not depend merely on the ease of deployment or historical efforts, or because of limited exposure or training in the various gears available (Rozas and Minello 1997). Specific objectives will also determine the size and species of fish to be targeted for collection and what habitats will be sampled (see Appendix A). These elements (purpose for collecting fish, target fish size, and habitat conditions where sampling is proposed) drive the selection of gear type and then seine type, length, depth, mesh size, and the method of setting and retrieving the seine.

We categorized objectives for seining into six types or purposes: (1) relative abundance estimation, (2) absolute abundance estimation via indirect measures, (3) relative survival estimation, (4) biological sampling, (5) estimating species diversity or presence, and (6) absolute abundance estimation via direct measures. There may be some studies in which two or more of these are applicable, but the most important objective should determine the capture method(s) of choice, which may include methods other than seining.

1. Relative abundance estimation

To obtain estimates of relative abundance, seining can be conducted with prescribed methods and nets such that the area sampled is nearly constant or where the area (and depth) swept can be measured and estimated. Results are often commonly reported as CPUE: fish/set, fish/area, or fish/volume. Results are compared across sites within a defined region (e.g., one estuary complex, shorelines within marine bays, straits, sounds) by time of year or across years or by time of day and night (Miller et al. 1977; Dawley et al. 1981; Nelson et al. 2004; Kagley et al. 2005; Nobriga et al. 2005). Seine data may be combined with CPUE results from other gear such as midwater trawls or tow nets (Brandes and McLain 2001). Annual results may be related to parent spawner population size or environmental variants. Estimates of residence or migration time can also be made using marked fish releases (Duffy et al. 2005).

Typical target fish in North America are age-0 chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, and pink salmon *O. gorbuscha* for beach seines and yearling chinook, coho, sockeye, and steelhead for purse seines. These are abundant migratory species that pass through specific habitats at specific times. There are also situations where eggs, larvae, and fry can be caught by fine-mesh purse seines (Bagenal and Nellan 1980). The capture of nontarget species is often not a goal for studies, and therefore, variation in capture efficiency or selectivity by species may not be an important issue. Often the same suite of sites is repeatedly sampled over time so that variation in efficiency caused by different habitats is not an issue again unless habitat is changing over time.

If the goal is to sample a variety of habitats to see which are utilized by the target species or the full suite of species, then seining efficiency is an issue to consider (Parsley et al. 1989; Rozas and Minello 1997). Techniques may have to be developed to estimate efficiency, and other capture techniques should be considered as alternates or complements.

2. Absolute abundance estimation via indirect measures

The primary method for estimating population size indirectly is the mark–recapture estimate. Seining becomes a tool to capture fish for marking and release or for recapture (Farwell et al. 1998, 2006; Hahn et al. 2004; Rawding and Hillson 2003). Estimating CPUE or the true proportion of the population sampled is not relevant. Maximizing catches (to reduce cost) and representatively sampling the population (low bias) is the goal. Generally, multiple capture techniques are desirable to overcome biases that may be inherent in a single method. Caution is warranted when the same technique is used for both initial capture and recapture (potential gear bias), particularly if the elapsed time is short between events (due to learned net avoidance by the target fish). Seines can be highly effective for capturing a wide range of sizes of adult salmon and can also be used to capture juvenile salmon, particularly in riverine situations. Species that are migratory and abundant and have constrained migration timing are well suited to capture by seines. Adult chinook, pink, chum, coho, and sockeye salmon are well suited, summer steelhead sometimes are, and other species may have populations that are vulnerable to seines. Salmon smolts might be captured and marked via smolt trap, and then seines may be used in the lower river to sample for recaptures.

3. Relative survival estimation

When two or more groups of marked fish of the same species are released in known numbers, later sampling can allow estimates of the relative survival for each group. This could be considered a subset of relative abundance estimation, but estimation of CPUE is not needed. Estimating relative survival is especially important for migratory salmonids that travel by various routes through or around dams (see Dawley et al. 1981 for the Columbia River, where both beach and purse seines were used). It can also be used to test experimental versus control hatchery rearing or time-of-release groups, or survival by various size groups (as long the seine has the same or known capture efficiency for all size groups). Seining could also be used in lakes and ponds or small streams. Comparing survival across species should be done cautiously because capture selectivity and efficiency may differ substantially by species.

4. Biological sampling

Some studies merely require that individual fish be captured (e.g., gut contents, tissue samples for analyzing DNA, electrophoresis, or contaminants) or that individuals of various sizes be caught (e.g., for scale or otolith sampling for length-by-age analysis). For these studies, seines can be a very effective means of collecting fish specimens. Seines may or may not function well to describe abundance across a range of fish sizes if capture efficiency varies greatly by size. In the Green River in Washington, mature chinook salmon 25–115 cm fork length seemed to be caught equally well, based on underwater observation of beach seines in action (P. Hahn, Washington Department of Fish and Wildlife, personal communication).

5. Estimating species diversity or presence

When estimating species diversity or documenting presence, several capture methods may be used, including seines (Klemm et al. 1993; Meador et al. 1993; British Columbia Ministry of Environment, Lands and Parks 1997; Lazorchak et al.

1998; Moulton II et al. 2002). Diversity estimates that incorporate abundance may require efficiency (calibration) tests because seines are known to have variable and species-specific efficiencies and are especially poor for epibenthic species in complex habitats. Other applications include documenting if and when certain habitats are used by certain species (e.g., electrochemical impedance spectroscopy studies, habitat restoration monitoring). Diurnal-nocturnal and tide stage effects must be considered.

6. Absolute abundance estimation

Studies that attempt to directly measure the absolute abundance per unit area or volume are difficult to realize with the use of seines alone (Rozas and Minello 1997). Varying habitats (e.g., substrate, vegetation, clarity, currents) can allow fish to escape capture by seines, and each species and sometimes even each size group may have different catchability (Bayley and Herendeen 2000). Tests may be needed in each habitat to measure the selectivity and efficiency for each type of gear. Underwater observation may be needed to document the behavior of the gear and the fish while the seine is being deployed and retrieved.

Effectiveness

Some objectives (e.g., biological sampling of individual fish) can be met very well by using a single haul with a seine. Seining in multiple sites over time can be an excellent way to capture fish for marking and release or to recapturing fish for survival studies. Repetitive seining over time with standardized nets and standardized deployment in relatively similar habitat can be an effective way to quantify the relative abundance of certain species over time and space, especially for small juvenile migrating salmon. Species richness (diversity index), species rank, and the size distribution within species can sometimes be estimated using a single seine haul (Allen et al. 1992, cited in Hayes et al. 1996). Knowing when this is true is problematic because each species and size often has its own selectivity or capture efficiency. These factors can vary greatly if nonsalmonid species are included, if habitat varies substantially from site to site, or if some habitats cannot be sampled. In Allen et al. (1992), the six dominant taxa had capture efficiencies (CE) that ranged from 7% to 91%, and the highest average CE was 52% (this was for a tidal pool isolated by low tide and block nets). Rare taxa were not well represented by a single haul; these were better assessed using multiple seine hauls and/or multiple gear types. Estimating absolute abundance or biomass by direct measure is not easily accomplished by the use of seines alone, especially by single seine hauls, without calibration studies (see pages 279–280). Thus, effectiveness of beach seining depends on the species sampled, the population of interest, the habitat that is seined, and the overall goal of the sampling effort. Refer to Factors that affect capture efficiency and selectivity on pages 274–279.

Sampling Design

General site selection

Seining may be carried out in a variety of habitat types, depending on the population and life stage of the targeted species (see Appendix A). Sites with firm sloping beaches are favorable but not required. Adult salmonids are seined from pool (holding water) and nearshore lake habitats adjacent to and on the migratory routes to spawning grounds. Juvenile salmon can be seined from streams, estuaries, or nearshore lake and reservoir areas. Sites with irregular bottom topography, significant accumulations of debris or larger rocks, or dense stands of aquatic vegetation may not be suitable for seining due to net snagging or lifting and reduced fish retention. Current velocity and depth influence site selection and choice of net design. For a general guide to seining methods that can be used in varying habitats, see Appendix A.

Gear and method selection

Seines vary greatly in size depending on the target species, water depth, habitat, currents, and purpose (see Appendix B). For estuary and intertidal habitats, smaller nets can be used for sampling the shallow, intertidal shoreline areas (less than 1.2 m deep) with relatively homogenous water depth, velocity, vegetation, and substrate. Larger nets can be used for the intertidal-subtidal fringe with depths ranging from 1.8 to 4.6 m or deeper. Faster current generally requires a larger mesh size, at least in net wings, to reduce drag while deeper waters require wider nets to reach from the surface to the substrate. Often the wings are tapered to reduce overall net mass and because the ends of the seine are usually in shallower water than the midsections (e.g., see figures 2 and 3). Larger mesh in the wings than in the bunt and bag reduces drag in the initial stages of retrieval. For wadable waters and juvenile salmonids, small net beach or pole seine methods are appropriate (see Appendix B). Nets ranged from 10 to 24 m in length with 3.2–6.4-mm knotless-mesh nylon netting. For juvenile sampling in nonwadable waters, larger nets are used (37–95 m long, with mesh 3.2–9.5 mm). Typical net constructions for capture of adult salmon in nonwadable rivers vary between 45 and 70 m in length (historically, nets up to 777 m long were used for commercial harvest) and 5 m and 9 m in depth with lead lines varying between 0.5 and 1.75 kg/m (Appendix B). Floats are typically installed at 30–50-cm intervals on the cork lines. Stretched mesh sizes vary, but 5–6.3-cm (2–2.5-in) mesh is commonly employed. Twines used in mesh construction range in gauge from 48 to 96, with 96 being heavy and 48 being light. Twines are sometimes tarred to increase durability.

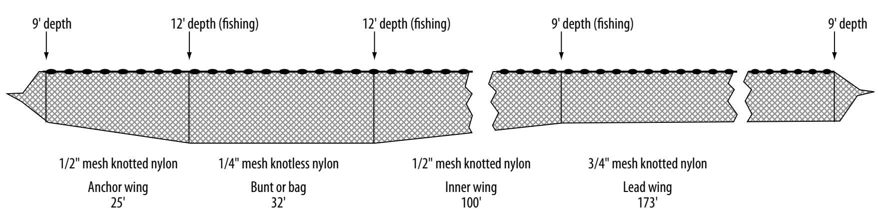


FIGURE 2. — Example of beach seine dimensions with unequal tapered wings (from Sims and Johnsen 1974) used in the Columbia River estuary, Washington. (Illustration: Andrew Fuller, from Sims and Johnsen.)

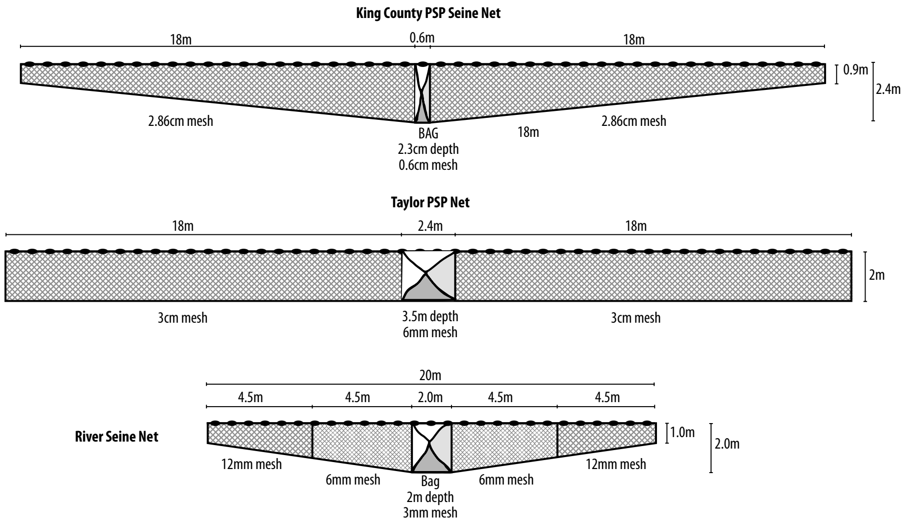


FIGURE 3. — Example of three beach seines used in Puget Sound, Washington. (Illustration: Andrew Fuller from Nelson et al. 2004, King County Department of Natural Resources.)

When to sample and sampling frequency

For purposes of mark–recapture estimates, seining for adult salmon should occur throughout the return run, such that returning fish are captured in a manner proportional to their abundance within the river (Farwell et al. 1998; Hahn et al. 2002; Rawding and Hillson 2002). For species such as sockeye, this may involve deployment of seining gear at passage sites downstream from spawning areas. For other adult salmon species, this may involve fishing at a variety of pool and glide locations throughout the spawning range (R. E. Bailey, Canadian Department of Fisheries and Oceans, unpublished data). Lazorchak et al. (1998) provide sampling schedules for use of beach seines in habitat assessments associated with juvenile salmonids as well as nonsalmonid species. Beach seining for juvenile salmonids is often conducted during the period of smolt out-migration in rivers and estuaries. Peaks in smolt migration vary by location and should be investigated as part of the planning process for a full-scale beach seining sampling effort.

To determine assemblage diversity or provide fish for biosampling, one or many sets may be employed, either on one day or throughout a longer period. To establish an abundance estimate, a single set per site may be adequate if the seine has been calibrated for efficiency. Alternatively, an area can be blocked off and seined until no more fish are caught, or a mark–recapture approach can be used for resident population estimate of small fish. A minimum of three sets per site is recommended (SSC 2003) if characterization of each site is an objective. If only the larger area needs to be characterized, single samples may be scattered randomly (but perhaps stratified into habitat types). If trend data is the objective, then nonrandomly selected permanent sites may be adequate (Brandes and McLain 2001). For capturing adult salmon for mark–recapture estimates, seining once per day or every other day at several sites may provide an adequate sample size. Some sites may allow two or more samples per day if migration is active. In small, clear rivers, like the Green River in Washington (Hahn et al. 2002), much of the chinook salmon migration may occur at night, so multiple sets per site per day are not fruitful. For coho salmon in the same river, however, active migration was noted during daylight (Hahn, personal communication).

Bias, selectivity, and efficiency

Factors that affect capture efficiency and selectivity

Gear selectivity is a quantification of the varying probability of capture for different sizes and/or species of fish (Backiel 1980). Capture efficiency (CE, sometimes called catch efficiency or catchability) is similar to selectivity but can be defined as the percentage removal or rate of exploitation for different sizes and/or species of fish in the area fished by the seine. Both terms may be understood for (a) the entire population in the body of water being sampled, (b) the subpopulation in the habitat area being sampled, or (c) that subpopulation of fish within the swept area of the seine. For this protocol, we follow Bayely and Herendeen (2000) and define capture efficiency as the product of encirclement efficiency when laying the net and retention efficiency while hauling in the net. Rozas and Minello (1997) suggest adding recovery efficiency as another component (see equation 1), defined as those fish that were retained within the net when pursed and were observed and counted; however, the individual efficiencies are difficult to estimate separately and no author has quantified all three. In some habitats (i.e., those without much vegetation) and for larger fish such as salmonids juveniles or adults, recovery efficiency is essentially 100%. CE for a beach seine is often in the range of 20–80%.

$$\text{CE} = \text{capture efficiency} = (\text{encirclement E})(\text{retention E})(\text{recovery E}) \qquad \text{(eq 1)}$$

We will define selectivity more broadly to acknowledge that the area that can be seined may contain only part of the total population of interest and species and fish of varying sizes are probably not randomly distributed over large areas. As an example, Duffy et al. (2005) sampled beaches in northern Puget Sound, Washington within single 24-h periods and found that size of chinook, coho, and chum salmon juveniles were significantly and often substantially smaller in daylight samples compared to crepuscular (dawn/dusk) or nocturnal samples. For southern Puget Sound beaches, differences were mostly insignificant and small. In the Columbia River estuary, purse seines consistently caught larger juvenile salmonids than did beach seines fished nearby (Johnsen and Sims 1973; Sims and Johnsen 1974; Dawley et al. 1986).

To help understand what affects selectivity and capture efficiency—and therefore, effectiveness of seining—we considered the following categories: habitat, water, fish, time of year and day, net, and method. Considering these factors in your study design before you sample and after you begin sampling (by underwater observation and calibration studies) will help you to decide when seining may be a good technique to meet your objectives; it will also help improve the analysis of data collected. We relied on our own experience, that of our peers, and the following authors: Allen et al. (1992), Backiel and Welcomme (1980), Bayley and Herendeen (2000), Dewey et al. (1989), Lyons (1986), Parsley et al (1989), Pierce et al. (1990), Rozas and Minello (1997), and others.

Habitat

- Substrate (e.g., roughness, softness)
- Vegetation (e.g., submergent, emergent, compressibility)
- Wood (e.g., trees, brush, and parts thereof)—underwater and above water and at shoreline

- Manmade objects (e.g., pilings, docks, junk, riprap)
- Small debris
- Seine rolling

Any object that snags a seine or causes it to lift off the bottom can allow fish to escape. Uniform, small substrates form a better seal with the lead line of the net than do larger cobbled or uneven bottoms. Aquatic vegetation weakens the seal and provides hiding places for small fish underneath or within clumps. Additional leads or adding a heavy chain (Penczak and O'Hara 1983) can reduce fish loss under the seine. In addition to substrate unevenness, snagging on logs, rocks, and other debris will slow down seining and decrease seining efficiency by allowing fish to escape prior to (delayed) net closure or underneath the net. Some soft substrates such as sand and silt will allow the lead line to sink and act like a dredge, which requires a reduction in weights. This dredging effect can also happen on gravel and pebble substrates and can fill the bag with unwieldy weight. One solution is to start the bag of the seine several inches above the lead line (J. Fryer, Columbia River Inter-Tribal Fish Commission, personal communication). Algae, leaves, small wood, and other debris also can clog seines, slowing retrieval and possibly lifting the lead line. Any inanimate matter in the bag or bunt can result in fish injury or death. Seine rolling (Pierce et al. 1990) may occur in dense vegetation where up to one-third or more of the width of a seine may roll upon itself. This net behavior increases the probability of fish escape. Additional tow lines clipped onto the lead line at intervals and pulled after initial setting is complete may reduce rolling. More lead on the lead line, by adding trailer sticks (Threinen 1956), may also help. For efficiency calibration studies, consider hand-pulling all the vegetation inside the deployed seine before retrieving if overall habitat impact is small.

Modifying habitat in seining sites with devices that lift the seine over obstructions (see Site testing and modification, page 283) can make seining possible, but it may result in temporary opportunities for fish to escape. It can allow seining when quite large obstructions, such as remnant vertical pilings up to 0.6 m tall, are present. It works best during the early phase of seine retrieval (before fish are concentrated) for large target fish (Hahn, personal communication) and when direct abundance estimates are not needed. Underwater observation should be used to confirm intended seine and fish action, and tending the net with snorkelers may be needed to keep fish from escaping.

Water

- Temperature
- Clarity (turbidity)
- Depth
- Currents
- Wave action
- Tide stage
- Ice depth

Within the preferred or tolerated range for each species, warmer water enhances fish swimming speed and thus increases the likelihood of escape. Compared to turbid water, clear water allows fish to see an oncoming net, boat, or tow line and initiate escape behavior earlier. Noise, vibrations, and changes in water pressure are induced by moving seines and perceived by fish. Some of these factors can drive fish ahead of the net and into the area it encircles, but it may also give them time to escape. Vibrating the tow lines may keep fish from darting out of the path of the seine. Water current either enhances or hinders the speed of seine retrieval. Currents and wave action affect the shape of the seine and can temporarily lift lead lines or submerge float lines. River currents, in particular, commonly can billow or push a net so that the lead line lags behind and allows fish to dive and escape under it. The tidal stage affects which substrate habitats are available to be seined and can affect where fish are prior to seining. Tidal channels are invaded with incoming tides and vacated on outgoing tides. For those who attempt to seine through ice, ice depth (via hole drilling speed) affects how rapidly a seine can be deployed to encircle schooled fish.

Fish

- Species
- Size
- Swimming speed
- Water column orientation (e.g., epibenthic, pelagic, epipelagic)
- Macro- and microhabitat association (e.g., nearshore/offshore, structure)
- Jumping ability and proclivity

Each species of fish has a suite of behaviors that characteristically cause fish to distribute vertically and horizontally in a water column in response to light, habitat, prey, other fish, and disturbance. This distribution may change with fish size (age) and time of year. Fish species that associate with the bottom (epibenthic) and with complex habitat (vegetation, rocks, wood) are generally more difficult to capture with seines than are fish that are pelagic or epipelagic (Murphy and Willis 1996). Sinking seines are sometimes used for fish that are epibenthic, and floating seines are used for fish that are (epi)pelagic. These two types of seining allow a greater reach from shore and thus a greater swept area. Usually, the sinking or floating occurs only during the first half of retrieval (typically a parallel set is used; see later section).

Fish that live in or migrate through nearshore waters are more often suitable targets for beach seines, whereas offshore fish can often be caught with purse seines or lampara seines if they are sufficiently close to the surface. Larger salmonid smolts tend to stay farther from shore, at least during the day. Johnsen and Sims (1973) compared catches of juvenile chinook salmon made in the same area and time of day in the Columbia River estuary: the mean length was 11.9 cm, versus 7.9 cm for fish caught by purse and beach seines.

If particular species or sizes of fish can outswim the net that is being set, encirclement efficiency is reduced and the accuracy of the CPUE estimate is likely to be low. In general, encirclement efficiency decreases and retention efficiency increases with bigger fish because swimming speed increases but ability to penetrate through net meshes decreases. Catches are higher for fish species that swim ahead of nets than for species that dive under or jump over nets. Mullet are notorious for jumping when startled or cornered. Scientists have seen chinook salmon turn on their sides, push their snouts under the lead line, and wiggle to escape under a seine (Hahn, personal observation). This behavior was avoided when the lead line remained ahead of the cork line; in those cases, fish tended to dart into the outward bulging main body of the net. Longer nets, more rapid deployment, and faster retrieval are needed as fish size increases. Herding or scaring fish toward the net may increase capture efficiency. Sometimes the haul lines (end ropes) create enough disturbance when retrieving the net so as to keep fish from passing under them. This can be enhanced by purposely slapping and splashing the water with these lines.

Time of year and day

- Time of year
- Time of day (which is interrelated with amount of light)

Effectiveness of seining is increased when fish are present! Therefore, learn about the behavior of your target fish species and design capture strategies to take advantage of their distribution and behavior. Time of year and day are very connected with the life history and behavior of the fish you wish to collect. Some species of fish migrate at certain times, places, or sizes. Resident fish gain size throughout the year and may seek different habitat as they age.

Within each day, fish often move in response to the amount of light. Larger fish often come into shallow water at night. The amount of light affects the ability of fish to detect and to avoid the sample gear; therefore, sampling at night can increase effectiveness of seining. However, nighttime seining also affects the ability of samplers to see what they are doing and may reduce safety.

Net (gear)

- Construction (how webbing is connected to float and lead lines)
- Mesh size (relative to fish size and different for wings, bunt, and bag)
- Mesh shape when retrieved (under tension)
- Twine size, knotless versus knotted
- Length of net
- Depth of net
- Float line (size of floats—does net sink or float when water depth is greater than net depth?)
- Lead line (amount of weight, lead-core versus weights, sinking speed)
- Wing and bunt design (with or without bag)
- Wear

Beach, pole, and purse seines need to have a tight attachment of webbing to the cork line and around floats so that openings are minimized. Beach and pole seines need to have a similarly tight attachment to the lead line. Worn nets may tear and allow fish to escape. To reduce wear, additional webbing is sometimes wrapped and sewn around the lead line and lead weights.

Larger mesh size and smaller twine diameter have reduced water resistance and allow quicker retrieval of seines. The trade-offs are greater encirclement efficiency from the gain in speed but possible lower retention efficiency. A weaker net may tear or rip more easily. Mesh size in the wings can often be larger than the cross-sectional dimensions of the target fish. Under tension, rectangular webbing assumes a diamond shape (i.e., the cords that form the sides of the mesh openings in a seine net run at 45° angles to horizontal and vertical), which reduces the space through which fish wiggle. Also, the early part of the seine retrieval often drives fish ahead of the net, so they do not usually attempt to wiggle through a net even when they could successfully do so. When fish finally sense that they are confined, they may panic and dive headlong into the net, but by then, the wings should be on the beach or in the boat; therefore, smaller mesh size is used in the bunt (center) section so that fish of all target sizes are unable to penetrate through individual meshes. Knotless twine tends to be gentler on fish (minimizes descaling) and is best for the bunt and bag sections, if not the whole seine. A bag helps concentrate fish away from cork and lead lines and reduces possibility of escape.

A long net can be effective in surrounding and trapping large and fast fish, but it is bulkier and harder to retrieve (requiring more people). Short nets are most appropriate for small fish capture in shallow water; however, shorter length reduces the swept area and thus the total capture. The width (depth) of the seine must exceed the maximum depth of the water to be fished, unless floating or sinking seine retrievals are intended. When relaxed, a seine can reach deeper than its width, but under tension and billowed with the current, its width is reduced by as much as 25% or more.

Floating seines have buoyancy that exceeds the weight of the lead line and can be used to capture fish that are epipelagic. Sinking seines have lead weight that exceeds buoyancy and can be used to capture demersal (epibenthic) fish. In both cases, the cork and lead line come in contact with the surface and substrate during the last half of retrieval to prevent fish from surfacing or diving to escape. Lead core line may offer less opportunity than external weights to snag in rocky substrate; however, external weights can be added or removed to customize a single seine for different conditions. Too little weight will allow the lead line to lift when the seine is pulled vigorously, allowing fish to escape. More lead means the seine sinks more quickly to reach the bottom, cutting off the escape of diving fish. Underwater observation should be used to confirm the intended action of the seine and fish.

Method (gear deployment)

- Speed of net deployment
- Boat motion and engine noise
- Speed of retrieval
- Shape of set (and effect of current)
- Tow line action

Speed is an essential part of successful seining. Fish should be given the least amount of time to flee and attempt escape. The size and swiftness of the target fish should influence both the length of the seine used and the speed at which it is deployed and retrieved. More power (additional personnel or winches) can increase the speed of retrieval. Boat and motor size affect the size of seine and the speed at which it can be deployed. Larger, faster boats create stronger vibrations and greater visual disturbance. Underwater observation can provide guidance on the adequacy of your seine size (sections can be added) and deployment speed. Pierce et al. (1990) wrote, "Fish [in lakes] generally seemed to ignore the [small] boat until it came within 2 or 3 m, so we assumed that evasion or other movements into or out of the enclosed area … were negligible." Bayley and Herendeen (2000) also noted that noise and disturbance effects attenuated quickly. Hahn et al. (2003) depended on jetboat noise and motion to scare, herd, and concentrate adult salmon downstream from the heads of pools and towards the tailouts in the Green River, whereas Farwell et al. (2006) used a second boat to chase fish upstream towards the seine boat.

Too great a retrieval speed will allow the lead line to lift (or the cork line to dive) when the seine is pulled vigorously, allowing fish to escape. Additional weight or floats may need to be added. It is best to always attempt to retrieve or pull the lead line even with or ahead of the cork line; otherwise, fish tend to be directed down the netting to the lead line, where they might be tempted to dive and wiggle under. The shape of the seine as set, and its subsequent shape when towed, can affect the outcome of attempted escape behavior by the target fish. A curved net probably reduces the opportunity for lateral escape, forcing the fish to attempt to outswim the net. For pole seines pulled along the shore, large and swift species can probably escape. For seines set rapidly in an arc away from and then back to shore—as compared to seines set parallel to shore—escapement may be reduced, but this depends on the size of the target species. Underwater observation should be used to verify seine action and fish behavior. This should be done during all stages of seining. In the final stages of retrieval and confinement prior to processing the fish, the lead line should be brought on shore (or into the boat) and the cork line elevated if fish are inclined to jump.

Calibration: Measuring seine efficiency

Although salmonids were not involved, a paper by Rozas and Minello (1997) provides one of the best overviews of the various issues involved with seining and elaborates on the need for knowing capture efficiency for certain uses of sampling data. They reviewed many studies, mostly related to sampling estuarine areas in the Gulf of Mexico. They outlined catch efficiency as having two components: gear capture efficiency (which describes the proportion of fish in the path of the seine that are caught) and recovery efficiency (which describes the proportion of the caught fish that are actually found and observed by the samplers; this is also called retention efficiency). Some of their conclusions and recommendations were as follows:

(1) Seines (and trawls) had low and variable catch efficiency and were particularly affected by aquatic vegetation;

(2) Enclosure samplers might be better than seines in estimating the density of small nekton in estuaries;

(3) Tide stage must be considered in designing and analyzing results in estuaries;

(4) Catch efficiencies can be estimated by mark–recapture within block nets;

(5) Observing and measuring gear avoidance by direct observation (diving and/or underwater cameras) was worthwhile; and

(6) Clumped distribution of fish (either due to habitat relationship or schooling behavior) requires an increase in the number of samples or a greater sample area per unit of effort (seines functioned well in this regard).

The most practical method of measuring the CE for a seine net (calibrating the net to particular habitats) is to use block nets to trap a representative group of fish within an enclosed space, introduce marked fish, conduct one or more seine sets within the enclosure so that perhaps 40–70% of the enclosed space is swept, retrieve the block nets carefully, and then calculate capture efficiency (Wiley and Tsai 1983; Parsley et al 1989; Bayley and Herendeen 2000). The first seine set is used to estimate CE for a single set (as in Bayley and Herendeen 2000), or the entire series of sets could be used in aggregate (as in Weinstein and Davis 1980; Wiley and Tsai 1983). This allows as natural a situation as possible in which fish can choose all options for escape. This is illustrated in equation 1, where CE is a product of three probabilities. Some authors chose to set tightly within a block net enclosure so that close to 99% of the area was swept (Penczak and O'Hara 1983; Lyons 1986; Pierce et al. 1990; Holland-Bartels and Dewey 1997). However, this technique does not allow fish much opportunity to escape the ends of the seine, thus increasing CE above its true value. A few authors chose to seine a naturally blocked population, such as a tidal estuary pool, and compared the first seine haul to the total population removed by repeated hauls and/or following rotenone application (Weinstein and Davis 1980; Allen et al. 1992). Calibration trials should be repeated in several locations to represent as best as possible the habitat sampled and also to compensate for erratic individual CE values caused by schooling fishes (wherein the school might or might not be caught within any one seine set).

When using a seine within a block net method, CE is calculated for each species (or species-size group) by dividing the number of fish caught by the total estimated population in the enclosure. Using marked fish allows for an estimation of the number of fish not recovered when the block net is retrieved (mark–recapture estimate), as summarized in equation 2. Some authors have used the removal method and repeated seining to estimate the total population (Lyons 1986) and others have used rotenone and marked fish (Weinstein and Davis 1980).

$$Ni = \text{total population species } i = \text{(recovered by seine)} + \text{(recovered by block net)} + \text{(estimated not recovered)} \quad \text{(eq 2)}$$

Fish for marking can be obtained nearby by seining outside the block net enclosure. This ensures that they are accustomed to the habitat enclosed and behave similarly to fish already inside the enclosure; however, there could be some learned net avoidance behavior (but this should not be much of a factor for slow and careful block net retrieval). Marked fish should be introduced gently into the enclosure (by using long-handled dip nets) and distributed evenly (Bayley and Herendeen 2000).

Calibration methods are only needed when seine catches must be expanded to estimate the total populations present in the selected habitat or when calculating species diversity indices that incorporate abundance. As mentioned before, other applications of seining simply capture fish for marking or mark–recapture , biological sampling, or estimating relative CPUE or survivals.

Data extrapolation within and among locations and times

Abundance estimates by seining, without using mark–recapture or efficiency estimates, would not be very comparable among different systems or habitats. Data could be somewhat comparable if most factors were the same, which is most likely to occur within a system being sampled by the same crews during the same sampling period. For example, comparing the catch rate (i.e., number per square meter sampled) may be somewhat comparable if species, species size, habitat characteristics (e.g., river gravel bar, of medium velocity, similar water clarity, time of season), sampling gear (e.g., seine dimensions, mesh size), and deployment methods were very similar.

Field/Office Methods

Planning and setup

Prior to the start of the sampling season, preseason preparation is needed to ensure a smooth implementation of a seining program. At this point, we assume that you have formally developed the purposes and objectives for your research. Now is the time to add detail to your written study proposal. Your general methods will now need evaluation and revision to accommodate the realities of the sampling sites.

You will face a number of questions: Where exactly do you want to sample? What are the habitat conditions there (e.g., lotic versus lentic, fast versus slow currents, substrate type, beach angle, depth)? What are your target species/life stage(s)/size range(s)? Answers to these questions will help determine the size of nets, boats, other gear, personnel, and permitting required for the project.

Site selection and inspection

If you are not personally familiar with the body of water and fish populations for which you believe seining may be a useful capture method, then first consult with local experts, who may be fishery biologists, fishermen, guides, or local residents. (See page 282, Preseason activities for seining.) Find out what research has already been conducted in the area of interest. Do a literature search and contact agencies, Indian tribes, and universities to see what monitoring activities may already have been conducted. Their reports and publications will describe sampling sites and when the target fish are likely to be present. Next, consult maps and aerial photos to look for likely new sites and to find potential access. Obtain a geographical information system-produced map that shows generic property ownership. Visit a local government office or Web site to look for specific property owners. Remember to contact the owners to inform and obtain consent before crossing private property. Make a list of the characteristics of seinable sites for your project. For example, to collect adult salmon in a river for a mark–recapture study, you might want to note: places where target fish aggregate in sufficient quantities to make their collection worthwhile with a 5–7-person crew, pools with fast and shallow water above and below, smooth substrate or only a modest amount of snagging objects that can be "fixed," and lateral sand or gravel bars where a seine can be hauled near the shore.

Use a boat to explore likely stretches of river, bay, or lake. Use a digital camera, global positioning system (GPS) unit, map notes, and sketches to document potential sites. Every potential site must have a suitable haul-out beach or shallow water with modest or no current where the fish can be held until processing. This must be located properly with respect to the anticipated seine deployment and retrieval location. For marine waters and estuaries, obtain a tide schedule and visit the sites at various tide stages to understand currents, substrate exposure, and access issues. For rivers, find the nearest flow gauge, record flows for every site visit, and compare them to help determine what is expected on the dates when seining needs to occur.

On the initial or subsequent inspection trip, for waters that are sufficiently clear, employ an experienced snorkeler or agency-certified SCUBA diver to look at the sites underwater. On a map, record locations of any objects that might snag a seine, the substrate composition, and the direction of currents.

Box 1: Preseason activities for seining

(1) Develop objectives; write a sampling and safety plan.
(2) Gather information on tides, currents, flow volumes, and water clarity for the proposed sampling time period and locations. Get aerial photos or visit Internet sites that have digital orthophotos as background.
(3) Collect local knowledge (contact expert biologists, anglers, tribal members, commercial fishers, and/or property owners.
(4) Inspect seining sites, access points, and routes for boat, vehicle, and foot travel where required. Use snorkel surveys to check sites. Use a GPS device to store coordinates of all sites and access points. Take pictures and make hand-drawn maps (including maps of underwater habitat features).
(5) Contact private landowners to ask whether boats, nets, and equipment may be stored securely on their property or if they will allow access.
(6) If needed, conduct a pilot study to demonstrate feasibility.
(7) Choose appropriate net designs and deployment vessels. Estimate requirements for winches or other mechanical aids to recover nets.
(8) Order nets and discuss needs with net company experts.
(9) Inspect nets to ensure that mesh, lines, floats, and weights are all secure and functional.
(10) Determine required crew size. List all equipment needed and gather or purchase items.
(11) Prepare data sheets and develop a data entry plan.
(12) Buy and prepare holding boxes and tags to apply to fish (if needed).
(13) Apply for permits (where required) for access or for take or handling of fish (that may be listed as threatened or endangered).
(14) Prepare vessels, vehicles, and trailers, including safety equipment.
(15) Arrange for and provide safety training.
(16) Prepare sites for seining and test the seines.

Suitable: shallow silt, sand, gravel, cobble, hard clay (Note: deep silt can “suck in” a lead line and can be impossible for humans to wade through).

Potentially "fixable" objects: rocks, small and scattered boulders, occasional short pilings (less than 1 m), loose wood, occasional imbedded wood (e.g., trunks, branches), very small rootwads, fishing lures and line, metal (e.g., wire, poles, shopping carts, bicycles). (Note: large rootwads or log jams, if they lie to the side of the main seining path, sometimes can be "fixed" or marked to prevent snagging a net that has been set too close.)

Unfixable objects: medium to large rootwads, tall or abundant pilings, abundant boulders and embedded wood, long sweeper branches, entire trees, car bodies (unless they can be hauled out).

Estimate likely net sizes that might accomplish fish capture in the identified sites. Is more than one net needed?

Site testing and modification (preparing for seining)

Testing

Once sites have been visually evaluated and inspected underwater, either plan for habitat modifications (see below) or use a bare lead line and conduct trial sweeps. Even seemingly small objects can be serious snags. This activity should occur well before the date when seining needs to occur. If a site seems to be devoid of snags or if water turbidity precludes visual underwater inspection, first use a bare leadline to conduct trial sweeps. Mark snag locations with a float and line tied to a heavy weight. After assurance that major snags are absent, use your seine for additional trials. All this will require advance planning and sufficient personnel (see later sections, including safety). If the sites are clean and usable as is (note that occasional snags may remain marked and avoided), then skip the modification steps. If the site seems to have a number of snags but is desirable for sampling, then read the next section and decide whether to abandon the site or modify it. After site modifications, testing with a seine should occur.

Modification

The following techniques are useful only when desirable seining sites have a modest amount of structure that can be overcome and when sufficient alternative sites do not exist. Our focus is on river sites, but there may be applicability to other environments. The amount of effort to invest in "fixing" a site is proportional to the belief and/or knowledge that target fish inhabit and can be caught by seines in the site, and the number of times sampling is planned. The answer to the question "Does it appear that seining can successfully occur if underwater obstructions were overcome?" should be yes before planning to modify a site. As always, safety is the first priority and good judgment is necessary in all steps in this process.

Remember that underwater objects are habitat for fishes. Often, the better the habitat, the more difficult it will be to seine. The goal of site modification is to find creative, temporary ways to allow a seine to slide over and around objects that normally might snag. Only as a last resort should occasional, small, protruding objects be cut. Unnatural objects (e.g., trash) may be removed. After your research is complete, you may remove the devices you had installed, and the habitat should be nearly identical to what it was before.

The devices that have been used to facilitate seining are pitchfork, J-bar, U-bar (or bridge), straight-bar, sandbags or gravel bags and marker buoys (P. Hahn, Washington Department of Fish and Wildlife, personal communication) (see Figure 4). The simplest are sandbags, which should either be made of biodegradable burlap (if left in place) or affixed with a short looped cord to facilitate later removal. These bags can be piled on and around rough cobble and small boulders or small protrusions from the substrate. They act to remove crevices into which lead lines may slide. The other devices all consist of 0.95-mm (3/8-in) iron rebar used in construction to strengthen concrete. This size can be bent underwater by a diver; thicker rebar is more difficult to work with. The straight bar can be up to 6.1 m long and is worked underwater to bend over and around large objects, often in a crosshatch fashion. The upstream ends must be embedded in the substrate. The U-bar has a washer welded on each end and is useful if there are large tree trunks underwater (generally oriented parallel to the current) that have snapped off limbs or jagged cavities. Usually, these trunks lie on either side of the seining path; the U-bar helps avoid snagging by the mesh, which might billow out or be set too close. The washer in this and the other devices allows the use of nails to fix the device to woody objects. The J-bar devices come with and without washers welded to or near the curved end. The long end is jammed into the substrate and the remainder angled downstream to cover boulders and woody snags. The pitchfork devices require the most welding and are constructed of two curved pieces of rebar with cross bracing (see Figure 4). They can be from 1 m to more than 3 m long. The tines are pointed upstream and jammed into the substrate, with the curved end over the obstacle. Several can be placed in overlapping fashion. The most common use is as a net-lifter, but they can also be placed around the sides of rootwads to deflect a seine laterally. They can successfully lift a seine up to 1 m over an object such as a piling. However, be aware that any lifting of the lead line allows the possibility of fish escape.

There are other habitat modification or avoidance techniques. Selective trimming of occasional, small sweeper branches may be necessary, but should be minimized to avoid permanently changing the habitat. Sometimes lone boulders (such as from highway shoulder riprap) can be moved back to the bank using tire chains, steel cable, and winches. Finding and removing tangles of fishing line, hooks, and lures is an important task of the snorkel team. Just one treble hook tied to stout line can stop a seine, be dangerous to remove underwater, or injure the seining crew. Last, buoys can be tied to underwater obstacles so that the boat operator can see and avoid them during seine deployment. If there is a fish escape route between the obstacle and the far shore, a snorkeler can splash and keep fish out of such an area until the seine has been deployed downriver.

FIGURE 4. — Devices built out of rebar to bridge over rocks, boulders, snags, large woody debris, and so forth, to allow beach seining for capturing adult chinook salmon in the Green River in Washington in 2000–2002: a pitchfork device (left); two J-bar and a bridge (U-bar) devices (right). The insets show placement of welded washers that allow nailing the devices to wood objects. (Photo: Peter Hahn, Washington Department of Fish and Wildlife.)

Freeing a snagged seine

Depending on bottom topography and the presence of debris or large rocks, nets may become trapped during retrieval. Slacking tension on lead lines and pulling up on the cork line and webbing (into any current) from a boat may work in deep water. A gaff hook on a long pole can be of assistance. Having snorkelers in the water can be very helpful (see the snorkel safety section, page 311, for detailed procedures and cautions); they can attach a pulling line to the lead line. In shallow water, a snorkeler simply wades to the snagged location and frees the net. Note that while a net is being freed, fish may escape.

Seining methods and events sequence

General

A variety of net types and sizes and usage methods have been used by scientists. In nonwadable lotic habitat, seines are typically set from unpowered crafts, such as drift boats or rowboats, or from jet or propeller-driven boats. For maximum efficiency of setting, a seine table (a flat deck free from obstructions or cleats) is desirable. For powered boats, when setting from the stern, a centrally mounted tow post equipped with a quick-release device is desirable, as is a cowling around outboard motors to reduce the chance of nets tangling. In wadable systems, smaller nets are used and deployed by hand with one end of the net anchored to the shore and the other end extended out from shore and then looped around to encircle the fish as the ends are pulled in against the beach. Alternatively, both seine ends may be fixed to poles held by people who walk and push or pull the net. Each pole is held vertically or slightly angled (bottom forward) to keep the lead line against the substrate. In the latter case, the net is generally shorter and may be brought up against the shore or swooped upwards into the air midchannel to trap the fish.

With most seine sets, lead and cork lines should be withdrawn at approximately equivalent rates until close to shore. Once the lead line approaches the shore, it should be withdrawn more than the cork line until a secure pond or corral is formed in the bag of the net and the lead line is on the beach. For circle sets, lampara sets, and purse seine sets, the lead line is retrieved first, followed by the remainder of the cork line and net. Fish may then be allowed to rest within the bag until they are withdrawn for sampling, tagging, or transport to hatchery for use as broodstock. For some methods (e.g., circle set), vegetation may need to be removed methodically and inspected for fish before the seine can be pursed.

Once all fish have been withdrawn from the net, the net is cleaned of all leaf litter, sticks, rocks, and other debris; checked for damage; and reloaded for the next set. Damage to seines can be repaired following instructions in Gebhards (in Murphy and Willis 1996).

Method details

We categorized seining methods into the following groupings. Methods and variations are described and illustrated below.

Pulled linear sets
1. Parallel set
2. Perpendicular set
3. Perpendicular quarter-arc set
4. Wandering pole seine
5. Lampara set

Arc sets
6. Simple arc set (and fast pursuit sets, including double-arc single net option)
7. Double-seine simple arc set
8. Beach-lay elliptical arc set
9. Rectangular arc set
10. Circle set

Trap sets
11. Cable-L trap set
12. Block net sets
13. Enclosure net tide set
14. Channel trap tide set

Purse-seine sets
15. Purse seine set

Pulled Linear Sets

General characteristics: A seine is fully deployed in a straight line, and then both ends are kept apart and pulled through the water some distance until brought to shore or pursed offshore. Usually used to capture small or "slow" fish, where extra speed, stealth, and/or long nets are not needed. (Here "slow" is relative to the length of net deployed; the longer the net, the faster a fish can be and still not escape.)

1. Seine method: Parallel set

Citations: Schreiner 1977; Fresh et al. 1979; Bax 1983; Simenstad et al. 1991; Brandes and McLain 2001; Toft et al. 2004 (see Appendix B).

Procedure: The seine net (see example in Appendix B) is fully deployed in a straight line (AB in Figure 5) by boat at a predetermined distance from shore and parallel to the shoreline. The pulling line AD has a marker a set distance from the seine (30 m for the Puget Sound protocol) (Simenstad et al. 1991 and others) so that the shore tender can signal the boat operator when to begin laying out the seine. When the boat reaches B, the end of pulling line BC is brought to shore without pulling the net. At a signal, people at D and C rapidly begin pulling the seine to shore. In the Puget Sound protocol, when a second marker 10 m from the net is reached, both groups of pullers begin to run towards each other (C–K and D–L) and finish pulling in the seine at HJ. The lead line (JNH) is pulled more rapidly than the cork line near the end of the retrieval.

Analysis: May be used for fish/set, fish/area, or fish/volume analysis. This procedure allows a fixed length seine to be fished in a consistent manner. Length and width of the swept area must be known, and maximum depth must also be known for volume estimates. Caution: the distance between ends of the seine decreases once pulling to shore commences (because the seine assumes an arc shape); thus area and volume should be based on the actual travel path (see approximate polygon LGABEK in see Figure 5).

Where: Lakes or protected marine shoreline with no or very little current.

Variations:

A. Clip-on/removable floats allow the seine to be fished initially as a sinking or a floating net. When sufficiently shallow water is reached during the retrieval, the cork and lead lines keep the seine stretched from surface to substrate.
B. Kubecka and Bohm (1991) and Kubecka (1988) oriented the two pulling lines about 45° away from the seine, apparently in an attempt to keep the seine stretched as much as possible and maximizing the swept area.
C. Brandes and McLain (2001) began a set with the seine piled on shore. One person pulled one end straight out from shore until maximum safe depth was reached and then turned and moved parallel to the beach. The second person followed the path of the first person until the seine was stretched parallel to shore. Both persons then pulled straight to shore. The length of the seine was used as the width of the swept area.

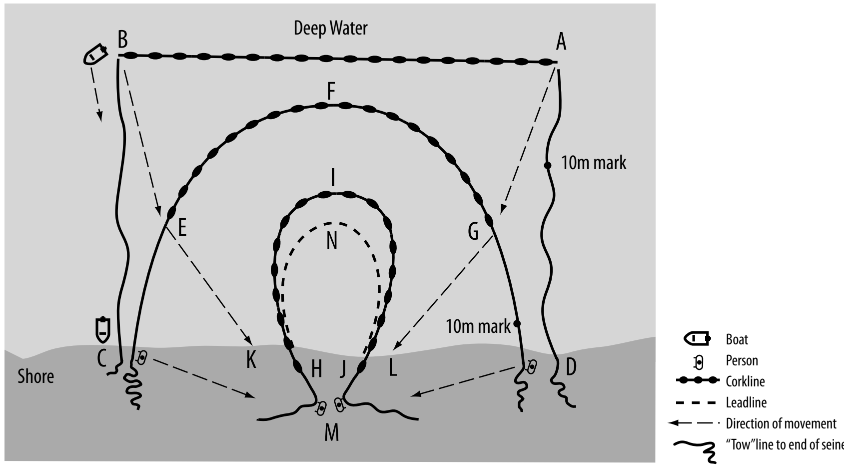


FIGURE 5. — Parallel set deployment and retrieval of a beach seine as used in Puget Sound sampling protocols (not to scale). (Illustration: Andrew Fuller from design by Peter Hahn.)

2. Seine method: Perpendicular set

Citations: Hayes et al. 1996; Fryer 2003 (see Appendix B).

Procedure: Two persons start on shore (at A, Figure 6); each one holds a pole (or stick) fastened to opposite ends of the seine. The seine is stacked on the beach in a looped fashion—lead lines under the cork lines—ready to pull out. One person pulls one end of the seine straight out from shore until the end of the net or the deepest safe water (1.2 m in Brandes and McLain 2001) is encountered (at C). The cork line is marked in 1-m increments so that the distance from shore can easily be noted (in case only part of the net is stretched out). Each pole is held to keep the cork and lead lines spread apart, and the bottom end of each pole keeps the lead line in constant contact with the substrate. Each pole is angled so that the lead line is ahead of the cork line. The nearshore end of the seine is kept in very shallow water or slightly on shore. Both persons then pull the seine along the shore some variable or set distance (CEF and ADI), whereupon both ends are brought onto shore (at G–I). Pole seines can be designed to be operated by one (very short net) or two persons (long net).

Analysis: May be used for fish/area or fish/volume analysis (length, width, and depth must be measured), but fish/set is appropriate only if the distance pulled is consistent. The poles may be marked with 0.1-m-depth increments to facilitate measuring the water depth at the offshore end of the seine (note: take an average of two or more depths). To ensure consistent width of swept area, a rope of known length can be attached to the upper end of each pole (DE in Figure 6) and stretched tight during seining.

Where: Large to small rivers, creeks, lakes, and protected marine shoreline. Currents must be modest or water so shallow that current is not a safety factor.

Variations:

A. A motorized boat or rowboat may be used on the deepwater end of the seine, which allows a greater reach from shore and thus greater swept area (see Figure 7). This variation causes greater difficulty in measuring the offshore depth or the distance between ends of the net; therefore, it is most appropriate for collecting fish for marking or biological measurement. The substrate must be known to be free of snags (note: test with bare lead line first).

B. The seine may be walked quickly through areas to be sampled, not necessarily tight to the shoreline (see Figure 8). The net is lifted to finish a set or pursed to shore. This variation is for collecting fish for marking or biological measurement, or for qualitative rather than quantitative analyses. (See Wandering Pole Seine method on pages 290–291.)

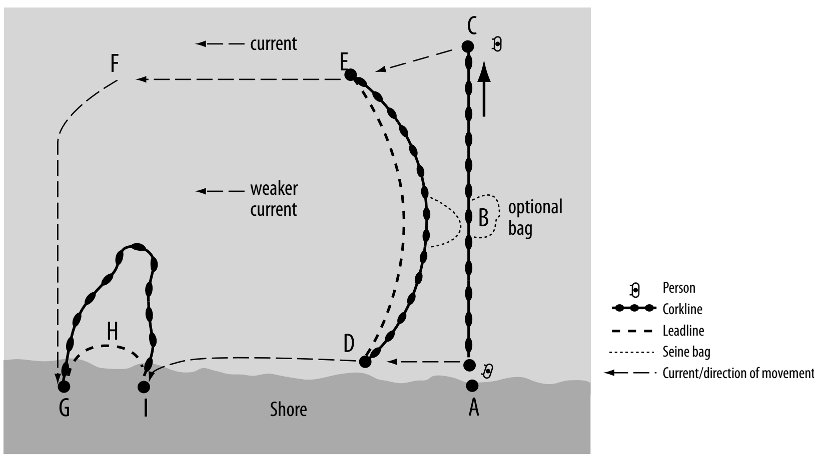


FIGURE 6. — Perpendicular set deployment and retrieval of a beach seine (not to scale). (Note: the distance A–I may be very long—perhaps several hundred meters.) (Illustration: Andrew Fuller from design by Peter Hahn.)

FIGURE 7. — Perpendicular set beach seine operated with a jet boat on the offshore end, Columbia River, Hanford Reach juvenile chinook salmon tagging study. (Photo: Jeff Fryer, Columbia River Inter-Tribal Fish Commission.)

FIGURE 8. —Perpendicular set two-person pole seine pulled along shore to catch juvenile chinook salmon, Columbia River, Hanford Reach juvenile chinook salmon tagging study. (Photo: Jeff Fryer, Columbia River Inter-Tribal Fish Commission.)

3. Seine method: Perpendicular quarter-arc set

Citations: Levings et al. 1986; Parsley et al. 1989 (see Appendix B).

Procedure: One person sets the seine straight out from shore until the end of the net or the deepest safe water is encountered. The end on shore is fixed, and the end away from shore is then pulled in a semicircle back to shore, keeping the net as elongated as possible. By using a fixed length of net and pulling the offshore end in a consistent manner, a consistent swept area can be attained. In the one citation where this method was used, the seine was set inside a rectangular block net, and the swept area was calculated as 64% of the area inside the rectangle.

Analysis: Parsley et al. (1989) used this method within a rectangular set block net to calibrate efficiency. May be used for fish/area or fish/volume analysis (note: length, width, and depth must be measured). The poles may be marked with depth increments to facilitate measuring the water depth at the offshore end of the seine. To ensure consistent width of swept area, a rope of fixed length can be attached to the upper end of each pole.

Where: Lakes, reservoirs, or protected marine shoreline with no current. This set may also be used in large rivers, but currents must be nil and water sufficiently shallow. (Currents would cause billowing of the seine and reduce the efficiency of the set.)

Variations: None.

4. Seine method: Wandering pole seine

Citations: Allen et al. 1992; Flotemersch and Cormier 2001; Toft et al. 2004.

Procedure: A pole seine is stretched out between two persons and pulled through the water, linearly or in a meandering path; neither end stays at the shoreline (see Figure 9). At the end of the set, the lead line is often simply scooped into the air, trapping the catch in the bunt of the net (see Figure 10); however, this only works with short seines.

Analysis: Generally qualitative; used to capture fish for tagging or sampling. Can be used for species presence documentation, but selectivity will be unknown.

Where: Any body of water (e.g., lakes, rivers, ocean) where two persons can safely walk and pull a seine.

Variations: Somewhat similar to perpendicular set when one end is not kept onshore. (A) Two seines can be used simultaneously by three persons (but it is better to prepare in advance and purchase a longer seine), or (B) two seines can be fished next to each other to take advantage of a broader uniform habitat.

FIGURE 9. — Wandering pole seine set in Whatcom Creek, Washington. (Photo: Charmane Ashbrook, Washington Department of Fish and Wildlife).

FIGURE 10. — Scooping the seine at the end of a wandering pole seine set, in order to capture fish entrained in the bunt section. The seine could also be brought to shore. (Photo: Washington Department of Fish and Wildlife).

5. Seine method: Lampara set

Citations: Hayes et al. 1996; Bayley and Herendeen 2000.

Procedure: This specialized net is made with a lead line that is much shorter than the cork line and is much wider in the middle than in the wings. It is generally set from one boat to a second boat so that the seine becomes stretched between them. Both boats then move in parallel, towing the seine some distance before coming together to purse the net.

Analysis: May be used for fish/set, fish/area, or fish/volume analysis (note: length of tow, width of opening between ends, and depth to lead line must be measured). Only pelagic and epipelagic fish will be caught. Acts much like a trawl, with the similar issues involving efficiency (fish avoidance).

Where: Used in large bodies of water that are too deep to wade or where the lead line cannot easily reach the substrate and with no or modest currents.

Variations: Motor-powered or hand-paddled boats may set and pull the nets.

Arc Sets

6. Seine method: Simple arc set (and fast-pursuit sets, including double-arc single net option)

Citations: Sims and Johnsen 1974; Healey 1980; Dawley et al. 1981, 1986; Levings et al. 1986; Pierce et al. 1990; Hayes et al. 1996; Bayley and Herendeen 2000; Hahn et al. 2003; SSC 2003; Kagley et al. 2005; Farwell et al. 2006 (see Appendix B).

Procedure: In its most simple and perfect form, a seine is laid in a half-circle by starting with one end on shore (A in Figure 11; see also Figures 13 and 14); a boat or people then carry and lay out the net into deeper water and then arc back to shore (at D). The lead line should be stacked in the direction of the arc (i.e., on the downstream side if making arc downstream). The speed at which this is done and the length of the seine depends on the target fish species and size.

Pursing the seine generally commences once the setting end of the seine reaches shore. The lead line is pulled to keep it in front of or even with the cork line. Once the lead line is on shore, the remaining part of the seine may be kept in shallow water until fish are processed (if intended for live release) or it is pulled and shaken to concentrate the fish into the bag or bunt section. Fish can then be emptied into a container. Aquatic vegetation may slow the retrieval considerably, especially if vegetation is pulled and carefully inspected to recover all fish. If a repetitive half-circle shape is not needed, the seine may be laid in an oblong or irregular shape that emphasizes sampling in a particular area (but area and volume calculations become impossible).

Analysis: May be used for fish/set, fish/area, or fish/volume analysis. This procedure allows a fixed length seine to be fished in a consistent manner, given that the boat operators or seine setters are experienced. If the seine can be consistently set in a semicircle (as in Figure 11), then it will be fairly straightforward to calculate area if the radius (GH) is known. Likewise, the volume can be calculated (Box 2) if the depth at the apex B in Figure 11 is measured. (After the set, a range finder or a rope equal to the length of radius could be used to find the correct distance offshore.) If the net is set in an elliptical or other shape, the user will need to determine how to estimate the volume. The fast pursuit options are used mainly to capture the maximum number of fish for tagging and release and not for quantitative analysis of CPUE.

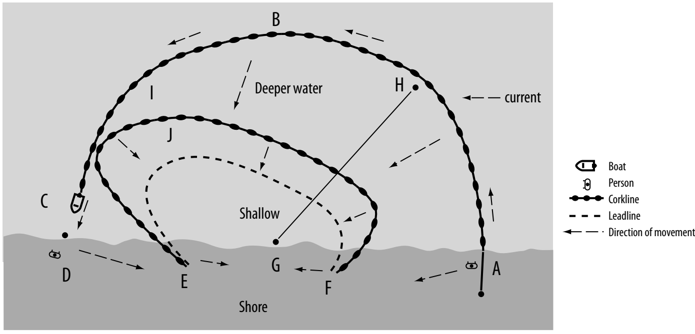
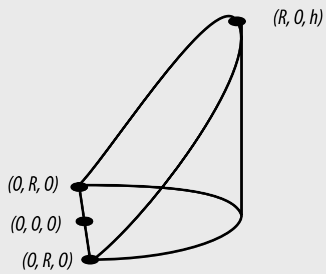


FIGURE 11. — Simple arc set for a beach seine using a motorboat. The seine is initially set from A to B to C. Note that a perfect semicircle is rarely attained (see radii GA, GH, GB, GI and GD in this example) so that area and volume calculations will be approximate. One possible position of the net is shown after half-retrieval (FJE), affected by a current coming from the right and the persons at A and D moving towards each other (note that the lead line is in advance of the cork line). (Illustration: Andrew Fuller from design by Peter Hahn.)



Box 2. Volume of a cylinder intersected by a plane.

A special case of the cylindrical wedge, also called a cylindrical hoof, is a wedge passing through a diameter of the cylinder base. Let the height of the wedge be h and the radius of the cylinder from which it is cut be *R*. Turn the above image upside down, and imagine the flat surface of the elliptical plane to be the bottom of a lake or river, and the half circle to be the seine corkline on the water surface. The perimeter of the ellipse is defined by the leadline. The water depth at the apex of the net is then *h*. The equation for the volume is: (Illustration: Andrew Fuller from design by Peter Hahn.)

$$V = \frac{2}{3} R^1 h$$

Where: Large-medium rivers, lakes, ponds, protected marine shoreline. Currents must be modest or absent. Small rivers, or any area with complex habitat, generally have space constraints so that only a small seine can be set in a consistent manner.

Variations:

A. The seine may be set by hand from a floating tub or small boat in shallow water (see Figure 13, parts B and C) (E. Beamer, Skagit System Cooperative, personal communication). (See also Rectangular Arc Set.)

B. The seine may be piled on the shore and pulled out by a boat and then around in an arc back to shore. This tends to be like a perpendicular quarter-arc set (see Levings et al. 1986).

C. Hold-open option: A boat starts by setting half the seine from shore into the current, holding the billowed seine against the current for specified time (e.g., 4 min), then completing deployment of the seine in an arc back to shore (Figure 12, part B). The intention is to allow fish to move down current into the seine. Recent evidence suggests that this strategy does not increase the catch and may actually decrease it due to avoidance by larger fish (Beamer, personal communication). A powerful engine is needed to counteract drag.

D. Double-arc single net option: Two boats, each with half the seine stacked on them, travel together to a point offshore. At a signal, each proceeds away from each other, each completing a quarter-arc back to shore. Using two boats increases the speed at which the entire net is set. This may be best used where an extremely long seine is to be set in relatively calm water. It could be considered a fast pursuit option.

E. Fast-pursuit, forward-setting option: (See Figures 15 and 16) (R. E. Bailey, Canadian Department of Fisheries and Oceans, personal communication) Although a seine may be deployed from the stern (forward travel) or bow (reverse travel) of a boat, where speed is required, setting from the stern is preferred. A fast, forward-moving boat can minimize the set time and maximize surprise and capture efficiency for large fish such as Pacific salmon. With this variation, the seine typically is not set entirely across the river but in something more like a half-circle arc.

Background: The lower Shuswap River in British Columbia runs about 23–34 m^3/s (800–1,200 ft^3/s) when this seining technique has been used, mainly in deeper glides and holding pools. In this river, 61 × 9 m and 61 × 12 m seines were used. In the wider Harrison River, a 73 × 12 m seine was used. The sites must be free of snags or prepared in advance for seining. Snorkeler assistance was not appropriate due to needed stealth and safety hazard from rapid boat motion. More than 600 adult chinook salmon have been caught in a single set.

Procedure: During daily operations, crews arrive at the seining site by boat and proceed to organize any sampling equipment prior to deploying the net. Once equipment is organized and the crew is ready to proceed, the net is loaded onto a custom seine deck (at the stern, note that a protective cowling is needed around the engine well). The tow line, connecting the upper (cork line) and lower (lead line) bridles, is attached to the quick release mechanism on the tow post. If needed, extra lengths of rope may be added to the tow line to facilitate passing the line to the crew on shore prior to release from the post. The net is stacked back and forth on the seine table, corks forward and lead line to the rear, more to the side of the vessel from which the line will exit. Sets are made by deploying the net in either a downstream or an upstream arc. For downstream sets from the left bank, the seine should exit on the port side of the vessel; for sets from the right bank, the seine should be arranged to exit from the starboard side of the vessel. In Figure 14, the crew is preparing for a set from the left bank, and thus the line is arranged to pull net from the port side of the stern. When the net has been fully stacked, the beach line from the head end should be tied off to a solid attachment point, preferably close to the waterline. Sets are typically made in a downstream arc at speeds up to 20 km/h. The boat operator should attempt to run out of net just as the boat reaches the beach, closing the set.

On very large rivers (more than 100 m wide), a beach line 50 m long is used and tied to a hydraulic (motorized) winch. After the boat takes off from shore, the net first starts to spill when the end of the line is reached. The winch then begins retrieving the seine head back to shore at about 1 m/s. The head should reach the shore just as the boat completes setting the rest of the net. The tail end of the net is then pulled in using a 4 × 4 pickup truck traveling perpendicular to the river. These modifications maximize retrieval speed and allow a fixed length of net to effectively reach farther but still cut off upstream escape.

F. Two-boat herding for the fast-pursuit arc set: When a signal is made to a waiting chase boat downstream, the chase boat proceeds to zigzag noisily upstream towards the seine boat (waiting on shore), herding fish before it. Before the chase boat arrives, the seine boat begins to set the seine rapidly in a downstream arc, timing movement to complete the set just after the chase boat arrives. This option can be used in rivers where fish escape routes are not limited by shallow water. (Bailey, personal communication.)

G. Fast-pursuit reverse set with snorkelers and site preparation:

This suite of modifications was developed by Peter Hahn (Hahn et al. 2003, 2004) in the Green-Duwamish River in Washington to capture adult chinook salmon. These techniques can be used in any small-to-medium river (less than 20 m^3/s, ~700 ft^3/s) to allow seining that might otherwise be precluded due to abundant snags. The key elements include

(1) site location and evaluation by snorkeling;

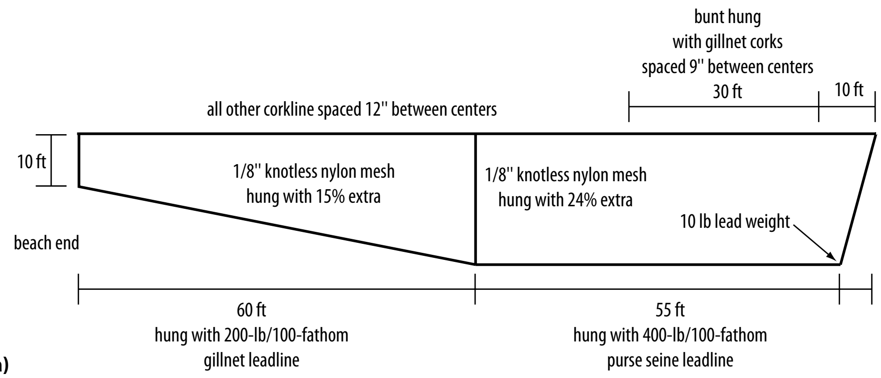
(2) site preparation to shield the seine from snags;

(3) use of a jet sleds, snorkelers, and human "beaters" to herd and keep fish from escaping (a jet sled is a flat-bottom, wide, stable boat with a blunt or squared bow, and with a jet-drive outboard on the stern; it could also be powered by an inboard engine);

(4) setting the seine bank to bank before turning downstream; and

(5) using snorkelers to help manage the seine during and after deployment and to keep fish from escaping.

Background: The Green-Duwamish is a small, clear river in August and September (7–14 m^3/s, ~250–500 ft^3/s) that has abundant natural snags (e.g., tree roots, trunks, and limbs), remnants of submerged pilings (from the historic log rafting period), and riprap boulder banks from extensive lateral dikes. Just prior to the onset of spawning in mid-September, large numbers of chinook began moving upstream and holding briefly in pools during the day. Usually, they congregate in the upper half of a 2–6-m-deep pool under a turbulent surface or in deep water (between B and S2 in Figure 16). Up to 400 adult chinook salmon have been caught in a single set.

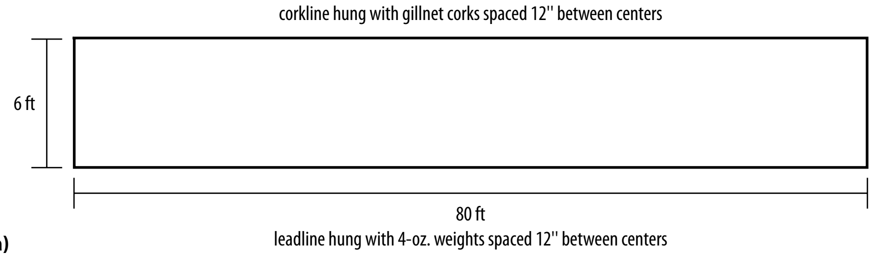


a)

b)

c)

FIGURE 12. —Large beach seine methodology. (a) Design of net (not to scale); (b) setting and towing net; (c) hauling or pursing the net to shore. (Credits: A—Eric Beamer, Skagit System Cooperative, 2003; B and C—Richard A. Henderson).



a)

b)

c)

FIGURE 13. —Small net beach seine methodology. (A) Design of net (not to scale); (B) setting the net on a shallow beach; (C) beginning to haul (pursing) the net. (Photos: A—Eric Beamer, Skagit System Cooperative, 2003; B—Karen E. Wolf; C—Richard A. Henderson).

FIGURE 14. — Fisheries and Oceans Canada stock assessment crew and beach seine boat, ready to make a simple arc, fast pursuit set on the Lower Shuswap River, British Columbia, October 2001. The crew is waiting for a second boat to begin herding fish upstream. Note the protective cowling around the motor, the seine stacked on the stern, and helmets worn by the crew. (Photo: Richard E. Bailey, Canada Department of Fisheries and Oceans)

FIGURE 15. — Making a simple arc, fast pursuit set in a downstream arc. The beach seine is rapidly paying out from the left side of the stern. Note that the first corks and net end are some distance from shore but will rapidly be winched back to shore. (Photo: Richard E. Bailey, Canada Department of Fisheries and Oceans.)

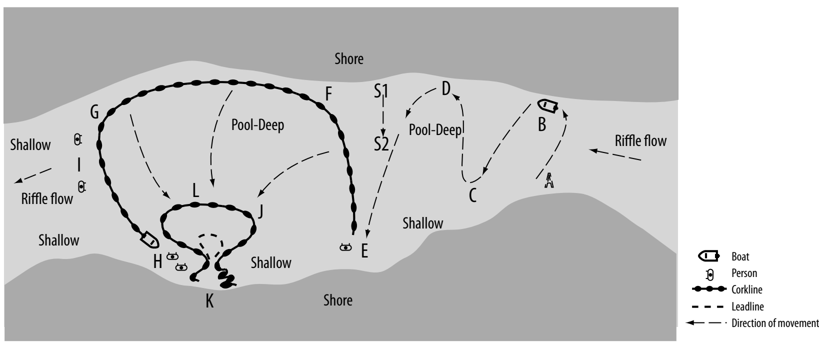


FIGURE 16. — A fast-pursuit variation of the simple arc set where fish are herded, the seine is set from bank to bank, and snorkelers are used to maximize the effectiveness of the set. (Illustration: Andrew Fuller from design by Hahn et al. 2003.)

Procedure: A 61-m beach seine was stacked on the bow of a jet sled, which approached the pool from upstream and held against a bank above the pool, engine off, until signaled. The remaining crew drove to an access point and quietly deployed to locations I, H, and E, crossing at the tailout I if necessary (Figure 16). Alternatively, a second boat could have been used, stopping to disembark crew members above the pool. Two snorkelers deployed by shore to S1 and held quietly against the far bank. One or two crew members with sticks waited at I in the tailout. When everyone was set, a snorkeler passed a signal to the jet sled operator, who started the engine and noisily proceeded to zigzag downstream into the pool (such as the path A–B–C–D–E). When the sled approached E and prepared to hand the end of the seine to a shore crew, the two snorkelers moved to midstream (S2) and thrashed the water with their arms, holding themselves against the current. This kept fish from turning back upstream while the boat was near shore at E. The sled then moved rapidly backward across the river (to F) and backed downstream towards G, while a sled crew facilitated laying the seine off the bow. As soon as the boat reached the far bank, the crew at I began flailing the water with sticks to keep fish from swimming downstream and leaving the pool. The crew at E began to pull the seine end towards K. The two snorkelers monitored the seine and lifted the net over minor snags (see Safety section, page 311). They also monitored the number, position, and behavior of the fish, which often dashed into the net between E and F and sometimes attempted to wiggle under the lead line if it happened to be upstream of the cork line. A snorkeler could move to prevent them from escaping and call for increased lead line retrieval speed.

The sled finished the arc set by backing to H and handing the seine end to the shore crew. The crew at I moved and joined in pursing the seine towards the shore at K, pulling the lead line more rapidly than the cork line. Quick and coordinated action was sometimes needed to prevent the seine from being sucked downstream into the riffle. The snorkelers followed the seine to J and L and lifted the cork line if fish attempted to jump out when in shallow water. When the lead line was fully retrieved, a portion of the seine was kept open (K–J–L) and one crew stationed at J to hold the net against the current and keep the corral from collapsing. This person recorded data as the other crew members processed fish.

Variations: When the pool tailout remained a modestly deep glide, and fish could easily swim downstream, the seine was fully deployed down the far bank (to G or beyond) and the end ropes released. A snorkeler kept the end of the net near shore while the sled moved downstream and then turned and zigzagged noisily back upstream, herding fish into the net. The snorkeler handed the tow line back to the sled crew, and the sled backed across to the other shore. The pursing was completed as described above.

7. Seine method: Double-seine simple arc set

Citations: None known; devised by Hahn, personal communication.

Procedure: Two seines and two fast boats are used, one seine per boat. The second boat drifts or motors quietly to G (similar to Figure 16) and waits until the first boat reaches E. The first boat begins a downstream set. As soon as it reaches the opposite bank and turns downstream, the second boat begins deploying its net across and slightly downstream (left of the area shown in Figure 16). A person holds the shore end and tow line of each seine. When the first boat reaches G, the person on shore hands the tow line of the second seine to this boat crew, and the first boat either (a) pulls each seine end over to the pursing shore, or (b) overlaps the two seines and waits to be pulled to shore by the pursing crew.

Analysis: This fast-pursuit method could be used to maximize the capture of fish for tagging and release, not for CPUE analysis.

Where: Large, medium, or small rivers or tidal channels. Currents may be modest to vigorous. Faster currents mandate good timing and rapid retrieval. The second seine acts like a block net in situations where the downstream channel configuration does not inhibit fish escape. It can be used in strong currents that would not allow a stationary block net to be held in place.

Variations: None.

8. Seine method: Beach-lay elliptical arc set

Citations: Sims and Johnsen 1974; Dawley et al. 1981; Dawley et al. 1986 (see Appendix B).

Procedure: The full seine was stretched onto the beach at water's edge (BD in Figure 17), with the short anchor wing (BN) towards the current, the lead line next to the water, and the seine fixed to shore (to an anchor or log at A). A boat was used to pull the end of the long wing (D) from shore (D to E) and then along the shore (E–F–G–H–I) into the current until the entire seine entered the water (MI). The boat stayed relatively close to, but kept a constant distance from, the shore while pulling and then brought the end to shore at J. The seine was then progressively pulled onto shore, starting with the long wing (JK), lead and cork lines first, while fish were concentrated towards the bunt section (KL). The anchor wing (LM) was brought ashore before the final gathering of the bunt.

Analysis: May be used for fish/set analysis if done consistently. Fish/area or fish/volume could be calculated if the distance from shore is measured and if the maximum water depth is measured; however, there are several difficulties. The length of the set is somewhat longer than twice the length of the seine because the anchor end may shift from B to M. Measuring the distance from shore may require a range finder and may not be constant, depending on the path of the boat. Maximum depth may be difficult for the boat crew to measure during seining. Furthermore, because of the current, there is greater volume actually filtered than estimated from swept area and depth. This method works well for capturing small fish for biological and mark sampling (e.g., relative survival).

Where: Lakes, estuaries, or protected marine shoreline with no to moderate current and small or no waves.

Variations: None.

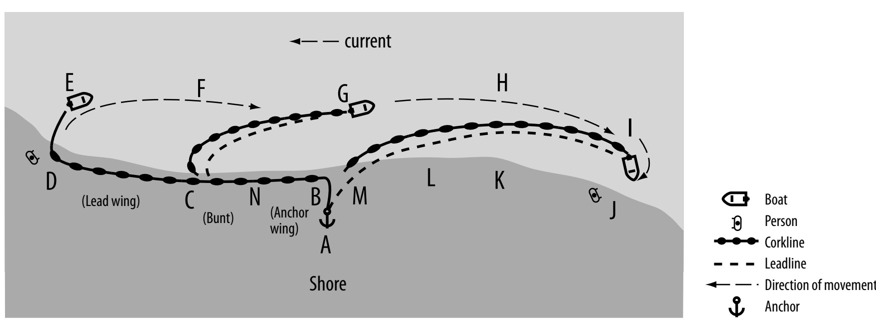


FIGURE 17. — Beach-lay elliptical arc set deployment and retrieval of a beach seine. (Illustration: Andrew Fuller from design by Peter Hahn.)

9. Seine method: Rectangular arc set

Citations: Yates 2001 (see Appendix B).

Procedure: Beach seining at the sites was performed by first setting metal stakes at 12-m (40-ft) intervals along the beach and setting anchored floats 6-m (20-ft) directly offshore. A short waiting period allowed nearby fish to recover from any preparatory disturbance. The seine, one end hooked to the first stake, was deployed from a floating tub waded out 6 m from the waterline to a marked net float held by a second person, turned up current for 12 m parallel to the beach to another marked net float and then returned perpendicular to the beach at the second stake. The up-current end of the net was then dragged along shore back to the original stake, the seine pulled onto the beach, and the trapped fish removed. Four contiguous rectangular sets were made at each sample site.

Analysis: May be used for fish/set, fish/area, or fish/volume analysis (note: length, width, and depth must be measured). This method is probably one of the most consistent and accurate for calculating area and volume. Works best for small fish that are not greatly alarmed by persons wading and that do not escape from the slowly set net.

Where: Lakes, estuaries, or protected marine shoreline with no to moderate current and small or no waves. Possibly the near shore areas of large rivers with slow currents.

Variations: See enclosure net tide set on page 302 (Toft et al. 2004).

10. Seine method: Circle set

Citations: Bayley and Herendeen 2000 (see Appendix B).

Procedure: A seine is set carefully in a circle using canoes, rowboats, or small or large motorized boats. If the area is vegetated, heavier weights must be used on the lead line, and the vegetation may have to be pulled by hand and sorted for entrapped fish. After setting, the net is slowly pursed together and the lead line gathered to allow all remaining fish to be concentrated in a section of the webbing.

Analysis: May be used for fish/set, fish/area, or fish/volume analysis (note: diameter and maximum and minimum depths at opposing points of the perimeter must be measured). If the seine can be set in a nearly perfect circle and the length of seine is known (subtracting the length of overlapped net), then the area is given by πR^2, where $R=C/2\pi$, and C=circumference. The volume is given by $0.5\pi R^2(h_1+h_2)$, where h_1=minimum depth and h_2=maximum depth. Efficiency must be calibrated.

Where: Submerged tide flats and estuaries, floodplains of large rivers, shallow lakes and ponds with no currents.

Variations: Possibly could be set around four poles to assume a rectangular shape. The poles should be set the day before or several hours prior to net deployment.

Block or Trap Sets

11. Seine method: Cable-L trap set

Citations: Farwell et al. 2006 and Richard E. Bailey (personal communication).

Procedure: On each day prior to seining, a taut, strong cable (13-mm or larger nylon or polypropylene rope) (ABC in Figure 18) is suspended across the river at the head end of a deep pool known to contain migrating salmon. Sturdy trees greater than 60 cm diameter at breast height are recommended as anchors, and sections of 2 × 4 lumber should be positioned to prevent girdling the trees (Figure 19). One or two jet sleds are used for setup. The cable must be flagged and high enough to preclude danger to boaters, kayakers, and rafters. Warning signs must be posted upstream. The pool should have a sluice of fast water entering at an angle towards the far bank, such that the near bank has a back eddy that is attractive to salmon and the far half of the river has moderate-to-fast current. The cable should be over or slightly upstream of the point where the back eddy meets the entering fast water.

A short sling with a pulley is attached to the cable by means of a prusik knot (a mountaineering knot typically made with a sling fastened to a line; the loose knot can be slid easily along the line but binds tightly when tension is applied to the free end of the sling [Cox and Fulsaas 2003]) and prepositioned on the cable above where the eddy line goes down the pool (at B). One end of a tender-line is passed from the far bank near C out to, and loosely attached to, the sling at B. The other end is held by a crew member near C. This line later moves downstream with the sled to become ED in Figure 18. A clip-line KB is passed through the pulley, and one end with a carabiner is clipped loosely to the sling or cable at B (Figure 19), and the free end of the clip-line is handed ashore and fastened at K. The sled with the seine stacked on the bow (the seine is folded back and forth with the lead lines towards the stern and cork line towards the bow) is then gently nosed to shore at H. Shore crew members pull part of the seine from the bow (which has a bridle connecting the lead line and cork line to a tow line) and then attach the tow line to a shackle (or carabiner) fastened securely to shore, perhaps at A. A second tender-line is tied or clipped to the sled and the remainder held on shore at H. This tender-line later moves downstream with the sled to become FD in Figure 18. The second sled (without the seine) is beached away from the pool on the near shore.

When ready to deploy the trap-seine, the seine-sled crew (two-person minimum) quietly grasps the cable and pulls the sled bow along the cable towards the middle of the river, letting the seine pay out as they go. The tenderline handlers on each shore (at H and C) can help move the sled across. When the sled reaches B, the sled crew unfastens and then clips the carabiner end of the clip-line to the cork line of the seine. Tension is applied to the clip-line from shore and the free end is refastened at K, thus holding the seine in place from H to B. The sled crew then allows the sled to drift downstream, paying out the remaining length of seine but remaining attached to the end of the seine (ending up at D, with the shore crew moving tender-lines from C to E and from H to F). The tenderline FD is then clipped to the end of the bridle joining the lead line and cork line (but remains attached to the sled, perhaps held by a crew), while tender-line ED remains attached to the bow of the sled. The shore crew at F and E help position the sled and seine end slightly to the fast-water side of the eddy, and keep the seine from collapsing into the eddy. The distance BD may be longer than HB.

All crews now quietly wait for 45 min or more, watching for salmon moving into or within the back eddy. A shore crew member (spotter) may be in a tree or at some vantage point with a two-way radio to relay fish sightings to the sled operator. When sufficient salmon are within the upper part of the back eddy a signal is made; the shore crew at K releases clip-line KB; the sled is released from the net and both tender-lines, and motors to E to pick up the shore crew; the seine end at D is quickly pulled towards shore by tender-line FD; and the lead line at H is quickly retrieved to make sure that it is downstream of the cork line at L (to keep fish from nosing under the lead line and escaping). As the seine is pursed towards shore, the sled motors along the cork line to help free any hang-ups (two crew members lie down and lean over the edge to pull up netting by hand as needed). As soon as further snags are not anticipated, the sled is beached and all hands help tend the seine. Both seine ends, and all the lead line, are pulled onto shore (at M and N), leaving the fish trapped near shore in the remaining pursed net (J). The purse is kept from collapsing while crew members handle and mark the fish (keeping them in the water, using a cradle restraint if appropriate). The processed fish are gently released over the cork line while one crew member records data. (More than 600 chinook salmon have been caught in a single set [Bailey, personal communication]). Generally, only one or two such sets are made per day per site.

Analysis: Qualitative only; used for the capture of fish for marking or for biological samples and inspection for marks.

Where: Small to moderate-size rivers with pools or other areas where fish are known to concentrate. Developed for the capture of adult salmon that are migrating upstream.

Variations: None.

12. Seine method: Block net set

Citations: Wiley and Tsai 1983; Lyons 1986; Parsley et al. 1989; Allen et al. 1992; Bayley and Herendeen 2000 (see Appendix B).

Procedure: Block nets are generally used (a) for efficiency tests on seine nets set within the block net perimeter, (b) to allow some other sampling gear (such as electrofishing and mark–recapture estimates between two block nets in a stream) to be used on a temporarily captive population, or (c) to prevent the escape of fish actively being pursued with another seine (see method 7 above).

Analysis: For efficiency tests, marked fish may be released into the enclosure prior to the seine set for which the efficiency is being calibrated (see previous section of this chapter). The block net is generally pursed carefully to shore and all remaining fish counted after the tested net is set one or more times within its perimeter. The known loss of marked fish is used to estimate the initial population of unmarked fish. The initial population forms the basis for estimating the efficiency of the tested net.

Where: For efficiency tests, any waterbody where currents and waves are sufficiently absent to allow the block net to remain in place. For creating a captive population, generally a stream or small river where currents and debris are modest enough to allow the net to remain anchored to both shores for the duration of the study.

Variations: See methods 13 and 14 below.

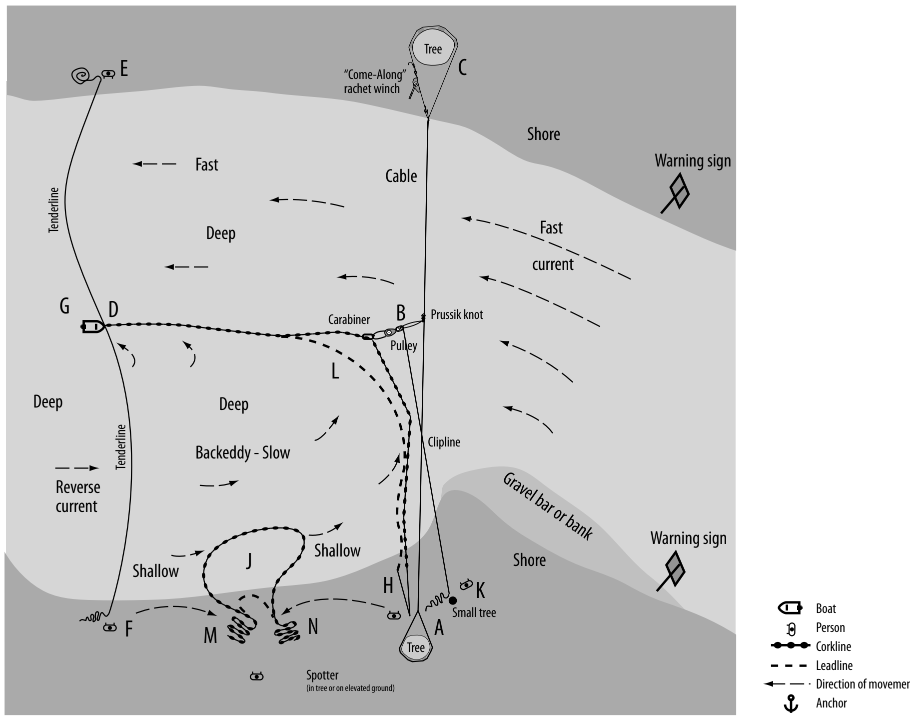


FIGURE 18. — Cable-L trap set with a beach seine to capture adult chinook salmon in the Shuswap River in British Columbia. (Illustration: Andrew Fuller from Richard E. Bailey, Canadian Department of Fisheries and Oceans.)

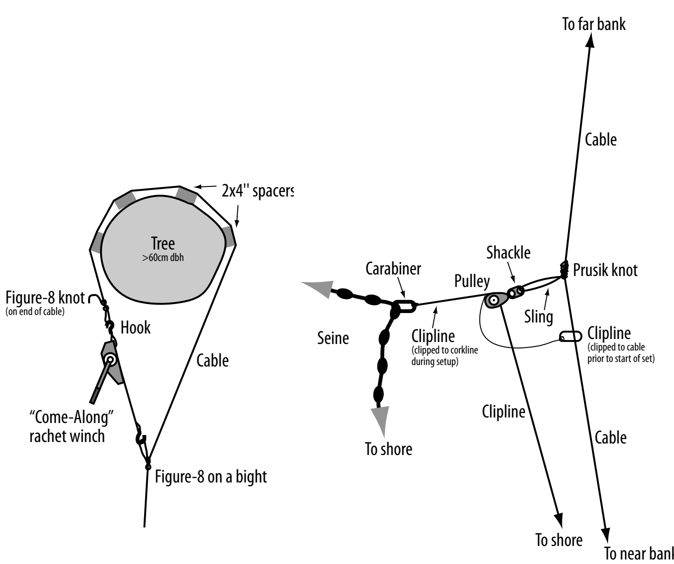


FIGURE 19. — Cable-L trap set details showing (1) how the cable is fixed to sturdy trees on each bank, and (2) how the beach seine is temporarily attached to the middle of the cable, allowing half the seine to stretch downstream. For "Figure-8 on a bight," see Cox and Fulsaas (2003). (Illustration: Andrew Fuller from design by Peter Hahn.)

13. Seine method: Enclosure net tide set

Citations: Toft et al. 2004 (see Appendix B).

Procedure: As described by Toft et al. (2004): Enclosure net sampling "consisted of using a 60 m long, 4 m deep, 0.64 cm mesh net placed around poles to corral a 20 m^2 rectangular section of the shoreline. The poles were installed at low tide the day before net deployment so as to minimize disturbance at time of sampling. The enclosure net was installed at high tide. Fish were removed with either a small pole seine (1.2 m × 9.1 m, 0.64 cm mesh) or dip nets as the tide receded, usually starting at midtide a few hours after net deployment. All fish were removed before low tide."

Analysis: May be used for fish/set, fish/area, or fish/volume analysis (note: depth needs to be measured along outer wall of the seine).

Where: Saltwater beaches with tidal fluctuations that allow the draining of the area enclosed by the net. This could include complex habitat (like boulders) that could not be swept by a seine, although care must be used to account for fish that might remain stranded in micropools under such structures. Probably most efficient for species that are pelagic (e.g., salmon fry) rather than demersal (e.g., sculpins).

Variations: None.

14. Seine method: Channel trap tide set

Citations: Cain and Dean 1976; Levy and Northcote 1982; Yates 2001; SSC 2003 (see Appendix B).

Procedure: A beach seine is pulled across the lower portion of a tidal channel at high tide and anchored to both banks. The seine may be unmodified or have a bag or a bag plus a box or hoop trap. Generally, poles are pounded into the substrate at intervals, and the lead line and cork line are tied to them. Keeping the cork line raised above the water level is important if any target species are likely to jump. The lead line may have to be pushed into the mud along the entire length of the net or very heavy weights should be used. Crabs may cut through the mesh and allow escape. Rotenone may be used for a complete kill but should be administered near low tide and channel areas monitored for stranded fish.

Analysis: Total number and biomass, fish/length of channel, fish/area, and diversity indices. Area can be calculated from aerial photographs taken at high tide. Volume is difficult to calculate due to sinuosity and varying channel dimensions; perhaps flow and cross section area could be monitored at the net site.

Where: Estuaries and marine bays where there are anastomosing channels that drain completely at low tide and have only one outlet.

Variations: Site specific. Trap design can be variable.

Purse Seine Sets

15. Seine method: Purse seine set

Citations: Durkin and Park 1967; Johnson and Sims 1973; Dahm 1980; Healey 1980; Dawley et al. 1981, 1986; Hayes et al. 1996 (see Appendix B).

Procedure: Two boats are used to lay the seine out in a circle, in water too deep for the lead line to reach the bottom. The seine boat passes the end of the net to the skiff, which attaches it to a stanchion. The skiff motors to hold the end of the net nearly stationary until the seine boat completes a circle. The pursing line runs through rings attached to (or hung from) the lead line. When both ends of the pursing line are winched onto the seine boat, the bottom of the net is closed together. Once the bottom is sealed, the cork line and remainder of the net is brought aboard, gradually concentrating the fish into the remaining section of seine (which may have smaller mesh than the wings). When the net is brought aboard and stacked, the lead line should be under the cork line. This reduces the chance of the lead line becoming looped over the top of the cork line when released into the water and assures maximal sinking rate of the bottom of the net.

Analysis: Fish/volume is typically used to report results, but fish/set may also be used. The known depth of net, plus the radius of the set, allows calculation of the approximate volume (πR2h) (approximate because a perfect circle can rarely be accomplished in practice).

Where: Any lentic waterbody deep enough to operate boats, and water depth is generally greater than the reach of the net. Some large rivers are also suitable for purse seining. Marine waters with turbulent currents are not suitable (but may be fished successfully at slack tide stages).

Variations: (See also Circle Set and the double arc single net option of the Simple Arc Set.)

- The end of the net initially released from the seine deck can be attached to a drogue chute, anchored buoy, or sea anchor that holds the net end stationary while the rest of the net is released by the rapidly moving boat. When the boat completes the circle, a boat hook can be used to grab the cork line and the pursing line and bring them aboard for retrieval.
- The seine can be set in shallow water so that the lead line and pursing line touch the bottom. The bottom must be free of snags to allow proper pursing of the net.
- A motorized or towed barge and small skiff can be used to set small purse seines.
- Two equal-sized boats, each carrying half the seine, can be used to set the net in opposite directions.

Measurement details

Sample processing

After the net is brought to shore, the fish can be handled to meet the objectives of the study design (Klemm et al. 1993; Meader et al. 1993; British Columbia Ministry of Environment, Lands and Parks 1997; Lazorchak et al. 1998; Moulton II et al. 2002). Beach seining induces relatively low stress on the fish, and thus mark–recapture techniques can be employed. All standard measurements (e.g., species, length, weight, scales, gut contents, sex) can be gathered. Additionally, if counts are all that is required, it is quick and easy to count and release the fish as the net is brought in.

Preventing transmission of disease and exotic organisms

The cross-watershed transmission of invasive aquatic diseases exotic animals is a serious threat to ecosystems. The U.S. Forest Service has developed an Invasive Species Disinfection Protocol (<www.reo.gov/monitoring/watershed/docs/InvasiveSpeciesProtocolFinal.pdf>) that has been adopted by a wide array of land management agencies. This protocol currently reflects the best known way to prevent the spread of New Zealand mud snails *Potamopyrgus antipodarum*, Port Orford cedar root rot *Phytophthora lateralis*, and sudden oak death syndrome *P. ramorum* in the western United States. The basic techniques include rinsing wading boots and sampling gear in a mild bleach solution and then in boiling water and using a high-pressure sprayer or car wash to clean vehicles prior to traveling to a new watershed. These techniques may prevent the spread of other organisms and diseases. Methods for disinfecting large seines are needed.

Data Handling, Analysis, and Reporting

Data categories

Data collection for each seine set should include the following:

- Time and date of set
- Tidal stage (e.g., ebb, flood, high-tide slack, low-tide slack)
- Water surface area seined (or measurement to allow calculation)
- Length of time the set is held open (large net only)
- Surface and bottom temperature of area seined
- Surface and bottom salinity of area seined (estuarine areas only)
- Maximum depth of area seined
- Average surface water velocity (small net only) using a flow meter
- Substrate class of area seined (small net only; see Appendix C)
- Vegetation type of area seined (small net only; see Appendix C)
- Fish catch records by species
- Subsample of fish lengths and weights (where appropriate, based on objective) (SSC 2003)

Data analysis

Once the surface area sampled has been calculated, data are generally reported as densities (fish/ha). Multiple sets from the same area should be averaged to get the fish number for that area. Multiple sets allow for more rigorous statistical analysis on mean density data and comparisons among sites for various variables. Nobriga et al. (2005) describe deployment and analysis for numerous sites and times in detail. Data can be extrapolated to larger areas if species distribution and habitat conditions are similar. Note that the reported estimate of fish/ha is an index value (unless adjusted for known net efficiency for the specific conditions) that would only be comparable to other results of very similar sampling gear, species composition, size distribution, and habitat conditions.

Effectiveness of seining is limited by gear, species, and habitat sampled. Rozas and Minello (1997) compiled a chart of effectiveness of different sampling gear, listing their advantages and disadvantages. Seines are easy to use, give clean samples, and have a large sample unit area (SUA). The disadvantages are that they can have a low and variable catch efficiency and can be ineffective in vegetation/soft substrate and that SUA can be difficult to define. As with all sampling methods, there is a degree of bias to seining. Mesh size, speed of area encirclement, and method of retrieval all affect the selectivity of the method towards certain species and sizes. It is important to understand these biases when analyzing data and perhaps incorporating other sampling methods in order to capture the entire range of fish assemblage in an area. Introductory insights into analysis of the data are noted under each of the 15 methods

Seining is typically used for six main purposes:

(1) biological sampling,

(2) species presence and diversity,

(3) relative abundance estimation,

(4) absolute abundance estimation via indirect measures,

(5) relative survival estimation, and

(6) absolute abundance estimation via direct measures.

Biological sampling reflects the basic collection and listing of fish species captured and the acquisition of morphological measurements (e.g., length, weight) and other biological samples (e.g., scales, tissues, presence of disease). Species presence and diversity reflects a listing of species captured, with data reported in CPUE, fish/set, fish/area, or fish/volume sampled. When using presence sampling to identify species richness, rare fish distributions, or simple presence/absence of a species at a particular geographical locale, considerations of sampling efficiency should be taken into account. Failure to identify an individual species at a location does not demonstrate that it does not exist there and may be the result of poor sampling efficiency. Detailed habitat descriptions often are reported as part of these sampling efforts, in support of subsequent fish–habitat relationship analysis.

Seining is frequently used for capturing small juvenile salmonids, where a measure of relative abundance or CPUE is needed. The use of standardized nets and deployment methods has provided a means to characterize abundance over time and space, either within or across years. A common assumption that is made when estimating relative abundance is that capture efficiencies are the same for different species and/or for different age-classes of fish. This assumption is unlikely to be true, particularly for species of different sizes and those that use different habitats.

Estimating population abundance with high accuracy and precision requires mark–recapture efforts. Seines allow the selective capture and subsequent release of a wide range of salmonid fish sizes. This characteristic makes seining a useful capture method for many mark–recapture-based salmonid assessments, where marking more fish allows for greater precision of the population estimate. There have been many statistical advances in evaluations of mark–recapture data through the years. Discussing the statistical developments associated with evaluating mark–recapture data is beyond the scope of this protocol. We refer readers to the detailed review and references contained in Schwartz and Seber (1999).

The basic premise of mark–recapture estimates is that the ratio of marked/unmarked fish collected in a sample where M fish are marked is the same as the ratio of marked fish in the total population (M/N). An estimate of abundance from mark–recapture data can therefore be calculated from equation 3:

$$N = MC/R \qquad \text{(eq 3)}$$

where N = the population estimate, M = number of fish marked during the mark run(s), C the total number of fish in the recapture sample(s), and R the number of marked fish captured in the recapture sample.

Bailey (1951) and Chapman (1951) presented mathematical corrections to the Petersen estimate when it was recognized that it may be biased when sample sizes are low. Chapman's modification of the Petersen estimate is provided in equation 4:

$$N = \frac{(M = 1)\,(C + 1)}{(R + 1)} - 1 \qquad \text{(eq 4)}$$

Robson and Reiger (1964) suggest that an unbiased estimate of N can be generated from the Chapman modification of the Petersen estimate when one or both of the following conditions are met:

1. The number of marked fish M plus the number of fish captured during the recapture sample C must be greater than or equal to the estimated population N.
2. The number of marked fish M multiplied by the number of fish taken during the recapture sample C must be greater than four times the estimated population N.

Calculations providing approximate 95% confidence intervals about the population estimate N are summarized by Vincent (1971) and can be calculated using equations 5 and 6:

$$\mathit{Estimate} \pm 2\sqrt{\text{Variance}} \qquad \text{(eq 5)}$$

where

$$Variance = \frac{(PopulationEstimate)^2\,(C - R)}{(C + 1)(R + 2)} \qquad \text{(eq 6)}$$

Equations 3–6 allow for hand calculation of population abundance estimates and confidence limits when all assumptions are met during sampling. There are many more complex estimators that can be used to estimate population abundance when assumptions cannot be tested in field settings due to budget or time constraints. Many of these estimators are available through Internet resources and are often free or inexpensive. These resources contain information as well as Internet links to computer software programs for estimating various population and community parameters beyond simple abundance calculations. Many computer programs contain complex procedures that will select appropriate population estimators based on the observed field data. Other programs use iterative calculus techniques to produce maximum likelihood estimates that are the most likely based on observed mark–recapture data.

Personnel Requirements and Training

Roles and responsibilities

The number of crew members required to deploy and retrieve the net will vary depending on the size of seine net being deployed, the force required to recover the net, and method of deployment. A minimum of two persons, up to crew sizes over five, may be required. Furthermore, where currents are strong and/or large nets are used, power winches may be needed to assist in net retrieval.

Boat operator

The boat operator is typically the crew supervisor and is responsible for ensuring that the net is properly loaded and will deploy freely from the boat. The boat operator is also responsible for securing the boat at the end of the set and ensuring all applicable safety regulations are met. An on-board assistant is responsible for throwing the tow line to shore crews as the set is closed, and, once the tow line is under control on shore, releasing it from the tow post. Where sets are made at speed, it is strongly recommended that boat crews wear swift-water helmets to prevent head injuries from rapidly moving cork and lead lines.

Shore crews

Shore crews are responsible for attaching the head end of the net securely to the shore and for net retrieval once the set is closed. Shore crews also clean, repair, and load the net with assistance from and under supervision of the boat crew. All personnel assist with sample processing.

Qualifications

All crew members operating in swift-water environments should have experience in safe swiftwater operations, including safe wading techniques. Boat operators should be experienced in operating the vessel type to be used in riverine environments. At least one crew member, preferably a qualified fish biologist, needs to identify fish species found in the system being sampled. Additional specialized qualifications may be needed, depending on specific information being collected and processed (e.g., fish disease, scale sampling, tagging techniques, fish preservation for biological sample collection). All snorkelers (and seining crew members) should be vaccinated against tetanus, hepatitis, typhoid fever, and polio (Lazorchak et al. 1998, 2000).

Safety and training

Water safety: Requirements and considerations

As with any field activity, safety is of paramount importance. Snorkelers, divers, seiners, and boat operators should always assess the potential hazards of the site before entering the water (Dolloff et al. 1996). In addition, a health and safety plan should be developed for any surveys of this type in which a risk assessment is conducted, and appropriate countermeasures for each risk are identified and implemented during the survey.

Snorkeling safety considerations

(a) A safety plan should be written in advance.

(b) The person in charge of any snorkeling operation should, at a minimum, have a SCUBA certification. All others participating in the operation should have mastered and demonstrated the basics skills needed to safely conduct the operation. These skills include strong swimming ability; familiarity with working in a wet or dry suit, proper snorkeling technique, the use of dive knives, and the hazards of working in and around nets; and the ability to hold one's breath while manipulating objects underwater. Greater expertise is required for working with seines than is required for simple snorkel surveys to count fish.

(c) All snorkelers must be good swimmers.

(d) Rivers and streams can be dangerous and unpredictable. Snorkelers must be familiar with river dynamics. This knowledge can be achieved through experience with kayaking, canoeing, drift boating, rafting, and/or snorkeling in rivers.

(e) A full wet (or dry) suit, including gloves, booties, and hood, should be worn. These items offer protection from snags and fishing lures that may be entangled on objects. Such suits also provide buoyancy, a positive safety factor. The preferred suit is smooth and without pockets or flaps that can snag. Buoyancy compensators or life vests add bulk, drag, and potential snag points. Knee pads built into the suit are a good addition.

(f) Narrow, smaller fins are best for acceleration and speed in rivers. Avoid large "jetfin" styles for river work. Tape fin buckles if they look like they could snag in webbing.

(g) When working around nets, two sharp knives should be worn. Both should be capable of cutting the type of webbing quickly. Both should be located in a position that allows for quick access and eliminates snag potential (e.g, inside of an arm or leg).

(h) No weight belt is to be used when assisting the seining operation (due to risk of snagging). It may be used when scouting sites for snags or preparing sites for seining. The belt must have a quick release mechanism that is in good working order. Additionally, the weight belt should be less than that required to gain neutral buoyancy. In other words, the snorkeler should always maintain some positive buoyancy.

(i) Two snorkelers should be suited and in the water if working with the seining operation. Both must remain reasonably close to each other and make frequent visual contact.

(j) A single snorkeler may be used for scouting and mapping but only when accompanied by a jet boat (i.e., no propeller drives) or other craft suitable for reaching and assisting the snorkeler.

(k) All stretches of river must be checked visually prior to snorkeling, and good judgment needs to be used to avoid debris jams, whitewater, or any other perceived hazard (Thurow 1994). It is remarkably easy for a snorkeler to negotiate most rivers, especially at low flows, but caution must always be exercised. High flows during freshets can make a normally benign river dangerous.

(l) Water quality can sometimes be of concern. Recent rain can flush contaminants from roads, parking lots, pastures, and backyards. Industrial outfalls should be noted and downstream areas avoided if at all questionable.

(m) If recreational or commercial boaters are likely to be encountered while seining, additional procedures should be devised and used to warn, reroute, or stop their approach. A dive flag would be useful to warn that there are snorkelers in the water.

(n) Never attach ropes or lines to divers in areas where currents or tidal action are factors.

(o) Hypothermia can be a hazard for snorkelers (although overheating can also occur). Crew members should all be trained in CPR and first aid, with an emphasis on recognizing and treating hypothermia (Dolloff et al. 1996). Swiftwater rescue training would also be useful for crew members working in larger river systems.

Scuba safety considerations

(a) Scuba diving is usually the method of choice when seining sites need to be modified. It offers the advantage of prolonged underwater work and speeds the process greatly. Snorkelers can sometimes install a small number of modification devices, but it is not practical for deeper pools and larger modification operations.

(b) Both certification by an internationally recognized training program (such as PADI, PADI Americas, 30151 Tomas Street, Rancho Santa Margarita, California 92688 USA; www.padi.com/padi/default.aspx) and certification through the employing agency's diving safety program are absolutely required for all divers. Certificates should be current. All dives should be logged. Divers are responsible for the use of safe equipment and following all agency safety procedures. If the agency does not have such a program, then it is in conflict with Occupations Safety and Health Administration regulations in the United States. Development of a diving policy must occur prior to any agency participation in SCUBA diving operations.

(c) A minimum of two divers shall be in the water at all times. One or more snorkelers may assist, especially to direct the placement of modifying devices.

(d) There should be a jet boat (i.e., no propeller drives) or other craft involved in all river dive operations (unless exceptions are granted by the agency's diving safety officer). This craft should be suitable for ferrying, carrying spare tanks, and reaching and assisting the divers. Two boat operators may be preferred, with the pilot focusing on maneuvering and the assistant watching the progress of the bubble streams and handing out tools and devices.

(e) The divers must be familiar with the snag bridging devices and how to install them before entering the water. All equipment, tools, and devices must be staged in advance to avoid delays.

Managing a river seine with snorkelers

A properly prepared and tested seining site should not cause major snagging events, but minor net-stopping hang-ups may still occur. Prior to production seining, inexperienced crew and snorkelers should be trained and should familiarize themselves with the seine, boat, and netting process in the water. A benign site such as a lake, pond, or pool should be used for practice deployments. The snorkelers should use this trial to familiarize themselves with the layout of the net and ensure that all dive gear is free from snags. Additionally, scenarios that test snorkelers' ability for dealing with snags should be rehearsed. They should also practice the procedures for getting in and out of the boat. The boat operator, crew, and snorkelers should review the expected seining procedures. A trial set of the net should be made. Snorkelers should always be upstream or to the outside of the seine until a substantial part of the seine has been pursed and/or is under control in shallow water. Note: The mesh size of a beach seine is sufficiently small, and twine size large, making them safe for working snorkelers. Gill or tangle nets are not safe for snorkelers to be near; however, drift or set gill-net sites can still be prepared in advance by snorkelers and divers.

Freeing a snagged net in moderate to strong currents

The snorkelers must evaluate the strength of the water flow near any snag point. If the divers cannot swim against the flow safely, a vessel must be used to free the snagged net. When lifting part of a seine net that is stuck on any object by currents, it is critical that the diver should never grab the lead line in a manner that would entrap fingers or hands. The snorkelers should also be aware of and try to avoid fishing lures that may be stuck to the net or the snagging object.

A snagged net quickly shows a cork line that points upstream in an inverted V. The lead line will be some distance upstream from the point of the V. After evaluating the cause of the snag, the snorkeler should position him/herself pointing upstream over the snag, while looking for the fold of netting that leads to the snag. After a few deep breaths, the snorkeler free dives down to the webbing, grabs it, and pulls him/herself down towards the snag. He/she should then pull upstream on the webbing and let the positive buoyancy of the exposure suit free the net. If not, on the next dive, the snorkeler should get closer to the lead line, grab the netting again, and, while kicking upstream, let the positive buoyancy of the exposure suit free the net. Another method involves grabbing the leadline on either side of the snag. Again, the snorkeler should swim upstream and let the positive buoyancy of the exposure suit free the net. If that fails, a line attached to a carabiner can be taken down by the snorkeler and attached to the lead line as close to the snag as possible. Once the line is attached, it can be used by snorkelers at the surface to try to free the snag by pulling upstream while swimming. If the current is strong, this can be facilitated by a drift boat or jet boat. In the unlikely event that the net can still not be freed, the set will have to be aborted. The surface support vessel can then be used along with additional rope or a long tender-pole to pull hard upstream and free the snag. If all else fails, the snorkeler can cut the lead line and/or webbing and free the net.

Boating safety

(1) Write a safety plan.

(2) Jet-boat and propeller-boat operators should be thoroughly familiar with the equipment and operation of their craft. They must also be familiar with boat behavior in flowing water, when heavily loaded (with seine and crew), and when towing or pulling objects.

(3) The boat operator must constantly be conscious of where all snorkelers or divers are.

(4) The boat operator must be trained/experienced in swift-water boat operations and rescue.

(5) The crew must be trained in swift-water operations.

(6) All field staff members need to be trained in wilderness first aid.

(7) All field staff members need to have medical clearance for field operations (e.g., routine physical).

Operational Requirements

Workload and field schedule

(1) Seining for adult salmon, if conducting census data, may continue throughout the run of salmon past seining sites.

(2) Seining can be continued all day by making sets at multiple sites or by allowing fish to reenter the seine site prior to making another set.

(3) Night seining is also possible if conditions are safe to do so. Night seining is more frequently used for juvenile salmon.

(4) Seining activity may be reduced as migrations taper off and crews are reassigned to other activities associated with the study.

Equipment needs

(1) Vessel suitable for setting seine. Vessel choices are jet-powered riverboats, propeller-powered riverboats, rafts, and drift boats. Choices are governed by the operating environment, size of net, and species to be seined. Surveying fish that are capable of fleeing rapidly require powered boats.

(2) Fuel and oil for powered craft

(3) Beach seines suitable for the operating environment

(4) Spare ropes
(5) Net repair equipment
(6) Dip nets
(7) Polarized glasses for boat operators
(8) Waders
(9) Life jackets
(10) Rain gear
(11) Swift-water operation helmets for boat crews
(12) Throw bags
(13) Marking, tagging, and sampling supplies (as needed); data sheets; and pencils
(14) Hydraulic winch (optional)
(15) Anti-snag devices (optional)
(16) Long-handled gaff hook

Budget considerations (in U.S. dollars)

(1) Personnel costs (2–5 or more people)
(2) Capital costs for boat ($10,000 to $50,000)
(3) Nets (under $500 to $5,000 or more)
(4) Expendable field equipment (e.g., waders) ($200)
(5) Fuel for boat(s)
(6) Transportation costs to/from project site

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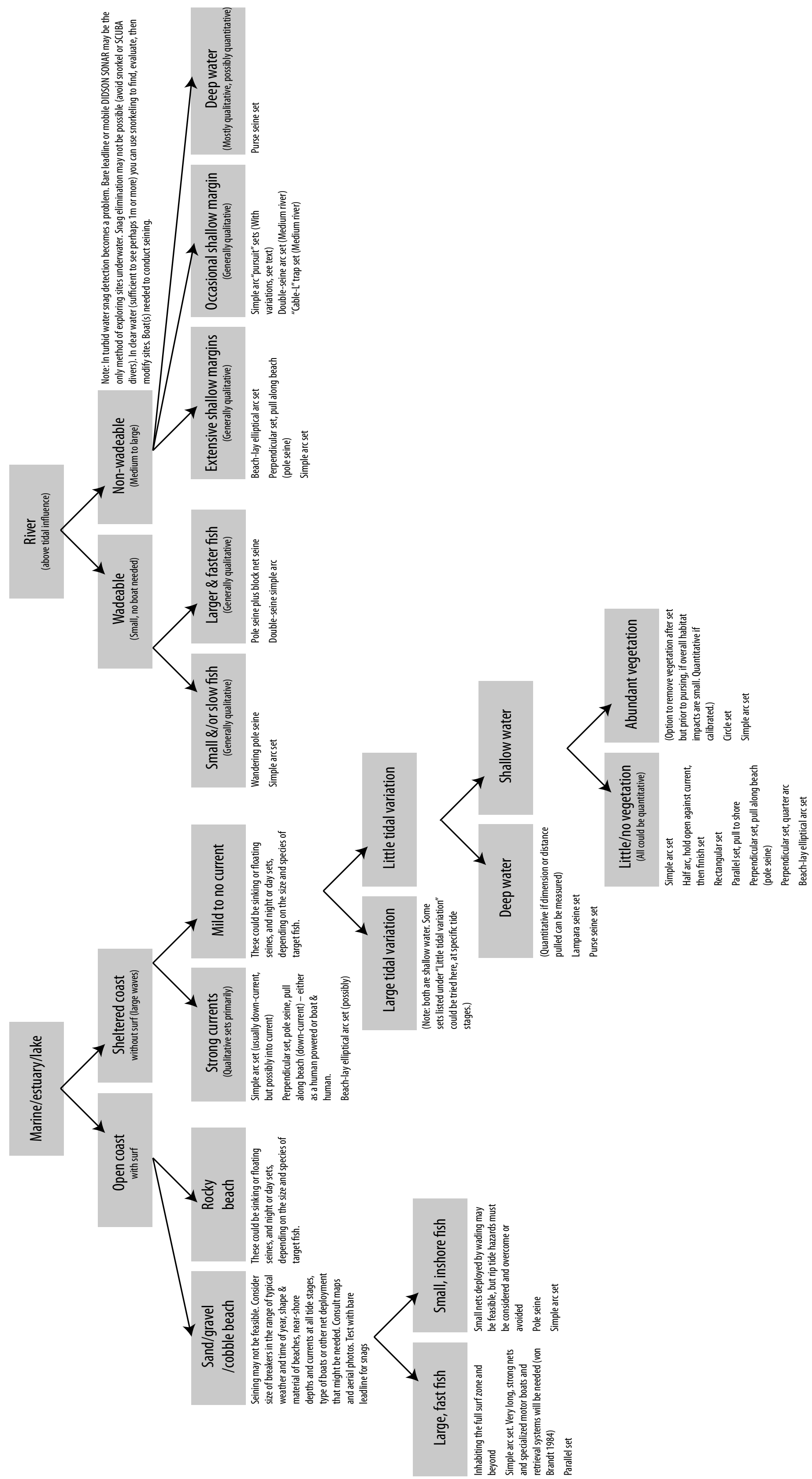
Appendix A: Key to Seine Methods



Appendix B: Seine Specifications and Citations

Citation	Target species	Habitat/Location	Net dimensions/construction: Length	Depth	Mesh	Cork/leadline	Twine	Crew size	Methods
Threinen 1956	Largemouth bass, other warmwater species	Eutrophic lake (Browns Lake, Wisconsin) USA	609.6m	4.6m	76.2mm & 50.8mm (50:50)	Trailer sticks added to leadline to prevent rolling.	?	?	Simple arc sets, somewhat variable in shape. 3.6 to 11.7 hectares enclosed by each set. Vegetation & soft mud presented difficulties.
Sims & Johnson 1974; Dawley et al. 1981 Dawley et al. 1986	Juvenile Chinook salmon (and coho, steelhead):	Estuary of large river (Columbia River, Washington -Oregon, 1800–6500 m^3/s) USA	95 m (4 panels)	3.6m wings to 5m at bunt	Variable	?	?	?	Simple arc sets
Yates 2001	Juvenile Chinook (35-100mm); pink & chum salmon	Estuary & ship channel near large river (Skagit River, Washington) USA	24m	3m	3.2mm	?	?	2 ?	Rectangular sets (6x12x6m), four at each site, by wading. (~75 m^2 per set).
Cain & Dean 1976	Misc. intertidal fish such as menhaden, killifish, & mummichog	Tidal channel in estuary (South Carolina) USA	33m with 8m bag	3.3m	6.4mm	Poles held cork line >=0.3m above water. Leadline pushed into mud.	?	2?	Seine set as a block (trap) net across a tidal channel at high tide. Rotenone used to help remove all fish in channel.
Levy & Northcote 1982	Juvenile Chinook, chum & pink salmon	Tidal channels of large river (Fraser River, British Columbia), Canada	("large"), bag with removable trap box	2.4m	6.4mm	Floats every 30 cm; 0.5kg/m (2.0 lb/fathom)	?	2+	Seine set as a block (trap) net across a tidal channel at high tide. Removable trap box allowed sampling periodically during ebb tide. Estimated gear efficiency.
Toft et al. 2004	Juvenile salmon, other fish species, crabs.	Protected marine, near-shore (Puget Sound, Washington). USA	1) 60m 2) 9.1m	4m 1.2m	6.4mm 6.4mm	? ?	? ?	2–3 2	1) "Enclosure net" 20x20x20m set at high tide around poles driven into beach on previous day. 2) Pole seine.
Durkin & Park 1967	Juvenile steelhead, coho & sockeye salmon	Brownlee Reservoir, Snake River, Idaho, USA	182.9m	10.7m	9.5mm wing; 6.3 mm bunt	Corks every 38cm Lead 0.3 kg/m (1.2 lb/fathom)	knotted nylon wing; knotless bunt	4	Purse seine set by motorized raft & 4.3m flat-bottom skiff (28 hp outboard on each).
Fred Goetz, U.S. Army Corps of Engineers, Seattle, Washington	Juvenile Chinook, coho, sockeye & steelhead (smolts).	Inside a lock, or in Lake Washington ("Ballard Locks", Seattle WA). USA	221m, tapered	9.1 to 3.8m	17.5mm	539g float/0.3m; 1.41kg/m leadline (5.7 lb/fathom). Doubled each end.	"210/15" black bonded nylon	4	Purse seine set from motorized barge, with motor skiff (25 hp outboard on each).
Healey 1980	Juvenile Chinook salmon.	Estuary & tidal channels of small river (Nanaimo River, British Columbia), Canada	1) 90m 2) 18m 3) 216m	7m 3m 18m	? 12mm ?	? ? ?	? ? ?	3+? 2–3? ?	1) Purse seine, hand hauled, set over tide flats at high tide. 2) Beach seine, simple arc set, pulled from beach. 3) "Drum seine" (purse seine used in outer estuary, near-shore areas).
Johnson & Sims 1973; Dawley et al. 1981; Dawley et al. 1986; Dahm 1980	Juvenile steelhead, coho & yearling Chinook salmon	Estuary & off-shore marine (Columbia R. Washington-Oregon, 1800–16500 m^3/s) USA	1) 228.6m 2) 152.4m	10.7m 4.9m	1+2)main 9.5mm; bunt 6.4mm	?(with braided nylon purse line)	1+2) knotted nylon main, knotless nylon bunt	3 ?	Purse seine set by boat ("gillnetter" 8.7m by 2.4m with 260 hp engine) & 6.1m surf dory skiff. Large net for main estuary & ocean, small net for shallower channels.

Citation	Target species	Habitat/Location	Net dimensions/construction					Crew size	Methods
			Length	Depth	Mesh	Cork/leadline	Twine		
Allen et al. 1992 **(Efficiency test)**	Misc. intertidal fish such as menhaden, killifish, & mummichog	Tidal channel in estuary (South Carolina) USA	15.2m with 8m bag	1.2m	6mm	"Heavily weighted"	?	2+?	Used block nets at each end of isolated tidal pool (22 x 14m, 1m deep). Pole seine repeatedly swept ~90% of pool, then rotenone used.
Bayley & Herendeen 2000 **(Efficiency test)**	Misc. South American species	Large river floodplain (Amazon River) Brazil	1) 25m (40m netting hung in pockets 2) 50m (85m netting)	1) 6m middle to 0.6m at ends 2) ?	1) 5mm 2) 5mm	1) 15cm dia. floats 30cm on-center. 120g lead cylinder 35cm on-center 2) Floats & leads 25 & 50cm on-center	1&2) 0.5mm twine, knotless, blue nylon	4+	1) Three methods: (a) Circle set, like purse seine, (b) simple arc set from beach, (c) like lampara seine. 2) Block net set first in all trials. About 25-50% of blocked area was seined. Marked fish also released to measure efficiency of block net.
Holland-Bartels and Dewey 1997 **(Efficiency test)**	Misc. warmwater species in central North America	Large river (upper Mississippi River)	9.1m	8m	3.2mm	tubular lead weights spaced 30.4cm	?	2+	Perpendicular set within rectangular enclosure, seine ends kept close to sides & shore. Block net enclosures were set around posts & were 15.2x7.6m & 15.2x4.6m in size.
Lyons 1986 **(Efficiency test)**	7 taxa: mimic shiner perch, logperch, bluntnose minnow, Iowa & Johnney darter, rock bass	Mesotropic clear water lake (Wisconsin) USA	1) 15.2m with 1.8x1.8x1.8m bag 2) 33m	1) 1.8m 2) 1.8m	1) 6.4mm 2) 6.4mm	1) 7x3.5cm Styrofoam floats 35cm on-center; tubular lead 23.5cm on-center	?	2+?	1) Parallel set, just inside block net with ends kept 0.5m from sides (thus ~92.5% of area seined). 2) Block net around rectangular area, 13.4m long, 5 to 10m wide.
Parsley et al. 1989 **(Efficiency test)**	Juv.Chinook salmon sunfish, sculpin, pikeminnow, shad, sucker, sandroller…	Impoundment of a large river (John Day Reservoir, Columbia River, Washington) USA	1) 30.5m 2) 92.5m	1) 2.4m 2) 3.1m	1) 6.4mm 2) 6.4mm	1) 61cm spacing for floats & leads. 2) 30.5cm spacing for both.	1&2) knotless nylon	?	1) Perpendicular set along a side of block net, offshore end pulled in ¼ circle to shore=64% of area in #2 2) Block net, square set (30m sides).
Pierce et al. 1990 **(Efficiency test)**	Perch, shiners, pumpkinseed sunfish, +17 other.	Littoral zone of 10 lakes (southern Quebec). Canada	1) 52m 2) (> 52m)	1) 2.6m 2)≥2.6 m	1) 6mm 2) 6mm	Plastic floats, lead-core bottom line.	1&2) knotless nylon	?	1) Simple arc set (~430m^2). 2) Block net set 2nd, close to wall of seine, left in place for more seine sets. Marked fish & rotenone used.

Appendix C: Substrate and Vegetation Types (SSC 2003)

Table 1. Definitions of intertidal substrate types modified from Dethier (1990).

Substrate Type	Definition
Bedrock	75% of the surface is covered by bedrock, commonly forming bluffs and headlands.
Boulder	75% of the surface is covered by boulders (>256 mm).
Cobble	75% of the surface is covered by clasts 64 to 256 mm in diameter.
Gravel	75% of the surface is covered by clasts 4 to 64 mm in diameter.
Mixed Coarse	No one size comprises > 75% of surface area. Cobbles and boulders are > 6%.
Fines with Gravel	No one clast size comprises more than 75% of the surface area. Cobbles and boulders make up > 6% of the surface area; coarse sediments combined make up < 55%. Rich with epibenthic fauna.
Sand	More than 75% of the surface area consists of sand 0.06 to 4 mm in diameter.
Mixed Fines	Fine sand, silt, and clay comprise 75% of the surface area, with no one size class being dominant. May contain gravel (<15%). Cobbles and boulders make up < 6%. Walkable.
Mud	Silt and clay comprise 75% of the surface area. Often anaerobic, with high organics content. Tends to pool water on the surface and be un-walkable.
Artificial	Anthropogenic structures replacing natural substrate within the intertidal zone, including boat ramps, jetties, fill, and pilings.

Table 2. Definitions of intertidal vegetation types from Dethier (1990).

Vegetation Type	Definition
Eelgrass	More than 75% of vegetative cover is Zoster marina, Zoster japonica Phyllospadix spp., Ruppia maratima
Brown Algae	More than 75% of vegetative cover is brown algae belonging to taxonomic groups Division Phaeophyta.
Green Algae	More than 75% of vegetative cover is algae belonging to the taxonomic group Division Chlorophyta.
Red Algae	More than 75% of vegetative cover is algae belonging to the taxonomic group Division Rhodophyta.
Mixed Algae	Areas in which red, green or brown algae coexist, no single type occupies more than 75% of vegetated cover.
Kelp	More than 75% of vegetative cover is large brown algae (Order Laminariales).
Salt Marsh	More than 75% of vegetative cover is emergent wetland plants.
Spit-Berm	More than 75% of vegetative cover is plants such as dune grass, gumweed, and yarrow, which generally occur above the highest tides, but still receive salt influence.
Unvegetated	More than 75% of the total surface area is unvegetated.