EFFECTIVENESS MONITORING OF THE DEEPWATER SLOUGH RESTORATION PROJECT FOR WILD JUVENILE CHINOOK SALMON PRESENCE, TIMING, AND ABUNDANCE

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The Deepwater Slough Restoration Project is located in the South Fork Skagit River delta. The project was constructed in August and September of 2000 by removing 2.77 miles of dike and restoring tidal and river hydrology to 221 acres of historic estuary (Figure 1). These natural hydrologic processes are expected to restore the area to naturally functioning estuarine marsh and channel habitats over time.

The monitoring plan called for use of "reference" and "treatment" sites after project construction to answer questions regarding juvenile salmon presence/absence and abundance within the project area. Blind tidal channels (also called dentritic channels) and distributary channels were selected near the project area for use as reference sites (Figure 1). Results from the reference sites were compared to results from treatment sites located within the area where dikes were removed. Treatment sites also consisted of blind tidal channels and distributary channels. The treatment sites were located in channels that juvenile salmon were not able to access until dikes were physically removed in the summer of 2000 (Figure 1). We sampled both reference and treatment sites from March through July on a bi-weekly basis. Fyke trap methods were used to sample in blind tidal channels and beach seine methods were used to sample in distributary channels. Methods are described in Beamer et al. (2005) and are attached as Appendix 1 of this document. We also monitored sites throughout the larger Skagit estuary (Figure 2). We used results from these sites to better interpret the results from specific Deepwater Slough restoration sites.

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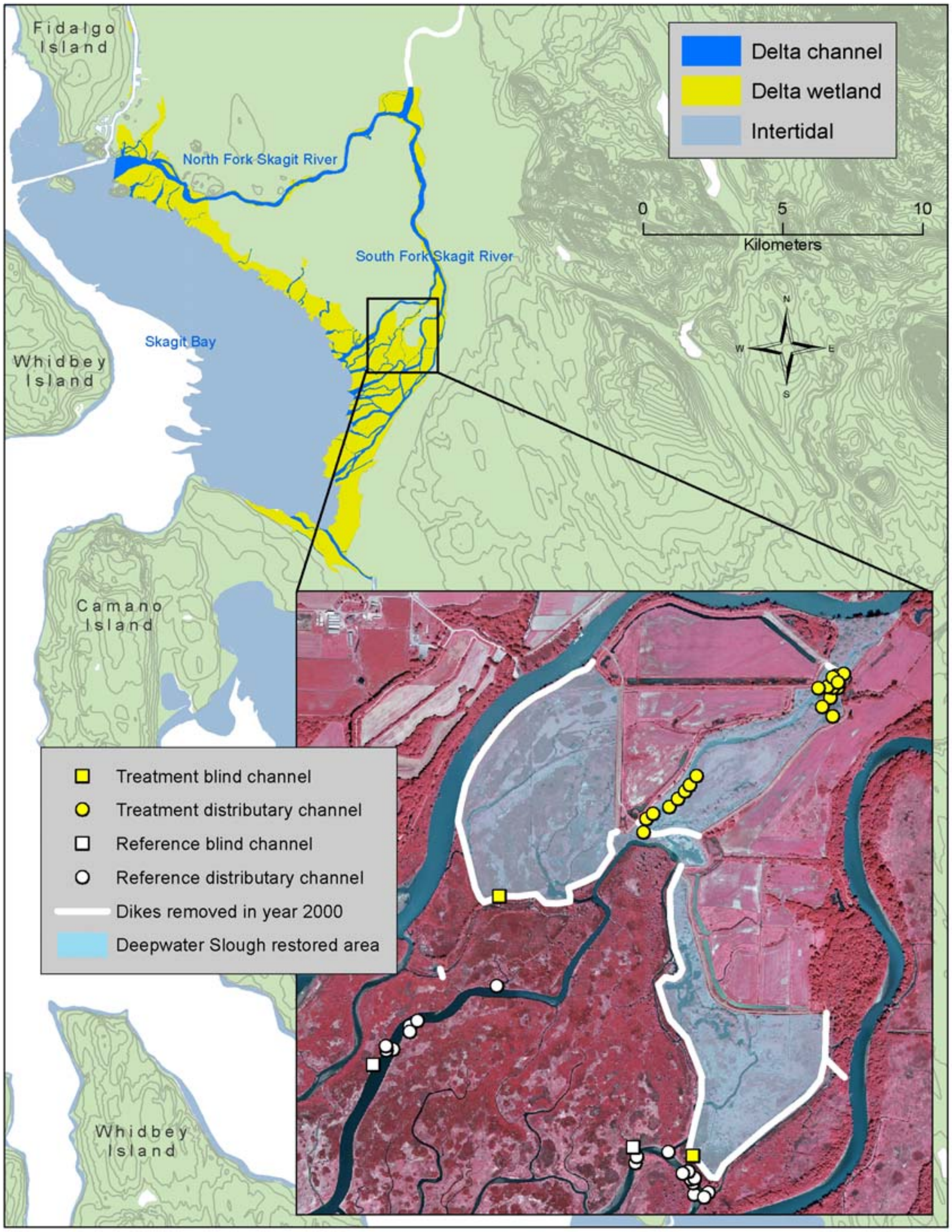

Figure 1. Location of the Deepwater Slough restoration project area, dikes removed in 2000, and reference and treatment fish monitoring sites.

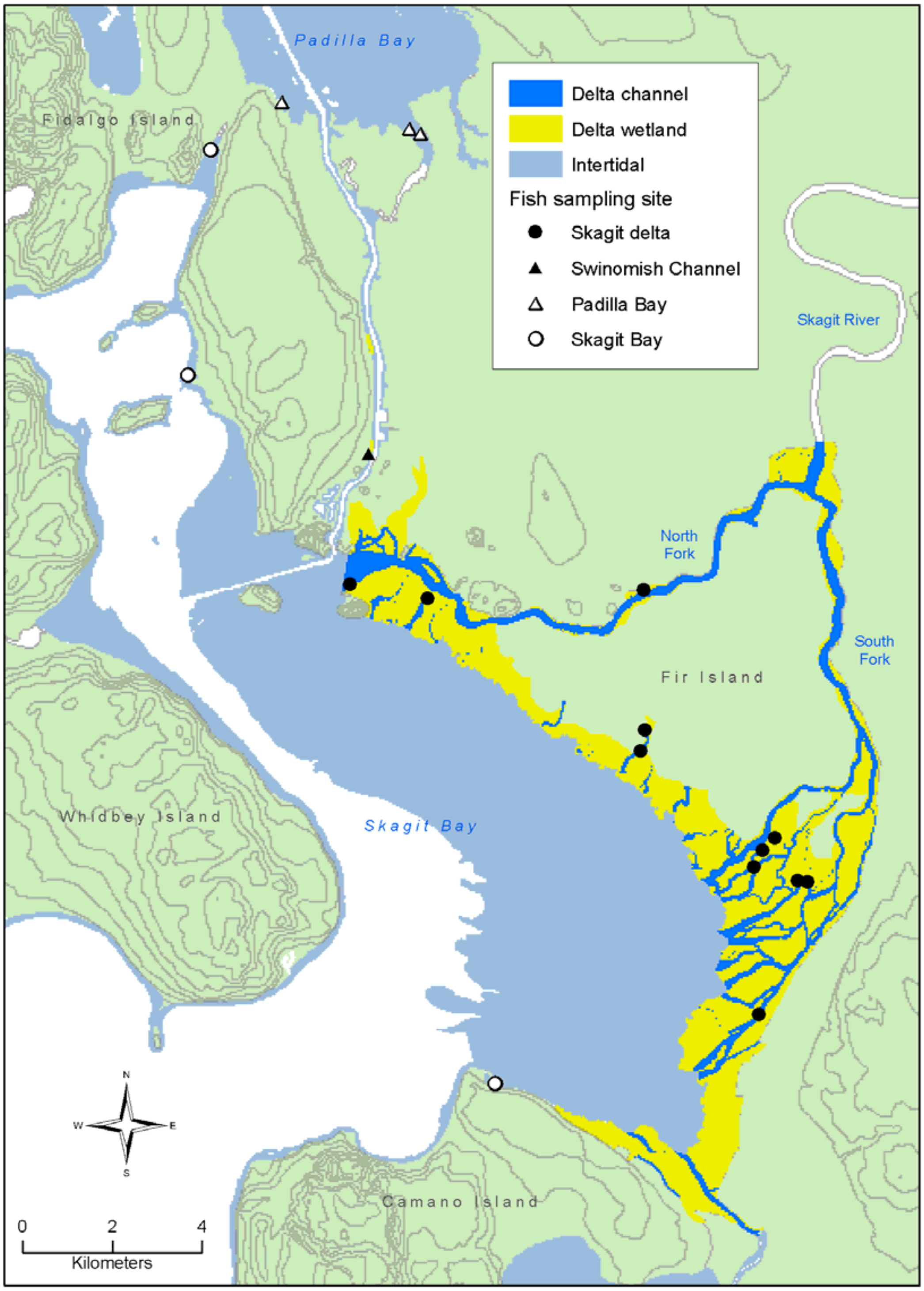

Figure 2. Location of the larger Skagit estuary fish sampling sites in 2003.

Our monitoring tested two hypotheses regarding juvenile Chinook salmon use of the Deepwater Slough restoration project area. The first hypothesis is related to fish presence or absence: we expected juvenile Chinook salmon to be present within treatment channels after dike removal during the normal seasonal outmigration curve period (late winter through early summer months). Results from each year (2001-2003) showed juvenile Chinook salmon were present in distributary and blind channel habitat at both treatment and reference sites (Figure 3). The results demonstrate that juvenile Chinook salmon colonized the restored habitat within the project area in the first year after construction. In fact, higher densities of juvenile Chinook salmon were often found in the treatment areas than in the reference areas. However, significant annual, monthly, and site level variability exists for juvenile Chinook salmon abundance.

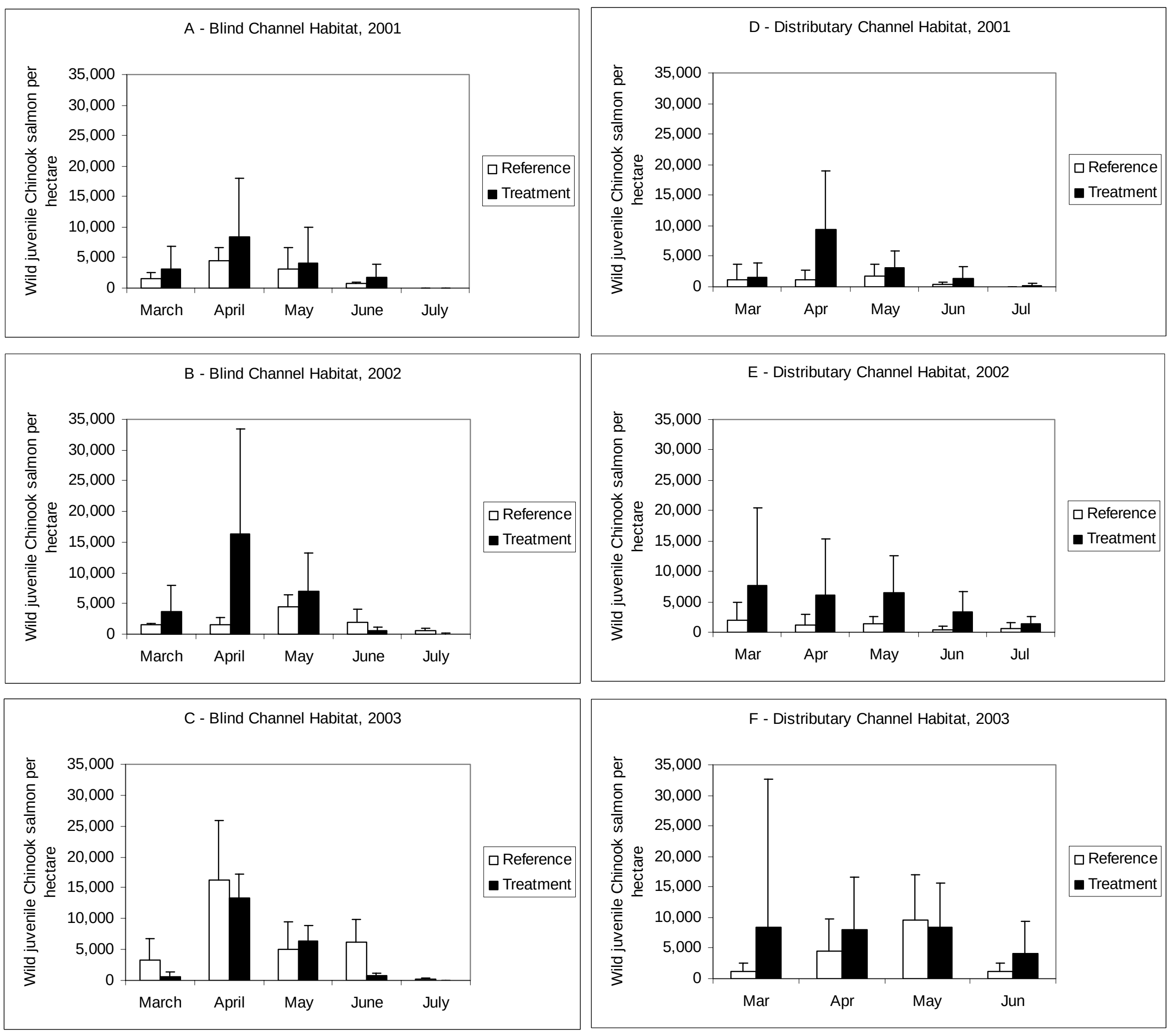

Figure 3. Monthly average juvenile Chinook salmon densities at reference and treatment sites for the Deepwater Slough restoration project. Yearly results for blind channel sites are shown as figures A-C. Yearly results for distributary channel sites are shown as figures D-F. Error bars are 1 standard deviation.

The second hypothesis is related to juvenile Chinook salmon abundance. If the restoration project is successful at increasing the tidal delta rearing capacity for juvenile Chinook salmon in the Skagit River, then we would expect the seasonal density of juvenile Chinook salmon within the Deepwater Slough project area to be similar to juvenile Chinook salmon densities in other tidal channels in the Skagit River delta. We can directly compare Chinook salmon densities in reference sites to those within treatment sites (as shown in Figure 3), but Beamer et al. (2005) showed that differences in landscape connectivity and annual Chinook smolt outmigration population size strongly influence the densities of juvenile Chinook salmon at any site within the Skagit River delta or its adjacent nearshore. The results from monitoring sites throughout the Skagit estuary (site locations are shown in Figure 2) are critical for doing this analysis. Because these sites are located throughout the Skagit estuary, we can analyze results from the Deepwater Slough restoration project over a wide range of landscape connectivity. Each year's monitoring results are compared separately, because each year represents a unique Chinook salmon outmigration population and migration timing.

For this report we show results from 2003, which had an outmigration population size of 5,500,000 juvenile Chinook salmon. In this year, landscape connectivity explained 68% of the variation in seasonal density of Chinook salmon at monitored sites within the Skagit estuary (Beamer et al. 2005). Landscape connectivity is a measure of the migration pathway that juvenile Chinook salmon must take to find available habitat. It is a function of both the distance Chinook salmon must travel to find habitat and the channel branching order within the delta (see pages 20-21 of Beamer et al. 2005). Figure 4 shows that average seasonal Chinook salmon density from the Deepwater Slough restoration sites is within the scatter of juvenile Chinook salmon density results from other Skagit estuary sites. This supports the conclusion that the new habitat created by the Deepwater Slough restoration project is being used by juvenile Chinook salmon at similar levels to other habitat found within the Skagit estuary when you account for landscape connectivity. This result also shows that landscape connectivity values for the Deepwater Slough reference and treatment sites are similar to each other, when compared to the range of connectivity values from the other Skagit estuary monitoring sites. Therefore a direct comparison of reference to treatment sites is appropriate. In doing these comparisons year by year, we find that juvenile Chinook salmon densities were higher in treatment sites in 2001 and 2002 but similar in 2003 (see Figure 3).

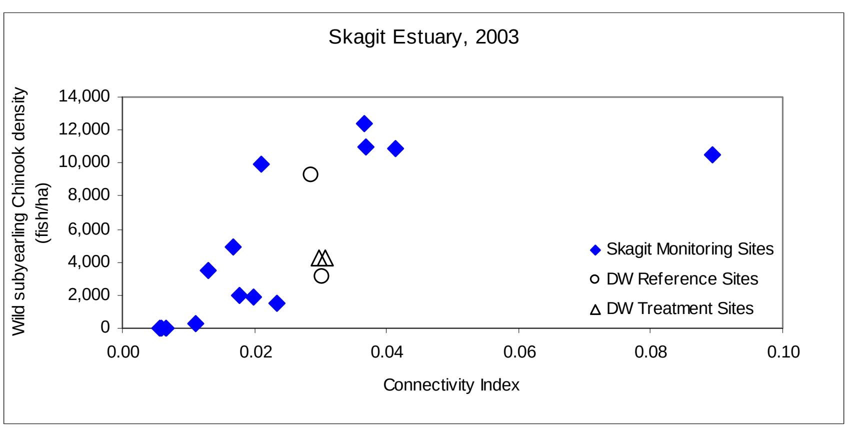

Figure 4. Relationship between average seasonal juvenile Chinook salmon density in blind channel habitat within the Skagit estuary as a function of landscape connectivity in 2003.

REFERENCES

Beamer, E.M., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larson, C. Rice, and K. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Skagit River System Cooperative. LaConner, WA. Available at www.skagitcoop.org.

FUNDING ACKNOWLEDGEMENTS

The US Army Corps of Engineers, Seattle District, funded monitoring in 2001, 2002, and 2003. These funds were used to monitor treatment and reference sites identified within the Deepwater Slough restoration project area (see Figure 1).

The Northwest Indian Fisheries Commission provided funding in 2003 through two initiatives, Pacific Salmon Treaty Implementation and Pacific Coastal Salmon Recovery, to help this monitoring effort. Some of this funding was used to monitor sites throughout the larger Skagit delta (see Figure 2). We used results from these sites to better interpret the results from specific Deepwater Slough restoration sites.

APPENDIX 1. ESTUARINE FISH SAMPLING METHODS[2]

We sample estuarine habitat using three different methods depending on the habitat types: small net beach seine, large net beach seine, and fyke trap. Small net beach seine methods are used for sampling shallow intertidal shoreline areas of Skagit and Padilla Bays, pocket estuaries with lagoon impoundments, or distributary channel habitat in the Skagit tidal delta and Swinomish Channel. The areas seined are typically less than 4 feet deep (1.2 m), and have relatively homogeneous habitat features (water depth, velocity, substrate, and vegetation). Small net beach seine methodology uses an 80-foot (24.4 m) by 6-foot (1.8 m) by 1/8-inch (0.3 cm) mesh knotless nylon net (Figure 1). The net is set in "round haul" fashion by fixing one end of the net on the beach while the other end is deployed by wading "upstream" against the water current, hauling the net in a floating tote, and then returning to the shoreline in a half circle. Both ends of the net are then retrieved yielding a catch. We typically conduct three sets per site. Average set area is 96 square meters.

Large net beach seine methods are used for sampling the intertidal-subtidal fringe of Skagit and Padilla Bays. These areas are typically 6-15 feet deeper than the areas seined by small net beach seine, requiring a longer and deeper net. Large net beach seine methodology uses a 120-foot (36.6 m) by 12-foot (3.7 m) by 1/8-inch (0.3 cm) mesh knotless nylon net (Figure 2). The net is deployed by fixing one end of the net on the beach while the other end is set by boat across the current, a distance of approximately 60% of the net's length. After the set has been held open against the tidal current for a period of four minutes, the boat end is brought to the shoreline edge and both ends are retrieved, yielding a catch in the net's bunt section. We typically conduct three sets per site. Set area varies because of varying tow times, set widths, and tidal current velocities moving past the site. Average set area for 6 index sites in Skagit Bay is 486 square meters.

Fyke trap methods are used for sampling blind tidal channel habitat in the Skagit tidal delta, Swinomish Channel corridor, southern Padilla Bay, or pocket estuary sites dominated by tidal channels. Fyke trap methodology uses nets constructed of 1/8-inch (0.3 cm) mesh knotless nylon with a 2-foot (0.6 m) by 9-foot (2.7 m) diameter cone sewn into the net to collect fish draining out of the blind channel site (Figure 3). Overall net dimensions (length and depth) are variable depending on the site's cross-sectional channel dimensions. All nets are sized to completely block fish access at high tide. The net is set across the blind channel site at high tide and "fished" through the ebb tide yielding a catch. The juvenile Chinook catch is adjusted by a trap recovery efficiency (RE) estimate derived from mark-recapture experiments using a known number of marked fish released upstream of the trap at high tide. The RE is usually related to hydraulic characteristics unique to the site (e.g., change in water surface elevation during trapping or water surface elevation at the end of trapping). Multiple RE tests (several times per season) at each site are used to develop a regression model to convert the "raw" juvenile Chinook catch to an estimated population within the habitat upstream of the fyke trap on any sampling day.

[2] These methods are found starting on page 51 of Beamer et al. (2005).

A - Small Net Beach Seine

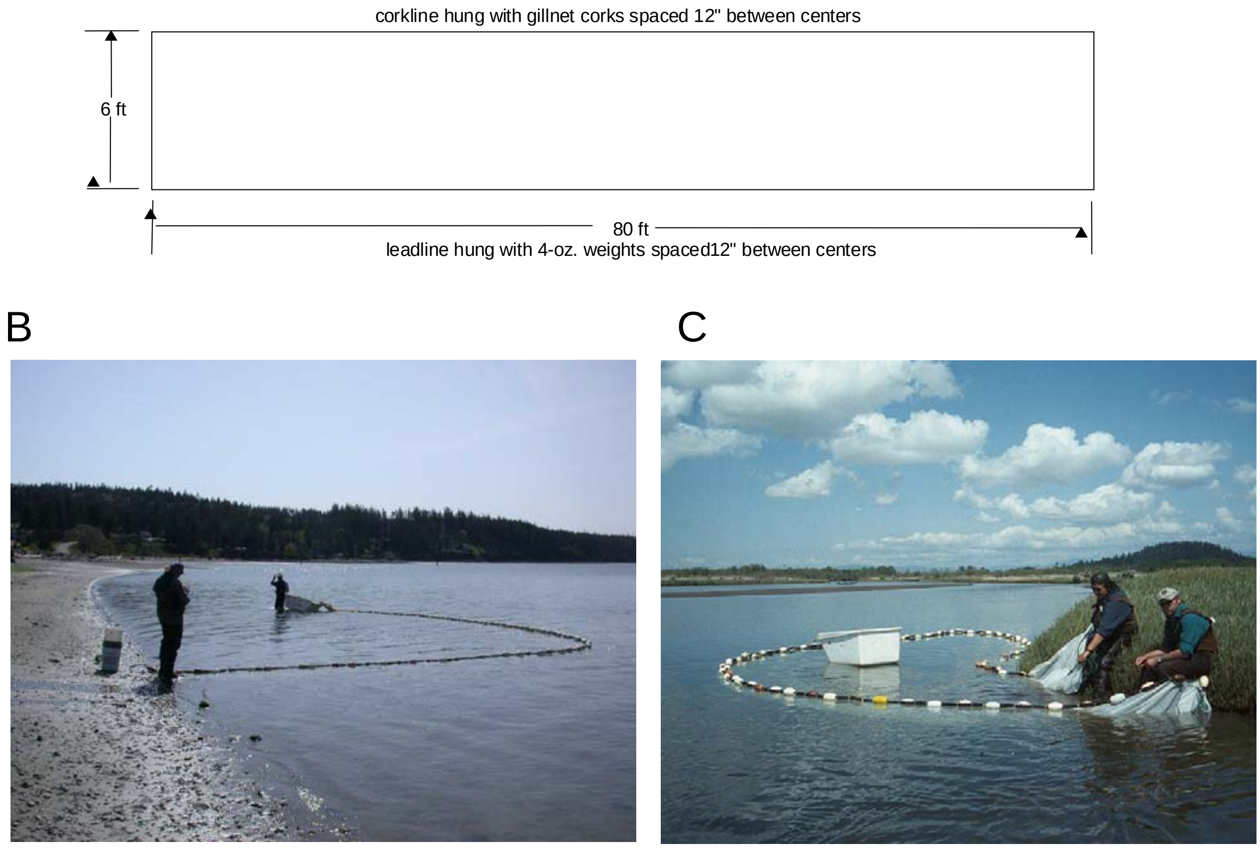

Figure 1. Small net beach seine methodology. (A) design of net (not drawn to scale), (B) setting net out of tote on shallow intertidal beach, (C) beginning to haul net in distributary channel.

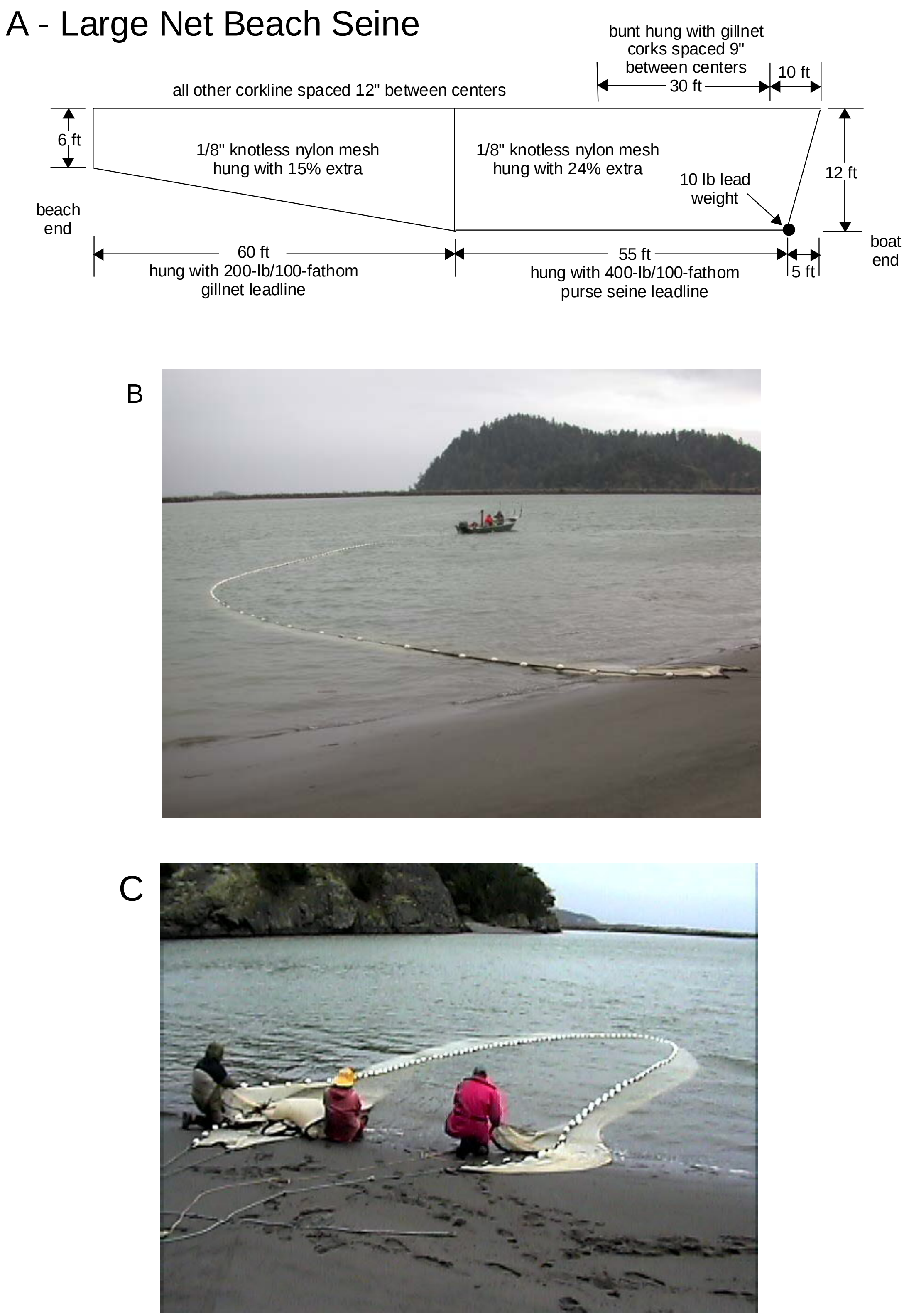

Figure 2. Large net beach seine methodology. (A) design of net (not drawn to scale), (B) towing on net, (C) hauling net.

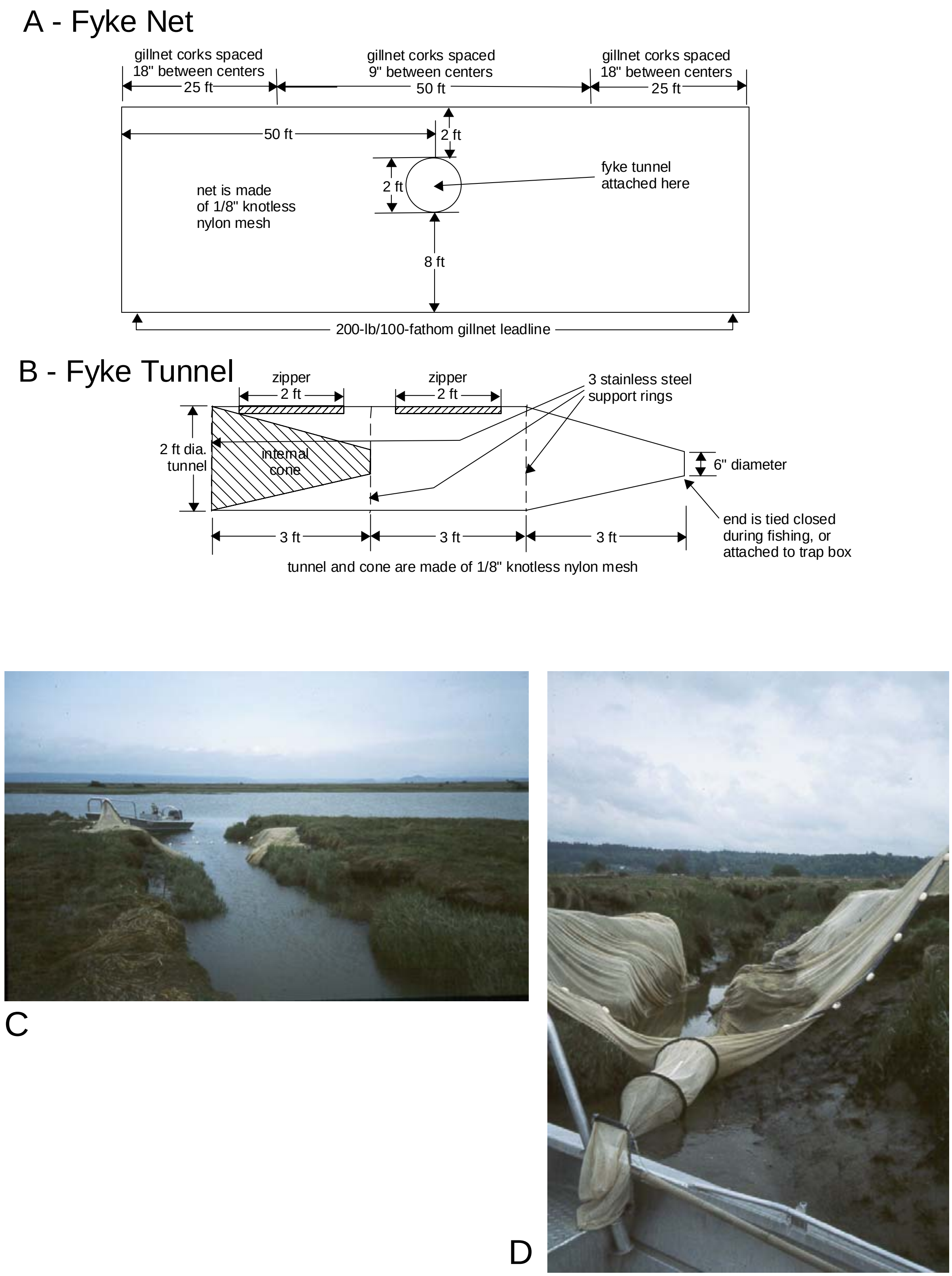

Figure 3. Fyke trap methodology. (A) design of net (not drawn to scale), (B) design of tunnel (not drawn to scale), (C) fishing during ebb tide, (D) net at low tide (end of fishing).