PRELIMINARY RESEARCH PROPOSAL (COE) (FY07)

TITLE: A study to estimate juvenile salmonid survival from Bonneville Dam through Columbia River estuary using acoustic tags

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PROJECT SUMMARY

The primary goal of this study is to use acoustic tag and concomitant detection arrays to estimate survival, travel time and residence, and ocean-entry timing of both stream- and ocean-type juvenile salmonids through the lower Columbia River and Columbia River estuary. Statistical basis for this work is the single-release survival model introduced by Cormack (1964), Jolly (1965), and Seber (1965) and referred to as the CJS single-release model. Information gained from these efforts may also be used to characterize how salmonids utilize estuarine habitats, explore mechanisms of hydropower system delayed mortality, and evaluate the effect from physical changes to the estuary (flow and habitat) on the recovery of listed salmon stocks. In 2007, we propose to implant micro-acoustic tags into non PIT-tagged run-of-the-river (ROR) juvenile salmonid fish obtained at the John Day and Bonneville dams' smolt monitoring facilities. Subsequent detections of tagged individuals on acoustic receivers located at downstream sites (transects) will provide survival and timing metrics to points through the lower river and estuary.

A key study element has been the development of an acoustic tag small enough for use in subyearling fall Chinook salmon *Oncorhynchus tshawytscha*. Using downsized acoustic microtransmitters, a wider variety of targeted groups and life histories can be evaluated to develop a broader understanding of the relationships among the hydropower system passage experiences, estuarine residence, and survival.

BACKGROUND

Mortality in the estuary and ocean comprises a significant portion of the overall mortality experienced by salmon throughout their life cycle, and seasonal and annual fluctuations in salmonid mortality in these environments are a significant source of recruitment variability (Bradford 1995). In recognition of the potentially important contribution of estuaries to overall survival, recent studies attempted to evaluate effects of estuarine conditions on salmon. Simenstad et al. (1992) suggest that estuaries offer salmonids three primary advantages: productive foraging, relative refuge from predators, and a physically intermediate environment in which the fish can transition from freshwater to marine physiological control systems. Thorpe (1994) reviewed information from three genera of salmonids (*Oncorhynchus*, *Salmo*, and *Salvelinus*) and concluded that salmonids are characterized by their developmental flexibility and display a number of patterns in estuarine behavior. He found that stream-type salmon migrants (some Chinook, coho, sockeye, and Atlantic salmon) move through estuaries and out to sea quickly, compared to ocean-type salmon migrants.

Most of our knowledge of how salmonids utilize estuaries is limited to smaller systems that can be more readily sampled. For example, Beamer et al. (1999) assessed the potential benefits of different habitat restoration projects on the productivity of ocean-type Chinook salmon in the Skagit River, Washington. They concluded that restoration of freshwater habitats (peak flow and sediment supply) to functioning levels would provide limited benefits unless estuary capacity or whatever factor that limits survival from freshwater smolt to estuary smolt is also increased. They used productivity and capacity parameters to estimate that estuarine habitat restoration could produce up to 21,916 smolts/ha. Reimers (1973) found a diverse number of estuary rearing periods and strategies for fall Chinook salmon in the Sixes River, Oregon.

Columbia River

Little information is available describing historical juvenile salmonid use of the Columbia River estuary. Rich (1920) found that 36% of the juvenile yearling and subyearling Chinook salmon collected from 1914 to 1916 demonstrated extensive rearing in the estuary. In a more recent study, as many as 70% of the fish sampled during July had resided in the estuary from 2 to 6 weeks (Jen Burke, Oregon Department of Fish and Wildlife, Pers. commun., June 2000). Subyearling Chinook salmon attained 20 to 66% of their fork length (FL) while in the estuary. In contrast, in more recent times where hatchery fish dominate the juvenile population, Dawley et al. (1985) noted that movement rates through the estuary were similar to rates from the release site to the estuary, indicating limited use of the estuary by juvenile salmonids originating upstream from Jones Beach (river mile xx). Schreck and Stahl (1998) found mean migration speed of radio-tagged yearling Chinook salmon was highly correlated with river discharge, and averaged approximately 2 mph from Bonneville Dam to near the mouth of the Columbia River. Movement in the lower estuary was influenced by tidal cycles, with individuals moving downstream on the ebb tide and holding or moving upstream during the flood tide. They reported a high proportion of tagged animals were lost to piscivorous bird colonies located on dredge disposal islands. Ledgerwood et al. (1999) also found that travel speed of PIT-tagged fish from Bonneville Dam to Jones Beach was highly correlated with total river flow. They observed significant differences in passages times at Jones Beach for spring/summer Chinook salmon PIT tagged and released at Lower Granite Dam to migrate in-river and fish transported to below Bonneville Dam and released. PIT-tagged fish detected at Bonneville Dam had significantly faster travel speeds than those released from a transportation barge below Bonneville Dam--98 and 73 km/day, respectively. These recent studies provide a cursory assessment of estuarine migration behavior.

The COE, along with BPA, NMFS, and other local, state, and federal agencies, is working to restore habitats to benefit salmonids and other species in the lower Columbia River and estuary ecosystem. There are a multitude of actual and potential restoration projects that would benefit from data on smolt migration behavior relative to habitat conditions. Data on smolt migration pathways and residence times will help restoration managers assess the effectiveness of ongoing projects and prioritize potential projects. For example, restoring habitats that juvenile salmonids are confirmed to reside in would have priority over others without such confirmation.

Smolt migration behaviors are generally understood from previous studies. For example, yearling fish typically migrate downriver faster than subyearling fish (Dawley et al. 1985). Yearling and subyearling fish, though, may spend time to feed in shallow water habitats out of the strong current in the main channel in the lower Columbia River and estuary. Although specific fish/habitat linkages are not always evident (Simenstad and Cordell 2000), it is reasonable to assume that salmon, especially those with ocean-type life history patterns, depend on shallow water, tidal habitats for rearing and refuge (Fresh et al. 2005). Thus, it is not prudent in light of the current Biological Opinion negotiations to assume the lower Columbia River and estuary is just a migration corridor for salmonids. Juvenile growth and survival in estuarine habitats is of critical importance to population growth and stability and therefore recovery of the species (Fresh et al. 2005). Availability of diverse shallow-water habitats, especially very shallow peripheral habitats, may be a limiting factor to the production and diversity of salmonids such as upriver fall Chinook salmon (Fresh et al. 2005; Quinn 2005). In sum, significant findings from these studies with relevance to the proposed research on yearling and subyearling salmon in the lower Columbia River and estuary (LCRE) include:

- Sampling sites included shallow water habitats in marine, estuarine, and freshwater areas mostly from the mouth to Jones Beach (RM 46). The tidal freshwater reach from RM 46 to Bonneville Dam (RM 146) has been studied little.
- Subyearling salmon from watersheds below Bonneville Dam are more abundant in shallow water habitats than subyearlings from upriver (Roegner et al. 2004).
- Peak abundance in shallow water habitats is in April-July for yearling and subyearling Chinook salmon and February-April for subyearling chum salmon (Dawley et al. 1986).
- Subyearling salmon may reside in the estuarine waters for extended periods of time (weeks to months; e.g., see Rich 1920), and smaller individuals using shallow water habitats to feed spend more time in the LCRE than larger fish (Dawley et al. 1986). Some juvenile salmon over-winter in the LCRE (Dawley et al. 1986).
- Subyearlings sampled in shallow water nearshore are typically smaller than those from mid-river (Dawley et al. 1986; Bottom et al. 1984; McCabe et al. 1986). Fish at tidal freshwater sites are on average smaller than those at estuarine and marine sites (Roegner et al. 2004).

- Subyearling fish eat *Corophium spp.* and terrestrial insects in shallow water habitats (Roegner et al. 2004; Kirn et al. 1986; McCabe et al. 1986). Average fork length tends to increase from spring to summer (Roegner et al. 2004; Dawley et al. 1986).
- Juvenile salmon migration characteristics in the LCRE are influenced by upriver forces, such as hydropower operations and hatchery practices (Bottom et al. 2001; Weitkamp 1994).

Thus, while juvenile salmonid use the lower Columbia River and estuary as a migration corridor is obligatory, questions remain concerning migration pathways other than the main channel and residence time in specific estuarine habitats.

Summary

Estimating survival rates for the reach below Bonneville Dam is an important first step toward developing an understanding of whether substantial mortality occurs between Bonneville Dam and the mouth of the Columbia River and the magnitude and inter-annual variability of that mortality. Survival can then be related back to the ESU, rearing history, and migrational experience (transported, in-river, multiply bypassed, etc.) This research complements current studies by NOAA Fisheries to evaluate effects of bypass systems on delayed mortality. The current micro-acoustic transmitter allows tracking of smolts for up to 60 days (transmitter life is related to the pulse rate interval) under field conditions to evaluate whether mortality occurs in a reach of the river where measurement is possible. If delayed mortality is measurable between Bonneville Dam and the mouth of the Columbia River using the acoustic transmitter, experiments could be designed to evaluate the relationships between changes to the hydropower system and survival.

APPROACH

With design work and preliminary testing realized, the goal of using this tool to make rigorous survival assessments was initiated in 2005. As of this writing, we are collating and analyzing the 2006 data. Based on the success of that effort to date, four objectives have been developed for implementation during FY07 to continue survival estimation using micro-acoustic tags as a management tool in the Columbia River system:

1) Using the single-release statistical model, estimate survival from Bonneville Dam to the mouth of the Columbia River for target groups of various ESU's, and rearing, transportation, and hydrosystem passage histories (2005-2008). Compare survival through the lower river and estuary for various target groups evaluated.

   Task 1a. Estimate survival of run-of-the-river yearling Chinook salmon from Bonneville Dam to the Pacific Ocean.
   Task 1b. Estimate survival of run-of-the-river subyearling Chinook salmon from Bonneville Dam to the Pacific Ocean.
   Task 1c – Analyze data from tag effects studies (laboratory and field) to determine impacts (if any) to juvenile salmonids.

2) Dependent on whether evaluation of 2006 data indicates unacceptably low survival below Bonneville Dam, partition the lower Columbia River into three or more reaches to identify relative survival among partitions for yearling and subyearling Chinook salmon.

3) Evaluate the use of mobile tracking as a means of determining lower river and estuary habitat use and potential mortality causative effect.

4) Use acoustic telemetry technology to facilitate estuary habitat use mapping and monitoring of behaviors relative to these habitats to support estuary habitat restoration activities. Continue to integrate findings with results from other COE and BPA funded estuarine habitat studies to link habitat use behaviors to growth, benefits, and survival into the near shore marine environment.

Objective 1

Using the single-release statistical model estimate survival from Bonneville Dam to the mouth of the Columbia River for target groups (2005-2008). Compare survival through the lower river and estuary for various target groups evaluated.

Task 1a. Estimate survival of run-of-the-river yearling Chinook salmon from Bonneville Dam to the Pacific Ocean.

In 2007, we propose to estimate yearling Chinook salmon survival from release at Bonneville Dam to the mouth of the Columbia River using acoustic telemetry to meet the requirements of the single-release statistical model. For this study, we will estimate survival to a primary detection array located near the mouth of the Columbia River estuary, at approximately river kilometer 9. We will also partition the lower river between Bonneville Dam and the estuary into four reaches using acoustic arrays at Camas (as part of study SPE-P-02_2), Kalama, and Cape Horn to identify reaches of the lower river where mortality is disproportionately high.

The most favorable transect for a primary detection array in the lower estuary was selected during system design and feasibility studies conducted in 2001, and secondary array locations have been identified to accommodate assumptions of the single-release survival model (Fig 1). Fully-populated detection arrays were deployed along the proposed transect routes in 2005 and 2006. Both arrays intercepted a substantial portion of the acoustically tagged outmigrant population reaching those sites. Fish from each of the 4 yearling Chinook salmon groups released in both years were detected on nodes in both arrays, and often individual fish were recorded on multiple nodes (McComas et al in prep). Information from interrogation of each the arrays is currently being analyzed for the data collected in 2006.

Currently, all detection arrays proposed for the lower river and estuary will be comprised of autonomous nodes. These nodes are individual, self-contained units suspended approximately

4.5 m (15 ft) above the bottom on an anchored tether. Acoustic releases will allow recovery for battery replacement and data retrieval at approximately 28-d intervals. Since nodes cannot be safely placed in the shipping channel for extended periods, each array transect in the Columbia River and estuary will consist of two sub-arrays to cover the line from south shore to the north shore. In the lower estuary, the primary array will run from West Sand Island to Clatsop Spit. Based on current information for detection ranges for these nodes and reception data from the 2005 and 2006 deployment, the northern (West Sand Island, WSI) sub-array will consist of nineteen nodes running from West Sand Island (46° 15.889' N, -124° 00.258' W) south to the north side of the shipping channel along the Lower Desdemona Shoal Navigation Range (46° 14.310' N, -123° 59.442' W). The second sub-array will be comprised of three nodes extending in a transect east from Clatsop Spit (46° 14.025' N, -123° 59.866' W) to the southwest side of the shipping channel (46° 14.245' N, -123° 59.546' W), terminating directly across from the south end of the northern sub-array. The distance across the shipping channel at this point is approximately 650 ft. This arrangement will result in a mean spacing of 155 m between nodes along the north array segment and 156 m along the south array segment.

Tests of node reception ranges indicate that a spacing of approximately 152 m (500 ft) between deployed nodes would be a conservative estimate to ensure that transmitters passing between nodes are detected. With a pulse repetition interval (PRI) of 5 seconds between code transmissions, this stationing will allow transmission of at least 9 pulses as the transmitter crosses the detection array reception range in a 11 km/h (6 knot) current. For a 7 second PRI, at least 6 transmissions would occur. Overlap in range of sub-array end nodes across the navigation channel (198 m, 650 ft), should provide detection of a minimum of 3 pulses for tagged fish migrating along the channel between the two arrays at 11 km/h.

Figure 1. Proposed primary and secondary detection array transects to be used to estimate juvenile salmonid survival through the Columbia River estuary using micro-acoustic transmitter tags.

A secondary detection array, downstream from the primary array, will be needed to satisfy the requirements for single-release survival estimate. The secondary array will consist of up to 30 autonomous nodes deployed on the Columbia River bar along a roughly north-south transect between U.S. Coast Guard navigation buoys 8 and 10 (Fig 1).

Approximately 12 of the secondary-array nodes will be located on the Washington side of the navigation channel and the remainder on the Oregon side of the channel along a transect from approximately 46° 16.338' N, 124° 04.258' W to 46° 14.454 N, 124° 03.375' W. Equidistant spacing will result in 130- to 137-m intervals between autonomous nodes; however, exact locations will depend on several factors, including weather and sea conditions at the time of deployment or the presence of commercial crab gear. This spacing will provide detection capability similar to that for the primary array over the deployed area. Separation between north-south midpoints of the primary and secondary arrays will be approximately 5.3 km.

We will also recover Secondary array autonomous nodes approximately every 28 days to replace batteries and data cards. Servicing dates will be coordinated with the tagged fish release schedule, anticipated travel times, and tide cycles to minimize omission of tagged fish passing the array during servicing periods. In 2006 nodes were replaced sequentially using previously serviced units. This strategy minimized the time that a position in the array was without detection capability to no more than 15 minutes. Depending on weather conditions in the area, servicing an entire array should require no more than 2 days of ‘field time’.

The geodetic position of each node in both arrays will be recorded at the time of deployment using coordinates obtained through the global positioning system (GPS). Beacon tags installed on each node will aid in location of orphaned or shifted nodes, and serve as system function checks throughout the course of the sampling season.

Initial deployment of the lower estuary and intermediate arrays will occur prior to 15 April 2007, subject to weather and sea conditions in the deployment area.

Deployment timing, transect locations, and servicing schedule for intermediate arrays (between Bonneville Dam and the lower estuary) will be determined based on the node availability and regional management criteria. However, these arrays will also be in place prior to the start of tagging at Bonneville Dam.

Sample Sizes and Study Design

Building on experience gained during the 2005 and 2006 outmigrations, fish to be acoustically tagged will be captured using the Bonneville Dam Second Powerhouse Juvenile Fish Facility (JFF) daily smolt monitoring sample. Only non-PIT-tagged hatchery-reared (adipose- clipped) yearling Chinook salmon will be targeted. Fish to be tagged will be separated from the daily sample on the day prior to the tagging date and held on river water in the JFF facility for tagging the following day.

All fish will be simultaneously tagged with acoustic and PIT tags. Evaluation of data from studies currently (as of July 2006) being conducted will determine whether PIT and acoustic tags will be fused or separate. Tagging will be accomplished in a manner similar to that described by Adams et al. (1998) for radio tags, modified to exclude the antenna procedure. Fish will be anesthetized to loss of equilibrium with tricaine methanesulfonate (MS-222) at a concentration of 50 mg/L of fresh water, buffered to a pH of no more than 7.2. While immobile, fish will be weighed to the nearest 0.1 g and measured to the nearest millimeter, and the PIT-tag code, acoustic-tag code, and metrics associated with the fish will be recorded to a database. Acoustic-tag functionality will be verified immediately prior to recording to the database. The subject fish will be placed dorsal surface down on a moist foam operating table, and a rubber tube will be inserted into the animal's mouth to provide a continuous supply of water during the procedure. An 8- to 10-mm incision will be made approximately 2 mm to the left of the midventral line between the pectoral- and pelvic-fin girdles. The PIT tag will be inserted into the parietal cavity through the incision first, followed immediately by the acoustic transmitter with attached PIT tag inserted through the incision. The incision will be closed by at least two interrupted sutures, and the fish will be placed in a bucket of fresh water for observation during recovery.

Following recovery from anesthesia after surgery, tagged fish will be placed in containers and held on river water for up to 24 h (12 h minimum) to evaluate short-term tagging effects.

Tagging dates and the numbers of fish to be tagged per date will be dependant on release strategy. The primary objective for all yearling Chinook salmon acoustically-tagged at and released below Bonneville Dam will be to estimate survival to intermediate points in the lower river and through the primary array in the lower estuary. However, by coordinating with other research efforts we will reduce resource impacts and augment the number of tags available for survival estimation.

Bonneville spill survival control group releases - We propose to tag and release fish to serve as paired-release control groups for treatment groups released above Bonneville Dam for the Bonneville spill survival effort (SPE-P-02-02, Survival of Juvenile Salmonids through the Spillway at Bonneville Dam). This strategy will maintain continuity with procedures established during earlier paired-release studies using radio-tagged fish (Counihan et al 2006). We will tag 1,300 yearling Chinook salmon in groups of 65 fish per day, 5 days per week, for 4 weeks. Following tagging, fish from a single daily tag group will be held in multiple 19 L containers (buckets) in sub-groups of up to 5 fish per bucket, for a minimum of 12 h. The buckets will be housed in a 2.43 m x 1.5 m x 0.46 m insulated aluminum box containing a 4 x 7 grid of compartments, each designed to hold individual buckets. The aluminum box will be supplied with oxygenated flow-through river water, and multiple holes in the buckets will assure flow through the containers during holding. The aluminum container will be attached to the deck of a release barge, and buckets will be transported to the barge for holding as soon as possible following recovery from tagging.

To maintain continuity with previous studies, control groups will be released near mid channel approximately 2 Km downstream from the Bonneville Second Powerhouse. During the previous study, Counihan et al. (2006) released radio-tagged fish groups at mid channel at approximately 1100 and 0000 h, when it was estimated that treatment fish released below The Dalles Dam should arrive below Bonneville Dam. We are proposing two modifications to this single-point release strategy for work in 2007.

First, we will release control fish in small groups estimated to coincide with the proportions of treatment fish arriving below Bonneville Dam. An initial estimate of these proportions for the first three days releases in 2007 will be calculated using acoustic and PIT-tag detections at Bonneville Dam for fish groups released at The Dalles Dam in 2006. Following those first releases, we will refine the process (if necessary), by identifying proportions of the first 3 days treatment releases using 2007 PIT-tag detections at Bonneville Dam (Bonneville Dam full flow detectors, smolt monitoring samples, and corner collector) and time of arrival information obtained from fixed, cabled acoustic detectors in the forebay at Bonneville Dam. We will release buckets of control fish to approximate, as closely as possible, the treatment release proportions estimated to be passing the release site in a one hour period. For example, if we estimate 40% of treatment fish to be passing Bonneville Dam over a 1 h period, and the treatment group consists of 400 fish, we will release 25 control fish (0.4 x 62 daily control fish available for release) over the appropriate hour interval at an approximate rate of 6 fish every 15 min. The interval between releases will allow time to verify that all acoustic tags functionality, tagging mortalities, and presence of rejected tags just prior to release. The actual numbers released will be recorded as the release is made.

The second proposed difference from earlier work involves a minimal variation in release location for control fish. We propose to release fish as near to center channel, 2 km below Bonneville Dam as possible. However, for safety reasons, we will not anchor a release vessel in the river. Rather, GPS positions of release points will be recorded as each release is made while the vessel is holding approximate position. For example, with the scenario described above, we will record four release points (one for every 15 min) near the target release site. This will allow maximum flexibility to respond to river traffic and to accommodating limiting conditions (weather and flows) over the course of the study.

Bonneville Second Powerhouse JBF bypass releases – For releases of smolts during earlier survival studies (2004 – 2006), acoustically-tagged fish entered the river as a group from the Bonneville Second Powerhouse JBF outfall. The genesis of this release strategy dates to the original perception of micro-acoustic, tag-group definition using the sort-by-code facility at Bonneville Dam to build survival treatment groups of interest from known-source PIT-tagged individuals passing the JBF. Though defining fish groups based on PIT-tag codes is no longer a primary objective, the numbers of juvenile Chinook salmon exiting through the bypass make survival from that release point a valid consideration. In 2007, we propose to continue releases of acoustically-tagged ROR yearling Chinook salmon through the Bonneville Second

Powerhouse JBS outfall to maintain continuity with previous years' research, and as an in-year comparison to spill survival control fish released near mid channel.

Up to 750 micro-acoustic tags will be available for this portion of the study during the spring outmigration. We propose to tag three groups of up to 250 ROR adipose-clipped yearling Chinook salmon for release through the JBS outfall in 2007. Tagging will occur near the beginning, middle, and end of May to characterize survival for early, middle and late segments of the outmigration. Other considerations, such as diel timing of releases may be warranted after analysis of 2006 data is complete or in consultation with regional managers. Prior to release, tagged fish will be held on flow-through river water in groups of 25 animals per 65 l container for a minimum of 12 h to assess tagging mortality.

Retention Groups – Two assumptions of tagged individual recovery models are that all there is no loss of tags from tagged individuals, and that tags are recoverable. To evaluate these assumptions we have, since program inception, held a portion of each tagged group. In 2007, we propose to retain approximately 2% of each tag group to evaluate longer term effects of tagging. Holding these retention groups from the same population as the release group has proven invaluable as a direct indication of released fish survival. For example, in mid-July 2005, poor survival of acoustically-tagged retention fish relative to PIT-tagged retention fish during a period of elevating water temperatures led to a to suspension of further tagging activities. Using the retention fish as an example, poor survival performance for the associated release group was probably biased by tagging at high temperatures, and those data could arguably be viewed as spurious by that bias rather than representing a real decrease in survival for the ROR population as a whole.

We will hold retention fish from each tagging date (spill survival controls and bypass). Up to three fish per daily spill survival tag group (up to 5% of each group) and up to five fish per outfall release tag group (up to 2% of each group) will be retained to assess longer term mortality and tag life. In addition, we will hold an equal number of retention control fish, which will be tagged with PIT tags only. These control retention fish will be handled and anesthetized, but will not have the surgical procedure performed. All retention fish (controls and acoustic-tagged) will be randomly selected from the respective tagged fish group and will be retained for a minimum of 2 weeks after tagging, or until the fish expire. All retention fish from one tagging date will be held in the same tank and fed daily over the retention period. At the end of the retention period, remaining retention fish will be sacrificed and necropsied to evaluate adhesion growth, encapsulation progression, abnormal organ development, and tag rejection.

Acoustic tags explanted from the acoustically-tagged retention fish will be held to expiration to verify tag longevity. In past studies, these tags were checked daily to verify function. Beginning in 2007, retention tags will be monitored continuously and data will be recorded to a file for evaluation later. In this way we should be able to very closely define tag life for each transmitter. In conjunction with other longevity evaluations using tags from each tag lot supplied by the vendor, this should provide an adequate assessment of tag performance.

Analysis of data from 2006 efforts is expected to result in survival and variance estimates for power analysis to empirically refine release group sizes for 2007. Until 2006 data are analyzed, we propose to use the smallest predicted tagged fish group size estimates which will result in approximately ± 0.10 precision based on an assumed minimum detection probability at the primary array of 0.60, survival to the primary array of 0.60, secondary array detection probability of 0.60, and survival between the primary and secondary arrays of 0.90 for preliminary planning. Using these parameters, a precision of approximately 0.094 can be realized using release groups of 250 fish. However, since the precision estimate from analysis of the 2006 data set may be different from this target estimate, the 2007 sample size may change to accommodate precision based on that analysis.

In 2007, sufficient numbers of yearling Chinook salmon should be available for tagging from 1 May through 2 June. We will tag groups of 250 fish each (750 fish total, for release through the Bonneville II JFB outfall) on 5 May, 19 May, and 2 June. Groups of 60 fish each will be tagged 5 days per week (Monday through Friday) for 4 weeks (1,300 total tagged fish) beginning 7 May and ending 1 June, 2007. For both release strategies, releases will occur on the day following tagging.

We do not expect array installation to be so severely delayed as to require abandoning this objective. However, in the unlikely event that funding or other constraints do not permit timely execution of all or part of this work, we will conserve resources and retain the remaining tags allocated for similar objectives during 2008.

Task 1b - Estimate survival of run-of-the-river subyearling Chinook salmon from Bonneville Dam to the Pacific Ocean

Since little is known about Columbia River subyearling Chinook salmon life history in the estuary and early-ocean life phases, the primary impetus driving the micro-acoustic tag development program was to produce a transmitter small enough for implant into the majority of subyearling Chinook salmon passing Bonneville Dam. In fact, initial tag design life was specifically set at 30 days to accommodate presumed increased travel time (compared to yearling smolts), and the possibility that some subyearling cohorts may use portions of the estuary as nursery areas for extended periods prior to final emigration into saltwater.

Though the current tag is slightly larger than original design parameters, dry and residual weights are sufficiently reduced to continue using this product for subyearling Chinook salmon survival estimation. For example, we successfully implanted the previous versions of this tag (19 mm long, ~650 mg in air) into subyearling Chinook salmon smolts down to 96 mm fork length during survival evaluations in 2005 (McComas et al. In prep.). These smaller fish all survived to pass detection arrays in the lower estuary. In an ongoing laboratory study being conducted at Astoria, Oregon, 87% of micro-acoustically tagged hatchery subyearling Chinook salmon ranging from 70 – 83 mm fork length survived to 30 d following post-operative implant of the 2006-style transmitter (17 mm long, ~630 mg in air). Survival for the group was 74% after 60 d (Michelle Rub, NOAA Fisheries, personal communication, July 2006). In 2007, transmitter specifications require vendors to produce a tag weighing ≤600 mg in air (<350 mg residual in water), with a total length of ≤14 mm and a volume of ≤0.2 cm^3. Using a transmitter with these specifications, we anticipate being able to tag subyearling Chinook salmon to at least 90 mm FL for field evaluations. This length should encompass approximately 85% of subyearling Chinook salmon smolts passing Bonneville Dam. We propose to estimate subyearling Chinook salmon survival from release at Bonneville Dam to the mouth of the Columbia River in 2007 using acoustic tags. We will obtain survival values for generalized ROR subyearling migrants passing Bonneville Dam by estimating survival to the primary detection array near the mouth of the Columbia River estuary described under Objective 1, Task

1a. In subsequent years, we will expand this effort by targeting groups of interest to regional managers.

We will tag up to 3,000 subyearling Chinook salmon during summer 2007. Smolts to be acoustically-tagged will be obtained from the Bonneville Dam Second Powerhouse JFF daily smolt monitoring sample. Only fish without PIT tags will be targeted for this study. Fish to be tagged will be separated from the daily sample on the day prior to the tagging date and held on river water until the following day. Subsequent tagging, handling, release group, and retention group sizes and release and necropsy protocols will be similar to procedures described for yearling Chinook salmon under Objective 1, Task 1a. However, subyearling Chinook salmon juveniles may experience a longer residence period in fresh water compared to yearling cohorts. To gain a better understanding of wound development and tag retention in release-group fish over the freshwater phase, retention fish may require a holding period longer than 2 weeks.

Sample Sizes and Study Design

We will tag groups of subyearling Chinook smolts to match release strategies for yearling Chinook salmon described under Objective 1, Task 1a above. While normal river temperatures are normally not excessive during the spring outmigration, procedures may have to be modified to accommodate anticipated temperature increase during July. Experience gained in similar efforts over the previous years has demonstrated that when river water temperature exceeds approximately 20.5º C, survival of acoustically-tagged fish can be impaired. We will therefore plan to complete all acoustic-tagging operations prior to mid July when conditions usually approach that temperature.

Bonneville spill survival control group releases - Up to 1,300 micro-acoustically tagged fish will be released as control fish to compliment treatment releases upstream from Bonneville Dam. To accomplish this, we will tag 65 fish per day, 5 days per week, over a 4-week period beginning in mid June, 2007.

Bonneville Second Powerhouse JBF bypass releases - Up to 1,750 acoustic tags will be available for tagging groups to be released through the Bonneville II JBF outfall to continue lower river and estuary survival estimation methods used during 2005 and 2006. We proposed to tag up to 7 groups of subyearling Chinook salmon (250 fish per release group) over the course of the summer outmigration from mid June through mid July to accomplish this Task. This will result in one release group approximately every 4 days. Successful release of all groups will provide, at minimum, data for comparing survival and timing among various segments of the subyearling Chinook salmon outmigration.

Task 1c – Analyze data from tag effects studies (laboratory and field) to determine impacts (if any) to juvenile salmonids.

The effects of the microacoustic tag on physiology and behavior of juvenile salmonid smolts have been under investigation under several programs during 2006. In 2007, we propose to bring together and evaluate the results of these efforts to determine whether there are effects on survival that may need further investigation, or which indicate changes to survival estimation protocols (holding or release strategies, surgical procedures, data handling and reporting, etc.). We will evaluate results from ongoing field and laboratory investigations of comparative performance between PIT- and acoustically-tagged smolts (SPE-P-06-2), as well as other investigations under evaluation.

Objective 2

Partition the lower Columbia River into three or more reaches to identify relative survival among partitions for yearling and subyearling Chinook salmon.

Analysis of data from survival studies in 2005 and preliminary data from similar studies in 2006 indicated that mortality in the lower river and estuary was higher than anticipated, particularly for yearling Chinook salmon (McComas et al. in prep). Based on this inference, we propose to begin the process of partitioning the lower river to establish where mortality is occurring. In the event this is necessary, we will partition the system by placing detection arrays near Kalama and Cape Horn, Washington, in addition to the array already in place near Camas, Washington (as part of Study SPE-P-02_2). We will estimate survival to each of these arrays and between each array using tagged fish released from Bonneville Dam for estuary survival studies, as well as acoustically-tagged fish of opportunity released at other points in the Columbia River system in conjunction with other studies.

Objective 3

Evaluate the use of mobile tracking as a means of determining lower river and estuary habitat use and potential mortality causation.

The intent of this objective is to establish protocols (target selection and target priority, individual track duration, and data handling) to be used to identify and track acoustically-tagged fish released in the Columbia River system. We will use resulting data to help establish route specific survival and identify habitat selection for outmigrants.

Mobile tracking has been recognized as a necessary component of survival estimation since program inception. For example, it was noted that fall Chinook salmon, for which the miniaturized acoustic tag is being optimized, have been shown to reside in estuarine habitats for extended periods before completing their emigration to the ocean environment (Reimers 1973, Levy and Northcote 1982). If this residence period exceeds the life of the micro-acoustic tag, survival estimates will overestimate mortality. In relation to fish released further upstream in the future (SPE-07-new), mobile tracking capability may provide a last point of detection near tag expiration. In either case, a mobile tracking effort would serve to determine residence, residualization, or migration timing which may otherwise result in tag expiration prior to passing a stationary detection site. Mobile tracking could also be used to monitor the selection and extent of estuarine habitat utilization, to identify migration routes through the lower river and estuary, to document predation events, and to define migration timing through selected reaches.

A mobile tracking unit for use with the JSATS transmitter is being developed and will be tested and ready for field deployment by early April 2007. This unit will have at least direction vector capability to identify targets within the reception range of the receiver hydrophone and will update in near real time. Reception information routed directly to a computer will include (at least) target identification (tag code), observation time and date, and GPS location of the vessel. Recording continuous reception data with successive transmitter pulses will allow us to establish a migration track for targets through time. We will record physical data (surface water temperature, tide stage, vessel speed, and weather conditions) for correlation to tracking data.

We will locate and track fish with implanted acoustic micro-transmitters using mobile tracking units. Based on travel-time information obtained to date, a logical approach would be to first begin tracking operations either just downstream from the release point or near the estuary entrance approximately 1 to 2 days following release. We will establish protocols and track selected targets for as long as practicable over the spring and summer outmigration seasons. A starting point for tracking operations will be established prior to the first yearling Chinook salmon release.

Track information from this objective will be used to identify differences in migration behavior which may result in differential timing past stationary detection arrays. Data from route specific tracks will be correlated with physical conditions, and we will attempt to compare survival among individuals using various routes. One goal of this type of research would be to establish a database which could be used to model migration path specific survival, possibly linked to specific cohorts or run timing for the general smolt population.

Objective 4.

Use acoustic telemetry technology to facilitate estuary habitat use mapping and monitoring of behaviors relative to these habitats to support estuary habitat restoration activities. Continue to integrate findings with results from other COE and BPA-funded estuarine habitat studies to link habitat use behaviors to growth, benefits, and survival into the near shore marine environment.

To define use of specific estuarine habitat types, we will use autonomous acoustic telemetry receiving nodes at selected locations in the lower river and estuary to detect acoustic transmitters implanted into outmigrant smolts for other research efforts using JSATS transmitters. We propose a study area (Figure 2) in the Upper Estuary (RM 30-50) because of the variety of habitat types (herbaceous and shrub scrub wetlands, sands, etc.) and braided channels (Figure X). This area is distinguished from most others in the lower Columbia River estuary because of its deep channels and steep shorelines. The various channels make it conducive to sampling smolt migration pathways and residence times inside and outside the main river channel. Possible locations for autonomous nodes are shown in Figure 2. Data from mobile tracking of JSATS-tagged fish would complement the fixed nodes for Objective 4. The nodes for this objective will be deployed from April 1 to August 31. They will be installed along with other nodes as part of the overall effort for this project. Data will be downloaded monthly. Data analysis will involve comparing main channel to off-channel migration pathways. Residence times between detections will be calculated and correlated with habitat type. This study will assess the feasibility of using fixed autonomous nodes to determine smolt migration behavior in the lower Columbia River and estuary.

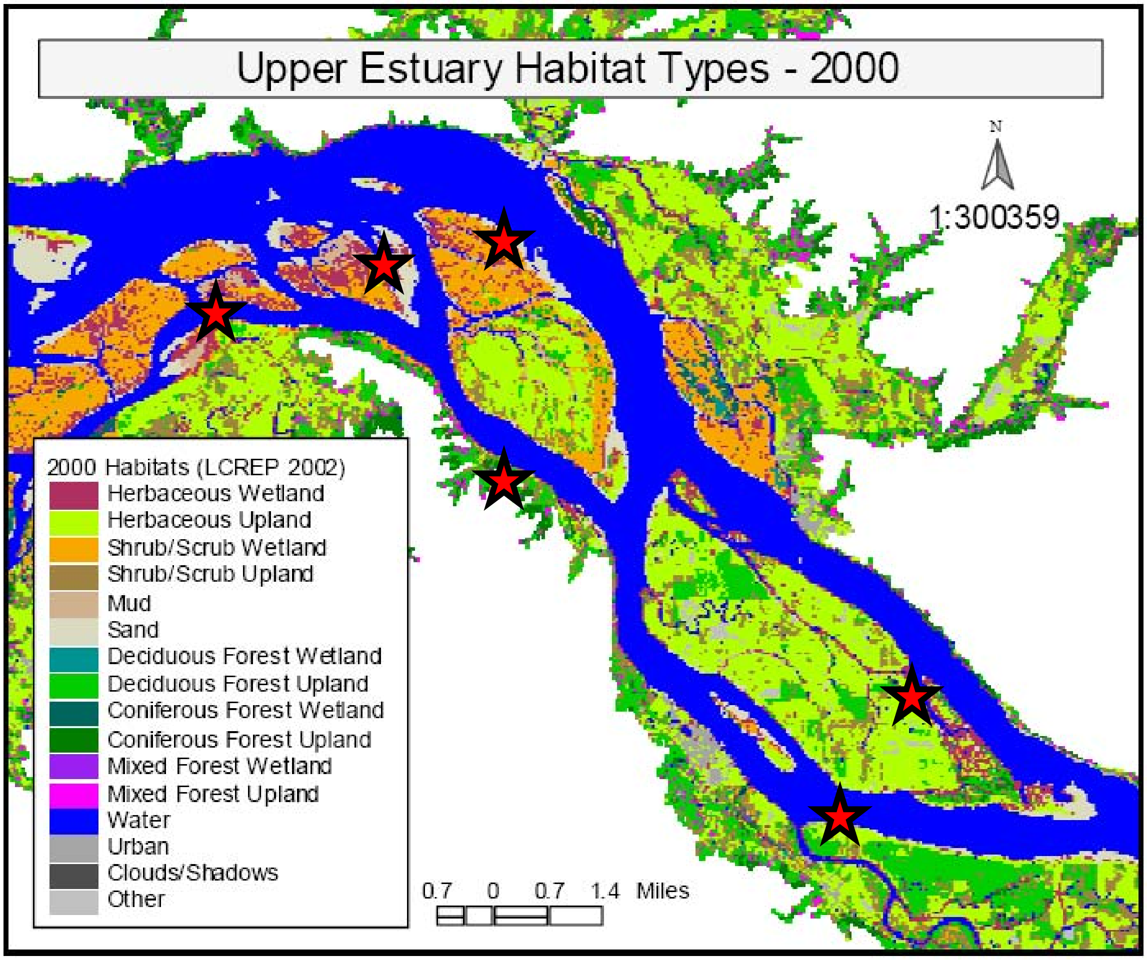

Figure 2. Upper Estuary Study Area for Objective 4, Smolt Migration Behavior. Figure modified from Johnson et al. (2003; p. 43). ★ This symbol depicts possible locations for autonomous nodes for Objective 4.

FISH REQUIREMENTS

FY 2006

Objective 1 - Up to 2,050 hatchery propagated river-run yearling Chinook salmon from the Columbia River watershed will be collected and acoustically tagged at Bonneville Dam. Up to an additional 200 hatchery propagated river-run yearling Chinook salmon collected will be PIT tagged as retention controls.

Objective 2 - Up to 3,050 river-run subyearling Chinook salmon from the Columbia River watershed will be collected and acoustically tagged at Bonneville

Dam. Up to an additional 200 river-run subyearling Chinook salmon collected will be PIT tagged as retention controls.

Objective 3 - None required

Objective 4 – None required

FYs 2008-2010

Large numbers of fish may be required during future implementation. The numbers of fish required for each target group will be determined dependent on estimated survival to the Columbia River mouth obtained in future years, variability about these estimates, detection probabilities, and requirements of the single-release model. Existing populations of PIT-tagged stream- and ocean-type migrants passing Bonneville Dam will be used to the fullest extent possible. The need for additional PIT tagging will be determined during annual planning stages, and will depend on which groups are selected for study, the number of PIT-tagged fish estimated to pass Bonneville Dam, and the numbers of those fish available for acoustic tagging.

SCHEDULES

During 2007, we will continue full implementation by securing baseline survival and timing estimates for generalized yearling and subyearling Chinook salmon. In future years, we will continue this effort by refining target groups to begin addressing specific management-related concerns.

It is important to consider this work in the context of environmental variability, since the importance of the estuarine environment may vary between years. Therefore, we will propose to implement the study over a number of years.

IMPACTS TO PROJECTS, FACILITIES, AND EQUIPMENT

In 2006, use of existing space and facilities at the Bonneville Second Powerhouse JFF will be required for capture, tagging, and holding of acoustically-tagged fish. We will use existing NOAA sampling facilities for tagging operations at Lower Granite Dam. Access to river water and a commercial electrical power supply will also be needed. We will coordinate with Bonneville and Lower Granite Dam Project Smolt Monitoring Facility personnel and other researchers to ensure our requirements for space and water fit within the needs of other user groups.

PROJECT PERSONNEL AND DUTIES

1. Project Leader, Lynn McComas, NOAA Fisheries
2. Project Leader, Geoffery McMichael, Battelle Pacific Northwest National Laboratory
3. Project Leader and Tag design, Thomas Carlson, Battelle Pacific Northwest National Laboratory
4. Project Leader, Gary Johnson, Battelle Pacific Northwest National Laboratory
5. Survival estimates, Steven G. Smith, NOAA Fisheries

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. Draft reports will be provided to the COE. Results will also be published in appropriate scientific journals and presented at scientific forums.

RELEVANCE

The NOAA Fisheries 2000 FCRPS Biological Opinion (NMFS 2000b) Research Action 47 stipulates that delayed mortality of transported versus non-transported fish be estimated. In Research Actions 158 through 160, the 2000 Biological Opinion also includes provisions to identify, catalogue, mitigate, and restore factors in the Columbia River estuary that are limiting to salmonid survival. Research Actions 161 through 164 include provision for development and funding of a monitoring program aimed at evaluating the dynamics among the hydropower system, the estuarine environment, and fish response to changing conditions. Information from this study can be used to directly or indirectly address these actions.

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