PRELIMINARY RESEARCH PROPOSAL (COE) (FY07)

TITLE:	Sampling PIT-tagged juvenile salmonids migrating in the Columbia River estuary
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PROJECT SUMMARY

Detection of passive-integrated-transponder (PIT) tagged juvenile salmon in the estuary will allow survival to be partitioned between river and ocean environments and facilitate a more complete understanding of survival and timing differences between transported and in-river-migrant groups. The information will provide system survival estimates which, when combined with smolt-to-adult-return rates (SAR) of all groups of transportation study fish, can be used to estimate differential delayed mortality or 'D' as called for in the 2000 and 2004 Federal

Columbia River Power System (FCRPS) Biological Opinions (BiOp). These data may also lead to management actions that increase survival by adjusting ocean entry timing or changing the proportions of fish transported or left to migrate in-river.

In 2007, we propose to assess migration timing to the estuary for yearling Chinook salmon and steelhead from tagging operations on the Snake and Columbia Rivers. For these studies, roughly 300,000 Snake River hatchery spring/summer yearling Chinook salmon, at least 10,000 Snake River wild steelhead, and an additional 26,000 Snake River wild yearling Chinook salmon tagged at Lower Granite Dam will be PIT tagged for release into the Snake River below Lower Granite or Ice Harbor Dams (D. Marsh, NMFS, NWFSC, Seattle, WA, pers. commun., July 2006). We will also evaluate migration timing and survival of more than 200,000 PIT-tagged yearling Chinook salmon released from major hatcheries throughout the Snake River basin, plus another 15,000 from Carson Hatchery in the lower Columbia River (L. Basham, Fish Passage Center, pers. commun., July 2006). If sufficient numbers of PIT-tagged fish are released by the mid-Columbia Public Utility Districts (numbers to be tagged uncertain at this time), we will evaluate migration timing to the estuary and may estimate survival through the hydropower system for mid-Columbia River stocks as well (D. Duvall, Grant Co. Fish, Wildlife and Water Quality Dept., pers. commun., July 2006).

Estuarine detections of PIT-tagged fish will provide an index of PIT-tagged salmonids known to be in the upper end of the estuary for use by researchers to assess how avian predators in the lower river select prey by comparing difference in prey selectivity by species and rearing or migration history. Further, if appropriately marked fish are available during the spring, we will compare migration timing of radio-, acoustic-, and PIT-tagged fish to and through the estuary.

If sufficient numbers of summer-migrating subyearling (fall) Chinook salmon are PIT-tagged as in 2006 and in some earlier years, we propose to again extend sampling during summer and fall to provide estuarine behavior and timing information for this ocean-type life-history strategy. This appears feasible because a variety of marking programs are being considered for 2007 to evaluate fish transportation during summer, including perhaps 600,000 hatchery subyearling Chinook salmon tagged at either Lyons Ferry Hatchery or Lower Granite Dam, plus as many wild ones as can be tagged (D. Marsh, NMFS, NWFSC, Seattle, WA, pers. commun., July 2006; R. Kalamaz, USCOE, Walla Walla District, Walla Walla, WA, pers. commun., Sept. 2006). Mid-Columbia River Public Utility District projects have proposed to tag another 50,000 or so wild and 200,000 hatchery subyearling Chinook salmon to be released for transportation evaluations (G. McMichael, Battelle PNNL, pers. commun., July 2006). We intend to have intermittent sampling activities from mid-March to mid-April. This sampling is essential to document the early-season migration passage of fall Chinook salmon thought to reside in reservoirs over-winter in the Columbia River basin. These early migrants possibly include a portion of PIT-tagged fish that had been transported from collector dams during the summer of 2006 as sub-yearling fish. Their subsequent detection in the estuary would provide positive evidence that at least a portion of those transported fish over-winter downstream from Bonneville Dam and migrate to sea early the following spring. Preliminary analysis of scale samples collected from PIT-tagged adult fall Chinook salmon tagged for study in 2002 support this life history strategy for transported fish. A significant portion of the scales studied were collected from fish transported in late summer and fall and had apparently over-wintered in fresh or brackish water prior to ocean entry during the spring of 2003 (D. Marsh, NMFS, NWFSC, Seattle, WA, pers. commun., June 2006).

Previous research at Jones Beach revealed a substantial component of the migrant population in the estuary was oriented along the shoreline (Dawley et al. 1985, Dawley et al. 1986, Ledgerwood et al. 1990). We also propose to continue a limited use of a trawl-like system anchored along the shoreline at Jones Beach to sample for PIT-tagged fish not accessible to the mid-channel trawl systems. Such a shoreline detection system was used periodically at Jones Beach in 2004-2006. The system proved to have low impacts on fish and worked reliably electronically. We installed a wireless underwater video system to enable monitoring of fish passage on shore. We established procedures for ‘flushing the net’ and could routinely sample through all stages of the ebb tide. Logistically, we made several minor improvements to the shoreline system and gained useful insights regarding fish behavior near PIT-tag antennas and nets. We intend to utilize both shoreline sampling and trawl equipment intermittently in the mid-March to mid-April time period and again during late summer and fall. Previous samplings at Jones Beach using beach seines had large catches of yearling Chinook salmon along the shoreline during early spring and substantial numbers of sub-yearling migrants during the fall period (Dawley et al. 1986).

BACKGROUND

Migration behavior and survival of juvenile salmonids passing through the lower Columbia River from Bonneville Dam to the mouth is poorly documented. Reasons include concern for impacts from physically handling large numbers of fish, inaccuracies in mark application and identification (brands and fin clips), and difficulties with sampling logistics which lead to inconsistent and biased results. However, precise estimates of migration timing and survival among juvenile salmonid populations traveling through the hydropower system and estuary would help evaluate factors affecting survival and the contribution of various enhancement activities to adult returns. In particular, timing and post-release survival of fish released from transportation barges could be compared to those for fish migrating in-river. These data would enable segregation of the effects of immediate mortality following barge-release from potential differential mortality associated with ocean entry or longer term effects on adults in the estimation of 'D' associated with transportation as called for in the 2000 and 2004 FCRPS BiOps.

In 1966, NOAA Fisheries researchers began evaluating migrational characteristics and relative survival differences between marked groups of juvenile salmonids released throughout the Columbia River Basin. Sampling was conducted in the estuary and occasionally in the nearshore ocean (Miller et al. 1983; Dawley et al. 1986; Johnsen and Sims 1973; Ledgerwood et al. 1990; Ledgerwood et al. 1991; Ledgerwood et al. 1994; Miller 1992). Purse and beach seines were selected as the primary sampling gear because of greater catch efficiency and less injury to the intercepted salmonids. Coded-wire tags (CWT) proved a useful marking technique for relative survival comparisons, compared to the uncertainty associated with poor mark application or retention using fin clip and cold brand methodologies. However, because of the large number of recoveries necessary to detect statistically significant differences among treatment groups using CWTs, it was necessary to sample as many as 367,000 fish. Concern over handling such large numbers of juvenile fish led us to seek alternative methodologies that greatly reduce impacts to fish when assessing migrational behavior and survival such as benignly detecting PIT-tagged juvenile salmonids. Detecting PIT-tagged fish in the estuary would also provide a means to evaluate juvenile salmon migrations independent of and downstream of hydroelectric facilities.

Therefore, in 1995, we began testing a PIT-tag detection system for use in the freshwater portion of the estuary. Between 1995 and 1999, we detected over 17,000 juvenile salmonids tagged with 400 kHz PIT-tags at the entrance to the Columbia River estuary at Jones Beach (RKm 75). In 2000, our electronic equipment was adapted to interrogate the 134.2 kHz PIT-tag used in the Columbia River Basin, and, through 2006, we have detected over 88,000 juvenile salmonids implanted with these tags.

In 2006, we continued evaluation of specialized pair-trawls and shoreline samplers using PIT-tag detectors for estuarine interception of PIT-tagged juvenile salmonids. Target fish were PIT-tagged juvenile spring/summer Chinook salmon *Onchorynchus tshawytscha* and steelhead *O. mykiss* released from April through early July each year to compare SARs between in-river migrating and barge-transported fish. We compared migrational behavior, timing and relative survival of fish groups transported and released downstream from Bonneville Dam with groups that migrated in-river. We provided dates of estuarine passage that allowed comparison of SARs for groups with similar ocean-entry timing and made estimates of survival for in-river migrants to below Bonneville Dam. We also provided observations on the diel behavior of juvenile salmonids in the estuary, on differences in migration timing between radio- , acoustic-, and PIT-tagged fish, and documented the presence of tagged smolts at the entrance to the estuary for use in assessing the relative vulnerability of juveniles to birds nesting in the lower estuary[1].

Our studies have suggested that the temporal distributions of transported PIT-tagged yearling fish at Jones Beach compared to in-river migrants were significantly different for fish tagged at Lower Granite Dam on the same date. We detected transport fish from each release for only a few days, whereas in-river migrants from each release at Lower Granite Dam were available for 2 to 3 weeks. We concluded that the longer, more uniform period of availability for fish released at Lower Granite Dam (in-river migrants) accounted for the increased number of detections for these fish compared to transported fish. Travel time for yearling fish to the estuary from Lower Granite Dam was correlated with available river flow. In normal flow conditions, the medians ranged from 13 to 18 days but in the low-flow drought year of 2001, the median travel time was 33 days. We also compared the daily differences in travel speed of fish to the estuary for fish released from barges or detected at Bonneville Dam and river flow. Fish

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[1]Large colonies of Caspian terns and double-crested Cormorants nest on dredge disposal and other islands located in the lower estuary downstream from Jones Beach.

released from barges generally traveled to the estuary slower than those detected at Bonneville Dam on the same date (i.e., compared with fish thought to have migrated to the estuary from Bonneville Dam under similar conditions). For example, in 2003, the median travel speed to Jones Beach for yearling Chinook salmon released from barges averaged 69 km/day compared to 87 km/day for in-river migrants detected at the dam, whereas for steelhead the median travels speeds were 81 and 88 km/day for barged and in-river migrants, respectively.

The PIT-tag detection system in our trawl operates independently from hydroelectric facilities and provides a unique opportunity to compare migration timing between fish detected or not detected at Bonneville Dam. For example, for fish released at The Dalles Dam in 1999 and 2000, the average travel times to Jones Beach for yearling Chinook salmon detected at Bonneville Dam were 6 and 9 hours longer than for those not detected at the dam, respectively; for coho salmon *O. kisutch* the travel times were 4 and 5 hours longer for detected fish in 1999 and 2000, respectively.

Daily estuarine sampling was consistent, and detections of PIT-tagged fish were sufficient during the spring to provide survival estimates for in-river migrating yearling Chinook salmon to Bonneville Dam from 1999 to 2006 and steelhead from 1998 to 2006, using a modified single-release model (Williams et al. 2001; Steven G. Smith, NOAA Fisheries, NWFSC, Seattle, WA, Pers. commun., July 2001).

In 2004, we modified a trawl by extending the floor 9.2 m forward of the foot-rope rather than 4.5 m as in previous designs. In 2005, we modified another older trawl to the same extended-floor configuration as a backup and constructed a new extended-floor trawl for use in 2006. The extended-floor design was apparently effective at decreasing the escape rate of yearling Chinook salmon from the trawl. This helped increase our detection rates of those fish previously detected at Bonneville Dam from about 2% in previous years to over 3% in 2004 and 2005 (n = 27,184 and 26,246 detections at Bonneville Dam respectively, during the date period of our 2-crew daily sample). In 2006, we detected 1.9% of the 62,716 fish previously detected at Bonneville Dam during the spring period of 2-crew sampling and this was slightly lower than desired. The lower sample efficiency was assumed to be primarily associated with the higher than average spring river flows in 2006. These gross estimates of sample efficiency are conservative in that we assume 100% survival to the estuarine sample site of fish detected at Bonneville Dam.

In 2006, we enlarged the fish passage opening of the large trawl PIT-tag detection antenna. Antennas used since 2000 had an 86-cm fish passage opening and, beginning in 2001, was configured with a 2-coil in series design (overall length 183 cm). This design provided two opportunities to decode passing fish and we believe the properly tuned antenna read over 95% of PIT-tagged fish passing from the trawl through the antenna. Improvements in PIT-tags and detection electronics within the basin in recent years prompted us to construct an enlarged 2-coil antenna for use in 2006. We also switched from older-style Whit-Paten transceivers to newer ‘multiplex’ Digital-Angle Model FS1000M (MUX) transceivers. The multiplex technology allowed for a shorter antenna design free from interference (overall length 122 cm) and use of ‘Super’ tags in the basin allowed for an enlarged fish passage opening (118 cm). Remaining within the footprint allowed by the RV *Electric Barge* for deployment and retrieval, the new antenna was more easily handled and reduced drag and a single MUX transceiver reliably recorded detections. Our standard empirical testing of the new antenna system using super PIT-tags placed at known spacing and orientations on a flexible tape measure and passed through the center of the new antenna showed equal or slightly improved detection performance over the previous system with a smaller diameter fish passage opening. The increased water volume passing through the new antenna improved its natural alignment with the trawl body and provided improved fish passage over the smaller diameter antenna. We intend to utilize the same 2-coil antenna with MUX transceivers in 2007.

Construction of much larger freshwater antenna was also theoretically possible (perhaps as large as 102-cm wide by 3-m tall, E. Prentice, June 2005, pers. commun.). In 2006, we constructed and tested a proto-type 'Matrix' antenna with a fish passage opening measuring 259-cm wide by 305-cm tall powered by a MUX transceiver. Too large for use from the Electric Barge, we adapted the wireless mobile battery-powered system mounted on a small raft as developed and used in the lower estuary in 2005 with the small trawl system (Ledgerwood et al. 2005). The antenna itself was constructed of 10-cm diameter PVC pipe using a parallel-pair of 305-cm long detection coils, each coil having an inside opening of 102 cm. Including the 15-cm gap between adjacent coils, the overall fish passage opening width was 305 cm. We tested this proto-type Matrix system attached to a small trawl for a few days in the water at Jones Beach using a charter vessel and a 26-foot NOAA vessel (*RV* Barracuda). Testing of the system will not be complete until September 2006, but it continues to look promising. The antenna is designed with a hinge to fold vertically in the center for easier handling; however, we have not as yet folded the antenna in 2006. The antenna required 111 kg of attached lead to sink it and overall weighed over 180 kg in air. Electronically, the system initially tested with good read rates in the center of each coil and in the gap, but developed unexplained electronics problems after a few days of sampling. Vibration did not appear to contribute to the electronic deterioration, and we soon developed satisfactory handling procedures. In 2007, we propose to continue testing of the Matrix system during the peak of the spring migration period and gain side-by-side evaluation of detection efficiency while supplementing our overall detection numbers. The goal is to eventually replace the RV *Electric Barge* and the required generator and AC power system computer with this magnitude larger antenna system and proven wireless mobile battery-powered system. By use of the multiplex transceivers now available, we could eventually power up to six antenna coils simultaneously without interference. This equipment would possibly allow us to chain two such large, 3-coil antenna grids together horizontally via a connecting sleeve. The resulting net would have reduced drag (by elimination of most of the trawl body), and should enable faster trawl speed without increasing impacts to fish. If adapted to operational use, this large-sized antenna grid could further increase detection efficiency (filter more water in less time) and perhaps facilitate development of a separation-by-code mechanism similar to those currently used at dams. Fish passage concerns and associated antenna handling logistics would be examined and verified in 2007, prior to making these major changes in configuration of the large trawl system in 2008. Conducting these developmental steps with a separate research system (the small trawl system) would avoid any disruption of the consistent sampling effort required by the large trawl for survival and timing estimates in 2007. By sampling intermittently in the same river reach as the large trawl system, experimental results can be compared using video observation, the hourly PIT-tag detection rate and relative species composition. The enlarged but folding antenna design and associated electronic components could potentially be utilized in on-going habitat investigations in tidal side channels of the estuary as well.

OBJECTIVES

Objective 1– Estimate survival through the Columbia River hydropower system for PIT-tagged yearling salmonids during April-June 2007 by conducting pair-trawl sampling.

In 2007, we propose to repeat previous PIT-tag detection efforts using a pair-trawl to estimate survival of major in-river migrating release groups to the tailrace of Bonneville Dam. Furthermore, if a transportation study is conducted for fish PIT-tagged on the Snake River, estuarine detection rates will be used to compare seasonal trends in relative survival of transported fish released just downstream from Bonneville Dam to those in-river migrants detected in the juvenile bypass system at Bonneville Dam. We will also collect specific migration timing information for many other PIT-tagged groups. These data will provide supplemental information on transport benefits by comparing ocean-entry timing for barged versus in-river groups, form a basis to evaluate relative effects of bird predation on PIT-tagged salmonids, enable completion of survival estimates through the entire hydropower system, provide the ability to estimate differential delayed mortality or 'D' for different transport groups and will provide the first post-release detection data on transported fish. Our goal is to detect 2% of PIT-tagged fish previously detected at Bonneville Dam.

Objective 2–Extend sampling during summer and fall for subyearling salmonids.

Evaluation of transportation of PIT-tagged subyearling Chinook salmon is a new endeavor, and little information on behavior and timing for these fish following release is available.

Sampling in mid-river at Jones Beach during late June and July in 2002, 2004, 2005, and 2006 indicated that detection rates of subyearling salmonids were adequate to determine timing and behavioral differences with a single sampling crew. In those previous sampling efforts, numbers of detections declined in mid- to late-July and increased with cooler water temperatures during September and October. We will match our sampling effort to this migration timing associated with numbers of PIT-tagged fish entering the estuary as indicated by detections at Lower Granite and Bonneville Dams and our detections. If indicated by decreased numbers, we may elect to interrupt sampling for a few weeks during late July and August and resume in September (as in 2006). We will also sample intermittently to estimate the proportion of subyearling migrants traveling along the shoreline at Jones Beach during these periods. Our goal is to detect 0.75% of the fish previously detected at Bonneville Dam. Sampling with the shoreline sampler coincidental with the peak in mid-river passage will be used to evaluate migration in shallower waters of the estuary and residency of Snake River subyearling Chinook salmon in these areas. We also intend to conduct intermittent sampling activities from mid-March to mid-April. This sampling is essential to document the early season migration of subyearling Chinook salmon thought to reside in the Columbia River Basin. These early migrants possibly include a portion of PIT-tagged fish that had been transported from collector dams during the summer of 2006 as subyearling fish. Their subsequent detection in the estuary would provide positive evidence that at least a portion of those transported fish over-winter downstream from Bonneville Dam and migrate to sea the following year.

Objective 3– Test and sample with new larger antennas and related equipment intermittently using a proto-type experimental system in the upper estuary in 2007.

During the peak of the yearling salmonid migration season, an experimental pair-trawl system will be deployed for about 30 test days to evaluate the feasibility and efficiency of a large multiplex antenna system. As part of these developmental efforts, we will consider the design and logistical requirements for a separation-by-code mechanism for diverting detected PIT-tagged fish of known migration history or treatment into a “live capture” holding container. Detections with this system will supplement fish numbers needed to accomplish Objective 1.

METHODS

Sampling for run-of-river fish will be conducted from as early as mid-March through June (yearling migrants) and continue in summer and fall (subyearling migrants) 2007. The duration of research will depend on the presence of PIT-tagged fish from the studies mentioned above and possibly other major release groups of PIT-tagged fish. To observe the behavior of fish as they move through the nets and PIT-tag detector tunnels, we will continue to use underwater video cameras and divers as available to evaluate fish and net interactions. Bi-weekly reports of preliminary research results will be provided to interested parties, and raw detection data will be available through the Columbia Basin PIT-tag Information System (PTAGIS) database (recovery site code is TWX--towed array experimental, large trawl).

Trawl Designs

Large Pair-Trawl Detection System

We will utilize a surface pair-trawl similar to those used in previous years (Ledgerwood et al. 2004; Ledgerwood et al. 2003; Ledgerwood et al. 1997). The operational procedures include towing the surface pair-trawl upstream with the wings open while juvenile salmonids pass downstream into the trawl and exit through the detector tunnels. PIT-tag decoding is accomplished electronically and requires no handling or removal of juvenile salmon from the net.

The pair-trawl consists of a 91.5-m wing attached to each side of the 14-m body of the trawl containing the PIT-tag detector located where the cod end is normally positioned. Two vessels are used for towing, thus the name pair-trawl. We will use the 118-cm diameter, two-coil PIT-tag antenna powered by a multiplex Digital-Angel transceiver as used in 2006. A GPS position will be recorded every 15 minutes and for each detection as in previous years.

Matrix Pair-Trawl Detection System

In 2006, we modified the small surface pair-trawl used previously in the lower river to fit the outside dimension of a proto-type 'Matrix' antenna (fish passage opening 259-cm wide by 305-cm deep). The body of this trawl extends ahead of the antenna about 8.1 m to the 4.9 m square entrance and is constructed of 1.8 cm (small) mesh. A 6.2-m-long floor of small mesh extends forward of the footrope. Wings are of two sections, the first 20.6-m section of small mesh and a second 15.2-m section of slightly larger mesh (3.8-cm stretch, same mesh as in the distal end of the large trawl wings). We will nearly continuously monitor fish passage using the established wireless video and data collection equipment.

Shoreline Sampler

In 2006, we continued use and development of a PIT-tag detection system for deployment in a fixed location along the shoreline at Jones Beach. Our shoreline system consisted of a wing leading from one side of a small trawl body to shore (tapered in depth from 2.4 to 1.2 m). A second 2.4-m-deep by 15-m-long wing was attached on the river-side to a 2.4-m-long pipe to keep the wing fully extended vertically in the water column. The pipe was floated by a buoy similar to our other trawls and a bridle-line from the pipe was attached via a 15-m-long line to another buoy from a permanent anchor system. The anchor was positioned such that, when in sampling position, the antenna was suspended in about 3-m of water. The oblong roughly 0.6-m by 1.8-m PVC antenna was supported on a buoy similar to that of our other trawls. Generally, we deployed the device near high tide and sampled the ebb current. Current velocities varied from 0 to 0.5 m/second. A video camera mounted within the antenna transmits a picture to a shore-side monitor allowing operators to view fish passage in real time (same system as used with the Matrix system). Using a line from the tip of the wing to shore, we developed a method similar to our pair-trawling procedure to “flush” the net for cleaning and to encourage fish to exit downstream through the antenna. We will again deploy the shoreline system, intermittently during the yearling and subyearling Chinook salmon migrations in 2007.

Detector Design and Efficiency

From 2000 to 2005, we used 86-cm diameter PIT-tag detector antenna coils. A single-coil antenna was used in 2000, and a two-coil front to back antenna 2-m-long through 2005. In 2006, we used a larger diameter (118-cm) but shorter (1.2 m) 2-coil antenna system. We will use the same antenna system with a Digital-Angel Mux transceiver system in 2007. We devised a test procedure to verify detector performance by positioning a 2.5-cm PVC pipe through the exact center of the antenna and passing a series of PIT-tags attached to a vinyl tape measure through the pipe. On each end of the PVC pipe, we used a plastic funnel to guide the tags smoothly into the pipe, (i.e.,“funnel tests”). There were 50 PIT-tags positioned along the test tape at various densities (lengths) and orientations (in-line with the coils or at 45 degree angles). The tape was designed such that not all tags could be read. Generally, high density (0.3 m spacing) and poorly oriented tags (45 degrees to the coils) would disappear from the data records when the electronic systems were not working properly. We tested each antenna about once a week by passing the tape through the antenna six times (300 tags). Through 2003 using ‘conventional’ 134.2 KHz tags the large two-coil antenna read about 70% of the test. In 2004 and 2005, using ‘Super tags’ the large trawl read about 80% of the test tags. In 2006, using Super Tags and a larger diameter antenna with MUX transceivers we again read about 80% of the test tags. Since the funnel-pipe was positioned in the center of the antennas, the procedure was conservative in that most fish pass closer to the antenna walls where read rates are higher. When the test funnel was mounted within 20-cm of the antenna wall, 98% of the same test tags were decoded. We believe that *in situ*, over 95% of all PIT-tagged fish passing through the 2-coil antenna system were detected in 2006. In 2007, we propose to continue “funnel tests” on a weekly basis or more frequently if needed to verify electronic system and detector performances. Similar testing will be used to validate performance of experimental proto-type antennas and the shoreline sampler equipment.

Detection Rates

In 1996, a relatively high flow year (flood conditions at Jones Beach), detection rates for 400 kHz PIT-tagged fish using the detector/trawl were 0.64% for in-river migrants previously detected at Bonneville Dam. This detection efficiency was similar to that attained at Jones Beach using a purse seine (Ledgerwood et al. 1994). In 1998, 1999 (400 kHz), and 2000-2003 (134.2 kHz PIT tags), we improved our detection efficiency by sampling 7 instead of 5 days per week and by extending our sampling effort using two daily sampling crews during the peak of the yearling salmonid migration each season. During the extended sampling periods, we detected over 2% of the in-river migrant salmonids previously detected at Bonneville Dam.

Since 2004, we increased the detection rate of yearling Chinook salmon by about 30% through use of a trawl with an extended floor (double previous floor length). We expect to again sample about 2 to 3% of the available PIT-tagged fish during the peak of the yearling Chinook salmon migration (April-June). During the sub-yearling Chinook salmon migration period, using a single crew four to six days per week, but with lower river flows, we expect to detect about 0.75% of the available PIT-tagged fish. Net cleaning and maintenance, river conditions, personnel, vessel considerations and PIT-tag-detector operation should be the only impediments to continuous operation of the PIT-tag detector equipped pair-trawl.

Efforts to refine the net configuration, antennae and operational procedures to increase detection percentages and stimulate rapid passage through the net and detector systems, will continue. To do this without compromising the detection efficiency of the large trawl system, we will utilize the equipment developed for use in the lower estuary. We will test the antenna at sizes and configurations that will push the technology further. As the new equipment and procedures developed prove reliable, safe, and demonstrate low impacts on fish, we will modify the large trawl system accordingly.

Physical Impacts to Intercepted Fish

Passage of intercepted fish through the net and detector tunnel will be visually assessed using video cameras, and we will periodically use divers (as available) to assess net configuration and impacts to fish in areas not readily monitored by cameras. In addition, we will occasionally inspect areas of the net using a video camera mounted on a pole and adjust operations as needed. For example, when debris accumulations or other problems are observed, we reduce tow speed and pull the detection antenna to the surface to access the cod end of the net. When necessary, we disconnect the electronics and invert the entire net to clear debris.

SCHEDULE

In 2007, we propose to sample PIT-tagged juvenile salmon beginning in March and continue into the fall, with a period of no sampling during the high water temperature and low detection period in mid summer. At the beginning and end of the yearling salmonid migration, and throughout the subyearling Chinook migration, a single crew will sample 3 to 6 days/week, depending on PIT-tagged fish abundance. During the peak of the yearling salmonid migration, mid-April to mid-June, we will utilize two daily sampling crews, 7 days/week. During this period of intensive sampling, catches are sufficient to enable calculations of survival probabilities for yearling Chinook salmon and steelhead to Bonneville Dam for in-river migrants and provide relative survival comparisons to the estuary among transported fish and in-river migrants detected at Bonneville Dam.

Beginning in 2003, we emphasized sampling at dawn and dusk (typical periods of increased detection rates) by running our evening shift through the night until relieved by a morning shift while leaving the trawl deployed. The period of decreased daily sampling was generally from about 1400 to 1700 hours, a period characterized by high winds and difficult sampling conditions. We propose to repeat this strategy in 2007. Also, we propose to sample intermittently with a shoreline sampler with an emphasis on monitoring yearling (mid-March to mid-April) and subyearling Snake River Chinook salmon.

An experimental pair-trawl system with a magnitude larger ‘Matrix’ antenna system will also be used during the peak of the yearling migration period for a total of about 30 days to test handling logistics and performance of new large multiplex antenna designs. We will attempt periods of simultaneous sampling in close proximity with the standard pair-trawl system. Data collected with the Matrix system will supplement data used in the above mentioned survival calculations.

FACILITIES AND EQUIPMENT

Facilities are located at the NOAA Fisheries Point Adams Field Station at Hammond, OR and at Jones Beach near Clatskanie, OR. Vessels are moored at Kerry West Marina near Westport, OR. We switched from older-style Whit-Paten transceivers to newer ‘multiplex’ Digital-Angle Model FS1000M (MUX) transceivers in 2006 and will continue their use in 2007. We will power the large-trawl antenna system using a 24-volt DC powered transceiver. The system operates using redundant battery bank recharged using a gas powered AC generator system which also powers the recording computers and video system. The multiplex transceiver makes it possible to operate up to six detection coils simultaneously (we use two). Backup units will be utilized when testing with the large matrix proto-type antenna and with the shoreline sampler system.

A new large trawl with an extended floor was constructed in 2003, and we extended the floor of our 1999 net in 2005. A new trawl was constructed and used extensively in 2006. The older trawls have many hours and many repairs so we again propose to construct a replacement trawl in 2007.

The 4.9-m square trawl (dimension at the entrance to the trawl body) used in the lower estuary in 2005 was modified to test the multiplex antenna grid in 2006 and we will utilize that trawl again in 2007. If these operations prove satisfactory, we may also modify our 1995 full-sized trawl (older style with a short floor) and test deployment from a larger tow vessel. A 2.4-m square shoreline sampler and associated equipment is available from previous years. NOAA Fisheries will provide towing and support vessels for the large trawl system and most vessels for the shoreline and Matrix systems. We will again charter a 10-m stern reeling gill-net vessel to deploy/retrieve the Matrix net and antenna.

DATA ANALYSIS AND STATISTICS

PIT-tag interrogations of run-of-the-river yearling Chinook salmon and steelhead from various studies throughout the Columbia River Basin will constitute the primary sources of PIT-tagged fish. Secondary sources will include PIT-tagged fish previously detected at Bonneville Dam and PIT-tagged fish diverted at upstream collector dams to transportation barges and released downstream of Bonneville Dam. Also, we will compare the detection patterns of PIT-, radio- and acoustic- tagged fish released from transportation barges with those from radio- or acoustic-tagged run-of-the-river fish released at Bonneville Dam. If sufficient numbers of in-river migrating fish are detected, we will also evaluate detection rates associated with passage through multiple bypass systems.

Diel-catch patterns (number of fish detected per hour during daylight compared to dark hours) of yearling Chinook salmon and steelhead are evaluated using one-way ANOVA (Zar 1999). The number of detections and the minutes within each hour that the detector was energized each day are separated into daylight- and darkness-hour categories, and mean hourly detection rates for wild and hatchery rearing types of each species are used as the source for the ANOVA. Diel detection curves are generally prepared for yearling Chinook salmon and steelhead based on the average number of fish detected each hour weighted by the minutes within each hour that the detectors were energized. For the other species, the numbers detected are generally too few for meaningful analyses.

Multiple linear regression will be used to evaluate differences in travel speed to Jones Beach between in-river migrants and transported fish. Factors used in the regression models of travel speed included Julian date, flow, "treatment" (in-river migrant vs. transported), and two-way interaction terms for the three main effects. Flow data will be daily average discharge rates at Bonneville Dam (ft^3 sec^{-1}).

Binary logistical regression analyses will be used to compare daily detection rates among in-river migrants previously detected at Bonneville Dam to those released from transportation barges on the same dates as detection at Bonneville Dam. The daily groupings are treated as "cohorts" in the analysis (Hosmer and Lemeshow 2001). The daily in-river groups will be paired to barged-released fish on date of barge-release and selected to include only those PIT-tagged fish released at sites from McNary Dam upstream. Components of the logistic regression model are treatment as a factor and date as a covariate. The model estimates the log odds of the detection rate of the daily cohorts (i.e., $\ln[p/(1-p)]$) as a linear function of the components, assuming a binomial distribution for the errors.

Detection data from the estuary are essential to estimate survival of juvenile salmonids to Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001, Williams et al. 2001, Zabel et al. 2001). The probability of survival through an individual reach of river is estimated from PIT-tag-detection data using a multiple-recapture model for single release groups (Cormack 1964, Seber 1965, Skalski et al. 1998). Seasonal average survival probabilities are estimated for yearling Chinook salmon and steelhead migrating in-river from the Snake and mid-Columbia Rivers (dependant on release numbers). Estimates are obtained using component reach survival probabilities for migration from Lower Granite Dam reservoir to McNary Dam and from McNary Dam to Bonneville Dam (Iwamoto et al. 1994, Williams et al. 2001). PIT-tag detection data from the estuary provided a minor contribution to estimates of survival probability from Lower Granite to McNary Dam. However, they were essential to estimates of survival to Bonneville Dam from any upstream release site.

EXPECTED RESULTS AND APPLICABILITY

It is important to assess fish migrational behavior and reach survival with the PIT-tag detector/trawl using a multi-year research approach to incorporate flow and the environmental variability into the analyses. The need for a multi-year repetition was demonstrated in 2001 and again in 2004, when, based upon preliminary analyses, low-flow conditions appeared to dramatically change migrational timing and survival for in-river and transport groups. Application of 134.2 kHz PIT-tag equipment has improved reliability and increased tag read ranges, particularly with the advent of ‘Super’ tags. Larger diameter antennas have lessened impacts to fish. Migration timing data from PIT-, radio- and acoustic-tagged fish allow comparison of these methodologies. Information gained on timing of PIT-tagged fish from various locations within the watershed to the estuary and the variability in timing between different groups, will help managers define future release strategies. These analyses now include data on transported fish, an addition that is essential to access recovery efforts for depressed salmonid stocks in the Columbia River Basin.

Little is understood regarding the behavior, utilization, and distribution of Snake River subyearling Chinook salmon. These are ESA-listed fish generally presumed to migrate to sea during the summer. Recent evidence suggests that a large portion of the adults returning to Lower Granite Dam entered the ocean as yearlings. Further, scale sample analyses of adults returning from the 2002 tagging study indicated that some adults that had been transported to downstream from Bonneville Dam as subyearlings delayed presumably in the lower river and entered the ocean as yearlings the following spring (D. Marsh, NMFS, NWFSC, Seattle, WA, pers. commun., June 2006). Currently hydropower operations are being legally challenged, but in recent years have included the use of transportation without spill to maximize SARs. In 2005, a judicial decision mandated spill and fewer fish were transported. An evaluation using PIT-tagged fish comparing transport to bypass and spill options for Snake River subyearling Chinook salmon is under consideration, and some PIT-tagged fish were released in 2005 and 2006. It is possible that a portion of these subyearling migrants over-wintered downstream of Bonneville Dam, perhaps even in the upper or lower estuary. Detections of PIT-tagged fish in the estuary during early spring, summer, and perhaps into the fall would help identify and correctly characterize their life history patterns.

COLLABORATIVE ARRANGEMENTS

Collaboration with Oregon State University, U.S. Fish and Wildlife Service, and other researchers involved with the radio- and acoustic-tracking studies in the Columbia River will continue. PIT-tag interrogation data from the Jones Beach sampling efforts (site code TWX) will be uploaded in batches to the PTAGIS database thus providing regional access to estuarine passage of PIT-tagged fish. PIT-tag detector/trawl interrogation data will be used by NOAA Fisheries and other researchers to assess differential predation on juvenile salmonids by Caspian terns and double-crested cormorants. When practical, we would again attempt to collaborate with NOAA Fisheries researchers and use beach seine captured fish at Jones Beach to evaluate the efficiency and impacts of the shoreline sampler.

KEY PERSONNEL

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REFERENCES

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429-438.

Dawley, E.M., R.D. Ledgerwood, and A.L. Jensen. 1985. Beach and purse seine sampling of juvenile salmonids in the Columbia River estuary and ocean plume, 1977-1983, Volume 1: procedures, sampling effort and catch data. NOAA Tech Memo NMFS F/NWC-74. 260p.

Dawley, E. M., R. D. Ledgerwood, T. H. Blahm, C. W. Sims, J. T. Durkin, R. A. Kirn, A. E. Rankis, G. E. Monan, and F. J. Ossiander. 1986. Migrational characteristics, biological observations, and relative survival of juvenile salmonids entering the Columbia River estuary, 1966-1983. Final report to Bonneville Power Administration, Contract DE-A179-84BP39652, 256 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Hosmer, D. W., and S. Lemeshow 2001. Applied Logistic Regression. 2nd Edition. Wiley, New York.

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R AI79-93BP10891, 126 p plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Johnsen, R. C. and C. W. Sims. 1973. Purse seining for juvenile salmon and trout in the Columbia River estuary. Trans. Am. Fish. Soc. 102(2):341-345.

Ledgerwood R. D., B. A. Ryan, E. M. Dawley, E. P. Nunnallee, and J. W. Ferguson. 2004. A surface trawl to detect migrating juvenile salmonids tagged with passive integrated Transponder Tags. NAJFM 24:440–451.

Ledgerwood, R. D., B. A. Ryan, C. Z. Banks, E. P. Nunnallee, B. P. Sanford, S.G. Smith, and J. W. Ferguson. W68SBV80622741, 84 p. plus appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, B. W. Peterson, and R. N. Iwamoto. 1997. Estuarine recovery of PIT-tagged juvenile salmonids from the Lower Granite Dam Transportation Study, 1996. Report to the U.S. Army Corps of Engineers, Contract Delivery Order E8960100, 54 p. + Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sandford, and

M. H. Schiewe. 1990. Relative survival of subyearling chinook salmon which have passed Bonneville Dam via the spillway or the Second Powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. Report to the U.S. Army Corps of Engineers, Contract E85890024/E86890097, 64 p. + Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, L. T. Parker, B. P. Sandford, and S. J. Grabowski. 1994. Relative survival of subyearling chinook salmon after passage through the bypass system at the First Powerhouse or a turbine at the First or Second Powerhouse and through the tailrace basins at Bonneville Dam, 1992. Report to the U.S. Army Corps of Engineers, Contract DACW57-85-H-0001, 53 p. + Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R.D., Thrower, F.P., and E.M. Dawley. 1991. Diel sampling of migratory juvenile salmonids in the Columbia River estuary. Fishery Bulletin, U. S. 89:69-78.

Miller, D. R. 1992. Distribution, abundance, and food of juvenile chinook salmon in the nearshore ocean adjacent to the Columbia River. Workshop on the growth, distribution, and mortality of juvenile pacific salmon in coastal waters. p. 1-33. Sidney, British Columbia, Oct. 17-18 1992. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Miller, D. R., J. G. Williams, and C. W. Sims. 1983. Distribution, abundance, and growth of juvenile salmonids off the coast of Oregon and Washington, summer 1980. Fish. Res. 2:1-17.

Muir, W. D., S. G. Smith, J. G. Williams, E. E. Hockersmith, and J. R. Skalski. 2001. Survival estimates for migrant yearling chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia Rivers, 1993-1998. N. Am. J. Fish. Manage. 21:269-282.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Skalski, J. R. S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia Rivers. Can. J. Fish. and Aquat. Sci. 55:1484-1493.

Williams, J. G., S. G. Smith, W. D. Muir. 2001. Survival estimates for downstream migrant yearling juvenile salmonids through the Snake and Columbia Rivers hydropower system, 1966 to 1980 and 1993 to 1999. N. Am. J. Fish. Manage. 21:310-317, 2001.

Zabel, R. W., S. G. Smith, W. D. Muir, D. M. Marsh, J. G. Williams. 2001. Survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia

River dams and reservoirs, 2001. Report of the National Marine Fisheries Service to the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Zar, J. H. 1999. Biostatistical analysis, 4th edition. Prentice Hall, Upper Saddle River, New Jersey.