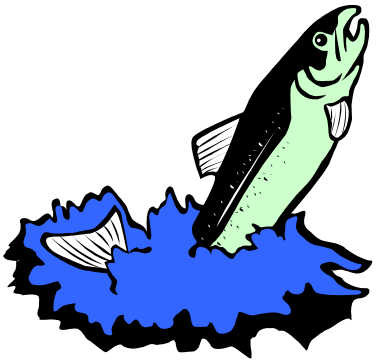
Evaluate Post-Release Losses and Barging Strategies that Minimize Post-Release Mortality



2005 DRAFT PROPOSAL

OREGON STATE UNIVERSITY
DEPARTMENT OF FISHERIES & WILDLIFE

OREGON COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

USGS
science for a changing world

DRAFT PROPOSAL
2005 Project Year

I. BASIC INFORMATION

A. TITLES: Evaluate Post-Release Losses and Barging Strategies that Minimize Post-Release Mortality

B. PROJECT LEADER:

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STUDY CODE: TPE-W-00-2

C. ANTICIPATED DURATION: 2005-2006

D. SUBMISSION DATE: July 27, 2004

GOAL

The goal of this study is to improve adult returns of transported juvenile salmonids in the Columbia River system. Specifically, the aim of this study is to determine if alternative transportation release locations will maximize the number of juvenile salmon reaching the ocean. High mortality rates (up to 47%), resulting from piscivorous birds, have been documented in the lower estuary and appear to be the result of specific migration paths and residence times of juvenile salmon in the lower estuary. We propose to test specific transportation release strategies designed to optimize migration routes through the lower estuary. These migration routes could increase successful marine recruitment of post-release juvenile salmon.

To achieve this goal we propose to investigate the spatial and temporal behavior, and its relation to the survival of transported juvenile salmon in the estuary and near shore ocean environment. Such information, when combined with knowledge of how the physical environment (flow, tides) of the estuary influences migration routes and speeds will enable managers to more adaptively manage releases of barged fish to minimize delayed mortality. These results will also enable managers to isolate sources or regions of mortality for future decisions or study.

USACOE OBJECTIVES

The wording for these objectives was taken directly from the USACOE one-pager.

TPE-W-00-2

<u>Objective 1.</u> Evaluate post-release survival, behavior, migration characteristics, and habitat use of juvenile salmon through the estuary, plume, and near shore environment. Identify potential trouble areas (delays and losses) and correlate to route of passage, stocks, seasons, and species. Recommend improvements in barge release locations (2004).

Tasks:

a. Obtain one year of spring Chinook data.
b. Confirm passage routes for proposed release sites.

<u>Objective 2.</u> Prepare logistics for an alternate barge release location (2005).

<u>Objective 3.</u> Evaluate barging strategies to reduce mortality (pending the result of the steelhead and fall Chinook post-release objectives). (2006-2009).

Tasks:

a. Determine SAR of smolts transported and released downstream from the current release point, possibly near the saltwater interface.
b. Develop and compare transportation strategies to increase seasonal survival.
c. Evaluate post-release migration behavior, ocean entry timing, and timing to the tidal cycle.

OCFWRU OPERATIONAL OBJECTIVES

The following objectives were reworded from those of the USACOE listed for TPE-W-00-2 above.

A number of the proposed USACOE transportation research studies are interlinked. We have assimilated several of these study objectives and tasks into TPE-W-00-2 (see Table 1) so that by careful design, our proposed work would meet our objectives and address those of other proposals at no additional cost.

TPE-W-00-2

<u>Objective 1.</u> Conduct analysis on data collected between 1996-2004 to determine how barging strategies could be modified to improve post-release survival of juvenile salmonids. Provide an extensive report of all work conducted between 1996-2004, including alternatives to the current release strategies. Recommend improvements in barge release strategies.

Tasks:

a. Assess data to deduce optimum release sites and times relative to diurnal and tidal cycles.

<u>Objective 2.</u> Perform a preliminary assessment of the effects of alternative release strategies (designed to reduce mortality) on the post-release survival, behavior, migration characteristics, and habitat use of juvenile salmon through the estuary, plume, and near shore environment (modify as necessary, based upon objective 1). Identify potential trouble areas (delays and losses) and recommend further improvements in barge release strategies.

Tasks:

a. Develop and compare transportation strategies to increase seasonal survival.

b. Using experimental transportation strategies (i.e., trucking), compare the effects of release location and timing to migration characteristics, survivability, and successful ocean entry throughout the season.

c. Determine if migration characteristics, survivability, and successful ocean entry are different between traditional truck releases and traditional barge releases below Bonneville Dam to provide quality assurance of using trucks as a "simulated barge".

d. Assess quality differences in juvenile salmon relative to successful estuarine performance and ocean survival.

e. Characterize hydrological variations in the Columbia River estuary and near shore ocean environment during juvenile salmon emigration from the estuary.

f. Correlate delays and mortalities with migration routes, release site, fish performance capacity, species, stocks, seasons, and hydrological conditions in the estuary and near shore ocean.

Objective 3. Prepare logistics for an alternate barge release location.

Tasks:

a. Propose release sites and barge strategies for evaluation in 2006.

b. Prepare comparable trials for juvenile salmon species/strains not analyzed in 2005.

Table 1. Listing of objectives and tasks of the USACOE transportation program that are germane to TPE-W-00-2. Several objectives and tasks in other proposed studies address the same questions.

OCFWRU Objectives TPE-W-00-2	OCFWRU Tasks TPE-W-00-2	Objectives and tasks of USACOE projects by other agencies
1	---	N/A
1	a	N/A
2	---	**EST-02-03, objective 2**: Characterize variations in physical conditions in the Columbia River estuary and near shore ocean environment.
2	---	**TPE-W-00-2004, objective 4**: Analyze variables leading to management decisions including seasonality of transport benefits, effects of river environment, project operations, and ocean environment.
2	---	**RPA 47, objective 4**: Evaluate the effects of current and proposed barging strategies (seasonal transportation, release location and timing) on post-release survival. Utilize information related to physiological condition of fish and the operational processes that result in the release of fish downstream of Bonneville at the optimal time and location for the highest survival.
2	---	**BPS-00-10, objective 2**: Investigate causes of delayed mortality (by species, stock, and origin).

Table 1. (Continued).

OCFWRU Objectives TPE-W-00-2	OCFWRU Tasks TPE-W-00-2	Objectives and tasks of USACOE projects by other agencies
2	---	**BPS-00-10, objective 3**: Isolate areas of post-system loss.
2	---	**TPE-W-04-1, objective 2**: Evaluate factors that may contribute to differences in SAR of early season transported juvenile salmonids.
2	---	**TPE-W-04-06, objective 1**: Determine the physiological disposition of fish during the juvenile fish migration season at transportation projects (Lower Granite and McNary Dams) to determine the relationship to the lower than expected early season transportation returns.
2	a	N/A
2	b, c	**BPS-00-10, objective 2, task b**: Evaluate behavioral changes in juvenile salmon attributed to route of passage that may be a cause of mortality.
2	b, c	**BPS-00-10, objective 2, task c**: Determine if fish with different passage histories have a different response to hydraulic stimulus.
2	b, c	**BPS-00-10, objective 2, task e**: Evaluate the logistical and mechanical barging processes that may be contributing to delayed mortality (such as release location, season, duration, and timing).
2	b, c	**TPE-W-04-1, objective 2, task a**: Evaluate timing of early spring migrants to the estuary.
2	d	**TPE-W-04-06, objective 1, task a**: Examine immunology, presence of BKD infections, smoltification levels, and fish condition of fish at transportation projects.
2	d	**TPE-W-04-06, objective 2, task a.i.**: Examine impacts to fish condition, including mechanical injuries.
2	d	**EST-02-03, objective 3**: Determine the level of physiological development and disease status of smolts at release.
2	d	**BPS-00-10, objective 2, task a**: Isolate physiological causes of delayed mortality.
2	e	**BPS-00-10, task c**: Determine if fish with different passage histories have a different response to hydraulic stimulus.
2	e	**EST-02-03, objective 2**: Characterize variations in the physical and biological conditions in the Columbia River estuary and near shore ocean environment.
2	f	**TPE-W-04-1, objective 2**: Evaluate factors that may contribute to differences in SAR of early season transported juvenile salmonids.
3	---	N/A
3	a	N/A
3	b	N/A

INTRODUCTION

The success of transportation, judged as the survival or successful recruitment of juvenile salmon to the ocean, depends not only on the state of fish before they are transported and conditions within the barges, but also on the performance of fish following release (Schreck *et al.,* 2002 & 2003; Congleton *et al.*, 2000). Based on our previous work it appears that post-release survival is largely dictated by the interaction between the fish and the environment in the lower river and estuary (Schreck *et al.,* 2002 & 2003). Our work, in collaboration with the Oregon Graduate Institute (OGI) has shown that fish appear to act passively in the estuary, responding to velocity fields set up by river flow (influenced largely by Bonneville discharge) and the tides. We have also shown, for steelhead, that both migration route and proximity to avian predators during the day influences survival (Schreck *et al.,* 2002 & 2003). Given that the physical environment of the estuary can be modeled and fish respond readily to this environment, the opportunity exists to manage the release of fish from experimental transportation trucks to optimize migration routes through the estuary during the most favorable periods of the day. Based on data from steelhead, it is conceivable that nearly one half of the fish released below Bonneville Dam never successfully migrate to the ocean (Schreck *et al.,* 2002 & 2003). Even a small increase in survivorship in this reach could lead to significant increases in adult returns. We are proposing specific release strategies to minimize the predation risk between Bonneville and the near shore ocean. Such scenarios would allow for adaptive management of transported juvenile salmon. At present, no basis exists for decisions related to enhancing the survival of transported juvenile salmon.

In order to understand the effects of tidal and river flow conditions on these fish once they reach the estuary, we propose to use radio and acoustic telemetry to assess migratory behavior and predation rates through the estuary and near shore ocean. In previous years (Schreck *et al.,* 2002 & 2003) we have observed that travel time of migrants through the lower Columbia River is influenced by river discharge and velocity. River discharge may also affect the relative influence and location of salinity gradients associated with tides, influencing smolt migration routes and passage rate through the estuary. Observations in 2001-2002 indicated that tides were affecting migrations as far upriver as Longview, WA. Ultimately, the goal of this research is to increase the post-release survival of transported juvenile salmonids migrating through the Columbia River estuary. Increasing post-release survival of transported juvenile salmon could translate to increased SARs.

Data from 2001-2003 shows considerable seasonal variation in the relative benefit of barging (which may relate to fish quality at loading) and even differences in survival between consecutive days in 2003 (that may relate to tidal and/or diel effects in the estuary) (Figure 1).

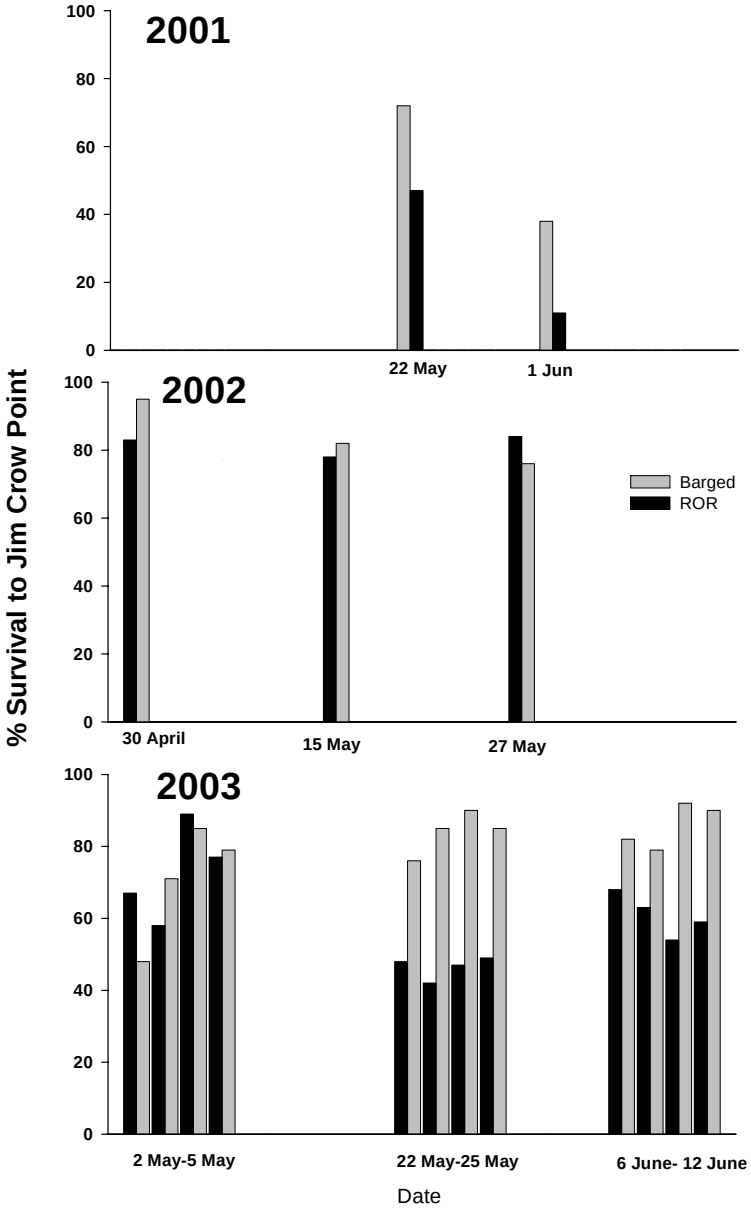


Figure 1. Survival of fish between release at Bonneville Dam and Jim Crow Point (Rkm 46.7) for 2001, 2002, and 2003. Barged fish were implanted with transmitters at Lower Granite Dam and transported below Bonneville. ROR fish were collected and implanted at Bonneville Dam and released coincident with the Barged fish. This data includes acoustic telemetry data from 2001-2003 and radio telemetry data from 2003. For 2003, the first four bars within each period are data from fish with acoustic tags, while the second four bars are data from fish implanted with radio tags. The number of tagged fish varied between years (2001-2002: 40-50/bar; 2003: 40-100/bar). Data for 2003 are preliminary until final analysis is complete; 2004 data are currently being analyzed.

Our research indicates a large percentage of radio-tagged steelhead (up to 47%) and spring Chinook (up to 30%) were taken by piscivorous birds in the Columbia River estuary (Schreck *et al.*, 1996; Schreck *et al.,* 2002 & 2003)

(estimates from PIT tagged spring Chinook are similar — Collis *et al.*, 2001). Data collected in 2001-2003 suggests a high rate for fall Chinook as well (see also Collis *et al.*, 2000), therefore the total number of Columbia River smolts taken by birds near the mouth of the river may have important impacts on outmigrating populations. It is currently unknown what percentage of juvenile salmonids are taken by other seabirds such as murres. It is also not known what factors determine the vulnerability of migrating juvenile salmonids to bird predators, although fish behavior in the estuary clearly has the potential to increase or decrease the likelihood of being eaten. For example, those individuals who swim higher in the water column, or linger in areas containing many birds, may have a higher risk. A number of factors relating to smoltification and stress have been shown to influence the migration behavior of juvenile salmonids, and by extension, survival (Price and Schreck, 2003; McCormick *et al.*, 2000; Whalen *et al.*, 1999; Dickhoff *et al.*, 1995; Jarvi, 1989).

The location of avian predator colonies, which is currently being studied for management possibilities to decrease smolt predation, may affect predation rates on outmigrating smolts; the effects of any management decisions regarding avian predators on smolts should therefore be studied (Collis *et al.*, 2002). Our data suggest that most smolts use one of three channels, one of which puts them in close proximity to bird colonies at East Sand Island. Future decisions to dredge and relocate spoils may alter the availability or quality of fish migration routes and location of bird colonies. Therefore, a better understanding of the spatial dimensions of bird predation on smolts is warranted. We propose to continue monitoring bird colonies and to link dead tagged fish with their previous migration pattern or release site in the estuary, based on active tracking via boats and fixed radio station sites established in 2002 and 2003.

We are only beginning to understand the behavior of juvenile salmon in saltwater. At present, the only method of tracking juvenile salmonids in saltwater (the area of interest), given their size (thus limiting the size of the telemetry "tag") is with acoustic tags. In the past, this was not feasible because the range of these tags was limited and no systems were developed that could cover an area as large as the near shore ocean of the Columbia River. However, with recent technological advancements, these systems (termed "buoy arrays" herein) exist at an affordable level. They have been successfully used for similar purposes in very large areas (Thorstad *et al*., 1999), such as the Bay of Fundy (much larger than the Columbia estuary and near-shore area; Voegeli and Lacroix, 1999) and Norwegian fjords (Thorstad *et al*., 1998), to study seawater entrance and oceanic migration of Atlantic salmon smolts. Similar technology is being used by our Canadian counterparts (Dr. David Welch, Kintama Research Corp.) along Washington and British Columbia[1].

We have utilized the same technology successfully in the lower Columbia River estuary and near shore ocean during 2001-2004. Our research on juvenile steelhead migrants suggests that the majority of mortalities occur within the lower

regions of the estuary (Clements et al. Submitted, Schreck *et al.*, 2002 & 2003). Our data from 2002 and 2003 suggest that migration route has a significant effect on survival (Schreck *et al.*, 2002 & 2003). The acoustic tags that are now available are small enough so as not to impair normal migrating behavior (Moore *et al*., 1990; Martinelli *et al*., 1998) or survival (Jepsen *et al*., 1998) of small Chinook smolts. Both buoy arrays and tags are reasonable in cost.

Once a relationship is established between fish migratory behavior, survival, and the influence of the physical environment on migration behavior the opportunity exists to manage the transportation of juvenile salmonids through the Columbia Basin hydropower system in such a way that their subsequent survival is maximized.

GENERAL METHODS

2005:

TPE-W-00-2

Objective 2.

Task b: Radio and acoustic telemetry will be used to assess downstream travel time, migratory behavior at the freshwater/saltwater interface, movement within tidal phases, and survival through the estuary and near shore ocean of hatchery juvenile salmon throughout the season. We will compare the migration characteristics of juvenile salmonids transported past Snake-Columbia River dams, by either experimental truck (release at locations and times deemed to be optimal for survival through the estuary) or by barge at the current release site.

Task c: Similar to task b, although comparisons between traditional truck release strategies and barge releases strategies will be made. Comparing trucked fish released below Bonneville to barged fish released at the same location will allow standardization of influences of transportation medium.

Tasks d: Assess quality of fish in the various test groups to determine if fish performance capacity is related to successful saltwater entry. Bioassays of smoltification status will be conducted at the collection site (Lower Granite Dam), during release at the current barge site, and during release at the Astoria Bridge site in the estuary.

[1] In 2004, Kintama Research Corp. detected one of our tagged spring Chinook on their buoy array off Grays Harbor, Washington (David Welch, personal comm.).

Task e: We are continuing collaborative work with the Oregon Graduate Institute (Baptista, OGI) to integrate information on fish movement with the time-specific physical attributes recorded in the Columbia River Estuary model (CORIE). Real time fish tracks are overlaid onto a physical model of the estuary and the behavior of the fish is compared to "virtual fish" that are released at the same place and point in time. Using the output of the model we are able to determine which parameters fish respond to.

Objective 3.

Task a: The release sites proposed and tested in objective 2, tasks a and b, will be analyzed, and further recommendations for alternative barging strategies will be provided for validation with the 2006 experimental barges.

Task b: This study can be done with any or all of the following species/strains: steelhead, fall Chinook, and spring Chinook. Any species/strain not studied in 2005 can be studied in 2006.

SPECIFIC METHODS:

2005:

TPE-W-00-2

Objective 2.

Task b: Using experimental transportation strategies (i.e., trucking), compare the effects of release location and timing to migration characteristics, survivability, and successful ocean entry throughout the season.

Task c: Determine if migration characteristics, survivability, and successful ocean entry are different between traditional truck releases and traditional barge releases below Bonneville Dam to provide quality assurance of using trucks as a "simulated barge".

Task f. Correlate delays and mortalities with migration routes, release site, fish performance capacity, species, stocks, seasons, and hydrological conditions in the estuary and near shore ocean.

Release schedule

Radiotelemetry As in 2002-2004, all fish in 2005 will be tagged with Lotek digitally-coded radiotags (nano tags, ~0.85 g). There will be six releases of 120 hatchery-reared fish that will be trucked to current and experimental (estuarine)

release sites, and two releases of 40 hatchery-reared fish that will be barged to the current release site (Table 2). All of these fish will be implanted with radio transmitters.

Acoustic telemetry In 2002-2004, all fish were implanted with the "original" acoustic transmitters (V8SC-6L tags, ~3.40 g). In 2005, we will be using the new, smaller tags (V7SC-2L tags, ~1.58 g). We are currently working to ascertain any differences in detection ranges and implantation effects of the new, smaller tags. There will be six releases of 120 hatchery-reared fish that will be trucked to current and experimental (estuarine) release sites, and two releases of 40 hatchery-reared fish that will be barged to the current release site (Table 2). All of these fish will be implanted with acoustic transmitters.

Rationale for release schedule

Releases of fish will be clustered around three dates during the migration season so that all aspects of the run are represented (Table 2). This release strategy also allows for the evaluation of variability in behavior and survival between days due to tidal and diel differences (see Figure 1). All tagged fish will also be implanted with a PIT tag. If designed correctly, we could also correlate upriver management practices (raceway and barge loading densities, species composition in raceways and barges) to migration routes, fish tracks, and mortality in the estuary and near shore ocean.

Rationale for telemetry tags

As in previous years, we choose to use both radio and acoustic tags. Each tag has benefits not provided by the other tag. Radio tags are useful for detecting upstream (freshwater) passage in the Columbia River and enable us to actively track fish to the saltwater interface (Astoria Bridge). These tags are readily detected in air (e.g., if the tag is deposited on the bird colony on East Sand Island). Acoustic tags provide adequate transmission in the saltwater environment, enabling passive detection at acoustic receiver arrays in the lower estuary and near shore ocean.

Rationale for sample size

There are cost limits to doing such work. In addition, we are limited by the number of tags that we can use simultaneously, as a large number of tags within a small area can cause transmission interference through signal collisions, confounding receiver detection. Therefore, our proposed sample size for each telemetry tag is similar to sample sizes that we have successfully used in previous years (Table 2). Sample sizes may change as we work with the vendor to determine the maximum number of tags which we can successfully detect in a given area during a given period of time.

Rationale for alternative release sites and times

Sites: Based on previous year's data and our experience in the Columbia River estuary, we have designated two alternative or "optimum" release sites: Jim Crow Point and the Astoria Bridge (Oregon side, in shipping channel). Both of these sites are within the main shipping channel and are influenced by tides, so that transportation releases may be timed to an outgoing tide to expedite smolt movement through the "predatory gauntlet" of the lower estuary (Hvidsten and Mokkelgjerd, 1987; Collis *et al.*, 2001 & 2002). Jim Crow point is approximately 15 river miles upstream of the Astoria Bridge, and would therefore enable us to actively track radio-tagged fish to determine migration behavior, particularly in relation to the tide, before they entered saltwater. Astoria Bridge is closer to the ocean, and tidal influences at this location typically arrive about five hours earlier than at Jim Crow. These sites will be compared to truck releases at the current site, which will be tested against barge release at the current site below Bonneville Dam (Table 2).

Times: We are currently planning to release fish at night and on an outgoing tide to minimize any potential losses to sight-oriented avian predators (Collis *et al.*, 2001 & 2002). The current plan is to synchronize estuarine releases (Jim Crow Point and Astoria Bridge) with the outgoing tide. This would mean that fish would be released at Jim Crow five hours later than at the Astoria Bridge.

***Caveat Emptor*:** Release sites and times may change based upon the completion of 2004 data analysis.

Table 2. Summary table of proposed work for 2005, indicating numbers of tagged fish for each of the six planned release days. The tagging schedule was determined from historical availability of spring Chinook at Lower Granite Dam. The schedule can be adjusted to include steelhead and fall Chinook. Release dates are offset so that all fish will enter the estuary at approximately the same time. Tags include radio (R) and acoustic (A).

	Release 1		Release 2		Release 3		Total Number
Release Day[1]	1	2	3	4	5	6	
Approx. Date[1]	**4/28**	**4/29**	**5/12**	**5/13**	**5/26**	**5/27**	
Current Release							
Barged to below Bonneville[2]	--	--	40R 40A	40R 40A	--	--	160
Approx. Date[1]			**5/15**	**5/16**			
Trucked to below Bonneville[2]	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	480
Approx. Date[1]			**5/18**	**5/19**			
Estuarine Release[3]							
Trucked to Jim Crow Point	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	480
Trucked to Astoria Bridge	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	40R 40A	480
Total Sample Size[4]	**240**	**240**	**320**	**320**	**240**	**240**	**1,600**

Notes: [1] Due to variability in barging and smolt migration, dates may change. Anticipated study period is from 25 April through 15 June, with training, moving, and reporting occurring before and after the study period.

[2] Comparing trucked fish released below Bonneville to barged fish released at the same location will allow standardization of influences of transportation medium.

[3] These release sites were deemed to be "optimum" sites for expediting smolts emigration through the estuary. Sites were based on our current knowledge of fish migration behavior in the estuary and may change, based on analysis of the 2004 data set. Releases will be synchronized with the outgoing tide.

[4] Sample sizes may change as we work with the vendor to determine the maximum number of tags which we can successfully detect in a given area during a given period of time.

Tag Implantation

Determination of rearing type will be made by the absence of an adipose fin (hatchery). Antenna length on all radio tags will be 20 cm, shorter than typically used on smolts (30 cm). Findings in 2002 and 2003 indicated that plane, boat, and fixed-location receivers efficiently detected tags with shorter

antennas, with minimal loss of range of detection. Antenna lengths will be shortened so performance of small fish will not be affected by long antennas, which trail behind the caudal fin and inhibit normal swimming behavior (Clements, personal observation; *sensu* Brown *et al.*, 1999).

Transmitters will be implanted into fish at the point of collection. Barged fish will be collected at Lower Granite Dam smolt collection facilities, tagged, held for 24 hours, then released into barge holds or truck holds (dependent upon the treatment, see Table 2) prior to their release downstream of Bonneville Dam.

All tags will be surgically implanted. In 2004, only non-moribund fish greater than 30 g were tagged so that tags were within 10% of body weight. Brown *et al.* (1999) found that tagging fish smaller than this with tags that were up to 12% body weight did not affect performance, with the conjecture that the length of the antenna and not tag weight was the factor contributing to performance differences. Jepsen *et al.* (2001 & 2002) suggest that tag and/or antenna-fish size relationships are dependent on many variables and that there is no recommended fixed upper limit. Clements *et al.* (Submitted) found that there were no differences in travel time or survival of juvenile coho salmon (similar size to yearling Chinook) that were implanted with radio (0.8 g) or acoustic (3.4 g) transmitters. After fish are collected they will be placed individually into holding containers containing water, anesthetic (MS-222), and buffer (sodium bicarbonate for pH control). Once the fish has lost equilibrium, a transmitter will be surgically implanted into the body cavity. Fish will be anesthetically-dosed by a gill irrigation apparatus during all procedures. An incision 8-10 mm long will be made ventrally near the center of the body cavity, through which the tag will be gently inserted. For the radio tags, a hypodermic needle will be used to guide the radio-tag's antenna to the exterior of the fish through a pierce in the skin posterior to the incision. The incision will be closed with two sutures. This procedure will take less than 2 minutes. Following surgery, the fish will be allowed to revive from anesthesia before being placed in large holding tanks. We have noted in past years that tagging can affect some aspects of behavior in small fishes; however, laboratory studies have shown that surgically tagged fish can successfully eat, grow, and swim (Adams *et al*., 1998; Martinelli *et al*., 1998). Our field studies and others in the Columbia basin, and elsewhere (Jepsen *et al.*, 1998) indicate that smolts can also migrate and survive with surgical implants.

Evaluation of behavior and survival

Radio telemetry A fixed monitoring station has been in use since 1996 near Stella, WA, and will be used to provide data for comparison to previous years (travel time and survival to the estuary). In addition to this site we have established 13 other fixed automated monitoring stations throughout the estuary (Figure 2). The purpose of these sites will be to monitor the movement provide estimates of detection efficiencies, side channel usage, behavior with tides, travel

time, and survival of the control fish released below Bonneville Dam (Table 2). The radio sites on East Sand Island will allow us to monitor the predation rates on juvenile salmon at all sites and release locations.

Radio-tagged fish will also be tracked intensively by boat to establish their post-release movements in the estuary. In previous years our efforts have concentrated on obtaining a maximal number of tracks.

Acoustic telemetry Acoustic VR-2 receivers (Vemco, Ltd.) will be used to monitor downstream progress of fish implanted with acoustic tags. An array of these buoys, representing an uninterrupted line which migrating fish must pass, will be placed in several locations in the estuary (Figure 3). Thus, survival, travel speed, and in some cases (in larger areas), migration route to or through these three different zones (river, estuary, near ocean) can be assessed. The first array will be placed in the upper estuary at approximately river mile 27.9, near Jim Crow Point, and will serve to monitor the control fish (fish released below Bonneville Dam). This will consist of 13 receivers set in two-three lines 200 m apart to reduce the possibility of tag collisions (multiple tags can interfere with each other so that the receiver cannot decode the signal). Additional receivers will be placed in key areas near Rice and Seal Islands to determine use of side channels by the fish released at Jim Crow. A second array will be located at the Astoria bridge to cover both the Oregon and Washington channels as well as a smaller channel that crosses a relatively shallow area near the center of the estuary. This will provide information on fish movement at the fresh/salt water interface and give some indication about the effect on timing and vulnerability of the fish that use either of these channels. The third array will be located near East Sand Island to provide additional information on movements between the Astoria Bridge and ocean arrays. The final array will be placed from the end of the north and south jetties to a point approximately five miles out into the near-shore ocean and will include two receivers to investigate possible sea lion predation (Figure 3).

In 2005, we will track fish in the lower estuary downstream of the Astoria Bridge. Due to saltwater intrusion at this point, we have been unable to amass fish tracks using radio tags. Therefore, we have been unable to compare lower estuary fish migration paths below the Astoria Bridge to water particle trajectories using the COlumbia River Estuary (CORIE) model. We have a VR-28 (Vemco, Ltd.) acoustic receiver that is towable from large vessels, and we have experienced success with locating fish in the near shore ocean. We have also conducted trials on tag reception distances at various depths in the near shore ocean. This system could be used to actively and extensively track fish below the Astoria Bridge and in the near shore ocean.

Figure 2. Proposed radio receiver locations for 2005, based on previous years. The dots denote the locations of fixed automated radio sites. The number of receivers and the river mile are indicated near array locations. The most upstream site, near Stella, Washington (3 receivers @ Rm 55), is not shown.

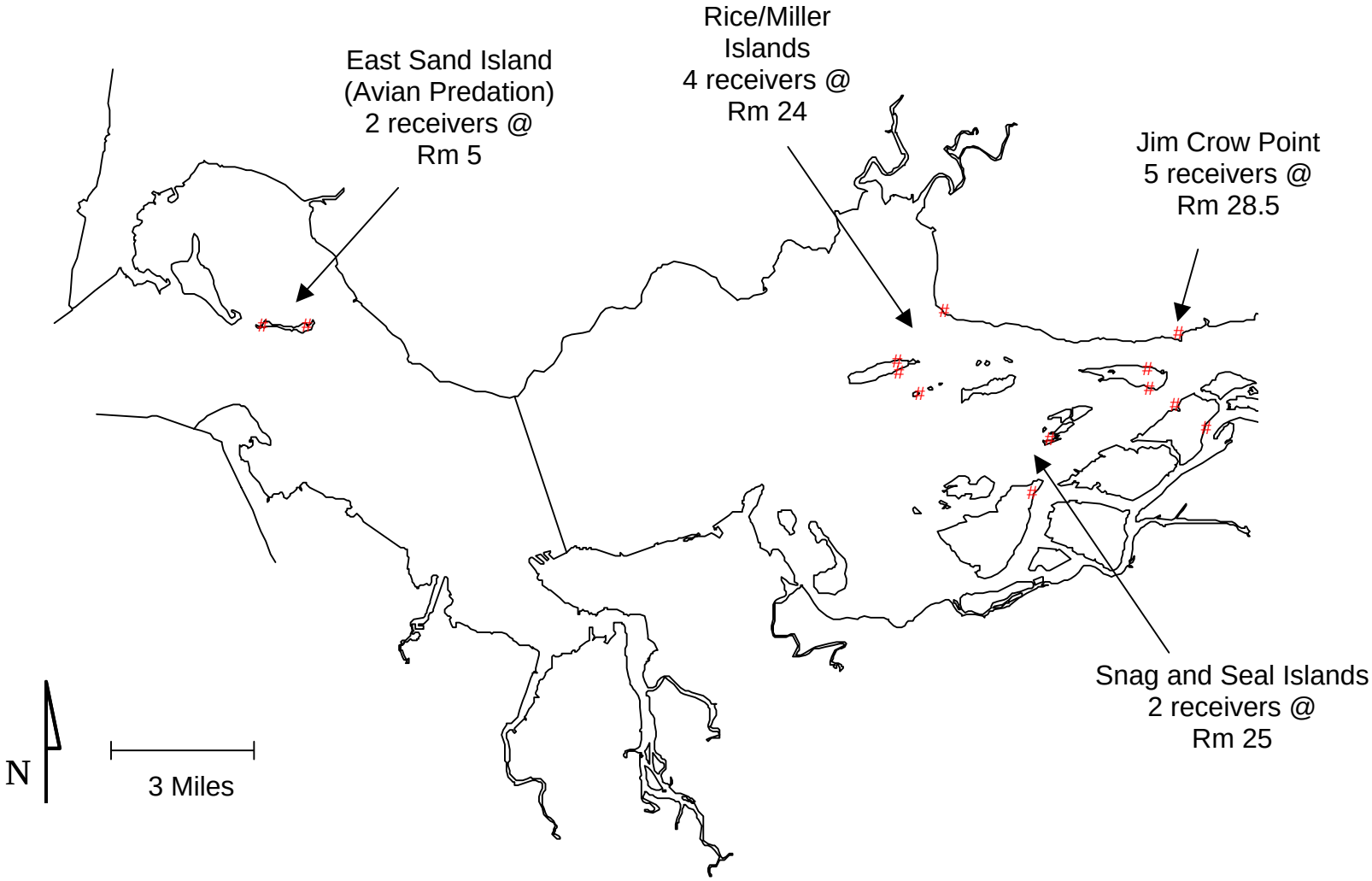
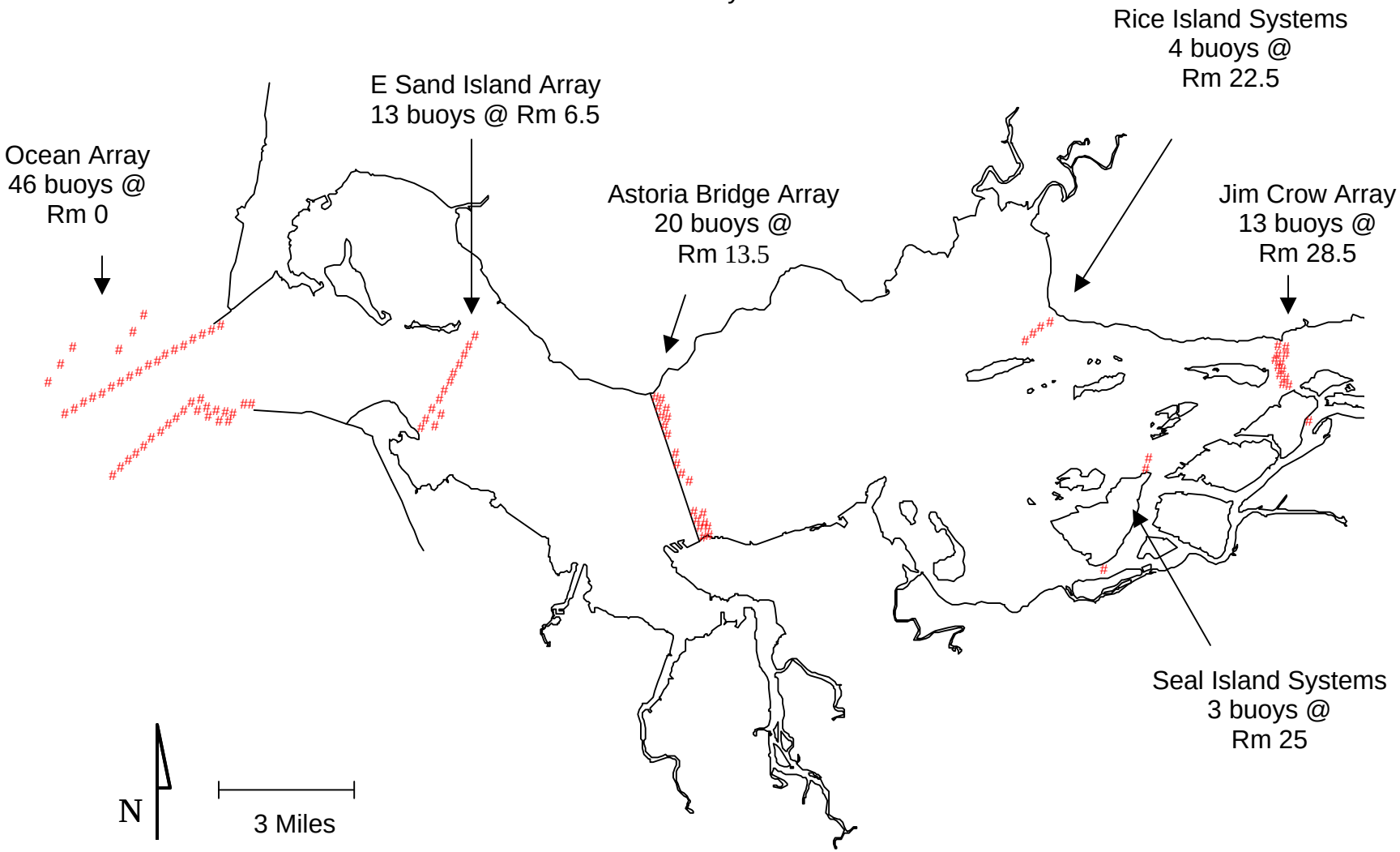


Figure 3. The proposed locations of acoustic receiver arrays and individual buoy-receiver systems (dots) for 2005. The number of receivers and the river mile are indicated near array locations.



Task d: Assess quality differences in juvenile salmon relative to successful estuarine performance and ocean survival.

Task f. Correlate delays and mortalities with migration routes, release site, fish performance capacity, species, stocks, seasons, and hydrological conditions in the estuary and near shore ocean.

Fish Gestalt

Researchers have noted extensive variations in the degree of smoltification indices between different hatchery releases, days, and across the run (Beckman *et al.*, 2000; Dickhoff *et al.*, 1995; Giorgi *et al.*, 1988). This indicates that large variations in the degree of physiological readiness for life in salt water exists (Dickhoff *et al.*, 1995) and that for some juvenile salmon, early transition into saltwater can be physiologically taxing (Hoar 1988).

Extensive variations in smolt energy reserves and stress have also been shown between days and across the run (Congleton *et al.*, 2004; Dickhoff *et al.*, 1995). Some juvenile salmon have been shown to revert to parr or show stunted growth when transferred to salt water prematurely (Hoar, 1988) and exhibit decreased predator evasion capabilities (Price and Schreck, 2003; Jarvi, 1989).

Differences in fish condition (smoltification and stress status) appear to be the result of differences in fish stocks, species, life history strategies (Stefansson *et al.*, 2003; Thorpe, 1994), environmental effects (McCormick *et al.*, 2000; Whalen *et al.*, 1999), dam passage history (Barton *et al.*, 1986; Budy *et al.*, 2002), or all of the above. These factors may affect consequent survival of juvenile salmon through the estuary and near shore ocean, particularly as stressed fish are more vulnerable to piscine and avian predators (Budy *et al.*, 2002; Price and Schreck, 2003; Jarvi, 1989).

The assays that we propose (DNA microchip, Na+/K+ ATPase, thyroxine, and cortisol) are lethal and can be done on the same fish to provide a relative measure of fish quality prior to transportation or release (Table 3).

Fish quality or condition collected for transportation differs over relatively short periods of time. There is a need to better understand the variability in condition and performance of transported fish prior to transportation. It is also essential to understand the variability in condition for fish released at different sites in relation to the saltwater environment, particularly since enzymes used by juvenile salmon in saltwater (Na+/K+ ATPase) have been shown to increase relative to migration distances in the river (Stefansson *et al.*, 2003; Beckman *et al.*, 2000; Zaugg *et al.*, 1985). Juvenile salmon transported to the lower estuary may have inadequate time within which they can acclimate to the saltwater environment in relation to ROR fish (3-4 week period

between Snake River and ocean), fish released at the current location (7 day period between release and the ocean), or fish released at the proposed alternative release sites (0-1 day).

Tests will be conducted on groups of pre-transported fish, as they are collected from the fish separator at Lower Granite Dam (n = 8), for barged fish (from the same group) just prior to their release below Bonneville approximately two to three days later (n = 8), and for experimentally trucked fish (same group) up to six days later (n = 8) (Table 3). In addition to providing quality control for releases of tagged fish, these three groups will help establish a baseline of variability in fish condition that can be used to develop a future barge monitoring program.

DNA microchip: The DNA microarray (also known as a gene chip or genome chip) is a useful diagnostic tool (Gracey *et al.*, 2001). We currently have a microarray that has 1,800 genes specific to the health of rainbow trout/steelhead. This microarray is currently being validated for Chinook. One test can look at activation or deactivation of all genes simultaneously, and can be used to assess which genes are affected by collection at the dams or by transportation processes in order to determine the causes of delayed mortality.
Na+/K+ ATPase: Activity of this enzyme is directly correlated to degree of smoltification (Nielsen *et al.*, 2004; Stefansson *et al.*, 2003; Beckman *et al.*, 2000; Hoar, 1988; Zaugg *et al.*, 1985.
Thyroxine: This hormone is correlated to metabolic rate in smolts, and when used in conjunction with Na+/K+ ATPase and cortisol, it can help pinpoint the degree of smoltification (Beckman *et al.*, 2000; McCormick *et al.*, 2000).
Cortisol: This hormone is also correlated with the degree of smoltification and also with stress (McCormick *et al.*, 2000; Barton *et al.*, 1985). Smolts are known to be highly susceptible to environmental perturbation or stress at the peak of their smoltification (Barton *et al.*, 1985). Therefore, when compared with Na+/K+ ATPase and thyroxine levels, measurements of cortisol levels will enable us to gauge the level of stress to the degree of smoltification.

Table 3. Summary table of the numbers of fish to be used for quality assessment. This study is designed to assess variation in fish quality over the early, middle, and late portions of the run. Tests will include the DNA microchip during the middle portion of the run, and Na+/K+ ATPase, thyroxine, and cortisol during all portions of the run. All tests are lethal and can be done on the same fish to provide a relative measure of fish quality prior to transportation or release.

	Release 1		Release 2		Release 3		Total Number
Release Day	1	2	3	4	5	6	
Approx. Date	**4/28**	**4/29**	**5/12**	**5/13**	**5/26**	**5/27**	
Current Release							
Lower Granite JFF	8	8	8	8	8	8	48
Approx. Date			**5/15**	**5/16**			
Barged to below Bonneville	--	--	8	8	--	--	16
Approx. Date			**5/18**	**5/19**			
Estuarine Release							
Trucked to Astoria Bridge	8	8	8	8	8	8	48
Total Sample Size	**16**[1]	**16**[1]	**24**[1, 2]	**24**[1, 2]	**16**[1]	**16**[1]	**112**

Notes: [1] Na+/K+ ATPase, cortisol, and thyroxine levels will be assessed on these fish.

[2] These fish will be tested with the DNA microchip.

<u>Task e</u>: Characterize hydrological variations in the Columbia River estuary and near shore ocean environment during juvenile salmon emigration from the estuary.

<u>Task f</u>. Correlate delays and mortalities with migration routes, release site, fish performance capacity, species, stocks, seasons, and hydrological conditions in the estuary and near shore ocean.

Modeling The CORIE modeling system integrates a real-time sensor network, data management system, and advanced numerical models to characterize and predict the complex circulation and mixing processes in the lower river, the estuary, and the near shore ocean environment. The focus is on the simulation of 3D circulation, in a region centered in the estuary and plume, but extending from Bonneville Dam to the Eastern North Pacific. Analysis of our data on actual fish tracks within the CORIE model allows us to assess if our predictions of fish migration paths through the estuary are driven by the environmental variables we think are responsible. It also offers us the opportunity to “fine-tune” the proposed release sites.

Hydrological data is collected from an extensive array of stations in the Columbia River estuary and one station in the nearby coastal ocean. Each active station measure one or more physical properties of water: temperature, salinity, water levels, and vertical and horizontal water velocity.

The real time senor network that consists of an array of 17 active stations located through out the Columbia River estuary (Figure 4). Combinations of *in situ* sensors at Sampling intervals typically range from 1-15 minutes.

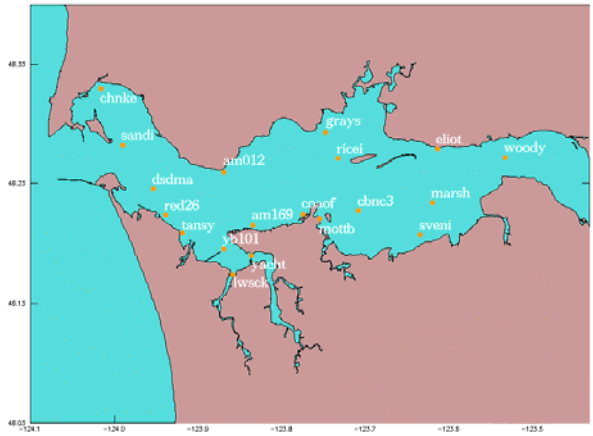


Figure 4. Station map of the CORIE model (courtesy of OGI).

The CORIE model is currently being used to generate accurate georeferenced, flow, temperature, and salinity fields that correspond to all 2002 and 2003 fish tracks. We expect to finish tracks from 2004 by summer of 2005. Flow fields generated from the CORIE model are then used to drive highly accurate numerical simulations of the release of a large number of passive particles (tracers). Tracers will be used to analyze fish behavior at critical decision making points in the Columbia River Estuary.

Analysis of data from the CORIE model with respect to salmon migration behaviors will utilize ArcGIS and Matlab to visualize large-scale spatial and temporal patterns of flow fields in the Columbia River Estuary. Tracer migration patterns will be examined to determine if the tracers migrate through specific channels during specific tidal stages and flow conditions. Tracer migration patterns will then be compared to smolt migration patterns. For example, if tracer analysis suggests that a fish should use a particular channel if it arrives at a specific river km at a specific tidal time, then fish tracks that correspond to that location and tidal time would be examined to determine if the predicted route was chosen by the migrating fish. All useful tracking data will be input into the CORIE model. The movement of the fish is compared to “virtual fish” that are released in the model at the same place and point in time as the real fish. Virtual fish can be released at different depths and their path following release is then compared to that of the fish. The output of the model will allow us to determine how fish movement relates to the physical environment of the estuary during that period of time. By inputting data from multiple fish it is possible to observe how fish respond to flow and tidal cycles. This information is then used to predict what would happen if fish were released a different locations and at different times.

Justification of Study Area: Studies conducted within the Columbia River estuary are necessary to determine the migration patterns, saltwater entry behavior/survival, and level of predation within the estuary, which will provide insight into the ways in which transportation strategies and management activities upstream (such as transportation or spill) may influence the subsequent survival of migrants.

Method of Analysis: The acoustic arrays and fixed radio sites provide multiple detection sites below Bonneville Dam, therefore, the "complete capture history" protocol (Burnham *et al.*, 1987) will be used to estimate survival and detection probabilities. The computer program SURPH ("Survival with Proportional Hazards"; Lady *et al.*, 2002) will be used to estimate these probabilities and perform statistical analyses using release-recapture data. The single release-recapture model (Cormack, 1964; Jolly, 1965; Seber, 1965) will be used to generate survival probabilities and associated standard errors. To assure that the single-release model is appropriate, the goodness of fit tests proposed by Burnham *et al.* will be used (1987; TEST 2 and 3).

Description of treatments: See the "Specific Methods" section above.

Fish Required: See text table in "Specific Methods" section above.

Limitations: Tracking efforts in general may be suspended in periods of extremely bad weather, but this has not been a problem in previous years. The number of boats and crew available limits the number of individual fish that can be followed in detail. Highly detailed tracks of individual fish may be difficult with large numbers of fish in close vicinity of each other. Acquiring fish at Lower Granite Dam smolt monitoring facilities may be difficult at times due to lack of numbers of fish in the bypass system. Given our fixed schedule, we will use the fish we can acquire and decrease our sample sizes if this occurs.

The acoustic system has a number of limitations that have been taken into account, including:

1. Releasing large numbers of fish in a single area may reduce the total possible number of fish detected and lower efficiencies of arrays (due to tag collisions). We will be testing acoustic tags and receivers this fall in order to get an idea of the detection limitations presented by this system.
2. The transmitter to buoy range may be less than expected in noisy conditions that may occur (i.e., passing ships or storms).
3. All tags that pass the near-shore ocean array may not be heard as the shipping channel must be avoided.
4. Receivers located near the shipping channel may be lost due to passing fishing or transportation ships.
5. It is possible that a receiver may acquire a tag which is no longer a free-swimming smolt, but inside a predator.

6. There may be problems detecting fish in areas that have a stratified salinity gradient.

Expected Results and Applicability: This work will provide information concerning migration behavior and survival of juvenile salmon migrants in the Columbia River estuary. Increased understanding of smolt behavior in the estuary is needed to determine how the transportation program may be improved by timing releases so that a large proportion of predation mortality is avoided in the lower river and estuary.

Schedule: Tagging will approximately begin on 1 May 2005 and repeat on a two-week schedule as described in the "Specific Methods" section (and detailed in Table 2). Work periods are largely dependent on juvenile salmon used in the study.

Objective 3.

Task a: Propose release sites and barge strategies for evaluation in next year (2006 experimental barges).

Task b: Prepare comparable trials for juvenile salmon species/strains not analyzed in 2005.

Continue analysis of earlier data on spring Chinook/steelhead/fall Chinook movement and survival, in order to determine whether post-release survival of all species can be improved by modifying the barge release location.

The tracking data collected in previous years for steelhead/spring Chinook and fall Chinook will be input into the CORIE model. Movement of the fish is compared to "virtual fish" that are released in the model at the same place and point in time as the real fish. Virtual fish can be released at different depths and their path following release is then compared to real fish tracks. The output of the model will allow us to determine how the fish movement relates to the physical environment of the estuary during that period of time. By inputting data from multiple fish it is possible to observe how fish respond to flow and tidal cycles. This information is then used to predict what would happen if fish were released at different locations and at different times. For steelhead the information would then be combined with data from the acoustic studies in 2002/2003 to examine the effect of migration route on survival.

RELEVANCE

Post-release survival of transported juvenile salmonids is affected by the interaction between the fish and the environment, which can result in delays in the estuary and hence increased vulnerability to predation due to increased exposure. This research will provide information on the efficacy of alternative

transportation strategies designed to expedite travel time through the estuary and reduce avian predation. By using PIT tagged fish stocks for our proposed telemetry study, we will be able to correlate survival rates of control fish released below Bonneville to the overall SARs of fish with the same transport history. This will allow us to assess whether changes in estuarine conditions, migration patterns, and avian predation drive SARs.

The mortality that occurs in the near shore ocean environment is currently unknown for juvenile salmonids. This early ocean mortality may either be due to large numbers of predators in the area or from the stress of entering a saltwater environment prematurely (Jarvi, 1989). Passage through the Columbia River hydropower system by migrating juvenile salmonids may cause a decline in condition through stress that does not cause immediate mortality, but is manifested once the added stress of saltwater entry is encountered in the estuary and near-shore ocean environment (Budy *et al.*, 2002).

Until recently, understanding of migration behavior in the estuary has been limited due to the difficulties of conducting research in the salt water environment; however, we are now able to study migration patterns in the near shore ocean with recent advancements in telemetry technology. Using acoustic telemetry we have successfully documented the behavior and survival of migrant steelhead (Schreck *et al.*, 2002 & 2003). The data we have collected has allowed development of new hypotheses regarding fish movements in the estuary. Our acoustic arrays have provided valuable first time information on behavior and survival of juvenile cutthroat trout in a collaborative study with USFWS and Portland District of USACE, as well as contributing to knowledge of sturgeon movements in the estuary (USGS and BPA). A number of researchers have expressed interest in using the acoustic array during 2004 for studies on green and white sturgeon, steelhead kelts, and in the past, on cutthroat trout and adult salmon.

Our research on juvenile steelhead migrants suggests that the majority of mortalities occur within the lower regions of the estuary and in the near shore ocean (Clements et al. Submitted, Schreck *et al.*, 2002 & 2003). Data from 2002 further suggests that migration route has a significant effect on survival. By combining data from radio and acoustic telemetry, we are working to develop a model that predicts movement of juvenile salmonids through the estuary as a function of hydrological conditions. We may be able to predict the impacts of flow regimes on channel use and resulting effects on survival of juvenile salmon within the estuary. Another potential benefit of our research is the ability to determine the effects of dredging on flow regimes and hence fish movement. With multi-year comparisons it will be possible to gain insight into the effect of variation in the system (barges, dam operation, location and timing of release, and tidal variation) on migration routes and survival. This will lead to more informed decisions about the management of the transportation program in relation to environmental conditions and hydro system operation, thereby

allowing salmon managers to increase survival of transported fish. At present there is no basis for decisions related to enhancing the survival of transported juvenile salmon. We hope to provide recommendations that could lead to an adaptive management protocol. This research complements, and is a continuation of, the telemetry work funded by the US Army Corps of Engineers to support the National Marine Fisheries Service, Biological Opinion RPA 49, 51, 52, 186, 187, and 195.

FACILITIES AND EQUIPMENT

Field work will be performed at the Lower Granite Dam fish separator, on transport barges, and in the Columbia River estuary. No modification of USACOE facilities are required.

Two special expenses are required for this work:

1) Digital radio-tags: We anticipate the purchase of 800 digitally-coded radio-tags (Lotek) by the USACOE.
2) Acoustic transmitters: We anticipate the purchase of 800 V8SC-6L acoustic tags (Vemco, Ltd.) by the USACOE.
3) Acoustic receivers: We anticipate the purchase of 44 additional acoustic receivers. These receivers will allow us to replace receivers lost in the 2003 and 2004 field seasons and to provide better resolution for detecting fish migration patterns between Jim Crow Point and the mouth of the Columbia River (Figure 3).

IMPACTS

1) Other Research: Our activities on U.S. Army Corps of Engineers' barges should not impact any other research. Collection of smolts at Lower Granite Dam will need to be coordinated with fish requirements for ongoing biotelemetry studies and gas bubble trauma monitoring. We were able to successfully coordinate these activities in previous years.

2) Projects: Research activities during the period of approximately 20 April to 10 June will result in a few minor project impacts, as follows:

We will require access to the Lower Granite separator to collect fish for tagging and physiology. In 2003, an arrangement with NMFS allowed us to use fish that had been held overnight as part of the PIT tag sample. If possible we will use this option again in 2004.

3) System Operation: No changes are anticipated.

4) Biological effects:

Total numbers of all fish to be used:

TPE-W-00-2, Objective 2	Total sample sizes	
Task	*Radio*	*Acoustic*
Telemetry, Tasks a-c	800	800
Fish quality, Task d (Lethal)	112	

All tagged fish (radio + acoustic = 1,600) will be released alive. Impacts on protected fish will be calculated when current NMFS estimates for these fish are obtained. OCFWRU/Carl Schreck currently holds an ESA section 7/10 permit for this work.

COLLABORATIVE ARRANGEMENTS

We are currently collaborating with Dr. Chris Bayne of the Department of Zoology and the Freshwater/Marine Biomedical Center on application of the DNA microarray/gene chip technology to assess the Columbia River fish transportation program. We are also continuing our collaborative work with Dr. Antonio Baptista (OGI) on the CORIE model. Personnel from CRITFC, ODFW, Sea Resources, USGS, USACOE, NOAA Fisheries, COA, and USFWS have expressed a desire to utilize the radio and acoustic arrays to gather information for other studies on cutthroat, green and white sturgeon, steelhead kelts, and juvenile salmonids. We are exchanging tag detection information with personnel from Kintama Research Corp. in Nanaimo, British Columbia, who are also tagging juvenile salmonids and have buoy arrays in the North Pacific Ocean.

KEY PERSONNEL AND PROJECT DUTIES

Carl Schreck	Principle Investigator
Ben Clemens	Project Leader
Mark Karnowski	Project Leader

TECHNOLOGY TRANSFER

This work will provide information that will be used to make recommendations for managing the migration of juvenile salmonids so that subsequent mortality is minimized. Results will be presented at meetings as requested by the USACOE, at professional meetings, and through publications in peer-reviewed literature.

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