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Technical Memo:

A STUDY TO ESTIMATE SALMONID SURVIVAL THROUGH THE COLUMBIA RIVER ESTUARY USING ACOUSTIC TAGS, 2005 and 2006 SYNTHESIS REPORT

by

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The Juvenile Salmon Acoustic Telemetry System (JSATS) continues to develop and substantial progress has been made in achieving the primary goal, which is to estimate survival of subyearling Chinook salmon over a large part of their range in the Columbia River basin from freshwater to ocean entry. This synthesis report is intended to provide interested parties with summary findings of this research. The annual project reports (e.g., McComas et al. in prep) provide details on the methods used as well as a more complete examination of the data, and should be considered comprehensive reports of data collected on this project.

This synthesis report will focus on the results of the research conducted in 2005 and 2006 using the JSATS to estimate survival of yearling and subyearling Chinook salmon between Bonneville Dam and the mouth of the Columbia River (MCR). An additional task was performed in 2006 in which yearling Chinook salmon were released to the tailrace of Lower Granite Dam in the Snake River to determine whether it was feasible to use the JSATS to conduct survival estimation throughout the Federal Columbia River Power System (FCRPS, system-wide).

Study objectives in 2005 were to:

1) evaluate run-of-the-river yearling Chinook salmon survival through the lower Columbia River and its estuary using fully-populated primary and secondary detection arrays, and

2) evaluate run-of-the-river subyearling Chinook salmon survival through the lower Columbia River and its estuary using fully populated primary and secondary detection arrays.

Objectives for this project in 2006 were to:

1) Evaluate run-of-the-river yearling Chinook salmon survival through the lower Columbia River and estuary using the CJS single-release survival model,

2) Evaluate run-of-the-river yearling Chinook salmon survival through the lower Snake River and through the Columbia River from McNary Pool through the Columbia River estuary using the CSJ single-release survival model,

3) Evaluate run-of-the-river subyearling Chinook salmon survival through the lower Columbia River and its estuary using the CJS single-release survival model, and

This synthesis report provides information on the numbers of fish released by date and location, locations of detection arrays, single-release model survival estimates from point of release to various primary detection arrays, and behavioral information such as travel time and cross-channel distribution.

Fish Releases

A total of 2,107 JSATS-tagged fish were released for this study in 2005 (Table 1). All fish were released through the Bonneville 2 juvenile bypass outfall in 2005. A total of 890 yearling Chinook salmon were released into the bypass between May 4 and June 1, 2005. A total of 1,217 subyearling Chinook were released into the bypass between June 18 and July 16, 2005.

Table 1. Yearling (SPC) and subyearling (FC) Chinook salmon released in the Columbia River in 2005 that were implanted with microacoustic transmitters and PIT tags.

Project	Species	Release date	Release location	Live fish released
JSATS	SPC	4 May	Bonneville	245
JSATS	SPC	15 May	Bonneville	243
JSATS	SPC	24 May	Bonneville	161
JSATS	SPC	1 June	Bonneville	245
JSATS	FC	18 June	Bonneville	240
JSATS	FC	25 June	Bonneville	245
JSATS	FC	2 July	Bonneville	245
JSATS	FC	9 July	Bonneville	245
JSATS	FC	16 July	Bonneville	245

In 2006, a total of 3,925 JSATS-tagged fish were released for this study (Table 2). Of those, 996 were yearling Chinook salmon released to the tailrace of Lower Granite Dam for Objective 2, listed above. A total of 972 yearling Chinook salmon were released into the Bonneville 2 juvenile bypass between May 6 and 27, 2006. A total of 1,957 subyearling Chinook were released into the bypass at Bonneville between June 17 and July 22, 2006.

Detection Arrays

Data were collected on two JSATS arrays at the mouth of the Columbia River (MCR) area. The primary array consisted of 22 individual acoustic receivers (nodes) located along a transect near river kilometer (Rkm) 8.3 (river mile 5.4) between East Sand Island and Clatsop Spit (Figure 1). The secondary array was composed of 21 nodes located at Rkm 2.8 (river mile 1.8) between the North and South Jetties. Additional detection arrays were deployed in the FCRPS and downstream from Bonneville Dam in 2006 (Table 3). In particular, yearling Chinook salmon were detected on the arrays upstream and downstream from both Lower Monumental and Ice Harbor dams. Detection arrays in the estuary were similar in 2005, with the exception that the north side of the primary array was more perpendicular to the navigation channel during the period when autonomous nodes were used in that area while the cabled system was under repair (April 25 to July 10, 2005).

Table 2. Numbers of acoustically-tagged yearling (SPC) and subyearling (FC) Chinook salmon released at Lower Granite Dam and Bonneville 2 JBF outfall during studies to estimate juvenile salmonid survival in 2006. All fish had acoustic and PIT tags concurrently implanted during surgery.

Project	Species	Release date	Release location	Live fish released
JSATS	SPC	2 May	Bonneville	239
JSATS	SPC	11 May	Bonneville	245
JSATS	SPC	19 May	Bonneville	244
JSATS	SPC	27 May	Bonneville	244
JSATS	FC	17 June	Bonneville	245
JSATS	FC	22 June	Bonneville	245
JSATS	FC	27 June	Bonneville	245
JSATS	FC	2 July	Bonneville	245
JSATS	FC	7 July	Bonneville	243
JSATS	FC	12 July	Bonneville	245
JSATS	FC	17 July	Bonneville	244
JSATS	FC	22 July	Bonneville	245
Tag Effects	SPC	6 May	Lower Granite	238
Tag Effects	SPC	13 May	Lower Granite	758

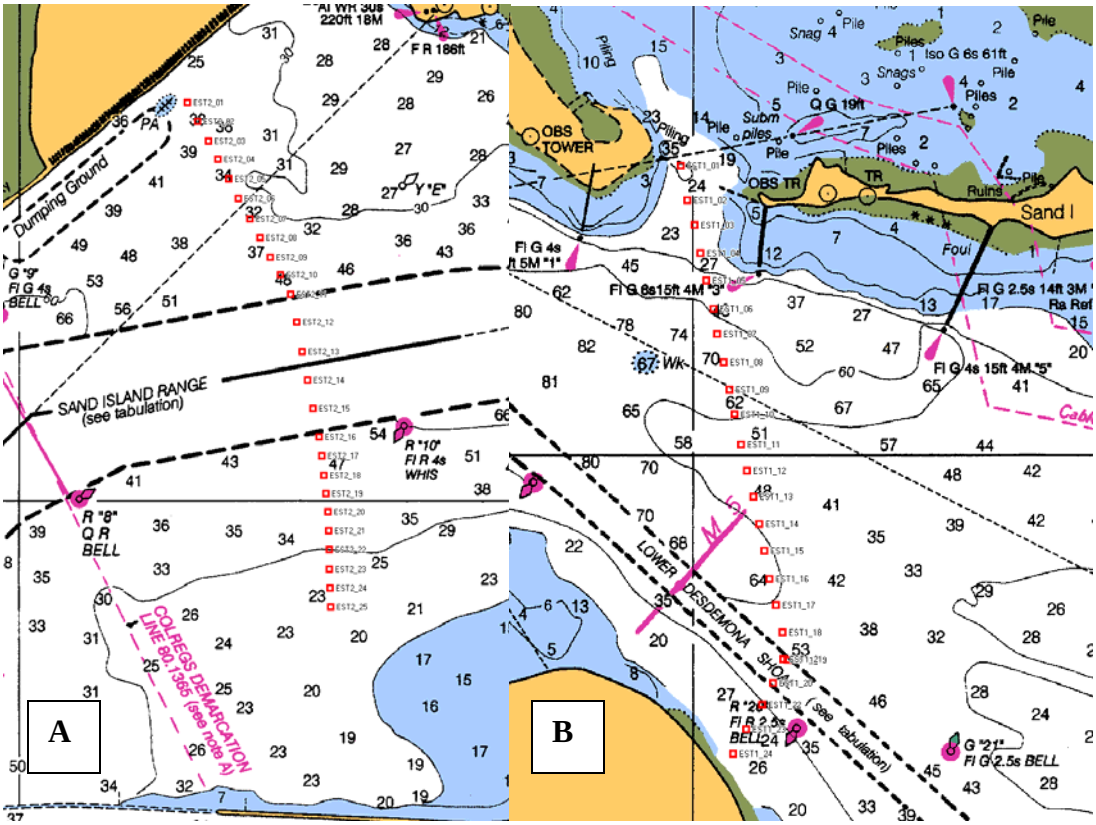

Figure 1. Secondary (A) and primary (B) JSATS arrays at the mouth of the Columbia River. Note: node positions (red squares) in the navigation channel on the secondary array were only used for temporary deployments in 2006. Nodes have not been deployed to date in the navigation channel on the primary array.

Table 3. Name, location (physical landmark description and river kilometers (Rkm) from the mouth of the Columbia River), and deployment and recovery dates of JSATS acoustic telemetry arrays in the Snake and Columbia river systems used to detect acoustically-tagged juvenile Chinook salmon released in 2006.

Array Code	Rkm	Physical Description	Date In	Date Out
LMDF	589.2	LMN Res, BRZ (~0.5 km from dam)	26-Jul	25-Sep
LMDT	578.5	LMN tailrace, ds of Windust	12-Apr	26-Sep
IHDF	538.1	IHR forebay BRZ (~0.5 km from dam)	11-Apr	26-Sep
IHT1	525.2	IHR tailrace primary, at Hwy 12 Br	10-Apr	26-Sep
IHT2	524	IHR tailrace secondary, at RR Br	10-Apr	26-Sep
JDAE	339.2	JDA Egress, us of Maryhill State Park	12-May	5-Jun
JDA1	325.6	JDA tailrace primary, us of Celilo	10-May	20-Sep
JDA2	324.2	JDA tailrace secondary, Celilo	10-May	20-Sep
JDA3	312.4	JDA tailrace tertiary, ds of Horsethief Lake	10-May	20-Sep
TDA1	275.6	TDA tailrace primary, Bingen Marina	12-May	16-Sep
TDA2	238.4	TDA tailrace secondary, ds of Bridge of the Gods	8-May	6-Sep
TDA3	236.4	TDA tailrace tertiary, ds of TDA2, us of TDA4	8-May	6-Sep
TDA4	235.2	TDA tailrace quaternary, us of BON spillway	1-Jun	7-Aug
BONC	235.1	BON spillway cabled array	3-Jul	7-Aug
BON1	208.8	BON tailrace primary, Rooster Rock State Park	2-May	21-Sep
BON2	204	BON tailrace secondary, Reed Island	2-May	21-Sep
BON3	193.8	BON tailrace tertiary, Lady Island	2-May	21-Sep
EST1	8.3	Estuary primary, E. Sand Island	17-Apr	27-Sep
EST2	2.8	Estuary secondary, between N and S Jetties	17-Apr	27-Sep

DATA SUMMARY

Survival

For all releases in both years, survival was estimated to a primary detection array using the single-release statistical model. Resulting survival estimates and detection probabilities are presented in Table 4 (2005) and Table 5 (2006). In 2006, fall Chinook salmon survival was high for the first four releases, after which survival progressively deteriorated. Whether this is an artifact due to annual variation, reflects mortality due to increasing summer water temperatures, or is a result of interrupted migration is unclear. A similar trend was indicated after the first two releases in 2005. However, subyearling Chinook salmon releases from Bonneville Dam were discontinued after 16 July in 2005 due to elevated water temperatures which appeared to contribute to unacceptably high tagging-related mortality.

Two groups of acoustically-tagged yearling Chinook salmon were released to the tailrace of Lower Granite Dam in 2006 as a pilot project to assess feasibility of using JSATS tags to evaluate system-wide survival (Table 5). Pooled survival was 0.787 (SE = 0.0147) to the mouth of the Snake River, and 0.384 (SE = 0.0278) through the lower Columbia River. However, additional research into longer term effects of this tag on migrant fish (ongoing) is needed before this application can be considered reliable.

Table 4. Primary array detection probabilities and survival estimates to the primary detection array by release date for acoustically-tagged yearling (SPC) and subyearling (FC) Chinook salmon groups released to estimate juvenile salmonid survival from Bonneville Dam (BON) through the lower Columbia River estuary (EST1), 2005.

Species	Release date	Number released	Release site	Survival estimation array location code	Estimated detection probability on primary array	Standard error of detection probability estimate	Estimated survival to primary array	Standard error of survival estimate
SPC	5/5/2005	244	BON	EST1	0.581	0.0752	0.564	0.0683
SPC	5/12/2005	240	BON	EST1	0.700	0.0512	0.702	0.0475
SPC	5/24/2005	161	BON	EST1	0.386	0.0734	0.611	0.0944
SPC	6/1/2005	245	BON	EST1	0.608	0.0483	0.873	0.0545
FC	6/18/2005	238	BON	EST1	0.851	0.0367	0.711	0.0358
FC	6/25/2005	245	BON	EST1	0.824	0.0534	0.748	0.0497
FC	7/2/2005	245	BON	EST1	0.794	0.0693	0.314	0.0360
FC	7/9/2005	245	BON	EST1	0.939	0.0264	0.595	0.0333
FC	7/16/2005	244	BON	EST1	0.929	0.0688	0.150	0.0245

Table 5. Detection probabilities and survival estimates to primary detection arrays by release date for acoustically-tagged yearling (SPC) and subyearling (FC) Chinook salmon groups released from Lower Granite Dam (LGR) tailrace and Bonneville Second Powerhouse juvenile fish bypass outfall (BON) to estimate juvenile salmonid survival, 2006. Primary array locations were near the mouth of the Snake River below Ice Harbor Dam (ITH1) and the lower Columbia River Estuary (EST1).

Species	Release date	Number released	Release site	Survival estimation array location code	Estimated detection probability on primary array	Standard error of detection probability estimate	Estimated survival to primary array	Standard error of survival estimate
SPC	5/6/2006	238	LGR	IHT1	0.893	0.0268	0.835	0.0281
SPC	5/13/2006	758	LGR	IHT1	0.905	0.0151	0.772	0.0172
SPC	5/6/2006	238	LGR	EST1	0.686	0.0758	0.409	0.0492
SPC	5/13/2006	758	LGR	EST1	0.590	0.0540	0.379	0.0341
SPC	5/2/2006	239	BON	EST1	0.935	0.0312	0.657	0.0351
SPC	5/11/2006	245	BON	EST1	0.833	0.0407	0.573	0.0362
SPC	5/19/2006	244	BON	EST1	0.833	0.0393	0.841	0.0378
SPC	5/27/2006	244	BON	EST1	0.862	0.0453	0.623	0.0403
FC	6/17/2006	245	BON	EST1	0.848	0.0360	0.914	0.0341
FC	6/22/2006	245	BON	EST1	0.730	0.0402	0.837	0.0376
FC	6/27/2006	245	BON	EST1	0.703	0.0434	1.005	0.0458
FC	7/2/2006	245	BON	EST1	0.820	0.0384	0.856	0.0367
FC	7/7/2006	243	BON	EST1	0.761	0.0445	0.671	0.0397
FC	7/12/2006	245	BON	EST1	0.741	0.0596	0.481	0.0428
FC	7/17/2006	244	BON	EST1	0.950	0.0487	0.194	0..0264
FC	7/22/2006	245	BON	EST1	0.615	0.1349	0.179	0.0410

Travel Time

Travel time for juvenile Chinook salmon to the estuary receiver arrays varied by release location, species, and year (Figure 2). Intuitively, yearling Chinook salmon released from Lower Granite Dam had longer travel times to the estuary (mean = 13.4 days to the primary array) due to a longer travel distance (687 km), whereas yearling Chinook salmon released from Bonneville Dam traveled to the estuary faster (mean = 4.1 days to the primary array, distance = 226 km). Subyearling Chinook salmon released from Bonneville Dam generally had longer travel times to the estuary receiving arrays than yearling Chinook salmon released from Bonneville Dam, which may be partially due to seasonal differences in river discharge. Travel time for yearling Chinook salmon to the primary array in 2005 was shorter than in 2006; however, subyearling Chinook salmon traveled faster in 2006 than in 2005.

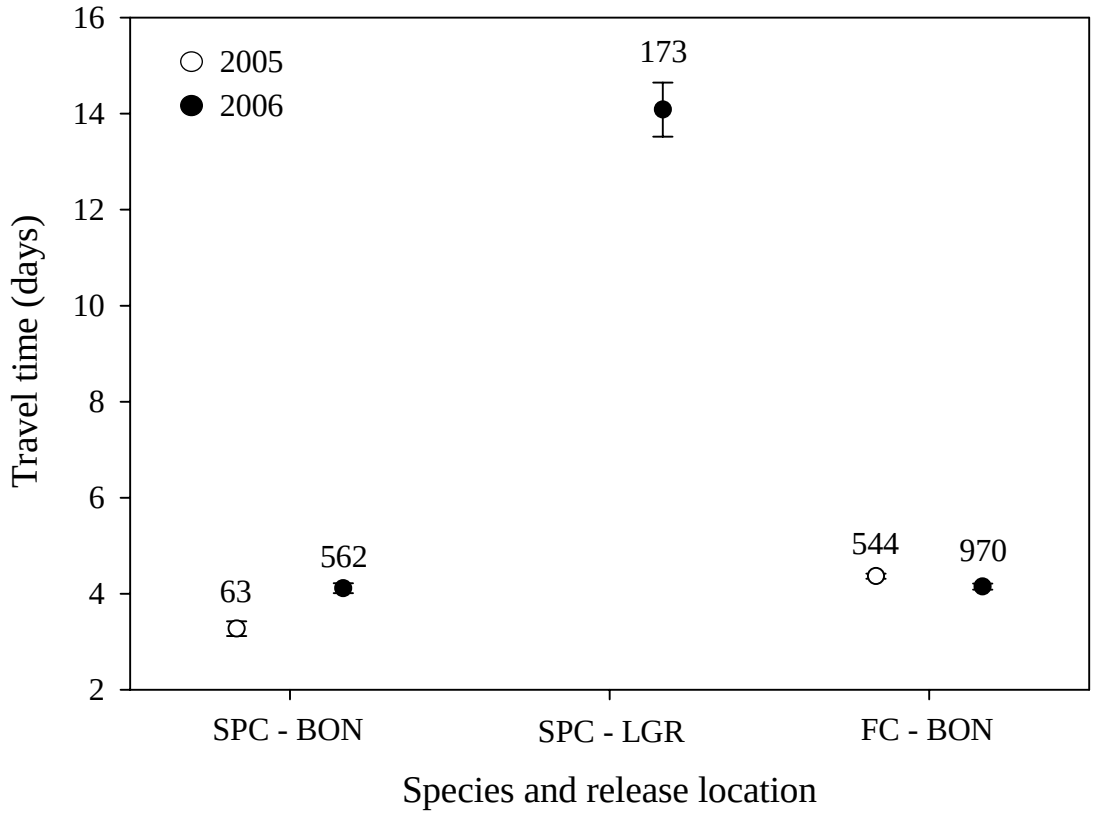

Figure 2. Mean travel time (days ± SE) from release to the estuary primary receiving array of yearling Chinook salmon (SPC) released at Bonneville Dam (BON) and Lower Granite Dam (LGR) and subyearling Chinook salmon (FC) released at Bonneville Dam, 2005 and 2006. The numbers above the points indicate sample size.

Cross-Channel Distribution

The majority of yearling and subyearling Chinook salmon passed the JSATS primary array near the Washington (north) side of the river channel in 2005 (Figure 3). The distribution of yearling and subyearling Chinook salmon across the primary array was similar in 2006 (Figure 4), though it appears somewhat shifted because of the change in location of the array from 2005 to 2006 (in 2005 node 1 was at approximately the same latitude as node 5 in 2006).

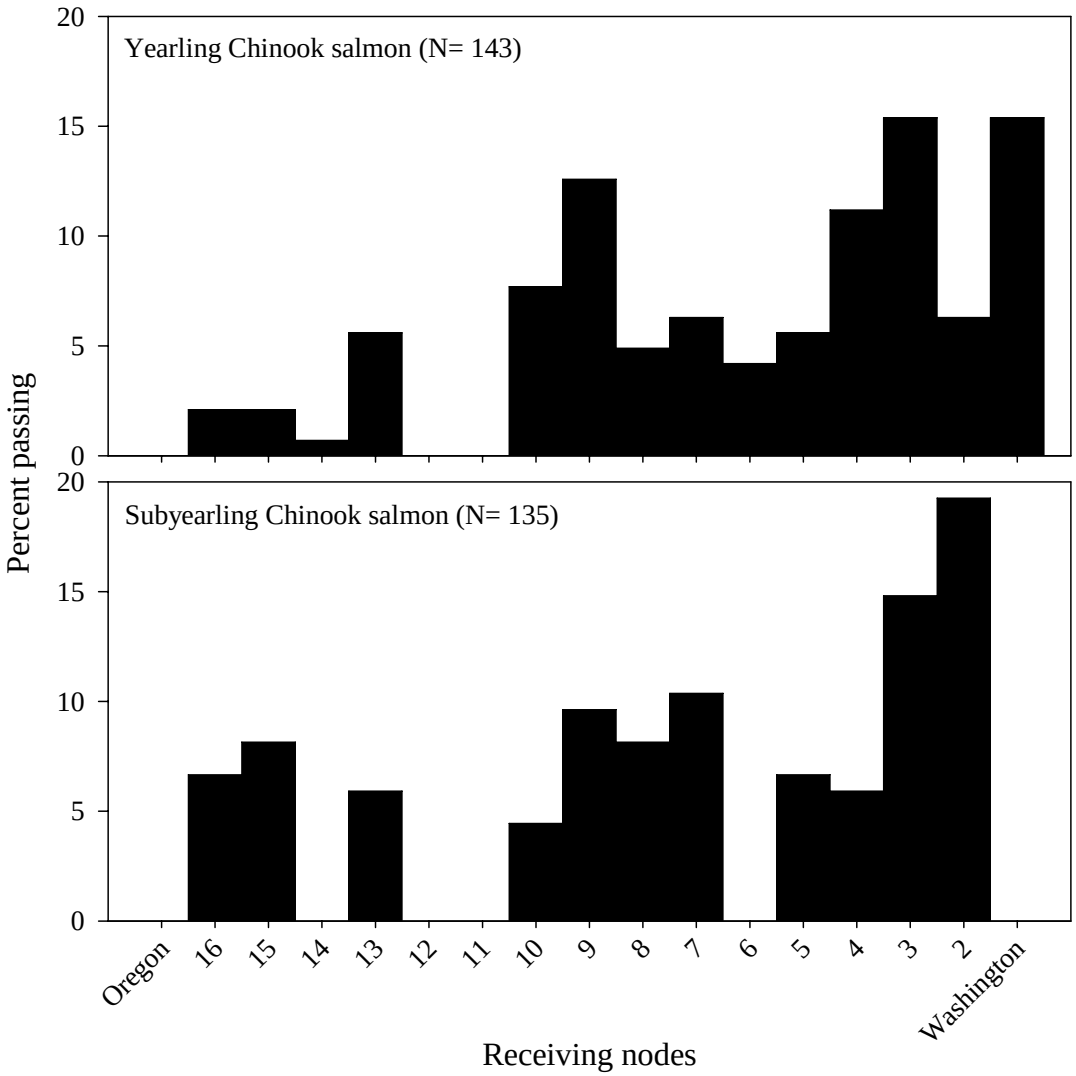

Figure 3. Cross-channel distribution of yearling Chinook salmon (top panel) and subyearling Chinook salmon (bottom panel) at the estuary primary array, 2005. Only data from the cabled array south of the navigation channel and the temporary autonomous array are included. The navigation channel is located between nodes fourteen and fifteen.

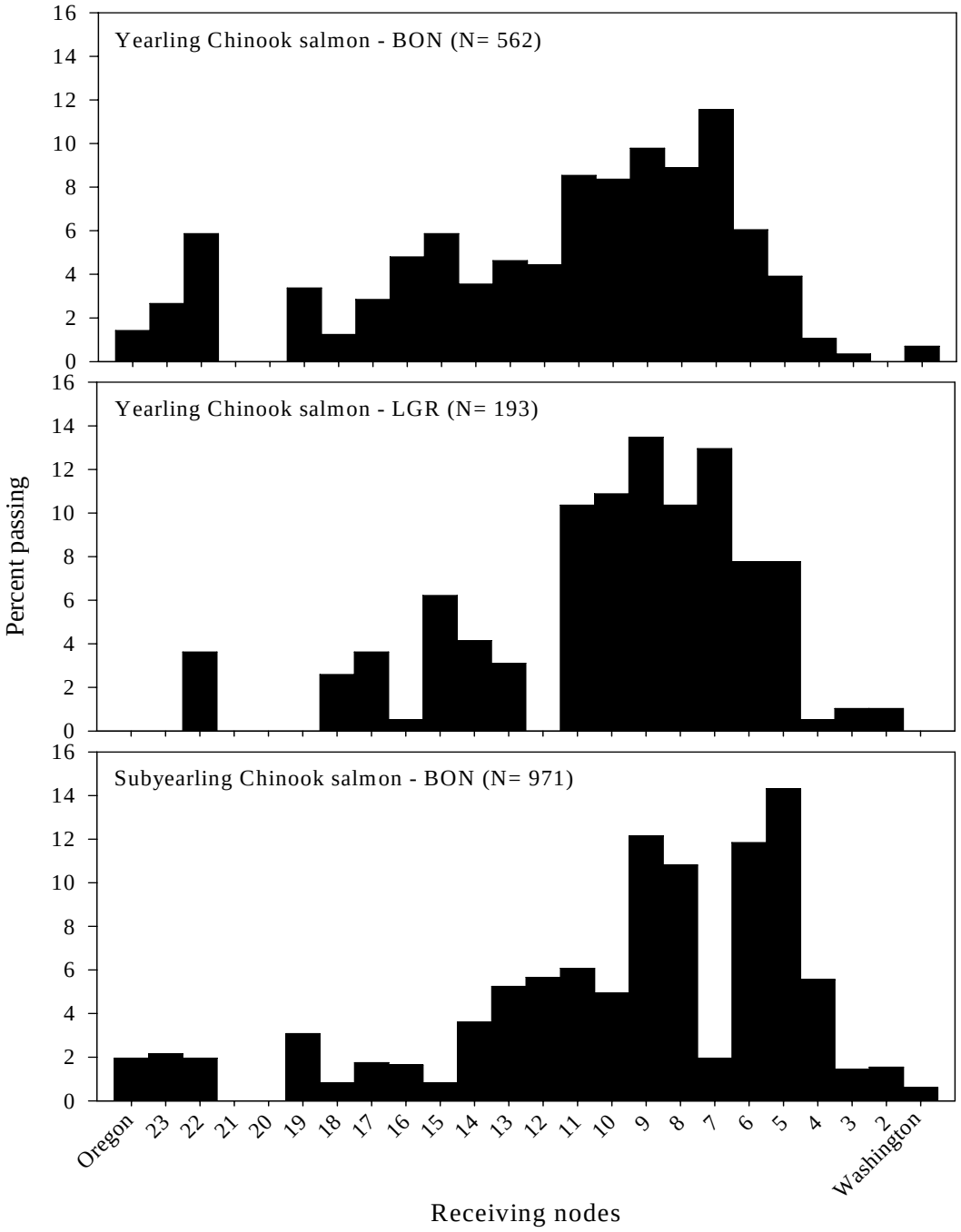

Figure 4. Cross-channel distribution of yearling Chinook salmon released from Bonneville (top panel) and Lower Granite (middle panel) and subyearling Chinook salmon released from Bonneville (bottom panel) at the estuary primary array, 2006. The navigation channel is located between nodes 19 and 22.

Residence Time

Subyearling Chinook salmon spent significantly more time in the MCR area than the larger yearling Chinook salmon in both 2005 and 2006 (Figure 5). This also may be partially due to seasonal differences in river discharge.

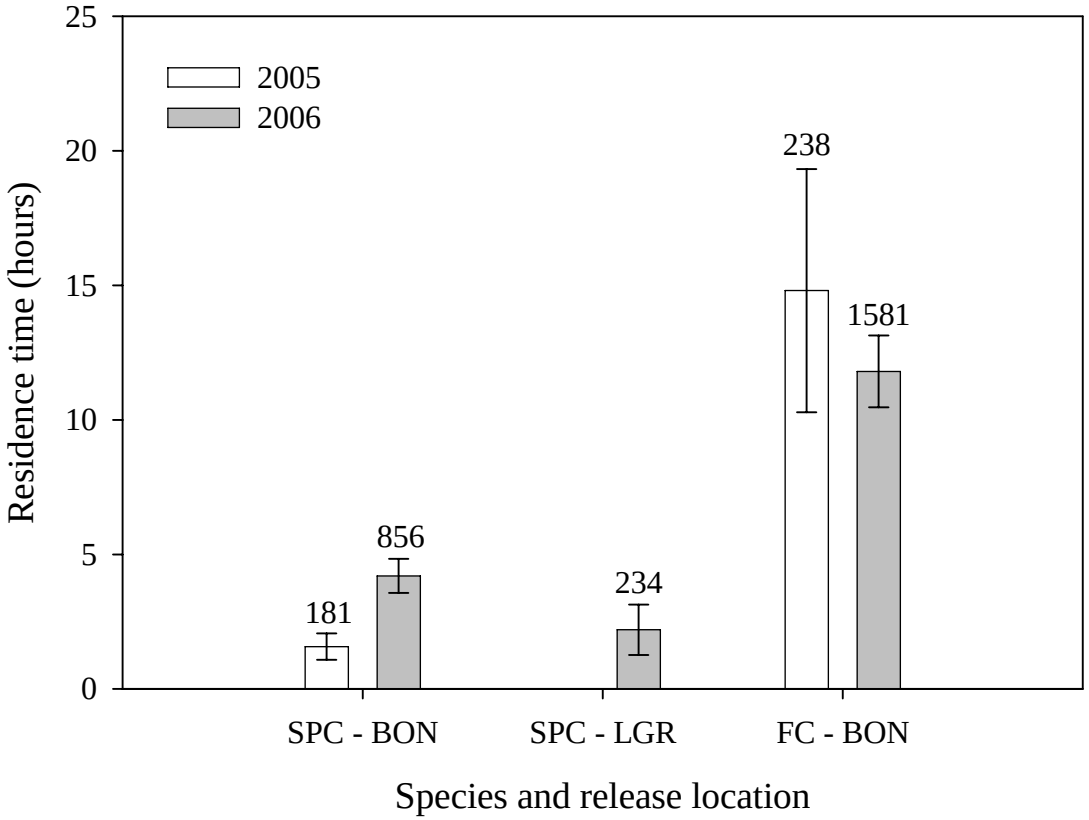

Figure 5. Mean residence times (± SE) at the mouth of the Columbia River (first detection at estuary primary array to last detection at estuary secondary array) for yearling Chinook salmon (SPC) released at Bonneville Dam (BON) and Lower Granite Dam (LGR) and subyearling Chinook salmon (FC) released at Bonneville Dam, 2005 and 2006. Numbers above the points indicate sample size.

Time of Arrival

Both yearling and subyearling Chinook salmon arrived at the MCR area during all hours of the day, but with an increase during daylight hours in both 2005 and 2006 (Figure 6). In 2006, yearling Chinook salmon tended to arrive at the MCR area during hours of daylight more than did subyearling Chinook salmon. However, this may be of limited significance since during this time of year (spring and summer) there are more hours of daylight than darkness. Also, it is likely that time of arrival is confounded by the effect of tide stage on the movement of these fish.

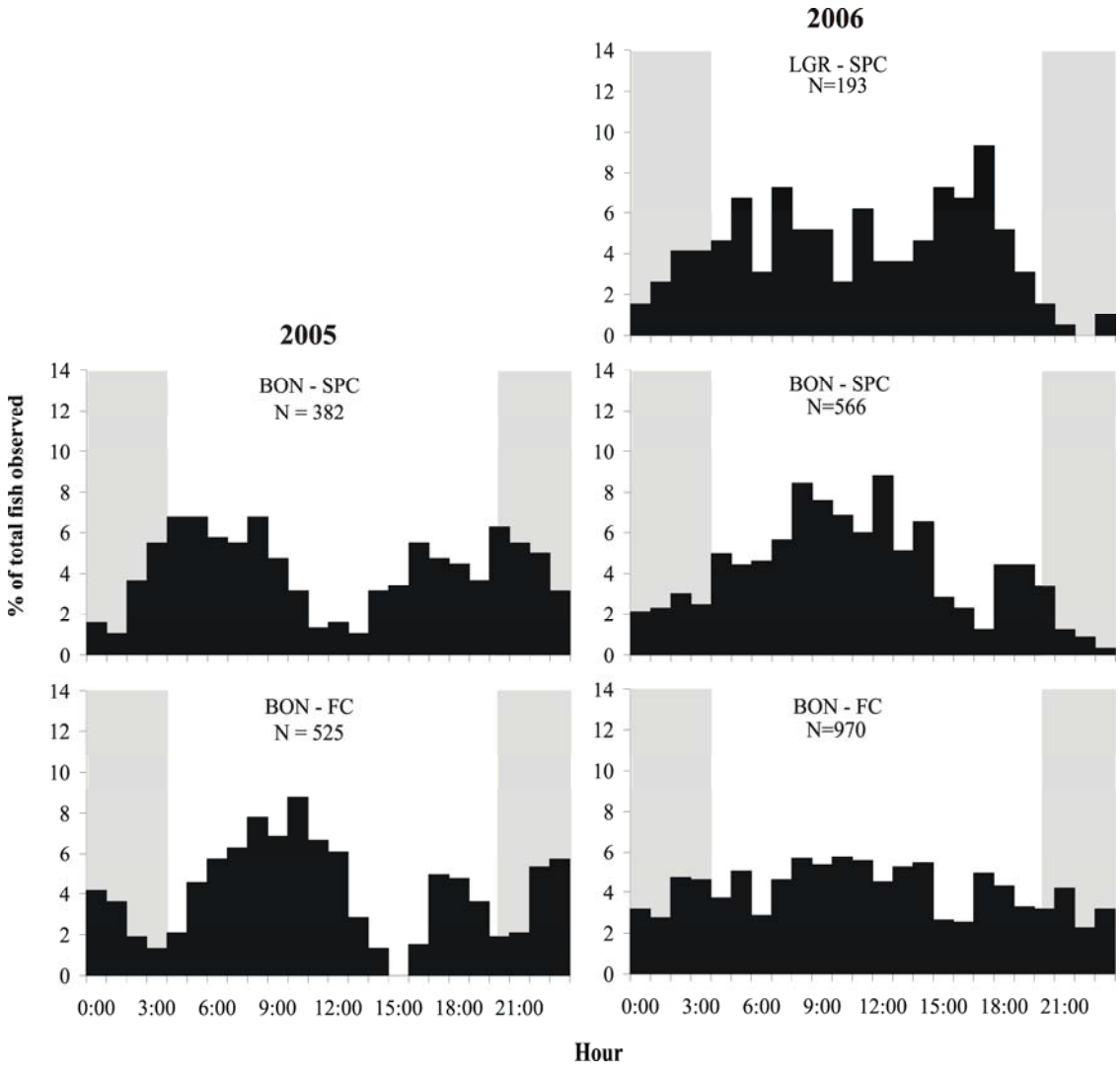

Figure 6. Time of arrival at the Columbia River estuary primary array of yearling Chinook salmon released at Lower Granite Dam in 2006 and yearling and subyearling Chinook salmon released at Bonneville Dam in 2005 and 2006. Shaded bars indicate approximate hours of darkness.

Influence of Tide on Movement

Yearling and subyearling Chinook salmon were most frequently detected for the first time (inferred as having just entering the area) in the MCR area during ebb tide conditions in 2005 and 2006 (Figure 7). These juvenile salmonids tended to take advantage of the higher velocities associated with the period between a high and low tide for the final stages of the freshwater phase of their seaward migration.

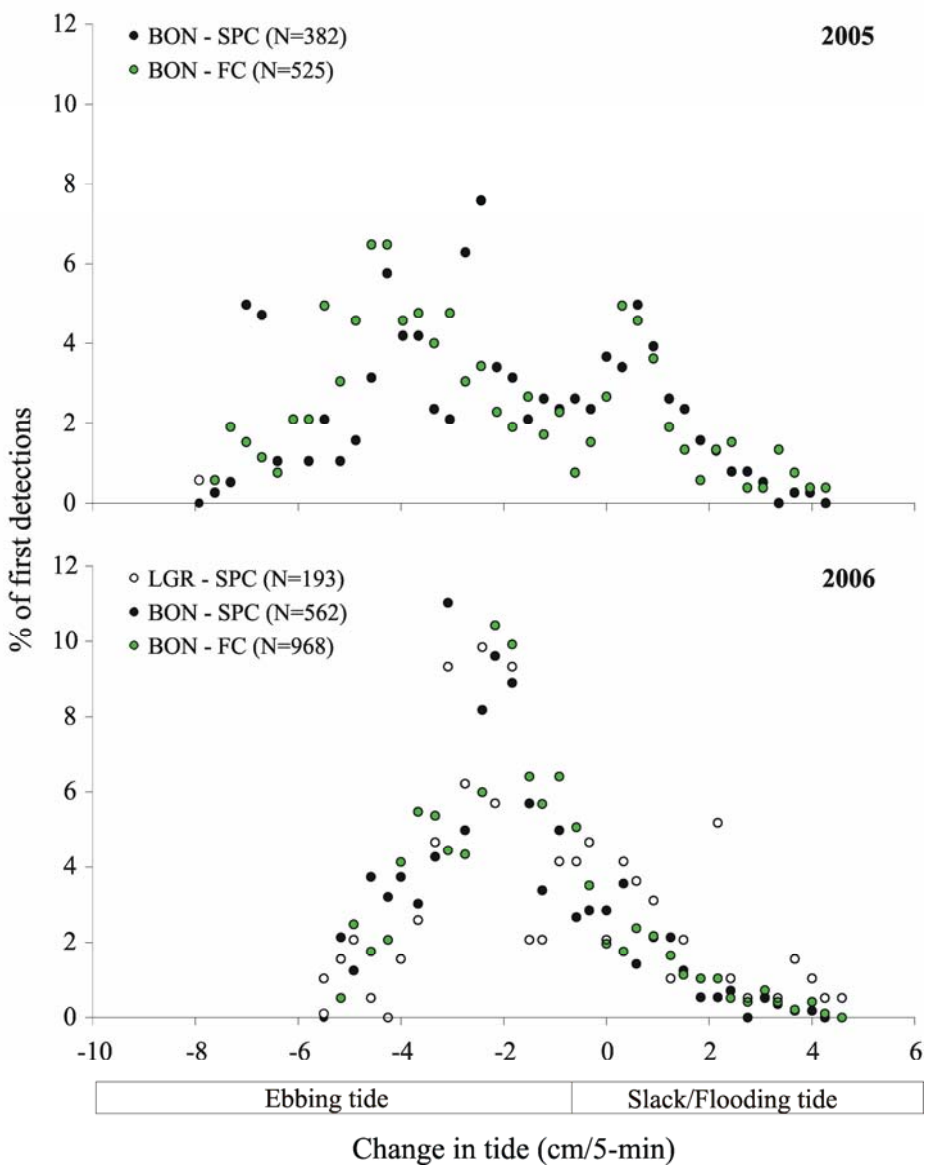

Figure 7. Percentage of first detections of yearling and subyearling Chinook salmon released at Bonneville Dam in 2005 and 2006 and yearling Chinook salmon released at Lower Granite Dam in 2006 versus tide at the estuary primary array.

SUMMARY

In 2005, survival estimates for acoustically-tagged Chinook salmon from release at the Bonneville Dam juvenile fish bypass outfall through the lower Columbia River estuary ranged 0.564 (SE = 0.0683) – 0.873 (SE = 0.0545) for yearling fish and 0.150 (SE = 0.0245) – 0.748 (SE = 0.0497) for subyearling fish. Estimates ranged 0.573 (SE = 0.0362) – 0.841 (SE = 0.0378) for yearling Chinook salmon in 2006, and 0.179 (SE = 0.0410) – 1.005 (SE = 0.0458) for subyearling Chinook salmon. Subyearling Chinook salmon estimates were higher during the early portion of the outmigration, and tended to deteriorate as the season progressed.

In 2006, a pilot study was conducted to explore the feasibility of using JSATS technology to provide FCRPS system-wide survival estimates. For two releases of yearling Chinook salmon to the tailrace of Lower Granite Dam, pooled survival was 0.787 (SE = 0.0147) to the mouth of the Snake River, and 0.384 (SE = 0.0278) to the primary array near the mouth of the Columbia River.

Yearling Chinook salmon released from Bonneville Dam generally traveled faster than subyearling Chinook salmon released from Bonneville Dam in both 2005 and 2006. However, travel time varied by year within species, possibly due to differences in river discharge.

Both yearling and subyearling Chinook salmon tended to migrate on the north (Washington) side of the navigation channel as they approached the Columbia River Bar. The larger yearling Chinook salmon also tended to spend less time in the MCR area and around the receiving array on the Columbia River Bar.

Most of the fish entered the Columbia River Bar area during daylight hours. This finding may be of limited significance for the simple reason that during this time of year (spring and summer) there is more daylight than darkness in this area. Further, entry of these fish into the MCR area may be influenced more by tidal changes than by daylight.

Most juvenile salmonids entered the Columbia River Bar area on an ebb tide. These juvenile fish take advantage of the increased water velocities to pass through this area and into the Columbia River Plume.

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