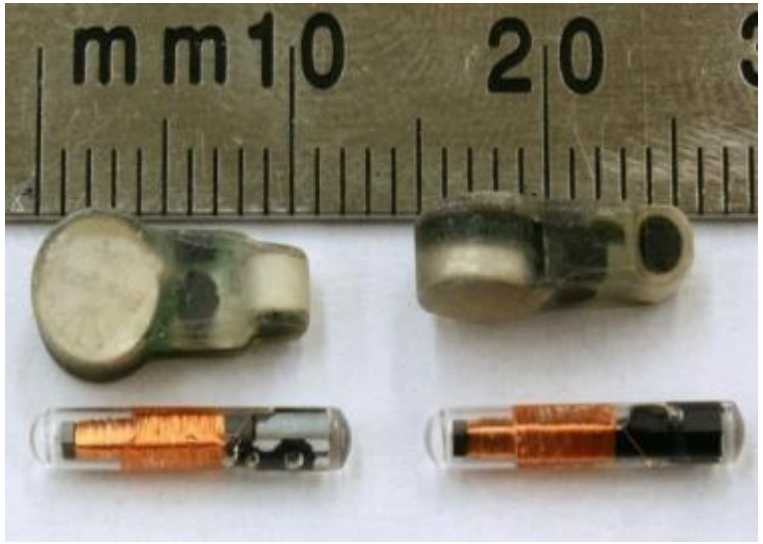
Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Factors affecting route selection and survival of steelhead kelts at Little Goose Dam in 2012 and 2013

RYAN HARNISH
ALISON COLOTELO
XINYA LI
KENNETH HAM
DANIEL DENG

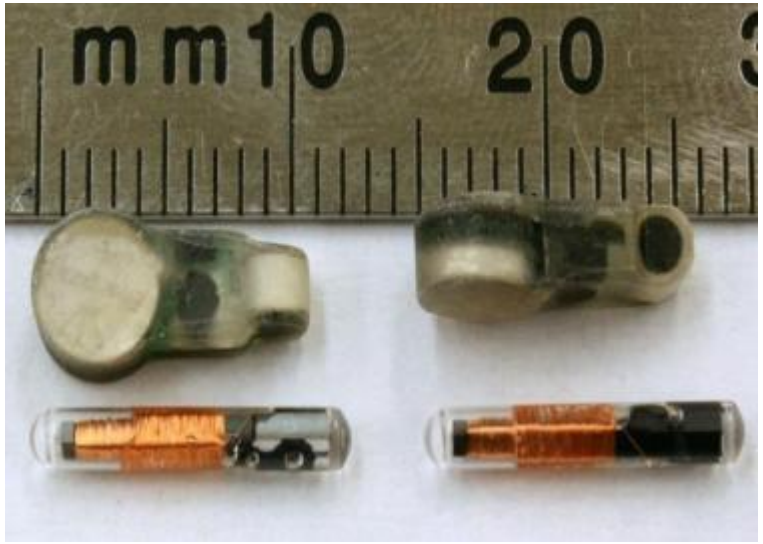
Background

- RPA 33 of 2008 FCRPS BiOp requires measures to increase the iteroparity rates of STH, with particular emphasis on B-run
- 2012 and 2013 juvenile salmon dam passage survival studies conducted at LGS and LMN
- Also wired LGR with cabled JSATS system
- Implanted 811 STH kelts with JSATS and PIT tags at tributary weirs and LGR JBS
  - Only “good” and “fair” condition fish tagged



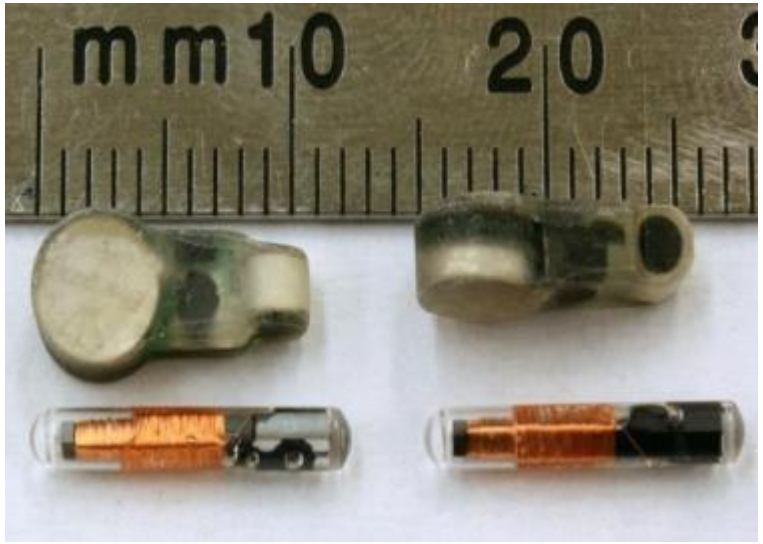
Background

- RPA 33 of 2008 FCRPS BiOp requires measures to increase the iteroparity rates of STH, with particular emphasis on B-run
- 2012 and 2013 juvenile salmon dam passage survival studies conducted at LGS and LMN
- Also wired LGR with cabled JSATS system
- Implanted 811 STH kelts with JSATS and PIT tags at tributary weirs and LGR JBS
  - Only “good” and “fair” condition fish tagged

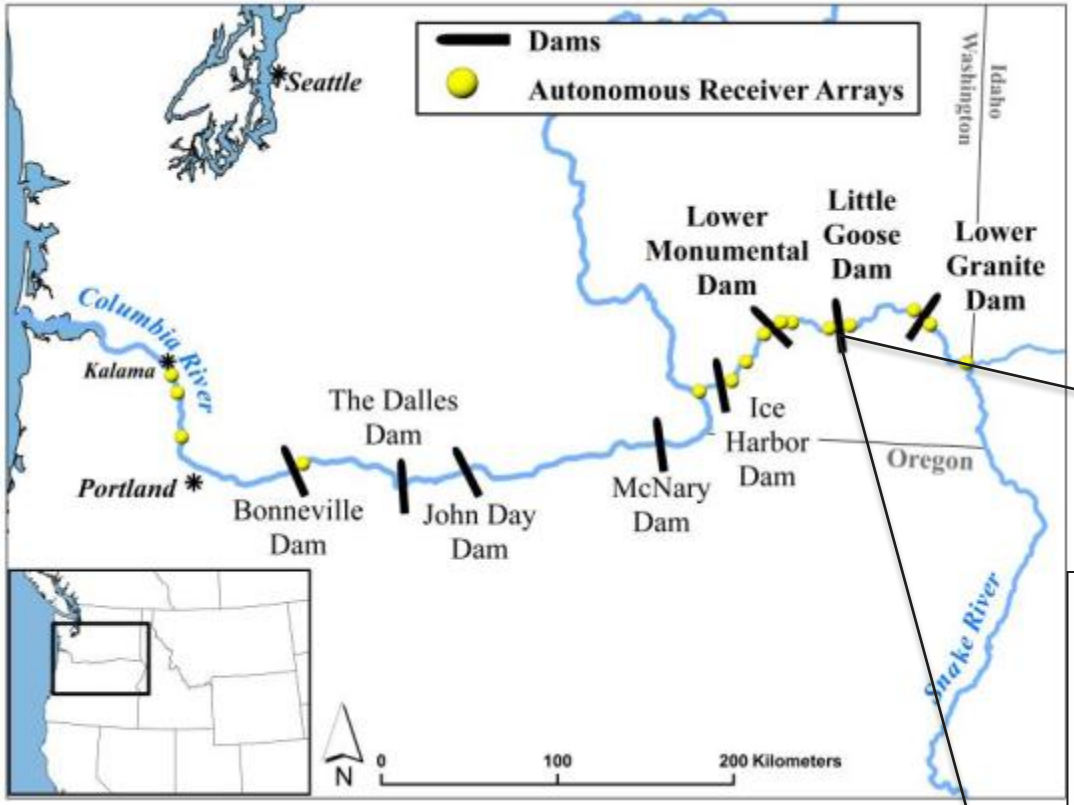


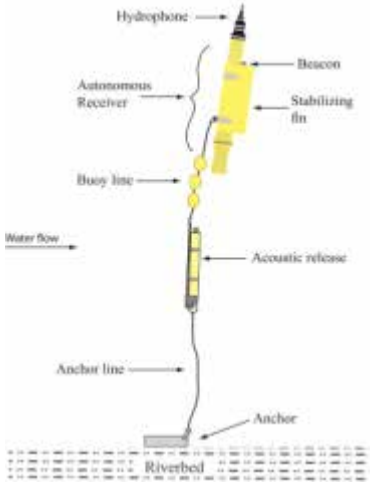
Background

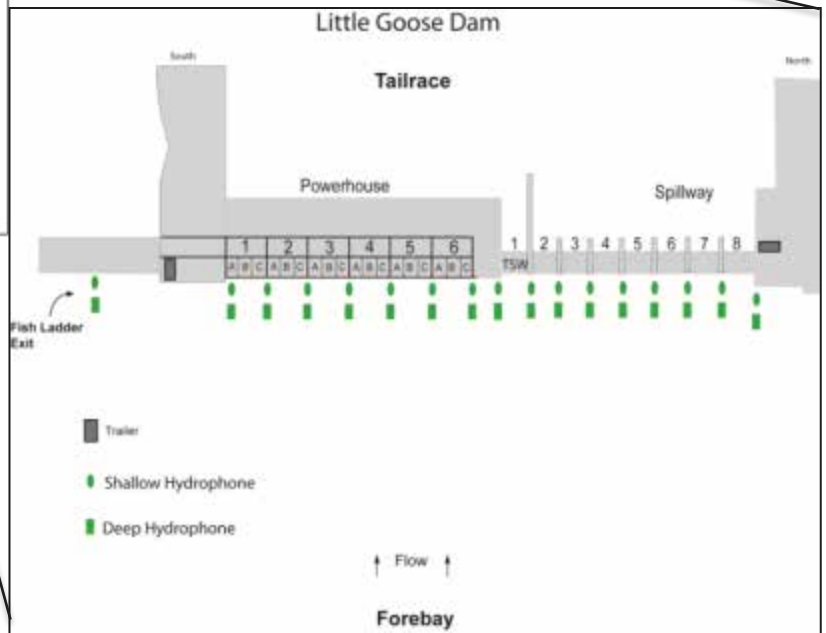
- RPA 33 of 2008 FCRPS BiOp requires measures to increase the iteroparity rates of STH, with particular emphasis on B-run
- 2012 and 2013 juvenile salmon dam passage survival studies conducted at LGS and LMN
- Also wired LGR with cabled JSATS system
- Implanted 811 STH kelts with JSATS and PIT tags at tributary weirs and LGR JBS
  - Only “good” and “fair” condition fish tagged



Background


Dams
Autonomous Receiver Arrays
Seattle
Washington
Idaho
Lower Monumental Dam
Little Goose Dam
Lower Granite Dam
Columbia River
Kalama
The Dalles Dam
Ice Harbor Dam
Oregon
Portland
Bonneville Dam
John Day Dam
McNary Dam
Snake River
N
0
100
200 Kilometers


Hydrophone
Beacon
Autonomous Receiver
Stabilizing fin
Buoy line
Water flow
Acoustic release
Anchor line
Anchor
Riverbed


Little Goose Dam
South
North
Tailrace
Powerhouse
Spillway
1 2 3 4 5 6
1 2 3 4 5 6 7 8
TSW
Fish Ladder Exit
Trailer
Shallow Hydrophone
Deep Hydrophone
Flow
Forebay

Background

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Passage route proportions and survival estimated at LGR, LGS, and LMN in 2012 and 2013

		2012						2013					
Dam	Measure	n	Traditional Spill	Spillway Weir	Turbine	JBS	Unknown	n	Traditional Spill	Spillway Weir	Turbine	JBS	Unknown
LGR	Passage percentage	124	25.8%	57.3%	6.5%	5.6%	4.8%	144	12.5%	79.9%	1.4%	4.9%	1.4%
	Survival (SE)		0.906 (0.052)	0.901 (0.035)	0.875 (0.117)	0.857 (0.132)	–		0.706 (0.111)	0.667 (0.046)	1.000 (0.000)	0.333 (0.193)	–
LGS	Passage percentage	288	24.7%	60.8%	4.5%	10.1%	0.0%	365	15.6%	71.0%	5.2%	6.8%	1.4%
	Survival (SE)		0.943 (0.028)	0.967 (0.014)	0.779 (0.119)	0.966 (0.034)	–		0.821 (0.051)	0.937 (0.015)	0.842 (0.084)	0.880 (0.065)	–
LMN	Passage percentage	258	20.5%	68.0%	4.6%	6.9%	0.0%	294	16.0%	71.1%	6.8%	5.4%	0.7%
	Survival (SE)		0.926 (0.036)	0.983 (0.010)	0.583 (0.142)	1.000 (0.000)	–		0.826 (0.056)	0.927 (0.018)	0.842 (0.084)	0.938 (0.061)	–

- Most kelts passed via spillway weir and traditional (deep) spill routes
- A higher percentage passed via spillway weirs in 2013 compared to 2012
- LGR had the lowest percentage through the JBS of the 3 dams
- Survival was generally highest through spillway weirs and lower in 2013

Objective

- Identify the factors that affected forebay residence time, route of passage, and survival of STH kelts at LGR, LGS, and LMN in 2012 and 2013

Variables: Passage route (*n* = 678)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Individual
  - Fork length
  - Condition (good/fair)
  - Relative condition
- Behavioral
  - Median depth in FB
  - Cross-sectional approach location
  - Near-dam searching
  - Total “Y” distance traveled
  - Forebay residence time
- Temporal
  - Ordinal day of dam passage
  - Diel passage (day/night)
- Environmental
  - FB water temperature at 1.5 m, 15 m, and 30 m
  - FB water temperature ratio (1.5 m / 30 m)
  - FB TDG%
  - Total discharge
- Operational
  - % of total discharge through each route
  - % spill
  - Spillway weir crest position (high/low)

Variables: Survival (*n* = 678)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Individual
  - Fork length
  - Condition (good/fair)
  - Relative condition
- Behavioral
  - Tailrace egress time
- Temporal
  - Ordinal day of dam passage
  - Diel passage (day/night)
- Environmental
  - Tailrace water temperature
  - TR TDG%
  - Total discharge
- Operational
  - % of total discharge through each route
  - % spill
  - Spillway weir crest position (high/low)

Methods

- Transformations (FB residence time, TR egress time, total "Y" distance traveled)
- Relationship between each variable and passage route and survival evaluated for strength, direction using logistic regression
  - Passage route: probability of passing through a particular route vs. all other routes
    - Spillway weir, traditional (deep) spill, JBS, turbines
  - Survival: probability of surviving to and being detected by array located 33 km downstream ($p \geq 0.95$) or any other downstream array
    - Overall survival (all routes), spillway weir survival
- Correlated variables ($\alpha = 0.10$) retained for inclusion in multivariable logistic regression model
- Bayesian model averaging used to identify the models that "best" explained route selection and survival
- Pairwise correlations assessed for multicollinearity
  - Model re-run if necessary

Passage routes: Spillway weir

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- "Best" 2 models
  - Kelts that migrated shallower were more likely to pass via the weir
  - Kelts that did more near-dam searching were more likely to pass via the weir
  - Kelts that passed LGS when the % discharge through spill bay 5 was high were less likely to pass via the weir
  - Kelts in good condition were more likely to pass via the weir than fair condition kelts

Variable	Probability	Direction
Median depth[1,2]	1.00	+
Near-dam searching[1,2]	1.00	+
S5 % Q[1]	0.63	–
Condition[2]	0.48	Good > Fair
Model 1 Posterior probability	**0.16**	
Model 2 Posterior probability	**0.16**	

Passage routes: Deep spill

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- "Best" model
  - Kelts approaching on spillway-side of river more likely to pass via deep spill
  - Kelts that did less travelling back-and-forth across the FB were more likely to pass via deep spill
  - Kelts that passed LGS when the % discharge through spillbay 2 was high were more likely to pass via deep spill

Variable	Probability	Direction
Approach location	1.00	+
"Y" distance	1.00	–
S2 % Q	0.40	+
Model Posterior probability	**0.21**	

Passage routes: JBS

- "Best" model
  - Kelts approaching on PH-side of river more likely to pass via the JBS
  - Kelts that did less near-dam searching were more likely to pass via the JBS
  - Kelts migrating at greater depths were more likely to pass via the JBS

Variable	Probability	Direction
Approach location	1.00	–
Near-dam searching	1.00	–
Median depth	1.00	–
Model Posterior probability	**0.33**	

Passage routes: Turbines

- "Best" model
  - Kelts migrating at greater depths were more likely to pass via turbines
  - Kelts approaching on PH-side of river more likely to pass via turbines
  - Kelts that did less near-dam searching were more likely to pass via turbines

Variable	Probability	Direction
Median depth	1.00	–
Approach location	1.00	–
Near-dam searching	0.89	–
Model Posterior probability	**0.73**	

Survival: All routes (*n* = 676)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- "Best" 2 models
  - Kelts in good condition were more likely to survive than those in fair condition
  - Kelts that passed LGS when the % of discharge through turbine unit 4 was high were more likely to survive
  - Kelts that passed LGS when discharge was high were more likely to survive

Variable	Probability	Direction
Condition[1,2]	1.00	Good > Fair
T4 % Q[1]	0.60	+
Discharge (Q)[2]	0.50	+
Model 1 Posterior probability	**0.37**	
Model 2 Posterior probability	**0.25**	

Survival: Spillway weir (*n* = 443)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- "Best" 3 models
  - Kelts that passed via the weir when the % of discharge through turbine unit 2 was high were less likely to survive
  - Smaller kelts were more likely to survive than larger kelts
  - Kelts in good condition were more likely to survive than those in fair condition

Variable	Probability	Direction
T2 % Q[1,2,3]	0.76	–
FL[1,3]	0.46	–
Condition[3]	0.44	Good > Fair
Model 1 Posterior probability	**0.10**	
Model 2 Posterior probability	**0.09**	
Model 3 Posterior probability	**0.09**	

Survival: All other routes

- Too few kelts passed or died during passage through the other routes to assess variable effects on route-specific survival
  - Deep spill: n = 129
  - JBS: n = 54
  - Turbines: n = 33

Conclusions: Passage routes

- Kelt behavior influenced route of passage more than individual characteristics, environmental conditions, or dam operations
  - Depth influences passage route
    - Deeper-migrating kelts more likely to pass via powerhouse routes
    - Shallower-migrating kelts more likely to pass via spillway weir
  - Side of the river in which kelts approached the dam influenced passage route
    - Kelts approaching on the spillway side more likely to pass via deep spill
    - Kelts approaching on the PH side more likely to pass via PH routes
  - “Searching” activity affects passage route
    - Kelts that did more searching along the dam face more likely to pass via spillway weir
    - Kelts that did less searching more likely to pass via deep spill and PH routes
- Operational influences less apparent
  - A greater % of discharge through deep spill routes may result in more kelt using those routes and fewer using the weir

Conclusions: Survival

- Individual characteristics, and operational and environmental conditions affected survival
  - Condition (good/fair) had the greatest effect on overall survival (all routes) and spillway weir survival
    - Good condition kelts were more likely to survive
  - Some evidence that smaller kelts had a higher probability of surviving spillway weir passage than larger kelts
  - Dam operations may have also influenced survival
    - Relatively large uncertainty associated with these models

Update on Returning Fish

- 2012 cohort: 4 of 324 (1.2%) returned to LGR
  - 3 females and 1 male
- 2013 cohort: 1 of 487 (0.2%) returned to BON
  - Female
- Lower than pre-dam repeat spawning rates (2%; Long and Griffin 1937)

- All fish:
  - Displayed a skip spawning life history strategy
    - Spent ~ 1 year in ocean before returning
  - Were in good condition at the time of tagging
  - Had an intact adipose fin

Management implications

- Relatively little can be done with operations to influence passage route selection (under the conditions studied)
  - Implications for collecting kelts for reconditioning
- Fair condition and larger kelts had a lower probability of survival
  - Implications for which kelts should be retained for reconditioning

- Reconditioning may be the best option for increasing iteroparity, particularly for larger B-run steelhead
  - Expand collection to tributary weirs and LGS JBS
  - An evaluation of post-reconditioning is needed
    - Fecundity, migration to spawning grounds, successful spawning

Acknowledgements

- **USACE:** C. Pinney, D. Fryer, B. Eppard, M. Halter, W. Gerbasch, R. Hilt, R. Lustig, R. Bliss
- **Nez Perce Tribe:** S. Everett, P. Kucera, J. Hatch
- **CRITFC:** N. Graham
- **Idaho Fish and Game:** B. Bowersox, T. Copeland, M. Corsi
- **WDFW:** E. Crawford
- **Cascade Aquatics:** B. James, E. Green
- **PSMFC:** G. Batten, S. Carpenter, D. Etherington, T. Mitchell, K. Prather, D. Trott
- **PNNL:** T. Abel, E. Arntzen, B. Bellgraph, R. Brown, G. Dirkes, E. Fischer, D. Geist, M. Greiner, K. Hand, A. Hanson, J. Hughes, J. Ingraham, B. Jeide, B. Jones, R. Klett, J. Kim, K. Larson, A. LeBarge, J. Martinez, S. Matzner, G. McMichael, R. Mueller, E. Oldenburg, B. Pflugrath, C. Price, B. Rayamajhi, H. Ren, G. Squeochs, J. Stephenson, C. Swartout, S. Titzler, R. Walker, M. Weiland, C. Woodley, J. Xu