Attachment 1

Rocky Reach Reservoir White Sturgeon Monitoring and Evaluation Program, 2016

P.U.D.
CHELAN COUNTY

Rocky Reach Reservoir
White Sturgeon Monitoring
and Evaluation Program 2016

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November 1st, 2017

BLUE LEAF ENVIRONMENTAL

LGL LIMITED environmental research associates

Columbia Research

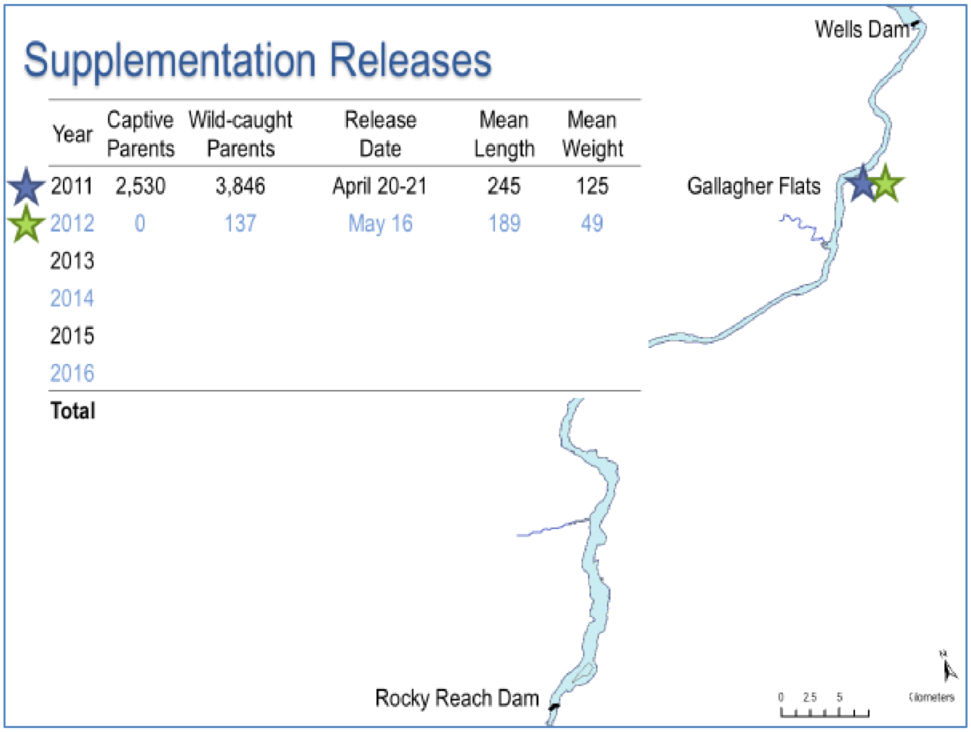
White Sturgeon Management Plan

- Need for supplementation identified and management plan adopted with overall goal of

  > "*promoting white sturgeon population growth in the Rocky Reach Reservoir to a level that is commensurate with available habitat*"

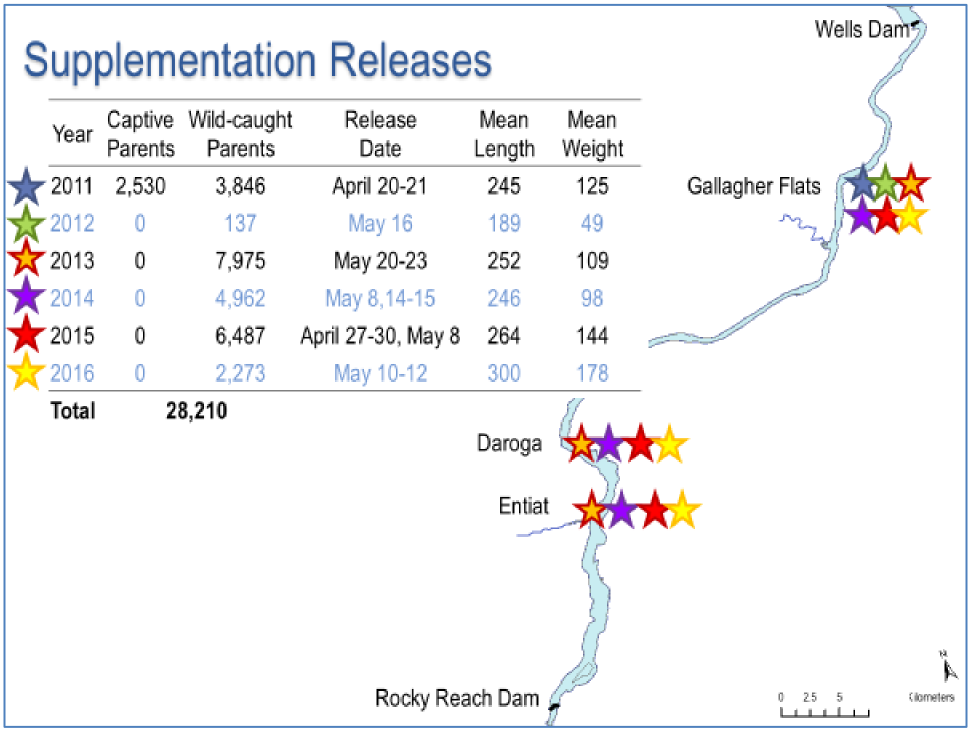
- **Supplementation Program** began in 2010 with first broodstock collection (first released in 2011)
- **Monitoring and Evaluation Program** began in 2012

Supplementation Program



Supplementation Releases

Year	Captive Parents	Wild-caught Parents	Release Date	Mean Length	Mean Weight
★ 2011	2,530	3,846	April 20-21	245	125
★ 2012	0	137	May 16	189	49
2013					
2014					
2015					
2016					
Total					



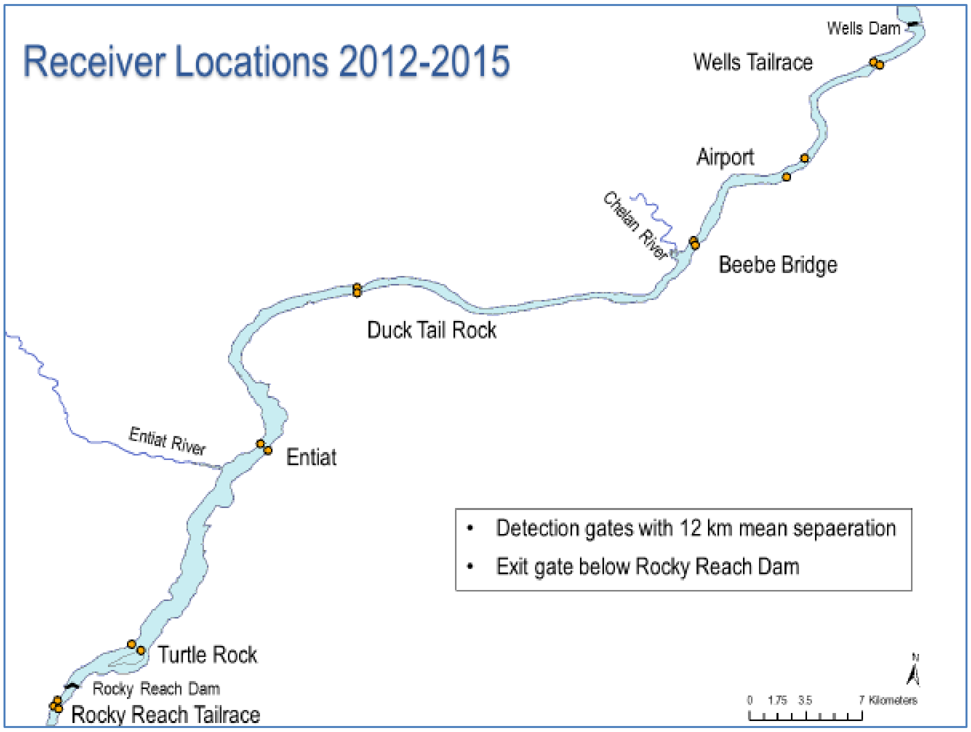
Supplementation Releases

Year	Captive Parents	Wild-caught Parents	Release Date	Mean Length	Mean Weight
★ 2011	2,530	3,846	April 20-21	245	125
★ 2012	0	137	May 16	189	49
★ 2013	0	7,975	May 20-23	252	109
★ 2014	0	4,962	May 8,14-15	246	98
★ 2015	0	6,487	April 27-30, May 8	264	144
★ 2016	0	2,273	May 10-12	300	178
Total		**28,210**			

Monitoring and Evaluation Program

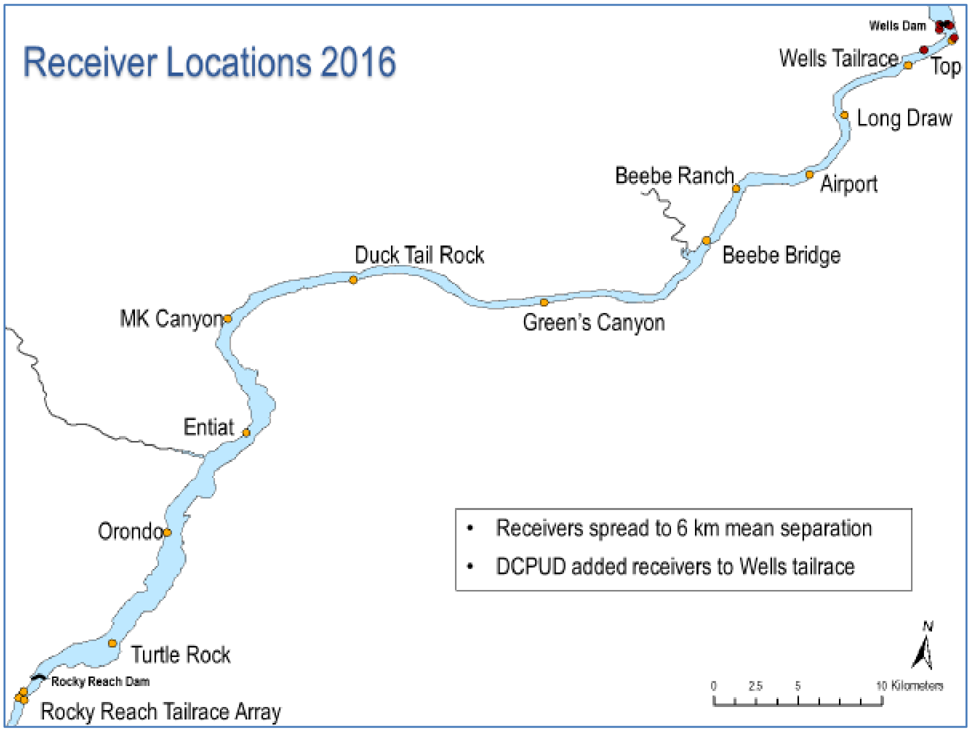
- **Acoustic Telemetry Study**: tracking tagged fish to determine emigration rates (part of survival analysis), investigate behavior & look at habitat use (2012 – 2016)
- **Indexing Study**: random sampling & mark-recapture study to look at survival, growth, and distribution (2013 - 2016)
- **Diet Study**: rod and reel angling with gastric lavage to determine diet of supplementation sturgeon (2016)

Acoustic Telemetry Study



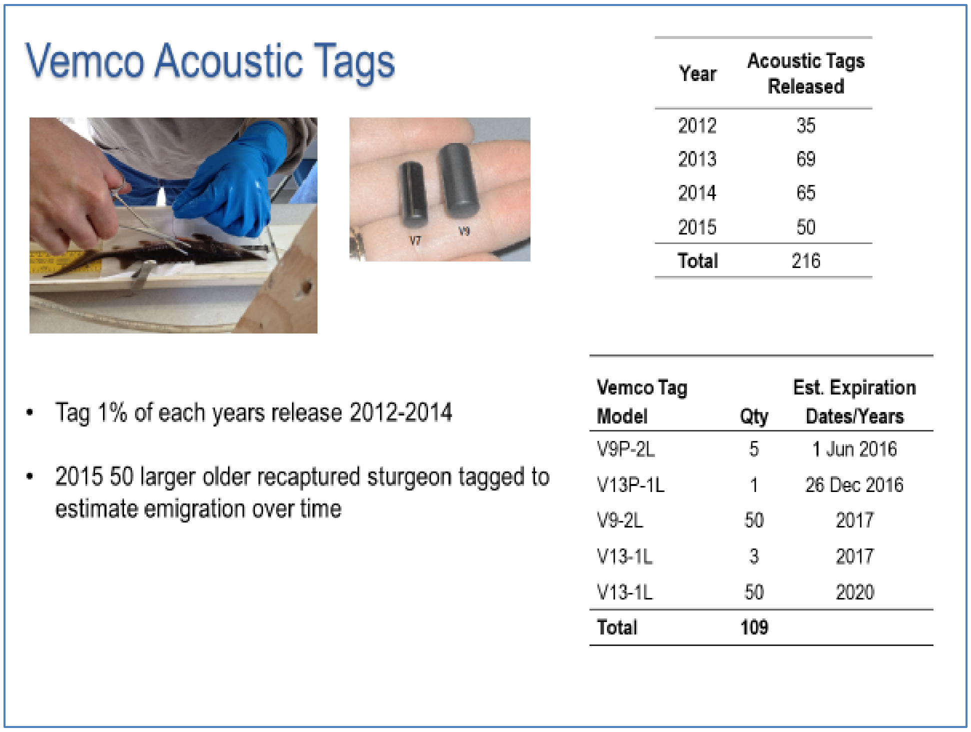
Receiver Locations 2012-2015

- Detection gates with 12 km mean sepaeration
- Exit gate below Rocky Reach Dam



Receiver Locations 2016

- Receivers spread to 6 km mean separation
- DCPUD added receivers to Wells tailrace

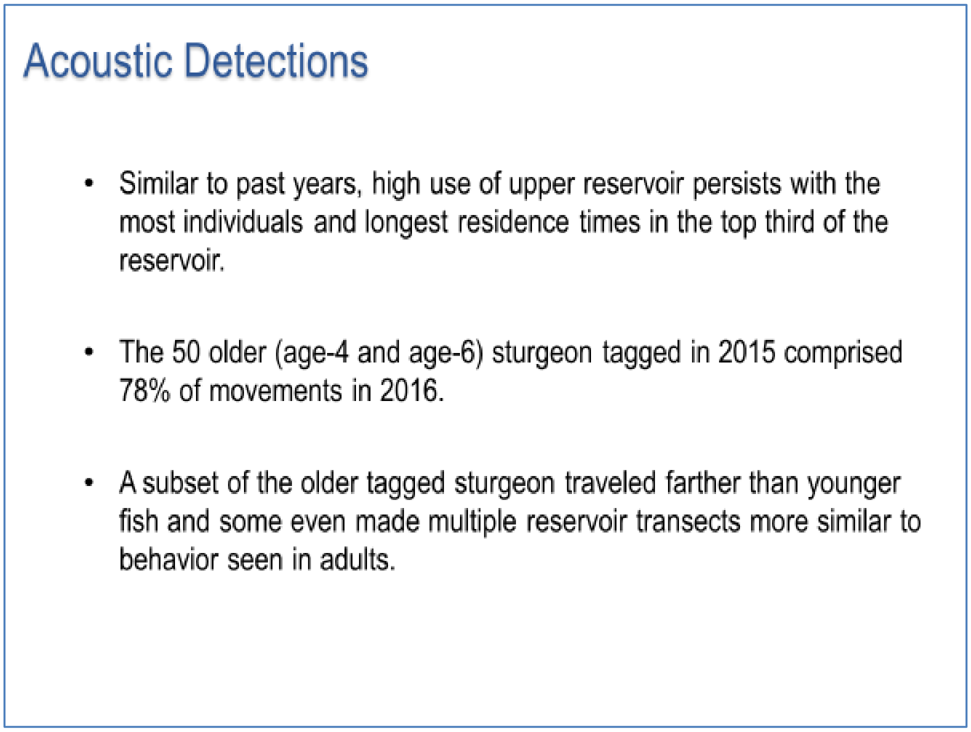


Vemco Acoustic Tags

Year	Acoustic Tags Released
2012	35
2013	69
2014	65
2015	50
Total	216

- Tag 1% of each years release 2012-2014
- 2015 50 larger older recaptured sturgeon tagged to estimate emigration over time

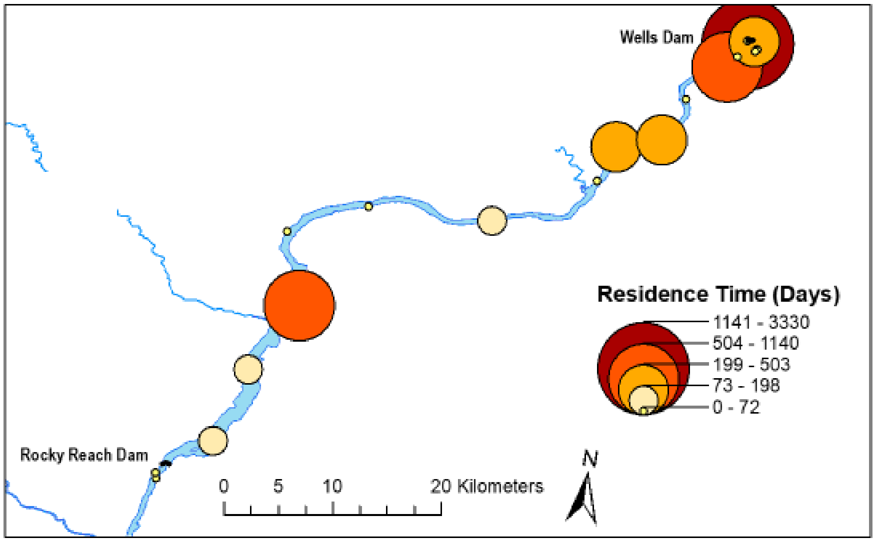
Vemco Tag Model	Qty	Est. Expiration Dates/Years
V9P-2L	5	1 Jun 2016
V13P-1L	1	26 Dec 2016
V9-2L	50	2017
V13-1L	3	2017
V13-1L	50	2020
Total	**109**	

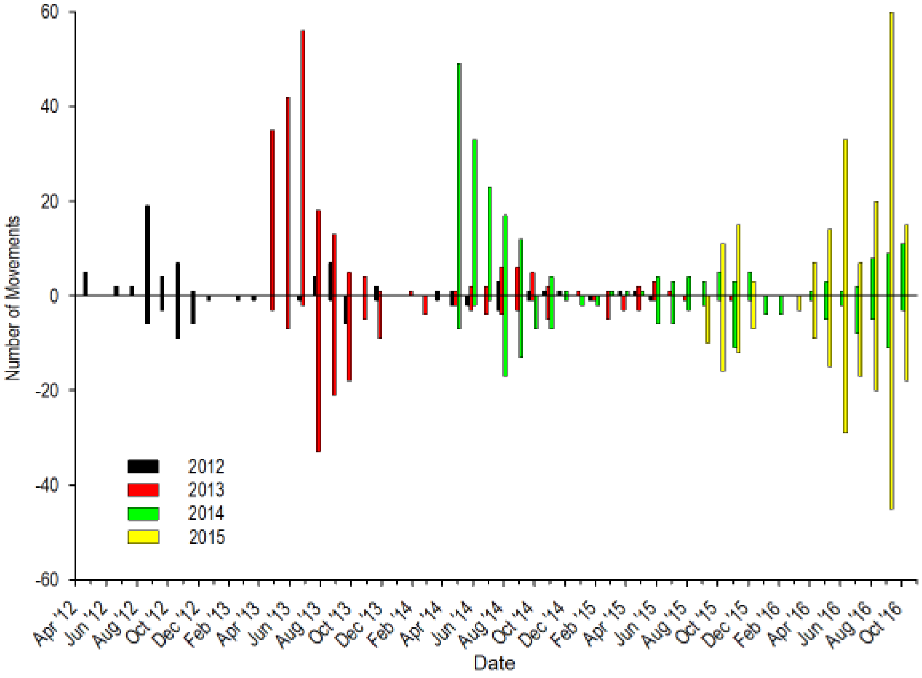


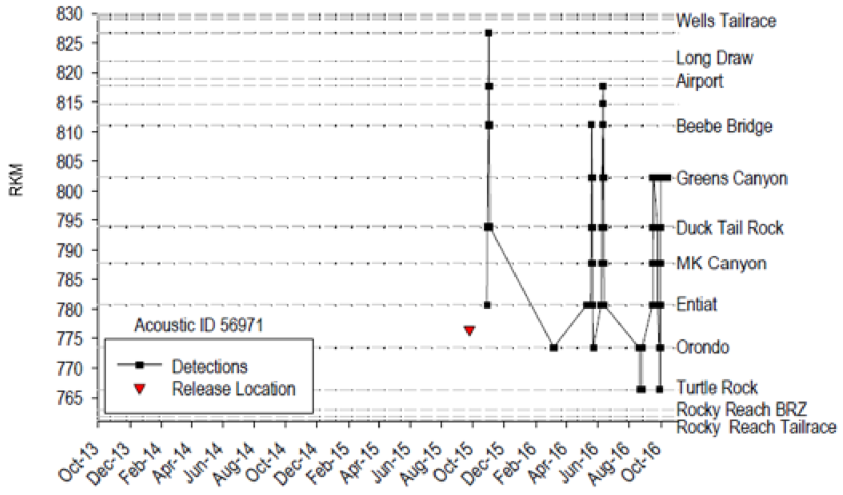
Acoustic Detections

- Similar to past years, high use of upper reservoir persists with the most individuals and longest residence times in the top third of the reservoir.
- The 50 older (age-4 and age-6) sturgeon tagged in 2015 comprised 78% of movements in 2016.
- A subset of the older tagged sturgeon traveled farther than younger fish and some even made multiple reservoir transects more similar to behavior seen in adults.

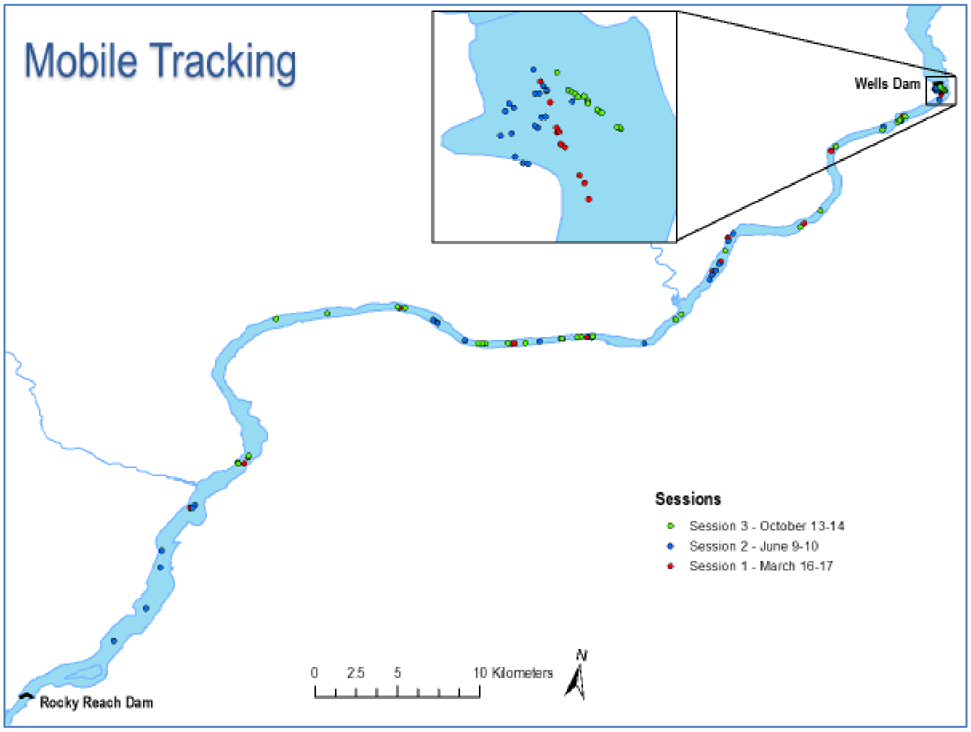
Residence Time



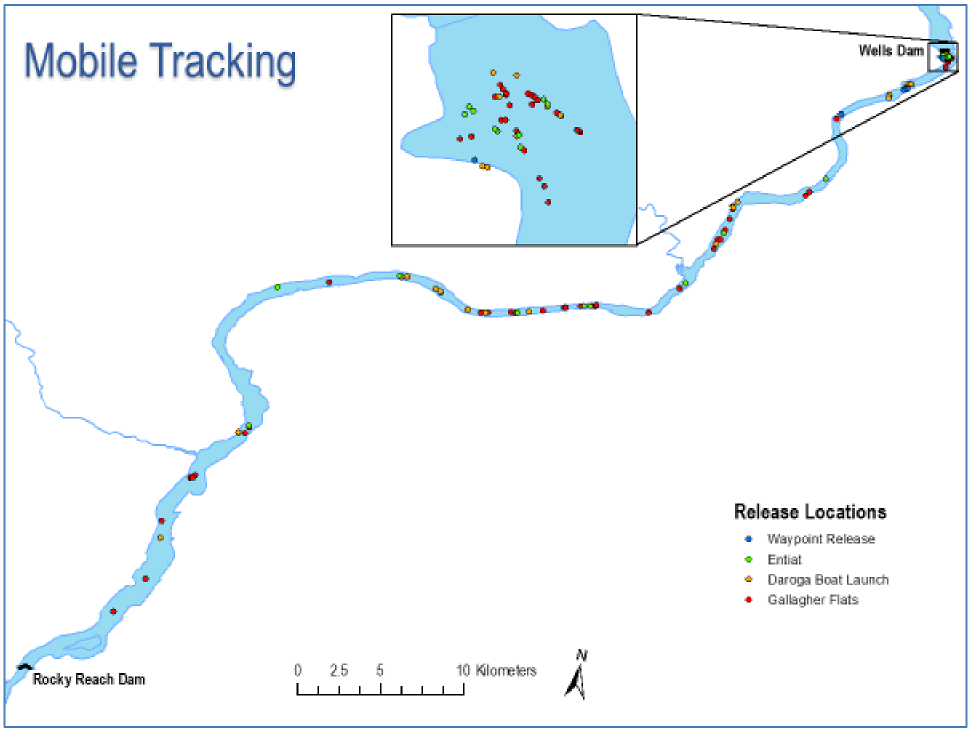




Mobile Tracking

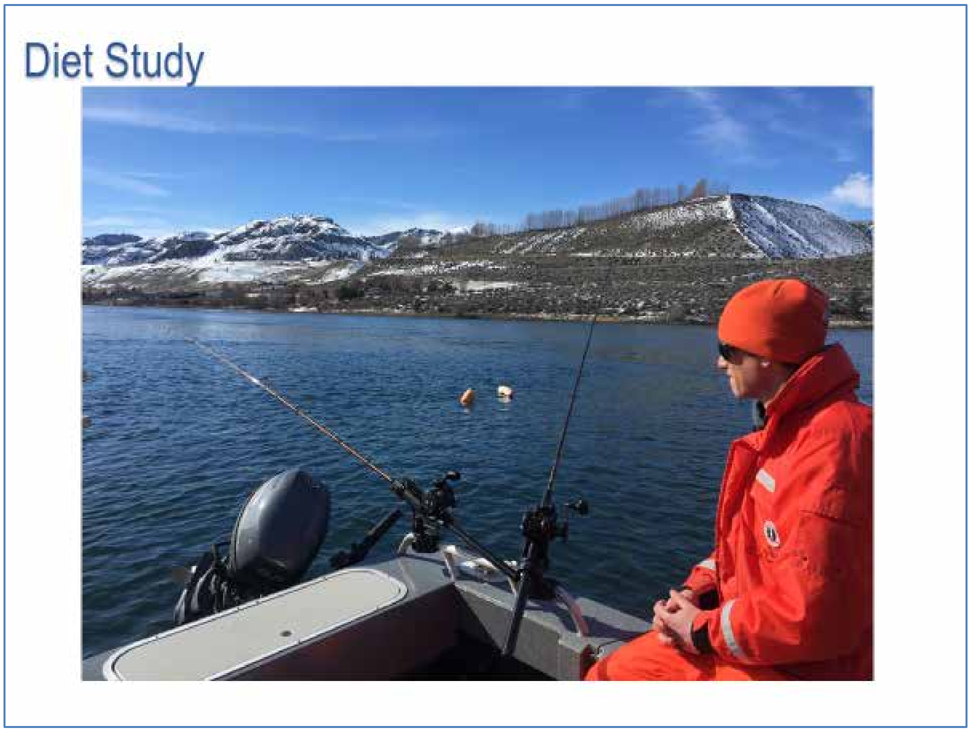


Mobile Tracking



Emigration

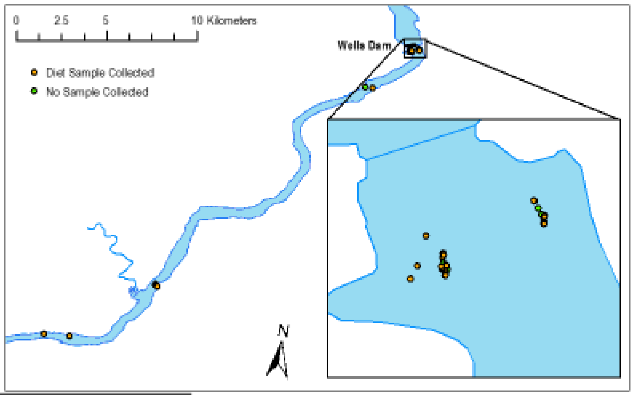
						Hypothetical: 10,000 Fish Released	
Time Interval	**Months After Release from Hatchery**	**Average Number of Active Tags**	**Total # of Emigration Events**	**Emigration Proportion**	**Equivalent Emigration Rate (% per year)**	***Emigrated***	***Remained***
Before 1st index	1-3	137.5	2	1.45%	5.82%	*145*	*9,855*
1st - 2nd index	5-15	118.0	3	2.54%	2.54%	*250*	*9,605*
2nd - 3rd index	16-27	127.8	3	2.35%	2.35%	*226*	*9,379*
After 3rd index	28+	95.1	2	2.10%	2.10%	*197*	*9,182*
TOTAL			**10**			***818 of 10,000 (8.2%)***	



Diet Study

Diet Study

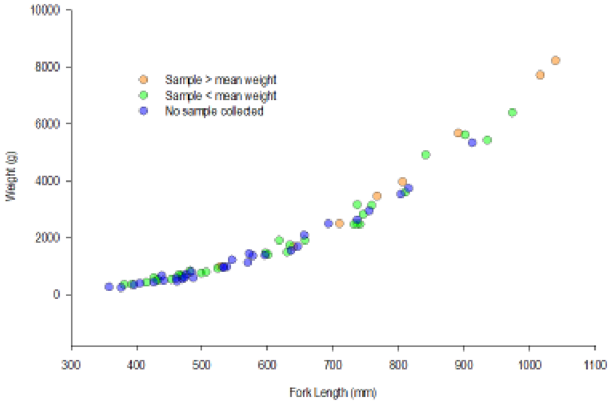
Diet Fishing

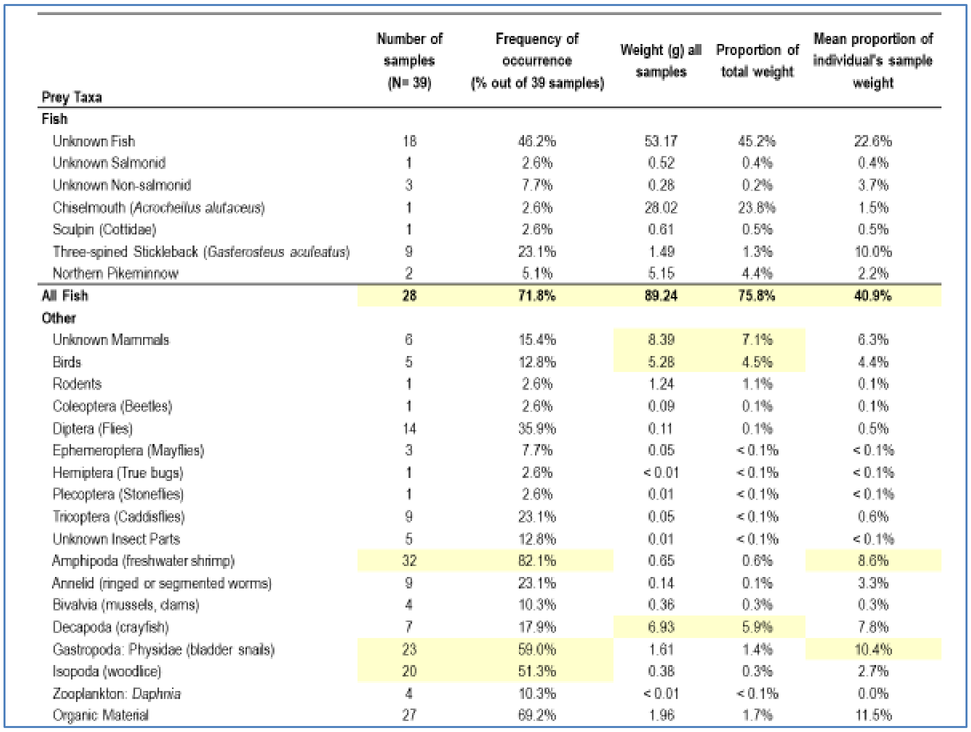


Category	Days fished	Catch	Samples Collected	'Non-empty' samples/day
Reservoir Zone				
Upper Reservoir	4	68	37	9.3
Mid-Reservoir North	1.3	2	2	1.5
Mid-Reservoir South	1.3	0	0	0.0
Lower Reservoir	2.3	0	0	0.0
Session				
18-20 April 2016	3	14	8	2.7
17-19 July 2016	3	27	13	4.3
19-21 October 2016	3	29	18	6.0
Totals	**9**	**70**	**39**	**4.3**

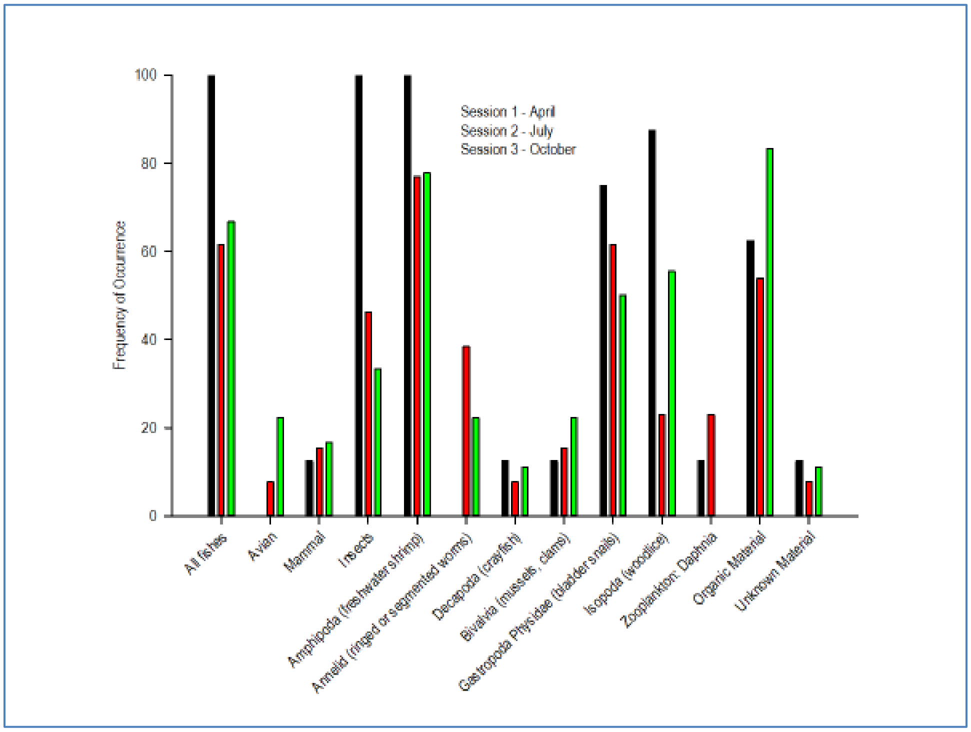
Diet Fishing

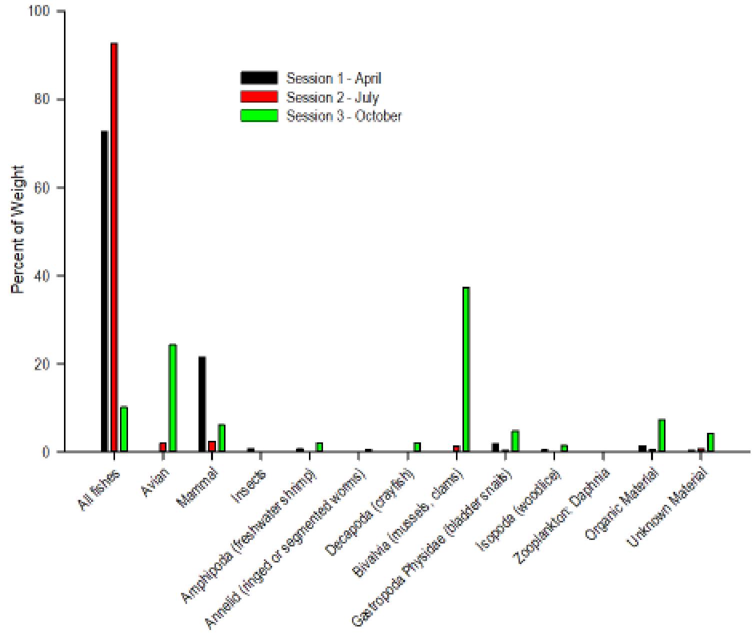
Release Year	Age	Catch	Empty Stomachs	'Non-empty' Samples Collected
2011	6	21	9	12
2012	5	1	0	1
2013	4	39	18	21
2014	3	2	2	0
2015	2	0	0	0
2016	1	3	2	1
Unknown		4	0	4
Total		**70**	**31**	**39**





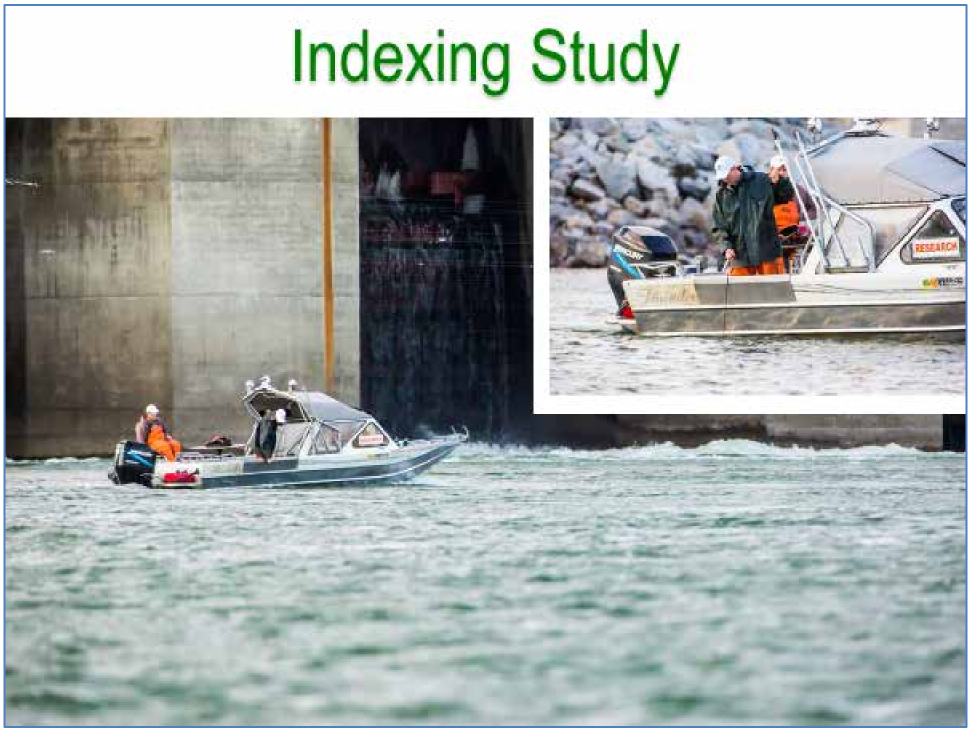
Prey Taxa	Number of samples (N= 39)	Frequency of occurrence (% out of 39 samples)	Weight (g) all samples	Proportion of total weight	Mean proportion of individual's sample weight
Fish					
Unknown Fish	18	46.2%	53.17	45.2%	22.6%
Unknown Salmonid	1	2.6%	0.52	0.4%	0.4%
Unknown Non-salmonid	3	7.7%	0.28	0.2%	3.7%
Chiselmouth (*Acrocheilus alutaceus*)	1	2.6%	28.02	23.8%	1.5%
Sculpin (Cottidae)	1	2.6%	0.61	0.5%	0.5%
Three-spined Stickleback (*Gasterosteus aculeatus*)	9	23.1%	1.49	1.3%	10.0%
Northern Pikeminnow	2	5.1%	5.15	4.4%	2.2%
All Fish	**28**	**71.8%**	**89.24**	**75.8%**	**40.9%**
Other					
Unknown Mammals	6	15.4%	8.39	7.1%	6.3%
Birds	5	12.8%	5.28	4.5%	4.4%
Rodents	1	2.6%	1.24	1.1%	0.1%
Coleoptera (Beetles)	1	2.6%	0.09	0.1%	0.1%
Diptera (Flies)	14	35.9%	0.11	0.1%	0.5%
Ephemeroptera (Mayflies)	3	7.7%	0.05	< 0.1%	< 0.1%
Hemiptera (True bugs)	1	2.6%	< 0.01	< 0.1%	< 0.1%
Plecoptera (Stoneflies)	1	2.6%	0.01	< 0.1%	< 0.1%
Tricoptera (Caddisflies)	9	23.1%	0.05	< 0.1%	0.6%
Unknown Insect Parts	5	12.8%	0.01	< 0.1%	< 0.1%
Amphipoda (freshwater shrimp)	32	82.1%	0.65	0.6%	8.6%
Annelid (ringed or segmented worms)	9	23.1%	0.14	0.1%	3.3%
Bivalvia (mussels, clams)	4	10.3%	0.36	0.3%	0.3%
Decapoda (crayfish)	7	17.9%	6.93	5.9%	7.8%
Gastropoda: Physidae (bladder snails)	23	59.0%	1.61	1.4%	10.4%
Isopoda (woodlice)	20	51.3%	0.38	0.3%	2.7%
Zooplankton: *Daphnia*	4	10.3%	< 0.01	< 0.1%	0.0%
Organic Material	27	69.2%	1.96	1.7%	11.5%





Questions

Acoustic Telemetry and Diet Analysis



Indexing Study

Setline Fishing

2011-2012: White sturgeon caught incidentally in Pikeminnow gear

- 12-14 setlines per day. Effort unknown.
- Lines 76 m, 100 treble hooks (size 2-6), baited with crickets or worms.

2013: Indexing Program – Phase I start

- 8-10 setlines per day. 50 days over five sessions.
- Stratified random site selection. Supplemented with targeted sets.
- Lines 76 m, 80 treble hooks (size 2-6), baited with crickets or worms.
- At end of year, experimented with circle hooks & squid bait.

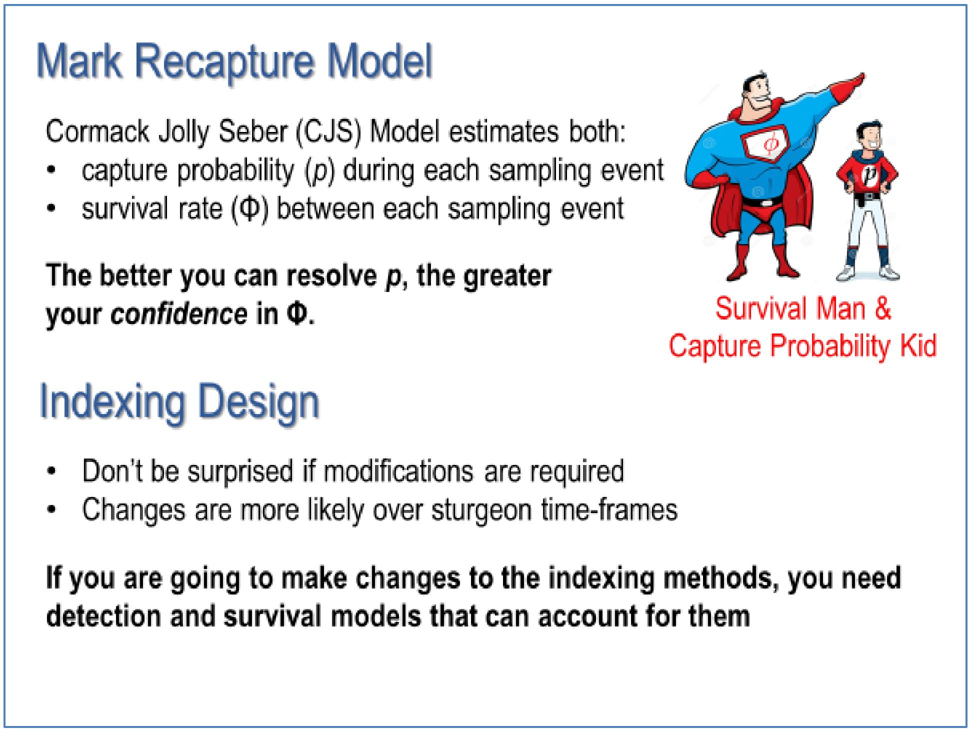
2014-15: Indexing Program – Phase I continued

- 8-10 setlines per day. 45 days over five sessions.
- Stratified random site selection. Supplemented with targeted sets.
- Lines 76 m, 80 hooks (some with treble hooks with crickets or worms; others circle hooks with squid)

2016: Indexing Program – Phase II start

- 8-10 setlines per day. 45 days over five sessions.
- Method standardized with other mid-Columbia River PUDs.
- Random location selection. No more targeted sets.
- Lines 122 m, 40 circle hooks (2.0 and 4.0 gauge), baited with squid.

Recapture Data
PIT Tag ID
Depth
GPS Location
Length
Weight
Girth
Scute Marks
Bait
Hook Type



Mark Recapture Model

Cormack Jolly Seber (CJS) Model estimates both:

- capture probability (p) during each sampling event
- survival rate (Φ) between each sampling event

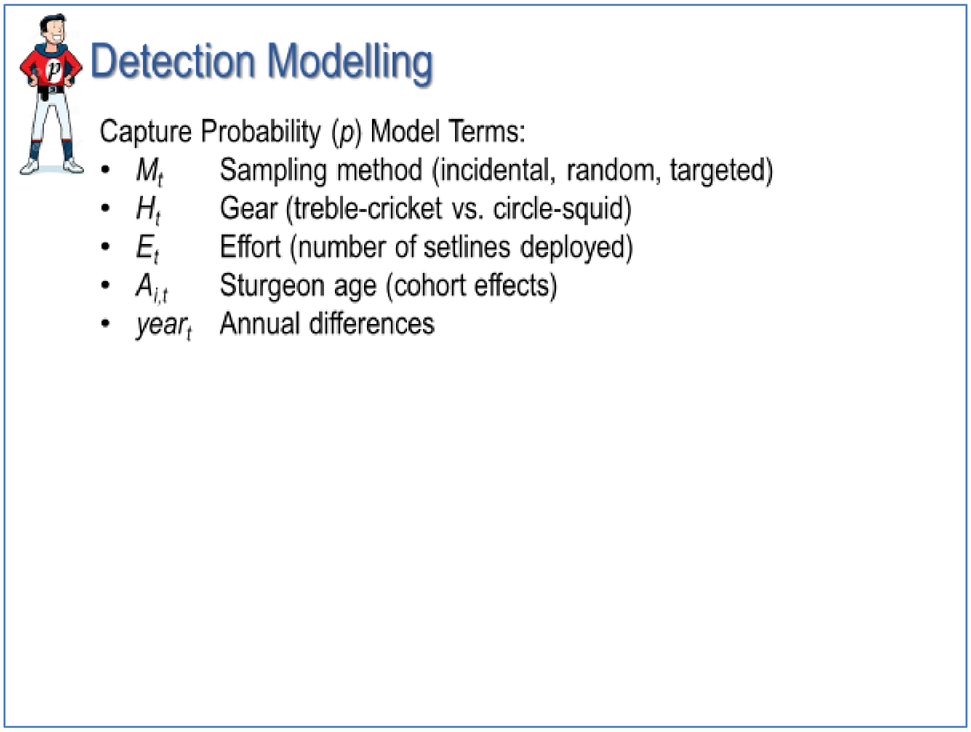
The better you can resolve p, the greater your *confidence* in Φ.

Survival Man &
Capture Probability Kid

Indexing Design

- Don't be surprised if modifications are required
- Changes are more likely over sturgeon time-frames

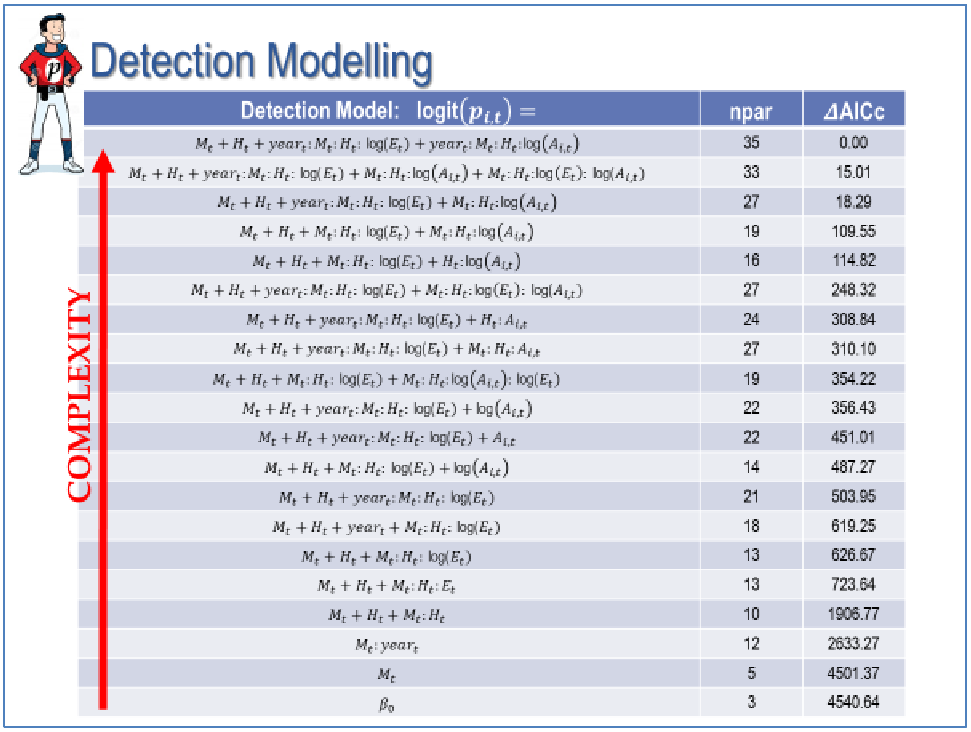
If you are going to make changes to the indexing methods, you need detection and survival models that can account for them



Detection Modelling

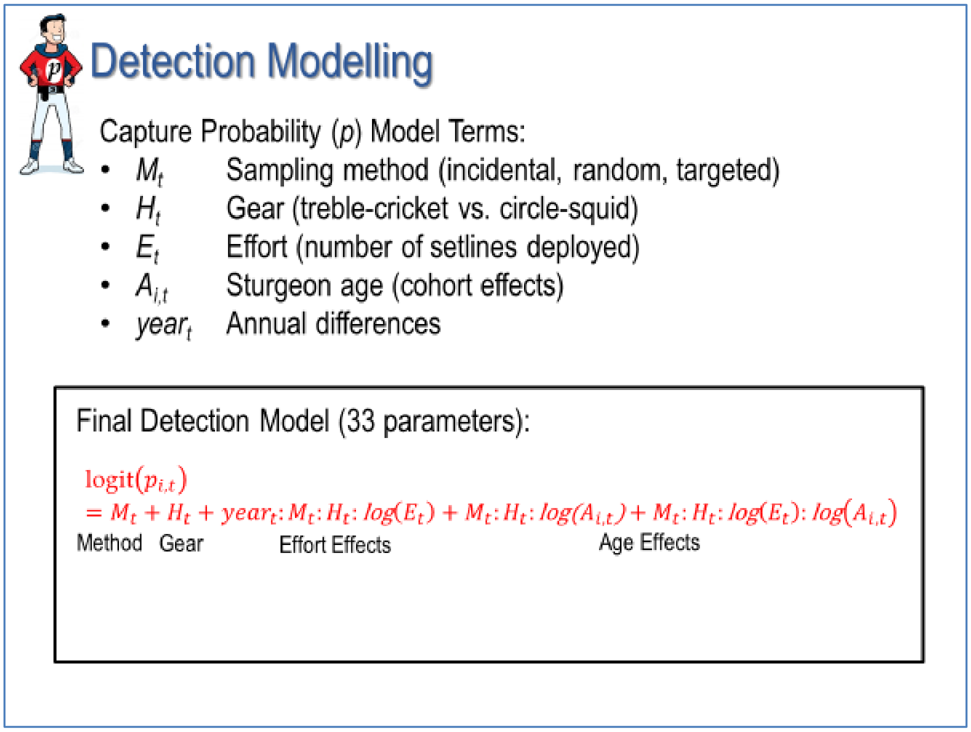
Capture Probability (p) Model Terms:

M_t	Sampling method (incidental, random, targeted)
H_t	Gear (treble-cricket vs. circle-squid)
E_t	Effort (number of setlines deployed)
$A_{i,t}$	Sturgeon age (cohort effects)
$year_t$	Annual differences



Detection Modelling

Detection Model: $\text{logit}(p_{i,t}) =$	npar	ΔAICc
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + year_t{:}M_t{:}H_t{:}\log(A_{i,t})$	35	0.00
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}\log(A_{i,t}) + M_t{:}H_t{:}\log(E_t){:}\log(A_{i,t})$	33	15.01
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}\log(A_{i,t})$	27	18.29
$M_t + H_t + M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}\log(A_{i,t})$	19	109.55
$M_t + H_t + M_t{:}H_t{:}\log(E_t) + H_t{:}\log(A_{i,t})$	16	114.82
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}\log(E_t){:}\log(A_{i,t})$	27	248.32
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + H_t{:}A_{i,t}$	24	308.84
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}A_{i,t}$	27	310.10
$M_t + H_t + M_t{:}H_t{:}\log(E_t) + M_t{:}H_t{:}\log(A_{i,t}){:}\log(E_t)$	19	354.22
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + \log(A_{i,t})$	22	356.43
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t) + A_{i,t}$	22	451.01
$M_t + H_t + M_t{:}H_t{:}\log(E_t) + \log(A_{i,t})$	14	487.27
$M_t + H_t + year_t{:}M_t{:}H_t{:}\log(E_t)$	21	503.95
$M_t + H_t + year_t + M_t{:}H_t{:}\log(E_t)$	18	619.25
$M_t + H_t + M_t{:}H_t{:}\log(E_t)$	13	626.67
$M_t + H_t + M_t{:}H_t{:}E_t$	13	723.64
$M_t + H_t + M_t{:}H_t$	10	1906.77
$M_t{:}year_t$	12	2633.27
M_t	5	4501.37
β_0	3	4540.64



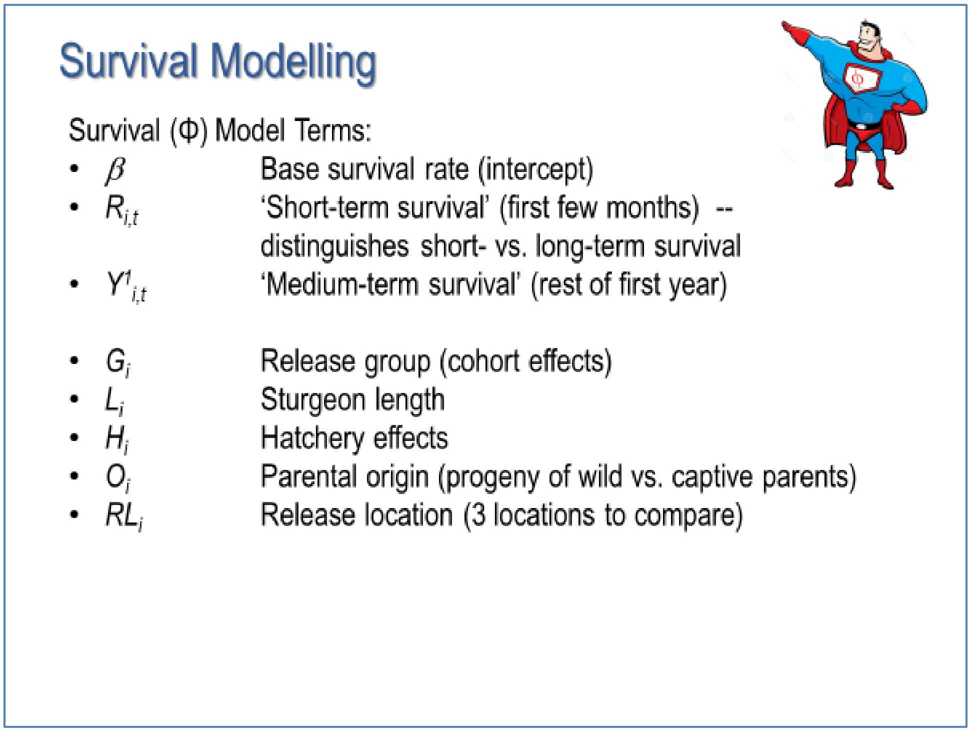
Detection Modelling

Capture Probability (p) Model Terms:

- M_t Sampling method (incidental, random, targeted)
- H_t Gear (treble-cricket vs. circle-squid)
- E_t Effort (number of setlines deployed)
- $A_{i,t}$ Sturgeon age (cohort effects)
- $year_t$ Annual differences

Final Detection Model (33 parameters):

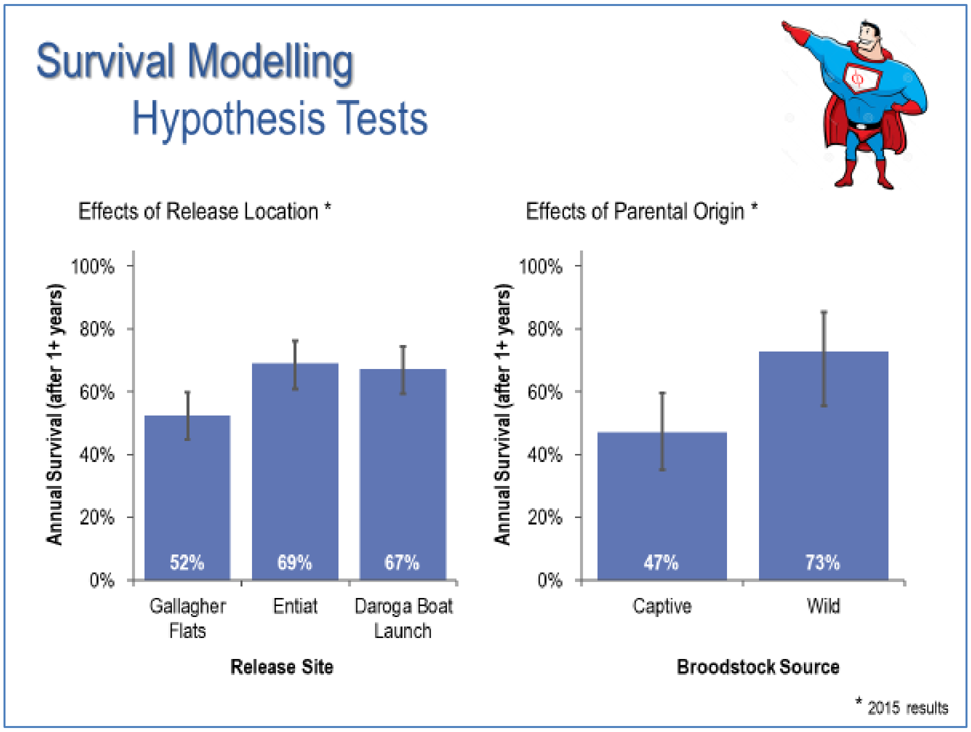
$$\text{logit}(p_{i,t}) = \underbrace{M_t}_{\text{Method}} + \underbrace{H_t}_{\text{Gear}} + \underbrace{year_t{:}M_t{:}H_t{:}log(E_t)}_{\text{Effort Effects}} + \underbrace{M_t{:}H_t{:}log(A_{i,t}) + M_t{:}H_t{:}log(E_t){:}log(A_{i,t})}_{\text{Age Effects}}$$



Survival Modelling

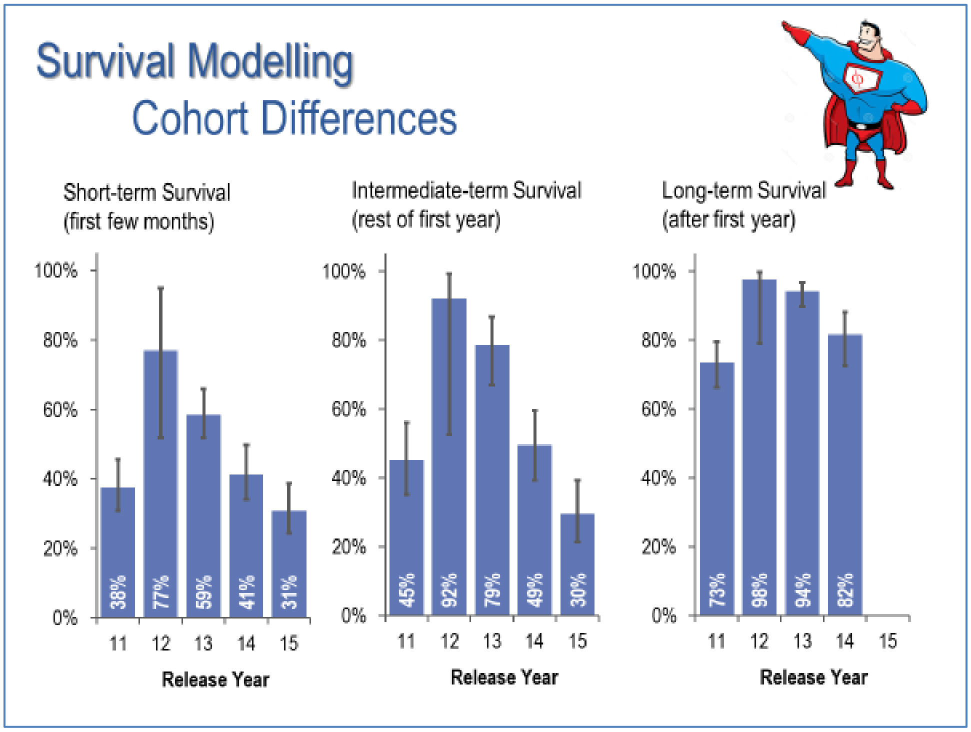
Survival (Φ) Model Terms:

β	Base survival rate (intercept)
$R_{i,t}$	'Short-term survival' (first few months) -- distinguishes short- vs. long-term survival
$Y^1_{i,t}$	'Medium-term survival' (rest of first year)
G_i	Release group (cohort effects)
L_i	Sturgeon length
H_i	Hatchery effects
O_i	Parental origin (progeny of wild vs. captive parents)
RL_i	Release location (3 locations to compare)

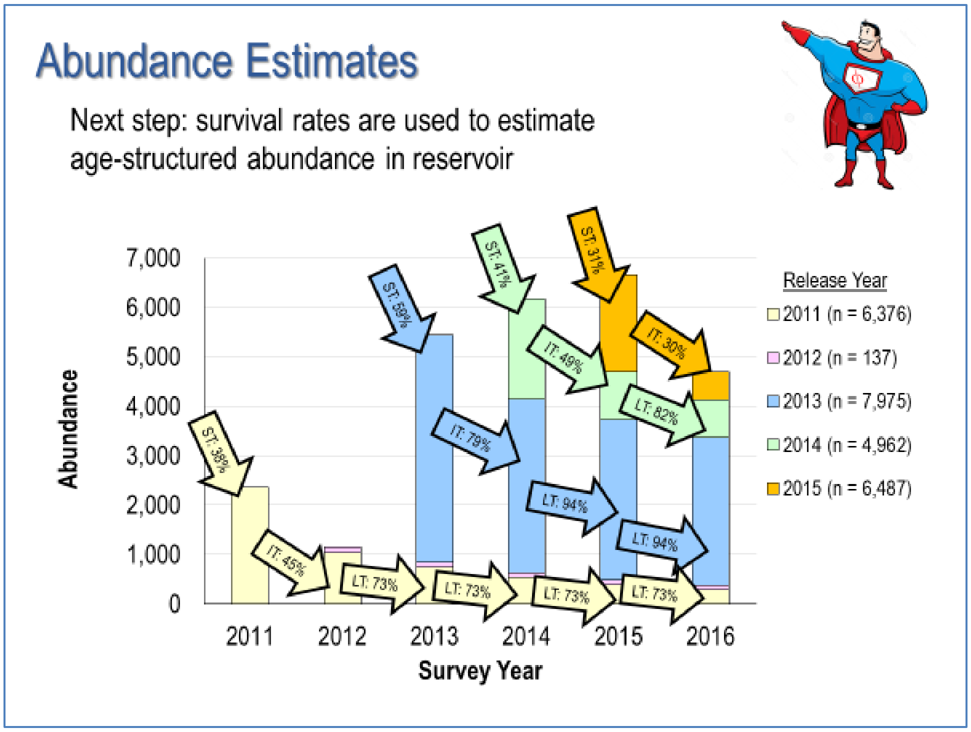


Survival Modelling
Hypothesis Tests

* 2015 results

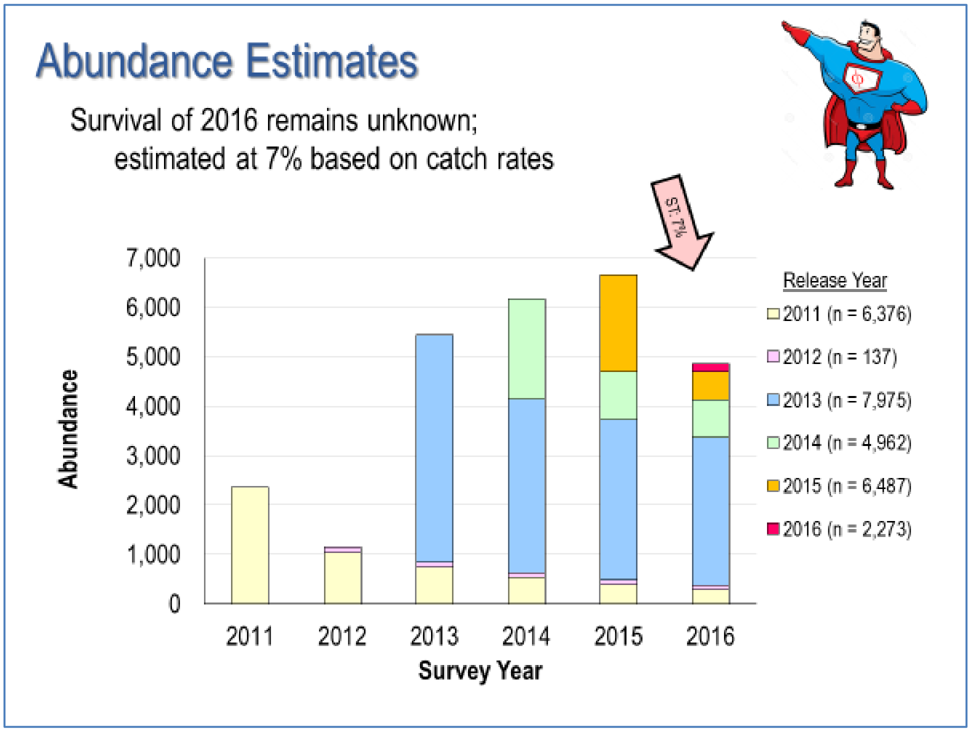


Survival Modelling
Cohort Differences



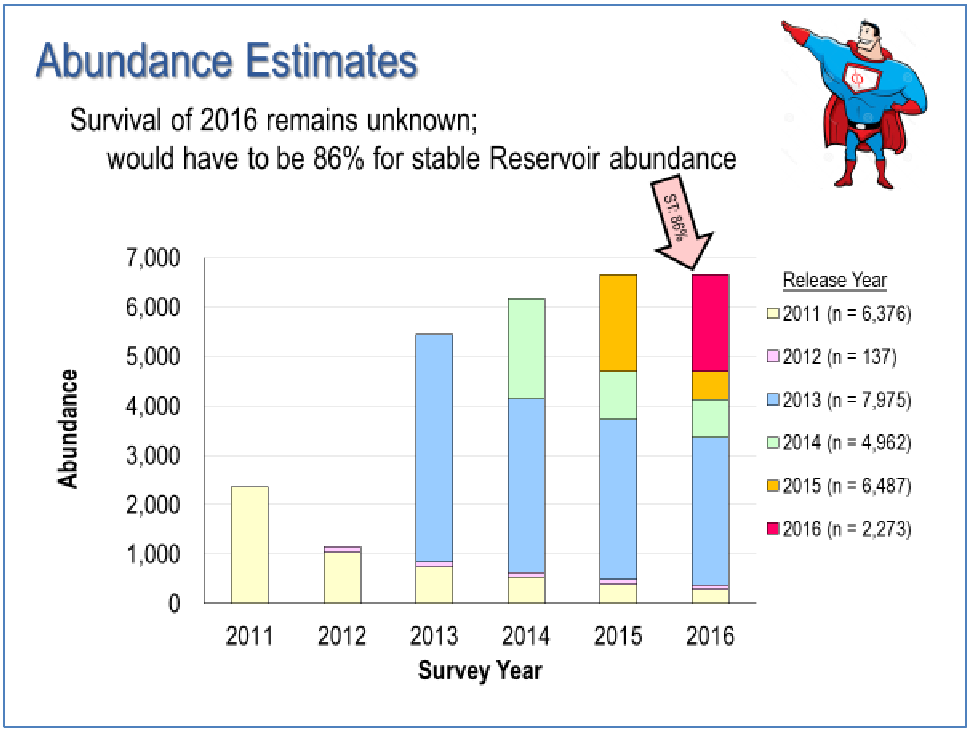
Abundance Estimates

Next step: survival rates are used to estimate
age-structured abundance in reservoir



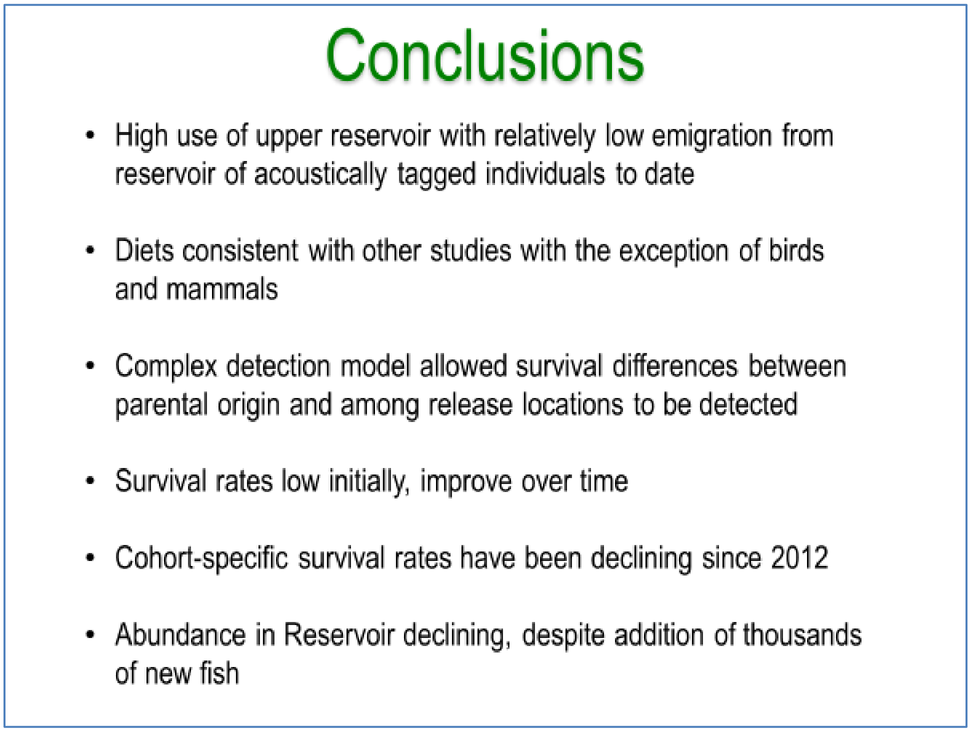
Abundance Estimates

Survival of 2016 remains unknown;
estimated at 7% based on catch rates



Abundance Estimates

Survival of 2016 remains unknown;
would have to be 86% for stable Reservoir abundance



Conclusions

- High use of upper reservoir with relatively low emigration from reservoir of acoustically tagged individuals to date
- Diets consistent with other studies with the exception of birds and mammals
- Complex detection model allowed survival differences between parental origin and among release locations to be detected
- Survival rates low initially, improve over time
- Cohort-specific survival rates have been declining since 2012
- Abundance in Reservoir declining, despite addition of thousands of new fish