Habitat Modeling and Assessment for the Missouri River Recovery Program

EWN for Water Operations
Strategic Meeting
March 31 – April 1 2015

Craig Fischenich, ERDC Environmental Lab

Background/Context

Background/Context

- 2000/2003 BiOp (plover, tern, pallid sturgeon)
- Missouri River Recovery Implementation Committee (MRRIC) and Independent Science Advisory Panel (ISAP)
    - Spring Pulse
    - Adaptive Management
    - Effects Analysis

Background - MRRP

Management Plan: The scope of the effort is **focused on removing or precluding jeopardy status and contributing to the recovery** of the three species. Will identify preferred alternative to be implemented within an adaptive management framework, collaborate with stakeholders and **fulfill NEPA requirements**.

- Team: USACE, USFWS, Effects Analysis leads
- Timeline: began in 2013, concludes in August 2016
- Products: PEIS and AM plan; ROD

Effects Analysis: Provides a mechanism for **quantifying the effects of past, ongoing and future USACE actions** on the 3 listed species and evaluating the potential benefits of proposed management actions

- Teams: Three teams, including ERDC, USGS, PNNL, USACE, and USFWS staff
- Timeline: Began fall 2013, phase 1 complete spring 2015
- Products: EA Phase 1 draft reports in October 2014, final Phase 1 reports in spring/summer 2015

Background - MRRP

Objectives and Targets: process to define objectives and targets for birds and sturgeon management. Quantitative targets for birds are focused on plovers.

- Team: USFWS, assisted by EA leads and modelers
- Timeline: summer 2013 – spring 2015
- Products: Objectives (available), quantitative targets for plovers and criteria for sturgeon
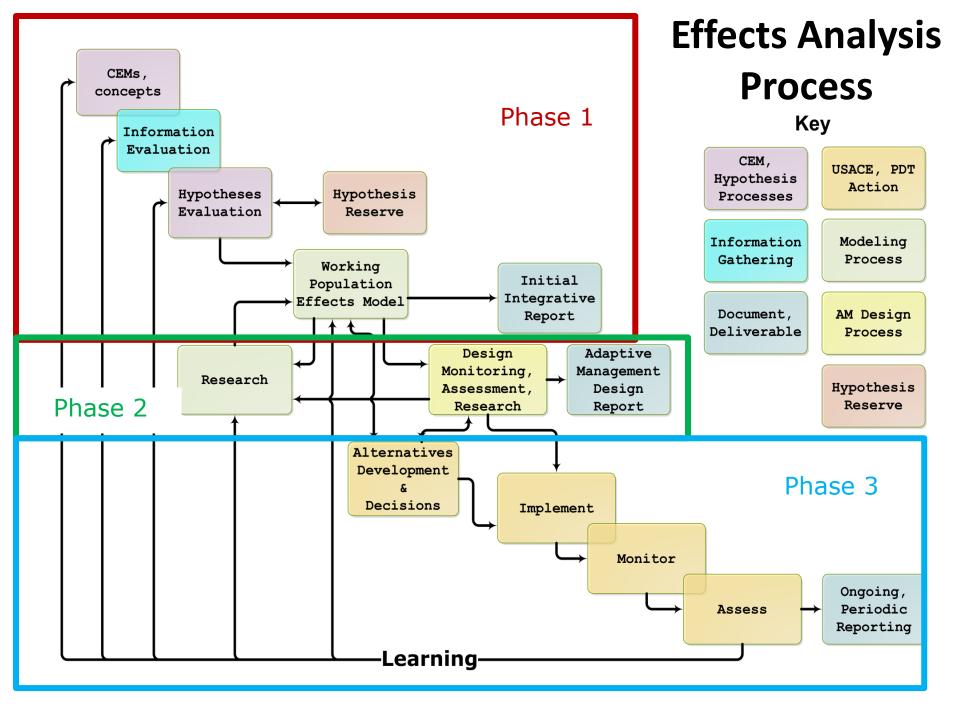
Alternatives Development/PrOACT: process to define management alternatives (suites of actions) using a structured decision-making (PrOACT) approach with MRRIC to assess the effects of the management actions on species and a set of "human considerations" metrics reflecting stakeholder interests and trade-offs.

- Team: USACE, USFWS, EA leads
- Timeline: driven by MRRIC schedule: "test" alternatives (exploratory management actions) presented in February 2015, Round 1 alternatives in May 2015, Round 2 in August 2015, selection of preferred alternative to follow
- Product: Preferred alternative

Adaptive Management Planning: Development of Adaptive Management Plan to accompany the PEIS that results from the Management Plan. Includes a research-focused "first increment" framework for pallid sturgeon management and a more traditional AM strategy for plovers and terns, as well as a governance and decision process that addresses both.
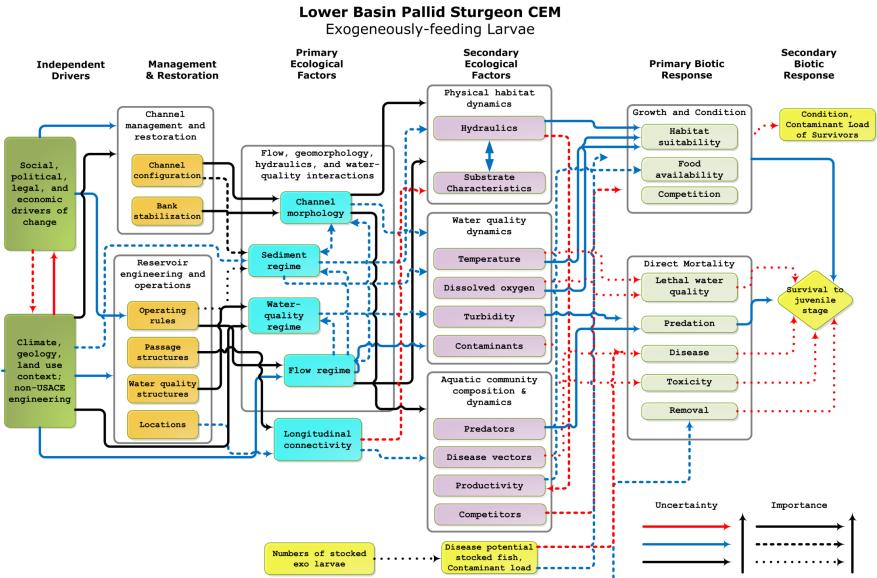
- Team: AM Process Team including staff from USACE, USFWS, PNNL, ERDC, Louis Berger
- Timeline: AM Governance structure and documentation in August 2014, began introducing pallid sturgeon framework in spring 2015, draft AM plan due October 2015
- Product: AM plan

Effects Analysis Process
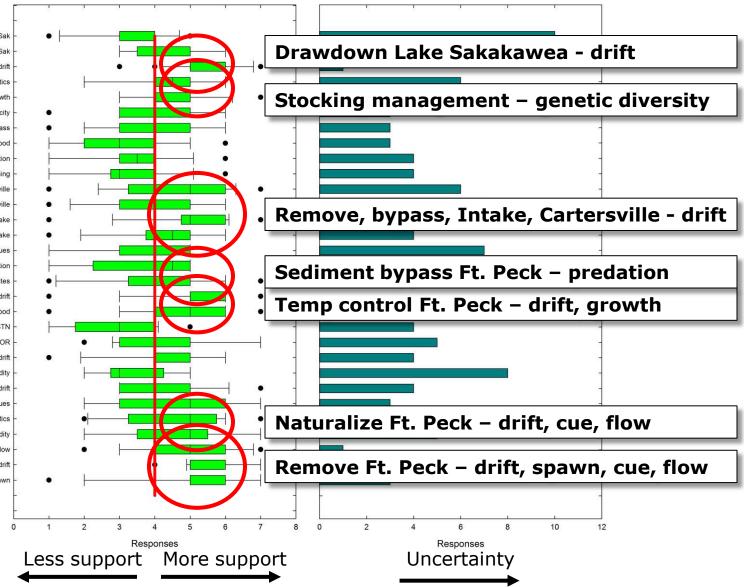
Phase 1

CEMs, concepts

Information Evaluation

Hypotheses Evaluation ⟷ **Hypothesis Reserve**

Working Population Effects Model → **Initial Integrative Report**

Phase 2

Research

Design Monitoring, Assessment, Research → **Adaptive Management Design Report**

Phase 3

Alternatives Development & Decisions

Implement

Monitor

Assess → **Ongoing, Periodic Reporting**

Learning

Key

CEM, Hypothesis Processes	USACE, PDT Action
Information Gathering	Modeling Process
Document, Deliverable	AM Design Process
Hypothesis Reserve	

Conceptual Models

Lower Basin Pallid Sturgeon CEM
Exogeneously-feeding Larvae

CEM provided by Robb Jacobson
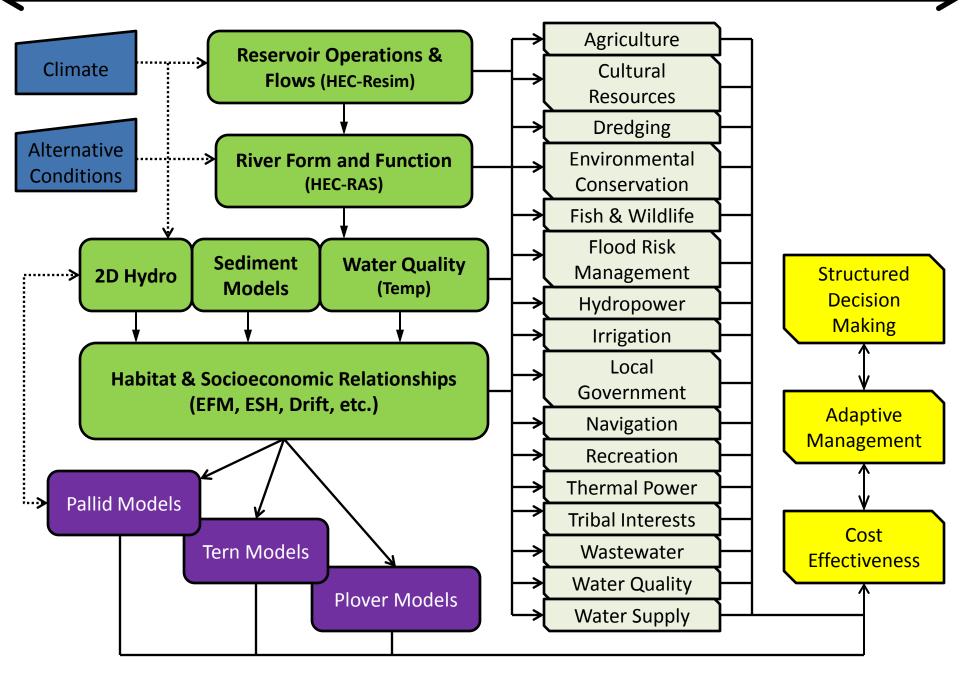
Management Hypotheses Expert Survey

Less support   More support   Uncertainty

Effects Analysis ← → **Management Plan Analysis**

Climate

Alternative Conditions

Reservoir Operations & Flows (HEC-Resim)

River Form and Function (HEC-RAS)

2D Hydro

Sediment Models

Water Quality (Temp)

Habitat & Socioeconomic Relationships (EFM, ESH, Drift, etc.)

Pallid Models

Tern Models

Plover Models

Agriculture
Cultural Resources
Dredging
Environmental Conservation
Fish & Wildlife
Flood Risk Management
Hydropower
Irrigation
Local Government
Navigation
Recreation
Thermal Power
Tribal Interests
Wastewater
Water Quality
Water Supply

Structured Decision Making

Adaptive Management

Cost Effectiveness

H&H Modeling

Stream Alignment

Network Reach

Network Reservoir and Dam

Network Junction

2D Model Reach

Sediment Model

Sediment Model

6 ResSim Models
8 HEC RAS Models
+ WQ & Drift Variants
3 ESH Models
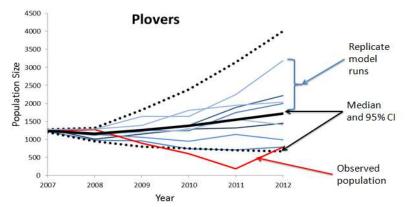Several EFM Models

Plovers (and Terns) Emergent Sandbar Habitat

- Need for flow-dependent ESH relation
- Limited data & geomorphic modeling capability
- Previous model construct is sound but limited
  - Improved stage-area relations
  - loss rate function

Aging of Mechanically Created Sandbar
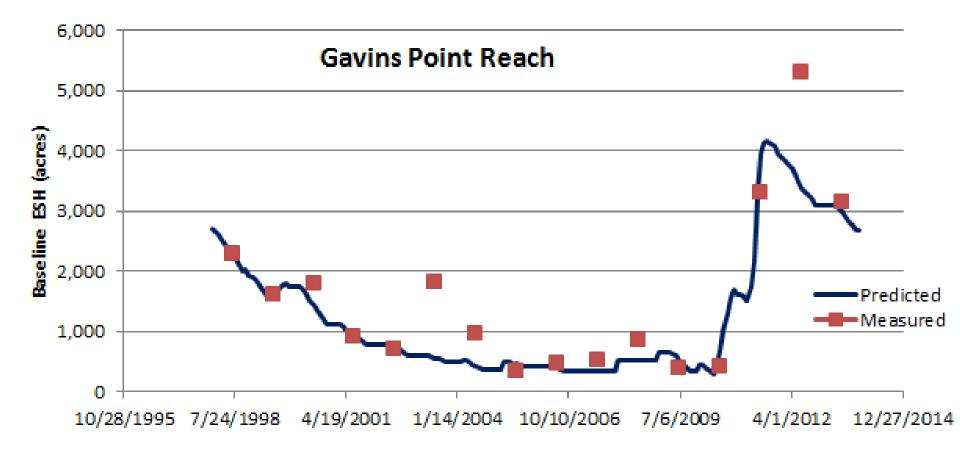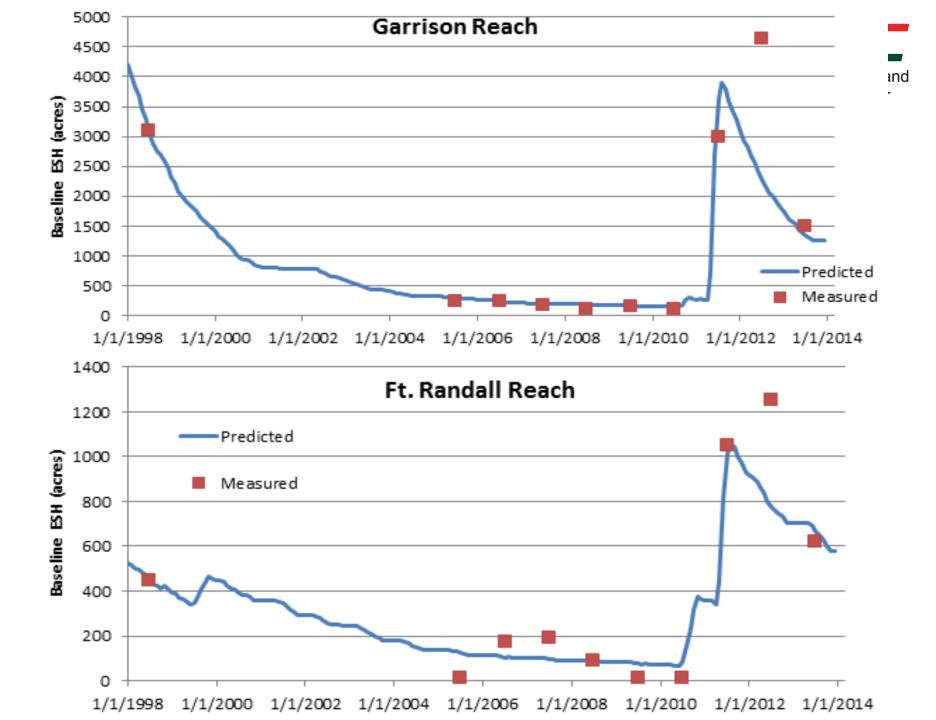
ESH Model Performance

Gavins Point Reach

Garrison Reach

Baseline ESH (acres)

— Predicted
■ Measured

Ft. Randall Reach

Baseline ESH (acres)

— Predicted
■ Measured
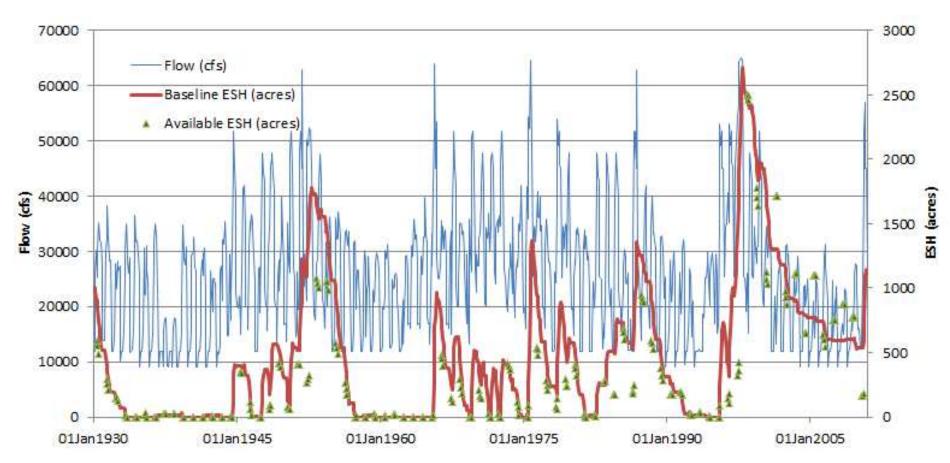
Hindcast of ESH
1930 – 2010 Fully Regulated
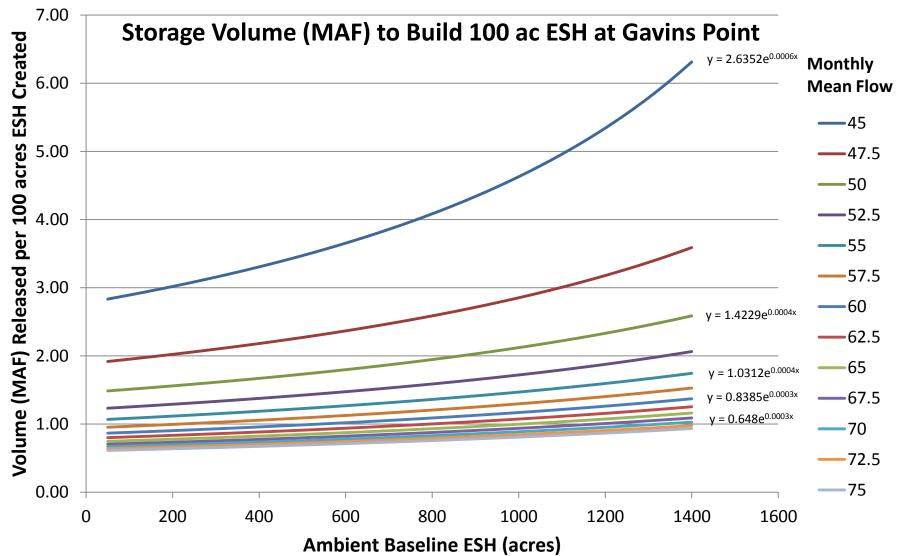
Alternative Formulations

Storage Volume (MAF) to Build 100 ac ESH at Gavins Point

Equations shown on chart:

$y = 2.6352e^{0.0006x}$

$y = 1.4229e^{0.0004x}$

$y = 1.0312e^{0.0004x}$

$y = 0.8385e^{0.0003x}$

$y = 0.648e^{0.0003x}$

Y-axis: Volume (MAF) Released per 100 acres ESH Created

X-axis: Ambient Baseline ESH (acres)

Monthly Mean Flow: 45, 47.5, 50, 52.5, 55, 57.5, 60, 62.5, 65, 67.5, 70, 72.5, 75
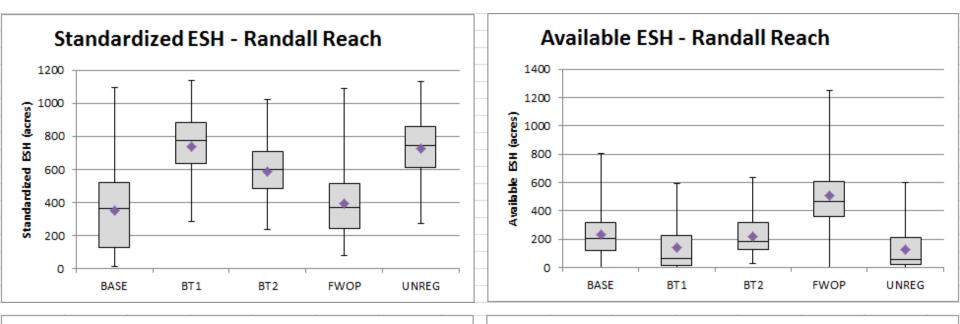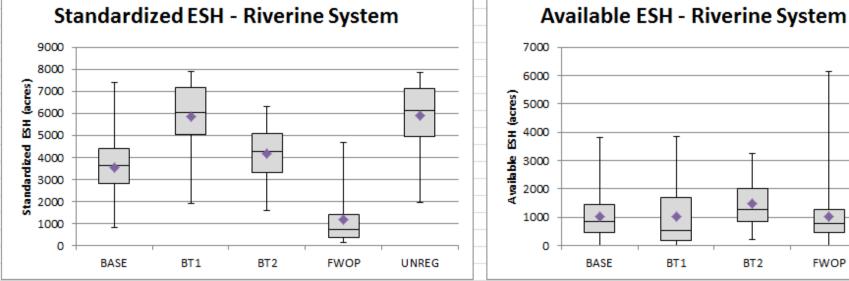
Alternative Comparisons

Pallid Sturgeon (*Scaphirhynchus albus*)

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Migrate upstream
hundreds of km

Grow to sexual
maturity, 7-14
years

Spawn over hard,
coarse substrate,
adhesive eggs,
fertilize, 4-7 days
incubation

"Settle" into lotic
marginal habitats

11-14 days
drift as free
embryo (or 6-9?)

DeLonay and others (2009)
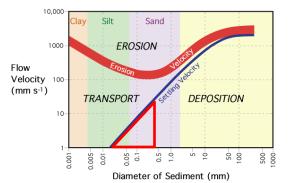
Drift –Dispersal of Free Embryos
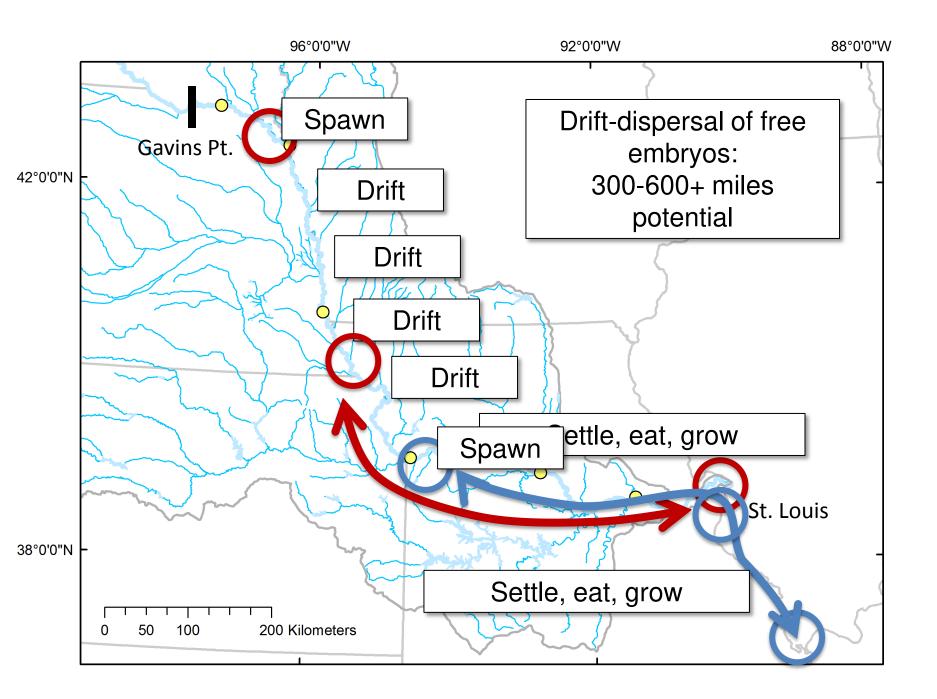
- 11-14 days to use up yolk sac
  - Temperature dependent
  - Interstitial residency: possibly - 5 days
- Adaptive behavior to drift, avoid predation
  - Probably not good to settle before transition
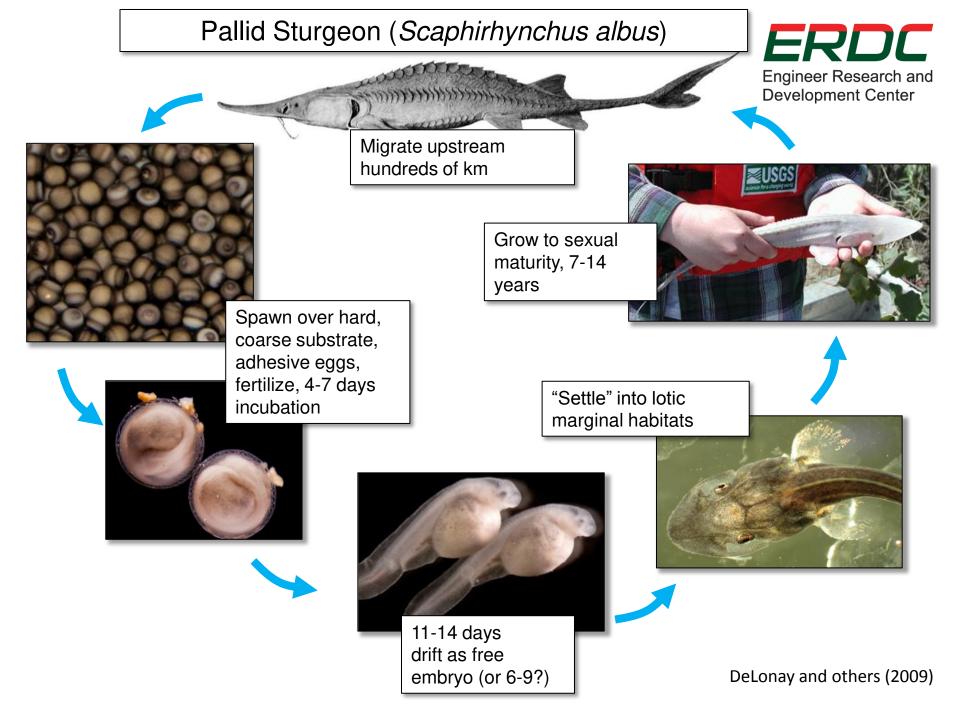- At transition, need to feed immediately
  - Need food source – mostly chironomid larvae

Uncertainties:

- Immediate/delayed drift
- Ability to move
  - Really passive?
  - Lab observations vs field observations.
  - 90% within 1 m of bottom.
  - Drift at ~.9 * v
- Deleterious effects of turbulence?
- Importance of spawning substrate, interstitial space?

Spawn

Drift

Drift

Drift

Drift

Drift-dispersal of free embryos:
300-600+ miles potential

Gavins Pt.

Spawn

Settle, eat, grow

Settle, eat, grow

St. Louis

42°0'0"N

38°0'0"N

96°0'0"W

92°0'0"W

88°0'0"W

0   50   100   200 Kilometers

Working Definitions: Functional Habitats
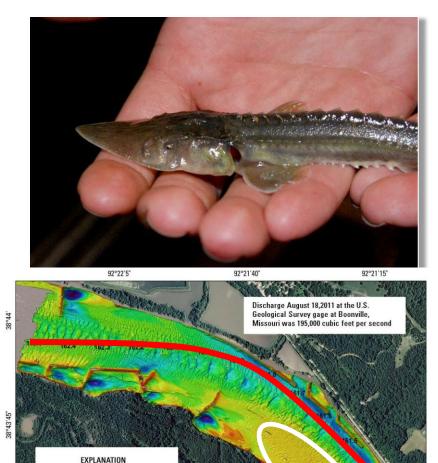
Hypotheses point to four functional habitat types that may be responsible for recruitment failure; limiting factors not yet identified:

- **Spawning habitat -** Convergent flow, high velocity, high turbulence, enhanced definitions based on Yellowstone reference.

- **Food habitats -** Stable, fine substrate especially for chironomid production for age-0 fish diet – depositional areas, velocities < 0.08 m/s

- **Foraging habitats -** Enough depth and velocity to provide access to drifting food, not too much, age-0 CPUE peaks at 1-3 m and 0.5 – 0.9 m/s (Ridenour and others, 2011)

- **Free embryo interception, retention -** Geometries that promote free-embryo transport from thalweg and retention

Interception Rearing Complexes

- Provide needed habitat for free embryos through first winter (at least) – age0 – age1
- Located downstream from spawning sites
    - Spawning site minus typical drift distance
- Off-ramp hydraulics from navigation channel
- Food-producing and foraging habitat available, neither limiting.

Discharge August 18,2011 at the U.S. Geological Survey gage at Boonville, Missouri was 195,000 cubic feet per second

EXPLANATION

Depth, in meters

1.6

22.1
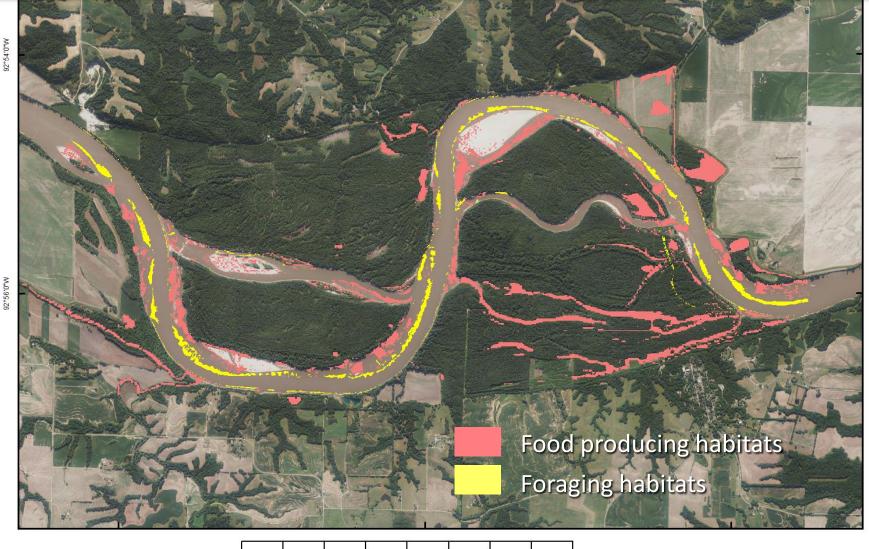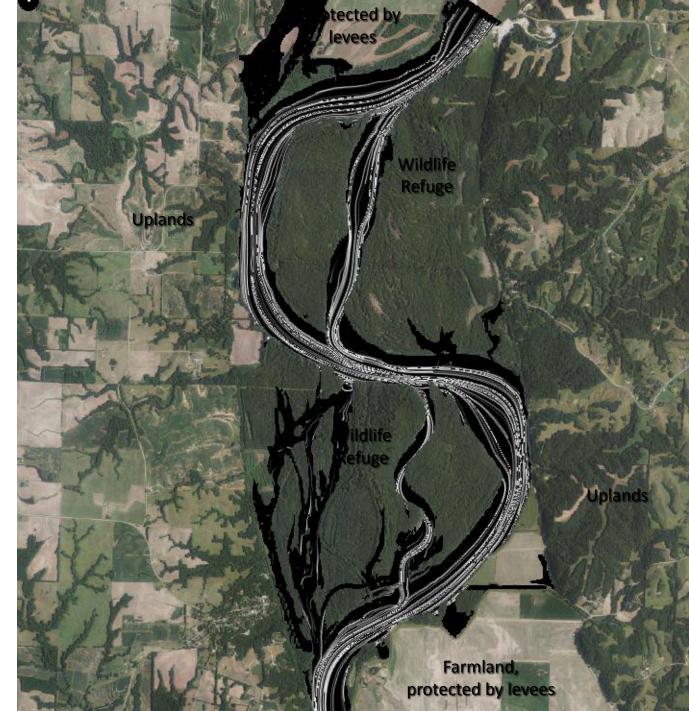
230 ⊙ River-mile marker—
Number is distance upstream from the junction with the Mississippi River

0   100   200 METERS

0   500   1,000 FEET

Lisbon-Jameson best-available example, lower lower river Hydrodynamic habitat model. Flow is from left to right 35,000 cfs

Lisbon – Jameson Complex

198,000 cubic feet per second
Exceeded 16 days per year on average

Just under flood stage

Protected by levees

Wildlife Refuge

Uplands

Wildlife Refuge

Uplands

Farmland, protected by levees

Decision Trees

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Successful fertilization, incubation, and hatch? — No → **Potential to implement:**
- Reconfigure channel for spawning habitats
- Increase number of adults
- Manipulate flows and/or temperature for reproductive cues

Yes ↓

Can free embryos survive turbulence? — No → **Potential to implement:**
- Decreased discharges to lower velocities
- Increase interstitial space in spawning substrates

Yes ↓

Can free embryos transition, feed in the thalweg? — No → **Is interception habitat limiting?** — Yes → **Potential to implement:**
- Reconfigure channel for interception

No ↓

Is food or foraging limiting? — No → **Look for other recruitment failure hypotheses**

Yes → **Potential to implement:**
- Reconfigure channel to increase food-producing and/or foraging habitats

Pallid Sturgeon Framework

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	Stocking	**Spawning Habitat**	**Spawning Cues**	**Interception Habitat**	**Food Habitat**	**Foraging Habitat**
Level						
1 ➡	Is limiting? Technical?	Is limiting? Technical?	Is limiting? Technical?	Is limiting? Technical?	Is limiting? Technical?	Is limiting? Technical?
2 ➡	Pilot effort	Pilot effort	Pilot effort	Pilot effort	Pilot effort	Pilot effort
3 ➡	Partial scale	Partial scale	Partial scale	Partial scale	Partial scale	Partial scale
4 ➡	Increase stocking	Create spawning habitat	Spring spawning cue flows	Create interception habitat	Create food producing habitat	Create foraging habitat

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Free Embryo Drift and Survival Upper Missouri & Yellowstone Rivers

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Management Working Hypotheses:
- Upper Missouri
  - Low flows from Fort Peck – drift and development
  - Spawning/aggregation cues
  - Increased temperatures from Fort Peck – development and food
  - Drawdown of Lake Sakakawea - dispersal
- Yellowstone
  - Provide passage at Intake
  - Drawdown of Lake Sakakawea
- Both
  - Stocking strategies
  - Genetic fitness

1D Advection/Dispersion

01Jul2010 00:00:00

Ft. Peck Dam

Miles City

Lake Sakakawea Pool

Legend
0.1
1
5
10
50
100
500
1000
3000
5000

Retention for 2003 – 2012; Spawn at Milk River Confluence

Year	% Retained @ T=5	% Retained @ T=6	% Retained @ T=7	% Retained @ T=8	% Retained @ T=9	% Retained @ T=10
2003	97	82	24	2	1	0
2004	99	100	79	29	7	3
2005	99	100	90	43	10	2
2006	99	98	71	23	6	3
2007	99	99	82	33	8	4
2008	100	99	76	26	4	0
2009	99	84	26	2	0	0
2010	80	20	3	0	0	0
2011	0	0	0	0	0	0
2012	84	17	0	0	0	0
Total	**86**	**70**	**45**	**16**	**4**	**1**

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Preliminary Effectiveness of Management Actions

Percent Larvae U/S of Pool at T = 4 Days

		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	100%	100%	100%	100%	100%	100%
5	5500	100%	100%	100%	100%	100%	100%
10	6100	100%	100%	100%	100%	100%	100%
25	7150	100%	100%	100%	100%	99%	99%
50	8600	99%	99%	99%	99%	99%	97%
75	11000	100%	100%	100%	100%	98%	92%
90	14400	100%	100%	100%	100%	95%	80%
95	16100	100%	100%	100%	100%	89%	63%

Percent Larvae U/S of Pool at T = 6 Days

		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	100%	100%	100%	98%	85%	70%
5	5500	100%	100%	97%	80%	33%	22%
10	6100	100%	99%	96%	75%	23%	14%
25	7150	99%	98%	91%	60%	11%	6%
50	8600	98%	96%	85%	49%	6%	4%
75	11000	98%	94%	83%	44%	3%	1%
90	14400	92%	86%	68%	30%	2%	0%
95	16100	85%	76%	57%	20%	1%	0%

Percent Larvae U/S of Pool at T = 8 Days

		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	92%	85%	60%	26%	7%	3%
5	5500	53%	41%	14%	6%	1%	1%
10	6100	47%	34%	11%	4%	0%	1%
25	7150	29%	20%	6%	2%	0%	0%
50	8600	16%	11%	3%	1%	0%	1%
75	11000	12%	8%	2%	0%	0%	0%
90	14400	5%	3%	1%	0%	0%	0%
95	16100	3%	2%	1%	0%	0%	0%

Percent Larvae U/S of Pool at T = 10 Days

		Lake Sakakawea Pool Level					
Flow		HMin	Min	10	50	90	Max
Exceed	Ft. Peck	1805.0	1812.6	1821.6	1843.2	1850.4	1856.0
Min	3000	21%	19%	6%	3%	1%	1%
5	5500	4%	5%	1%	1%	0%	0%
10	6100	0%	3%	1%	0%	0%	0%
25	7150	1%	1%	1%	0%	0%	0%
50	8600	0%	0%	0%	0%	0%	0%
75	11000	0%	0%	0%	0%	0%	0%
90	14400	0%	0%	0%	0%	0%	0%
95	16100	0%	0%	0%	0%	0%	0%

Reserve Slides for Questions

Near-Term Activities

- Assist with establishment of targets
- Alternative development support
  - Identification/refinement
  - Effectiveness & trade-offs
- Adaptive management plan development
  - Hypothesis refinement, organization, prioritization
  - Decision-making and analysis process
- Hypothesis testing/data analysis
- Additional drift modeling (interception?)
- ESH model updates
  - New protocol for image processing & classification
  - Addition of vegetation component
  - Alternative time steps

Acknowledgements

EA Co-PIs:

Kate Buenau	PNNL
Robb Jacobson	USGS

Work Team:

Craig Fischenich	ERDC
Stan Gibson	HEC
John Hickey	HEC
Jeff Tripe	Corps
Dan Pridal	Corps
Don Meier	Corps
Tom Econopouly	USFWS

Others: A large cast of District, and outside SMEs

Cadre:

Paul Boyd	Corps
Jean Reed	Corps
Ryan Larsen	Corps
Christine Cieslik	Corps
Marian Baker	Corps
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Joshua Mellinger	Corps
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Michelle Whitney	Corps
Doug Clemetson	Corps
Doug Latka	Corps
Nate Clifton	ERDC
Bobby McComas	ERDC
David Smith	ERDC

EWN Essential Elements

- ✓ Use science and engineering to produce operational efficiencies supporting sustainable project benefits.
- ✓ Use natural processes to maximum benefit, thereby reducing demands on limited resources, minimizing the environmental footprint of projects.
- ✓ Broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits.
- ✓ Use science-based collaborative processes to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

EWN Principles

- ✓ **Holistic** – an ecosystem approach for planning, designing, constructing and operating projects where social, economic and environmental factors are equitably weighed in the decision making process.

- ✓ **A Systems Approach** – reflecting the reality that USACE projects exist in complex physical and social/cultural systems, and that a single action influences many other parts of the system.

- ✓ **Sustainable** – focused on the long-term sustainability and resilience of project solutions and the benefits streams provided by the system over time.

- ✓ **Science-based** – built on first understanding, then working deliberately with natural forces and processes to accomplish engineering goals.

- ✓ **Collaborative** – based on effective partner and stakeholder communication, engagement and collaboration through the entire life cycle of a project, beginning at the earliest conceptual stages.

EWN Principles (concluded)

? **Efficient and cost effective** – reducing time and rework, while minimizing social friction.

✓ **Socially responsive** – aligned with the values, objectives, interests and priorities of USACE, partners, stakeholders and society at large.

✓ **Innovative** – embracing new and emerging technologies and incorporating continuous learning, technology transfer and adoption of new and leading practices.

✓ **Adaptive** – demonstrating adaptive attitudes, structures and processes that enable a living, evolving and sustainable practice.

Background

Background

What is an Effects Analysis?

"Evaluation of the effects of a federal agency action that has the potential to harm a listed species…
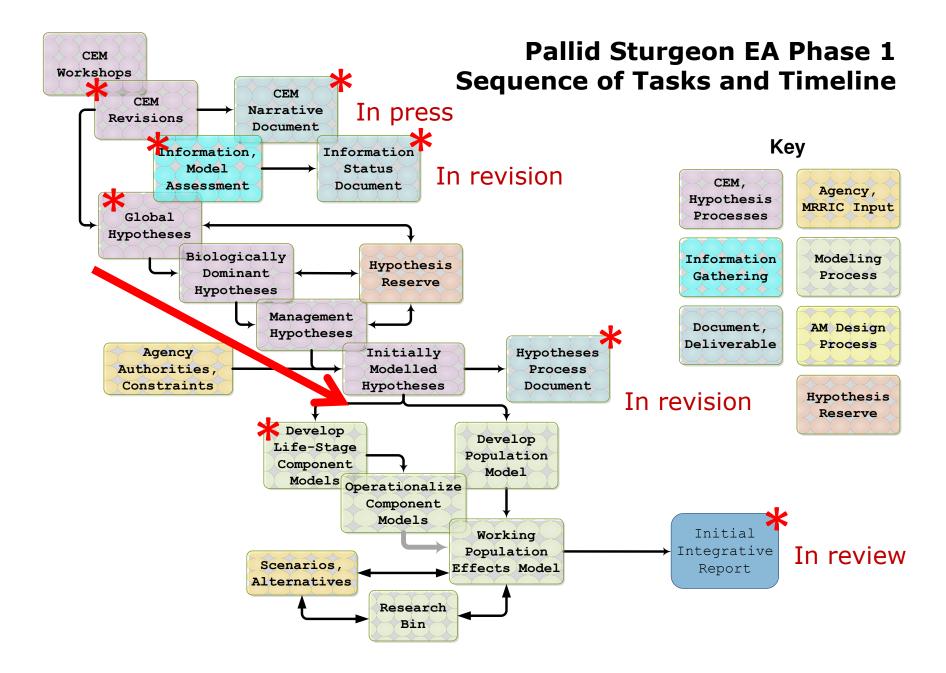
The framework includes three essential steps:

- the collection of reliable scientific information,
- the critical assessment and synthesis of available data and analyses derived from those data,
- and the analysis of the effects of actions on listed species and their habitats"

Three Teams:
- Hydrology, hydraulics, geomorphology (Craig Fischenich)
- Plovers and terns (Kate Buenau)
- Pallid sturgeon (Robb Jacobson)

Murphy, D., and Weiland, P., 2011, The Route to Best Science in Implementation of the Endangered Species Act's Consultation Mandate: The Benefits of Structured Effects Analysis: Environmental Management, v. 47, no. 2, p. 161-172. 10.1007/s00267-010-9597-9.

Pallid Sturgeon EA Phase 1 Sequence of Tasks and Timeline

CEM Workshops

* CEM Revisions

CEM Narrative Document *

In press

* Information, Model Assessment

Information Status Document *

In revision

* Global Hypotheses

Biologically Dominant Hypotheses

Hypothesis Reserve

Management Hypotheses

Agency Authorities, Constraints

Initially Modelled Hypotheses

Hypotheses Process Document *

In revision

* Develop Life-Stage Component Models

Develop Population Model

Operationalize Component Models

Working Population Effects Model

Scenarios, Alternatives

Research Bin

Initial Integrative Report *

In review

Key

CEM, Hypothesis Processes

Agency, MRRIC Input

Information Gathering

Modeling Process

Document, Deliverable

AM Design Process

Hypothesis Reserve

Model Framework Scope

Geographic: Missouri River from Ft. Peck to St. Louis, including the lower Yellowstone River

Temporal: Forecast conditions for 30-50 years

Resolution: Dictated by species requirements and the processes and actions simulated

Assessment Capabilities: Includes, but is not limited to, management actions identified in the BiOp

Other: Support the broader management planning effort and future adaptive management needs by developing and employing models that can be used to support those purposes

H&H Modeling Backbone

HEC-ResSim
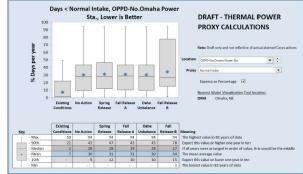
- Simulates reservoir storage , pool levels, releases and downstream flows based on inflow, depletions, evaporation and reservoir operation criteria. The model will allow simulation of multiple reservoirs as a system.

- Used for comparing impacts/benefits of operational alternatives. Also used to provide input to sturgeon habitat, ESH, EFM and HEC-RAS models.
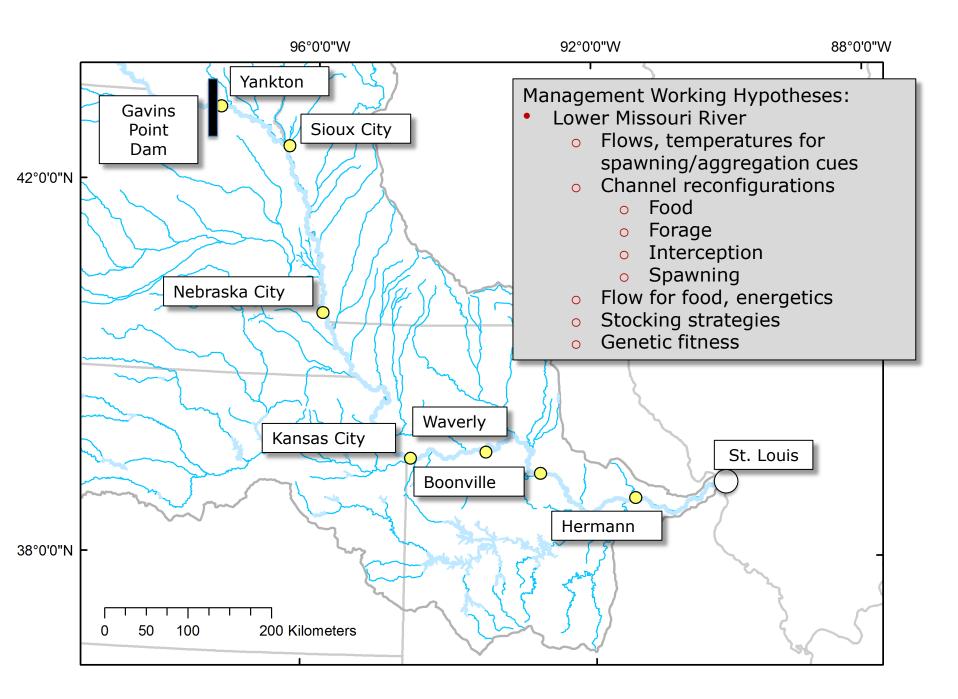
HEC-RAS

- Simulates one-dimensional steady and unsteady flow and changes in river stage, flow rate, and storage areas in the river and floodplain over time and by transect/river mile. Stage, flow, and other hydraulic data provides inputs to the species models (and HC analyses).

- The software also has capabilities for sediment modeling, water temperature analysis, and water quality modeling.

HEC-EFM
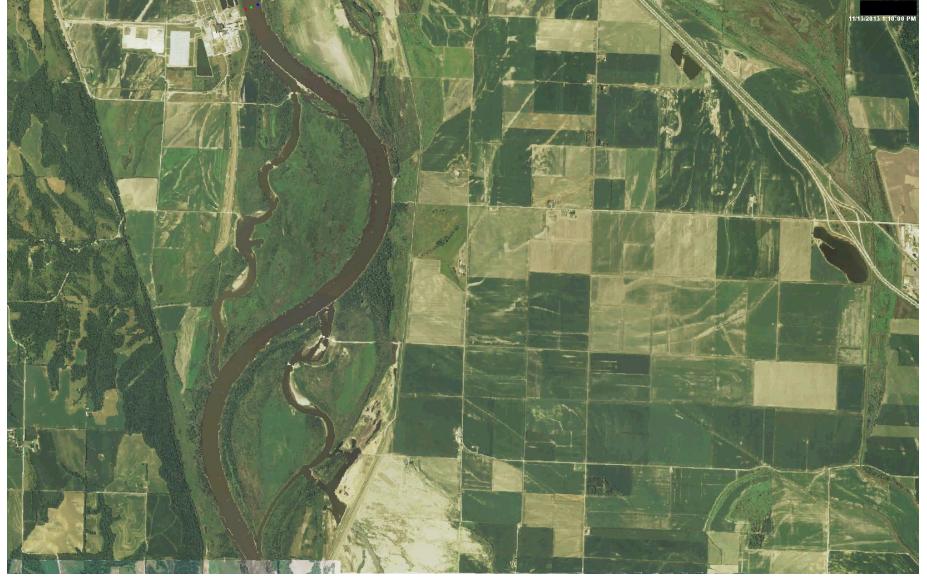
- Used to assess spatial/statistical outcomes

6/21/2015

Management Working Hypotheses:
- ● Lower Missouri River
  - ○ Flows, temperatures for spawning/aggregation cues
  - ○ Channel reconfigurations
    - ○ Food
    - ○ Forage
    - ○ Interception
    - ○ Spawning
  - ○ Flow for food, energetics
  - ○ Stocking strategies
  - ○ Genetic fitness
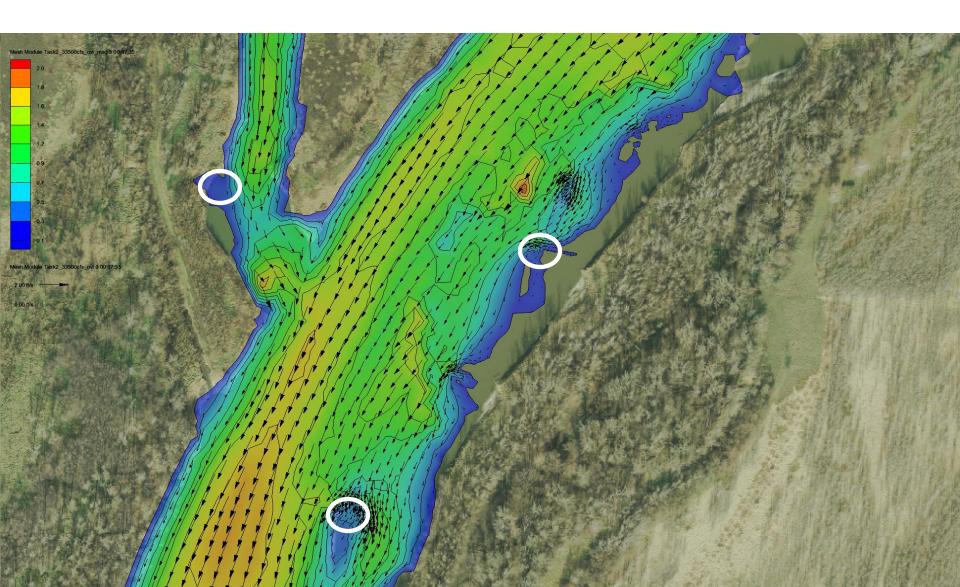
Modeling of Free Embryo Drift

Particle Trapping

Lower River (Gavins Pt. – St. Louis)
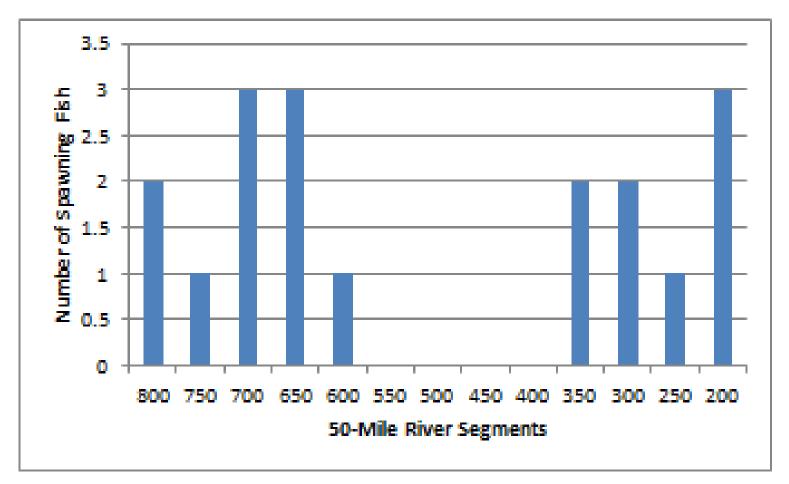
Figure 32. Probable spawning locations on the lower river, grouped in 50-mile segments, 2007 - 2012. (information based on telemetry data provided by USGS).

Free Embryo Drift (RM600)
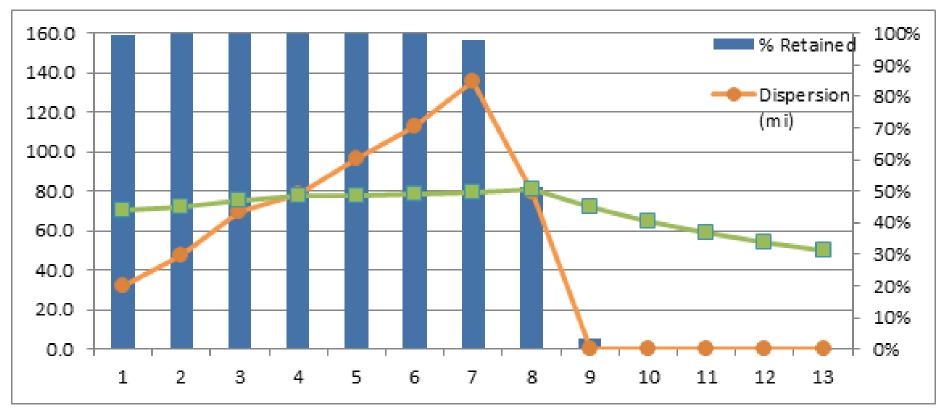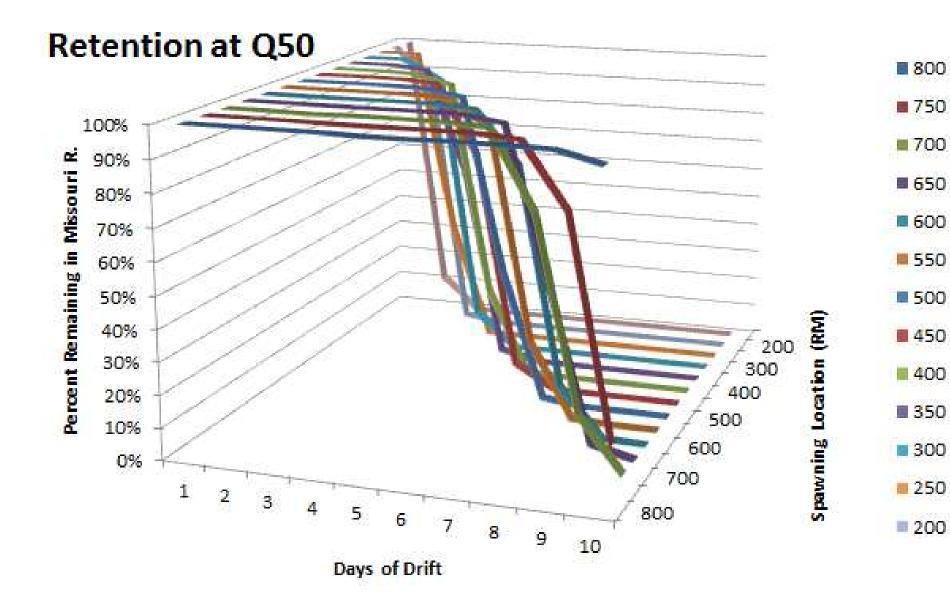
Figure 43. Retention, advection and dispersion for median June/July flows with drift initiated at RM 600 (Platte River Confluence). (Note: Need to correct and update this figure)
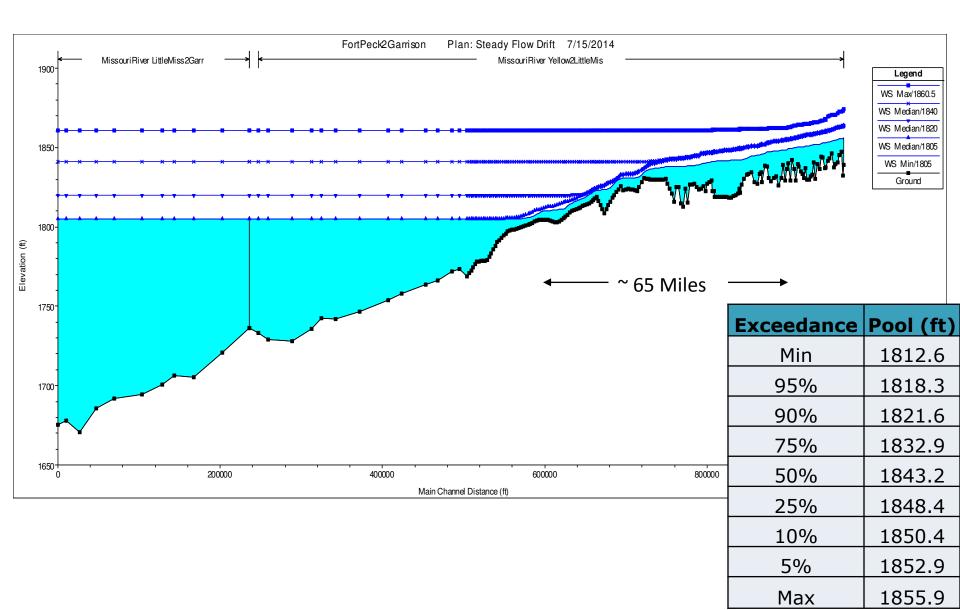
Retention/Distribution

Lake Sakakawea Pool Levels

Exceedance	Pool (ft)
Min	1812.6
95%	1818.3
90%	1821.6
75%	1832.9
50%	1843.2
25%	1848.4
10%	1850.4
5%	1852.9
Max	1855.9
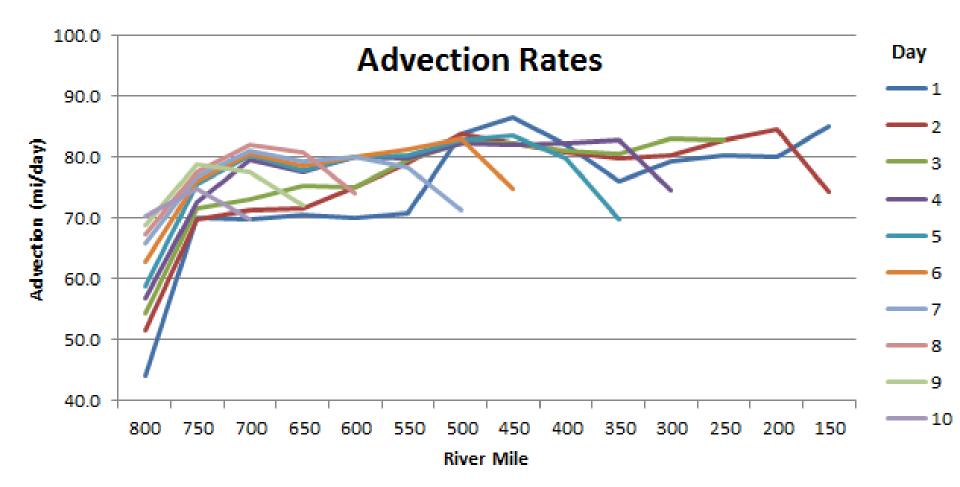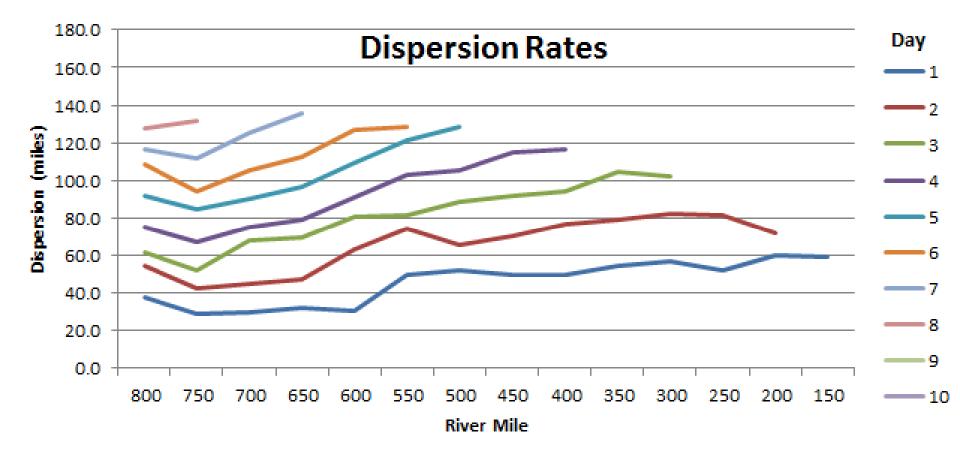
Advection Rates Q50
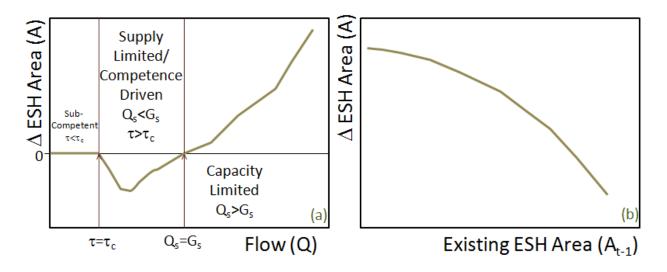
Dispersion Rates
(at Q50 for Spawning Sites on 50-mi Increments)

ESH Conceptual Model
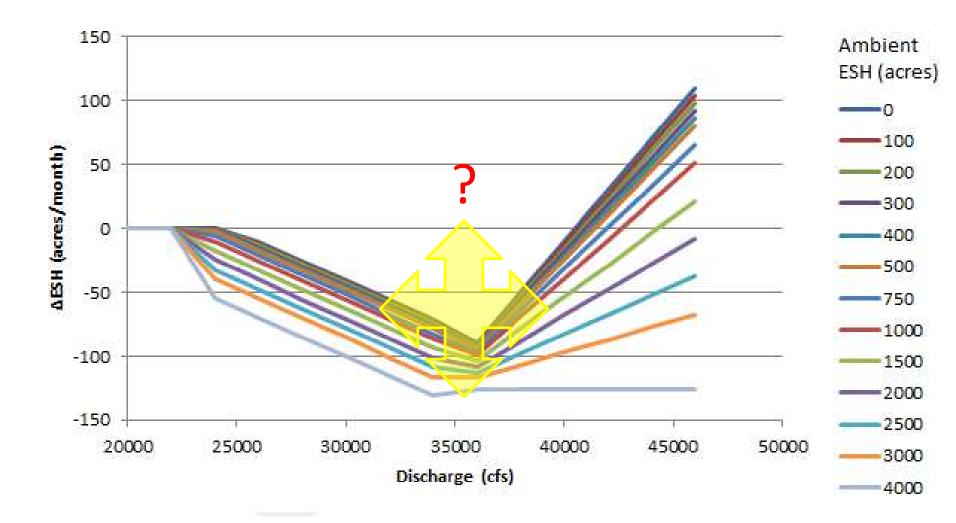
- Supply limited and competence driven
- Critical thresholds for erosion and transport
- Ambient ESH area affects response function
- $A \sim f(Q, d, A_{t-1})$

Model Construct
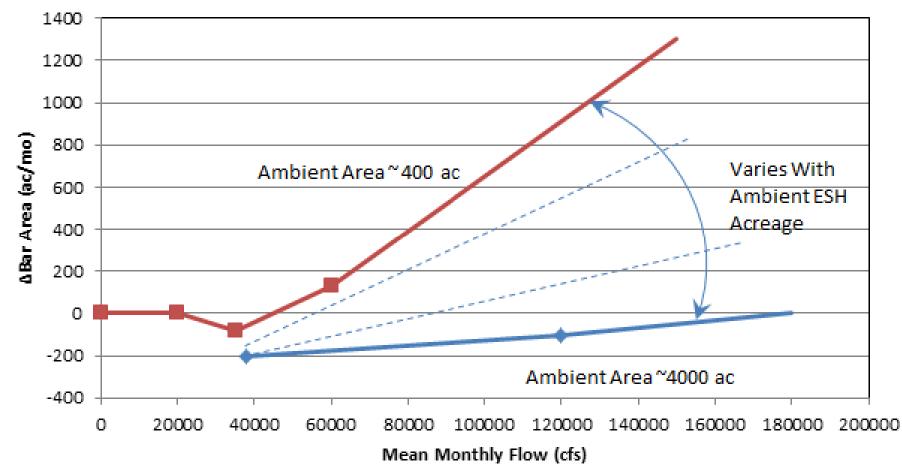
Parameterization

Assumption: Change in ESH due to flow magnitude and/or duration depends on ambient conditions
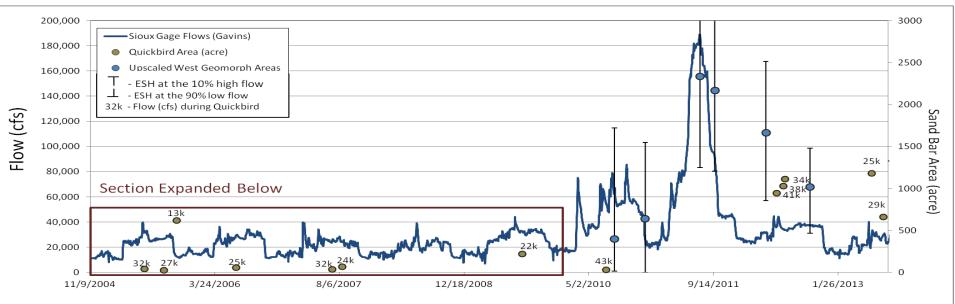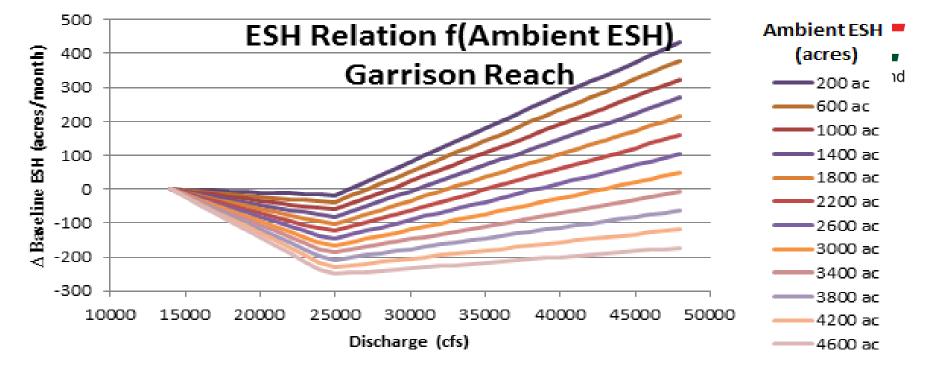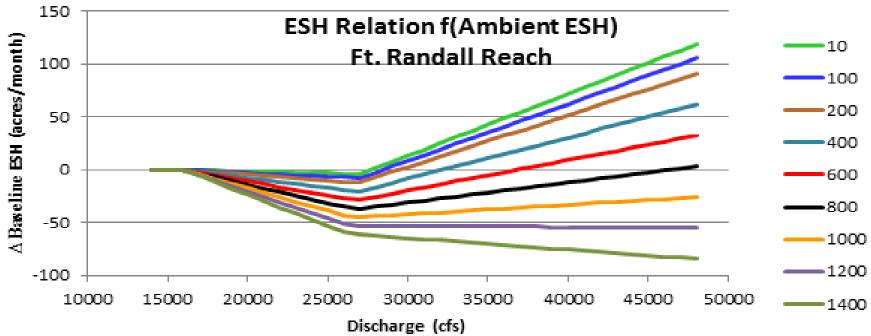
Empirical Data

	WEST (2014) NWO Geomorph Study	QuickBird (USGS – Strong, 2007, 2012)
Coverage	Six 0.5-1 mile sections in the Gavin's Reach (8% of the reach)	Total coverage of Gavins and Garrison Reaches
Temporal Coverage	Seven measurement between 2010 and 2013, concentrating on the aftermath of 2010 elevated flow and the 2011 flood.	Thirteen coverage between 2005 and 2013.
Flow Control	ESH measurements independent of flow at time of measurement.	ESH measurements dependent on flow (e.g. higher flows return smaller ESH)

Supplemental data: Biedenharn et al. (2001), Elliott et al. (2006) and USACE (2013)

ESH Relation f(Ambient ESH)
Garrison Reach

Ambient ESH (acres)

- 200 ac
- 600 ac
- 1000 ac
- 1400 ac
- 1800 ac
- 2200 ac
- 2600 ac
- 3000 ac
- 3400 ac
- 3800 ac
- 4200 ac
- 4600 ac

ESH Relation f(Ambient ESH)
Ft. Randall Reach

- 10
- 100
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400

Algorithms

Gavins Point:

$$A_t^* = A_{t-1}^* + \begin{cases} 0, & \&Q \le 22{,}000\ cfs \\ -0.0076Q + 168 + .015(1300 - A_{t-1}^*), & 22k < Q \le 35k\ cfs \\ (-0.0000046A_{t-1}^* + 0.02)Q + 0.171A_{t-1}^* - 810, & \&Q > 35{,}000\ cfs \end{cases}$$

Garrison:

$$A_t^* = A_{t-1}^* + \begin{cases} 0, & \&Q \le 13{,}000\ cfs \\ (Q - 13000) * (-0.000005A_{t-1}^* - 0.0006), & 13k < Q \le 25k\ cfs \\ (-0.0000037A_{t-1}^* + 0.02)Q + 0.0396A_{t-1}^* - 517, & \&Q > 25{,}000\ cfs \end{cases}$$

Ft. Randall:

$$A_t^* = A_{t-1}^* + \begin{cases} 0, & \&Q \le 16{,}000\ cfs \\ (Q - 16000) * (-0.0000035A_{t-1}^* - 0.0003), & 16k\ cfs < Q \le 28k\ cfs \\ (-0.000005A_{t-1}^* + 0.0059)Q + 0.094A_{t-1}^* - 163, & \&Q > 28{,}000\ cfs \end{cases}$$
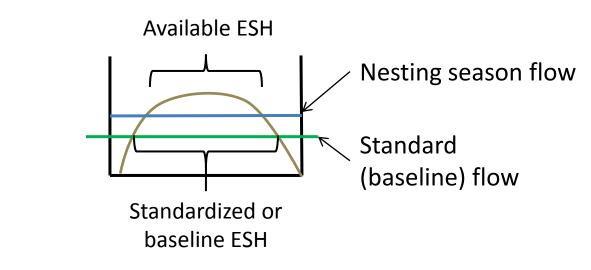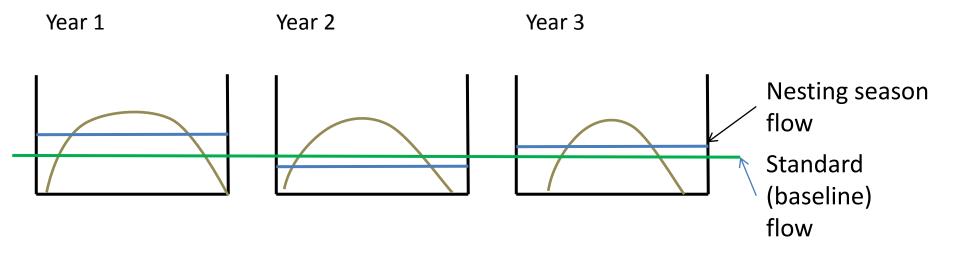
Hydrology for Assessments

- Based on the POR from 1930 – 2012

- Historical inflows with current depletions and evaporation

- Current reservoir operating criteria, except as dictated by a given scenario

- Mean Daily conditions (flow, stage, pool elev) available for each reservoir and at ten computation points
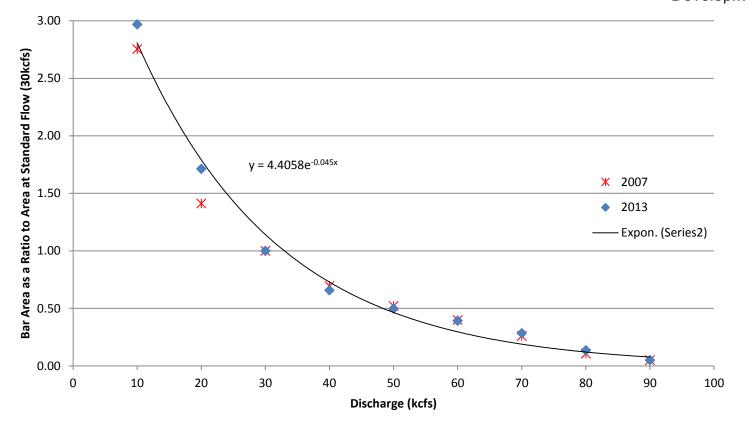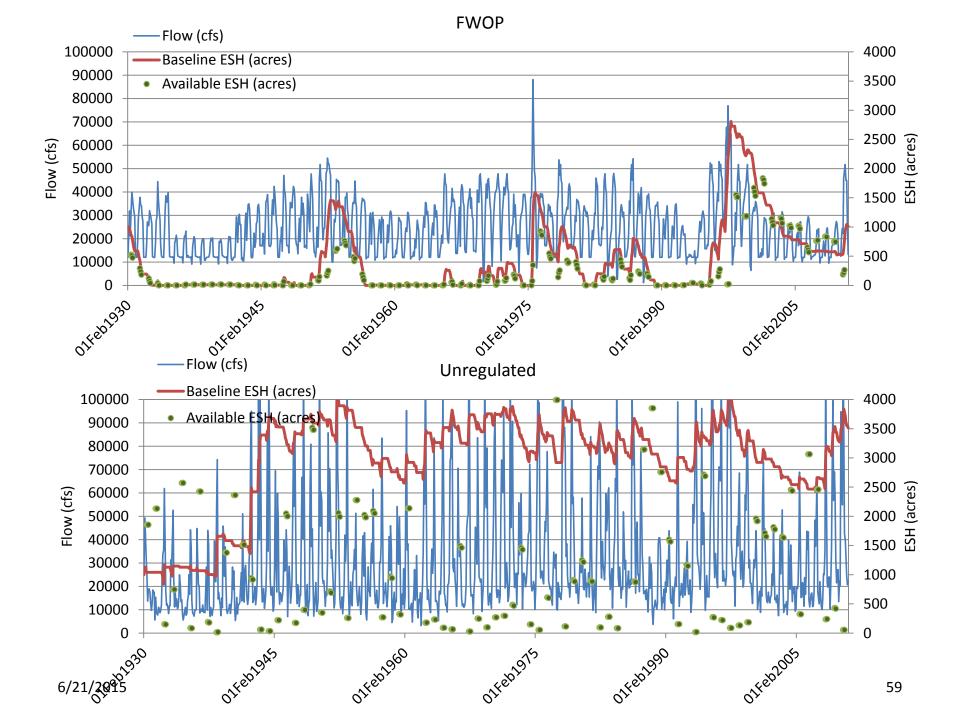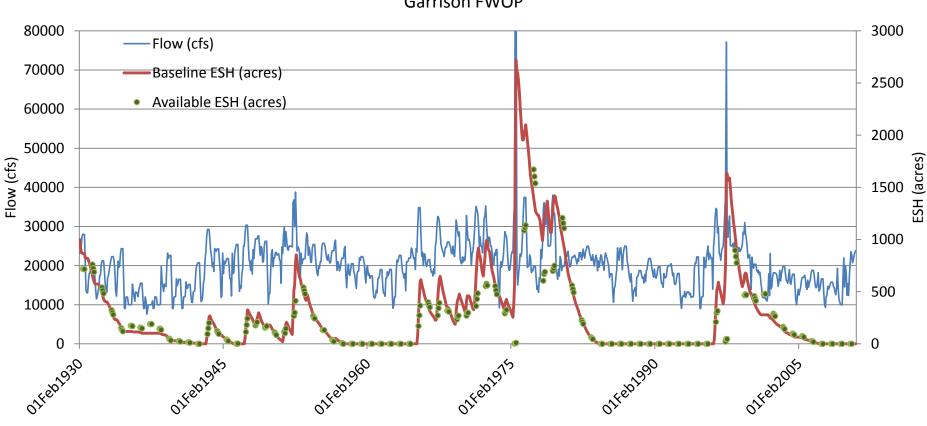
Definition of ESH Metrics

Available ESH

Nesting season flow

Standard (baseline) flow

Standardized or baseline ESH

Year 1

Year 2

Year 3

Nesting season flow

Standard (baseline) flow

Stage-Area Relation

$$Y = 4.123e^{-0.045Q}$$
$$ESH_Q = Y * ESH_{base}$$

FWOP

Unregulated

Garrison - Oahe

Garrison FWOP

Ft. Randall - LCL