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Evidence-Based Evaluation of the Cumulative Effects of Tidal Freshwater and Estuarine Ecosystem Restoration on Endangered Juvenile Salmon in the Columbia River

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Columbia River Estuary Workshop
May 30, 2014
Astoria, Oregon

Purpose and Contents

- Purpose: Explain results of the evidence-based evaluation (EBE) of the Columbia Estuary Ecosystem Restoration Program (CEERP)
- Contents
  - EBE Basics
  - CEERP Results
  - Summary

CEERP is a joint effort of BPA and the Corps and their partners to implement ecosystem restoration in the lower Columbia River and estuary as mandated in the FCRPS BiOp.

Management Question

Is CEERP having positive, system-wide cumulative effects to the benefit of ESA-listed juvenile salmon and steelhead?

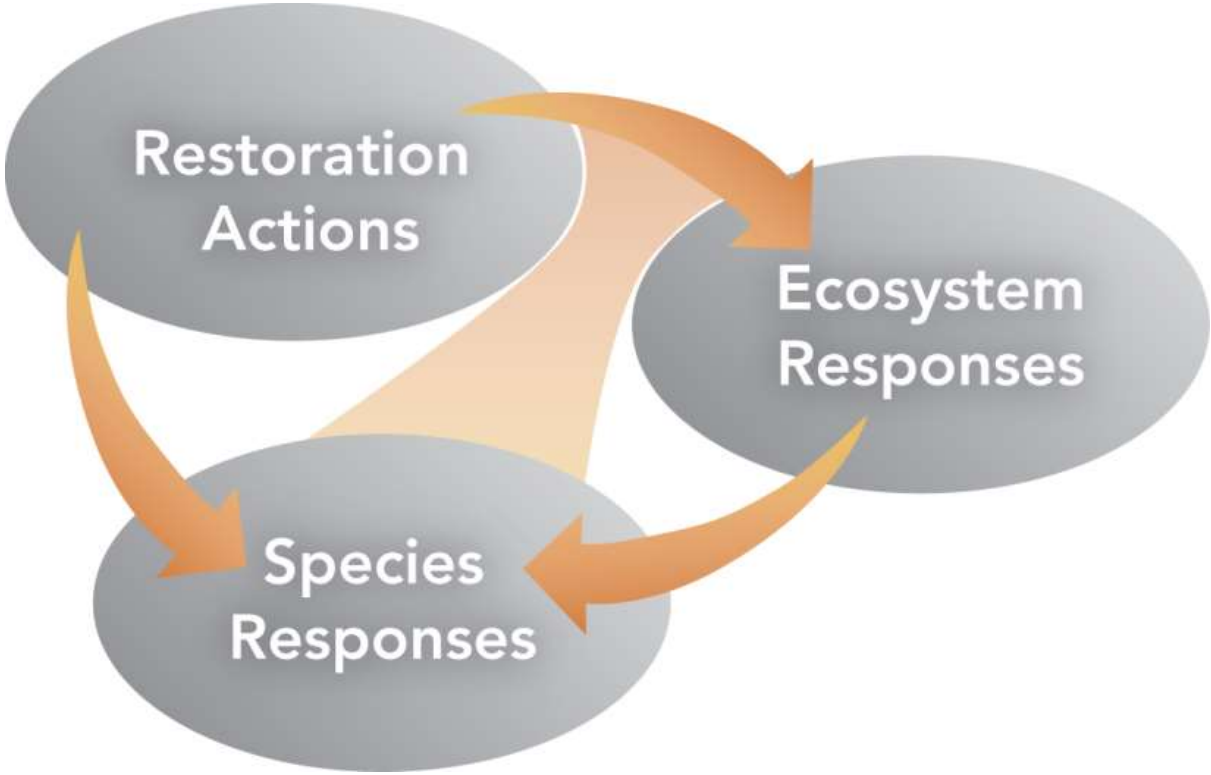
Map courtesy of LCEP

Cumulative effects are defined as changes to salmon and the ecosystem resulting from collective actions of CEERP partners.

EBE's Role in the CEERP Adaptive Management Process

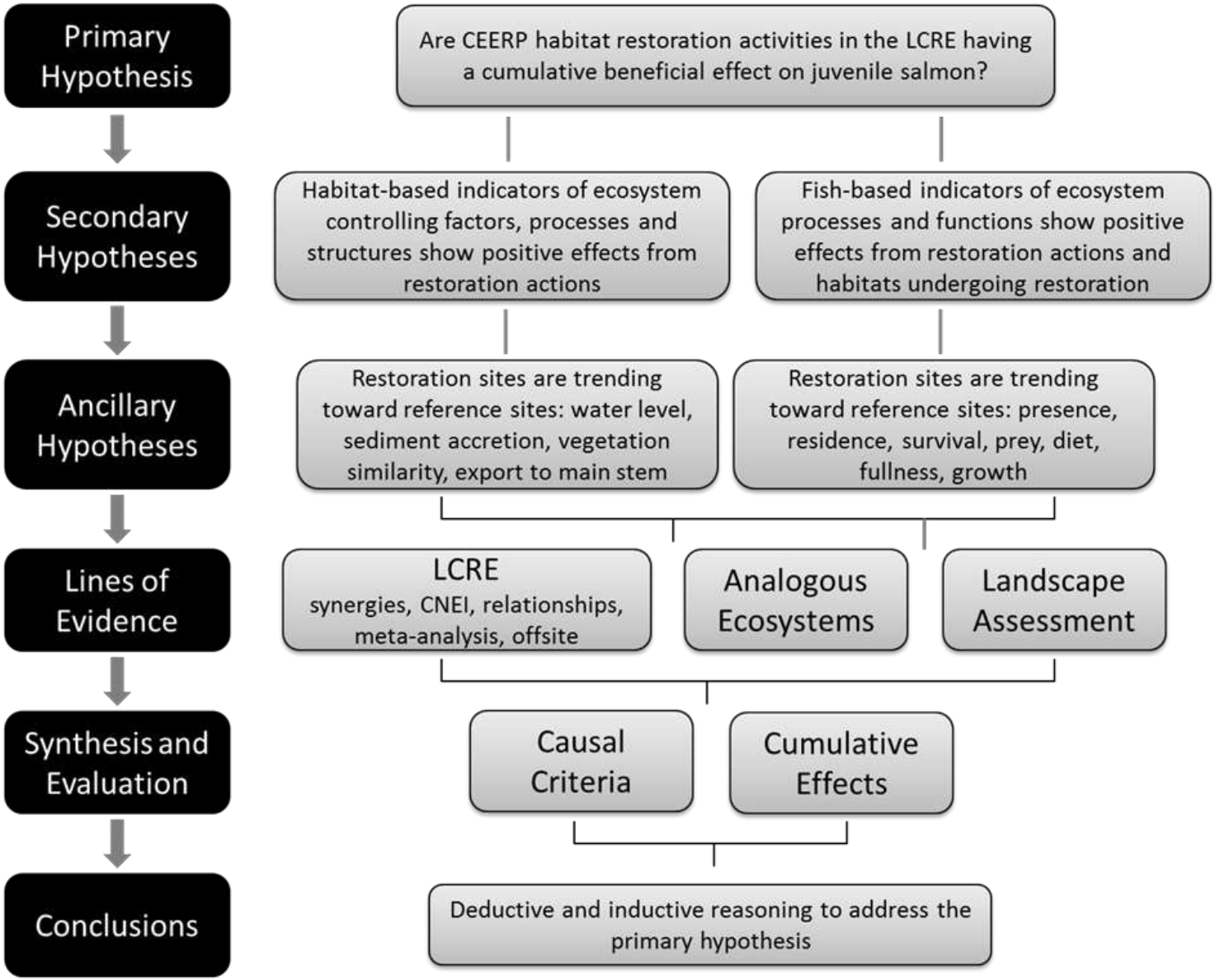
Evidence-based Evaluation

General Model of the Cumulative Effects of Ecosystem Restoration



Actions can have direct effects on species as well as effects mediated by ecosystem processes

EBE Approach



Standardized Monitoring Protocols and Data Reduction Procedures for Indicators of Ecosystem Responses

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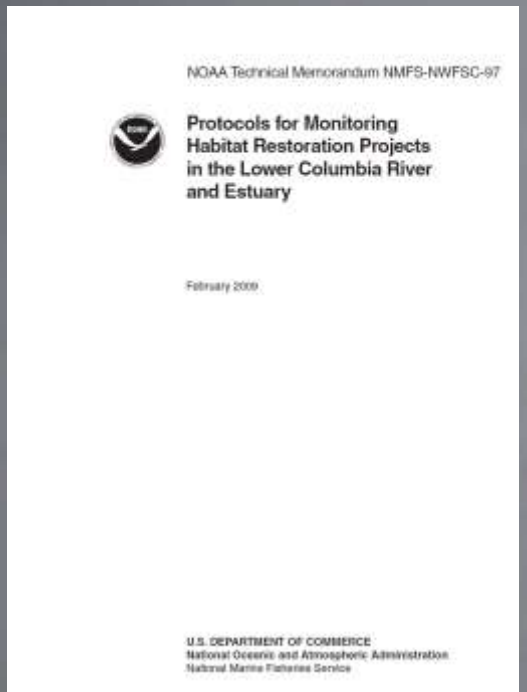
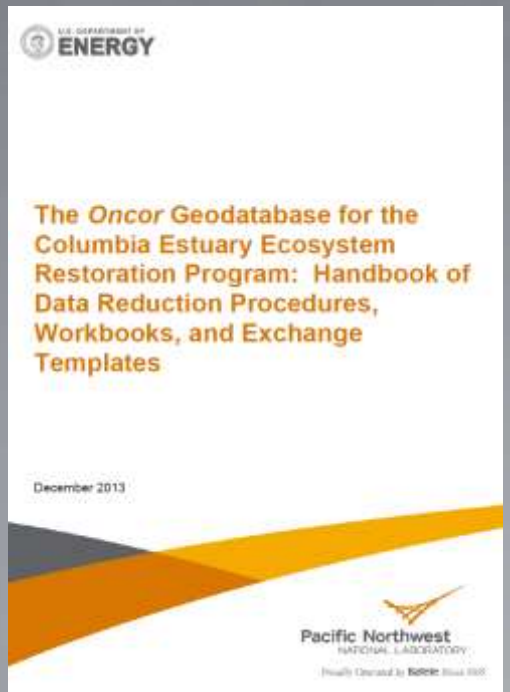

NOAA Technical Memorandum NMFS-NWFSC-97

Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary

February 2009

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service


U.S. DEPARTMENT OF ENERGY

The *Oncor* Geodatabase for the Columbia Estuary Ecosystem Restoration Program: Handbook of Data Reduction Procedures, Workbooks, and Exchange Templates

December 2013

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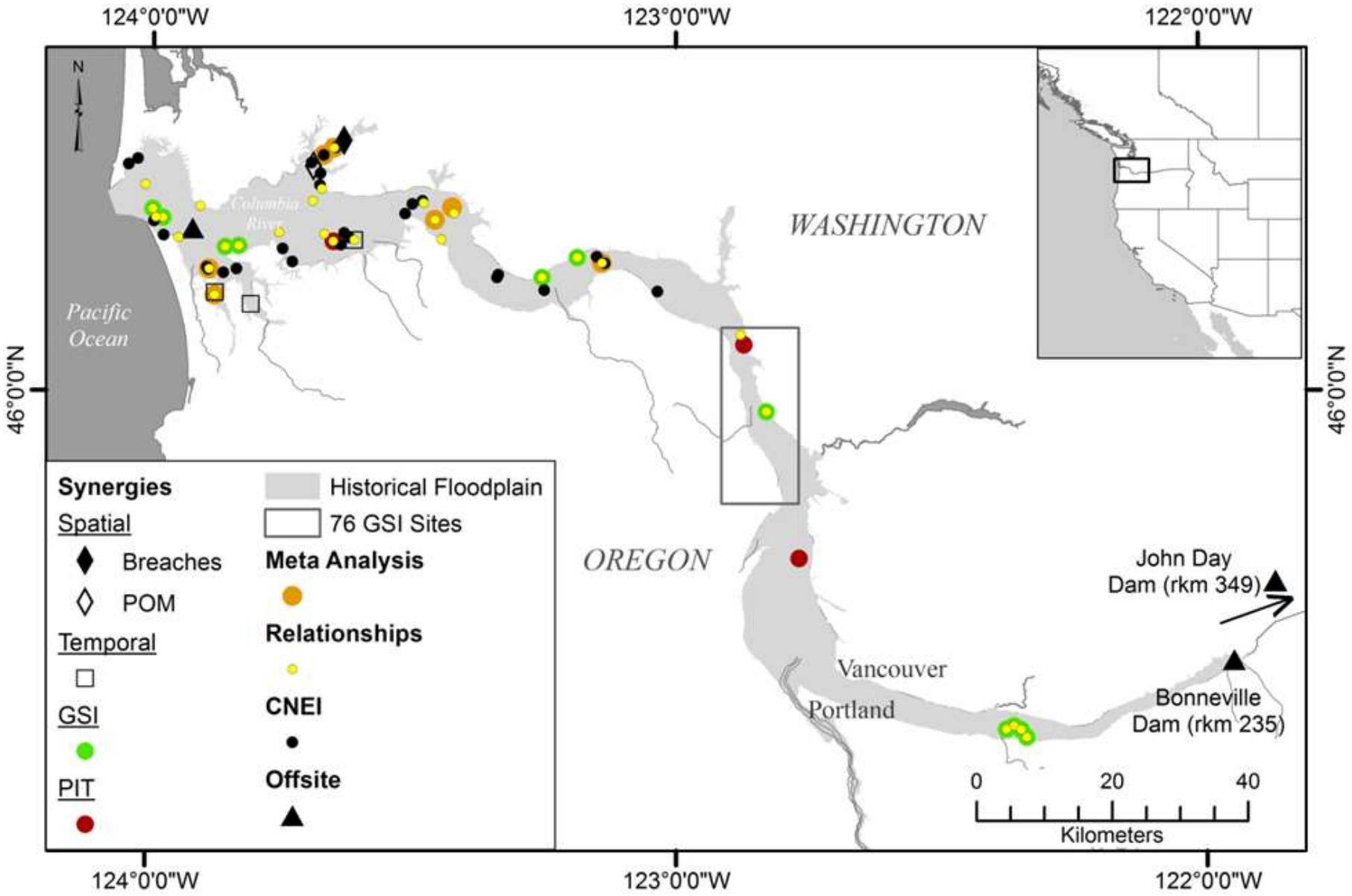
Lines of Evidence Used to Evaluate the Hypotheses

Line of Evidence	Description	Cumulative Effects Category
Evidence from the Lower Columbia River and Estuary (LCRE) Floodplain		
Spatial and temporal synergies ("synergies")	Interaction among multiple effects to produce an outcome that is greater or less than the sum of the individual effects	Synergistic, space crowding, indirect, time lags, cross-boundary, nonlinear, compounding
Cumulative net ecosystem improvement ("CNEI")	Change in ecological function from the areas restored across multiple sites with various probabilities of success	Landscape, compounding
Site-scale ecological relationships ("relationships")	Cause/effect associations between one or more independent variables and a response (dependent) variable	Indirect, time lags, compounding
Estuary-wide meta-analysis ("meta-analysis")	Use of statistical (quantitative) and non-statistical (qualitative) methods to summarize multiple site-scale monitoring results to make inferences at an estuary-wide scale	Landscape, time lags
Offsite benefits to juvenile salmon ("offsite")	Beneficial effects on juvenile salmon from ecosystem restoration that are realized indirectly at locations away from the restoration site, e.g., in the main-stem river	Cross-boundary, indirect, compounding
Evidence from the LCRE Landscape and Analogous Ecosystems Outside the LCRE		
Landscape condition evaluation ("landscape")	Description of trends in indicators of aquatic ecosystem condition at the landscape scale, specifically, the watershed context within which wetlands on the LCRE floodplain are being restored	Landscape
Evidence-based scoring of global literature ("global literature")	Systematic global literature search, filtering, review, and scoring based on formal criteria applied to selected response variables	Not applicable to cumulative effects

Data Collection Locations

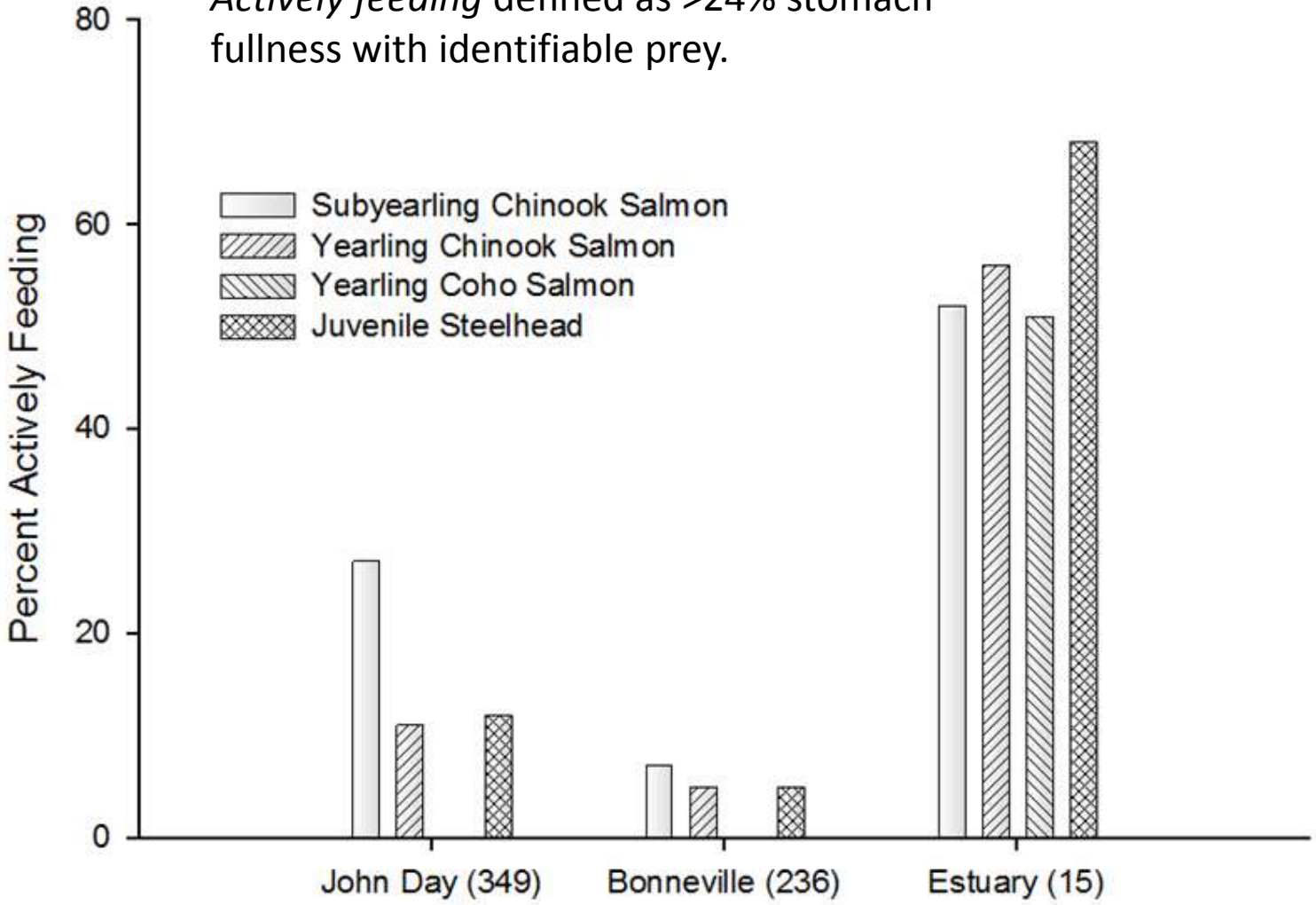


Meta-Analysis of Action Effectiveness Data

Restoration Project	Restoration Action	Water Level	Sediment Accretion	Water Temperature	Vegetation Similarity	Salmon Presence
Crims Island	Channel Excavation, Grading	Haskell and Tiffan 2011	Thom et al. 2012[a]		Thom et al. 2012	Haskell and Tiffan 2011
Johnson Farm	Dike Breach					Eaton 2010[b]
Kandoll Farm	Dike Breach, Culvert Installation	Roegner et al. 2010	Thom et al. 2012[a]	Roegner et al. 2010, Thom et al. 2012	Thom et al. 2012[e]	Roegner et al. 2010[f]
South Slough	Dike Breach, Culvert Removal	CREST 2012		CREST 2012		CREST 2012
Julia Butler Hansen NWR	Tide-Gate Replacement	Johnson J et al. 2009, 2011[c]		Johnson J et al. 2009, 2011		Johnson J et al. 2009, 2011[d]
Tenasillahe Island	Tide-Gate Replacement	Johnson J et al. 2008		Johnson J et al. 2008		Johnson J et al. 2008
Vera Slough	Tide-Gate Replacement	Thom et al. 2012[c]	Thom et al. 2012, In Prep.–b[a]	Thom et al. 2012	Thom et al. 2012	Thom et al. 2012[g]

Offsite Benefits

Actively feeding defined as >24% stomach fullness with identifiable prey.



Summary of Analyses of Fish & Habitat Hypotheses and Indicators

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			Fish Response						Habitat Response			
Analyses	Presence	Residence	Survival	Prey	Diet	Fullness	Growth	Water Level	Sediment Accretion	Vegetation	Water Temperature	Export
Particulate organic matter flux model												
Hydrodynamic model of dike breaches												
Historically breached sites												
Detections of known Interior Columbia ESUs/DPSs												
Cumulative net ecosystem improvement model												
Meta-analysis of LCRE sites: tide-gate replacements												
Meta-analysis of LCRE sites: all other reconnections												
Offsite benefits to juvenile salmon condition												
Evidence-based scoring of LCRE post-restoration reports												
Analogous cases in the global literature												

Key: green = support; red = lack of support; yellow = inconclusive; gray = insufficient or no data; white = not applicable, or not collected under the sampling design, for this evidence-based evaluation.

Causal Criteria Synthesis

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Causal Criterion (CC)	Short Definition	Finding
Strength of association	The magnitude of the effect	Supported
Consistency of association	The repeated observation of the association in varied times and circumstances by multiple observers	Supported
Biological plausibility	Knowledge of the mechanism	Supported
Biological gradient	The level of response is associated with a gradient in the hypothesized cause	Supported
Experimentation	Manipulation of the hypothesized cause	Not evaluated
Temporality	The effect is shown to follow the hypothesized cause	Supported
Specificity of association	Limitation of the association to particular causes and effects	Supported
Analogy	Comparison to similar systems	Supported
Coherence	Lack of serious conflict between the cause-and-effect interpretation and known facts about the case under consideration	Supported
Complete exposure pathway	In a floodplain river system context, this is hydrologic connectivity	Supported
Predictive performance	Ability to accurately and precisely predict restoration outcomes	Not evaluated

Conclusions (from EBE report, p. 6.8)

- "Based on the evidence, we concluded that the primary hypothesis was supported, i.e., that the habitat restoration activities in the LCRE are likely having a cumulative beneficial effect on juvenile salmon, including interior basin salmon.
- Salmon in restored wetland areas are directly affected by the habitat structures and processes.
- Salmon actively transiting main-stem river habitats are indirectly affected through the food web by allochthonous materials from floodplain wetlands.
- **The beneficial effect of restoring tidal wetlands is expected to increase over time as existing restoration projects mature and new ones are implemented."**

NOTE: We are reasonably certain about the positive direction of the relationship between restoration and benefits to juvenile salmon, but we are uncertain about the magnitude.

Contact Information and References

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- Contact Information
  - HLD, (360) 681-3619, heida.diefenderfer@pnnl.gov
- Reference
  - Diefenderfer et al. 2013. An Evidence-Based Evaluation of the Cumulative Effects of Tidal Freshwater and Estuarine Ecosystem Restoration on Endangered Juvenile Salmon in the Columbia River. PNNL-23037. Final report prepared for the U.S. Army Corps of Engineers Portland District, Portland, Oregon, by Pacific Northwest National Laboratory and NOAA Fisheries. Richland, Washington.
- Upcoming Session on EBE at the **Conference on Ecological and Ecosystem Restoration,** New Orleans, July 2014

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Thank You

ANNEX

The Science Question

Are large-scale changes in quality and landscape pattern of ecosystems contributing to the recovery of species and ecosystem services?

Cumulative Net Ecosystem Improvement (CNEI)

To calculate cumulative net ecosystem improvement as an additive change in function, we used the general equation (Diefenderfer et al. 2011)

$$CNEI = \sum_{i=1}^{n} \Delta F_i A_i P_i$$

where n = number of restoration projects

ΔF = change in ecological function

A = project size (area)

P = probability of success of the restoration action.

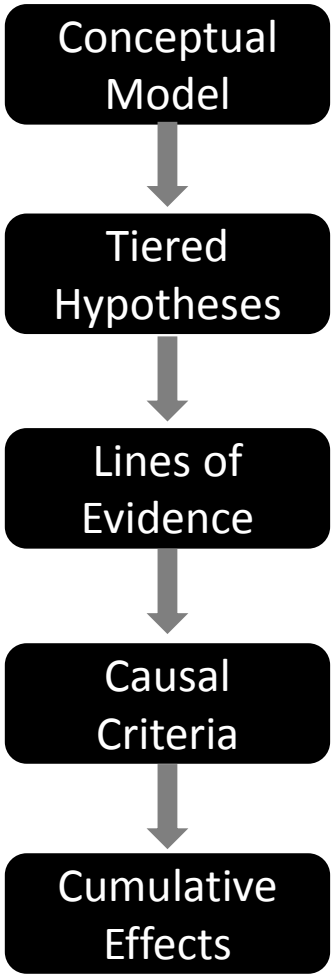
Maximum potential productivity increase from areas restored: 8,529 metric tons annual herbaceous plant biomass flux; and 7 billion dipterans/48 h based on fallout trap data collected in the months of April–June.

Need for a New Approach to Evaluate Ecosystem Restoration

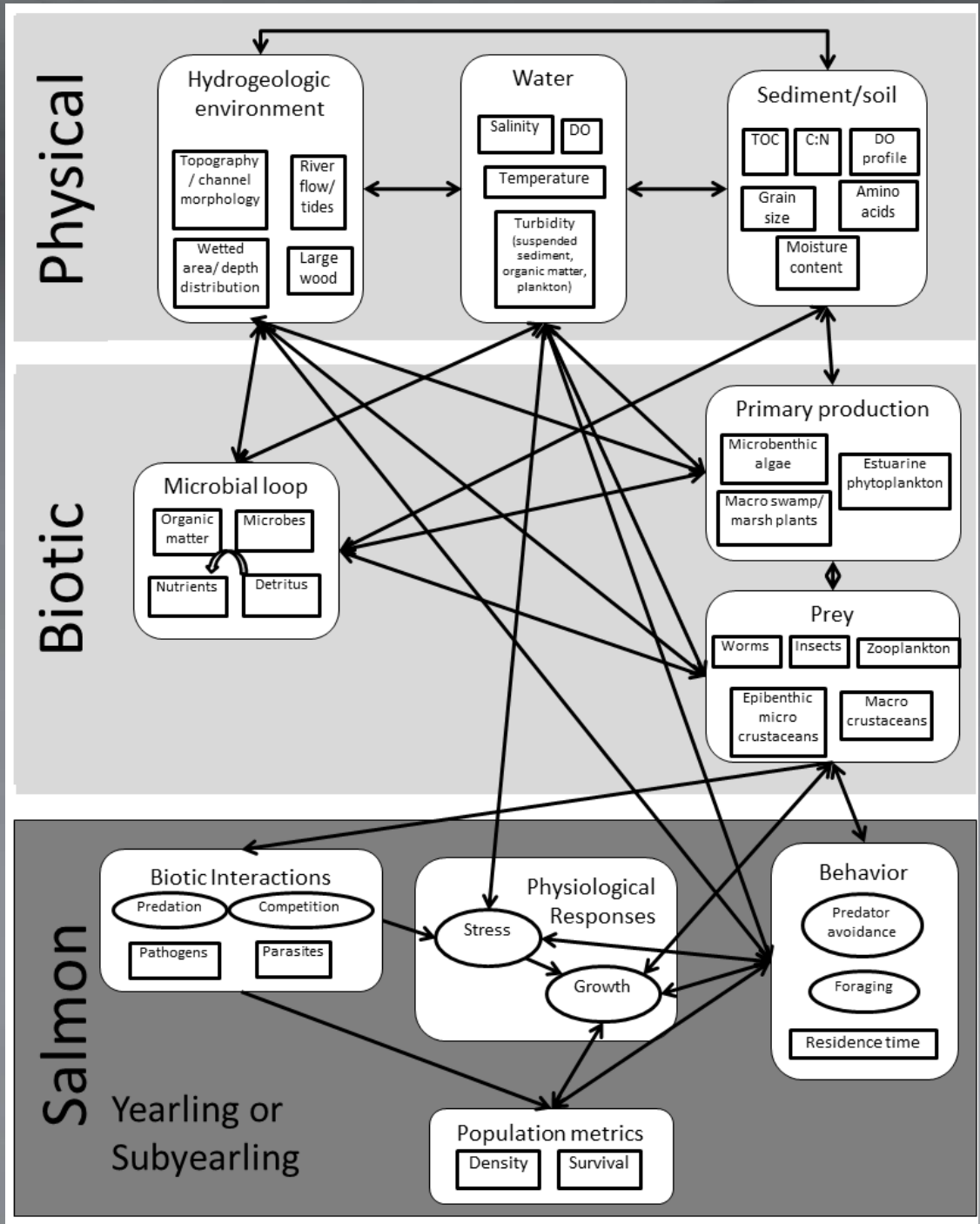
- Need to evaluate cumulative effects, because of the complexity of the ecosystems, restoration actions, and responses.
- Existing evidence-based approaches were rigidly embedded in published literature; time lags make this unacceptable for active large-scale ecosystem restoration programs.
- Need for program-level evaluations to support adaptive management, decision-making and accountability to stakeholders and taxpayers.

EBE Elements – Large Scale Restoration

- Derives **tiered hypotheses** from the overall **science question** and an ecosystem **conceptual model**
- Employs **standardized monitoring methods**
- Involves **causal criteria** synthesis of multiple **lines of evidence** obtained from **analyses** using field research, monitoring, modeling, meta-analysis, etc.
- Evaluates **cumulative effects** of many site-specific actions to provide managers with program-level information for reporting or decision making



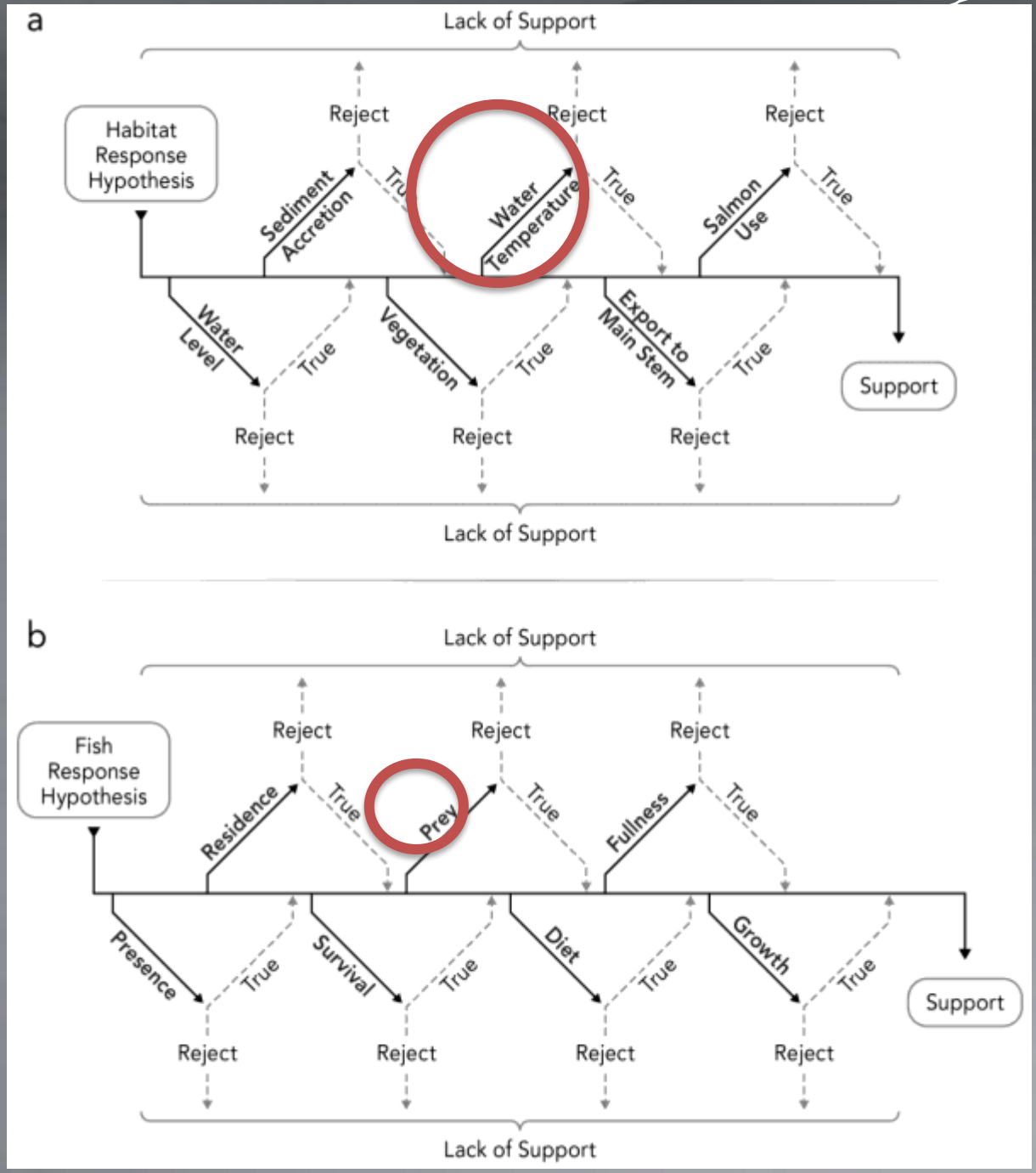
An **ecosystem conceptual model** is the basis for selecting response indicators and developing hypotheses regarding the effects of restoration actions on the ecosystem and species of interest



Tiered Hypotheses

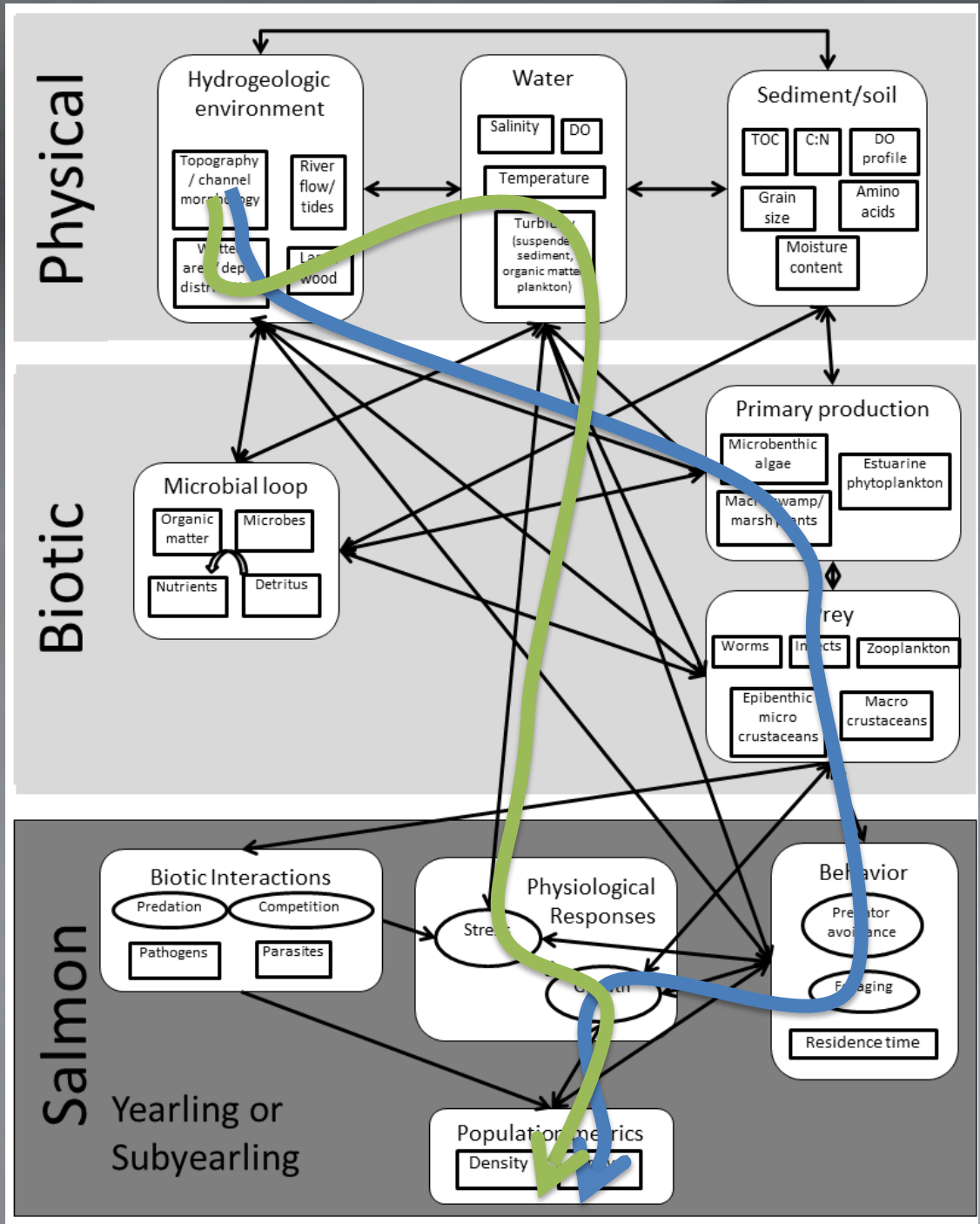
Primary Hypothesis: Habitat restoration activities have a cumulative beneficial effect on the species of interest.

Here, 12 **indicators** are grouped under secondary **Habitat** and **Fish Response Hypotheses**



Drawing **hypotheses** from the **conceptual model**:

- Changes in the hydrogeologic environment affect water quality that affects physiological response;
- These changes also affect primary production, which affects prey and ultimately behavior
- Population metrics



EBE Approach – What's New?

- Accounts for cumulative effects categories identified by the President's Council on Environmental Quality (1997).
- Takes advantage of critical-thinking tools.
- Develops multiple program-specific lines of evidence and analyses.
- Includes, as one line of evidence, the comprehensive review of the literature emphasized in prior evidence-based approaches.
- Applies causal criteria to examine associations between ecosystem restoration actions and response variables.
- Systematically analyzes multiple monitored indicators having various units, scales of time and area, and levels of quantification.
- Synthesizes and evaluates restoration program effects.

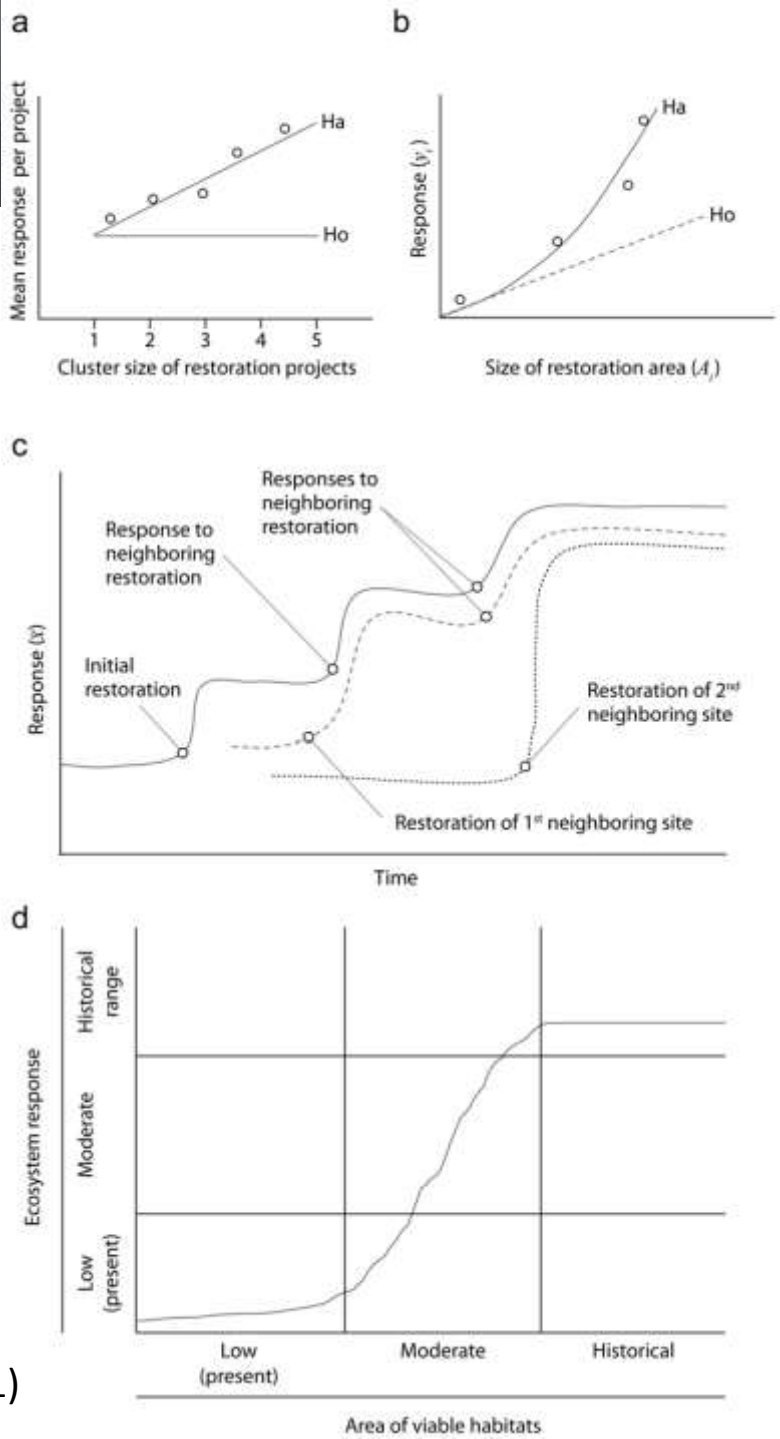
Hypothetical Restoration Cause-and-Effect Associations

a) mean response per project vs. number of restoration projects in a **cluster** – under the null (Ho: no relationship) and alternative (Ha: cumulative effects) hypotheses;

b) the magnitude of environmental response vs. size of the restoration **area** under the null (Ho: proportionality) and alternative (Ha: cumulative effects) hypotheses;

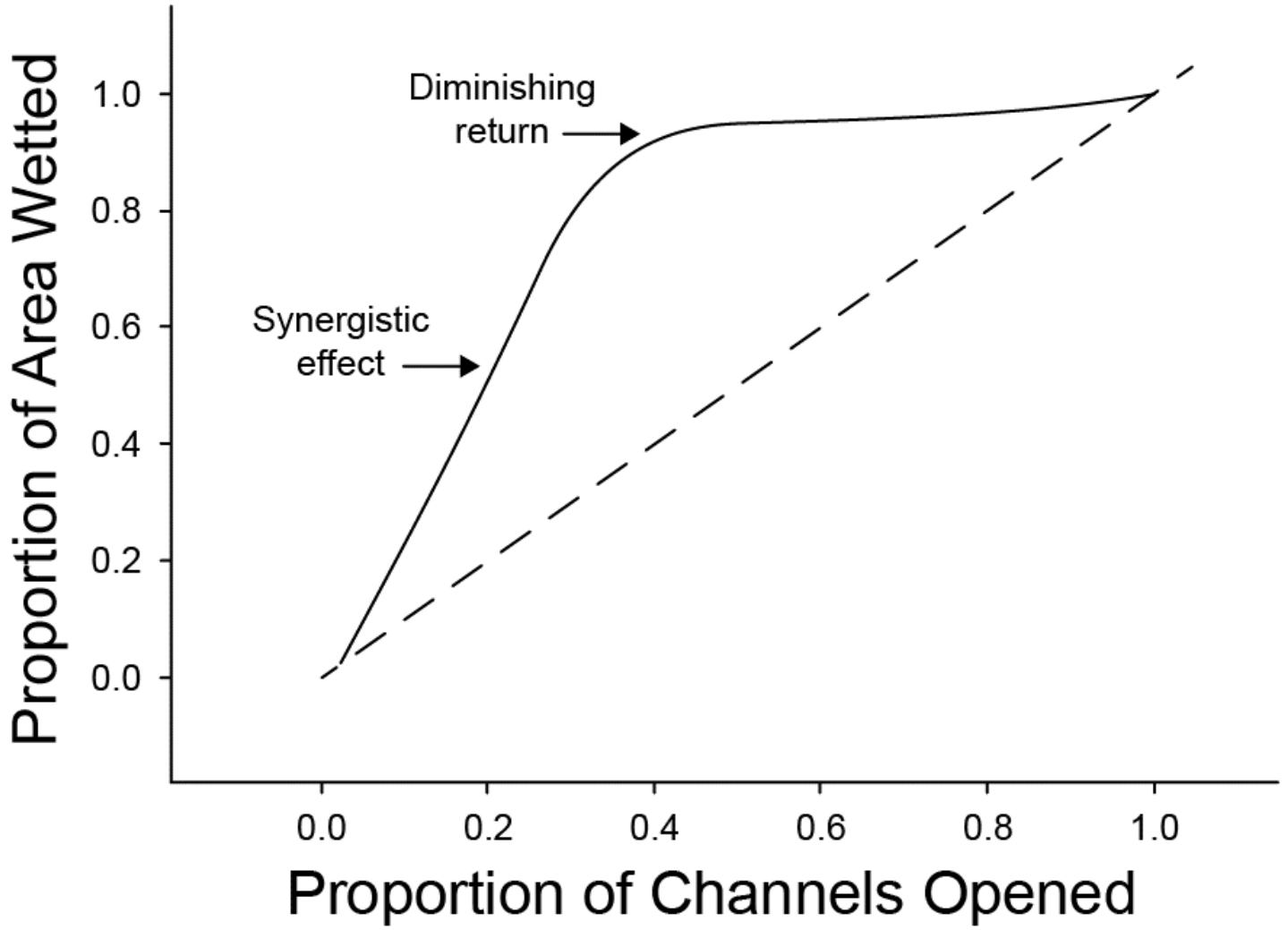
c) temporal patterns of site response vs. one or more **interventions** at nearby restoration sites;

d) ecosystem response vs. area of **viable habitats**.



From Diefenderfer et al. (2011)

Results – Mean response per project vs. number of restoration projects in a cluster



From Diefenderfer et al. (2012)

Demonstration of EBE Application

- Columbia Estuary Ecosystem Restoration Program (CEERP)
  - Implemented by USACE Portland District and Bonneville Power Administration with partner organizations
  - Goal: Understand, restore, and conserve LCRE ecosystems, especially as they benefit juvenile salmon
  - Primary strategy: restore hydrologic connections to improve access and productive capacity (dike breaches)

- Acknowledgments
  - This research was sponsored by the U.S. Army Corps of Engineers, Portland District. The USACE is an Action Agency under the National Marine Fisheries Service (NMFS) Biological Opinion on Effects of Federal Columbia River Hydrosystem Operations on Salmon.
  - Special thanks to Blaine Ebberts and Cynthia Studebaker, USACE

Methods of Hydrological Reconnection of Sites Across the River Floodplain

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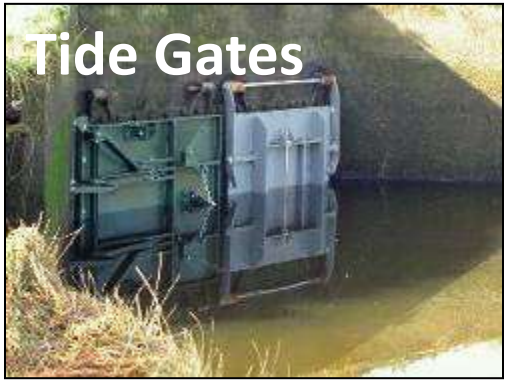
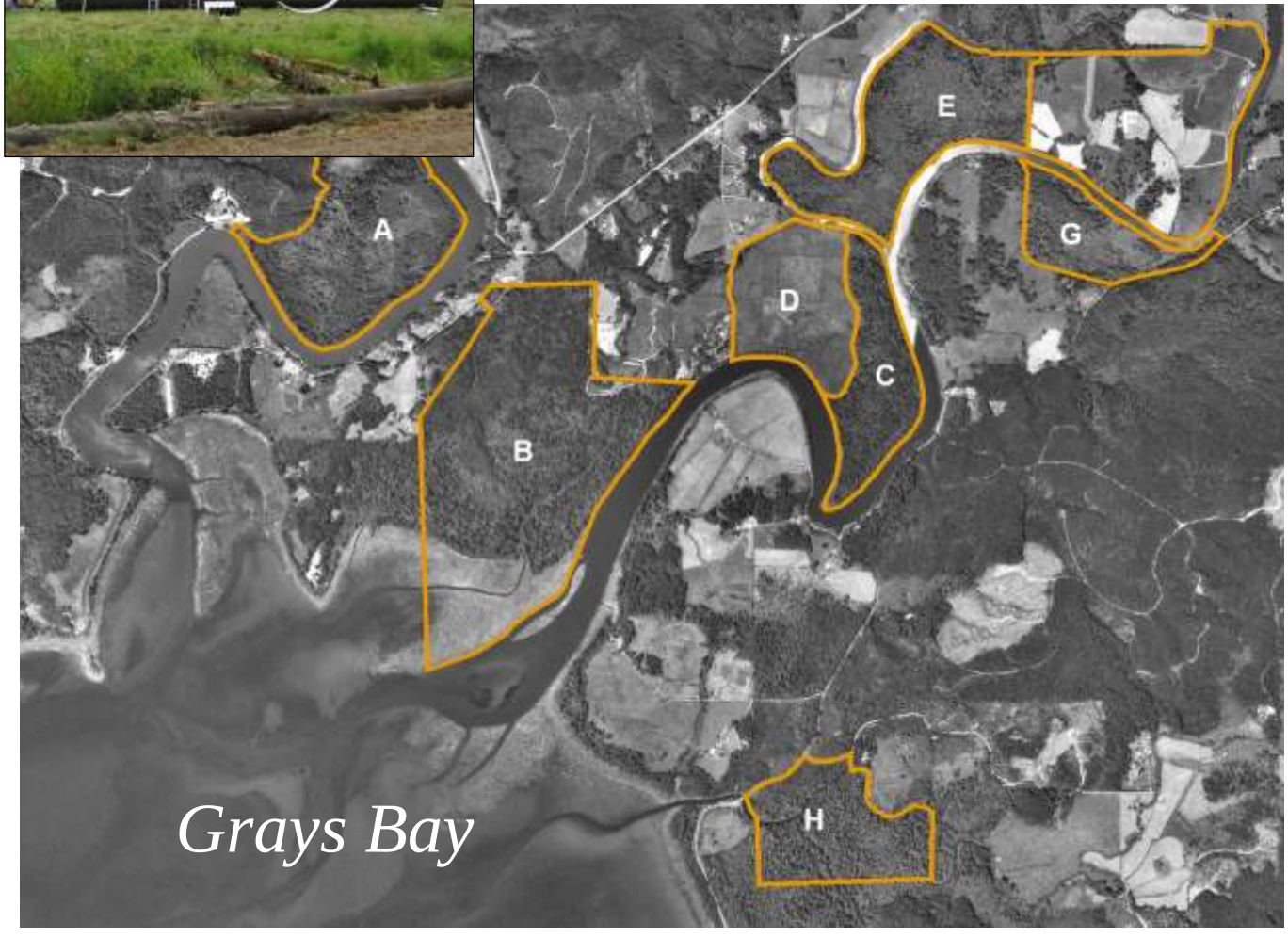


Example: 8 parcels in vicinity of Grays Bay, lower Columbia River



Advances in EBE

- A peer-reviewed approach for ecological restoration- melds earlier methods in evidence-based assessment, cumulative effects, and critical thinking.
- Unlike evidence-based approaches evaluating literature, the EBE is implemented periodically during the long-term, dynamic restoration process; it can evolve as priorities do.
- Flexible lines of evidence, including meta-analysis, are developed for the ecosystem and objectives at hand.
- Considers cumulative effects complex in space and time (scales), e.g., linear, non-linear, synergistic and pulsed.
- Separates critical thinking, e.g. synthesis from evaluation.
- Uses both deductive and inductive reasoning in a redundant system of lines of evidence and causal criteria.

Causal Criteria Synthesis of Lines of Evidence

Causal Criterion (CC)	Short Definition
Strength of association	The magnitude of the effect
Consistency of association	The repeated observation of the association in varied times and circumstances by multiple observers
Biological plausibility	Knowledge of the mechanism (not a necessary condition of causation because knowledge depends on state of the science [Hill 1965])
Biological gradient	The level of response is associated with a gradient in the hypothesized cause
Experimentation	Manipulation of the hypothesized cause
Temporality	The effect is shown to follow the hypothesized cause
Specificity of association	Limitation of the association to particular causes and effects
Analogy	Comparison to similar systems
Coherence	Lack of serious conflict between the cause-and-effect interpretation and known facts about the case under consideration
Complete exposure pathway	In a floodplain river system context, this is hydrologic connectivity
Predictive performance	Ability to accurately and precisely predict restoration outcomes

Analyses Associated with Lines of Evidence

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Line of Evidence	General Methods (Analyses)
Synergies	Analysis of field data from historically reconnected sites, hydrodynamic modeling of inundation patterns and of particulate organic matter transport; detections of interior Columbia salmon in the LCRE
CNEI model	Additive modeling of change in function, restored area, and probability of success
Ecological relationships	Summarization of concurrent advances in the state of the restoration science in LCRE; use of new information to improve the LCRE ecosystem conceptual model
Meta-analysis	Compilation and systematic qualitative assessment of results of action-effectiveness studies in the LCRE
Offsite benefits	Comparative analysis of salmon stomachs; particulate organic matter export modeling; CNEI of prey production
Landscape condition	Remote-sensing data analysis to determine land-cover change trajectories of forest cover and urbanization in the contributing watersheds to the LCRE

Categories of Cumulative Effects

- Frequent and repetitive effects on an environmental system (**time crowding**)
- Delayed effects (**time lags**)
- High spatial density of effects on an environmental system (**space crowding**)
- Effects occur away from the source (**cross-boundary**)
- Change in **landscape pattern** (e.g., fragmentation or the reverse)
- Effects arising from multiple sources or pathways (**compounding** effects)
- Secondary effects (**indirect** effects)

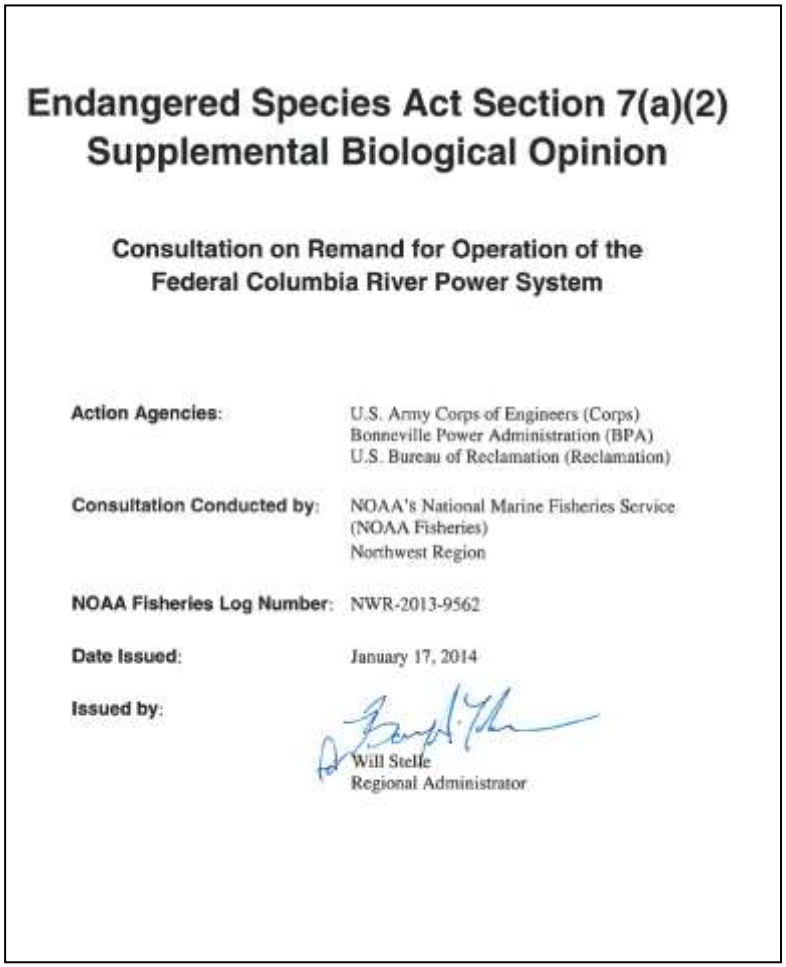
(Council on Environmental Quality 1997)

EBE - Foundations in Prior Research

- A method of evaluating a collection of published, peer-reviewed literature to determine the weight of evidence for or against a hypothesis
- Uses “causal criteria”: aspects of an association that should be studied before claiming causation
  - none can prove the case alone, and none is indispensable according to Hill (1965)
- Originated in the medical sciences in the U.S. and England
  - Surgeon General’s Advisory Committee on Smoking and Health 1964; Hill 1965, *Proc. of the Royal Acad. of Sci.*
- Further developed later in epidemiology and ecotoxicology
  - Sackett et al. 1996, British Medical Journal; Suter et al. 2002, *Environmental Toxicology and Chemistry*
- Recent concurrent applications in ecology
  - Greet et al. 2011, *Freshwater Biology;* Norris et al. 2012, *Freshwater Science*

Program Assessment & Accountability

- EBE results supported positive conclusions regarding CEERP that were reached in the *Supplemental Biological Opinion on Federal Hydrosystem Operations* by NMFS, January, 2014



Endangered Species Act Section 7(a)(2)
Supplemental Biological Opinion

Consultation on Remand for Operation of the Federal Columbia River Power System

Action Agencies:	U.S. Army Corps of Engineers (Corps) Bonneville Power Administration (BPA) U.S. Bureau of Reclamation (Reclamation)
Consultation Conducted by:	NOAA's National Marine Fisheries Service (NOAA Fisheries) Northwest Region
NOAA Fisheries Log Number:	NWR-2013-9562
Date Issued:	January 17, 2014
Issued by:	Will Stelle Regional Administrator

http://www.westcoast.fisheries.noaa.gov/fish_passage/fcrps_opinion/


Discussion to be continued at
a session at the
Conference on Ecological and
Ecosystem Restoration
in New Orleans, July 2014