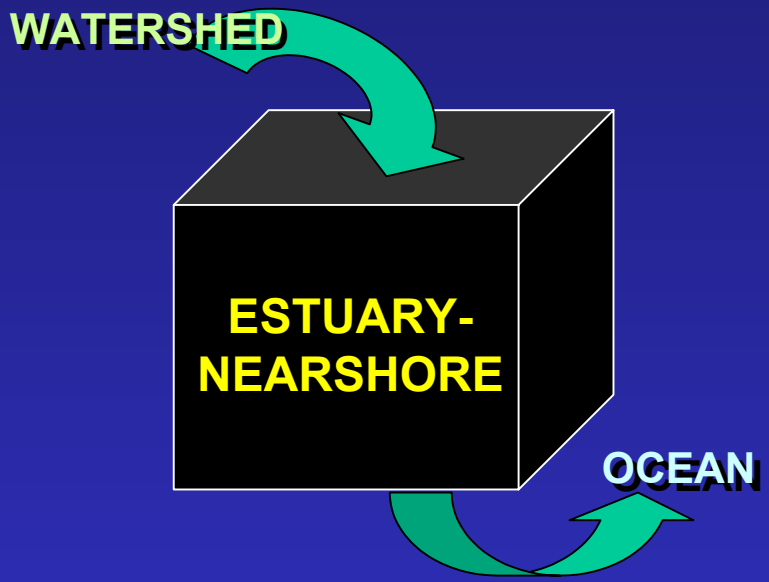
FISH513: May 8

LINKING SALMON TO ESTUARINE AND NEARSHORE HABITAT CHARACTERISTICS

or

Estuaries: Looking Into the Black Box



Charles ("Si") Simenstad
Wetland Ecosystem Team
School of Aquatic and Fishery Sciences
University of Washington

and

Kurt L. Fresh
Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service

GENERAL QUESTIONS

1. *How do nearshore and estuarine habitat characteristics affect salmon in one or more life stages, and how do you recommend that those effects be translated into predictions about population capacity, growth or productivity?*
2. *What are the 2 (or 3 or 4) biggest sources of uncertainty in making predictions about how nearshore and estuarine habitat characteristics affects salmon in one or more life stages?*
3. *What 2 (or 3 or 4) alternative scenarios of current or future conditions would you suggest should be explored to make our model predictions about the effects of nearshore and estuarine habitat change on salmon more robust to uncertainties?*

STUDENT QUESTIONS

1) *Si: Once estuarine habitats have been removed or extensively modified by development, how successfully can their functionality as salmon rearing habitats be restored (can you rewind the function of estuarine areas, once disturbed)? Is restoration of moderate to highly disturbed estuarine areas an effective use of management dollars, or would these funds be better spent limiting development and modification of less disturbed estuarine areas?*

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5) *Si/Kurt: Can you contrast patterns of use and relative importance of estuarine areas to chum and fall chinook populations in Puget Sound?*

RESILIENCE

- **Should fish production be the only metric for salmon recovery?**

  For species that are so pervasively affected by ocean variability, what about population resilience

  = strength to stand up to shocks, especially the ability of an ecosystem to return to it's normal state after being disturbed

Fundamental assumptions:

- **Population resilience derives from life history diversity**
- **Life history diversity is related to habitat diversity/complexity**

- **Thus, from a metapopulation perspective, population resilience depends upon habitat diversity in both freshwater and estuarine-nearshore (and ocean?) phases of juvenile salmon; likely are linked.**

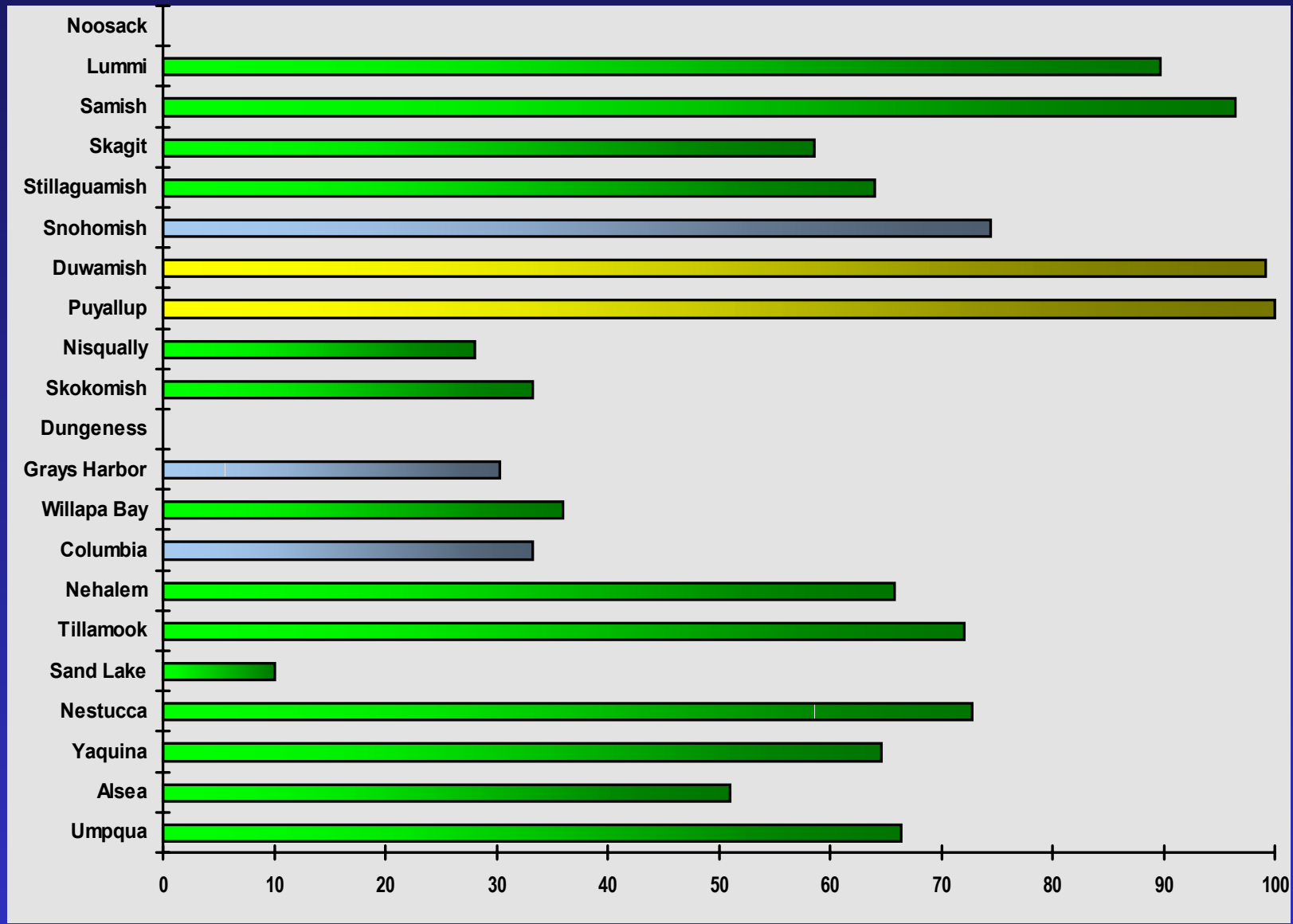
PERSPECTIVES ON SALMON RECOVERY: *Production* vs. *Resilience*

Production	Resilience
Deterministic	Stochastic
Bottlenecks	Cumulative factors
Seeks optimization of habitat	Diversity and sub-optimal life history types and habitat just as important
Core habitat is target	Diffusion is more desirable

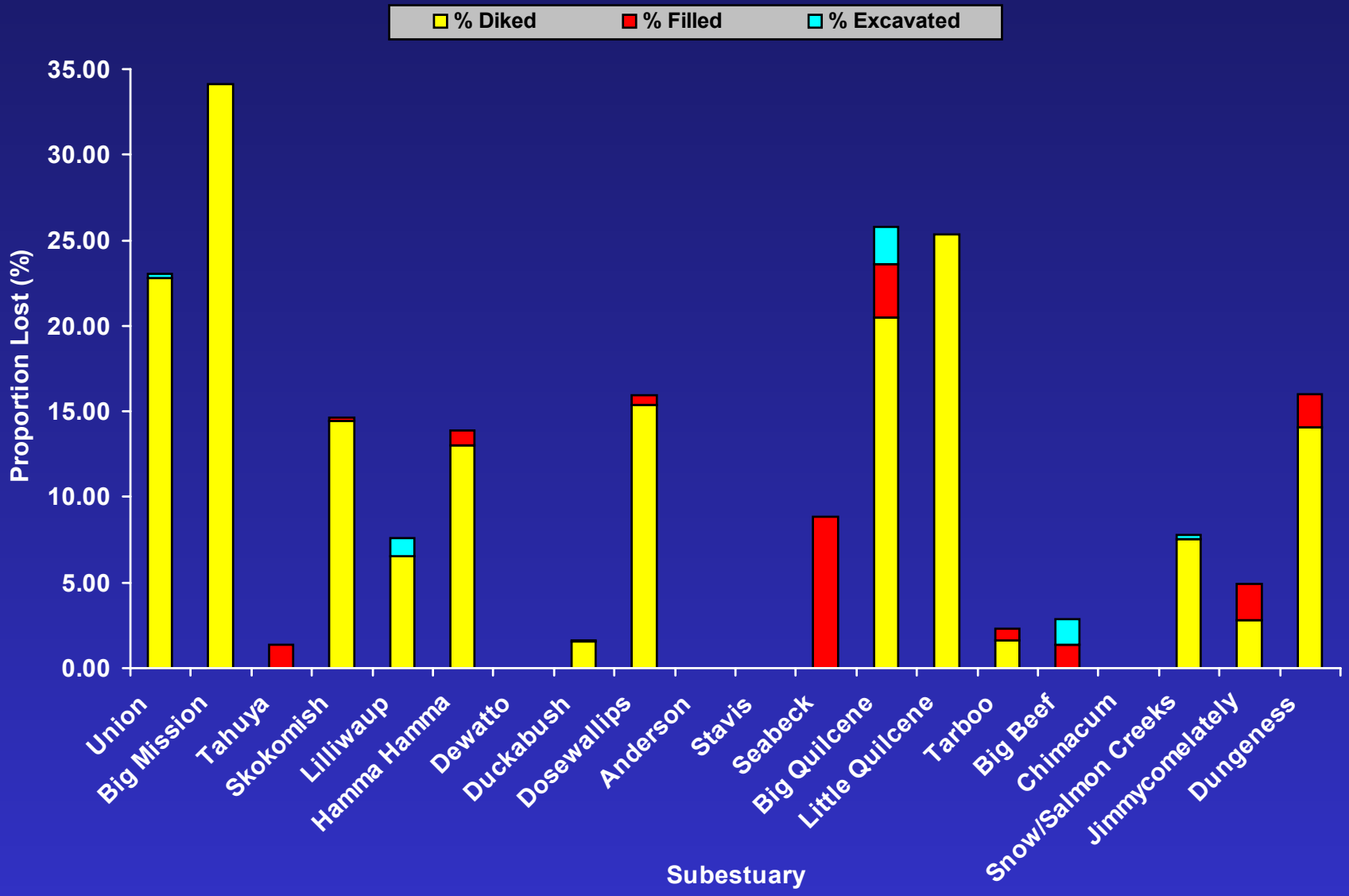
SALMON AND ESTUARIES

- Life histories
- Patterns of occurrence
- How and why they use them
- So what?
- Implications for salmon recovery

Estuarine Wetland Loss in the Pacific Northwest

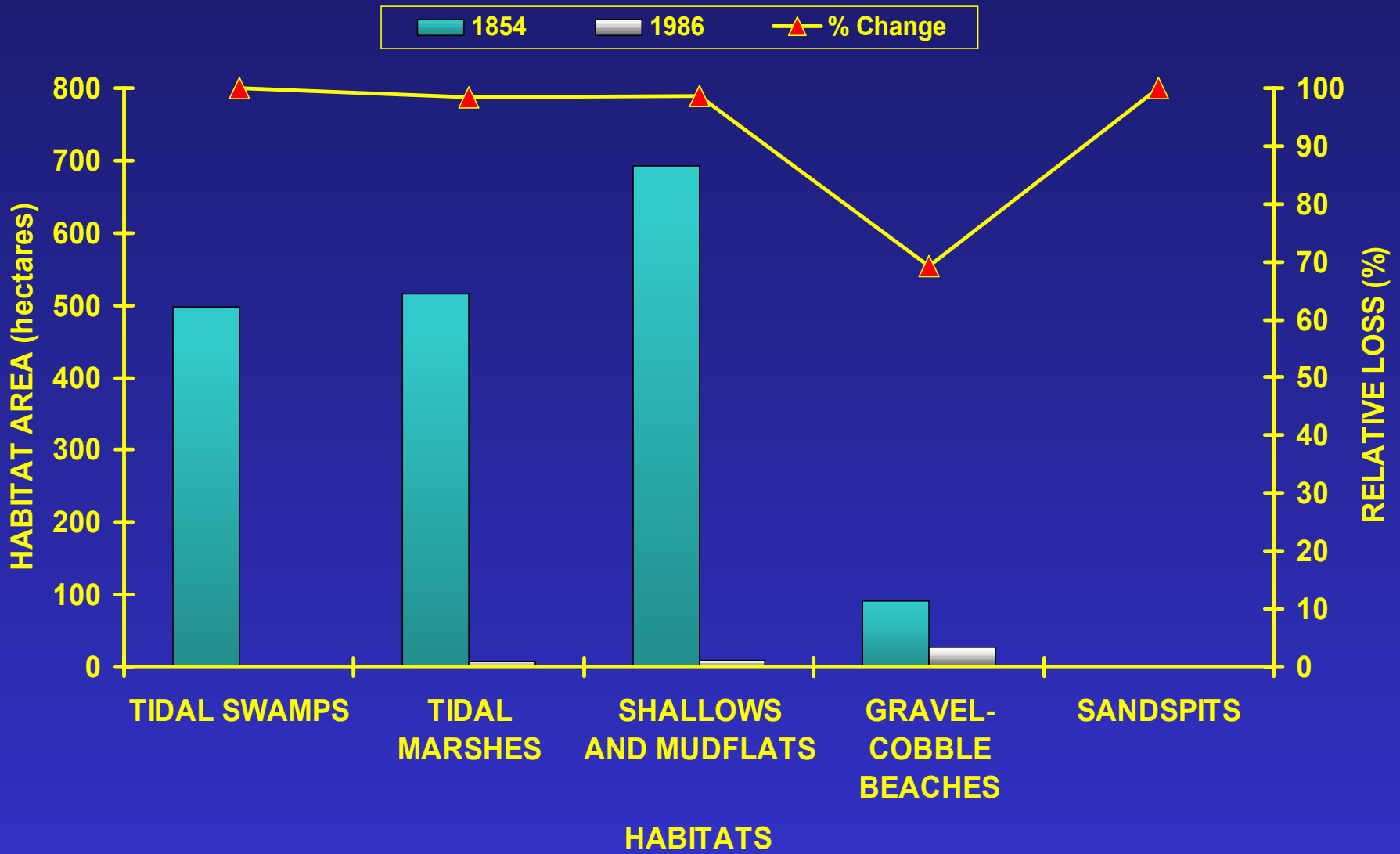


SUBESTUARY DEVELOPMENT OF HOOD CANAL AND EASTERN STRAIT OF JUAN DE FUCA

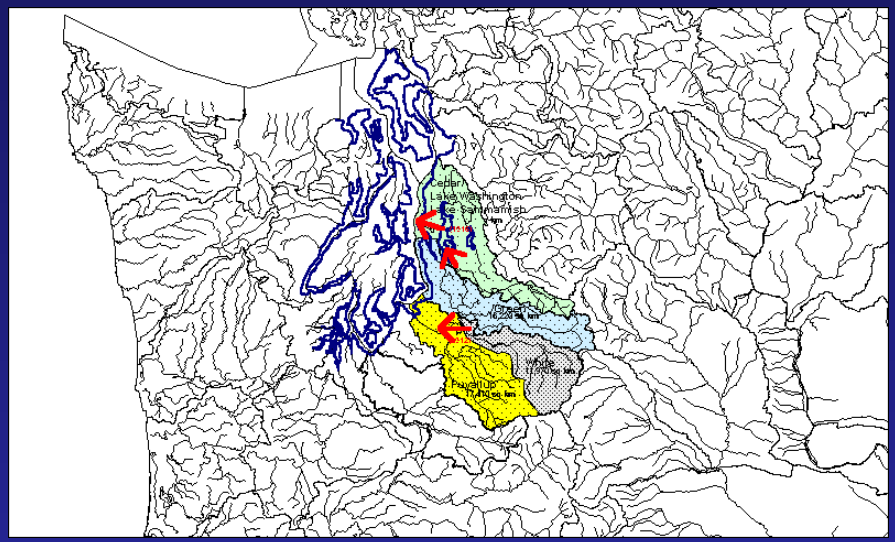


May 8: Simenstad & Fresh--Linking Salmon to Estuarine and Nearshore Habitat Characteristics
(Source: Simenstad, unpubl.)

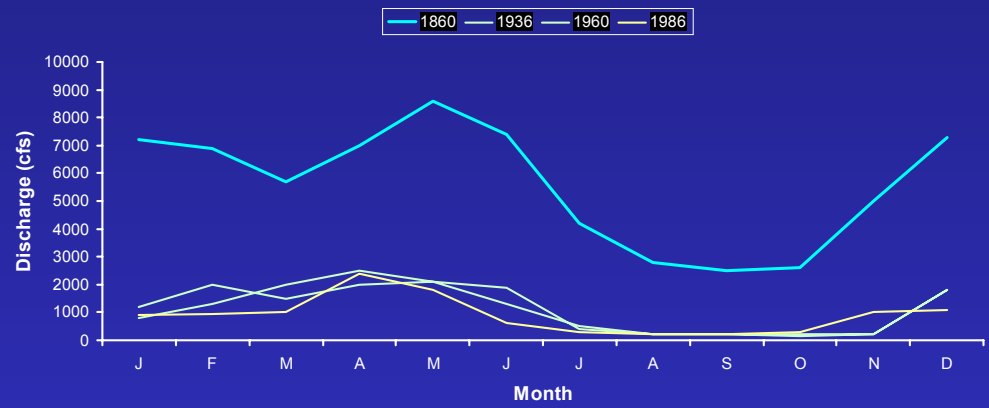
DUWAMISH RIVER/ELLIOTT BAY ESTUARINE HABITAT LOSS 1854-1986



WATERSHED-SCALE CHANGES IMPACTING ESTUARIES



HISTORICAL CHANGES IN DUWAMISH RIVER DISCHARGE, 1860-1986



Changes in Duwamish River Watershed:

1912 Diversion of White River to Puyallup River watershed (-25.2%)

1916 Diversion of Cedar and Lake Washington-Lake Sammamish watersheds to Lake Washington Ship Canal (-40.6%)

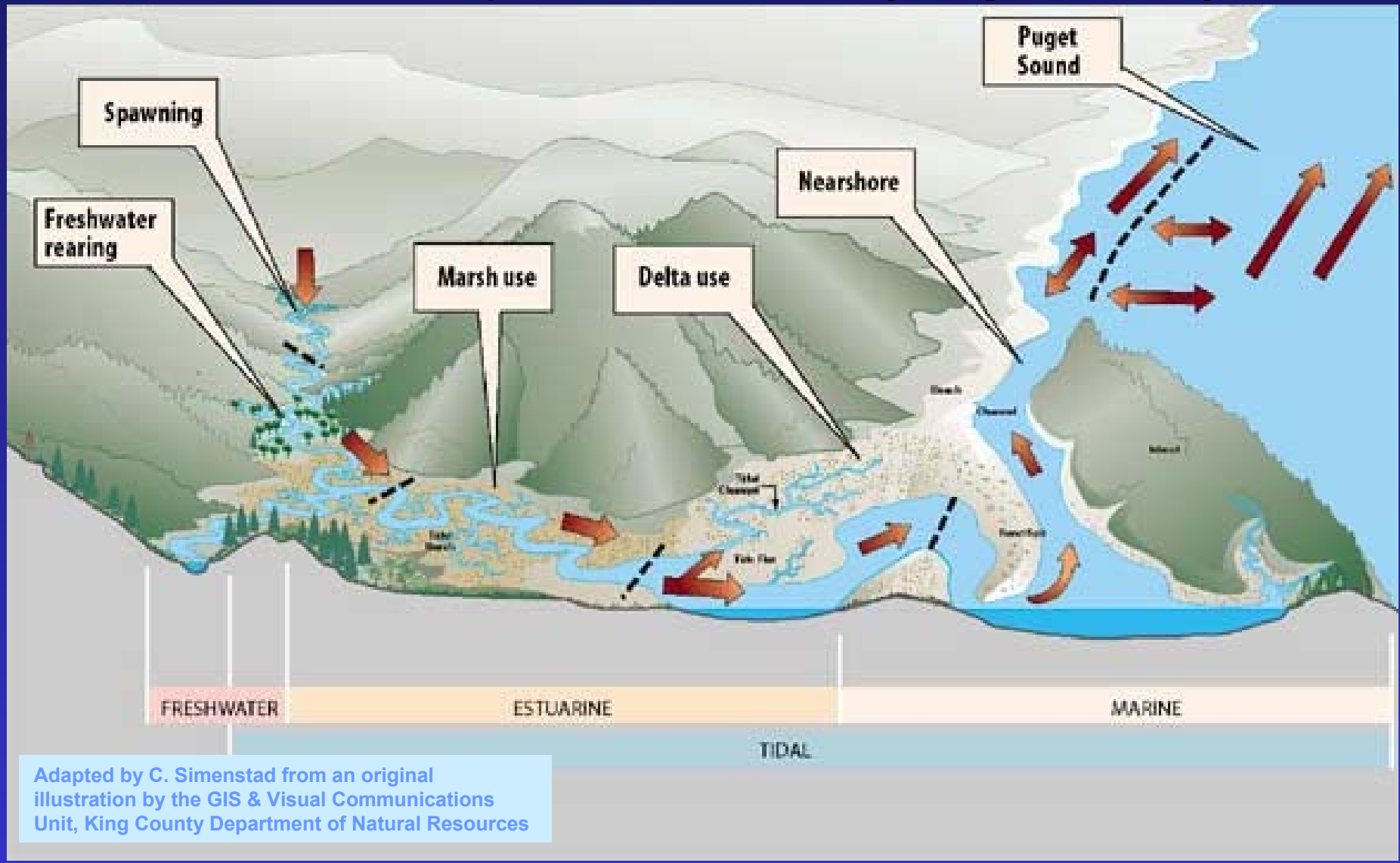
= 70-75% reduction in freshwater inflow to estuary

FOR PACIFIC SALMON,
LIFE IS JUST A CONTIMUUM OF BOTTLENECKS!

Species-LH Type	*Freshwater Residence*	*Downstream Migration*	*Estuarine Residence*	*Estuary-Ocean Transition*	*Ocean Residence*	*Possible Life History Types*
PINK	Virtually none	Immediate & rapid, as fry	Short; ~2 weeks	Rapid	Fixed; 2 years	1
CHUM	Virtually none	Immediate, as fry	Short-moderate, 2-3 weeks	Rapid	Variable: 1-5 years	10
SOCKEYE-lake type	Extensive, 1-3 years in lakes	Relatively rapid, as smolts; 1-2 weeks	Short; few days	Highly variable	Variable: 1-3 years	9
-ocean type	Short	Rapid, as fry	Often extensive: 1 week-5 months	Unknown	Fixed; 1 years	1
COHO-stream type	Extensive; 1-4 years	Relatively rapid, as smolts; 1-2 weeks	Short; few days	Highly variable	Variable: 1-5 years	11
-ocean type	Virtually none	Rapid, as fry	Long? May involve protracted overwintering, and return upstream to rear?	Unknown?	Fixed; 1 year	1
CHINOOK-stream type	Variable; 1-2 years	Variable: few days to months	Short; few days	Highly variable	Variable: <1 to 6 years	>13
-ocean type	Variable: few days to months	Variable: rapid as fry, longer as fingerlings	Highly variable: days to 6 months	Highly variable: often prolonged	Variable: <1 to 6 years	36

PACIFIC SALMON ECOSCAPE, Puget Sound

denoting freshwater, estuarine and nearshore habitat continuum, where different salmon species and life history stages diversify



Adapted by C. Simenstad from an original illustration by the GIS & Visual Communications Unit, King County Department of Natural Resources

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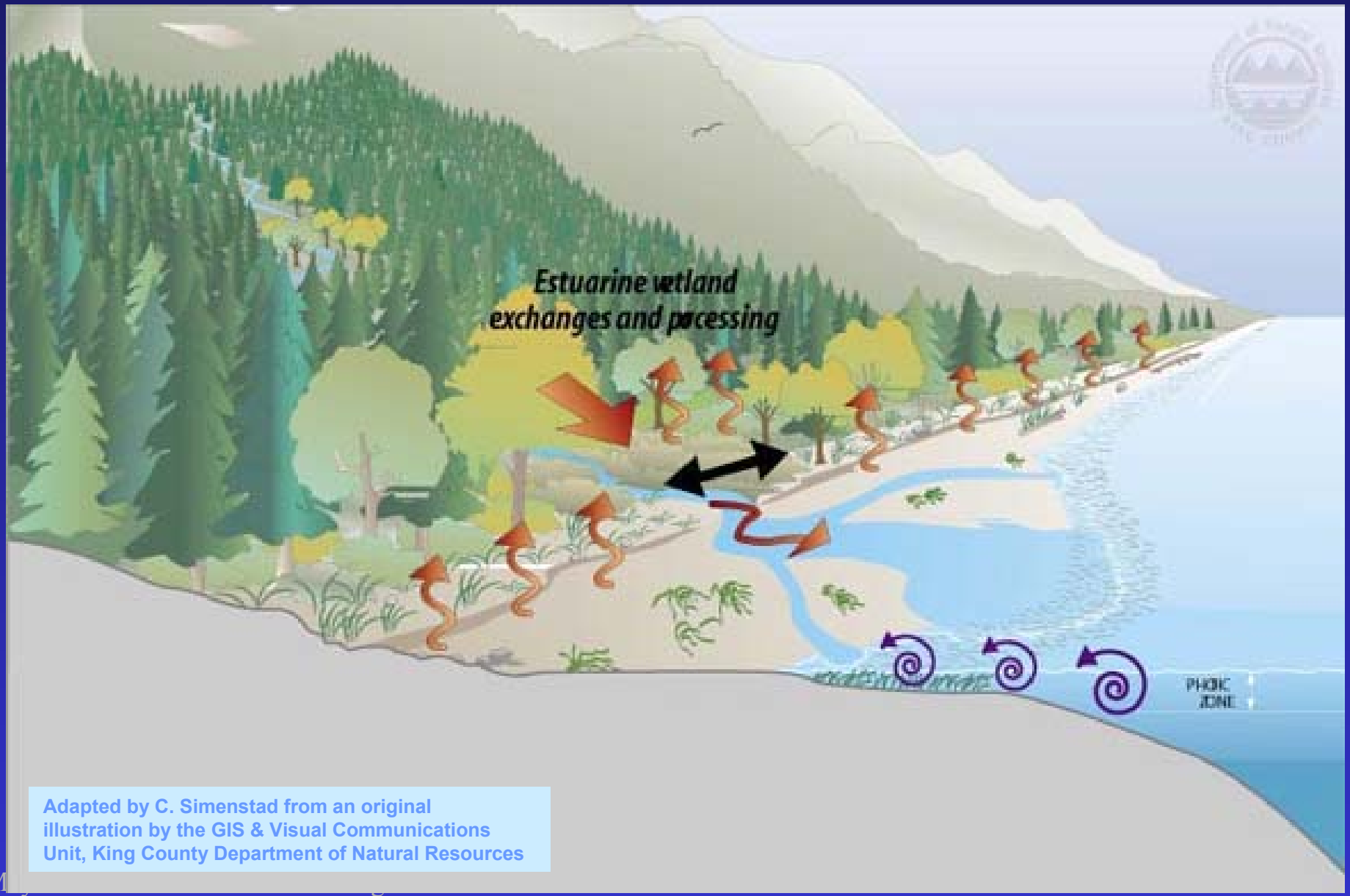
STREAM MOUTH, Puget Sound



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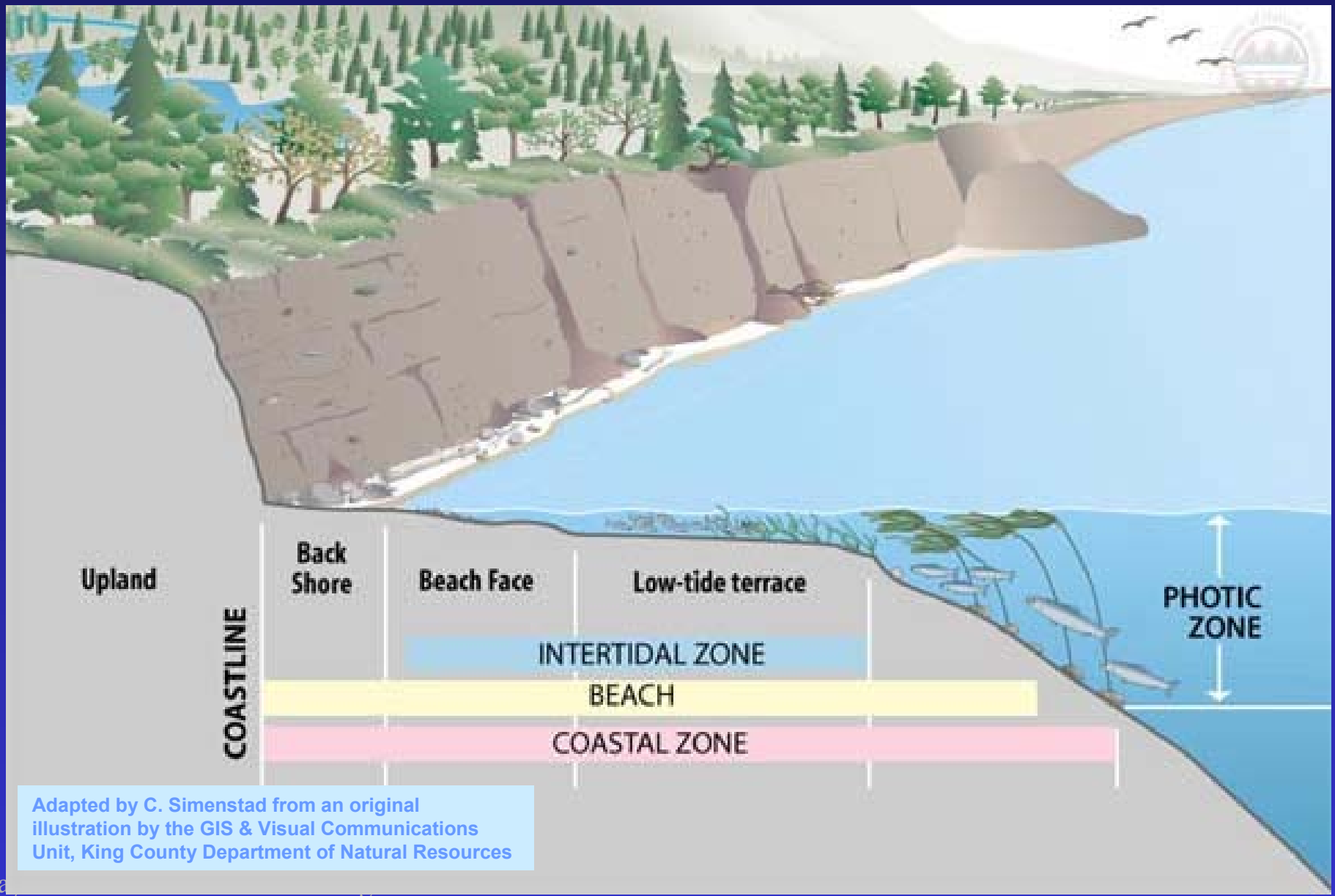
ERODING BLUFF, Puget Sound Nearshore



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ROLE OF ESTUARIES IN SALMON EARLY LIFE HISTORY

- Juveniles of “ocean-type” salmon, rather than “stream-type” and typical hatchery races, e.g., are the most estuarine dependent (and frequently in jeopardy?)
- Physiological transition during migration
- Significant shift in feeding and predation regimes
- Buffer freshwater rearing during extreme events

VARIABILITY IN ESTUARINE AND NEARSHORE DEPENDENCE BY PACIFIC SALMON

high dependence

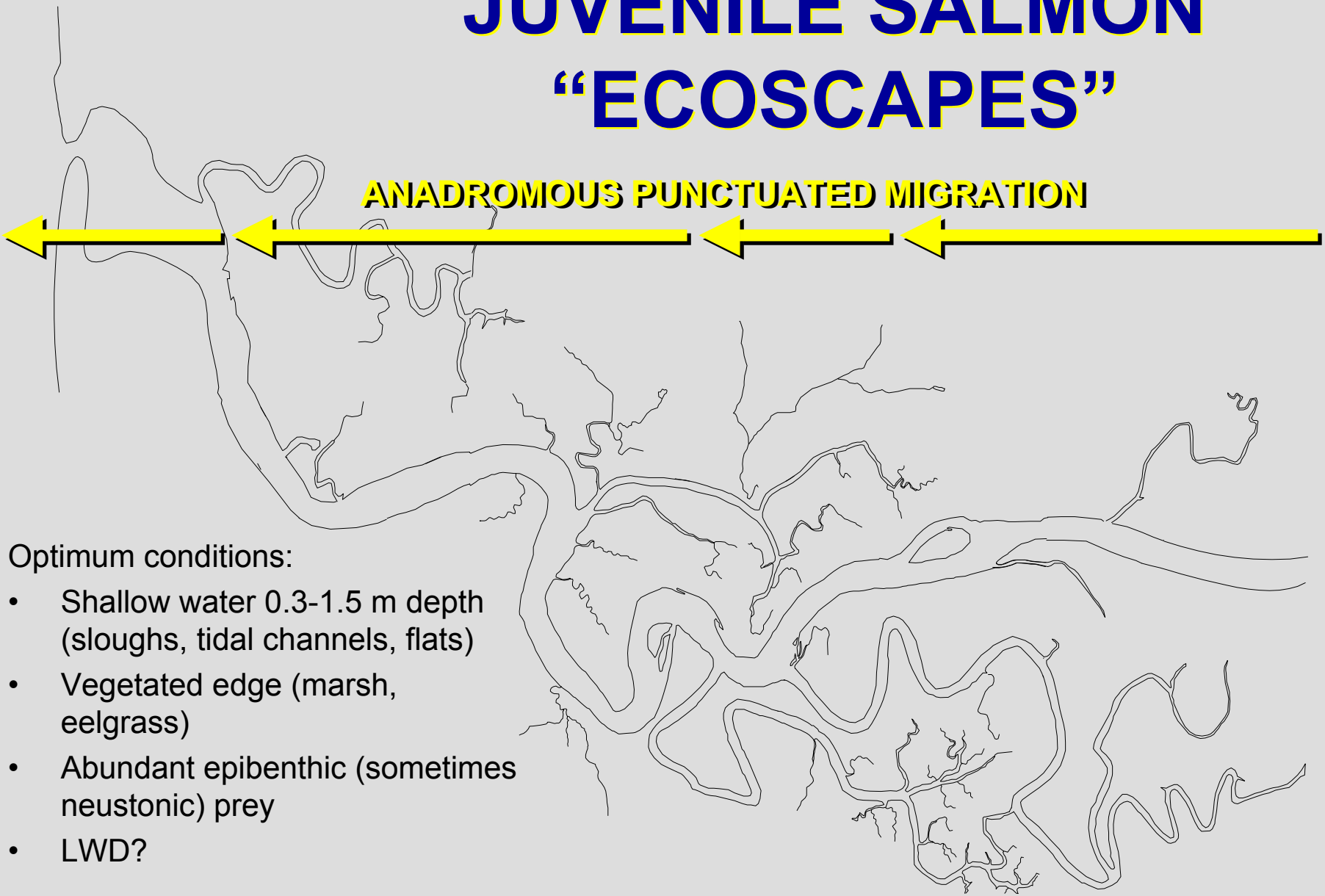
low dependence

ocean type chinook
chum
ocean type coho (?)
pink
stream type chinook
stream type coho
steelhead
sockeye

"HABITATS" OF ANADROMOUS SALMONIDS

- Traditional definition of habitat: *locality, site, and particular type of local environment in which an organism is found ("oikos")*
- In contrast, juvenile salmon migration across the land margin:
  - spans habitat mosaics and corridors = landscaoe ir "ecoscapes"
  - is dynamic and punctuated
  - depends on <u>both</u> opportunity to occupy preferred environments and capacity of those environments to support fish growth and survival

JUVENILE SALMON "ECOSCAPES"



Optimum conditions:

- Shallow water 0.3-1.5 m depth (sloughs, tidal channels, flats)
- Vegetated edge (marsh, eelgrass)
- Abundant epibenthic (sometimes neustonic) prey
- LWD?

euhaline-euryhaline brackish-oligohaline tidal-freshwater

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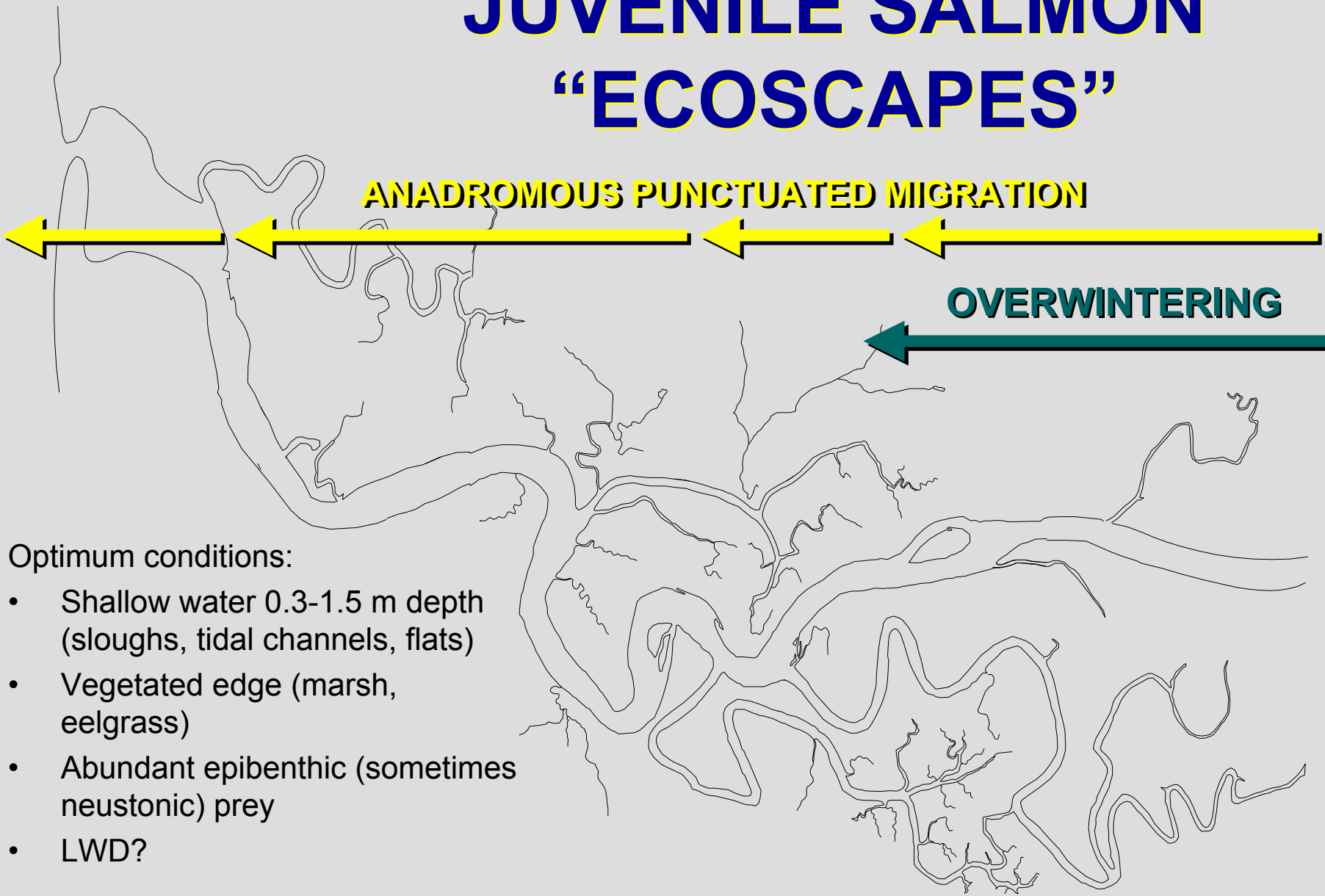

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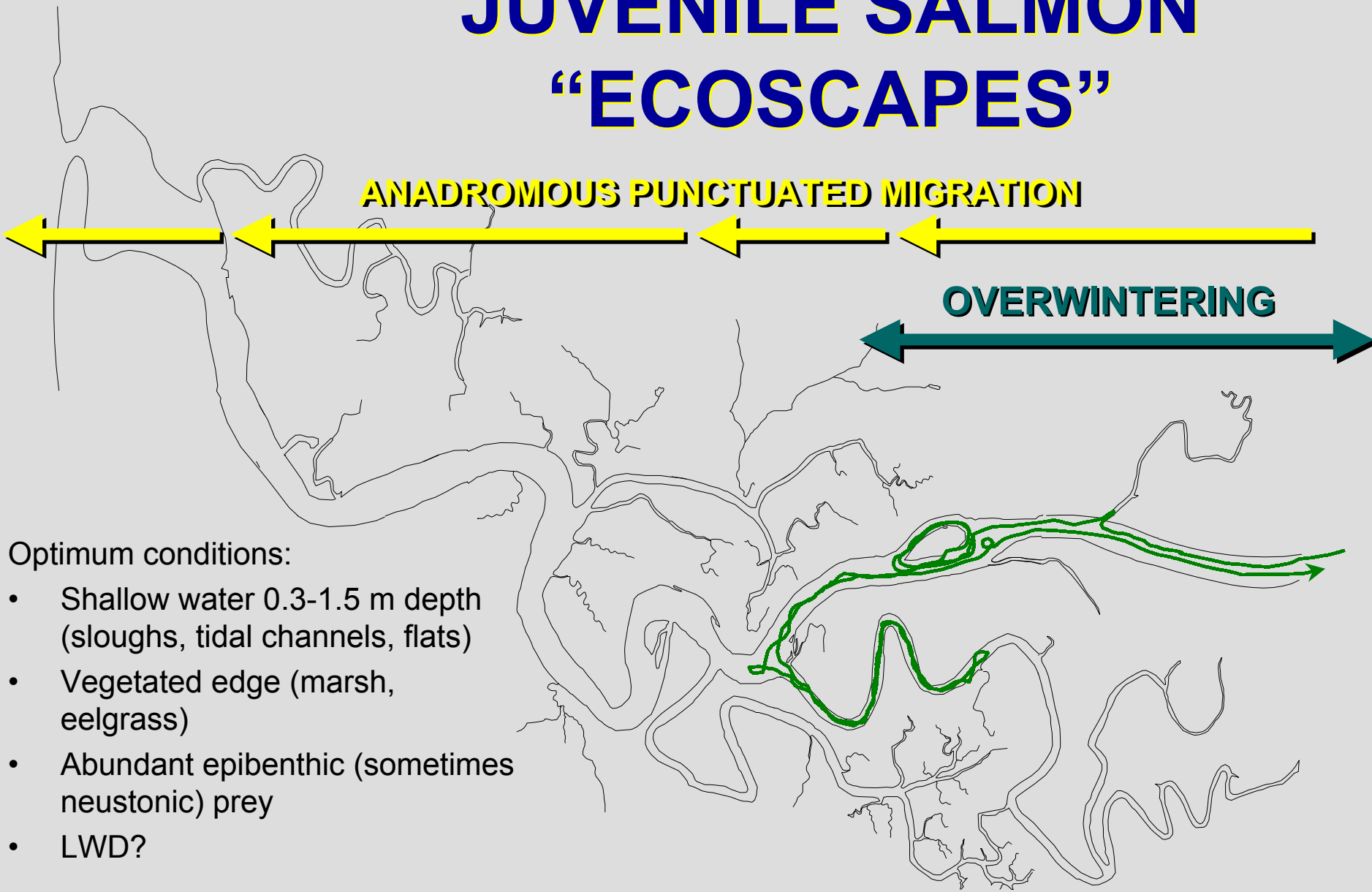

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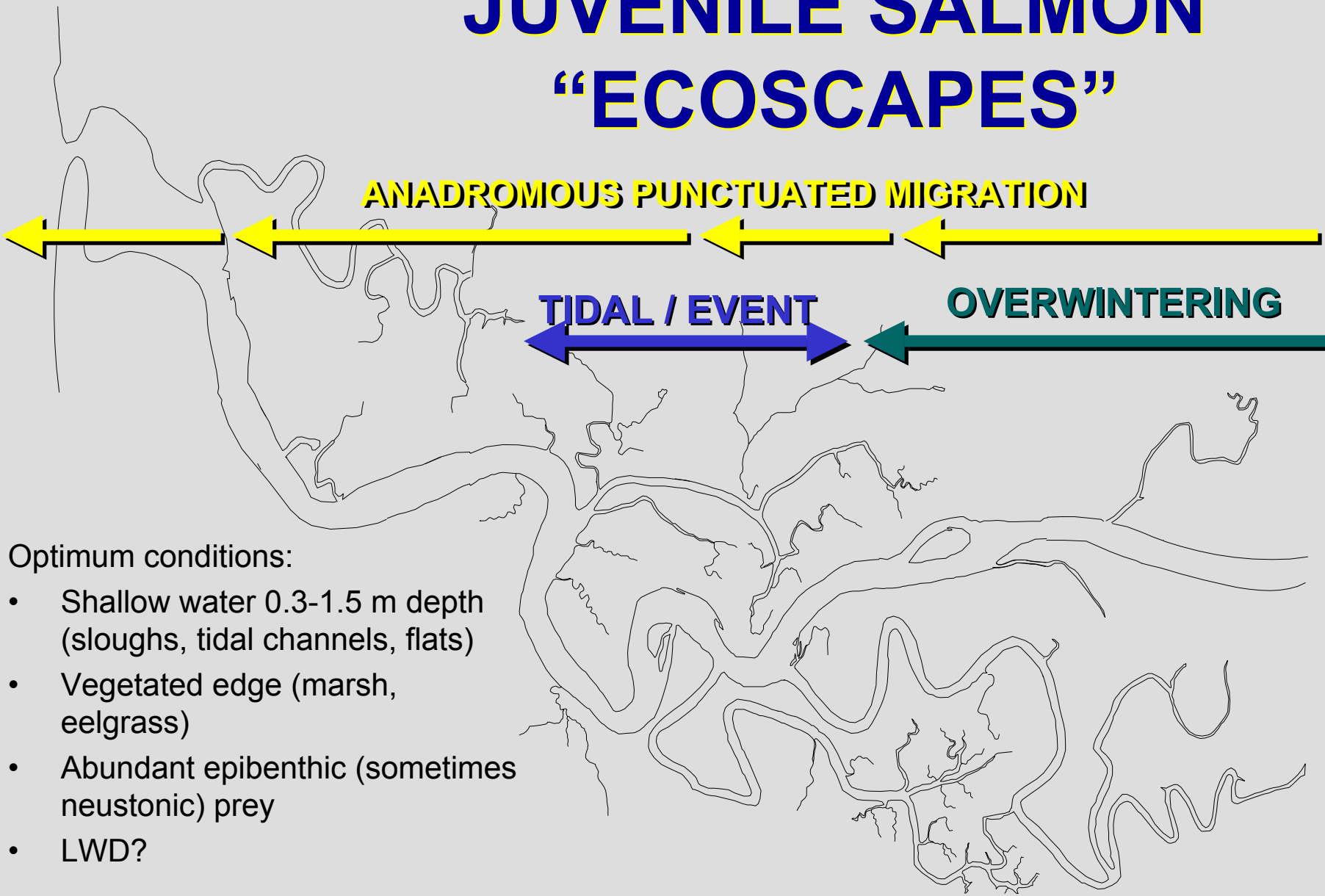

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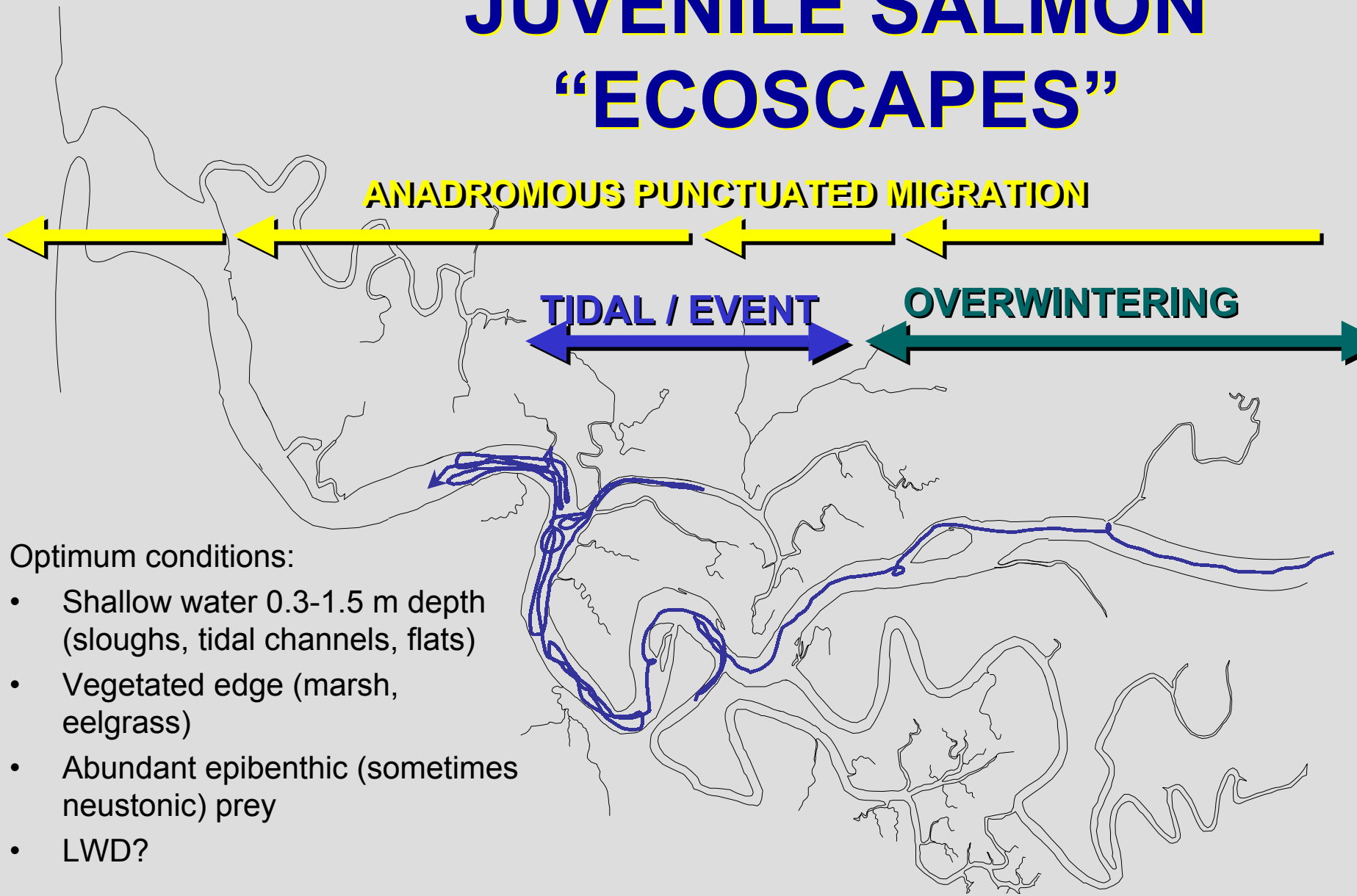

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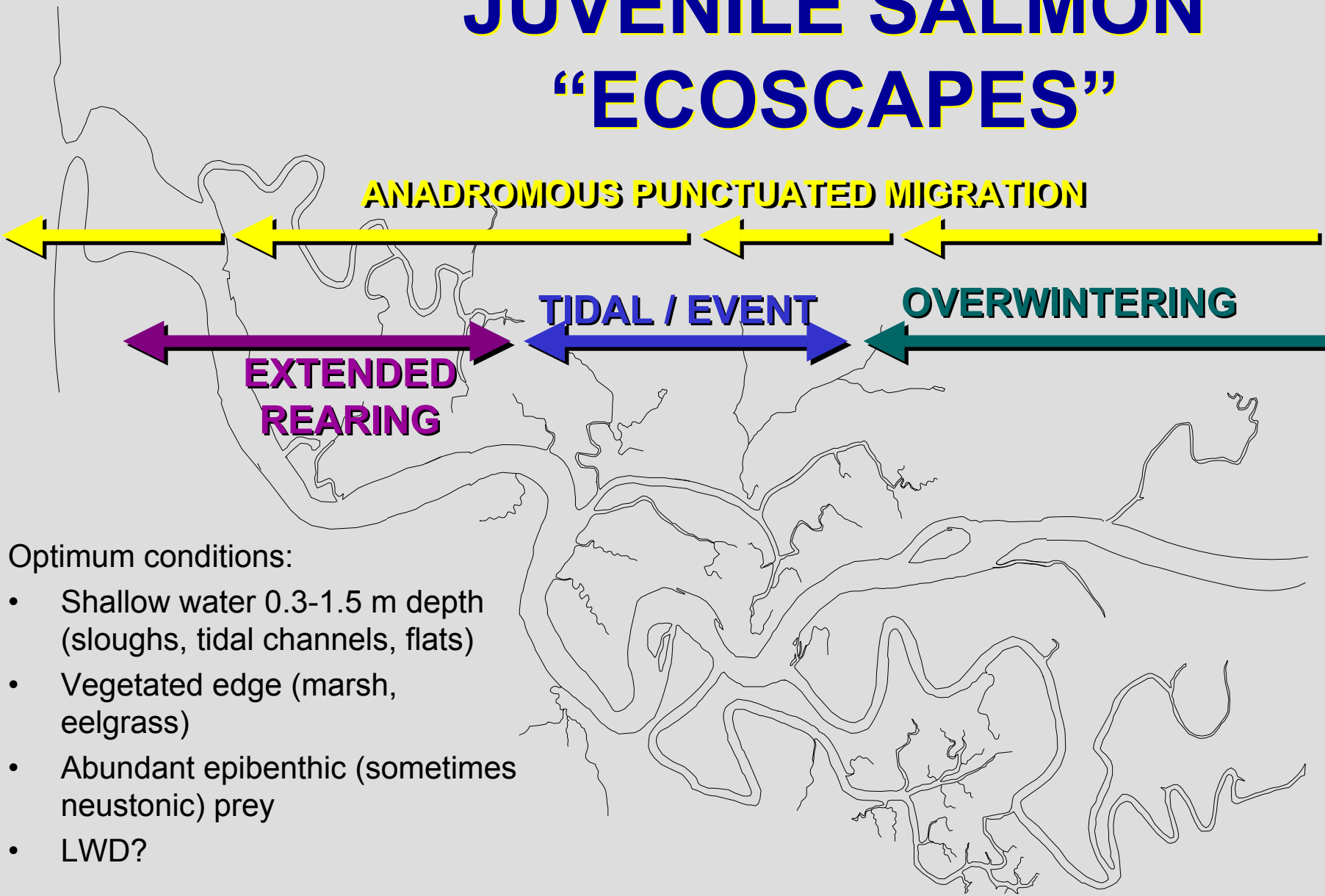

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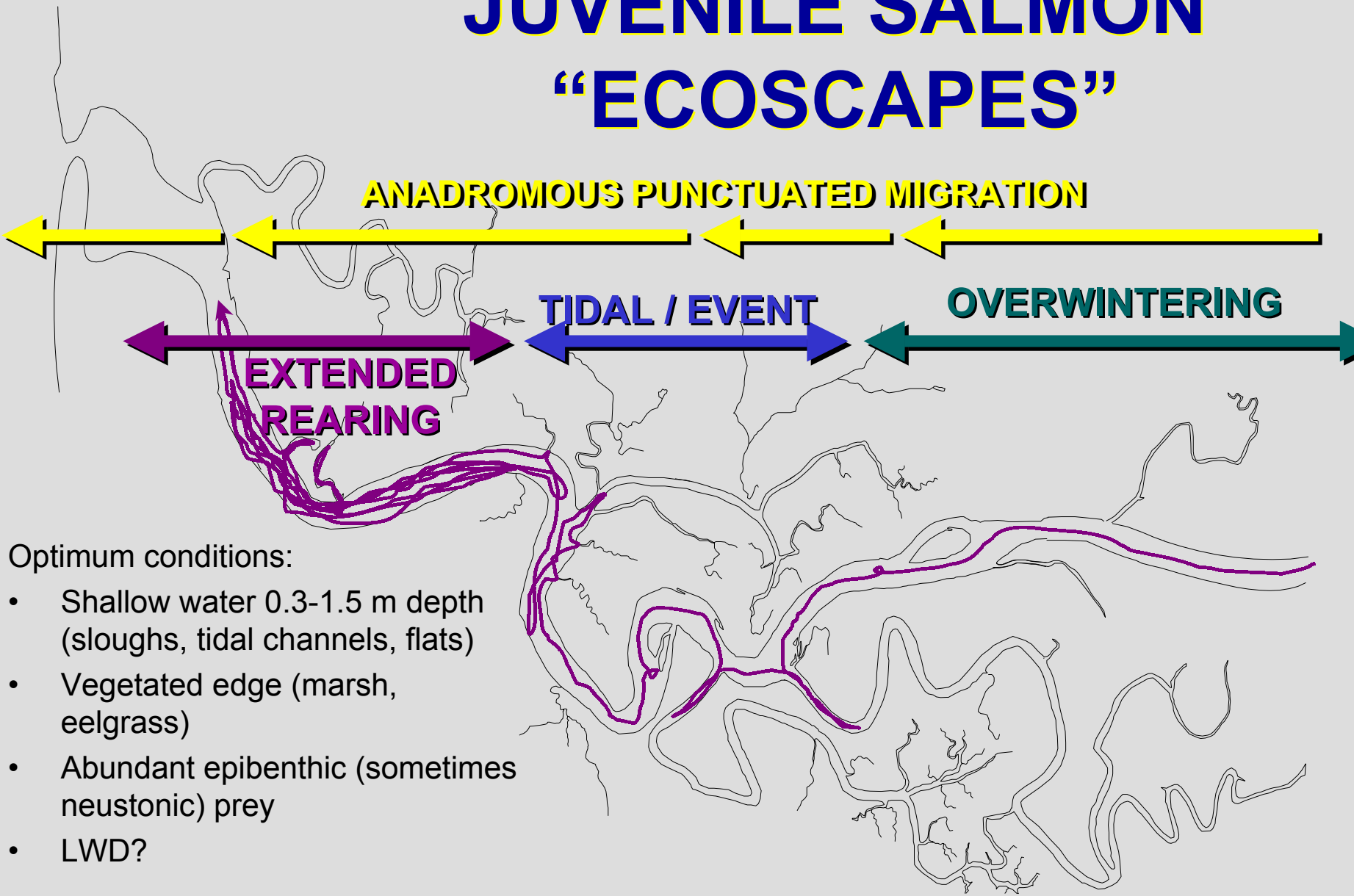

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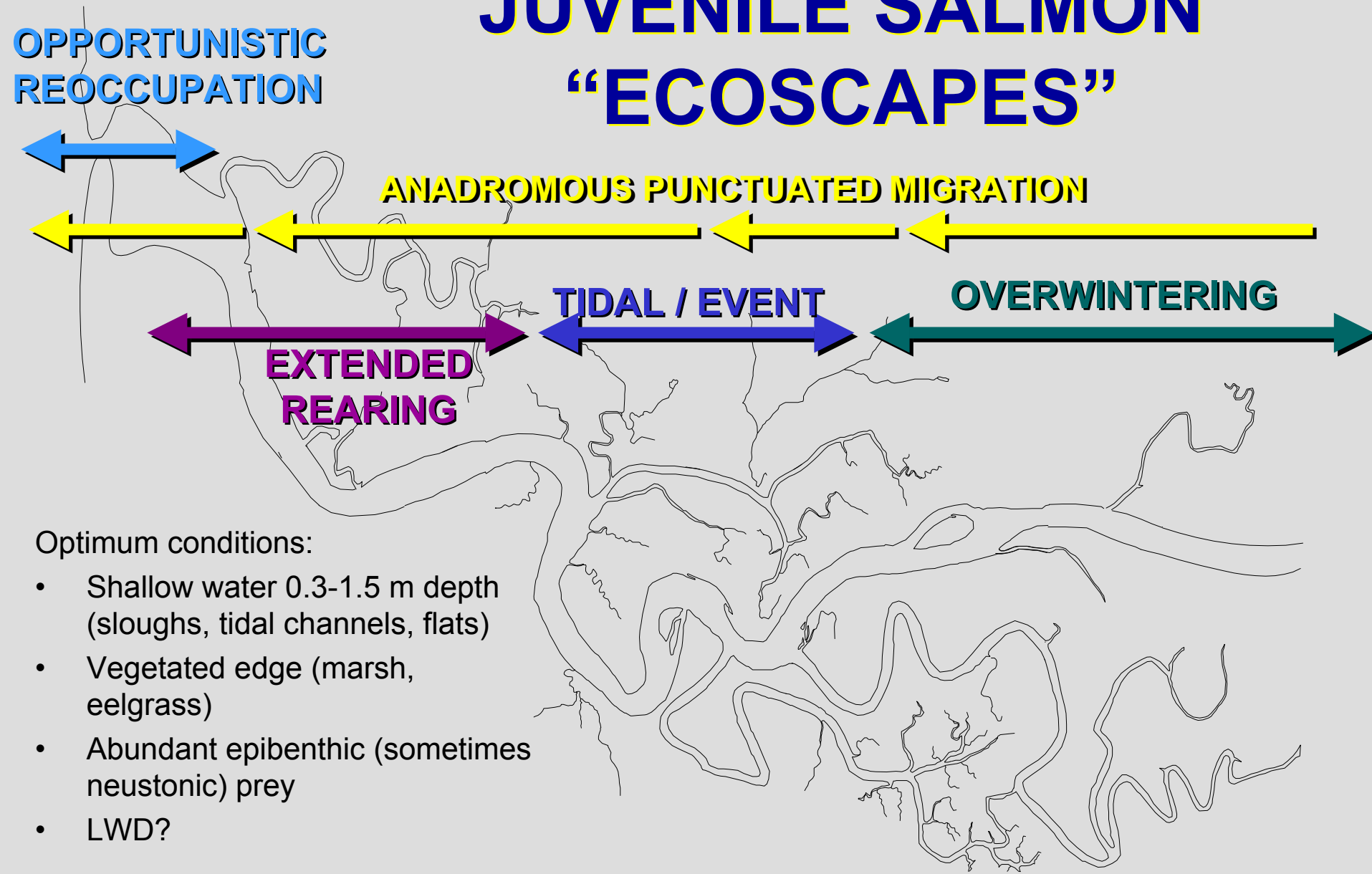

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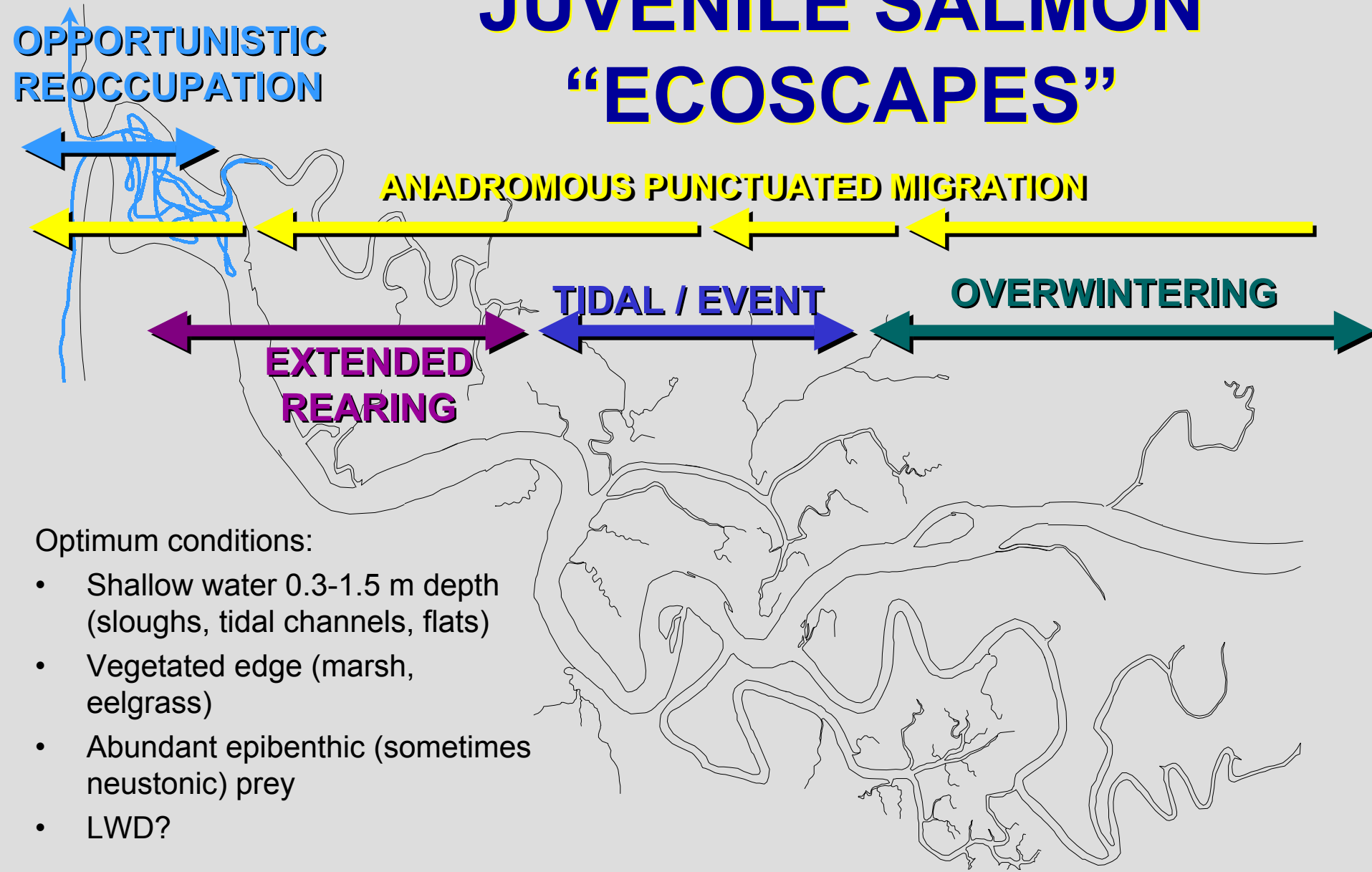

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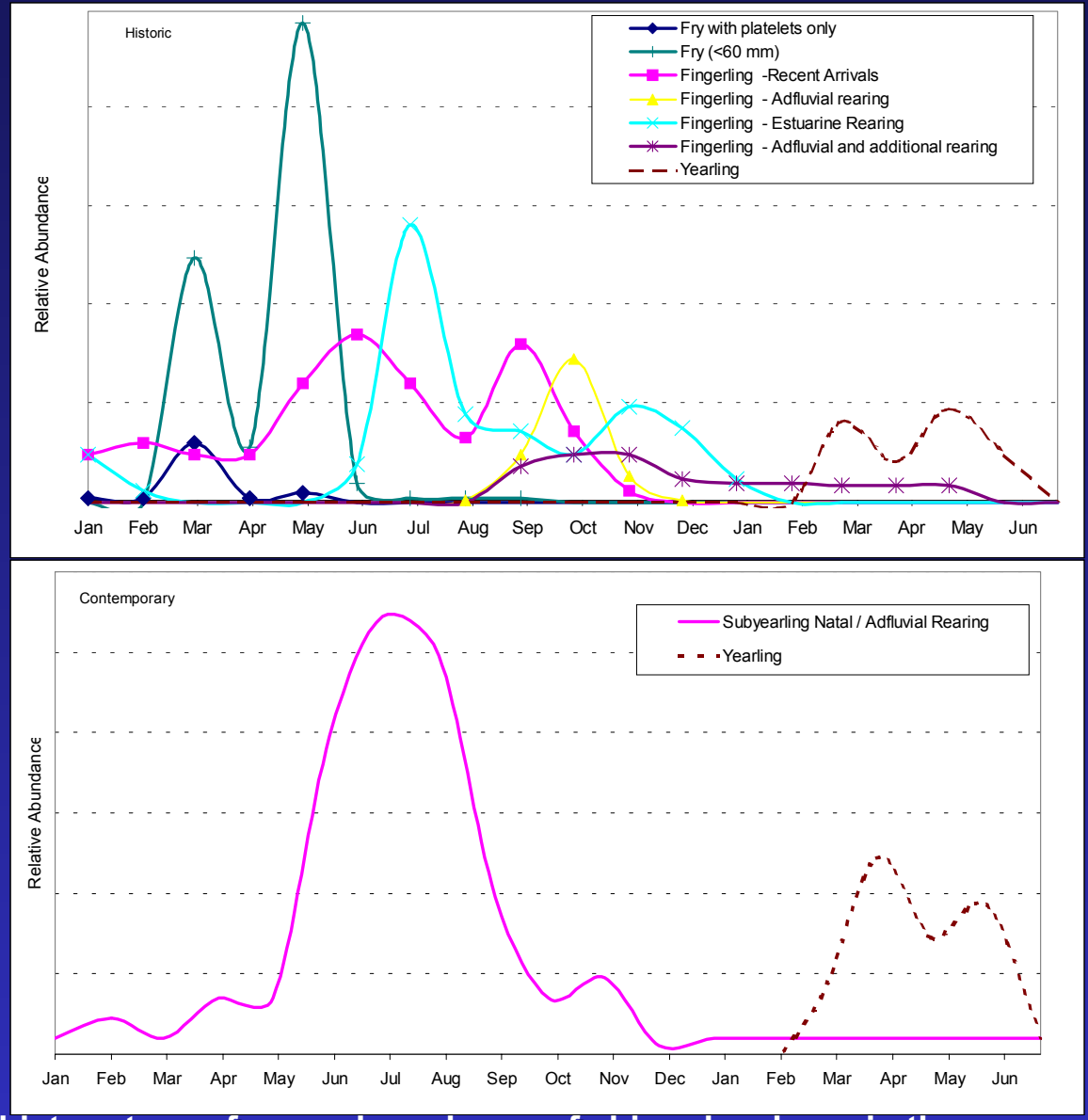
HISTORIC LOSS IN JUVENILE CHINOOK SALMON LIFE HISTORY DIVERSITY IN THE COLUMBIA RIVER ESTUARY



Historic and contemporary early life history types for one-brood year of chinook salmon in the Columbia River estuary. Historic timing and relative abundance based on historic sampling throughout the lower estuary (Rich 1920). Contemporary timing and relative abundance derived from Dawley et al. (1985) sampling at Jones Beach (Bottom et al. in prep.)

TACTICAL TYPES OF JUVENILE CHINOOK SALMON FRESHWATER AND ESTUARINE REARING IN SIXES RIVER (Reimers 1973)

Type 1 emergent fry move directly downstream and into the ocean within a few weeks (least abundant) [0%]

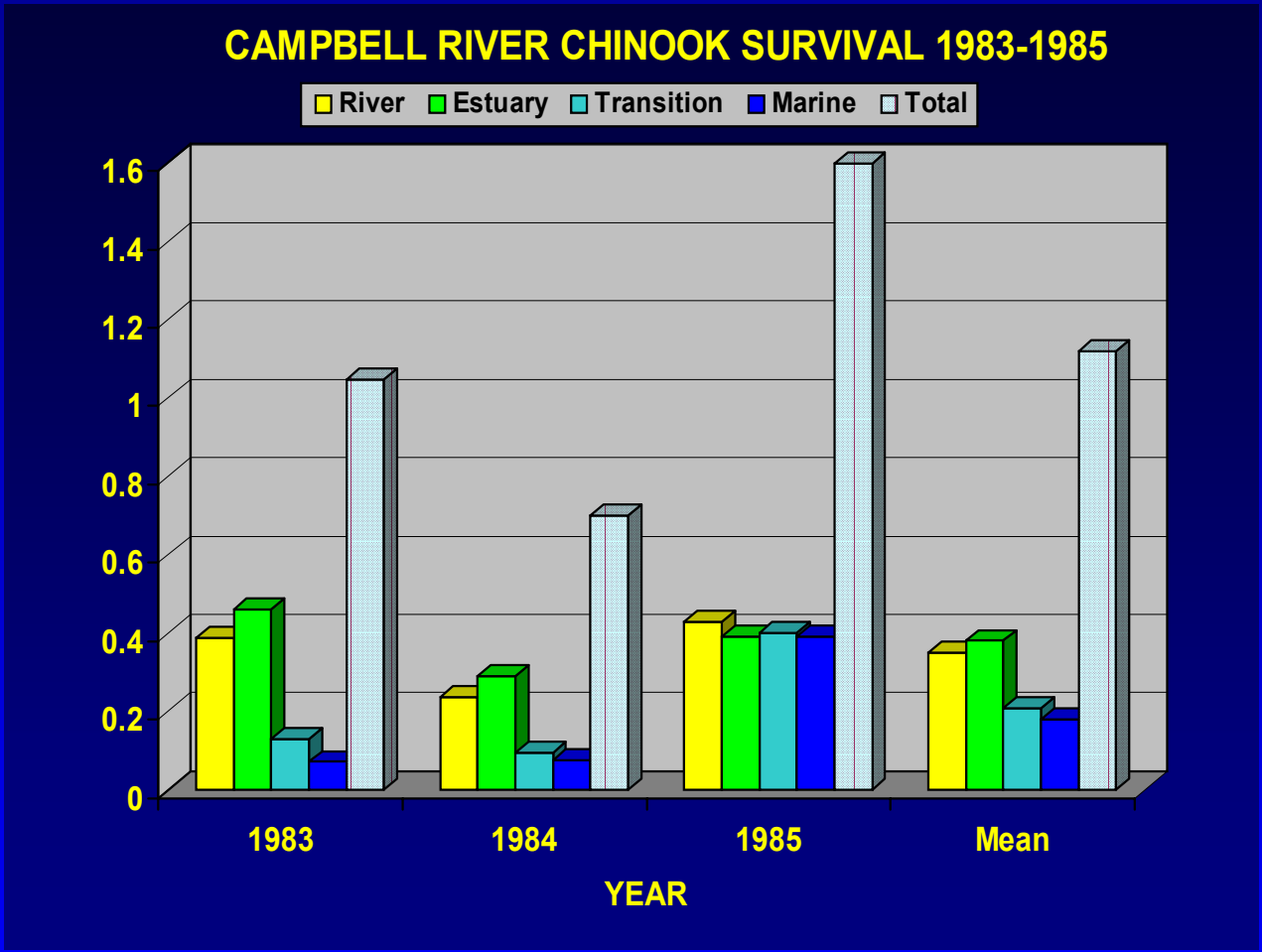
Type 2 juveniles rear in the main river or remain in tributaries until early summer, then emigrate into the estuary for a short period of rearing and enter the ocean before the improved growth in late summer (most abundant) [2.5%]

Type 3 juveniles rear in the main river or tributaries until early summer, then emigrate into the estuary for extended rearing during the period of improved growth in late summer and enter the ocean in autumn (intermediate abundance) [90.7%]

Type 4 juveniles remain in the tributary streams (or rarely in the main river) until autumn rains, then emigrate to the ocean (intermediate abundance) [3.7%]

Type 5 juvenile remain in the tributary streams (or rarely in the main river) through the summer, rear in Sixes River until the following spring, and enter the ocean as yearlings (least abundant) [3.1%]

ESTUARINE DEPENDENCY (SURVIVAL) OF CHINOOK SALMON ON THE CAMPBELL RIVER ESTUARY (Levings et al. 1989)



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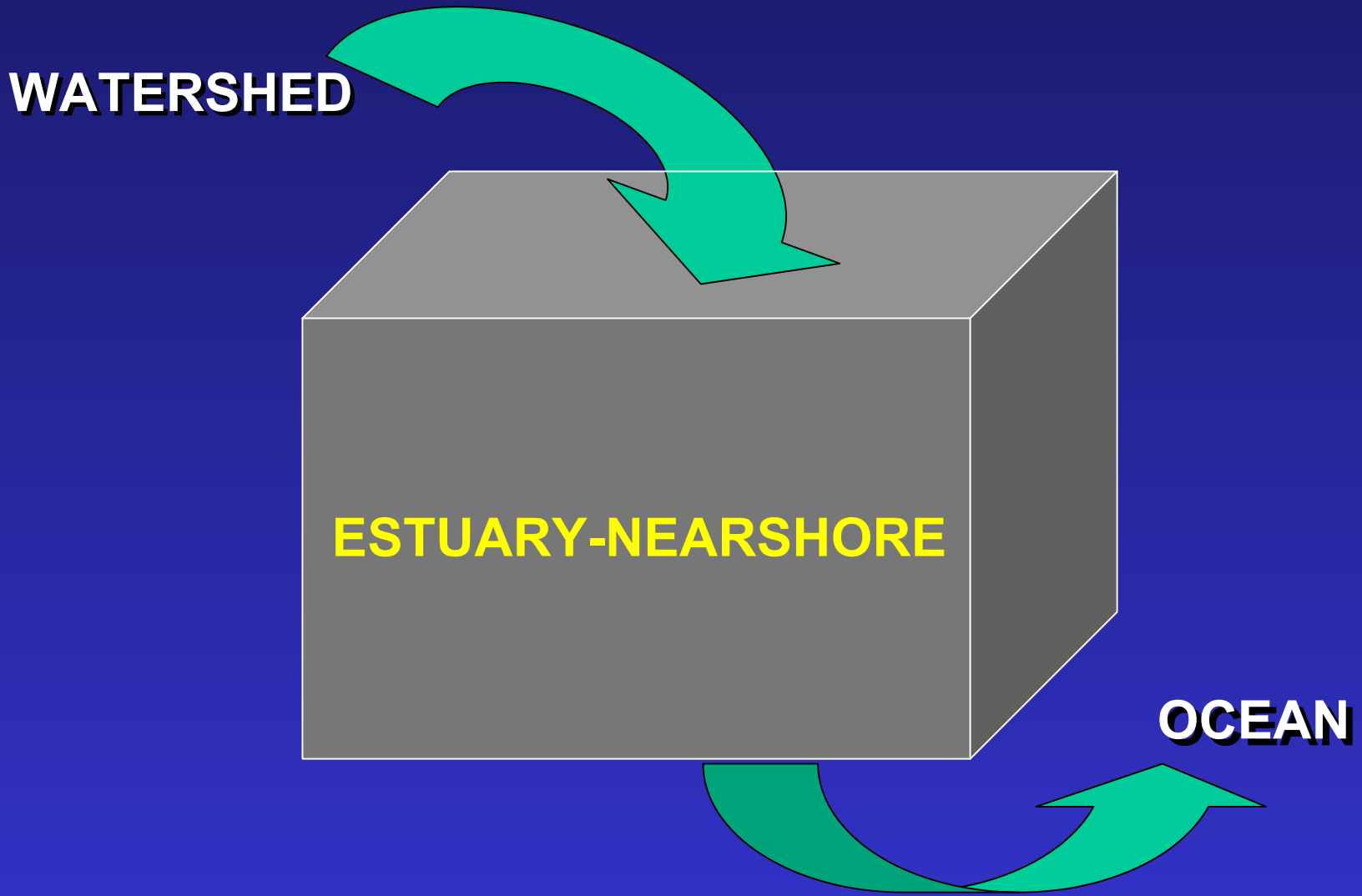
RESTORING ESTUARINE-NEARSHORE HABITAT

- Return processes, not simply habitat (attributes)
  - Restore tidal inundation
  - Restore sediment transport
- Promote both habitat diversity and complexity (both optimal and sub-optimal)
- Adopt landscape (watershed-nearshore) perspective; need to be strategic
- Avoid habitat *creation*
- Don't expect instant response…..ecosystems take time to (re)develop; but salmon are robust and will use restoring systems

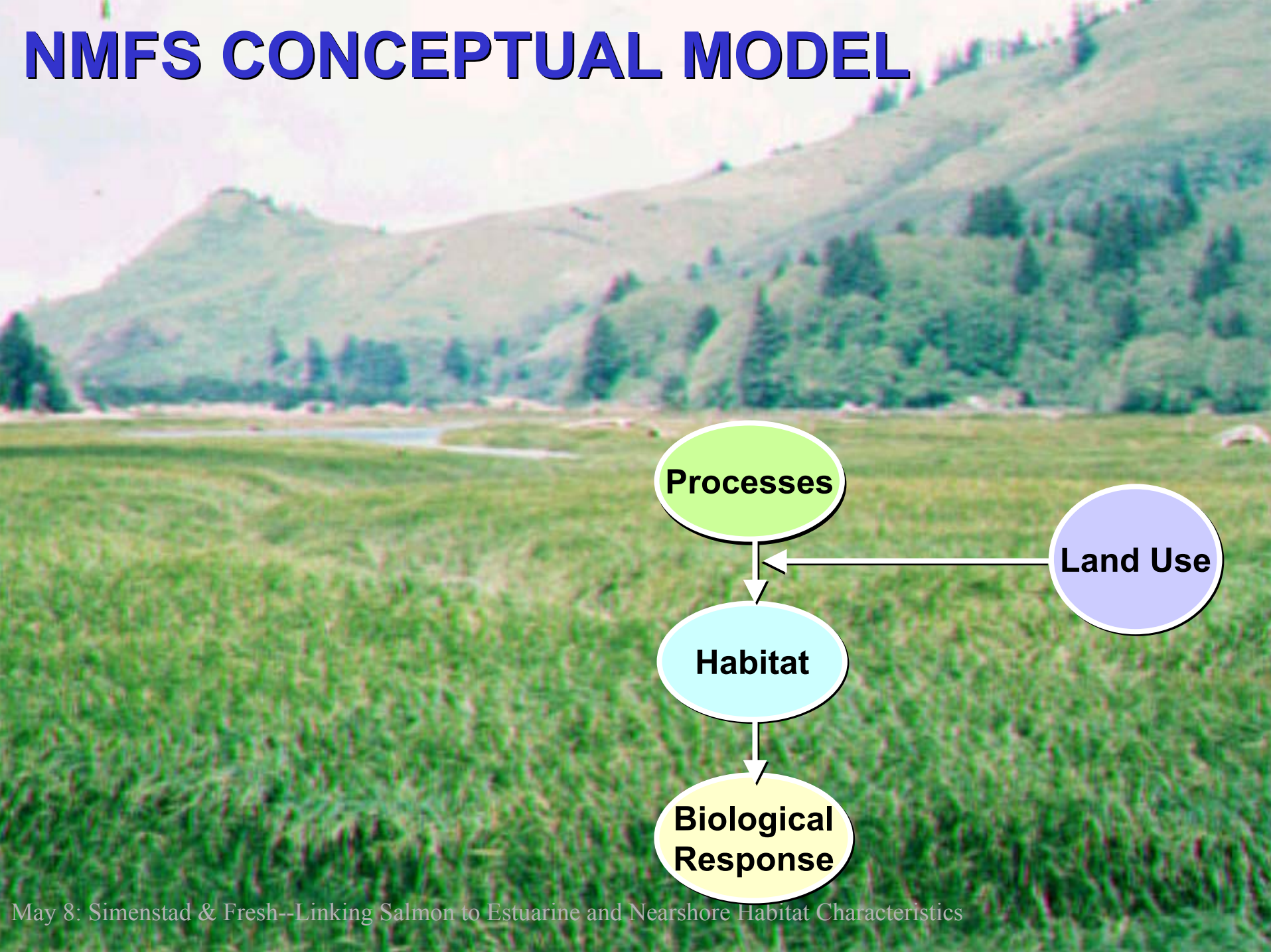
THE ESTUARY-NEARSHORE LIFE HISTORY STAGE AS A "BLACK BOX"

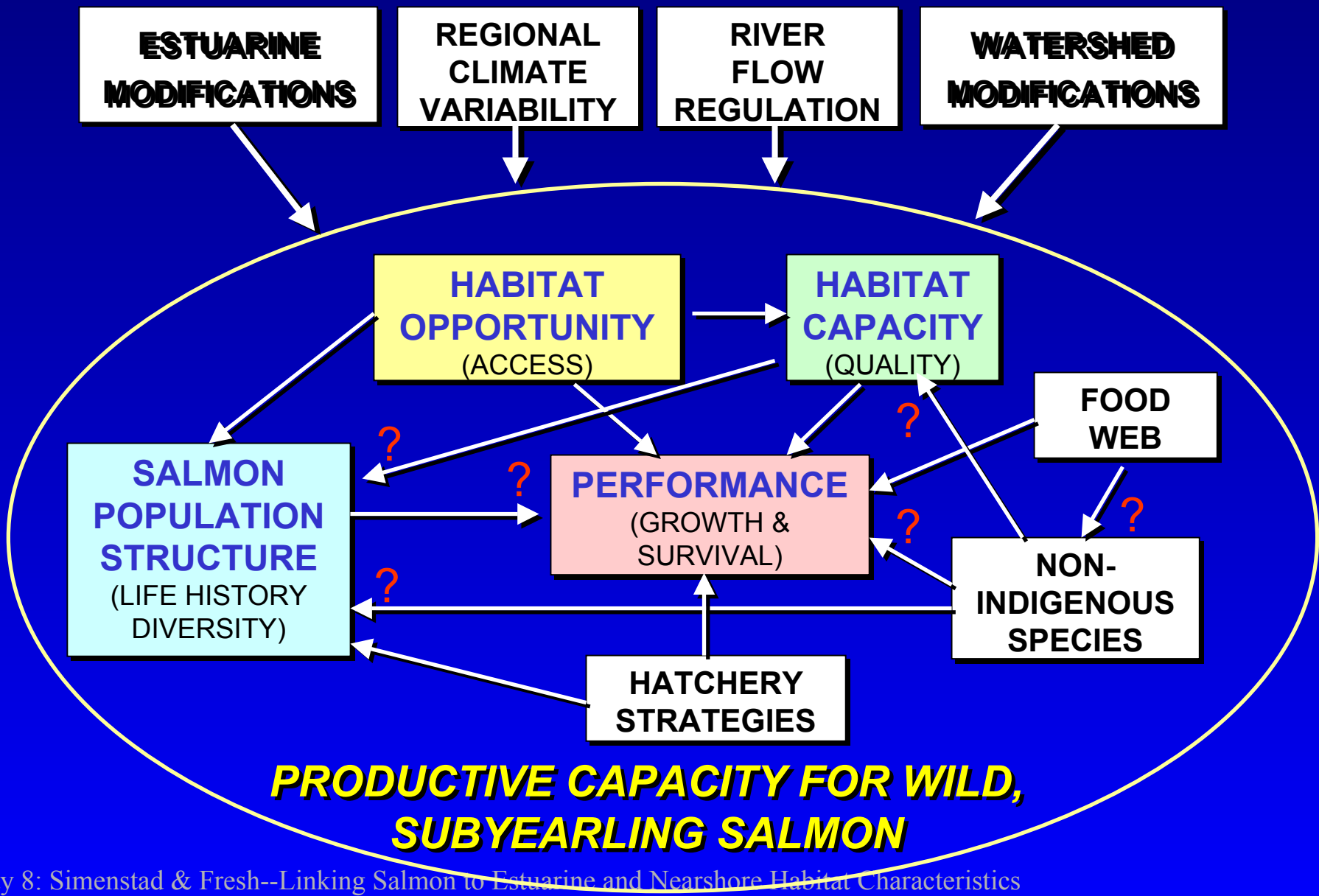


OVERVIEW

A. Looking into the black box
   1. Certainties
   2. Uncertainties
   3. What can we know
B. Role of Estuaries in the Recovery of Salmon Populations

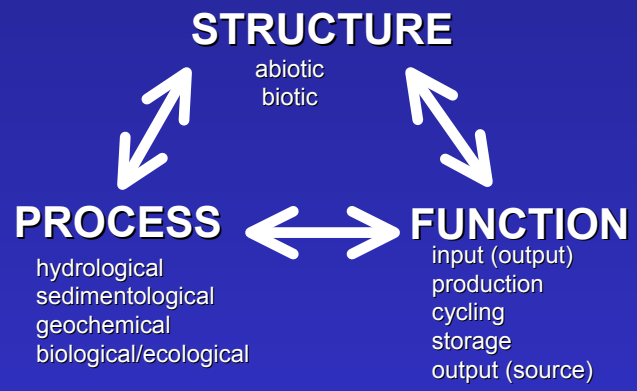
NMFS CONCEPTUAL MODEL




ESTUARINE MODIFICATIONS
REGIONAL CLIMATE VARIABILITY
RIVER FLOW REGULATION
WATERSHED MODIFICATIONS
HABITAT OPPORTUNITY (ACCESS)
HABITAT CAPACITY (QUALITY)
FOOD WEB
SALMON POPULATION STRUCTURE (LIFE HISTORY DIVERSITY)
PERFORMANCE (GROWTH & SURVIVAL)
NON-INDIGENOUS SPECIES
HATCHERY STRATEGIES
?
PRODUCTIVE CAPACITY FOR WILD, SUBYEARLING SALMON

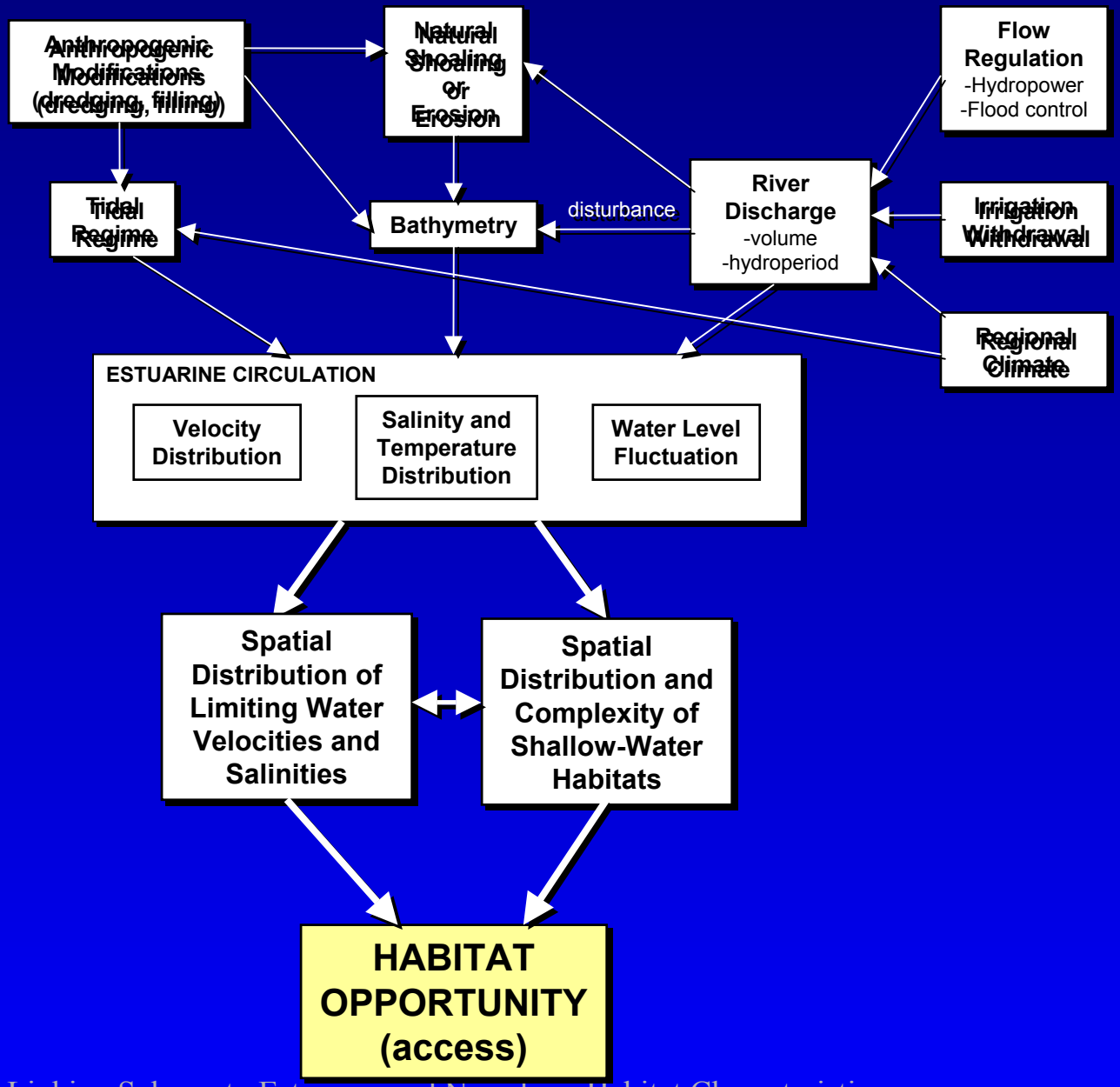
KEY ESTUARINE AND NEARSHORE PROCESSES

- ESTUARINE
  - INTERACTION BETWEEN RIVER INFLOW, BATHYMETRY AND TIDAL REGIME
  - AFFECTS ON HABITAT STRUCTURE AND SALINITY
- NEARSHORE
  - SEDIMENT PROCESSING
  - DETRITUS FOOD WEBS

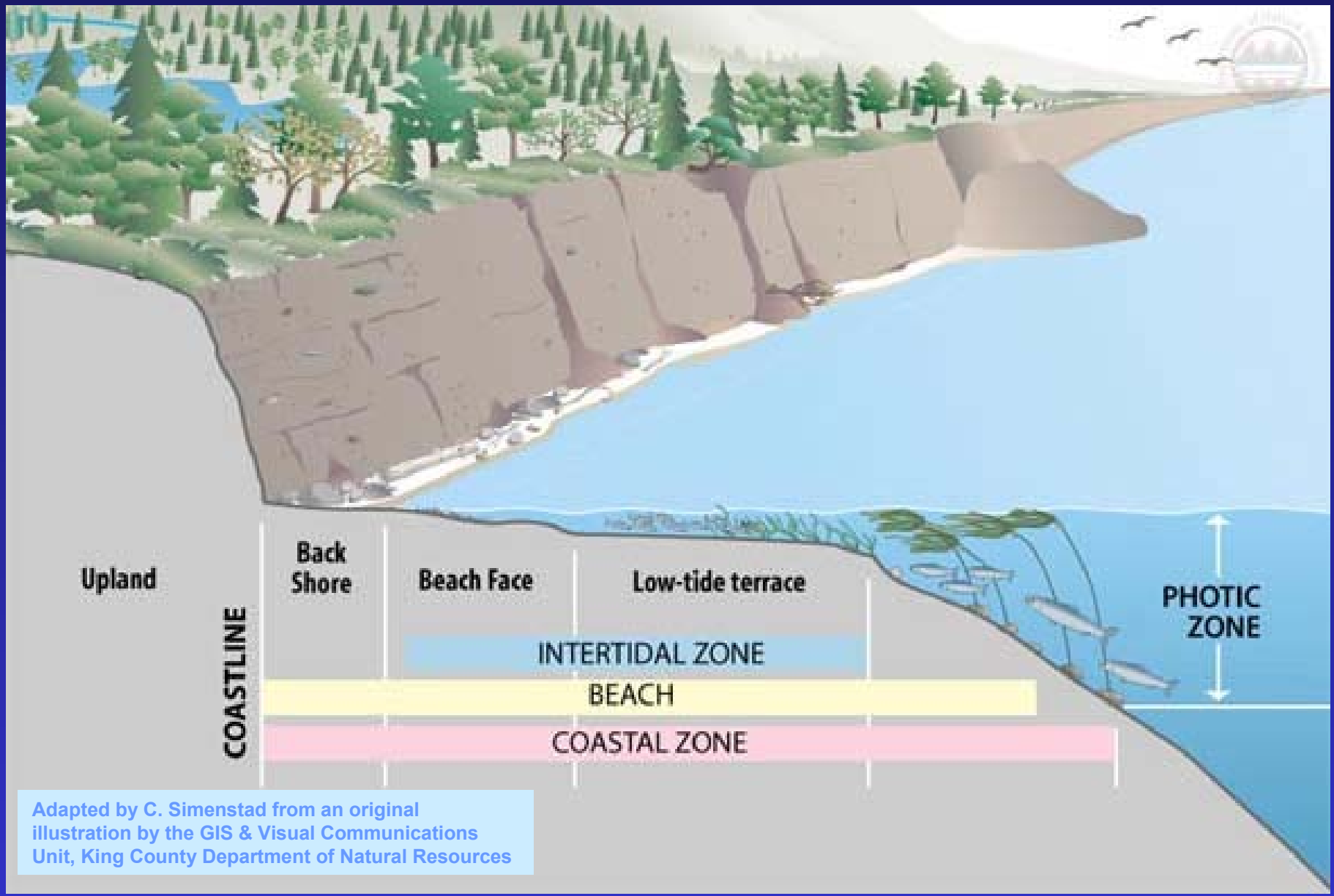


PROCESSES INFLUENCING JUVENILE SALMON PERFORMANCE IN THE COLUMBIA RIVER ESTUARY

Factors Influencing Habitat Opportunity



ERODING BLUFF, Puget Sound Nearshore



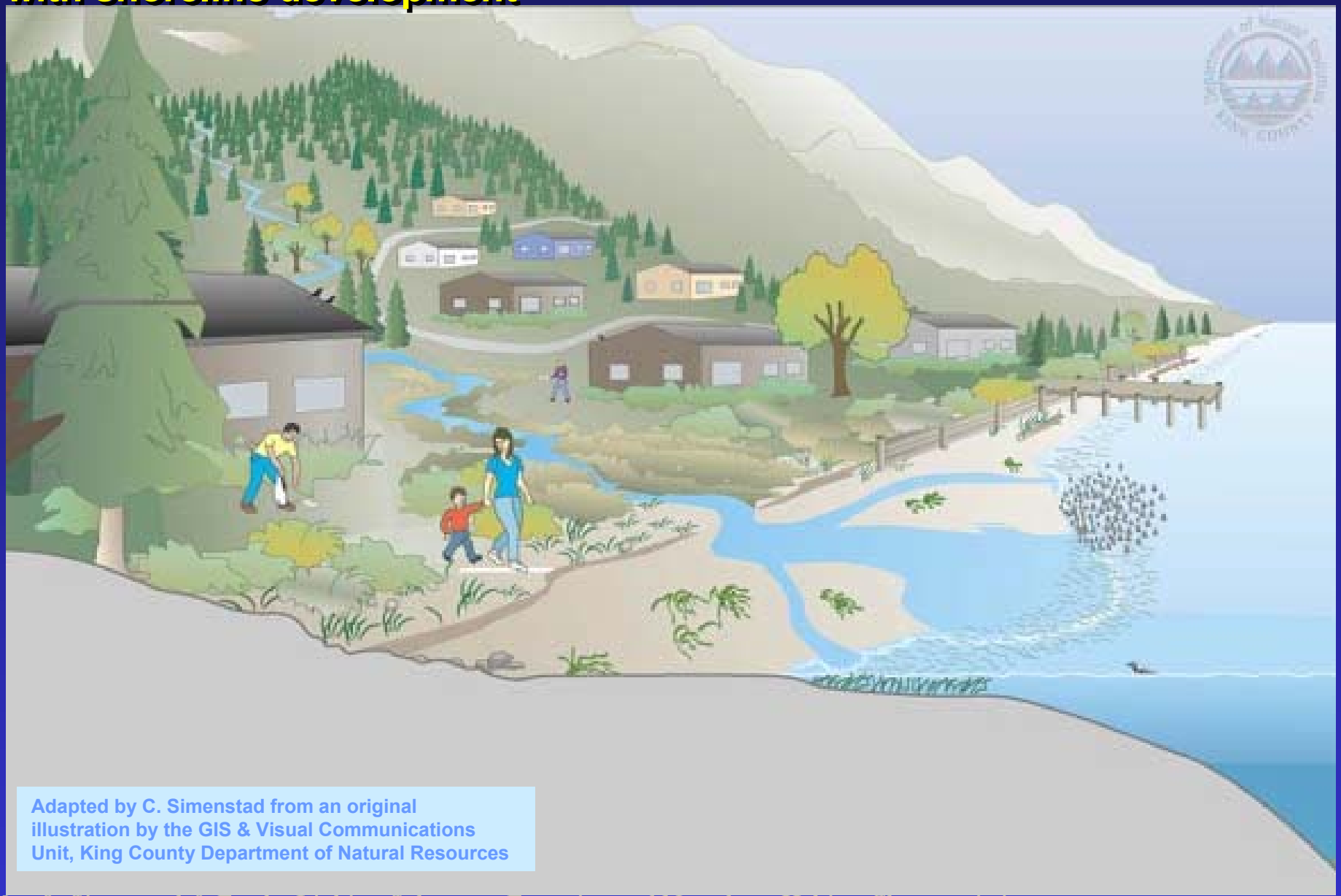
Adapted by C. Simenstad from an original illustration by the GIS & Visual Communications Unit, King County Department of Natural Resources

ESTUARINE AND NEARSHORE HABITAT

- ESTUARINE HABITAT
  - HABITAT ASSESSMENT
  - SPATIAL ARRAY OF HABITATS
  - WHAT HABITAT ATTRIBUTES ARE IMPORTANT TO FISH USE
- NEARSHORE HABITAT
  - HABITAT ASSESSMENT
  - SEDIMENT AND VEGETATION
  - RIPARIAN (IS FW A USEFUL MODEL)

NEARSHORE MARGIN, Puget Sound
with watershed and shoreline development

STREAM MOUTH, Puget Sound
with shoreline development



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CUMULATIVE IMPACTS

BIOLOGICAL RESPONSE

- QUANTIFY PERFORMANCE
  - USE DOES NOT EQUAL PERFORMANCE
- HOW SALMON USE THE ESTUARINE AND NEARSHORE LANDSCAPE
- FISH USE OF ESTUARY, NEARSHORE, OFFSHORE, MIDWATER

STUDENT QUESTIONS

1) *Si: Once estuarine habitats have been removed or extensively modified by development, how successfully can their functionality as salmon rearing habitats be restored (can you rewind the function of estuarine areas, once disturbed)? Is restoration of moderate to highly disturbed estuarine areas an effective use of management dollars, or would these funds be better spent limiting development and modification of less disturbed estuarine areas?*

2) *Kurt: Can you discuss to what level researchers have been able to quantify the effects of individual factors on the estuarine environment (on smolt survival) and distinguish salmon estuarine survival from marine survival. Are more studies needed in this area? In what areas are we missing information, i.e what types of studies should be prioritized to understand and enhance estuarine survival of juvenile salmonids?*

3) *Si: We know that something on the order of 70% of Puget Sound estuarine wetland areas have been lost to development, but we have seen some large recent runs of chum salmon in the south Puget Sound area. In other areas, like Hood Canal, chum salmon remain listed and returns relatively low. Can we correlate the drainages with greater chum returns with available estuarine areas, or are other factors at work?*

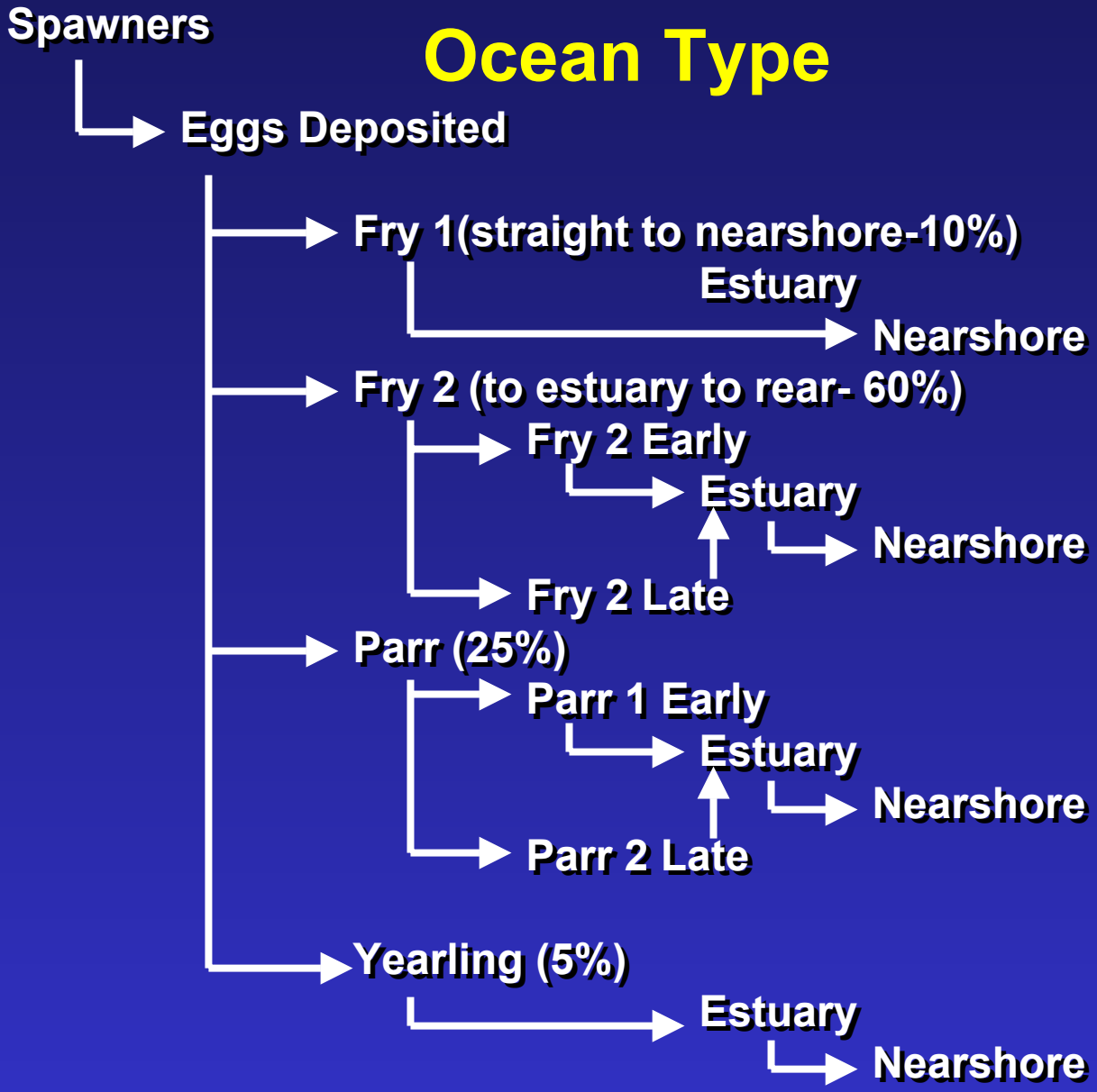
4) *Kurt: Much of your recent work has involved chinook salmon in Lake Washington. Juvenile chinook spend a significant period of time rearing in Lake Washington before moving into estuarine areas, a somewhat unusual behavior for the species. Are these fish substituting the lake environment for an estuarine rearing habitat (are the two areas serving similar ecological functions?). Do Lake Washington Chinook spent a correspondingly lesser time in estuarine areas than other chinook populations that do not pass through a lake environment during their outmigration?*

5) *Si/Kurt: Can you contrast patterns of use and relative importance of estuarine areas to chum and fall chinook populations in Puget Sound?*

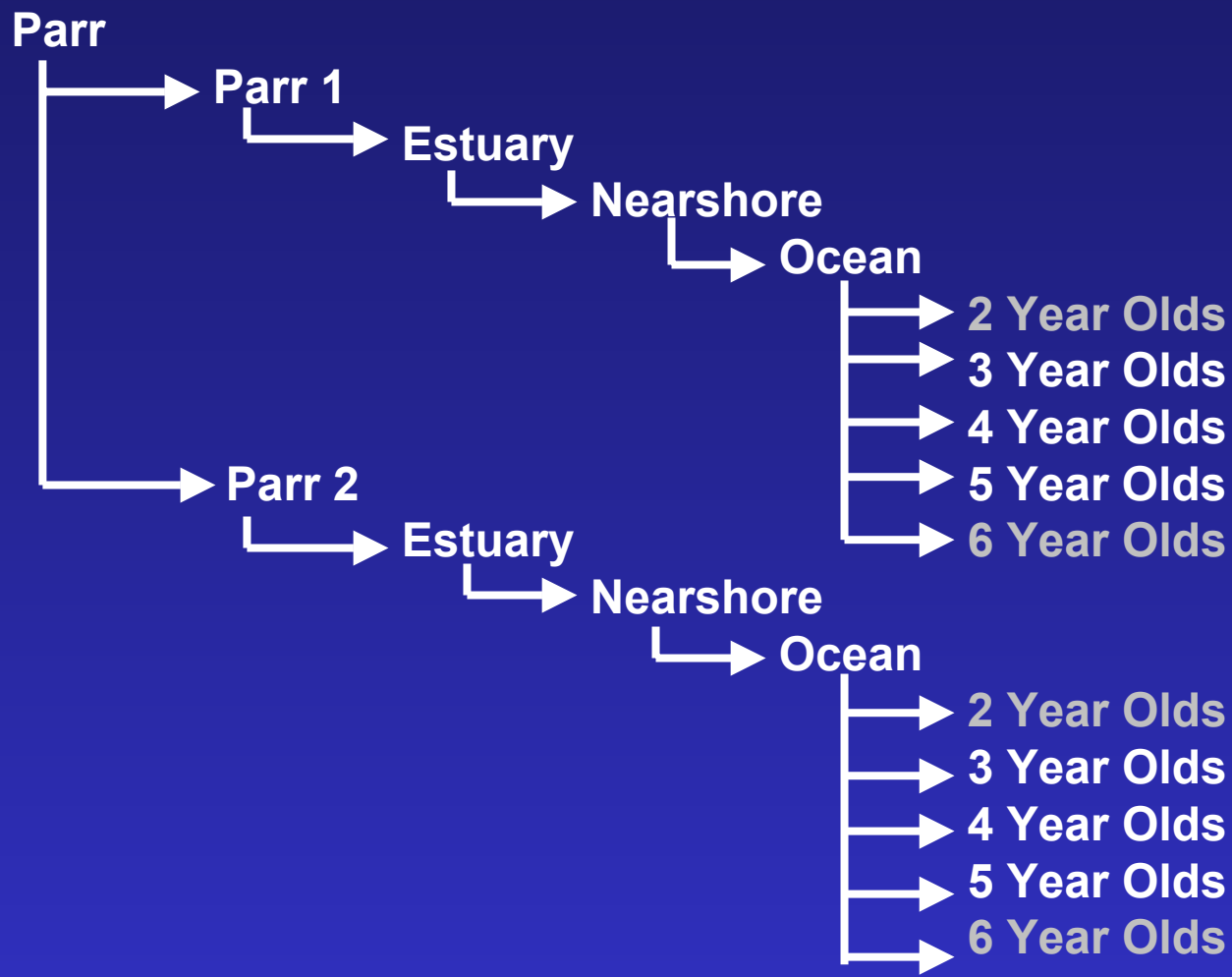
ROLE OF ESTUARY IN RECOVERY OF SALMON

- CHINOOK POPULATIONS PERSIST WITH A VARIETY OF ESTUARY-NEARSHORE TYPES
- MUST BE STRATEGIC
  - RECOVERY REQUIRES FISH, WATERSHED, ESTUARY, NEARSHORE AND OCEAN.
- RESILENCE

CHINOOK OCEAN TYPE LIFE HISTORY MODEL-Ocean Type



CHINOOK OCEAN TYPE LIFE HISTORY MODEL-Stream Type



LIFE HISTORY DIVERSITY SCENARIOS

	Flooding	Estuary Impact	FW Rearing Impact	Mean of Last 5 Years to First 5	R/S
Chinook 1	Yes	25% Permanent Loss	None	.60	.96
Chinook 2	Yes	None	Temporary for 4 years	2.4	1.1
Chinook 3	Yes	25% Permanent Loss	Temporary for 4 years	.53	.95
Chum	Yes	25% Permanent Loss	None	.32	.96

MODELING- LESSONS #1

- TRACK LIFE HISTORY TYPES SEPERATELY.
- SOME VARIABILITY MIGHT BE MORE PREDICTABLE-
  - FLOODING
  - *El Niño*

MODELING- LESSONS #2

- ROLE OF DISTURBANCE
  - PRESSED= PERMANENT
  - PULSED= TEMPORARY
- TIMING OF EVENTS IS CRITICAL
- STRAYING
- LARGER TIME SCALES
- CHUM MORE SENSITIVE TO ESTUARY LOSS BECAUSE THEY HAVE LESS DIVERSITY
- WHERE ARE SUCCESSFUL RECRUITS COMING FROM
- HATCHERIES
- IMPORTANCE OF TIME, SIZE, SPATIAL ARRANGEMENT

STUDENT QUESTIONS

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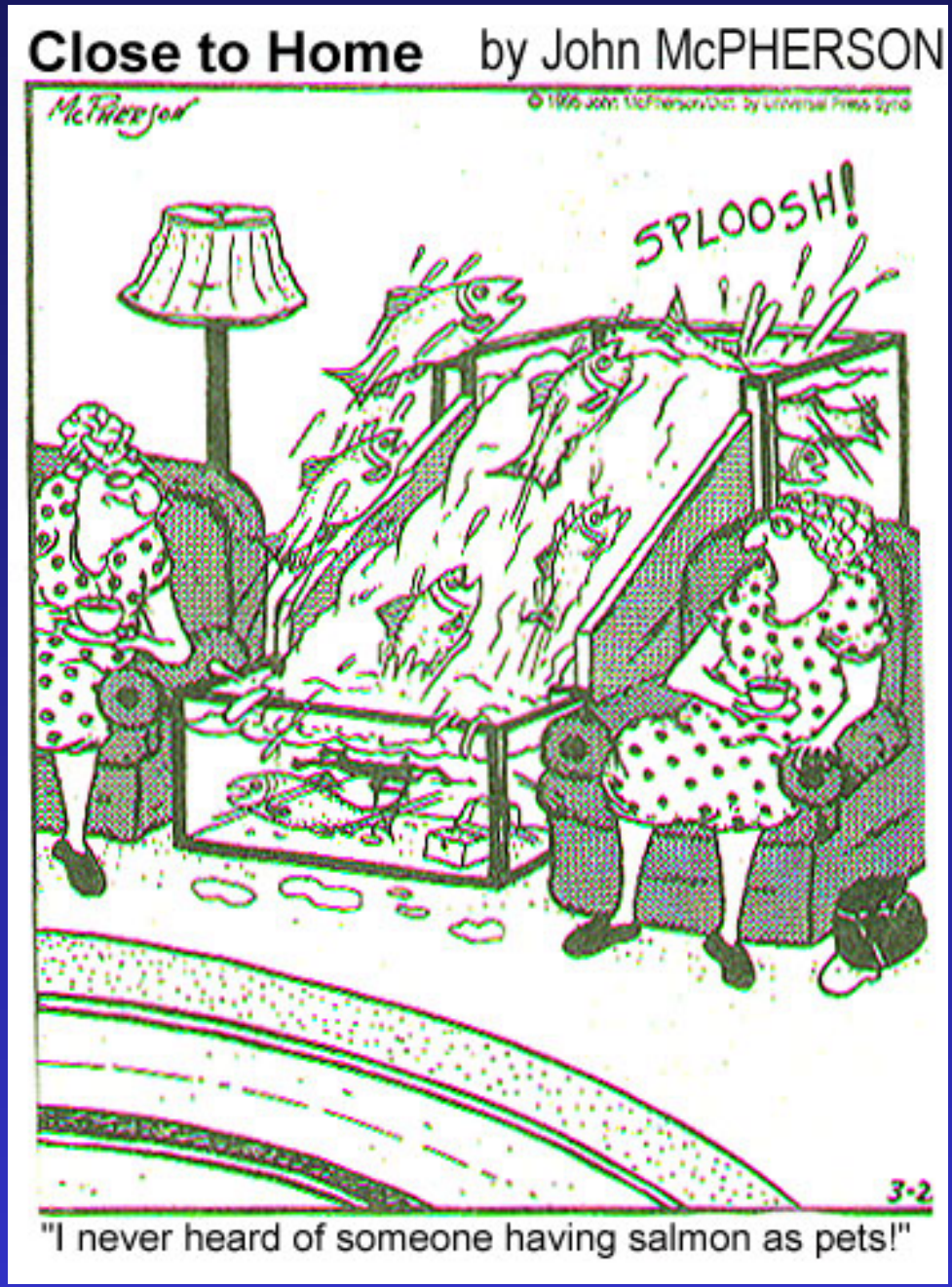
Close to Home by John McPHERSON
SPLOOSH!
3-2
"I never heard of someone having salmon as pets!"