



# Ecological indicators webinar

## Approximate agenda

10:00 – 10:10: Introduction to Washington’s Marine Spatial Planning

10:10 – 10:40: Conceptual models of Washington’s coastal estuaries

10:40 – 11:00: Discussion of conceptual models

11:00 – 11:30: Indicators and indicator evaluation process

11:30 – 11:45: Discussion of indicators

11:45 – 12:00: Next steps and wrap -up



# Introduction to Washington's Marine Spatial Planning Process

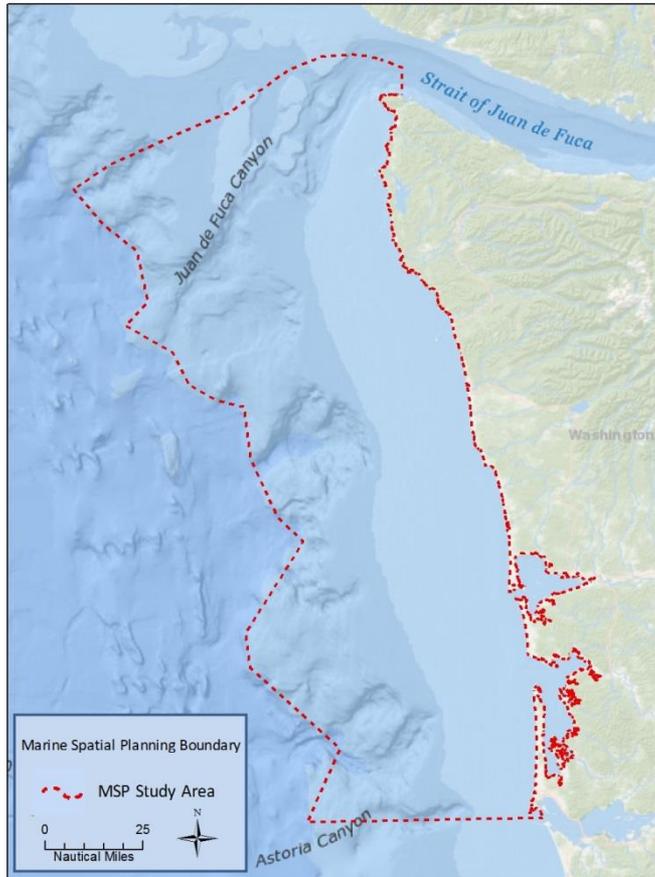
Jennifer Hennessey, Katrina Lassiter, Libby Whiting



**WASHINGTON MARINE SPATIAL PLANNING**

<http://msp.wa.gov/>

# Scope of MSP



The study area is 700 fathoms offshore and includes federal waters and estuaries.

## INTENT:

Address location of potential new marine uses.

## PLAN GOALS/OBJECTIVES:

- Protect existing uses
- Protect cultural uses/resources
- Preserve environment
- Integrate decision-making
- Provide new economic opportunities

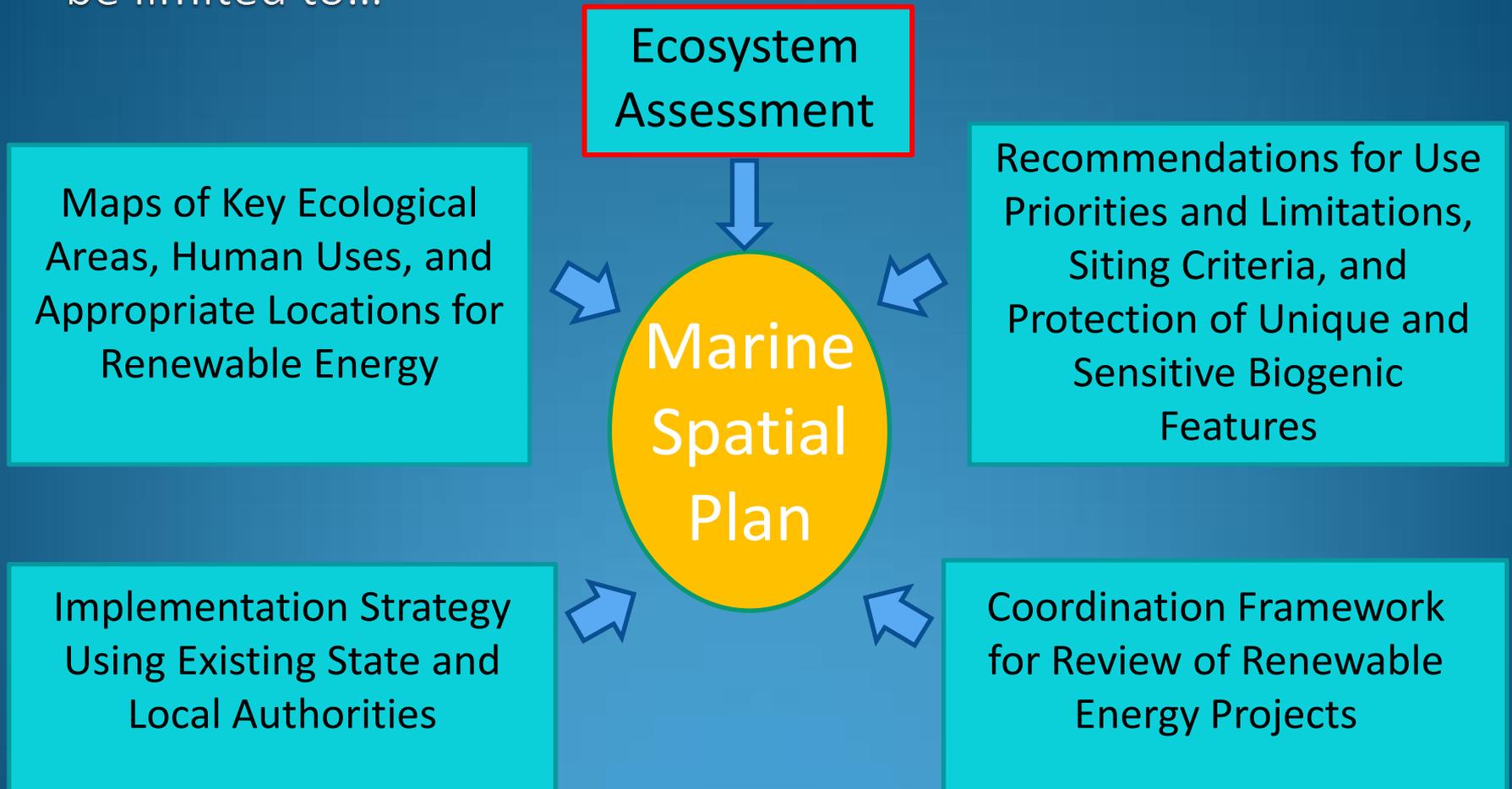
**NON-REGULATORY PLAN**

# What does the state expect to gain from the MSP process?

- Better baseline information and ecosystem indicators
- Analyses to support decision-making
- Recommendations for new uses
  - Siting – ID areas to avoid and suitable areas
- Implementation framework across agencies
  - Integration of other existing policies and management
  - Adaptive management strategy

# MSP Context: RCW 43.372.040

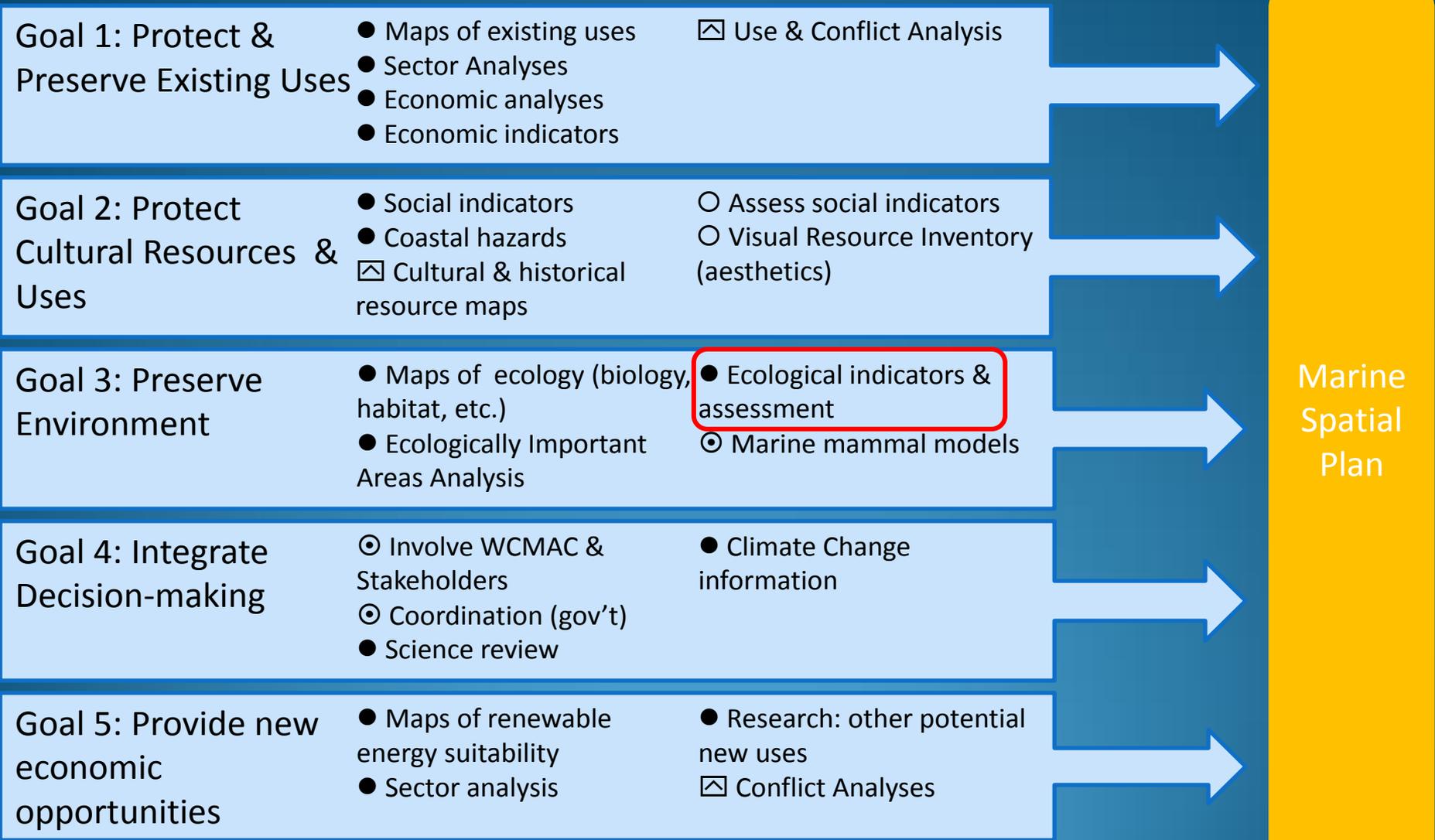
(6) The marine management plan must include but not be limited to...



# Marine Spatial Planning – Requirements (RCW 43.372.040)

**Legend:**

- Complete by June '15
- ☒ Underway before June '15
- Not underway
- ⊙ Extends past June '15

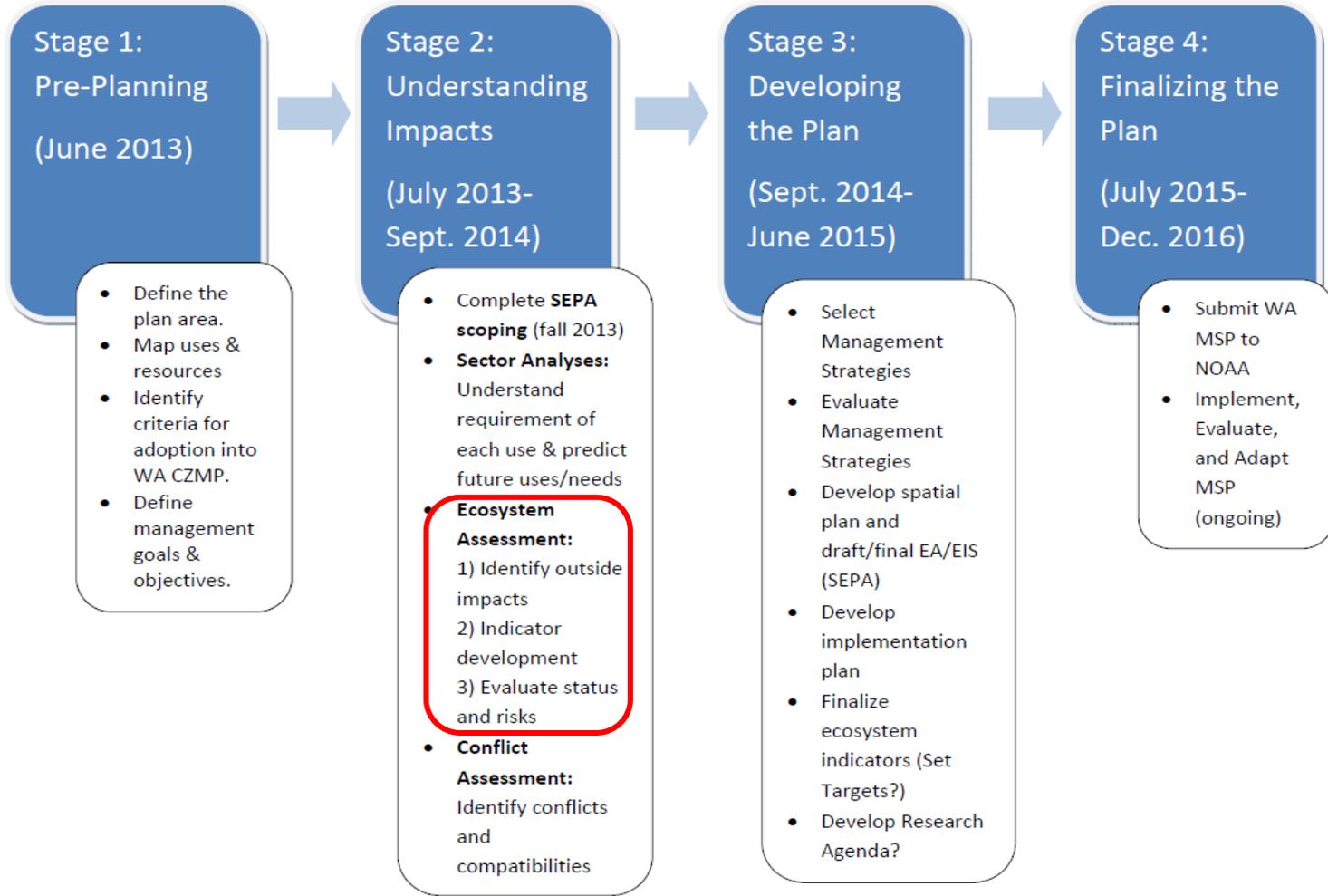


Marine Spatial Plan



# MSP Process Timeline

Stakeholder involvement, tribal consultation, government coordination and public input throughout process



# Ecological Indicators for Washington State's Marine Spatial Planning



Kelly S. Andrews and Chris J. Harvey  
Northwest Fisheries Science Center, Seattle, WA



# WHAT IS AN IEA?



IEAs provide *‘a synthesis and integration of information on relevant physical, chemical, ecological, and human processes in relation to specified management objectives’*

IEAs draw on **both the natural and human-dimension sciences**

IEAs determine the status of **coupled Socio-Ecological Systems** and Evaluate management options

IEAs are both a process and products



# INTEGRATED SOCIO-ECOLOGICAL SYSTEM OF THE CALIFORNIA CURRENT ECOSYSTEM

## FOCAL ECOSYSTEM COMPONENTS

### Ecological Integrity

Diversity, Seabirds, Marine mammals, Salmon, Forage species, Groundfish



### Human Well-being

Conditions, Connections, Capabilities (e.g., safety, community, livelihood)

## MEDIATING COMPONENTS

### Habitat

Marine  
Estuarine  
Freshwater



### Human Activities

(e.g., fishing, farming, mining, recreation, research, education, activism, restoration, management)



### Local Social Systems

(e.g., laws, policies, economies, institutions, social networks, hierarchies, cultural values, built environment)

## DRIVERS AND PRESSURES

### Climate & Ocean Drivers

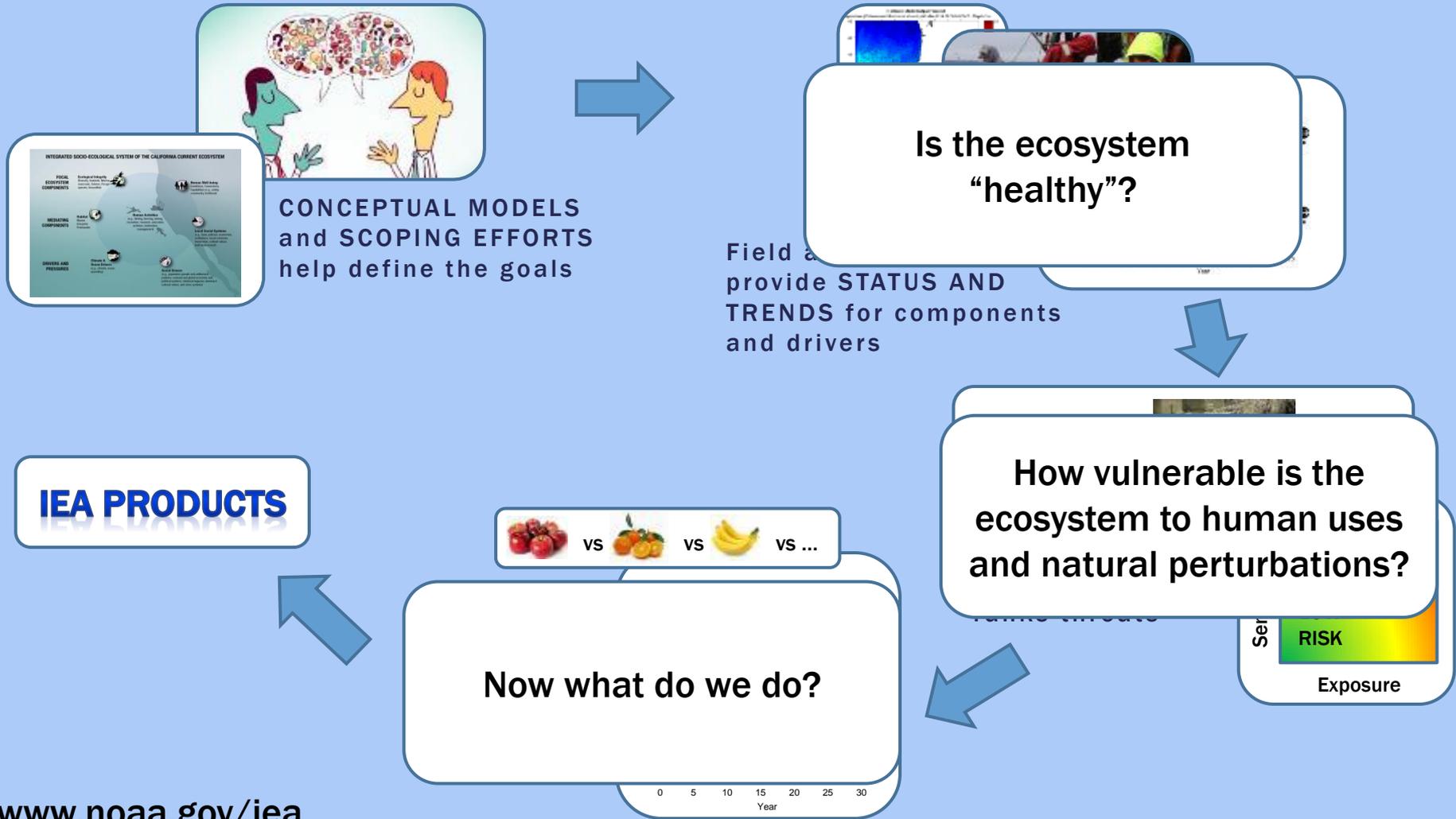
(e.g., climate, ocean upwelling)



### Social Drivers

(e.g., population growth and settlement patterns, national and global economic and political systems, historical legacies, dominant cultural values, and class systems)

# THE CCIEA IN ACTION

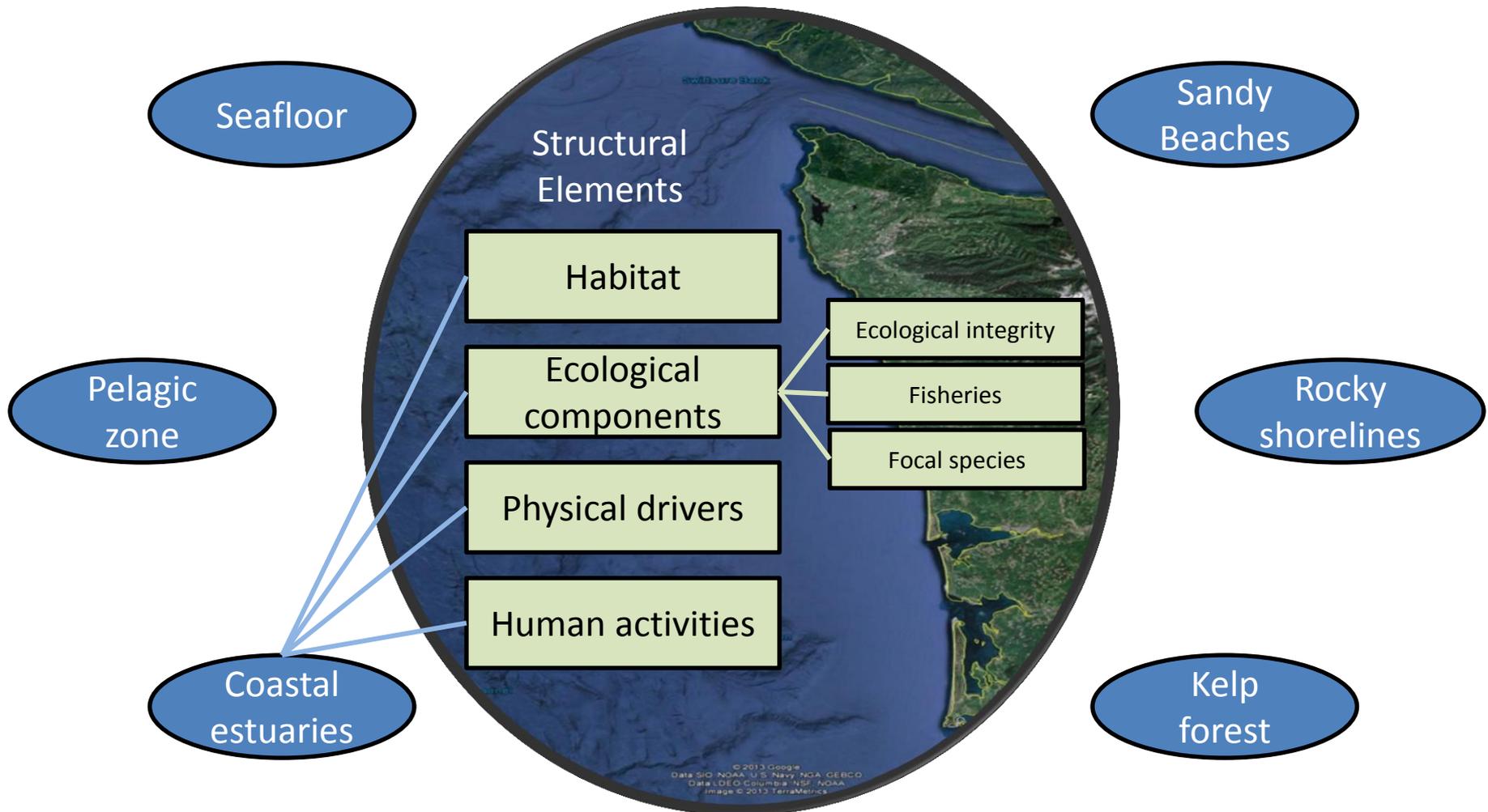


# APPLICATION TO WASHINGTON STATE



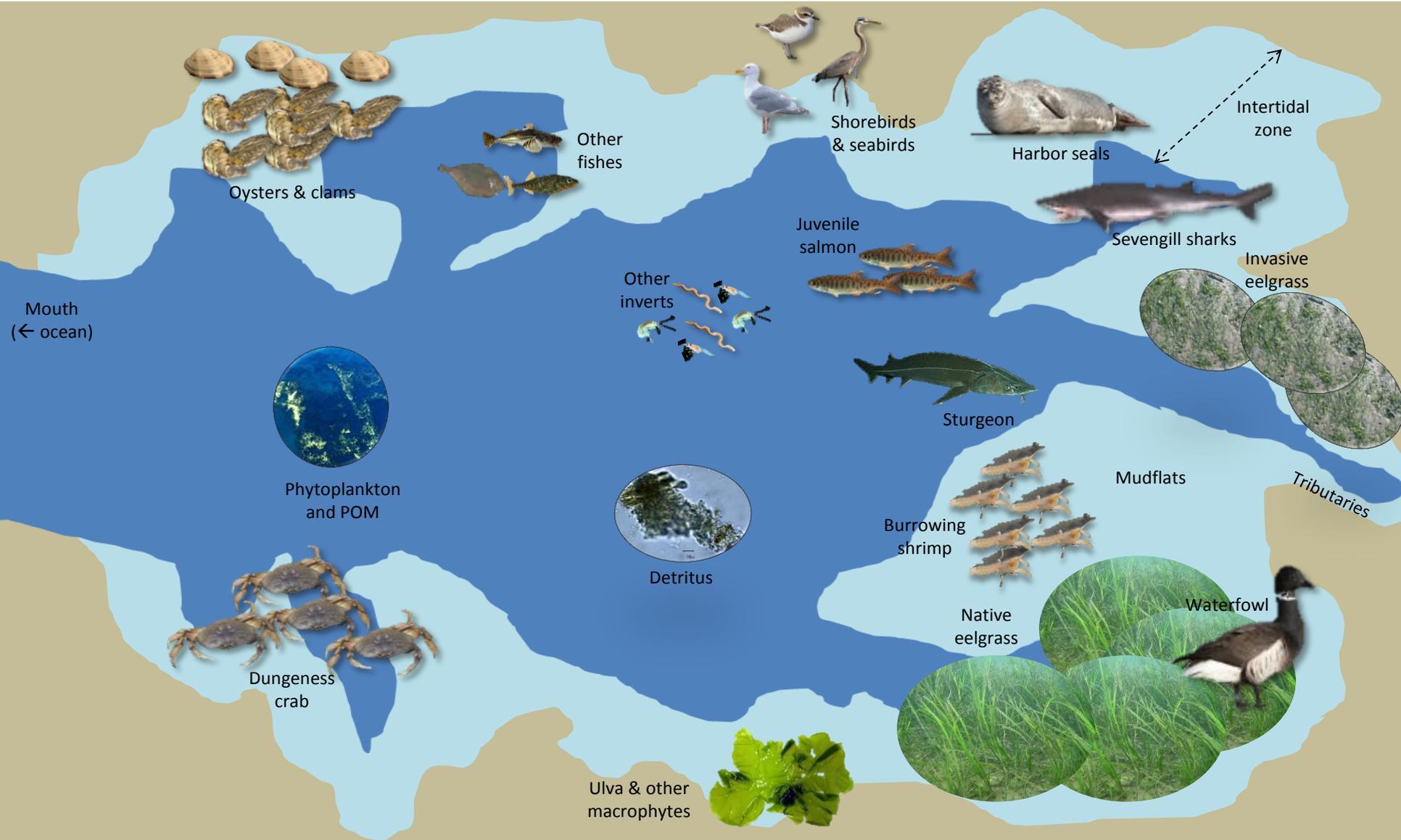
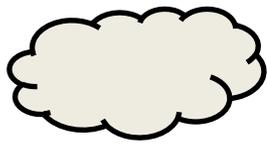
- **Washington Marine Spatial Planning**
  - **Requires the development of key indicators and an assessment of “the health and trends of the ocean ecosystem.”**
    - **Develop conceptual models of Washington’s ocean ecosystem**
    - **Evaluate indicators for components of the conceptual models**
    - **Develop time series of indicators to help determine status and trends**

# Conceptual framework of ecological indicators for marine spatial planning



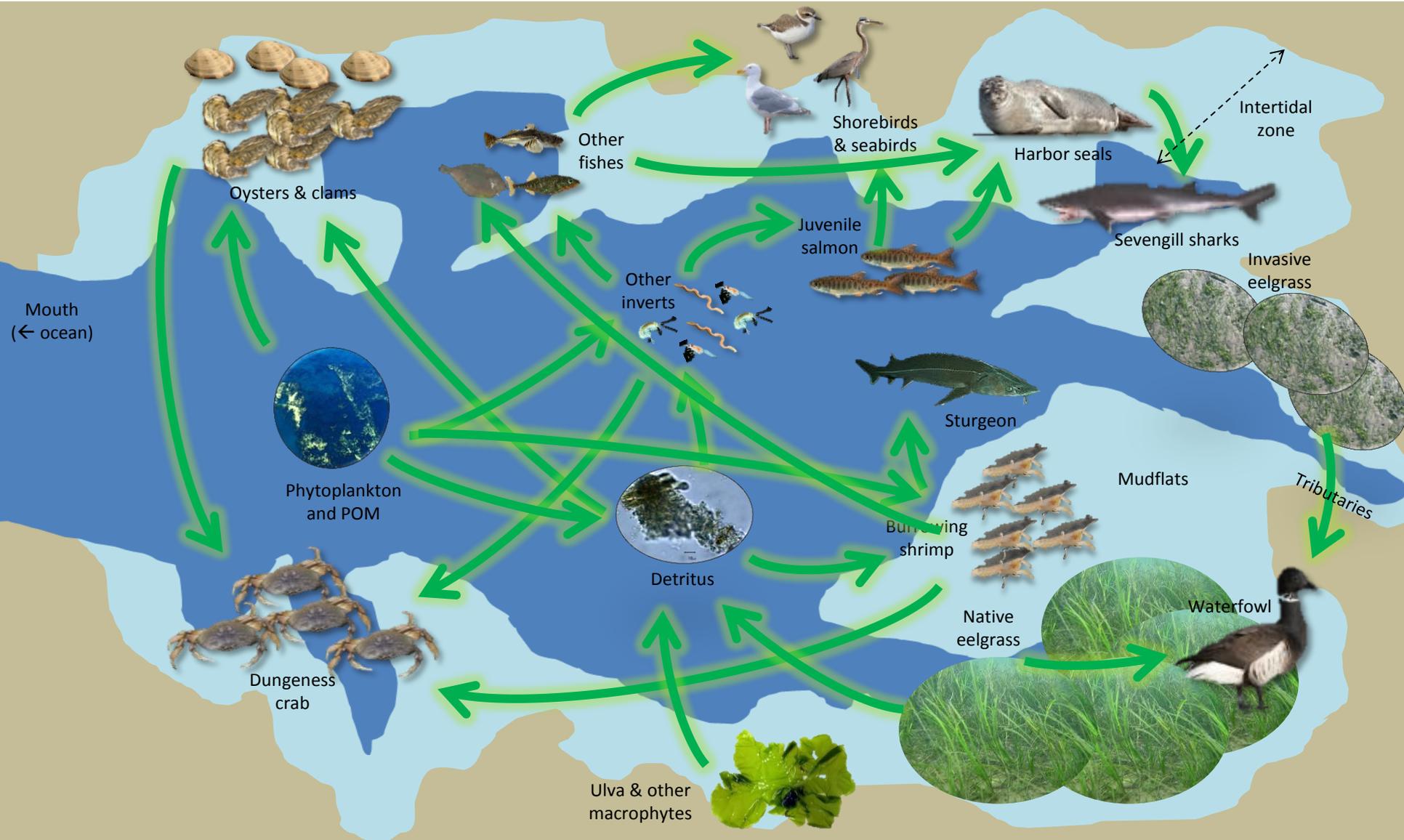
Coastal estuary habitat  
(what are the key components?)

# Estuary habitat components



# Estuary habitat components

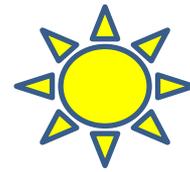
Food web connections



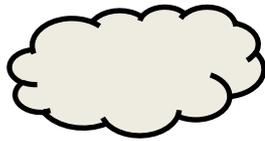
# Estuary habitat components

## Physical drivers

Other weather relevant to intertidal: Winter storms, desiccation, air temp gradients



Solar energy



Climate Change (including OA)

Other fishes

Oysters & clams

Shorebirds & seabirds

Harbor seals

Intertidal zone

Sevengill sharks

Juvenile salmon

Invasive eelgrass

Other inverts

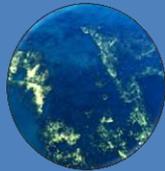
Sturgeon

Freshwater input  
Mudflats

Tributaries

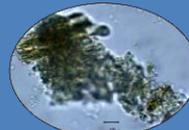
Mouth (← ocean)

Tides, Upwelling, Plumes



Phytoplankton and POM

Sediment resuspension/bioturbation



Detritus

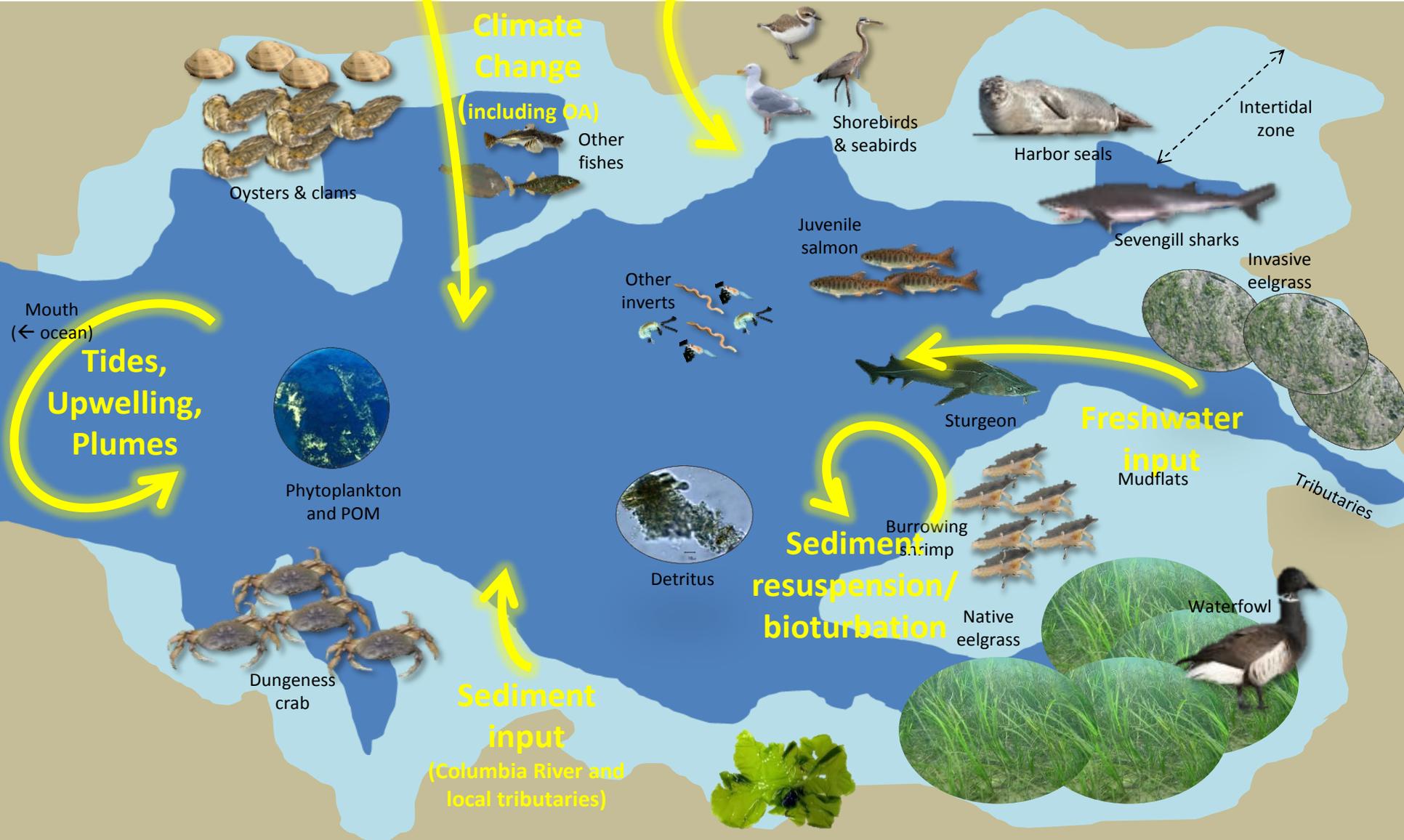
Burrowing shrimp

Native eelgrass

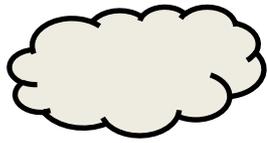
Waterfowl

Dungeness crab

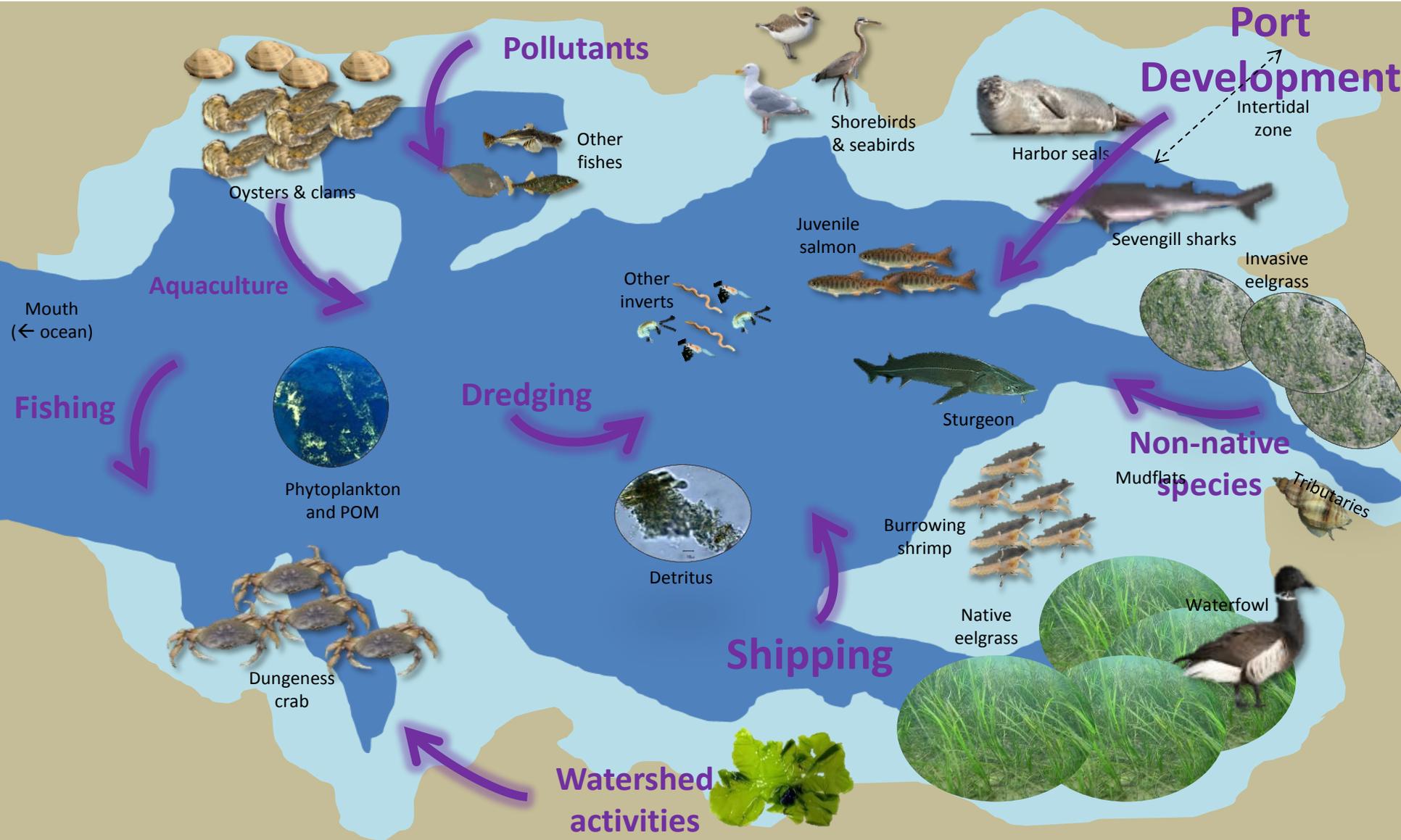
Sediment input (Columbia River and local tributaries)



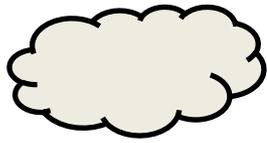
# Estuary habitat components



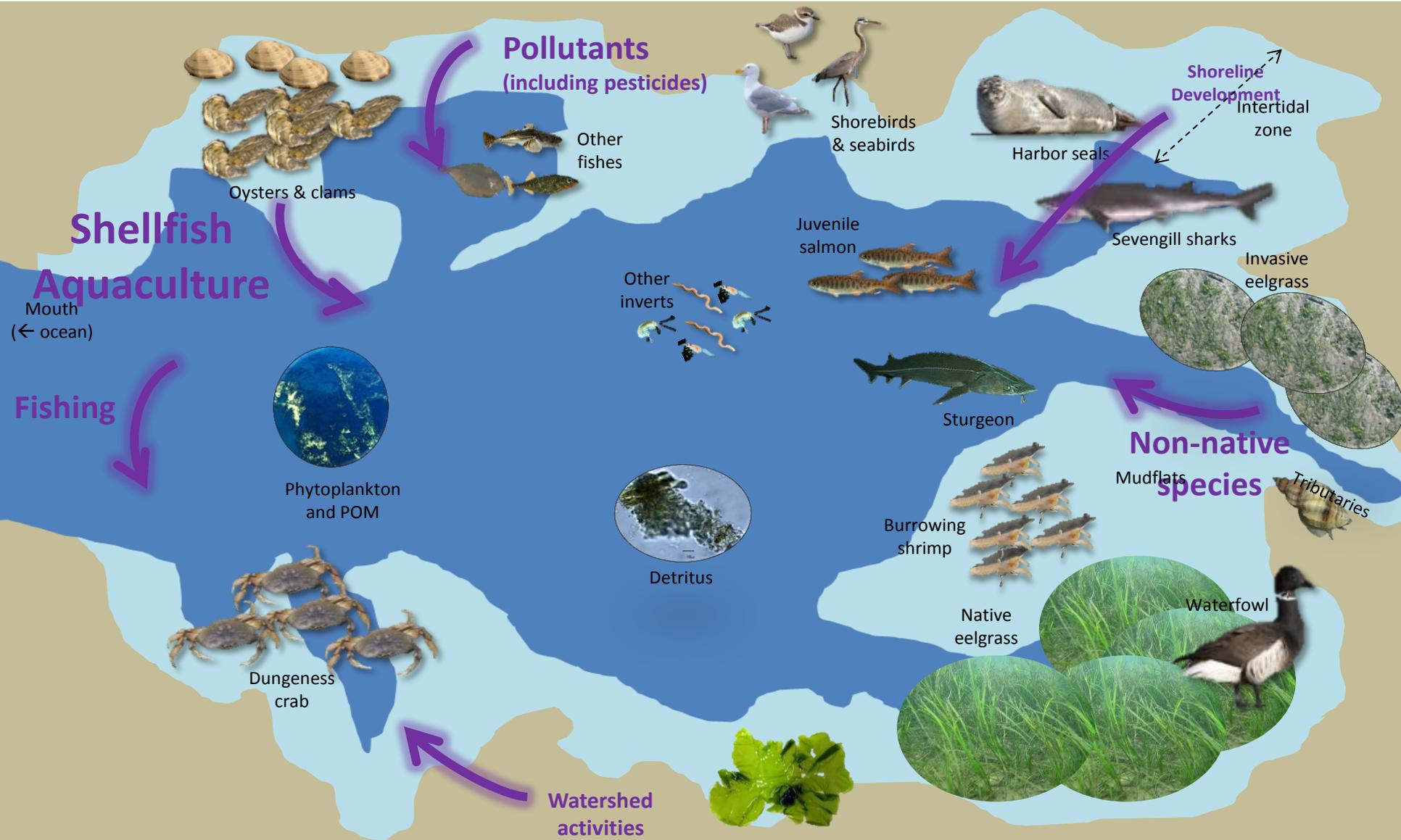
## Human activities – Grays Harbor



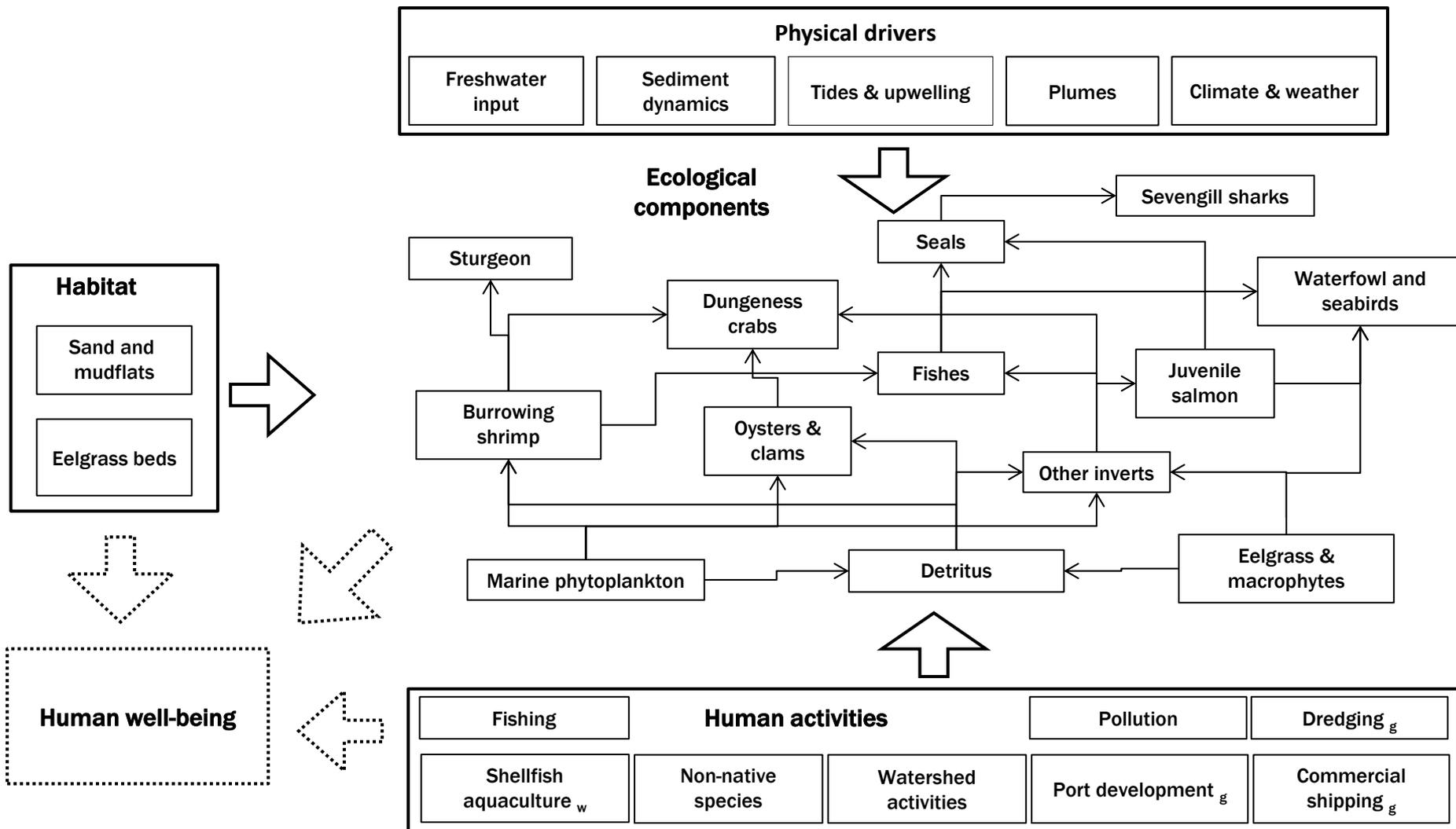
# Estuary habitat components



## Human activities – Willapa Bay



# ESTUARY CONCEPTUAL MODEL

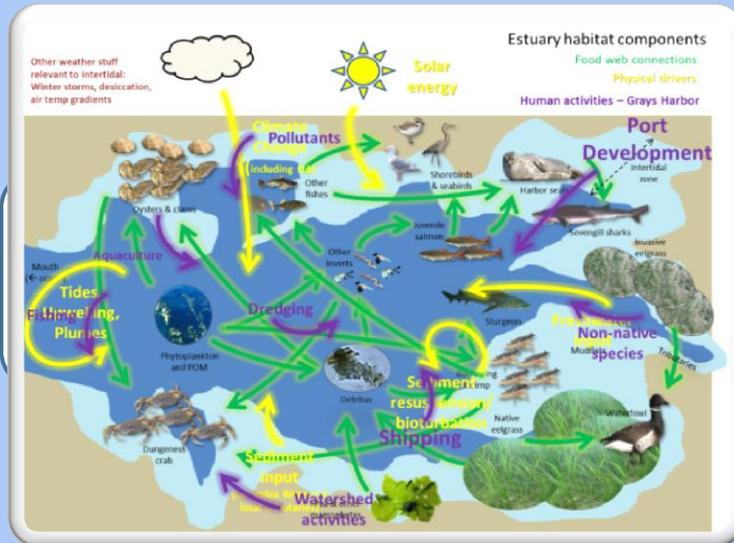


# Questions?

- What components are missing or should be removed from these conceptual models?
  - Ecological components or food web connections?
  - Physical drivers?
  - Human activities?



# THE CCIEA IN ACTION



Is the ecosystem "healthy"?

Field data provide STATUS AND TRENDS for components and drivers

How vulnerable is the ecosystem to human uses and natural perturbations?

Now what do we do?

IEA PRODUCTS

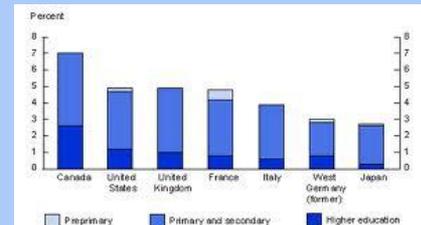
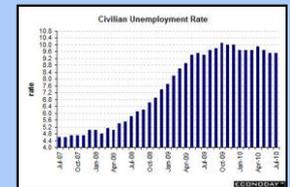
# ECOSYSTEM INDICATORS



- Empirically tractable metrics that reflect the status or trend in ecosystem attributes
- Where are we now? Where are we going?

## Examples of **Indicators** in other fields:

- Economics: Unemployment rate, Housing starts
- World Health: Infant mortality rate, Immunization (%)
- Public Safety: Homicide rate, Traffic accidents per capita
- Human Health: Blood pressure, Body temperature
- Education: Adult literacy rate, Expenditures as %GDP



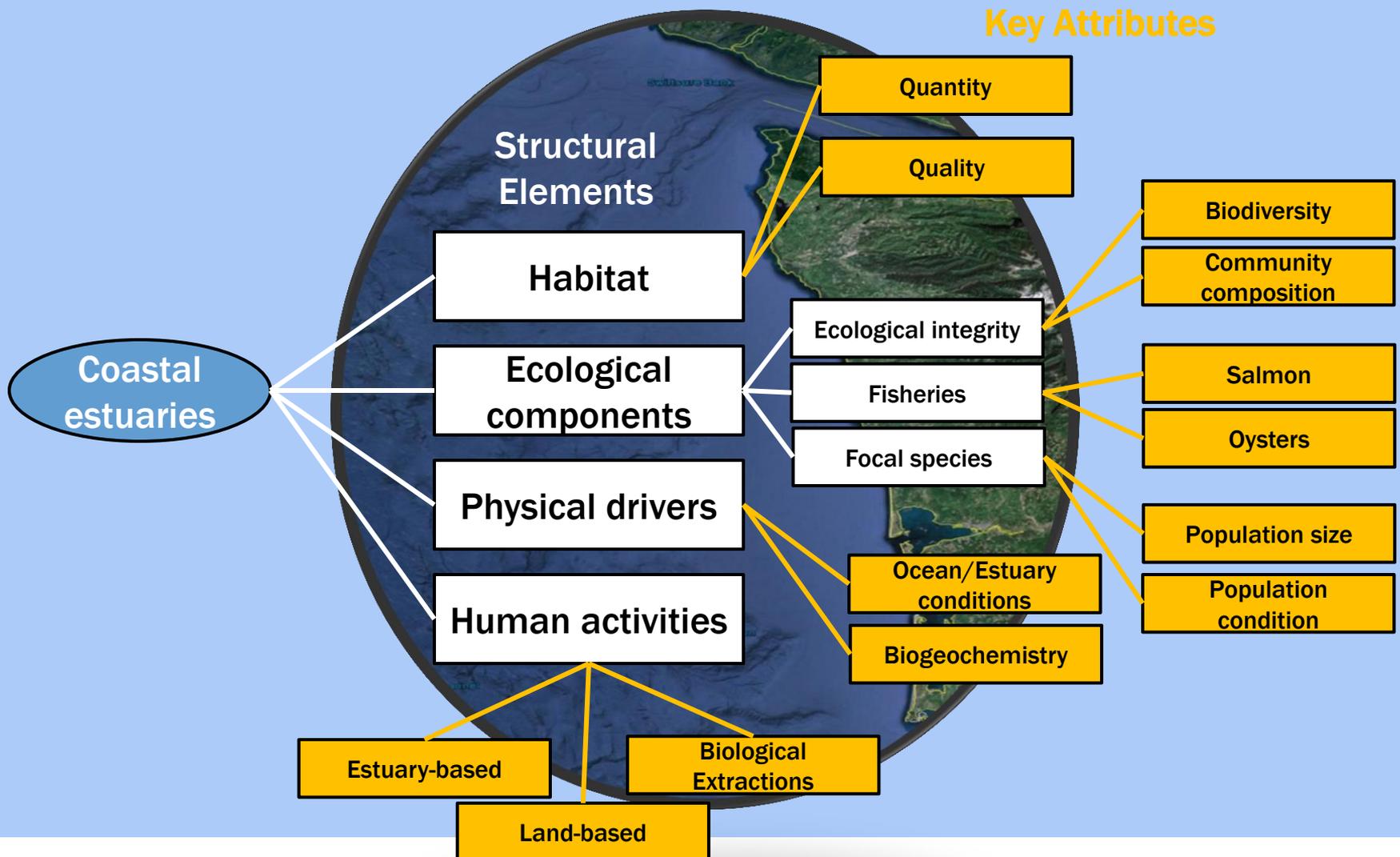
# EVALUATING THE UTILITY OF INDICATORS



## Evaluate potential indicators based on:

- Relevant to the goals of Washington's Marine Spatial Planning process

# CONCEPTUAL FRAMEWORK OF ECOLOGICAL INDICATORS FOR MARINE SPATIAL PLANNING



# EVALUATING THE UTILITY OF INDICATORS



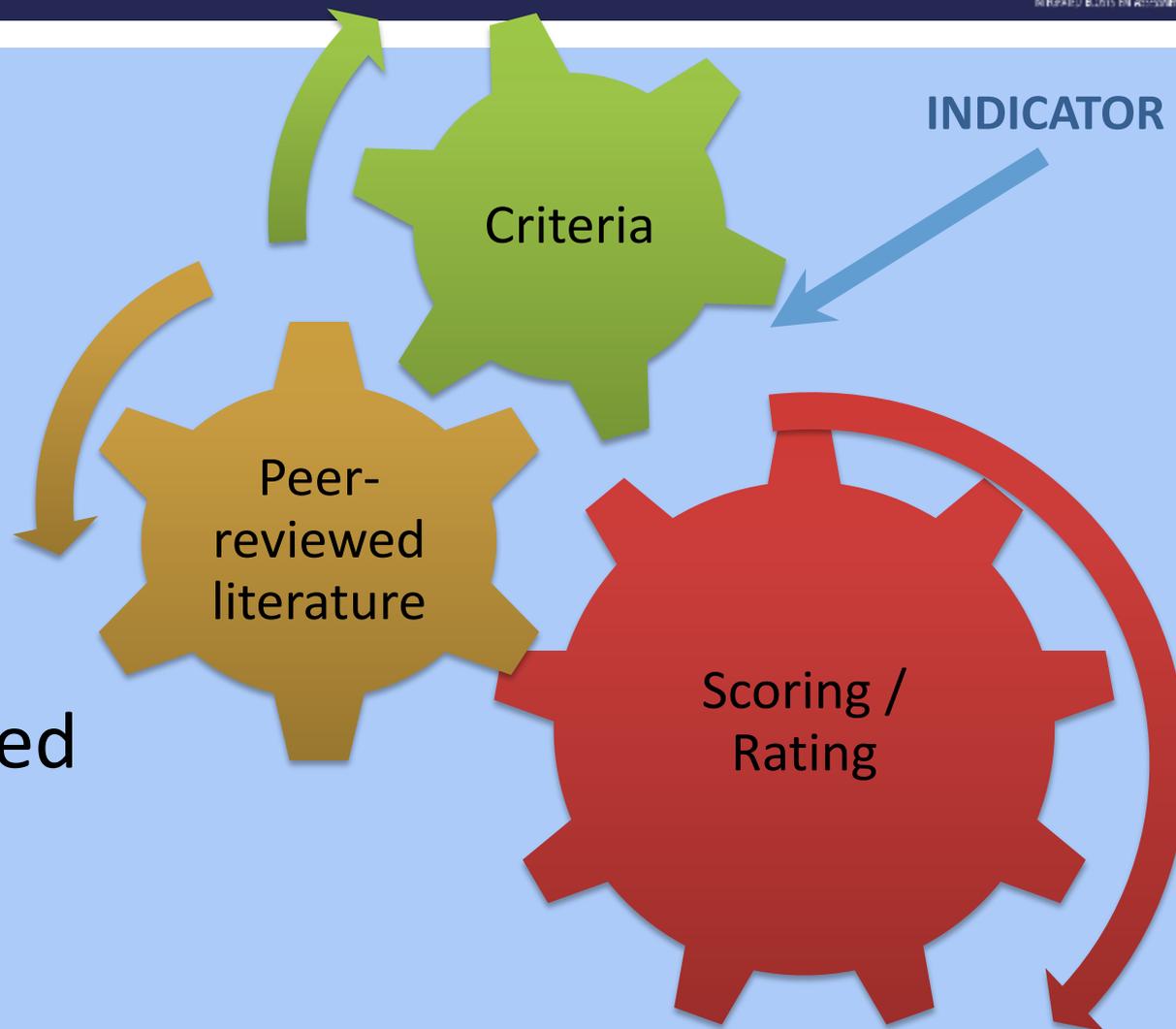
## Evaluate potential indicators based on:

- Relevance to Washington's Marine Spatial Planning process
- Standardized indicator evaluation process

# INDICATOR EVALUATION PROCESS



- Transparent
- Repeatable
- Scientifically Defensible
- Readily Updated

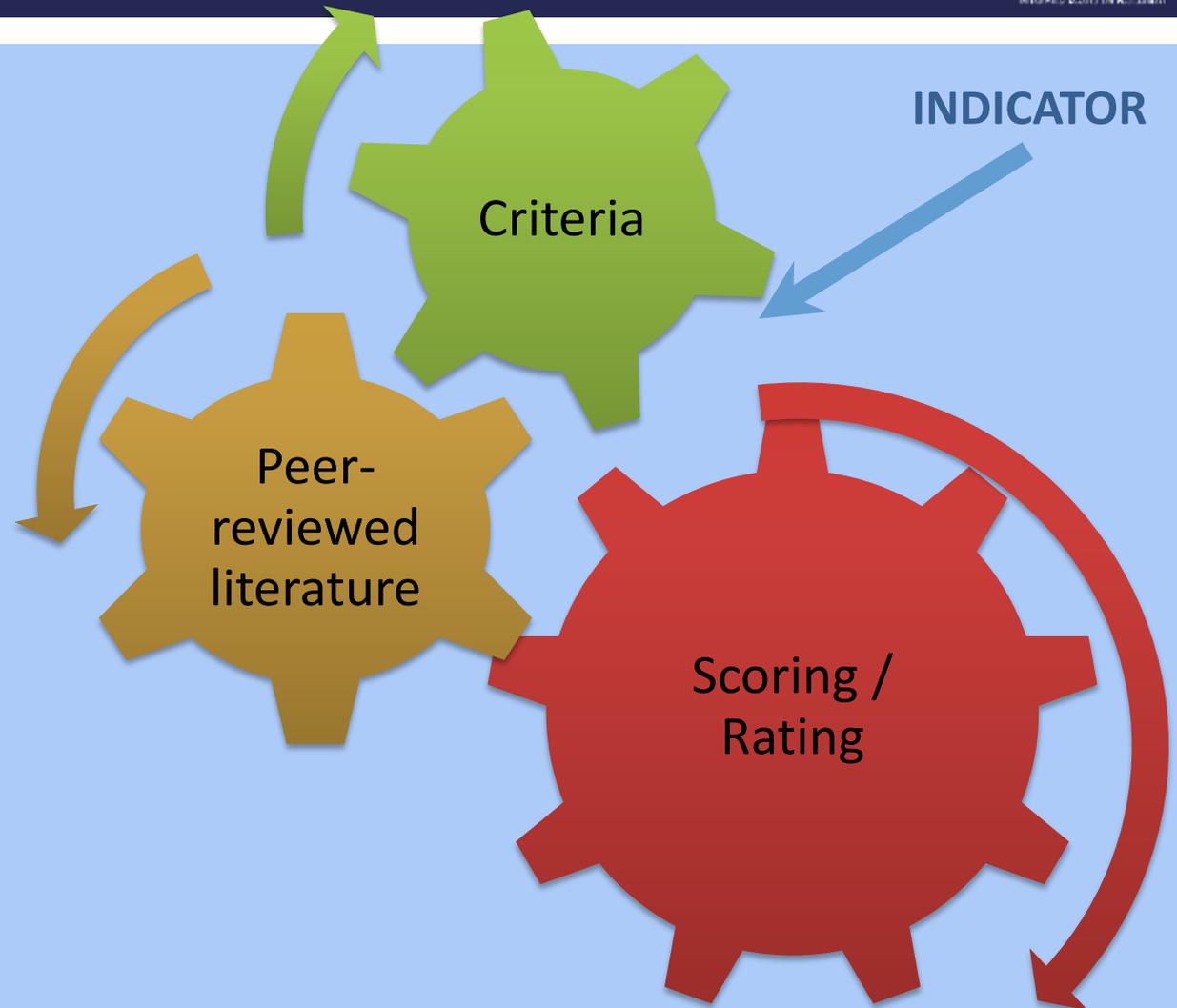


# INDICATOR EVALUATION PROCESS



## 5 Steps:

1. Identify
2. Screen with criteria
3. Literature-based scoring
4. Criteria weighting
5. Final suite selection



# STEP 1: IDENTIFY INDICATORS



**Compile a list of potential indicators that could be used to measure key attributes of each structural element**

**Sources of potential indicators:**

- **California Current IEA-developed indicators**
- **Puget Sound Vital Signs**
- **OCNMS condition report**
- **Other West Coast indicator portfolios & indicator development efforts**

# STEP 2: SCREEN WITH CRITERIA



## Indicator Evaluation Criteria (Kershner et al. 2011)

### Primary considerations (5)

- Theoretically sound
- Relevant to management concerns
- Responds to changes in attributes
- Responds to changes in management
- Linkable to targets

### Data considerations (7)

- Concrete and numerical
- Historical data
- Simple
- Broad spatial coverage
- Continuous time series
- Spatial & temporal variation understood
- Signal-to-noise ratio

### Other considerations (6)

- Understood by the public
- History of reporting
- Cost-effective
- Anticipatory
- Lagging
- Compatible (regional, national, international)

Indicators “rated” for each criterion based on information in peer-reviewed literature



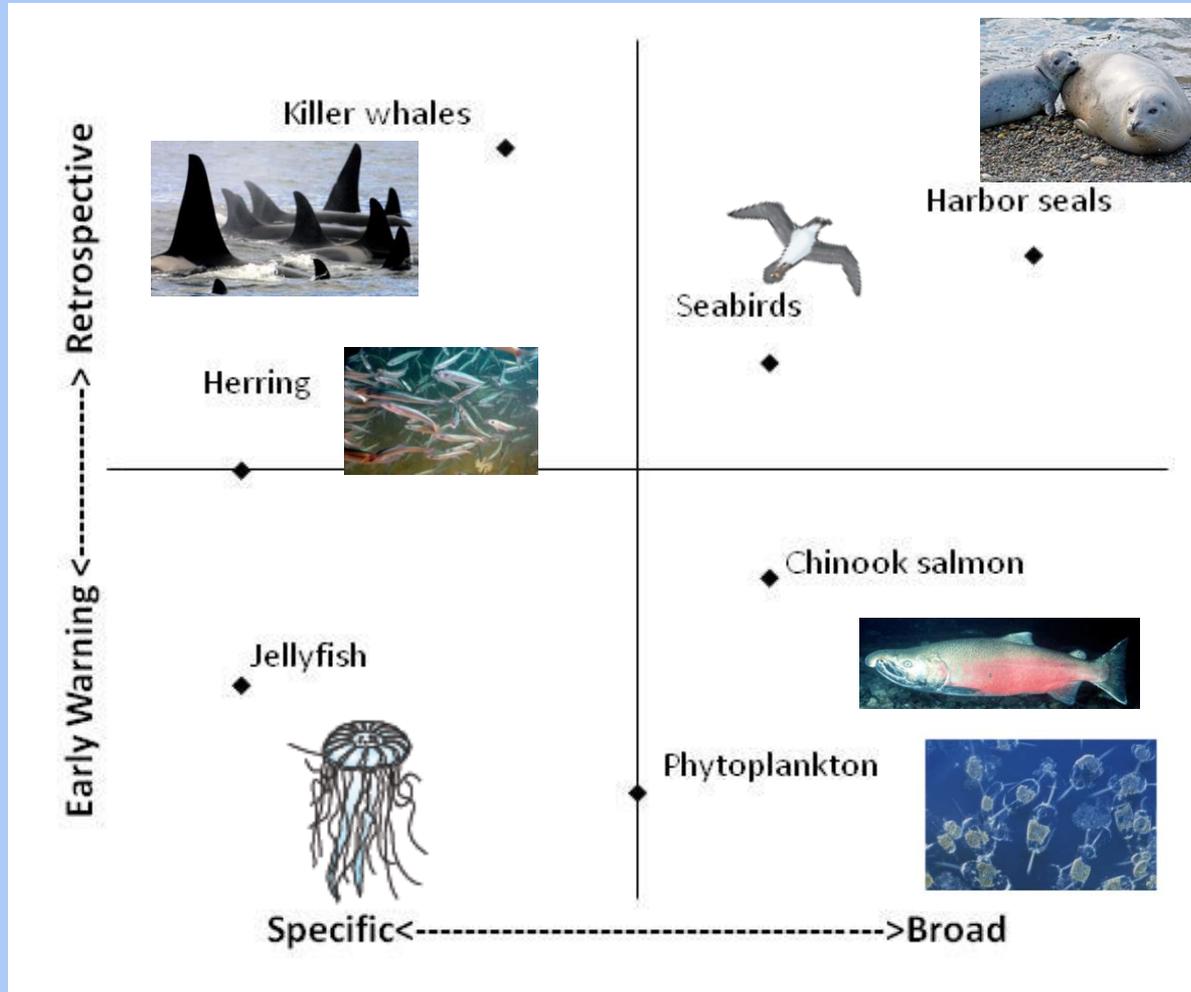
# STEP 4: CRITERIA WEIGHTING



- Weight Evaluation Criteria – not all are equally important
- For California Current IEA we polled managers to get weightings
- For Puget Sound IEA, a mixed science-policy group generate weightings in a workshop setting

<b>Understood by public and policy makers</b>	<b>Spatial and temporal variation understood</b>	<b>Broad spatial coverage</b>
<b>1</b>	<b>0.25</b>	<b>0.5</b>

# STEP 5: COMPLEMENTARY PORTFOLIO



# INITIAL SELECTION OF INDICATORS FOR COASTAL ESTUARIES IN WASHINGTON

- The following tables are lists of potential indicators to evaluate for Washington's coastal estuaries.
  - We'll go through one (habitat) or two (physical drivers) lists, depending on time, to give an example of the help we need from you.
    - Think about what indicators are missing from the list that could be used to monitor the structural elements of the conceptual models.
    - Think about what data sets you are aware of that could be used to quantify the status and trends of these potential indicators.

# HABITAT INDICATORS

**Structural  
Element**

**Key  
Attribute Indicator**

Structural Element	Key Attribute	Indicator	Indicator	
Habitat	Quantity	Areal inundated wetland coverage	River flow	
		Isohaline position	Detrital production	
		Areal eelgrass extent	Sediment deposition (mm)	
		Eelgrass density	Floodplain area : drainage area	
		Areal macrophyte extent (Ulva spp.)	Estuary surface area : drainage area	
		Macrophyte density	Network complexity (# of nodes)	
		Structure forming invertebrate extent		
		Area of oligohaline, mesohaline, and euryhaline zones		
	Quality	Water quality index	Fish size and growth	
		River flow extremes	Diversity of sediment grain size	
		Temperature	Habitat connectivity/ fragment	
		Dissolved O2	Sediment quality index	
		Nitrogen : Phosphorus ratio	Eutrophic status	
		Shellfish growth	Beach closures	

# ECOLOGICAL INTEGRITY INDICATORS

## Structural Element

## Key Attribute Indicator

Structural Element	Key Attribute	Indicator	Indicator
Ecological components	Ecological Integrity	Jellyfish biomass; status and trends	Scavenger biomass
		Crustaceans - Catch/Survey trends; larval surveys	Mean Trophic Index / Mean Trophic Level
		Benthic invertebrate biomass	Forage fish / jellyfish ratio
		Zooplankton abundance/biomass	Piscivorous/Zooplanktivorous fish ratio
		Copepod species ratio (cold vs. warm)	Pelagic / demersal fish ratio
		Species Richness	Zooplankton/Phytoplankton ratio
		Hurlbert's Delta - Evenness	Invertivore/Herbivore ratio
		Simpson Diversity Index	Finfish / Crustacean Biomass Ratio
		Shannon Diversity Index	Trophic level of catch (Mean Biomass)
		Taxonomic distinctness	Total catch / Landings of target species
		Top predator B (trophic level > 4)	Total fishery removals of all species
		Invertivore B	Total fishery removals of all species
		Detritivore B	Mean length, all spp
		Herbivore B	Slope size spectrum, all spp
		Diatom : dinoflagellate ratio	Phytoplankton cell counts
Phytoplankton pigments	Chl a (phytoplankton biomass)		
PPC:PSC ratio (photoprotective:photosynthetic carotenoid ratio)			

# FISHERIES INDICATORS

Structural Element	Key Attribute	Indicator
Fisheries	Salmon	Age structure of populations
		Size structure of populations
		Spawning escapement
		% natural spawners to hatchery spawners
		Population growth rate
		Smolt-to-adult survival
	Pacific oyster aquaculture	Oyster condition index
		Percent cover of potential oyster beds
		Density of oysters
		Density of burrowing shrimp

# FOCAL SPECIES INDICATORS

Structural Element	Key Attribute	Indicator	
Focal species (Protected species, Species of concern, Other species of particular interest)	Population size	Population biomass (best method)	Commercial landings biomass
		Population numbers (best method)	Commercial landings numbers
		Population growth rate	Recreational landings biomass
		Local Ecological Knowledge	Recreational landings numbers
		Egg/larval abundance	Bycatch
		Total harvest biomass; CPUE	
	Population condition	Size structure of populations	Condition factor & index
		Age structure of populations	Parasitic load
		Genetic diversity of populations	Body growth
		Size at maturity	Cortisol/Vitellogenin
		Age at maturity	Disease (liver & gall bladder)
		Reproductive output	Diet
		Spatial structure of population	Contaminant levels in tissues

# PHYSICAL DRIVERS INDICATORS



**Structural  
Element**

**Key  
Attribute**

**Indicator**

Structural Element	Key Attribute	Indicator	Indicator
Physical drivers	Ocean/Estuary conditions	Sea surface temperature	Multivariate ENSO Index (MEI)
		Pacific Decadal Oscillation	Northern Oscillation Index (NOI)
		North Pacific Gyre Oscillation (NPGO)	Copepod species ratio (northern vs southern species)
		Nutrient concentrations (NO <sub>2</sub> + NO <sub>3</sub> )	Stratification based on pycnocline depth
		Eddy Kinetic Energy (EKE)	Estuarine water residence time
		Shellfish closure days (HABS)	Concentration of dissolved oxygen
	Columbia River Plume	Salinity	Sea surface temperature
		Columbia River discharge	Seasonal winds
	Juan de Fuca Eddy	Salinity: saltwater intrusion index	Radius of eddy
		Sea surface temperature	
	Ocean Acidification	pH, pCO <sub>2</sub> , DO	aragonite saturation
	Upwelling	Meridional winds	Spring Transition Index (STI)
		Upwelling index (UI)	Length of Upwelling Season Index (LUSI)
		Cumulative Upwelling index (CUI)	Total Upwelling Magnitude Index (TUMI)
	Sea level	Coastal sea level height (tide gauge data)	

# HUMAN ACTIVITIES INDICATORS (LAND-BASED)



Structural Element	Key Attribute	Indicator	
Human activities (land-based)	Extractions	Fisheries landings	Aquaculture production
	Freshwater input	Runoff magnitude - average discharge	Consumption (e.g. irrigation, domestic supply, etc.)
		Dam/Reservoir storage area (acre-ft)	Flow regulation and irrigation indices
	Nutrient input	Nutrient loading (TN, TP), by river	Fertilizer loading by watershed
	Trash	Estuarine coastal debris (trash cleanup programs)	Estuary-based measurements
	Pollution	Atmospheric deposition concentrations	Avg. nighttime light pixels (light pollution)
		Total inorganic pollutants in watersheds	Toxicity-weighted pesticide concentrations in watershed
		Total inorganic pollutants * Toxicity	Beach closures
		Total inorganic pollutants * Toxicity * Impervious surface area	
	Sediment input	Dam/Reservoir storage area (acre-ft)	Suspended sediment loading (TMDL)

# HUMAN ACTIVITIES INDICATORS (ESTUARY-BASED)



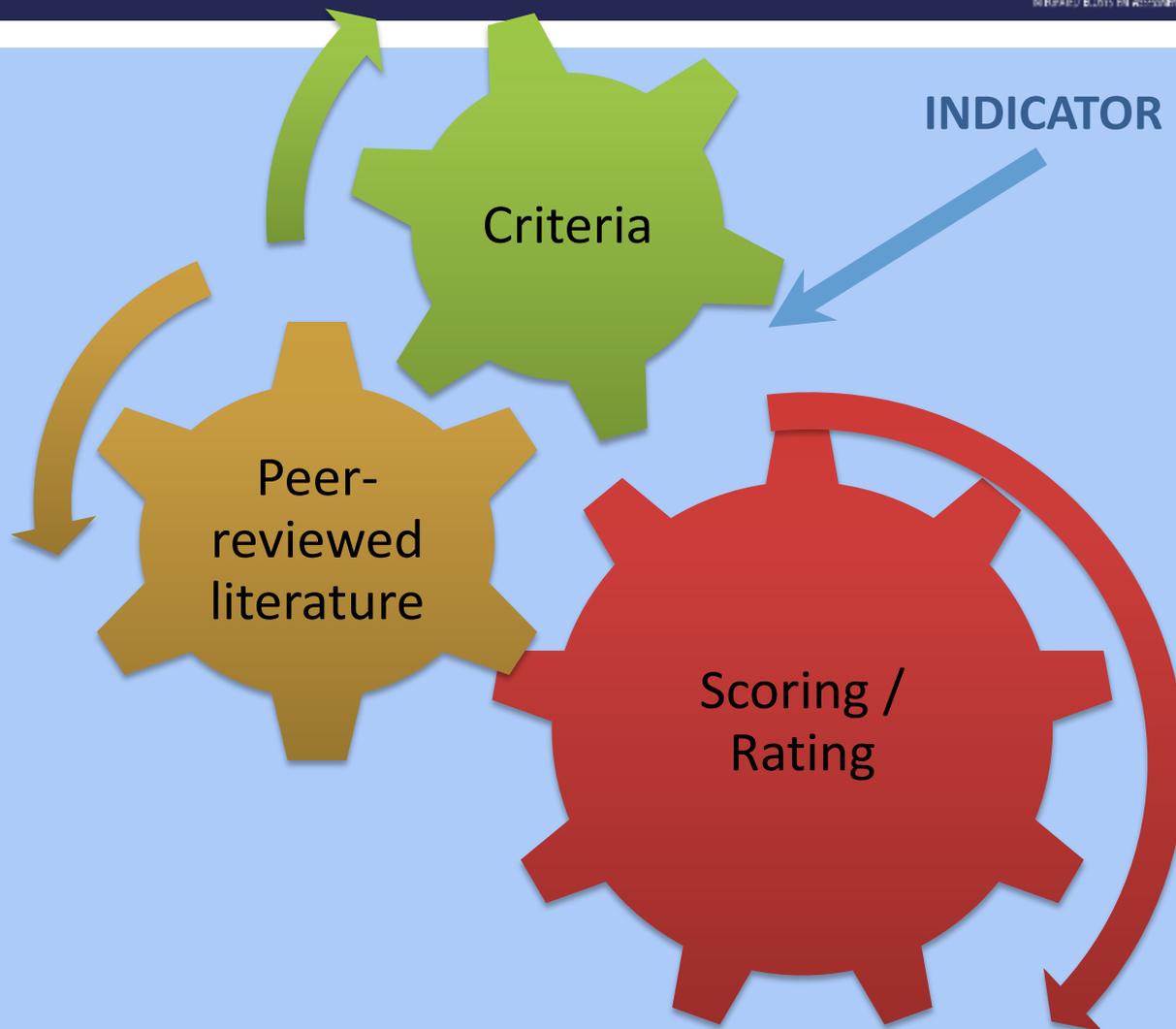
Structural Element	Key Attribute	Indicator	
Human activities (estuary-based)	Shoreline modification	Acres of area used in aquaculture	Coastal population
		% modified (armored) shoreline	Beach attendance
	Dredging	Dredge volumes	Dredge dump volumes
	Invasive species	Number of (harmful) alien species	Proportion of native to non-native shellfish (areal coverage ratio)
		Areal coverage of non-indigenous flora species ( <i>Zostera japonica</i> and <i>Spartina alterniflora</i> )	Shipping cargo volume
	Pollution	Shipping activity plus port volume	# of ship trips
		Tons of cargo moved	Concentration of pollutants in port
	Pest control	Amount of herbicide/pesticides applied to the intertidal	
	Tourism	Gross domestic product of tourism & recreation in estuarine counties	
	Seafood demand	Per capita U.S. consumption	Total U.S. consumption

# INDICATOR EVALUATION PROCESS



## 5 Steps:

1. Identify
2. Screen with criteria
3. Literature-based scoring
4. Criteria weighting
5. Final suite selection

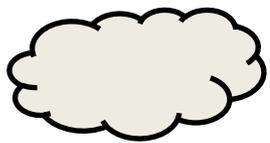


# EXAMPLE OF FINAL SUITE OF HIGHLY-RANKED ESTUARINE INDICATORS



Structural Element	Key Attribute	Indicator	
Habitat	Quantity	Areal extent of eelgrass	Total estuary area
	Quality	Eutrophic state	Water quality index
Ecological Components	Ecological integrity	Simpson diversity and species richness (fishes, birds, inverts)	Top predator biomass, [Chlorophyll a]
	Fisheries	Salmon smolt-to-adult survival	Age structure of salmon stocks
		Oyster condition index	% cover of potential oyster beds
	Focal species	Biomass, numbers or density of focal species	Population growth rate
Age structure of populations		Reproductive output	
Physical drivers	Ocean/estuarine conditions	SST, Salinity maps, PDO, NPGO	Upwelling index, Spring transition index
	Biogeochemistry	Sediment deposition, DO	Aragonite saturation state, pH
Human activities	Extractions	Landings (commercial, recreational, tribal)	Aquaculture production
	Land-based	Avg. river discharge, Reservoir storage	Fertilizer and pollutant loadings in watershed
	Estuary-based	% armored shoreline, Volume dredged	Port cargo volume, Volume of pesticides applied
		Tourism & recreation revenue	U.S. consumption of seafood products

Other weather relevant to intertidal: Winter storms, desiccation, air temp gradients



Solar energy

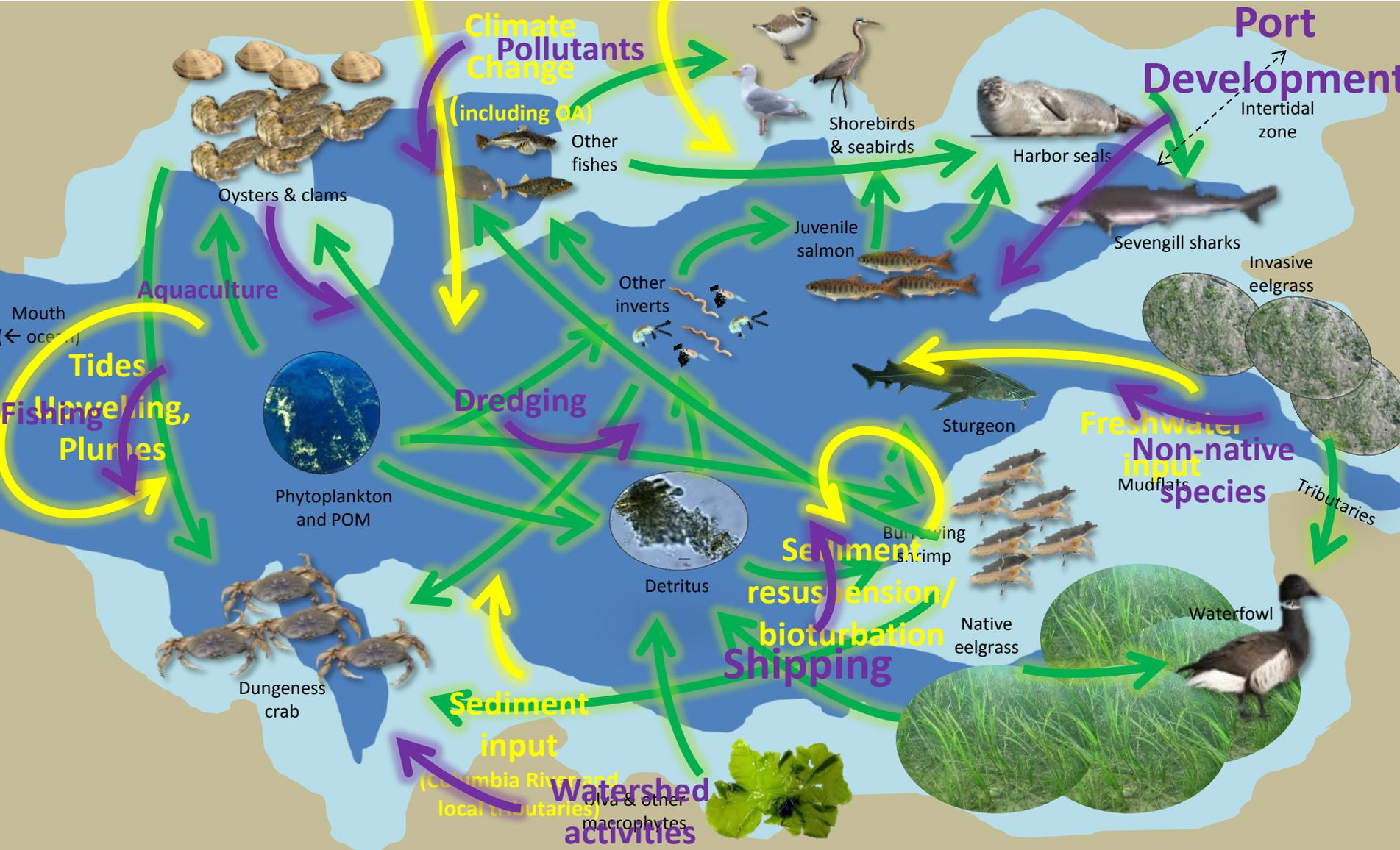
# Estuary habitat components

Food web connections

Physical drivers

Human activities – Grays Harbor

## Port Development



Mouth (← ocean)

Tides  
Flooding,  
Plumes

Aquaculture

Climate Change  
Pollutants  
(including OA)

Dredging

Sediment  
resuspension/  
bioturbation

Shipping

Sediment  
input  
(Columbia River and  
local tributaries)

Watershed  
activities  
(olive & other  
macrophytes)

Freshwater  
input  
Non-native  
species  
Mudflats

Intertidal  
zone

Tributaries

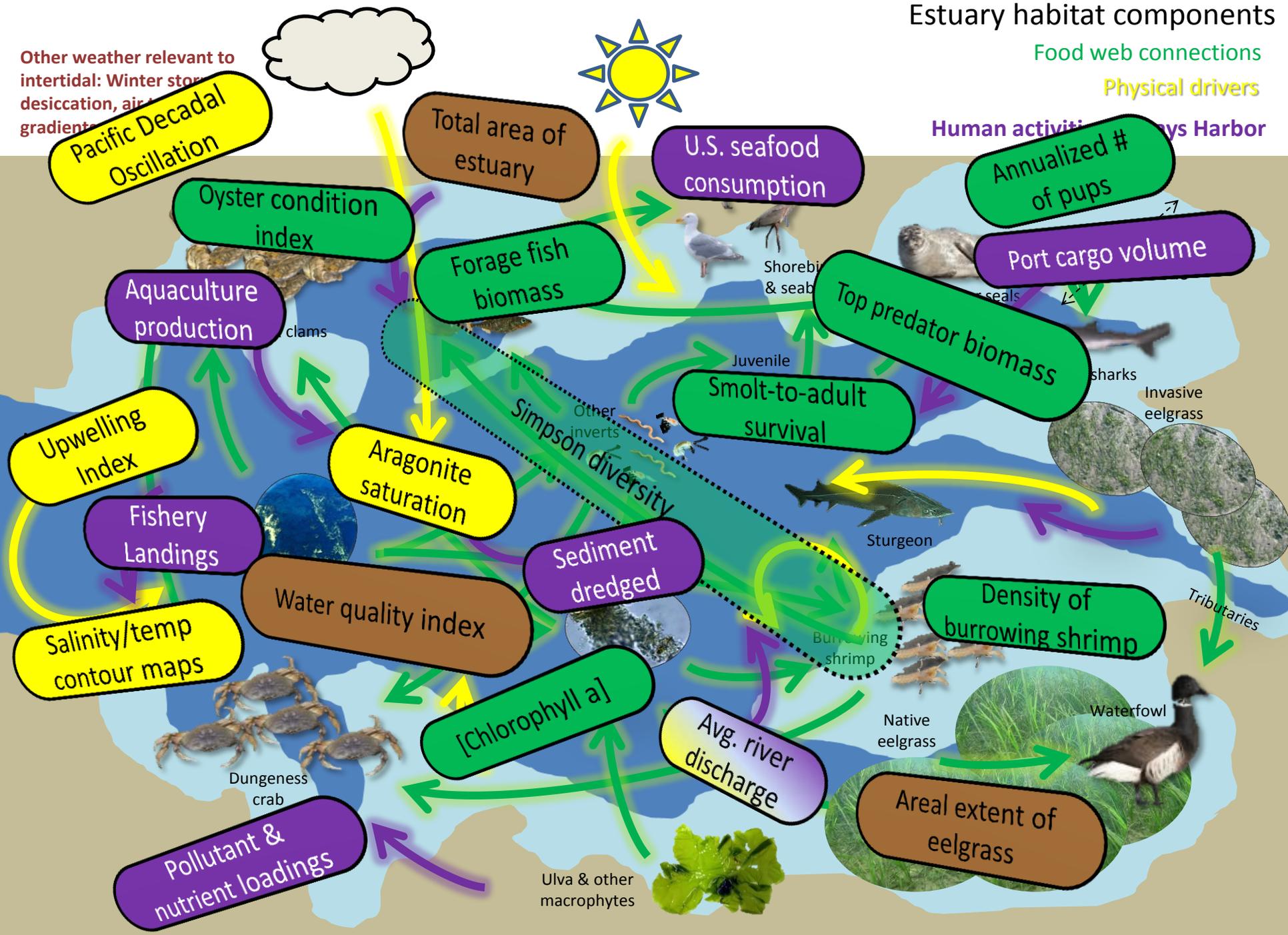
# Estuary habitat components

Food web connections

Physical drivers

Human activities

Other weather relevant to intertidal: Winter storms, desiccation, air temperature gradients



# Questions?

- What indicators are missing from these lists?
  - Ecological components?
  - Physical drivers?
  - Human activities?
- Do you know of data sources from Willapa or Grays Harbor that could be used to quantify any of these indicators?



# NEXT STEPS



- Complete evaluation of indicators: summer and fall 2014



# NEXT STEPS



- Complete evaluation of indicators: summer and fall 2014
- Perform survey of local experts to assign weightings to indicator evaluation criteria (link to survey will be at <http://msp.wa.gov/explore/msp-projects/ecosystem-indicators/>): summer 2014

# STEP 4: CRITERIA WEIGHTING



- Weight Evaluation Criteria – not all are equally important
- For California Current IEA we polled managers to get weightings
- For Puget Sound IEA, a mixed science-policy group generate weightings in a workshop setting

Understood by public and policy makers	Spatial and temporal variation understood	Broad spatial coverage
1	0.25	0.5

# NEXT STEPS

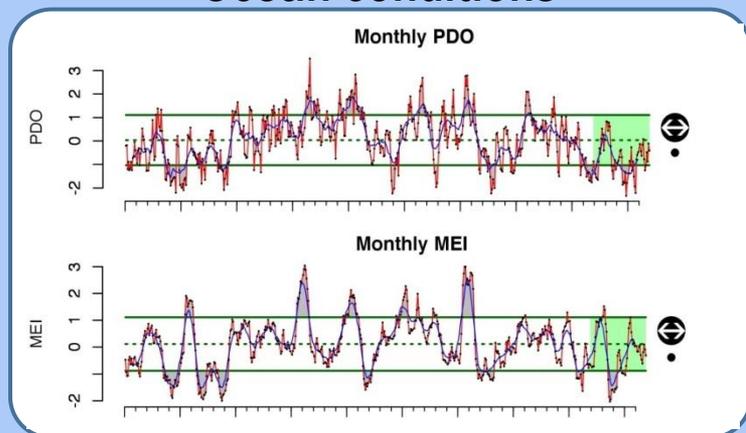


- Complete evaluation of indicators: summer and fall 2014
- Perform survey of local experts to assign weightings to indicator evaluation criteria (link to survey at <http://msp.wa.gov/explore/msp-projects/ecosystem-indicators/>): summer 2014
- Quantify status and trends of chosen indicators for final assessment: fall 2014 – June 2015

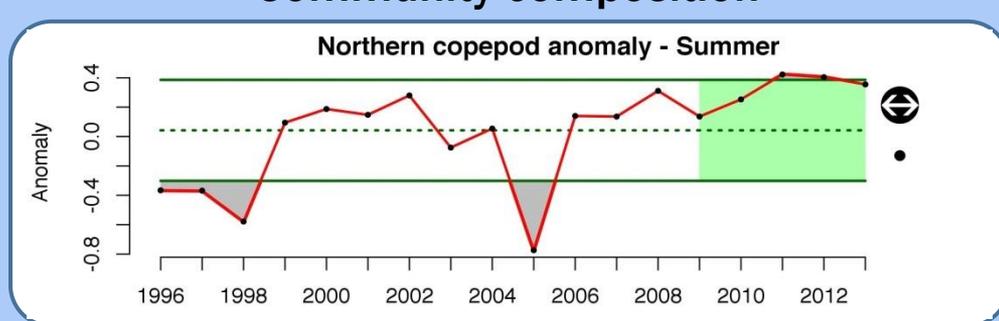
# STATUS AND TRENDS

(EXAMPLES FROM THE CCIEA: [WWW.NOAA.GOV/IEA](http://WWW.NOAA.GOV/IEA))

## Ocean conditions

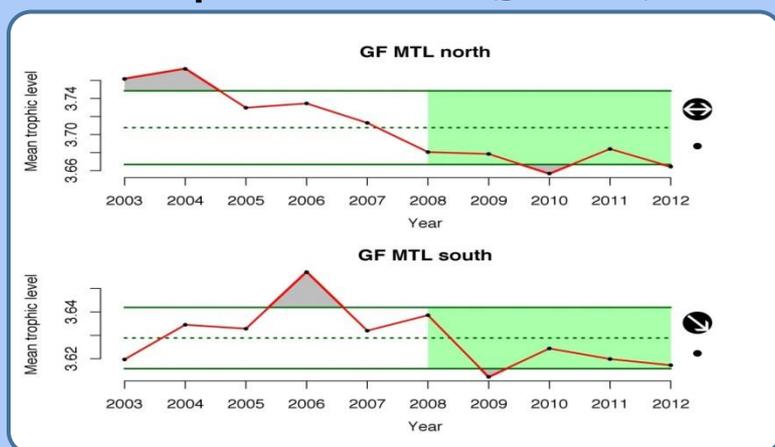


## Community composition

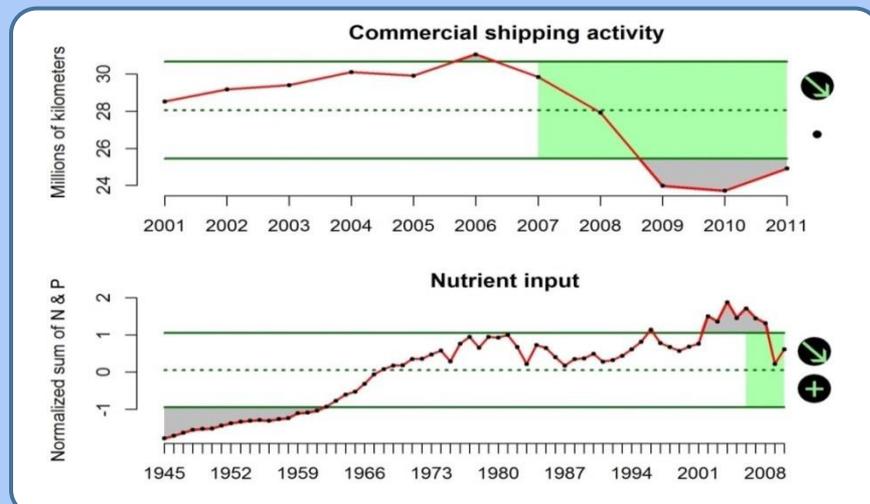


## Human activities

### Trophic structure (groundfish)



### Commercial shipping activity



# THANK YOU FOR YOUR PARTICIPATION!



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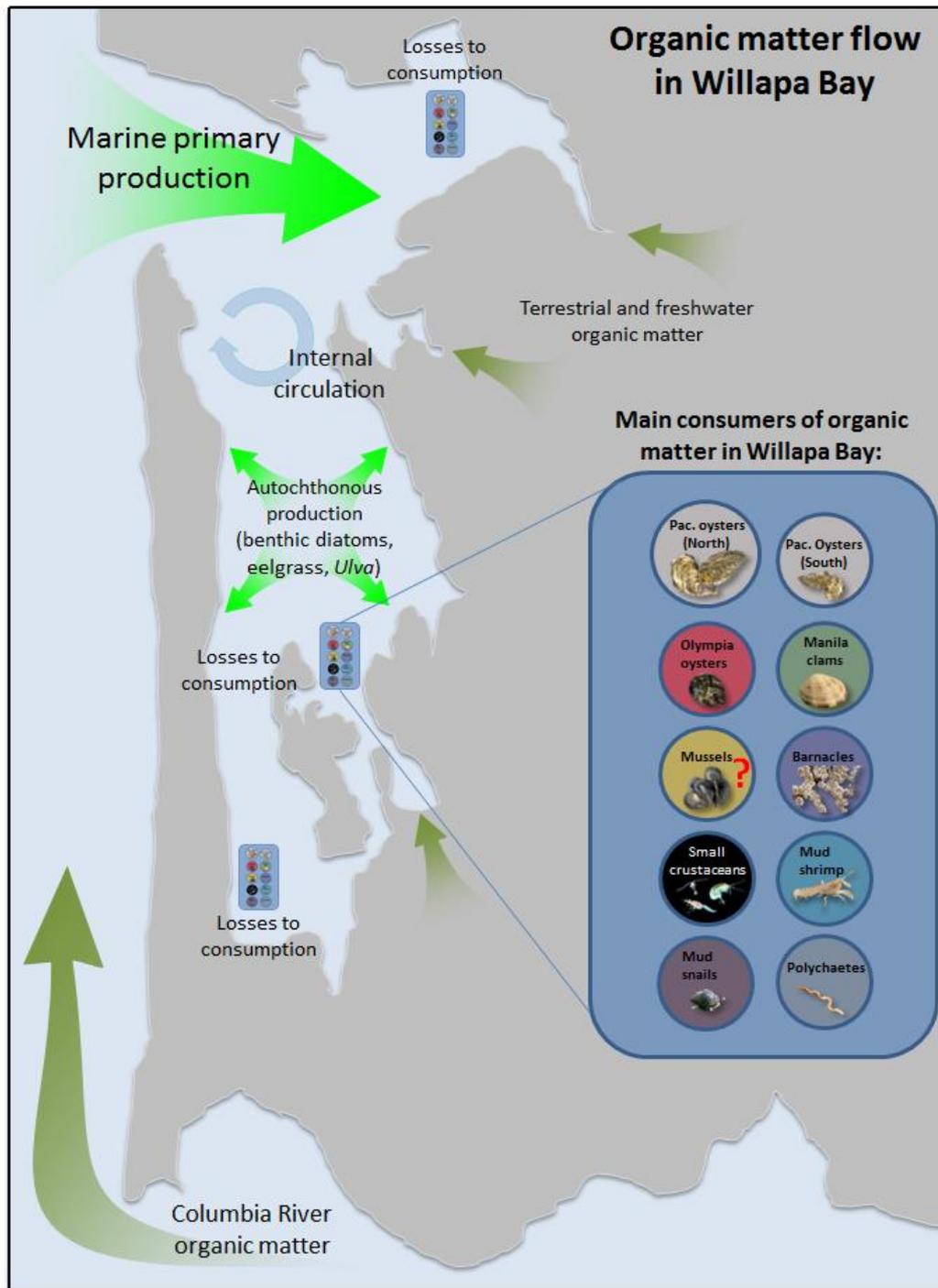
[www.noaa.gov/iea](http://www.noaa.gov/iea)



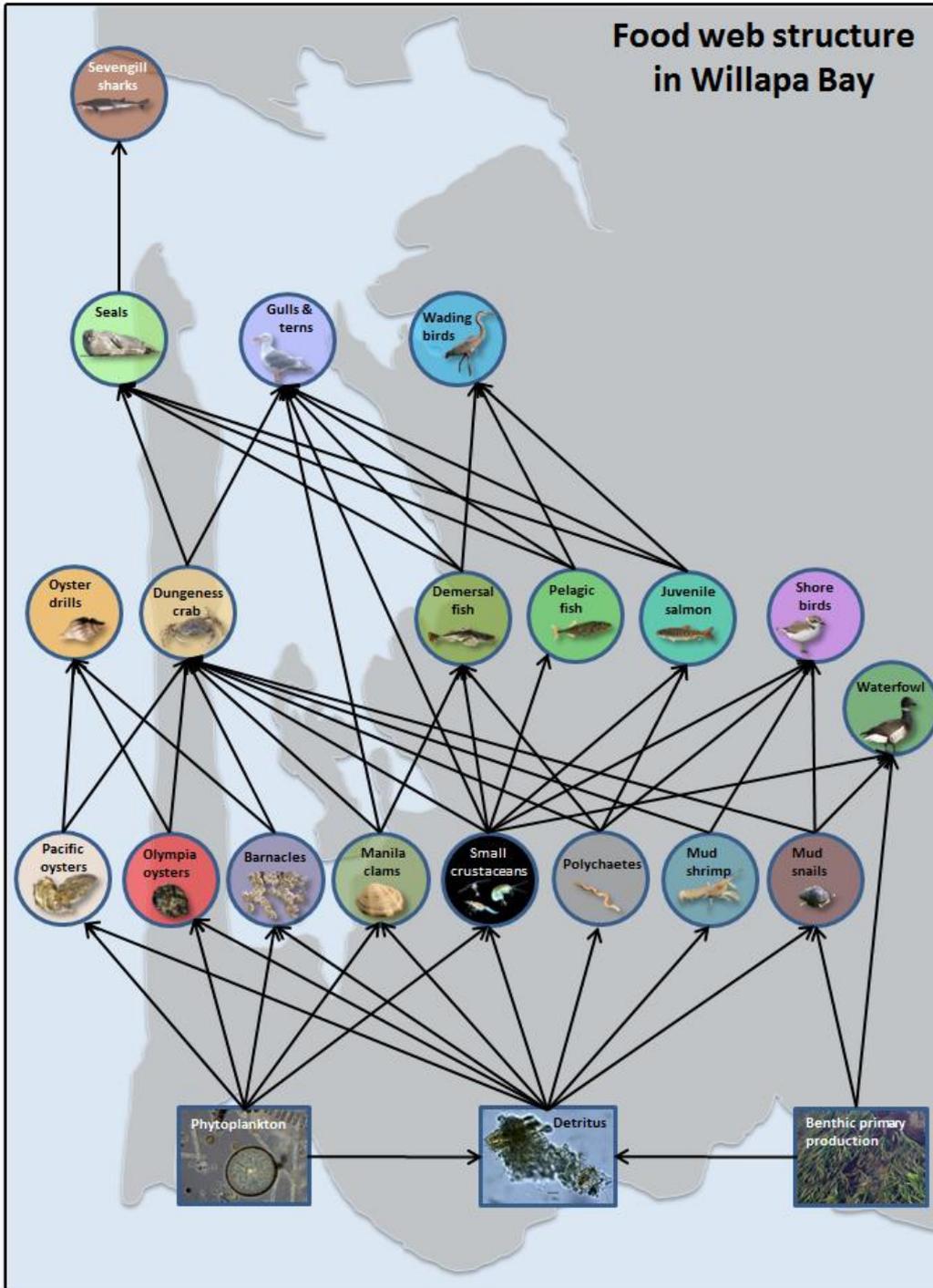
**WASHINGTON MARINE SPATIAL PLANNING**



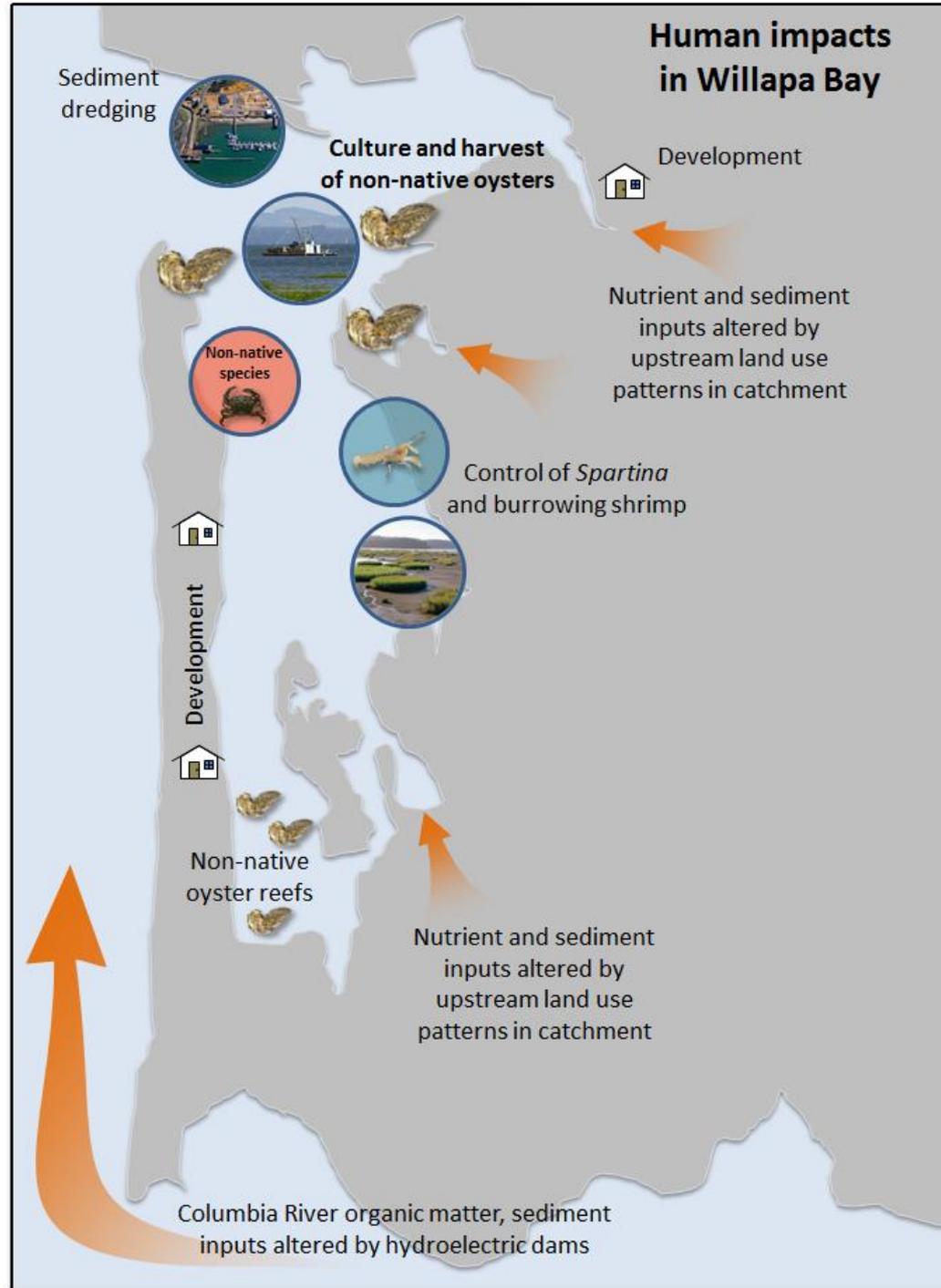
# Organic matter flow in Willapa Bay



# Food web structure in Willapa Bay



# Human impacts in Willapa Bay



# INDICATOR PORTFOLIO FOR THE CALIFORNIA CURRENT IEA - 2013



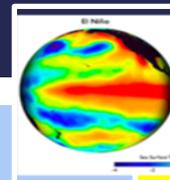
## Ecological Components

- **Ecological Integrity** - Mean trophic level, species diversity, scavenger biomass, Northern copepod biomass anomaly, gelatinous zooplankton biomass
- **Fisheries** -
  - **Salmon** - Age structure diversity, population growth rate, % natural spawners, spawning escapement;
  - **Groundfish** - # groups under management thresholds, age at length;
  - **Forage species** - Survey CPUE (biomass) by species, sardine age distribution
- **Protected species** -
  - **Seabirds** - At-sea abundance, annual reproductive performance, diet, mortality;
  - **Marine Mammals** – baleen and toothed whale survey abundance, CA sea lion pup annual count



## Human Activities

- **Fishery removals** – landings, total est. mortality
- **Habitat destruction** – distance trawled
- **Nutrient input** – land-based N and P fertilizer input
- **Invasive species** – tons shipping cargo
- **Coastal engineering** – human coastal population
- **Light pollution** – ave. nighttime visible light
- **Sediment input** – impoundment area



## Climate and Ocean Drivers

- **Timing/frequency of ENSO events** – MEI, NOI
- **Temperature change** – PDO, sea surface buoy temperatures
- **Sea level rise** – coastal sea level
- **Ocean acidification** – DO
- **Water column structure** – pycnocline depth
- **Timing and strength of upwelling** – winds, UI, STI