Developing a BC Provincial Assessment of Coastal Cutthroat Trout Using a Cumulative Effects and Semi-Quantitative Risk Assessment Framework

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Coastal Cutthroat Trout in BC

- Distributed along the province's coastline, up to 200 km inland
- Experiencing population declines and range contractions

- "Blue-listed' (vulnerable) in 1999 → no legal protections
- Last draft assessment was Costello & Rubidge 2005 → never finalized, never received federal review

- Risk assessment initiated by Coastal Cutthroat Working Group
- Intended to be the lead-up to a provincial management plan
- Funded by Habitat Conservation Trust Fund - in Year 2 of 3

Risk Assessments Through the Lens of Cumulative Effects

- Combined effects of multiple stressors (natural and anthropogenic)

1) Effects of multiple stressors simultaneously

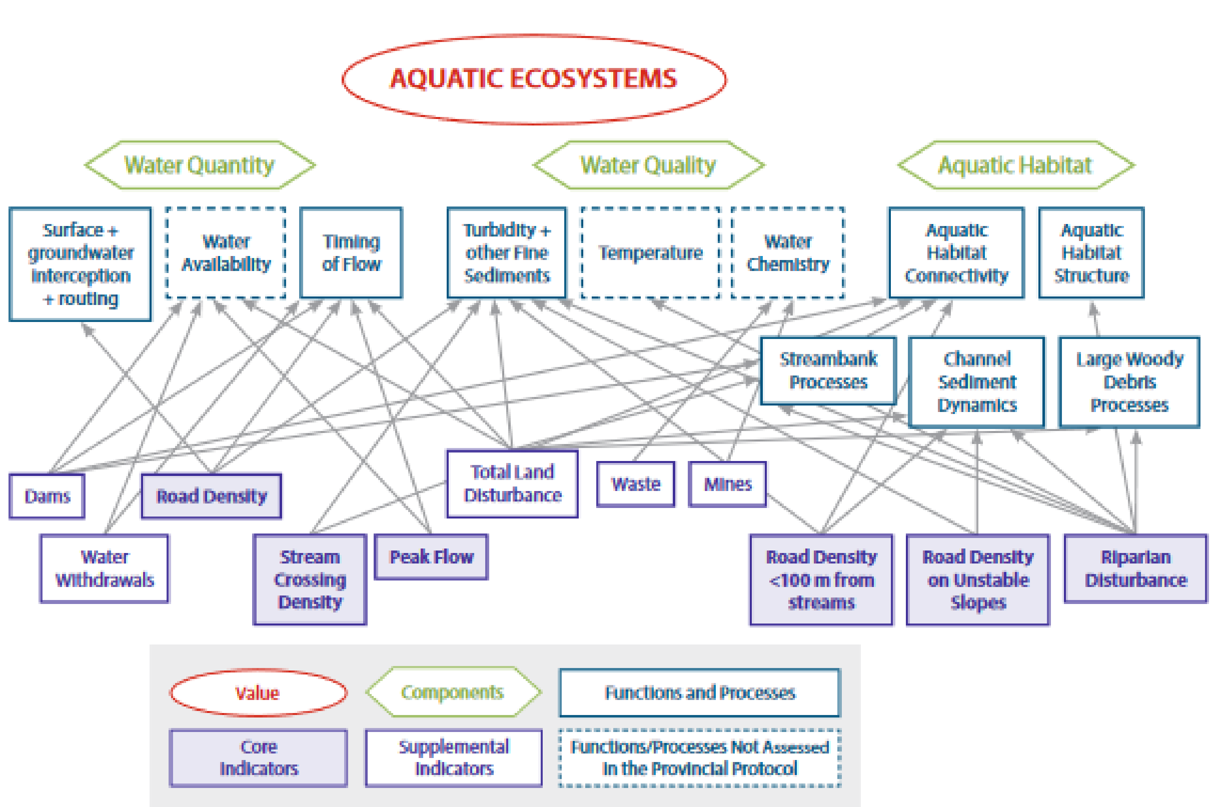
2) Accumulation of stressors spatially and temporally

Cumulative Effects Assessments

Cumulative Effects Assessments

Narrative Descriptions

- Data-deficient species
- Makes prediction and management difficult



Qualitative

Quantitative

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Qualitative

Barkley Sockeye Risk Assessment

1. Great Central Sockeye CU			
DESCRIPTION OF FACTOR		BIOLOGICAL RISK calculated for each factor limiting productive capacity	
Life History Requirement	Issue/Limiting factor & id number	Current Biol Risk category	Future Biol Risk category
A. Terminal Migration & Spawning			
2. Large volume of preferred water (VOPW, low temp, high O2) in estuary	LF2: Significant reductions of VOPW in inlet & estuary with chronic to impacts on adult "fitness".	Moderate	High
4. Favorable temperatures for low stress passage	LF4: High temps slow or stop upstream migration	Moderate	Very High
11b. Spawning habitat quantity sufficient to fully "seed" fry rearing habitat. TRIB SPAWNERS ONLY	LF12B: Inadequate TRIB spawning habitat (i.e. CU production potential limited by initial fry recruitment).	Moderate	Moderate

2. Sproat Sockeye CU			
DESCRIPTION OF FACTOR		BIOLOGICAL RISK calculated for each factor limiting productive capacity	
Life History Requirement	Issue/Limiting factor & id number	Current Biol Risk category	Future Biol Risk category
A. Terminal Migration & Spawning			
2. Large volume of preferred water (VOPW, low temp, high O2) in estuary	LF2: Significant reductions of VOPW in inlet & estuary with chronic to impacts on adult "fitness".	Moderate	High
4. Favorable temperatures for low stress passage	LF4: High temps slow or stop upstream migration	Moderate	Very High
11b. Spawning habitat quantity sufficient to fully "seed" fry rearing habitat. TRIB SPAWNERS ONLY	LF12B: Inadequate TRIB spawning habitat (i.e. CU production potential limited by initial fry recruitment).	Moderate	Moderate

3. Henderson Sockeye CU			
DESCRIPTION OF FACTOR		BIOLOGICAL RISK calculated for each factor limiting productive capacity	
Life History Requirement	Issue/Limiting factor & id number	Current Biol Risk category	Future Biol Risk Category
A. Terminal Migration & Spawning			
9. Stable channel banks and stable coarse bedload transport	LF10: Riparian disturbance resulting in bank erosion, increased bedload.	Very High	Very High
11b. Spawning habitat quantity sufficient to fully "seed" fry rearing habitat. TRIB SPAWNERS ONLY	LF12B: Inadequate TRIB spawning habitat (i.e. CU production potential limited by initial fry recruitment).	High	Very High
11. Spawning habitat quantity sufficient to fully "seed" fry rearing habitat. BEACH SPAWNERS ONLY	LF12: Inadequate BEACH spawning habitat (i.e. CU production potential limited by initial fry recruitment).	Moderate	High

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Stress-Response Models

- Threat directly linked to biological effect
- Data-rich or data deficient species

Qualitative ⟷ Quantitative

Cumulative Effects Assessments

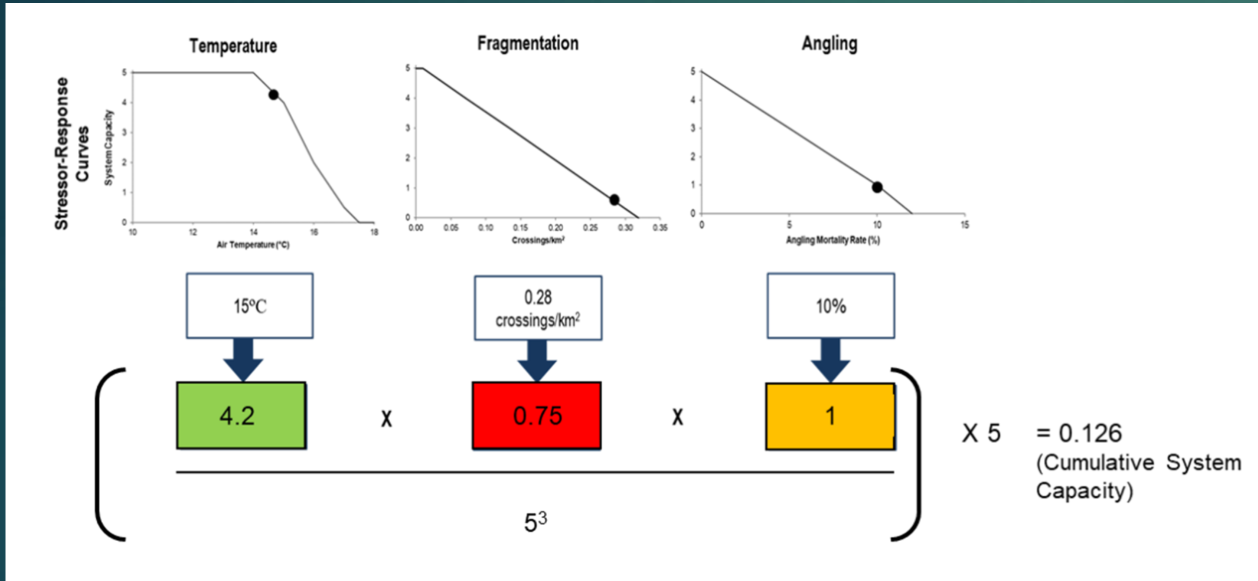

Figure 2. Illustration of the multiplicative effect of three hypothetical stressor-response curves on predicted total system capacity. 0.126 means a Very Low current adult density (see Table 2). Figure adapted from Reilly and Johnson (pers. comm.).

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Population Models

- Data-rich species
- System or population-specific

Qualitative ↔ Quantitative

Cumulative Effects Assessments

All H Analyzer (AHA)

Program Background

Go To Dashboard

Enter values in yellow cells only. Green cells contain formulas (do not edit). Orange cells contain dropdown menus (click on cell & select from the options).

Subbasin	*Population*	*Species*
Yakima	Yakima	Coho

Population Designation	*Current Phase*
Stabilizing	Recolonization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Conservation Priorities:	Prevent extinction, preserve genetic diversity, restore habitat.	Restore and populate habitat.	Increase population fitness	Maintain viability	NA
Recovery Phase:	Current	Phase 2	Phase 3	Phase 4	Segregated Hatchery

Program Goals

Program Goals		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Program Goals	Natural Origin Escapement (NOS)					
	Effective pHOS <				30%	
	pNOB >	5%	5%	30%	100%	
	PNI >				0.67	
	Total Harvest					
	Terminal Harvest					

Key Assumptions

See Habitat tab for assistance with calculating Adult and Smolt Productivity and Capacity (using the Habitat tab is

Go To Habitat tab

				Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
Habitat		Adult Productivity	Adult Capacity	1.52	3,185	1.52	3,185	1.52	3,185	2.59	5,446		
		Smolt Productivity	Smolt Capacity	43	89,972	43	89,972	43	89,972	73	153,842		
		Adj. Productivity	Adj. Capacity	2.43	5,101	2.43	5,101	2.43	5,101	4.15	8,723		
		Fecundity - NORs	% Females	1,500	50%	1,500	50%	1,500	50%	1,500	50%	1,500	50%
Hydro and Ocean		Ocean Survival	Basin-to-Basin SAR - obs	5.13%	3.54%	5.13%	3.54%	5.13%	3.54%	5.13%	3.54%	5.13%	3.54%
		Juv. Fish Passage Surviva	asin-to-Basin SAR - baseline	75.0%	2.21%	75.0%	2.21%	75.0%	2.21%	75.0%	2.21%	75.0%	3.54%
		Ad. Fish Passage Survival	Vary SAR?	92.0%	None	92.0%	None	92.0%	None	92.0%	None	92.0%	None
			Coeff. of Variation SAR		100%		100%		100%		100%		100%
Harvest	Ocean	NORs	HORs	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%		30.0%
	Lower Columbia R.	NORs	HORs	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%		24.0%
	Upper Columbia R.	NORs	HORs	35.0%	35.0%	35.0%	35.0%	20.0%	20.0%	35.0%	35.0%		35.0%
	Terminal	NORs	HORs	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%		1.0%
	Total Exploitation Rate	NORs	HORs	46.7%	46.7%	46.7%	46.7%	34.4%	34.4%	46.7%	46.7%	0.0%	65.8%
Hatchery	In-Hatchery	Pre-spawning Survival	% Females	98%	50%	98%	50%	98%	50%	98%	50%	98%	50%
		Fecundity - HORs		2,322		2,322		2,322		2,322		2,322	
		Egg to Smolt Survival	Egg to Sub Survival	74%	77%	74%	77%	74%	77%	74%	77%	74%	77%
		SAR (yearling)	SAR (subyearling)	0.75%	0.48%	0.75%	0.48%	0.75%	0.48%	0.75%	0.48%	1.47%	0.00%

See SAR tab for more options to incorporate variation into the

Go To SAR tab

See Harvest Rate calculators below to convert exploitation rates to harvest rates and account for selective

Go To Harvest Rate calculators

Population Models

- Data-rich species
- System or population-specific

Qualitative ⟷ Quantitative

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20 years +

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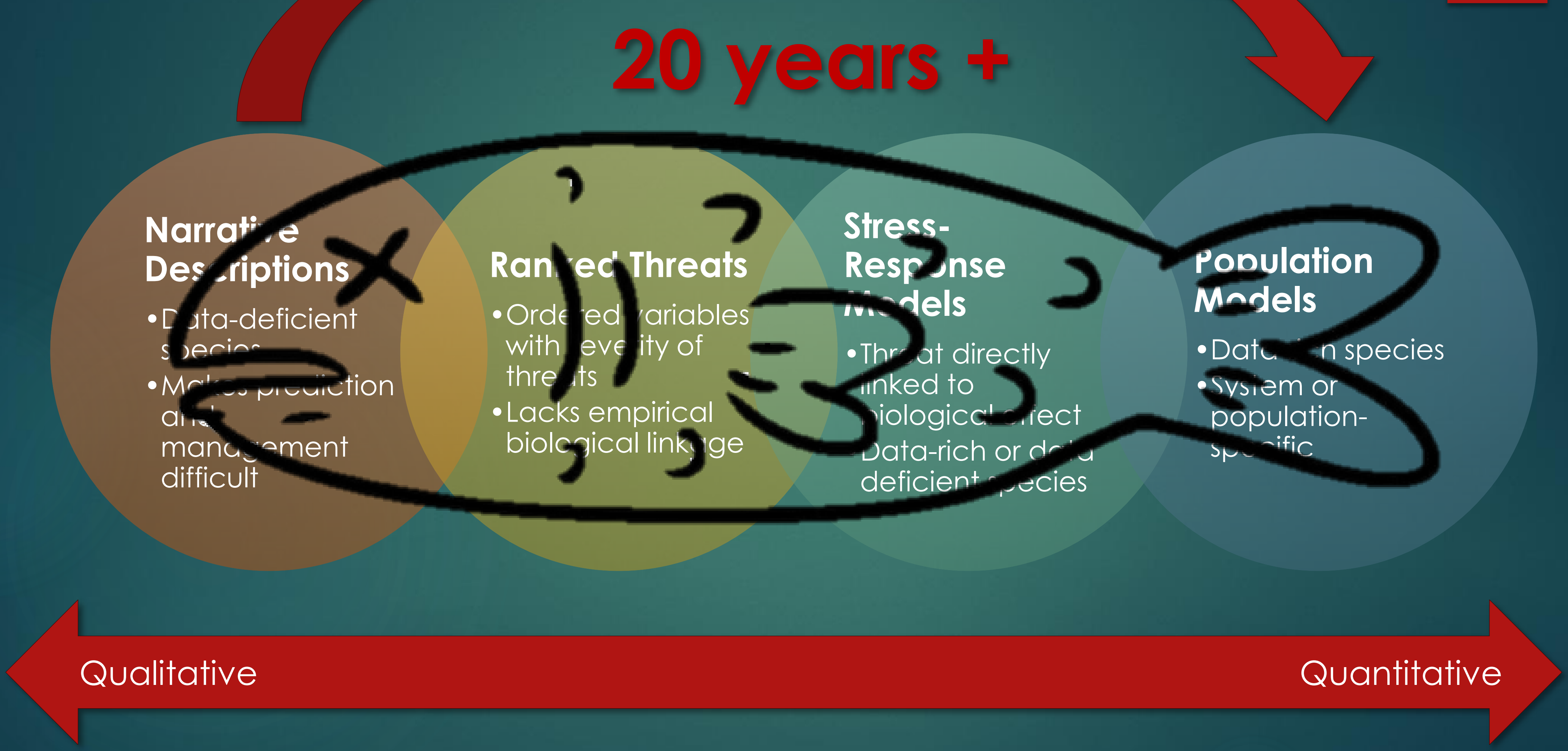

Cumulative Effects Assessments

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Stressor-Response Models

- Identify stressors
- Define stress-response curves based on empirical data
- Build a model that combines the functions

Application of Stress-Response Models

- Westslope Cutthroat Trout in Alberta
- Athabasca Rainbow Trout in Alberta
- Bull Trout in Alberta
- Plains Sucker in Saskatchewan
- Chinook Salmon in Nicola River, BC
- *(initiated)* Bull Trout in Williston Reservoir, BC
- *(initiated)* Arctic Grayling in Alberta
- *(proposed)* Nooksack Dace & Salish Sucker in BC

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ARTICLE

Prioritizing bull trout recovery actions using a novel cumulative effects modelling framework

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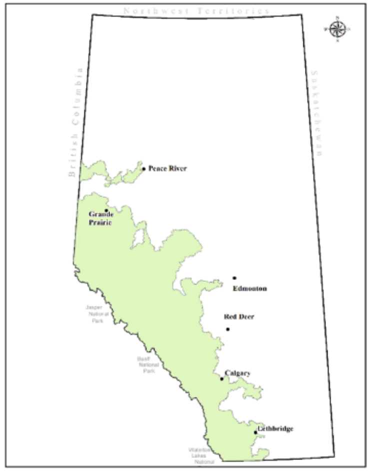
Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans
Central and Arctic Region
Canadian Science Advisory Secretariat
Science Advisory Report 2019/045

REVIEW OF ALBERTA ENVIRONMENT AND PARKS CUMULATIVE EFFECTS ASSESSMENT JOE MODEL



Stressors

- Stressor: **environmental driver** resulting in an observable **biological response** in a target population

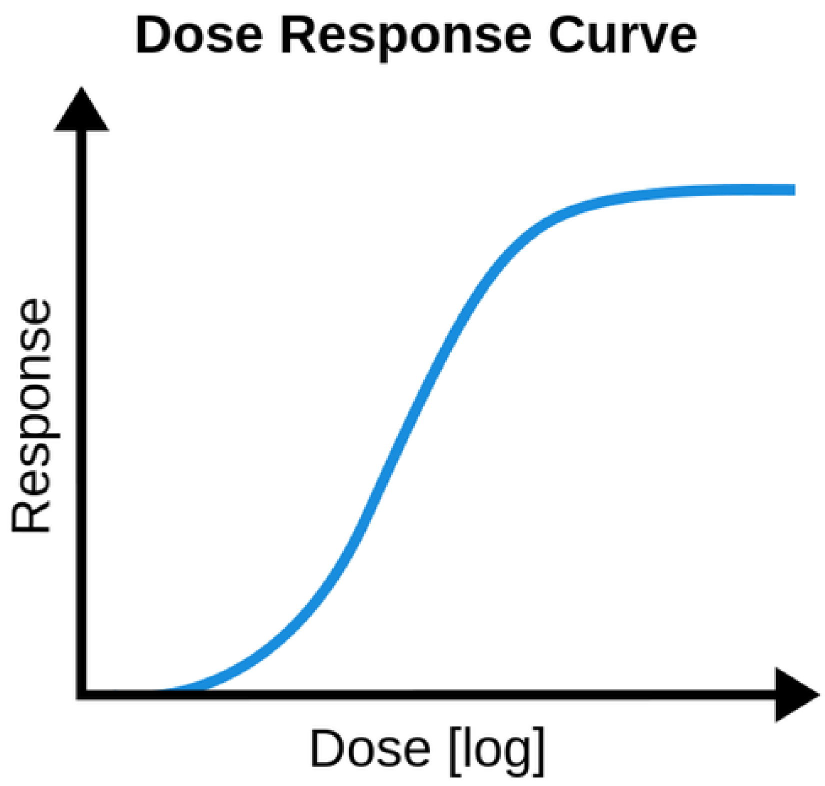
(Pirotta et al. 2022, Rosenfeld et al. 2022, Jarvis et al. 2023)

- Includes both natural & anthropogenic factors

Response

- Standardized response metric
- Population-level productivity, **system capacity**, density or total abundance of the adult population
- Specific **vital rates**
  - fecundity, spawning interval, stage-specific survival, age-at-maturity

Stressor-Response Functions



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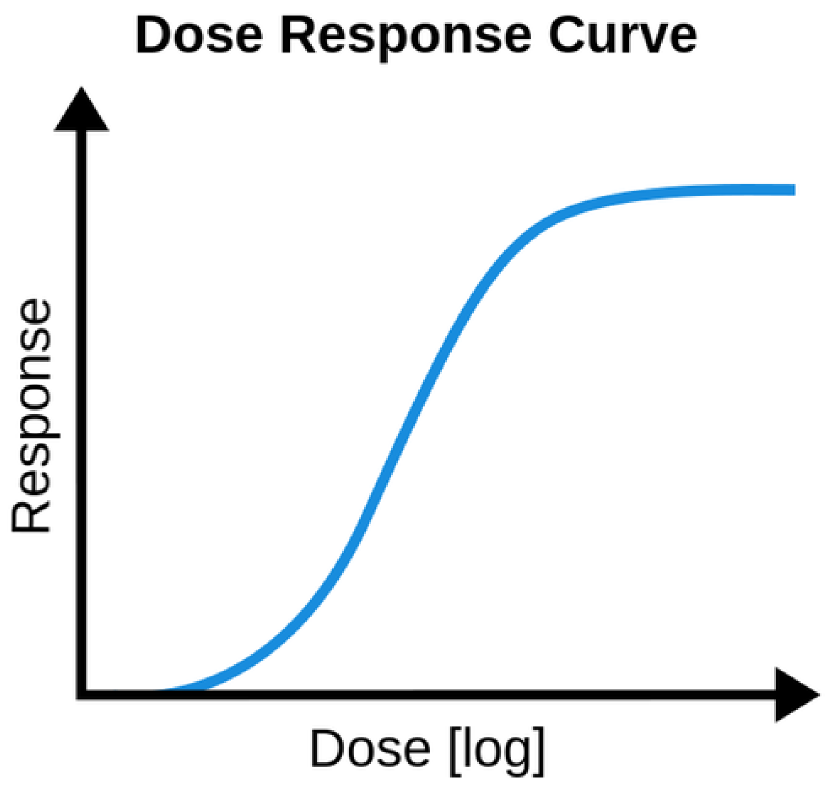

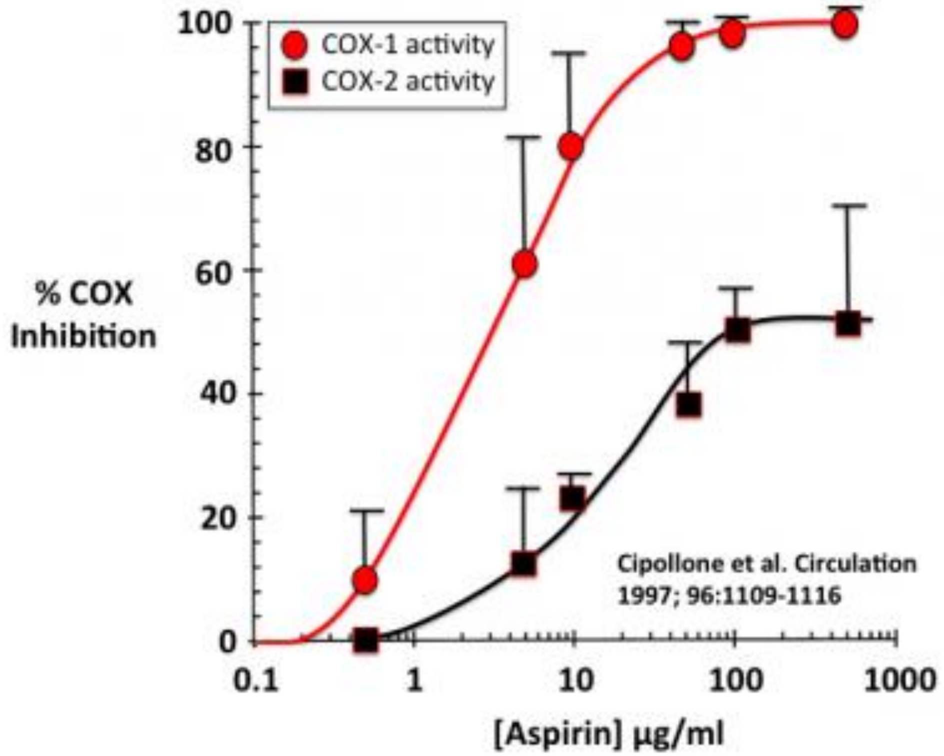

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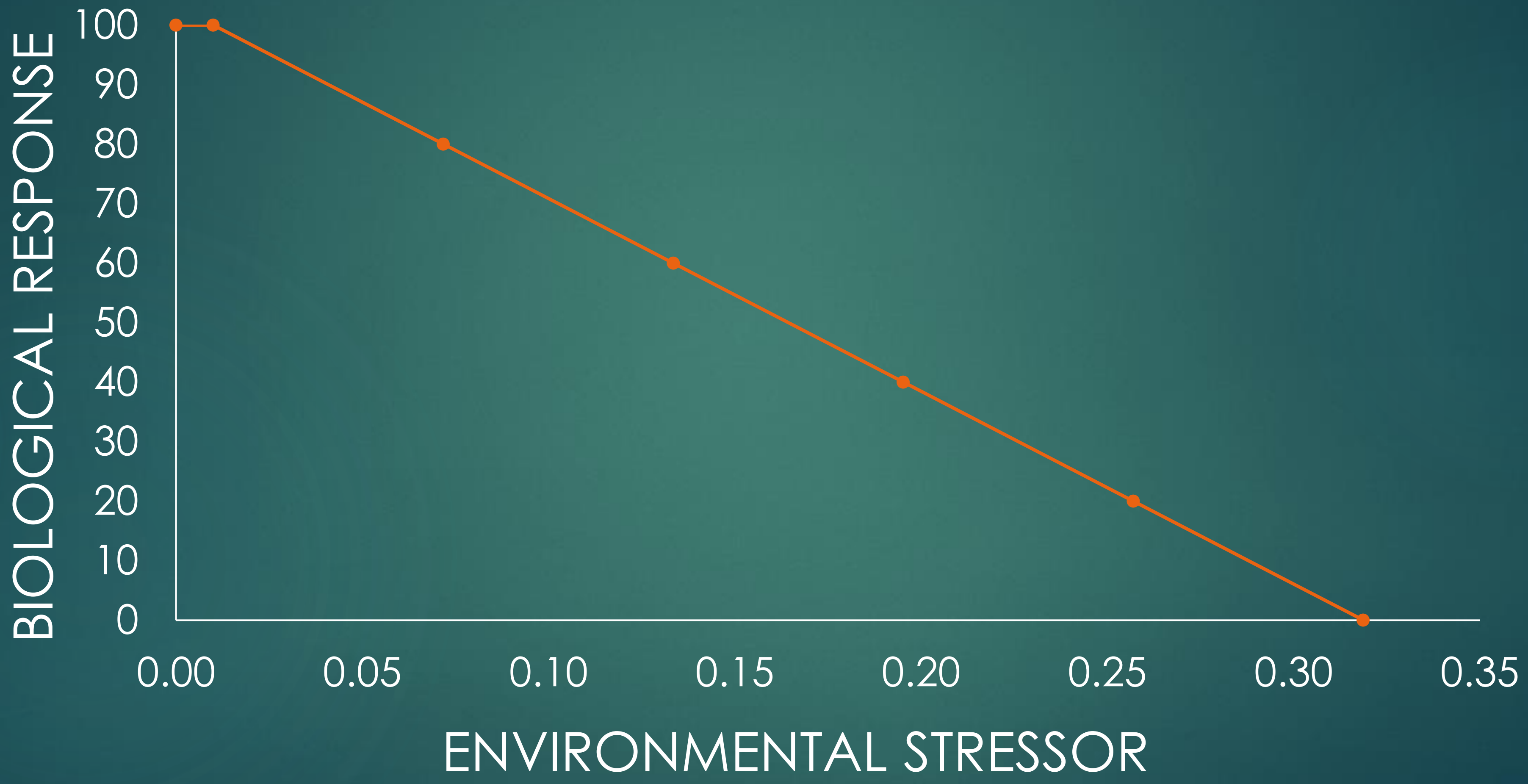

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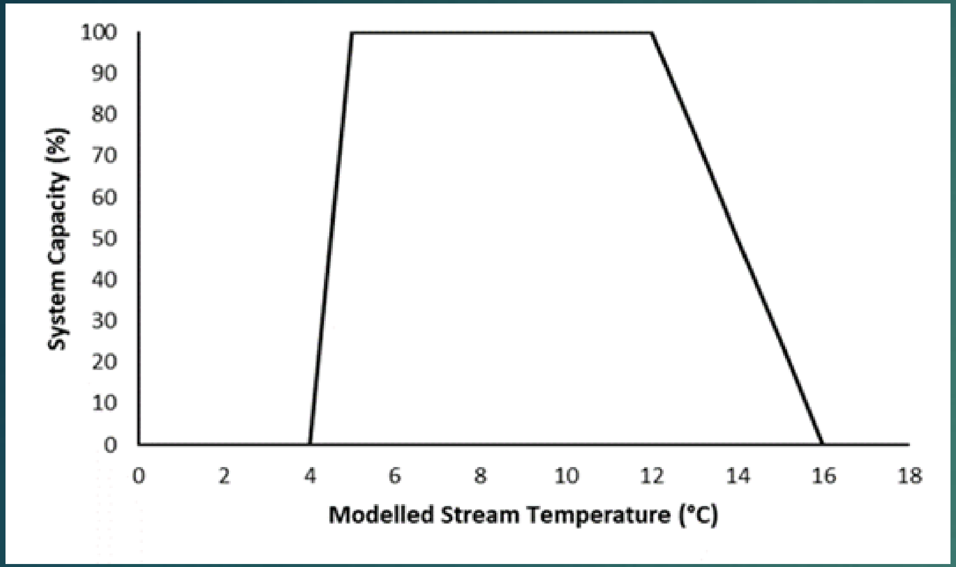

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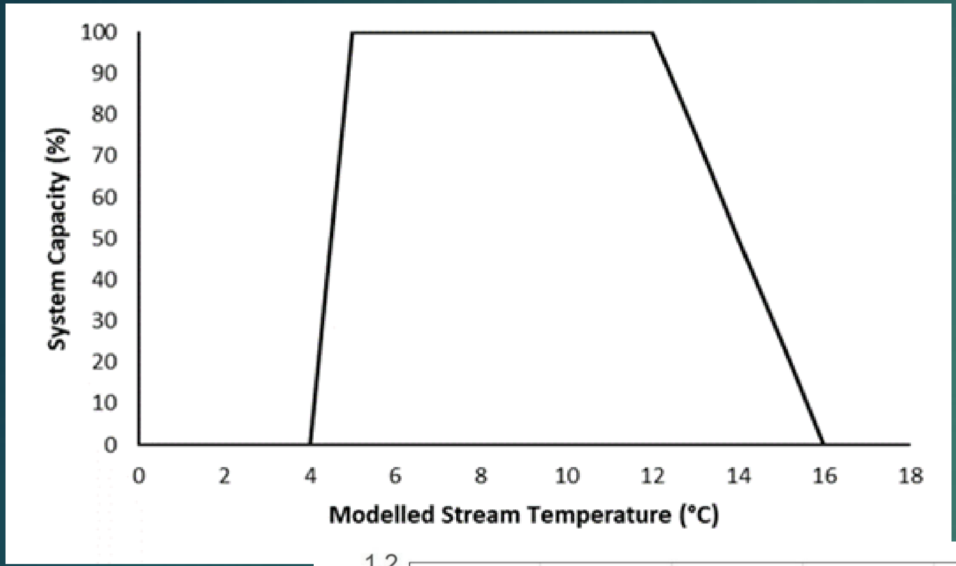

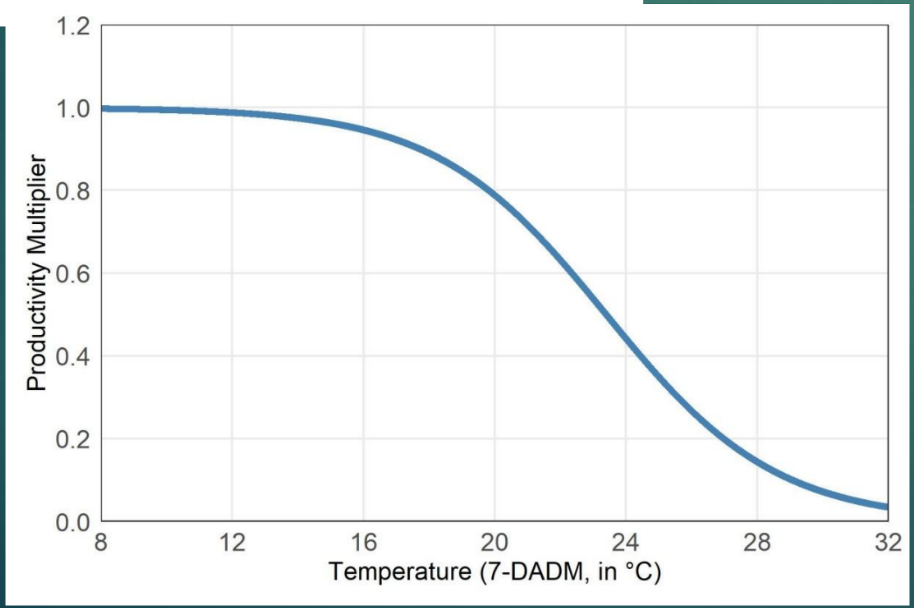

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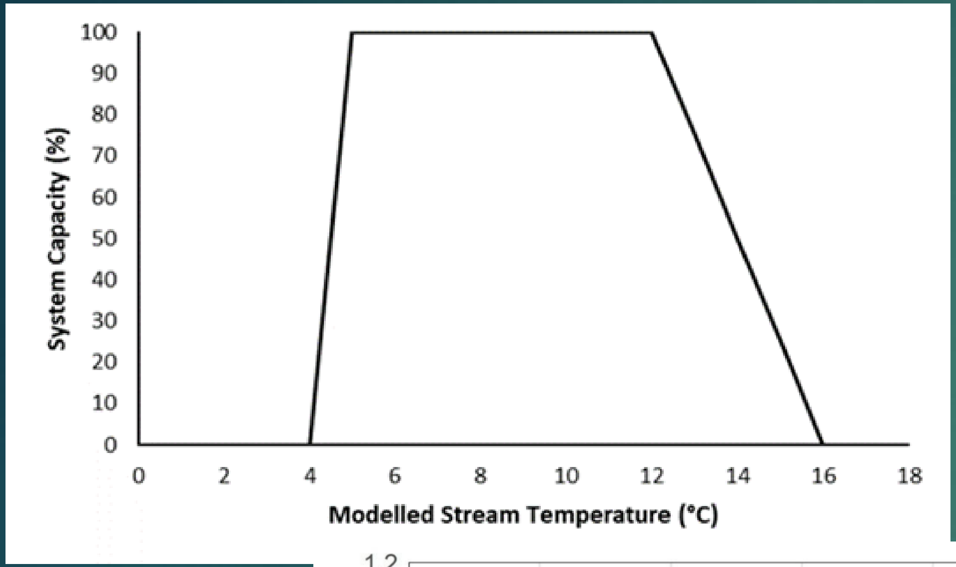

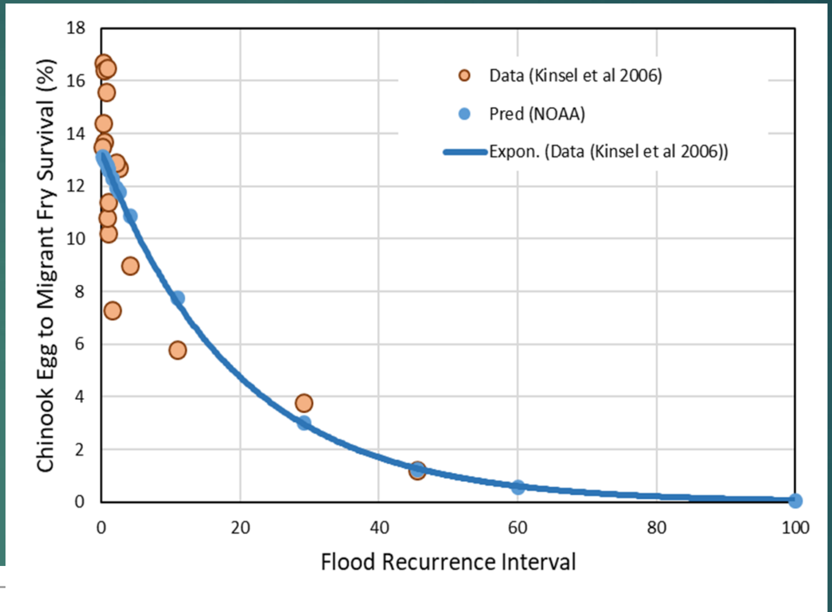

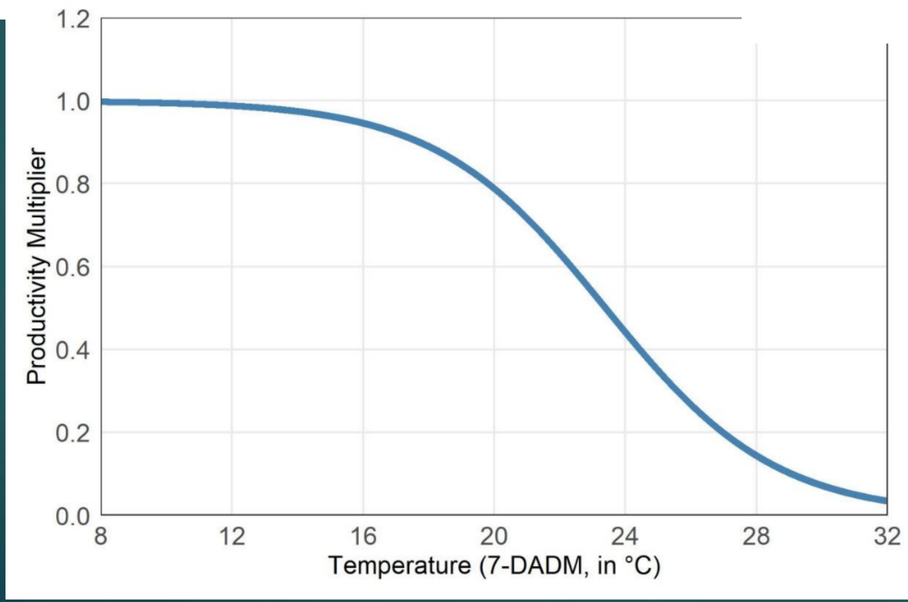

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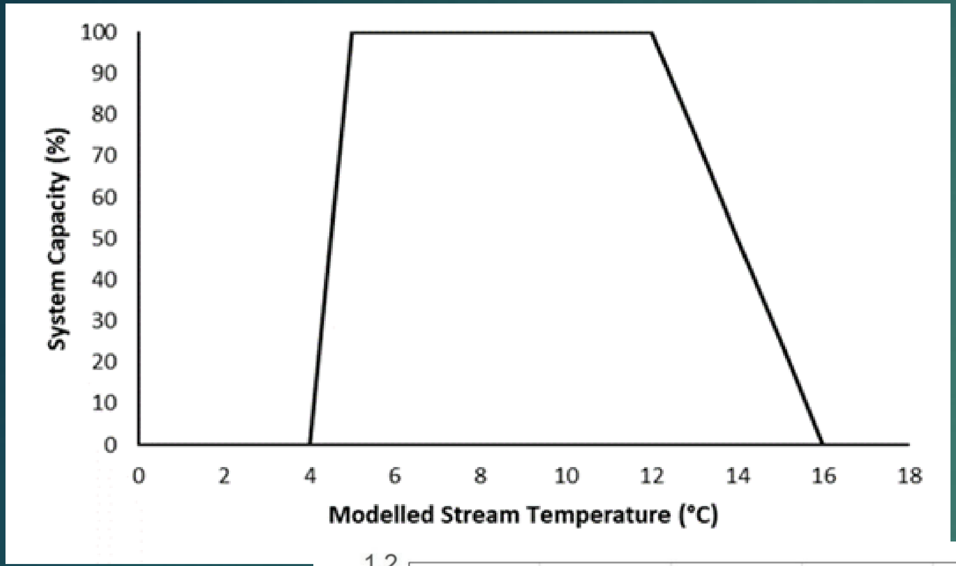

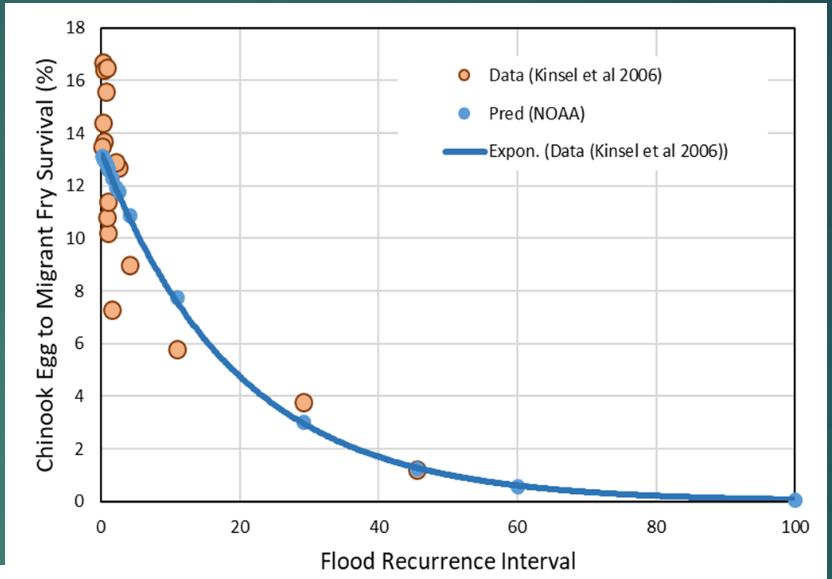

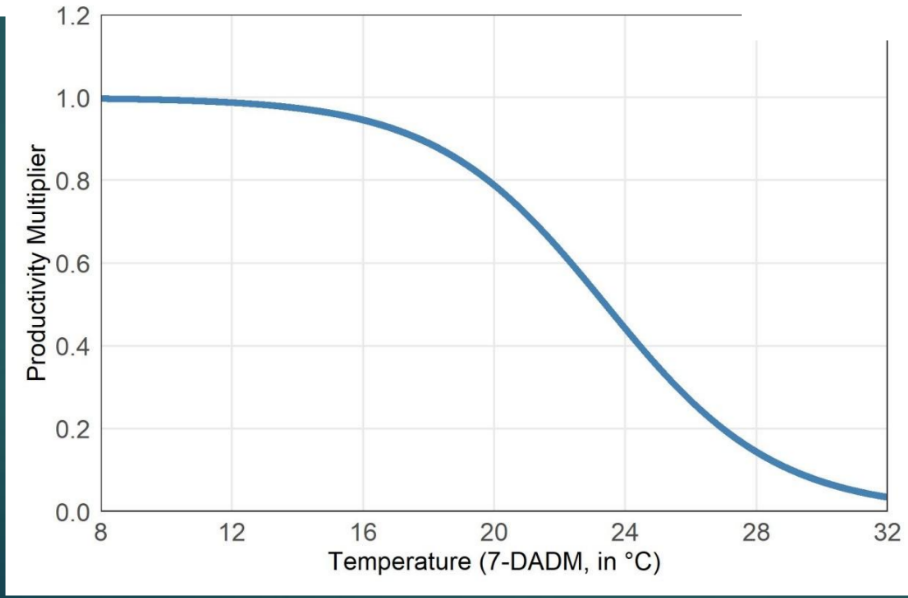

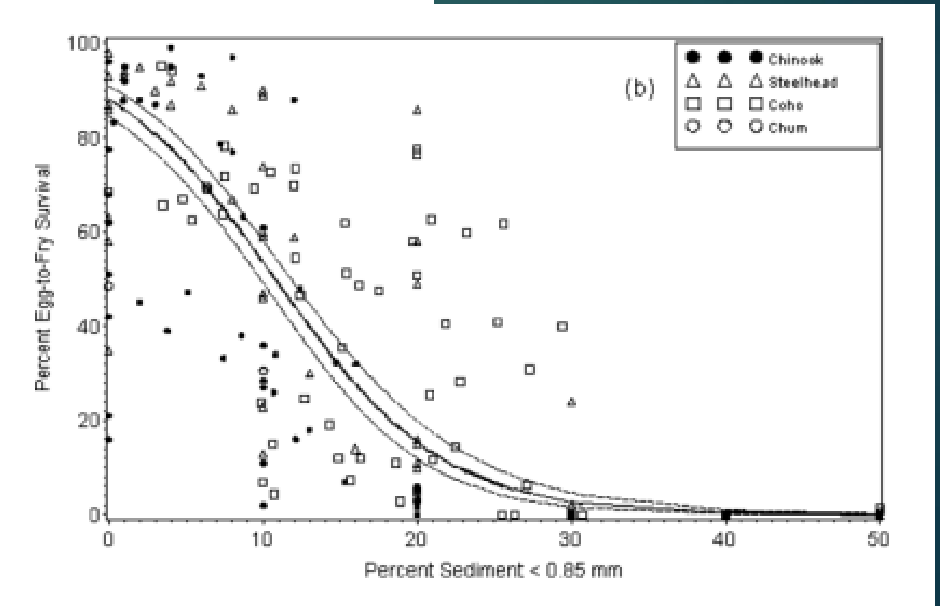

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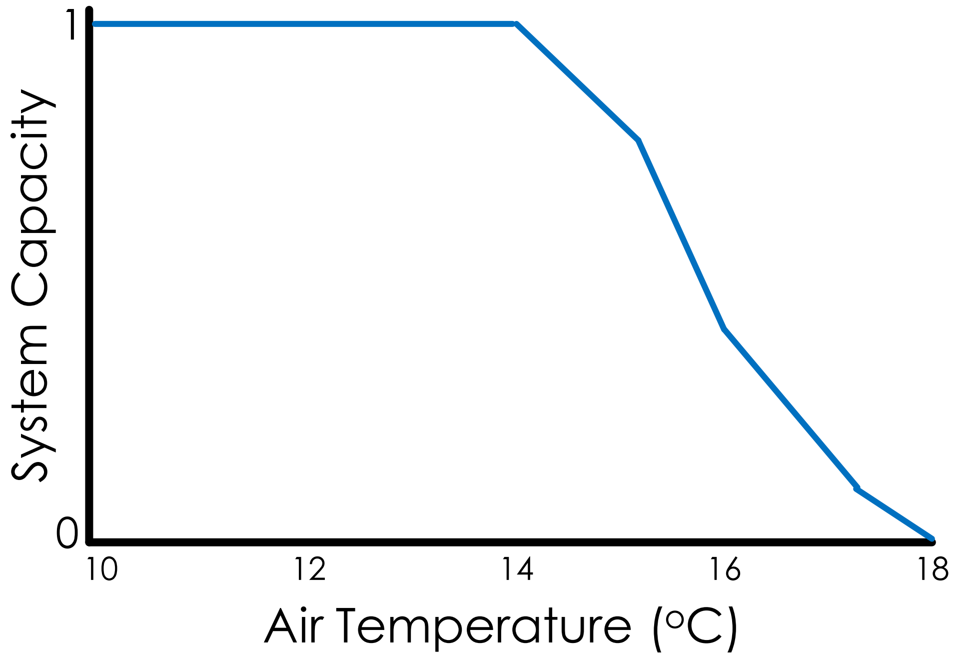

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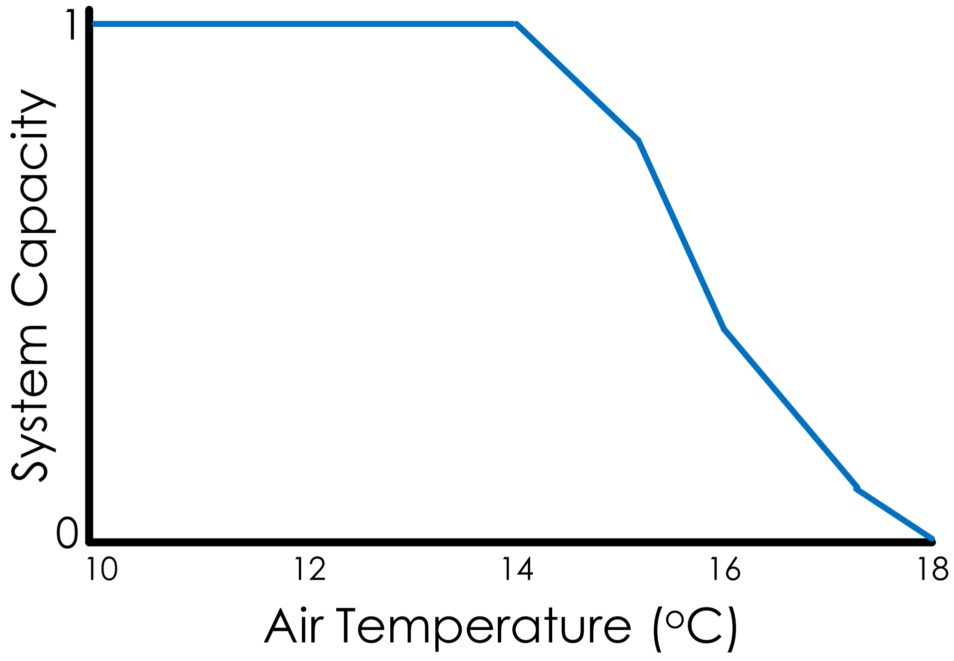

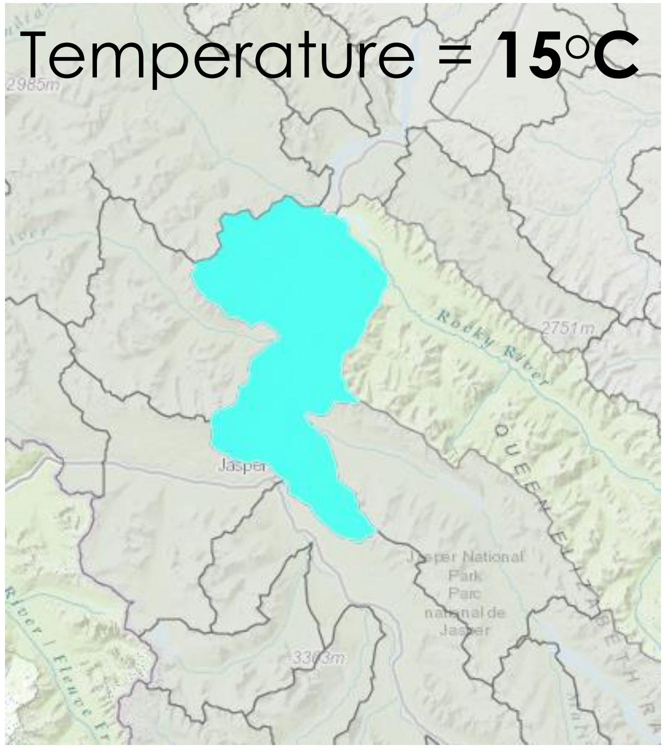

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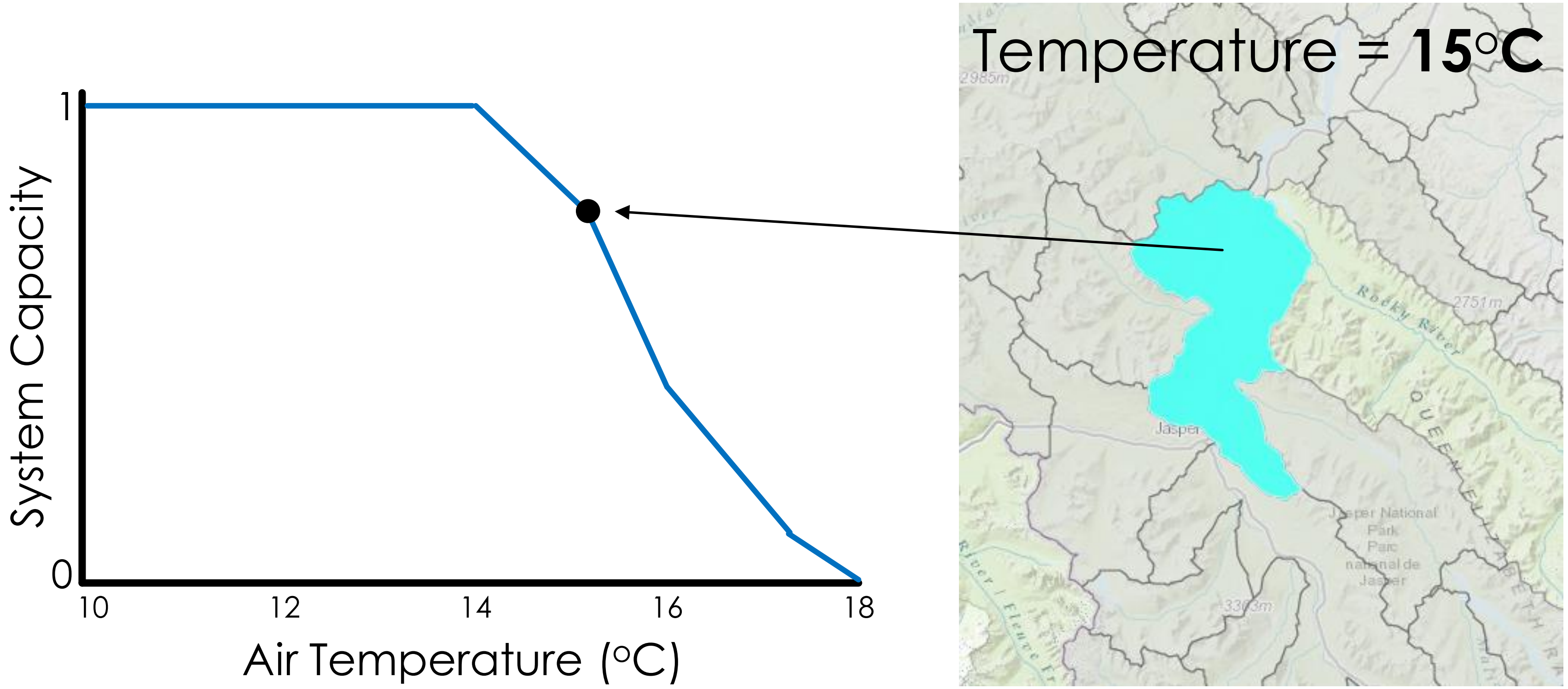
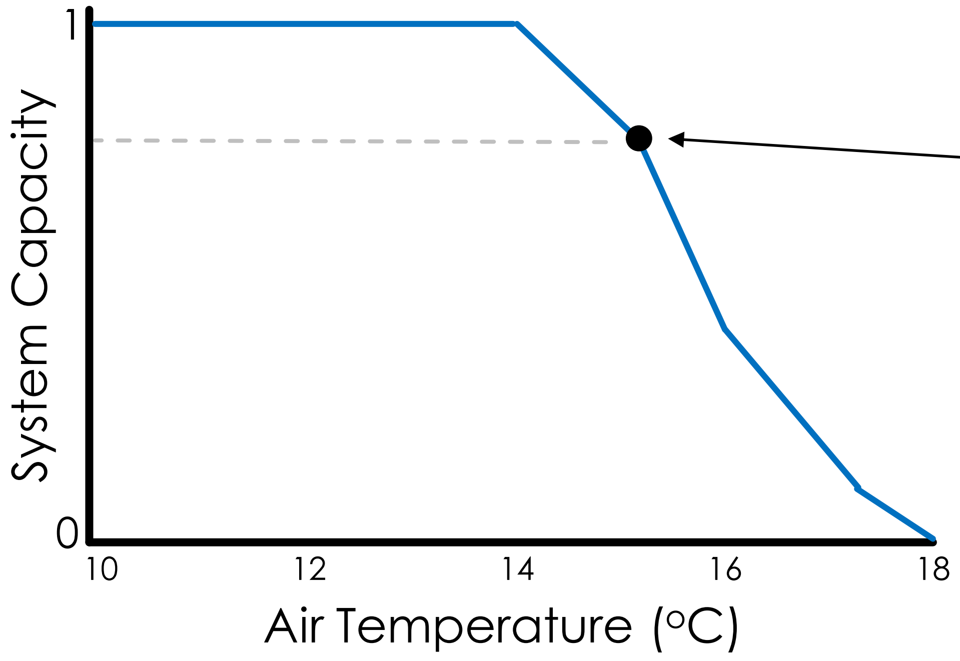
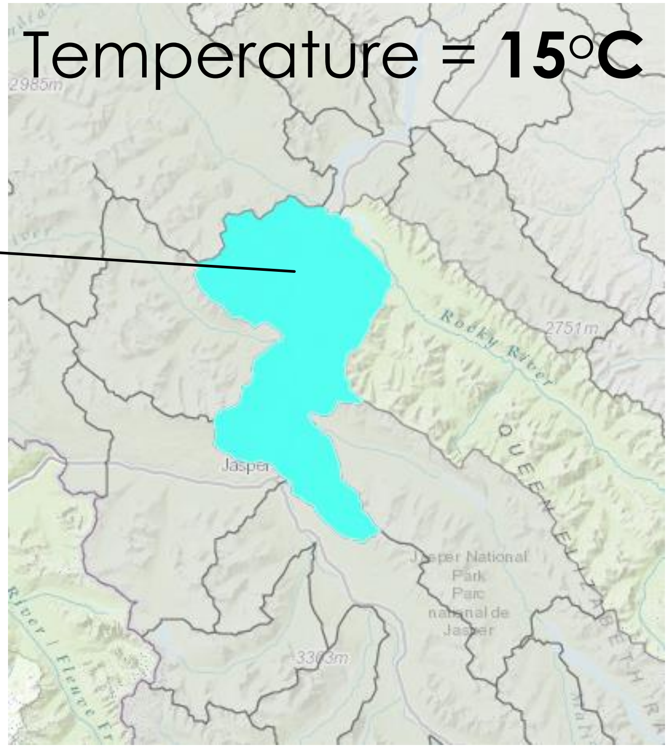


Stressor-Response Functions

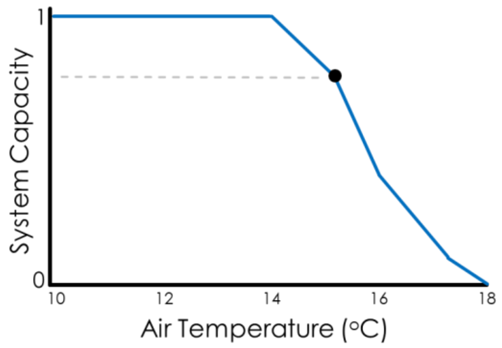
System Capacity = **0.81**





Stressor-Response Functions

Temperature



Stressor-Response Functions

Stress-
Response
Functions

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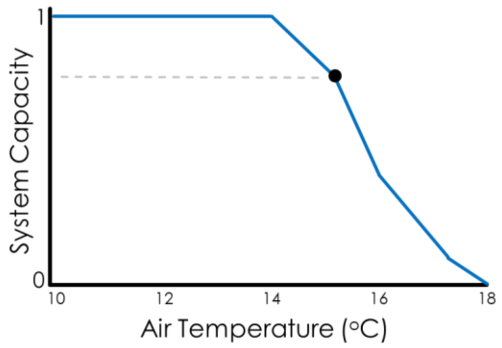
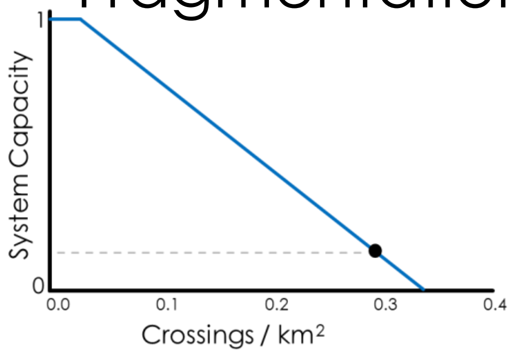
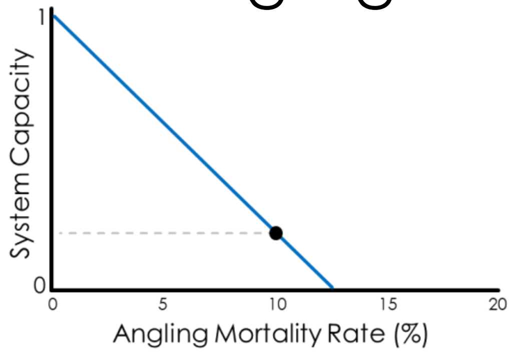


Fragmentation



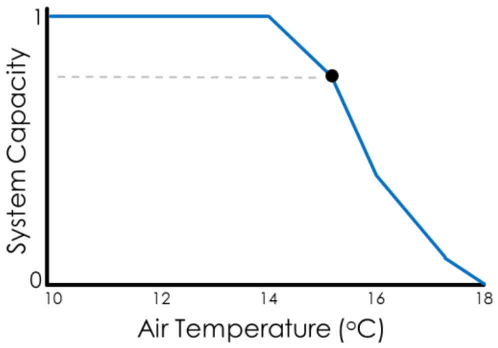
Angling



Stressor-Response Functions

Stress-Response Functions

Temperature



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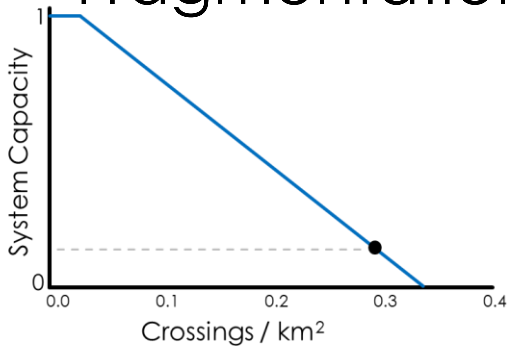

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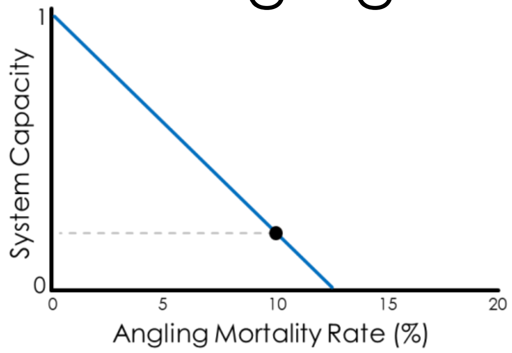


Stressor Magnitudes

15°C

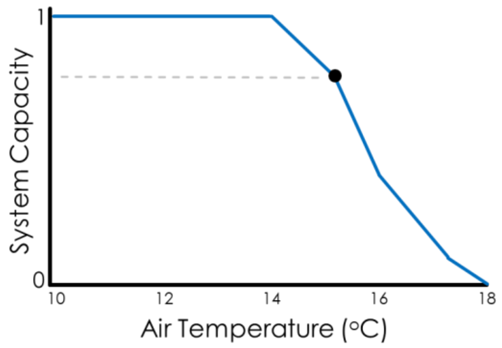
0.28
crossings/km^2

10%

Stressor-Response Functions

Stress-Response Functions

Temperature



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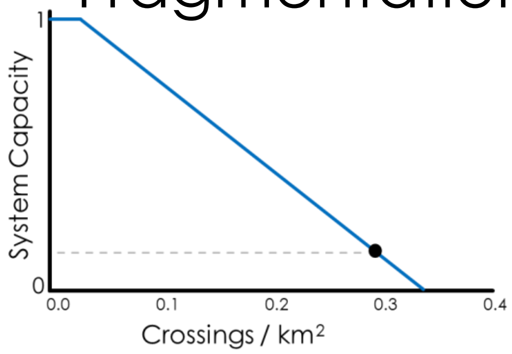

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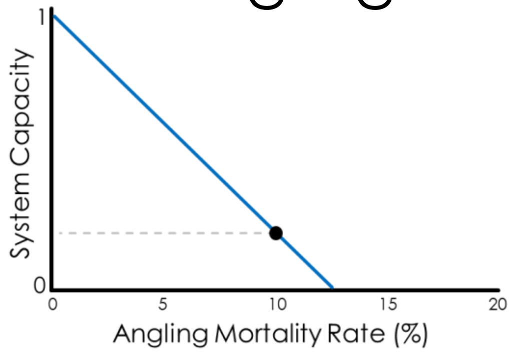

Stressor Magnitudes

Temperature	Fragmentation	Angling
15°C	**0.28** crossings/km²	**10%**

System Capacity

Temperature	Fragmentation	Angling
0.81	**0.13**	**0.20**

Stressor-Response Functions

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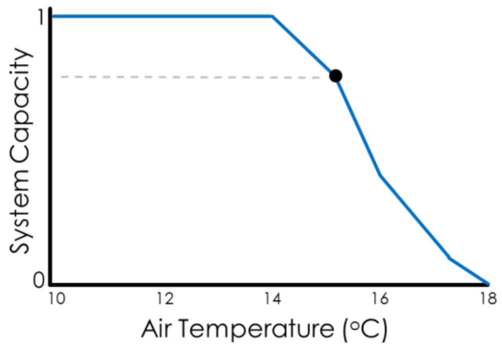

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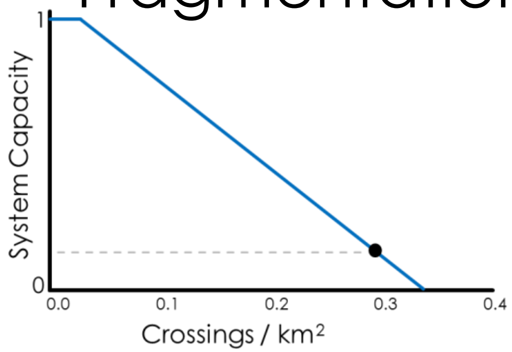
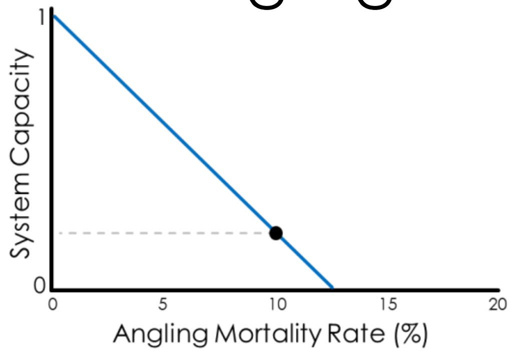


Angling



Stressor Magnitudes

Temperature	Fragmentation	Angling
15°C	0.28 crossings/km²	10%

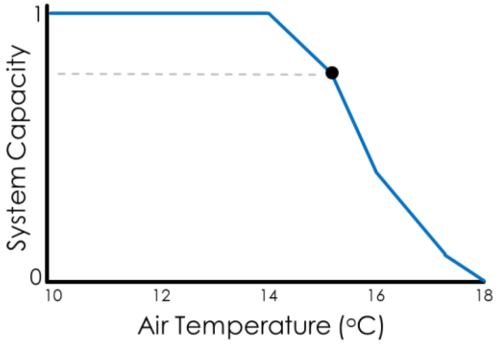
System Capacity

0.81 X 0.13 X 0.20 =

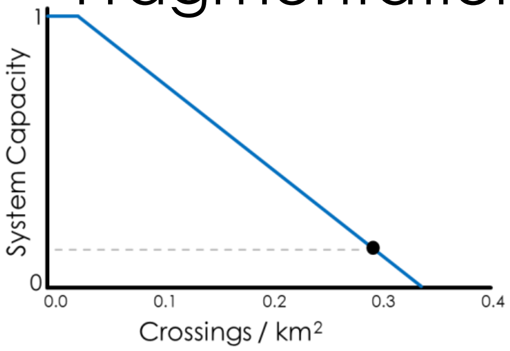
Stressor-Response Functions

Stress-Response Functions

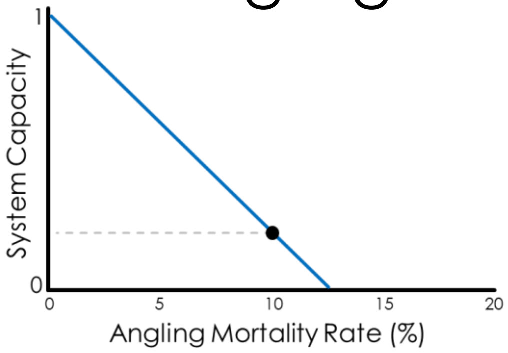
Temperature



Fragmentation



Angling

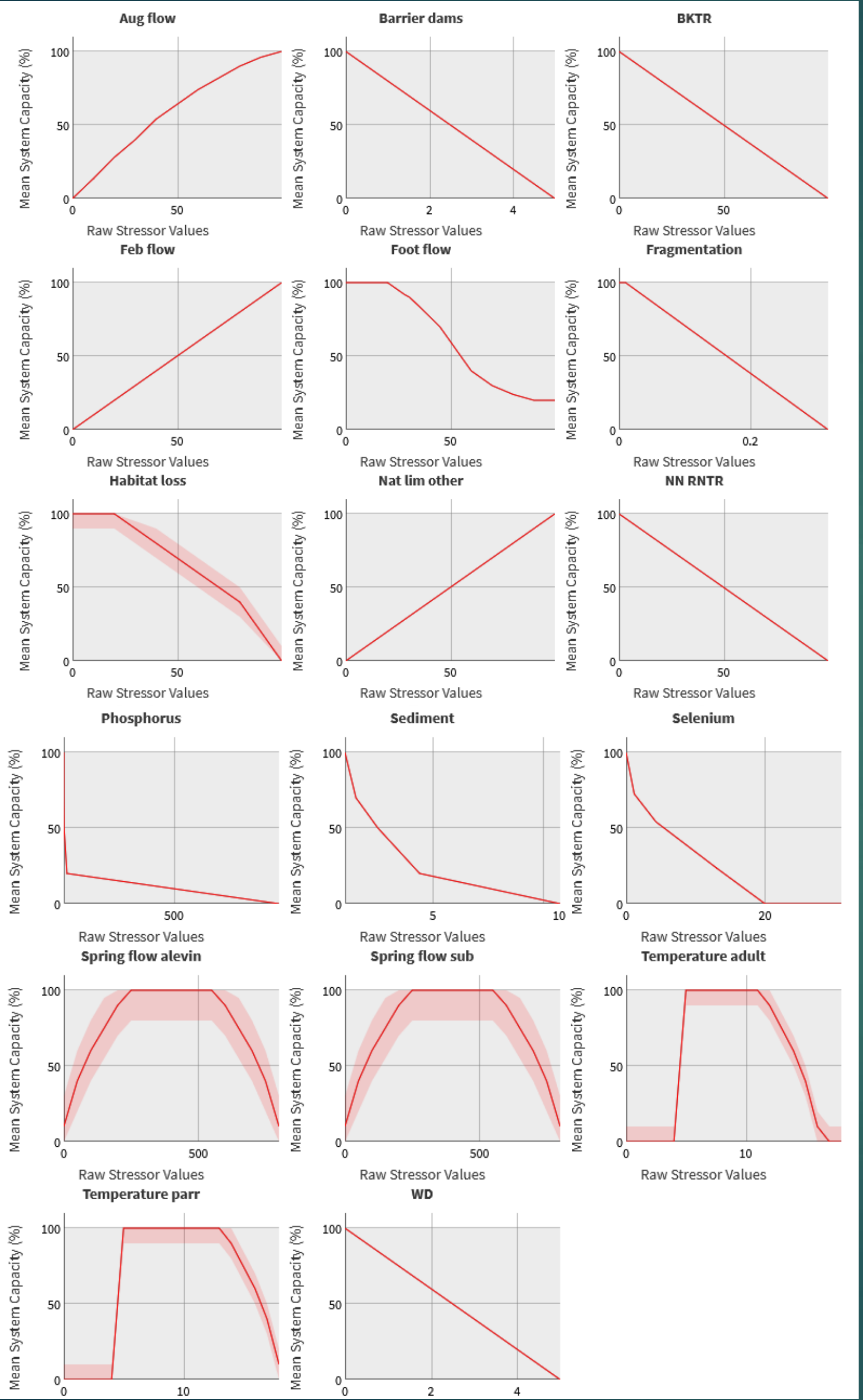


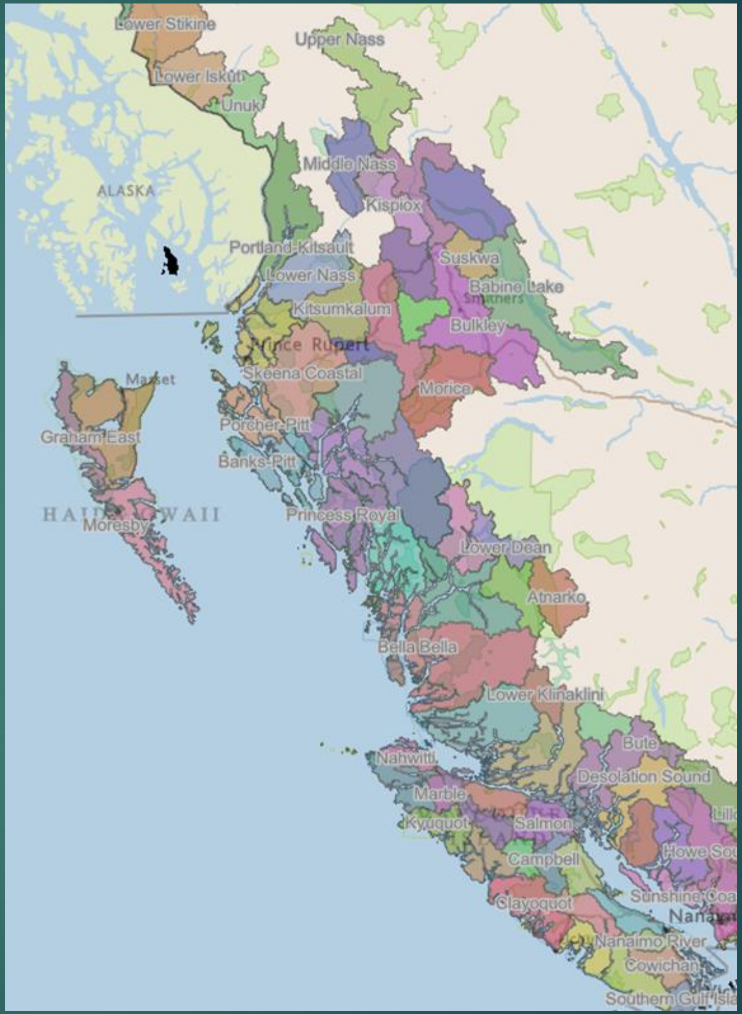
Stressor Magnitudes

Temperature	Fragmentation	Angling
15°C	0.28 crossings/km²	10%

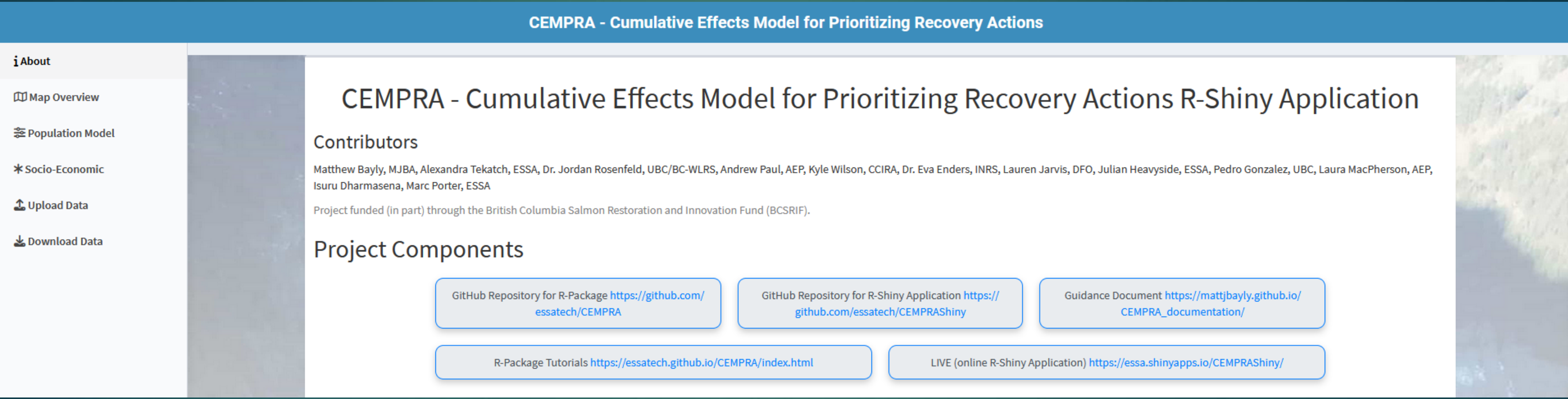
System Capacity

0.81 X 0.13 X 0.20 = **0.021** (**Cumulative System Capacity**)

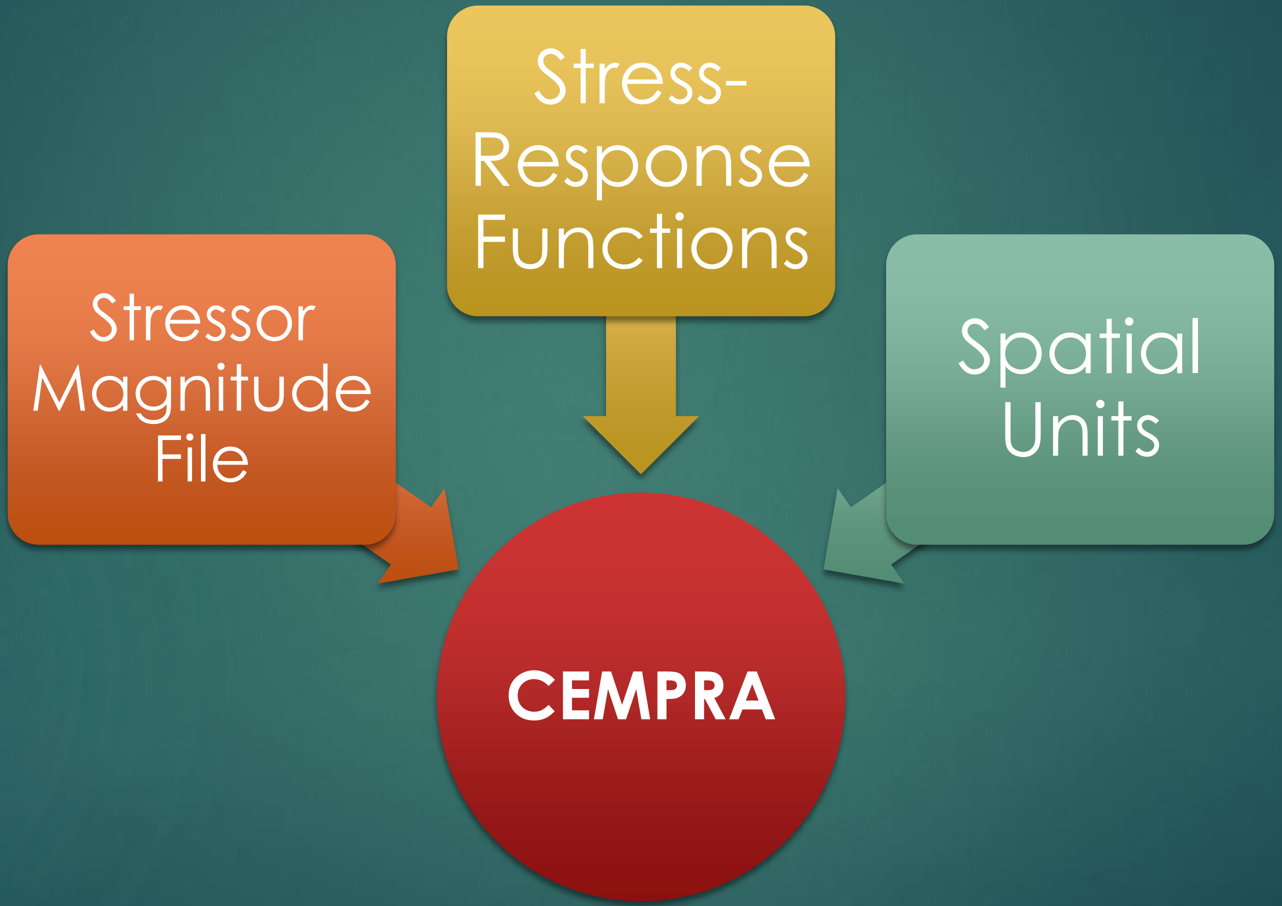

Aug flow
Barrier dams
BKTR
Feb flow
Foot flow
Fragmentation
Habitat loss
Nat lim other
NN RNTR
Phosphorus
Sediment
Selenium
Spring flow alevin
Spring flow sub
Temperature adult
Temperature parr
WD
Mean System Capacity (%)
Raw Stressor Values


Lower Stikine
Upper Nass
Lower Iskut
Unuk
Middle Nass
ALASKA
Kispiox
Portland-Kitsault
Lower Nass
Suskwa
Babine Lake
Smithers
Kitsumkalum
Bulkley
Prince Rupert
Masset
Skeena Coastal
Morice
Graham East
Porcher-Pitt
Banks-Pitt
Moresby
Princess Royal
Lower Dean
Atnarko
Bella Bella
Lower Klinaklini
Bute
Nahwitti
Desolation Sound
Marble
Kyuquot
Salmon
Campbell
Clayoquot
Nanaimo River
Cowichan

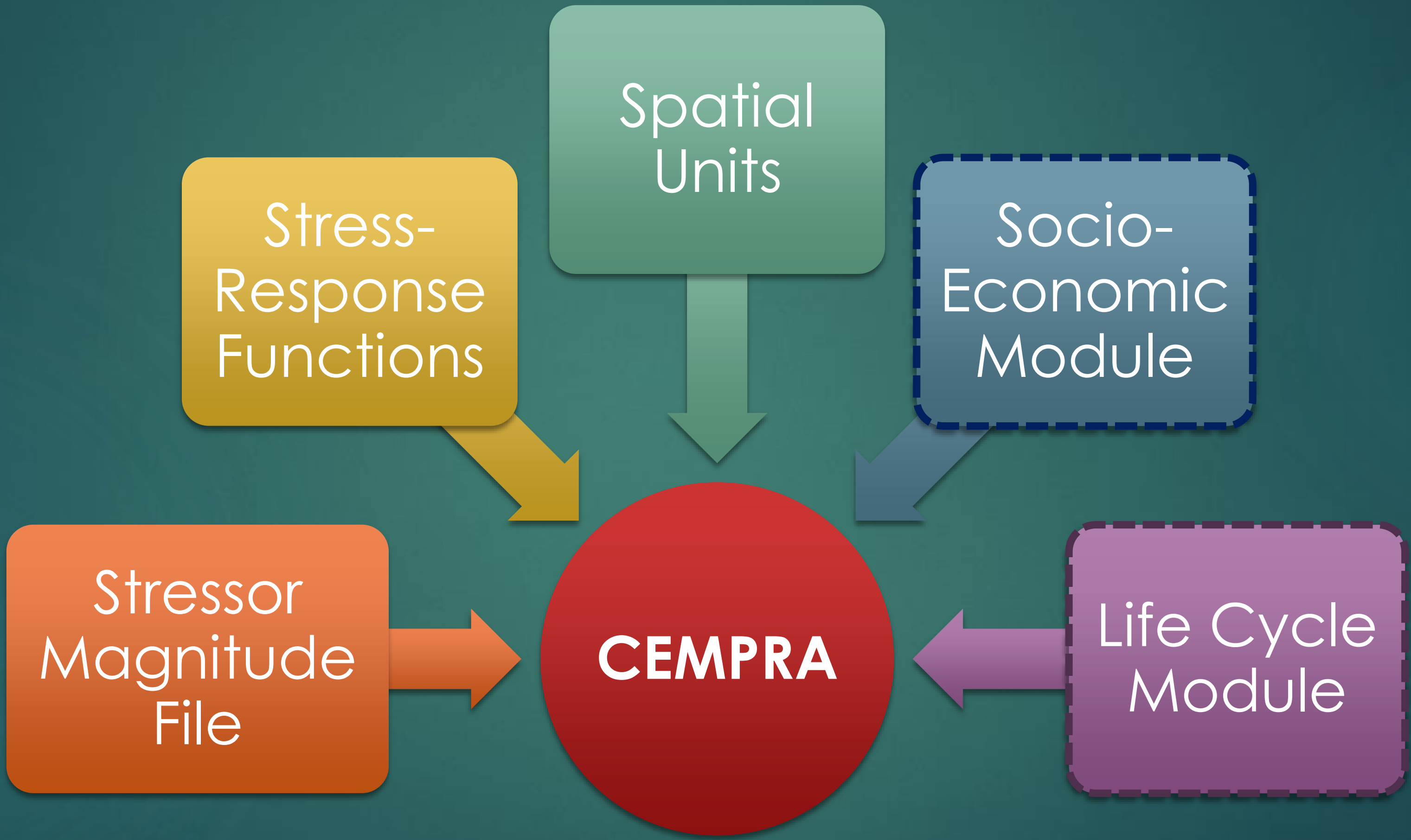
Cumulative Effects Model for Prioritizing Recovery Actions

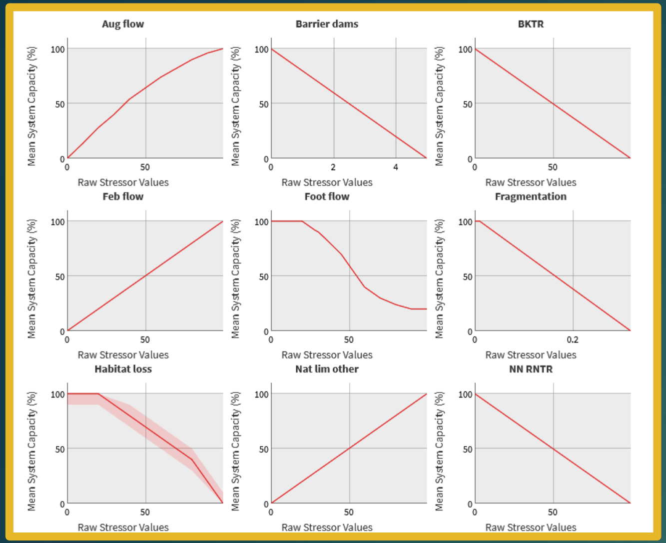


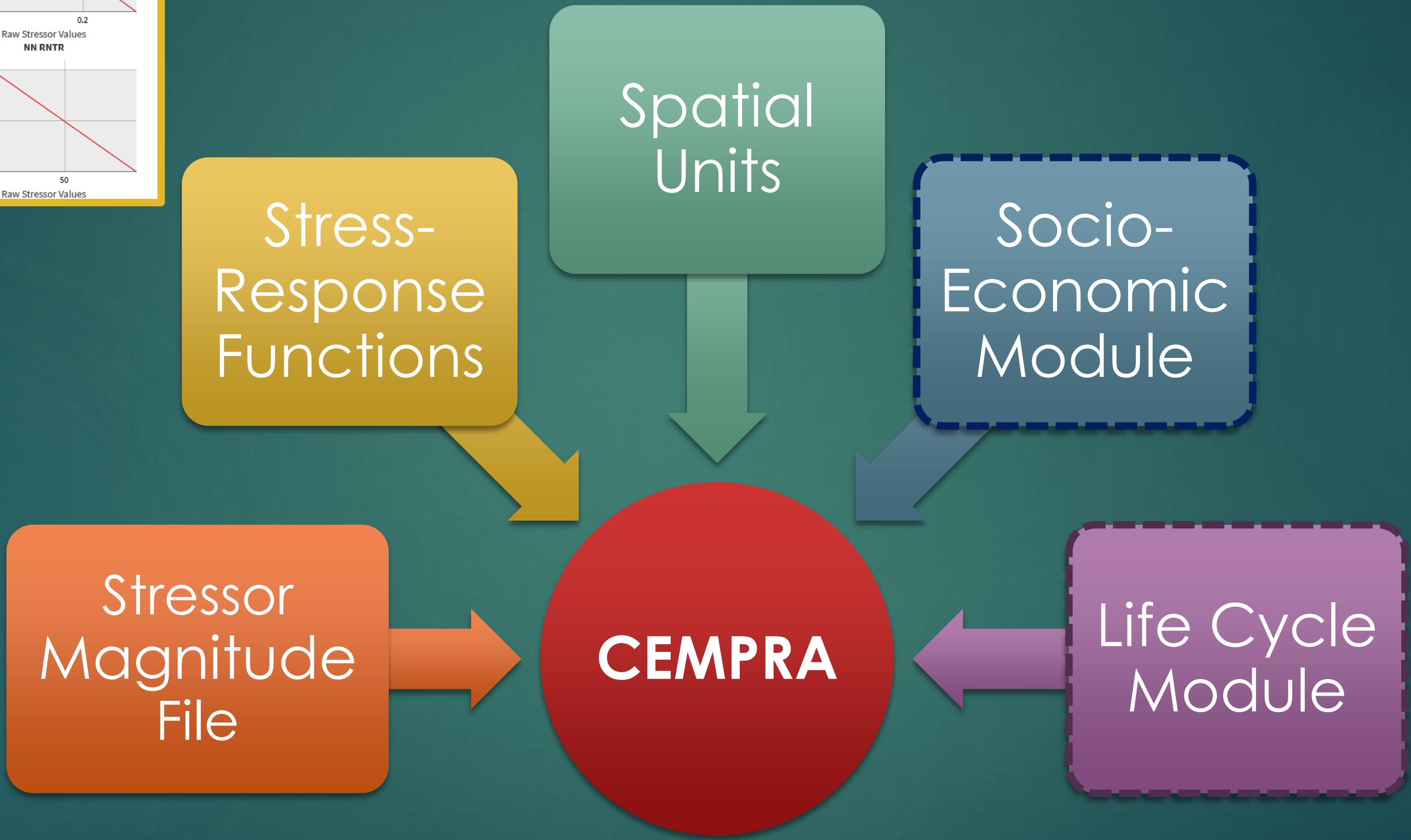
CEMPRA

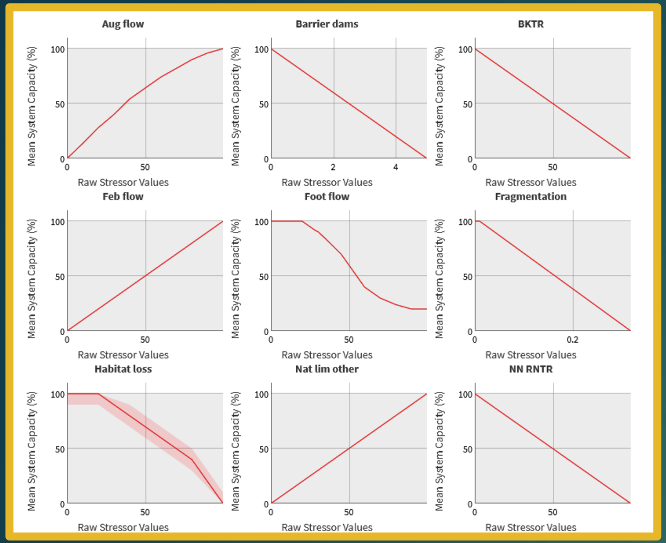

Stress-Response Functions
Stressor Magnitude File
Spatial Units
CEMPRA

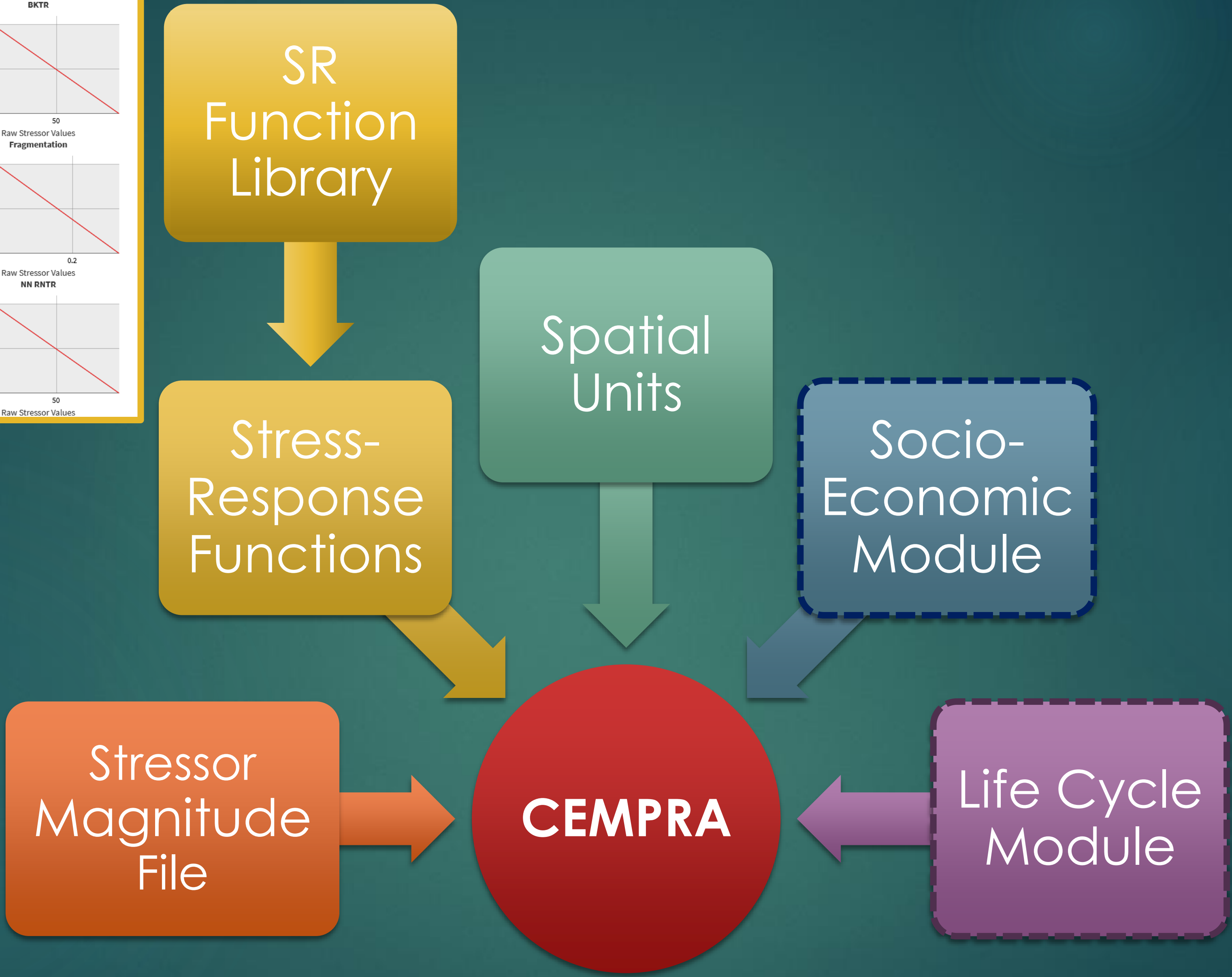
CEMPRA


Spatial Units
Stress-Response Functions
Socio-Economic Module
Stressor Magnitude File
CEMPRA
Life Cycle Module

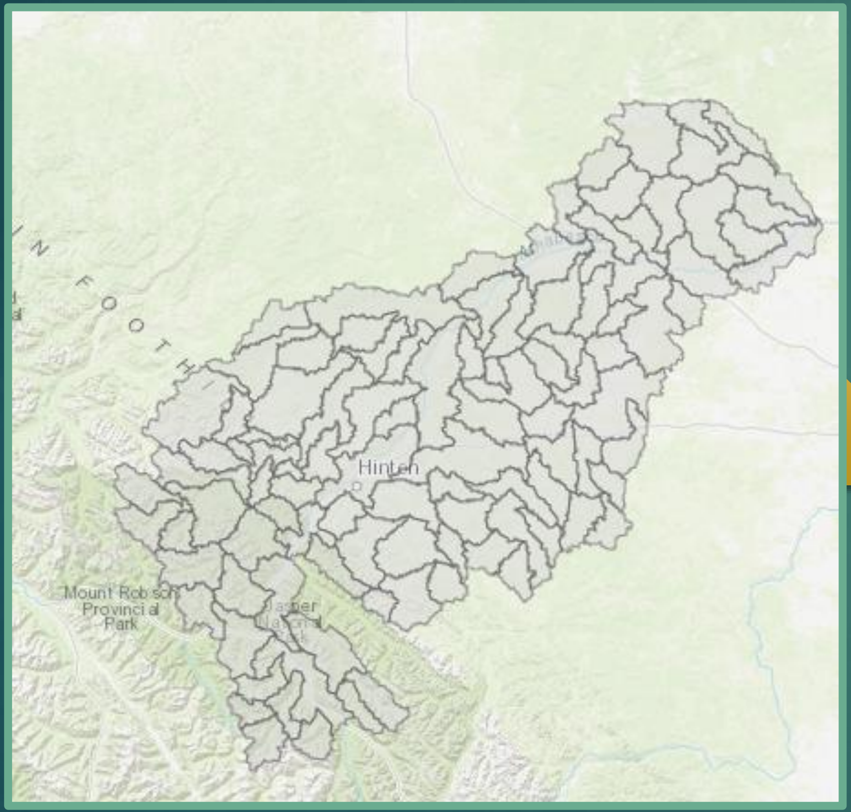

Aug flow
Barrier dams
BKTR
Feb flow
Foot flow
Fragmentation
Habitat loss
Nat lim other
NN RNTR
Mean System Capacity (%)
Raw Stressor Values


Spatial Units
Stress-Response Functions
Socio-Economic Module
Stressor Magnitude File
CEMPRA
Life Cycle Module

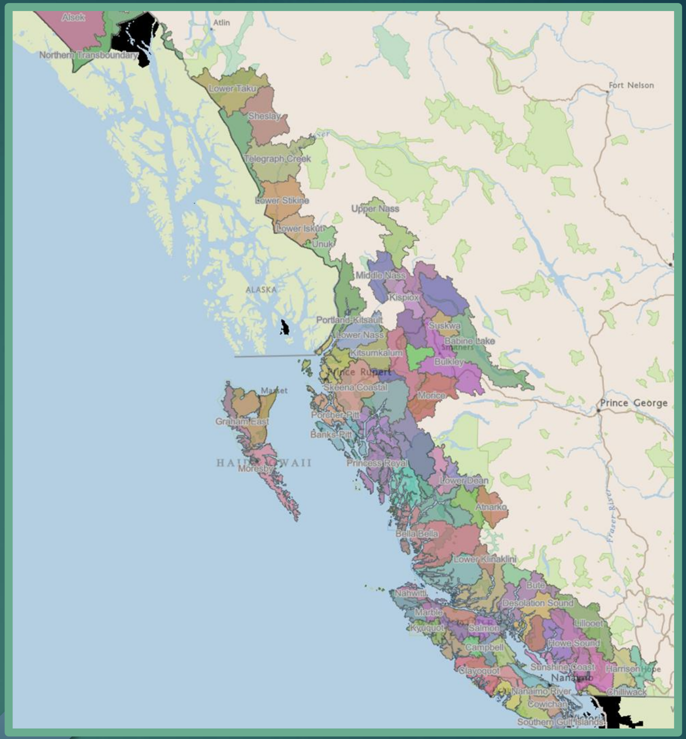

Aug flow
Barrier dams
BKTR
Feb flow
Foot flow
Fragmentation
Habitat loss
Nat lim other
NN RNTR
Mean System Capacity (%)
Raw Stressor Values


SR Function Library
Stress-Response Functions
Spatial Units
Socio-Economic Module
Stressor Magnitude File
CEMPRA
Life Cycle Module

CEMPRA



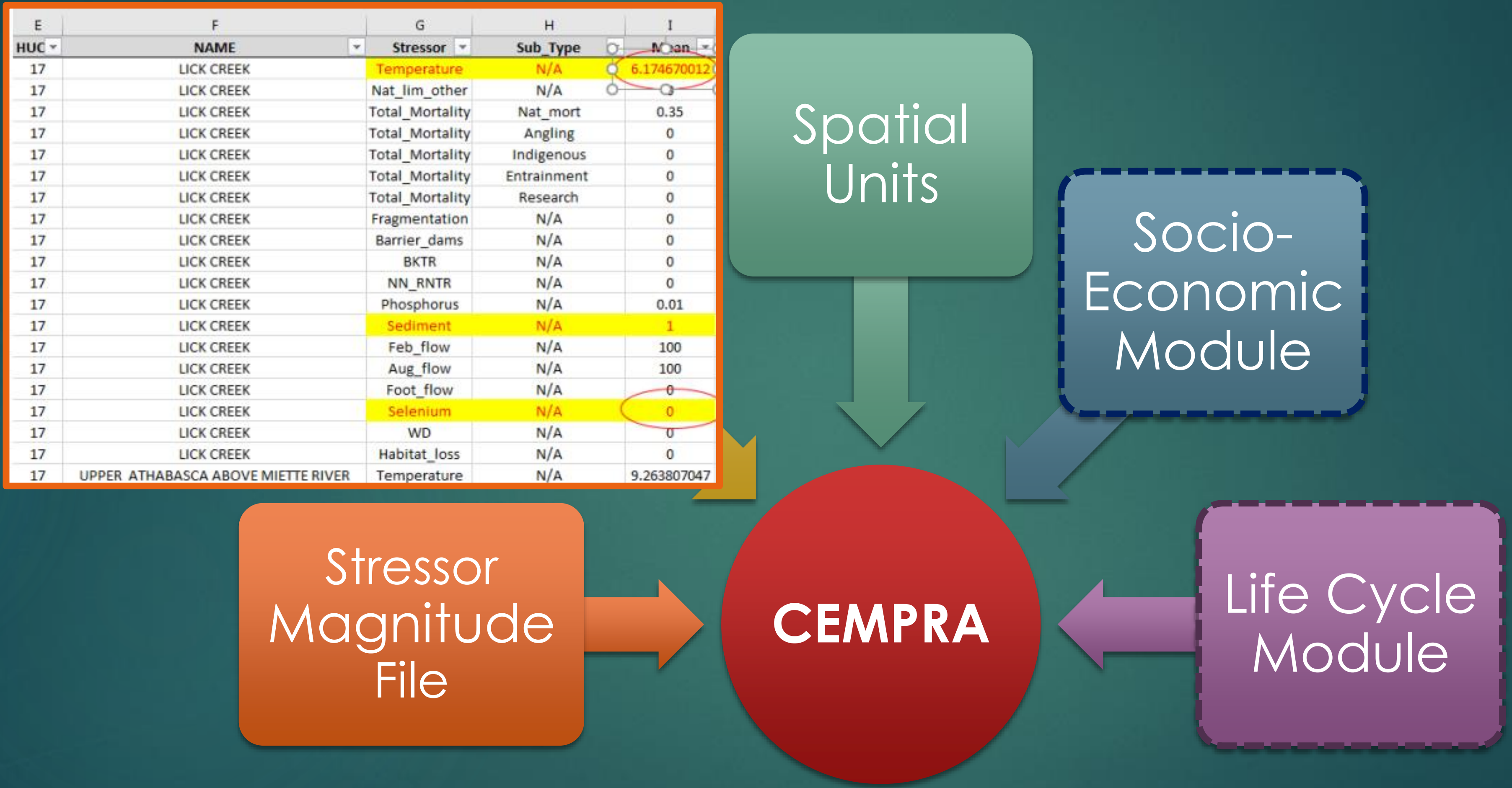
Spatial Units



CEMPRA

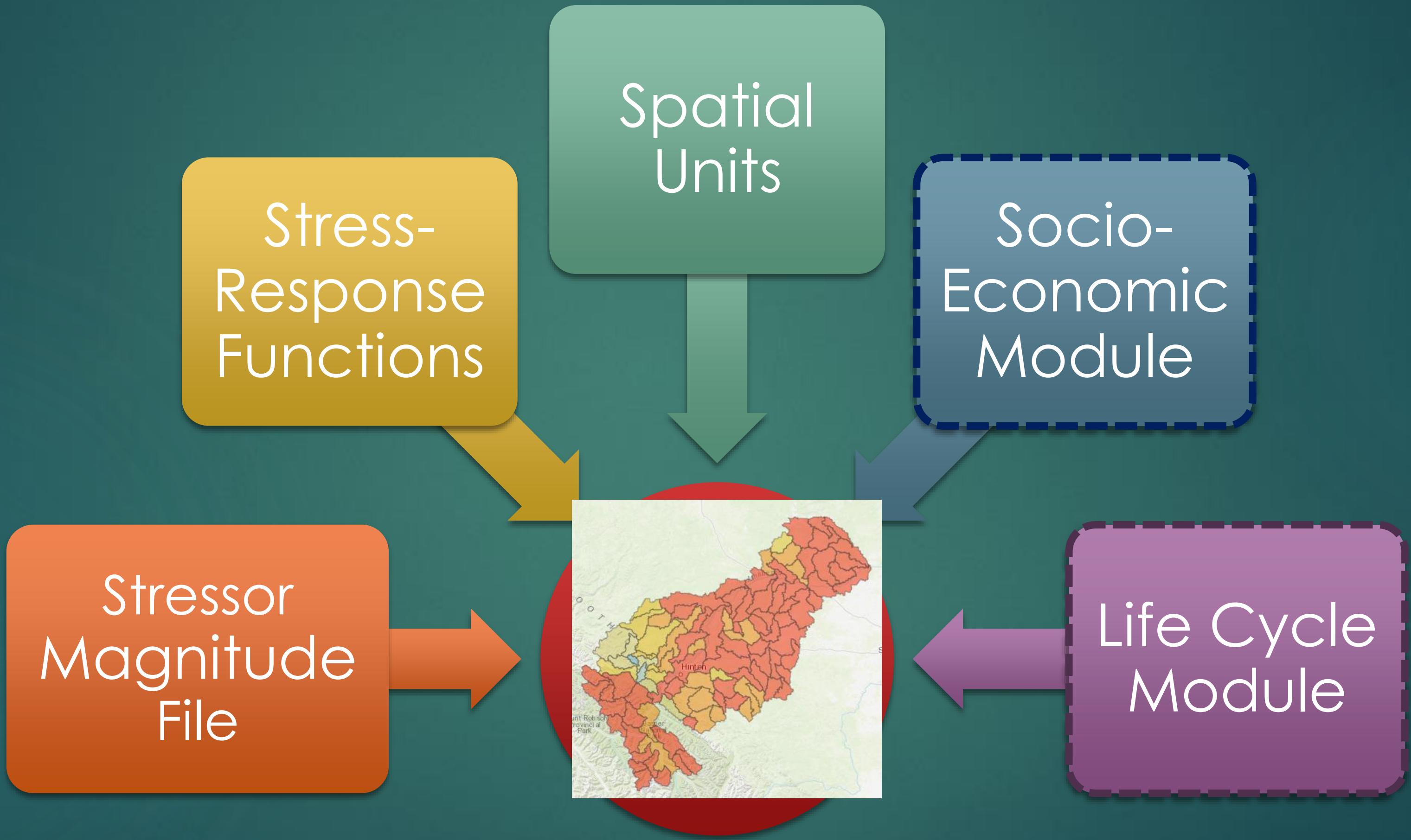
Life Cycle Module

CEMPRA

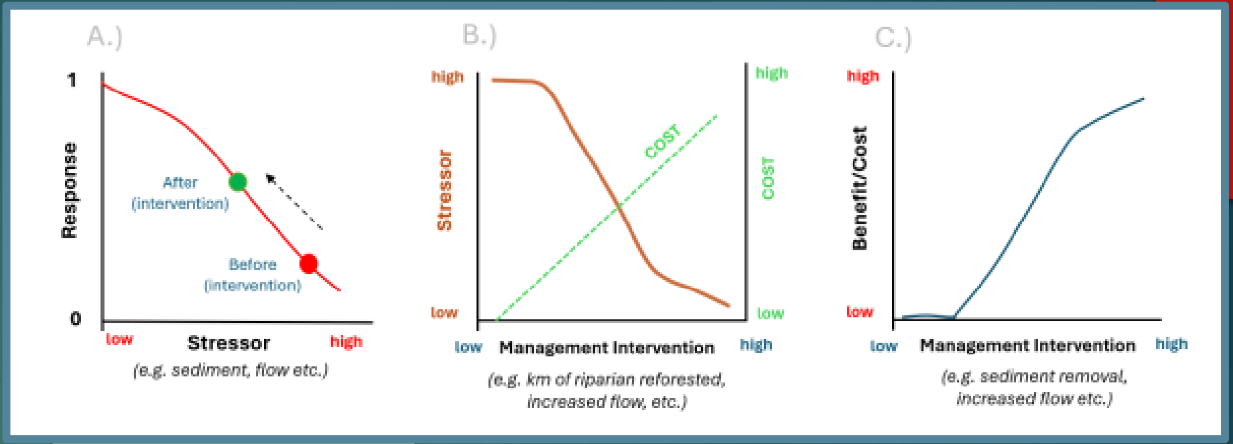


HUC	NAME	Stressor	Sub_Type	Mean
17	LICK CREEK	Temperature	N/A	6.174670012
17	LICK CREEK	Nat_lim_other	N/A	
17	LICK CREEK	Total_Mortality	Nat_mort	0.35
17	LICK CREEK	Total_Mortality	Angling	0
17	LICK CREEK	Total_Mortality	Indigenous	0
17	LICK CREEK	Total_Mortality	Entrainment	0
17	LICK CREEK	Total_Mortality	Research	0
17	LICK CREEK	Fragmentation	N/A	0
17	LICK CREEK	Barrier_dams	N/A	0
17	LICK CREEK	BKTR	N/A	0
17	LICK CREEK	NN_RNTR	N/A	0
17	LICK CREEK	Phosphorus	N/A	0.01
17	LICK CREEK	Sediment	N/A	1
17	LICK CREEK	Feb_flow	N/A	100
17	LICK CREEK	Aug_flow	N/A	100
17	LICK CREEK	Foot_flow	N/A	0
17	LICK CREEK	Selenium	N/A	0
17	LICK CREEK	WD	N/A	0
17	LICK CREEK	Habitat_loss	N/A	0
17	UPPER ATHABASCA ABOVE MIETTE RIVER	Temperature	N/A	9.263807047

CEMPRA


Spatial Units
Stress-Response Functions
Socio-Economic Module
Stressor Magnitude File
Life Cycle Module

CEMPRA

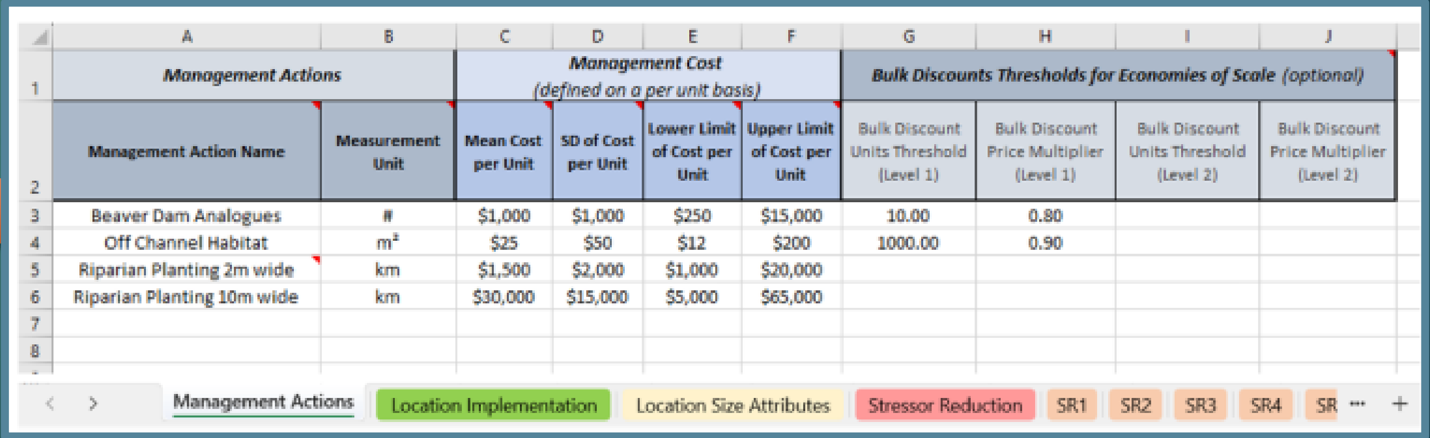


Units

Stress-Response Functions

Socio-Economic Module

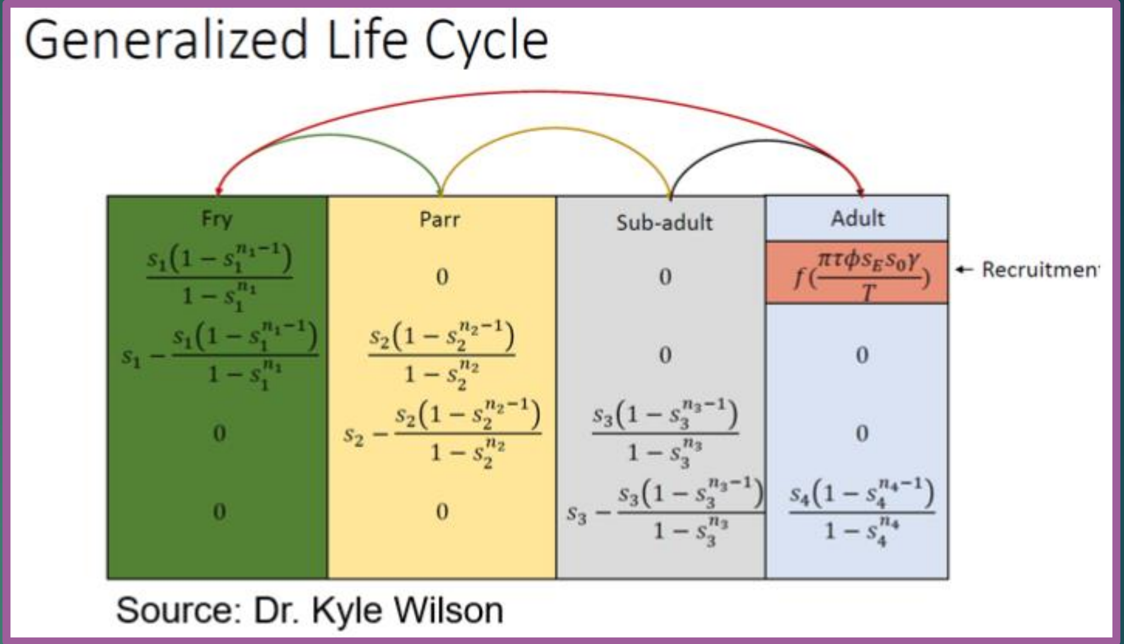
Stressor Magnitude File



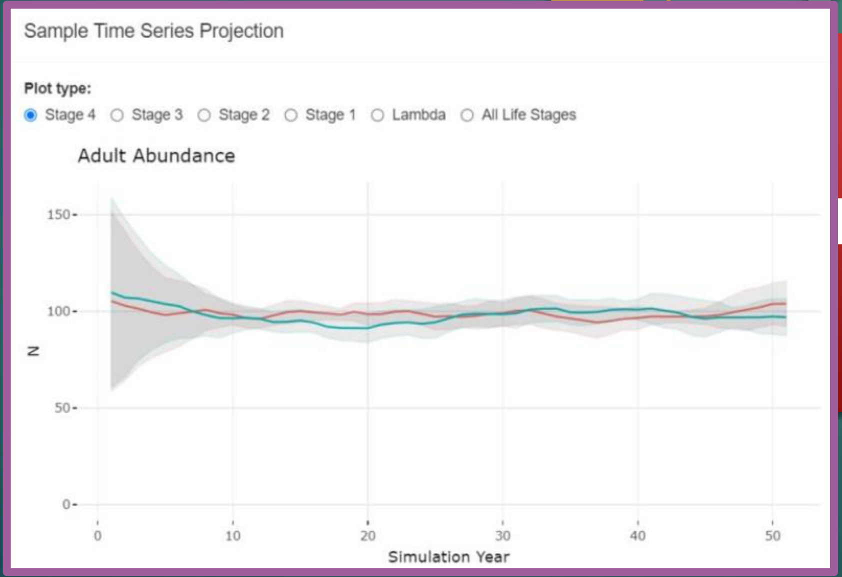
Management Actions		Management Cost (defined on a per unit basis)				Bulk Discounts Thresholds for Economies of Scale (optional)			
Management Action Name	Measurement Unit	Mean Cost per Unit	SD of Cost per Unit	Lower Limit of Cost per Unit	Upper Limit of Cost per Unit	Bulk Discount Units Threshold (Level 1)	Bulk Discount Price Multiplier (Level 1)	Bulk Discount Units Threshold (Level 2)	Bulk Discount Price Multiplier (Level 2)
Beaver Dam Analogues	#	$1,000	$1,000	$250	$15,000	10.00	0.80		
Off Channel Habitat	m²	$25	$50	$12	$200	1000.00	0.90		
Riparian Planting 2m wide	km	$1,500	$2,000	$1,000	$20,000				
Riparian Planting 10m wide	km	$30,000	$15,000	$5,000	$65,000				

Management Actions | Location Implementation | Location Size Attributes | Stressor Reduction | SR1 | SR2 | SR3 | SR4 | SR

CEMPRA



Stress-Response Functions



PRA

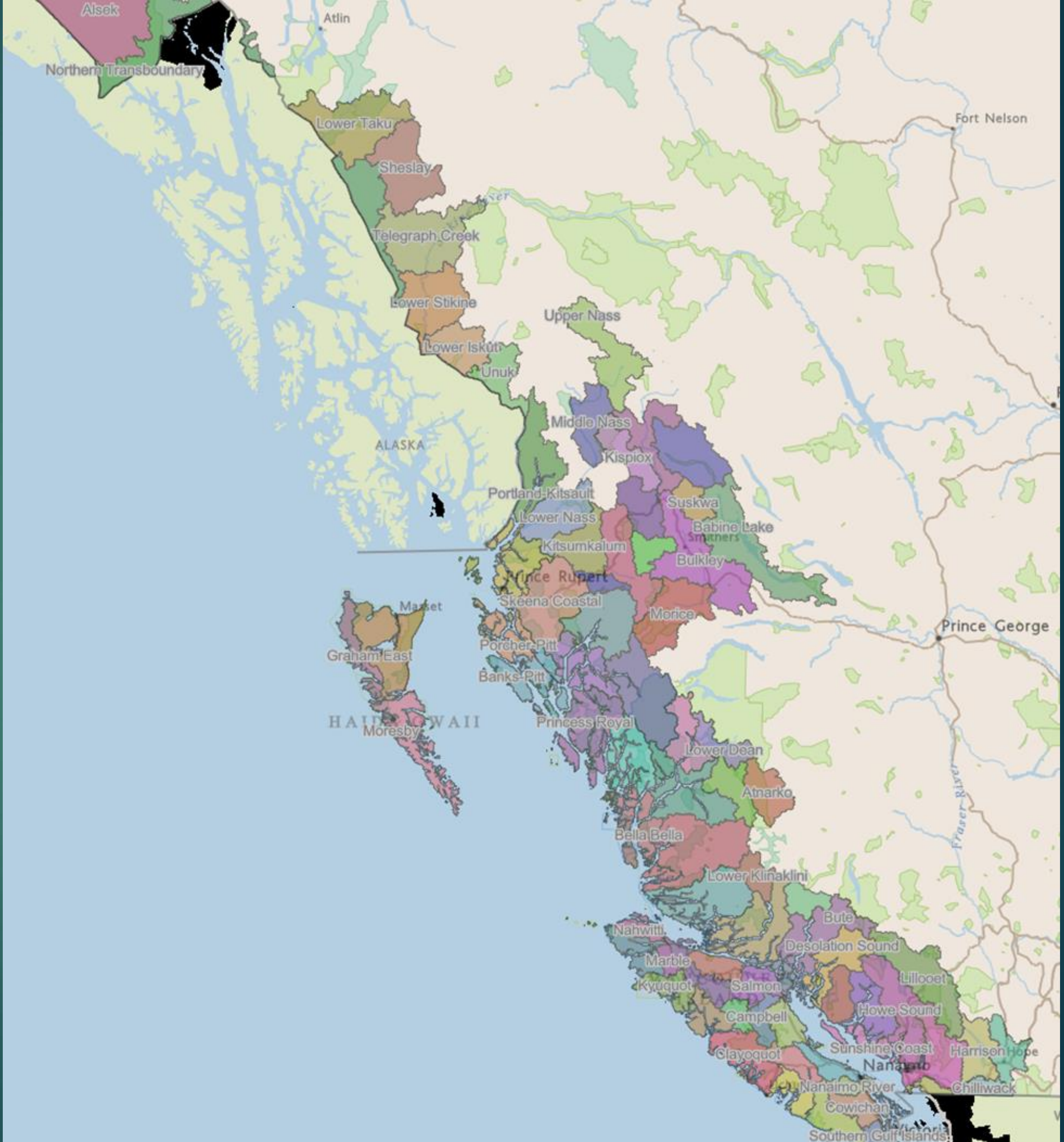
Life Cycle Module

Progress // Coastal Cutthroat Modelling

- ✓ Delineate Conservation Units + Assessment Units
- ✓ Establish Stressor List
- ✓ (in progress) Develop/Find Stress-Response Functions
- Collect Stressor-Magnitude Data
- Run CEMPRA: Status Quo Scenario
- Run CEMPRA: Alternative Future Scenarios

BC Draft Conservation Units (CUs)

- N = 76 draft CUs
- Hypothesized to be demographically & genetically connected

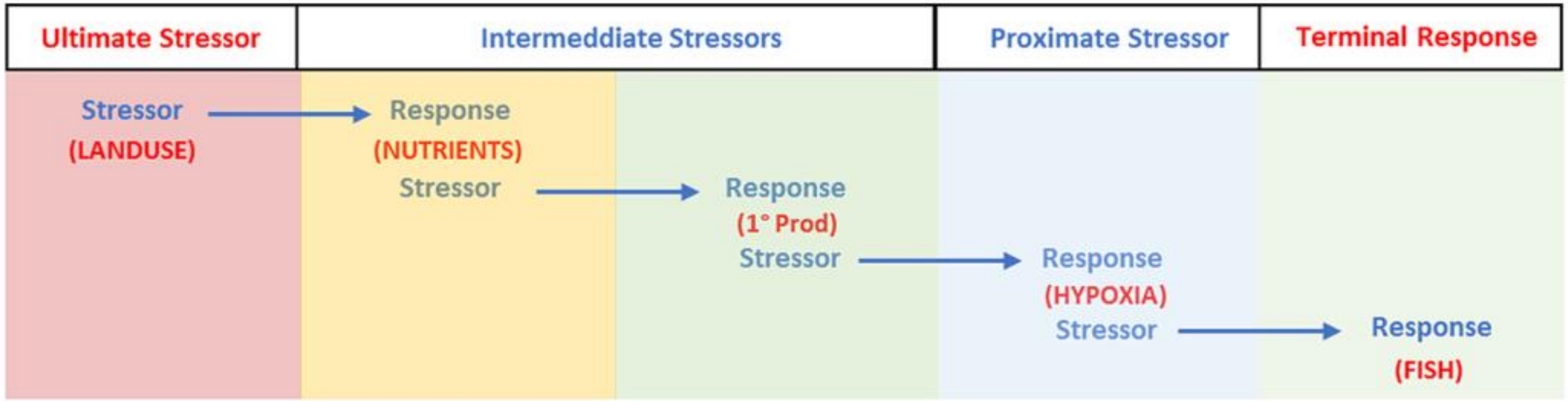


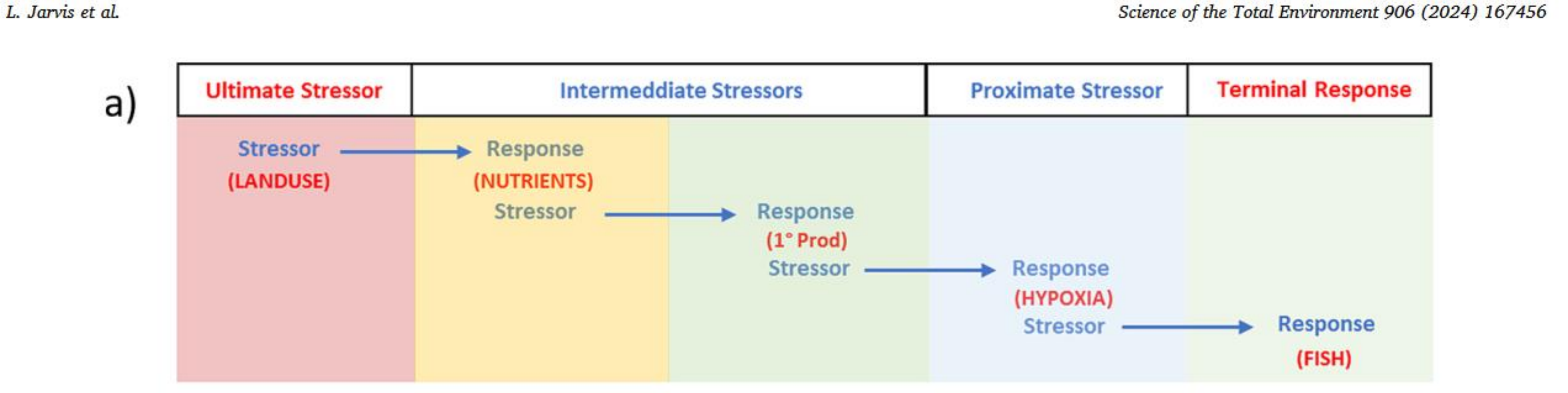
Establishing Stressor List

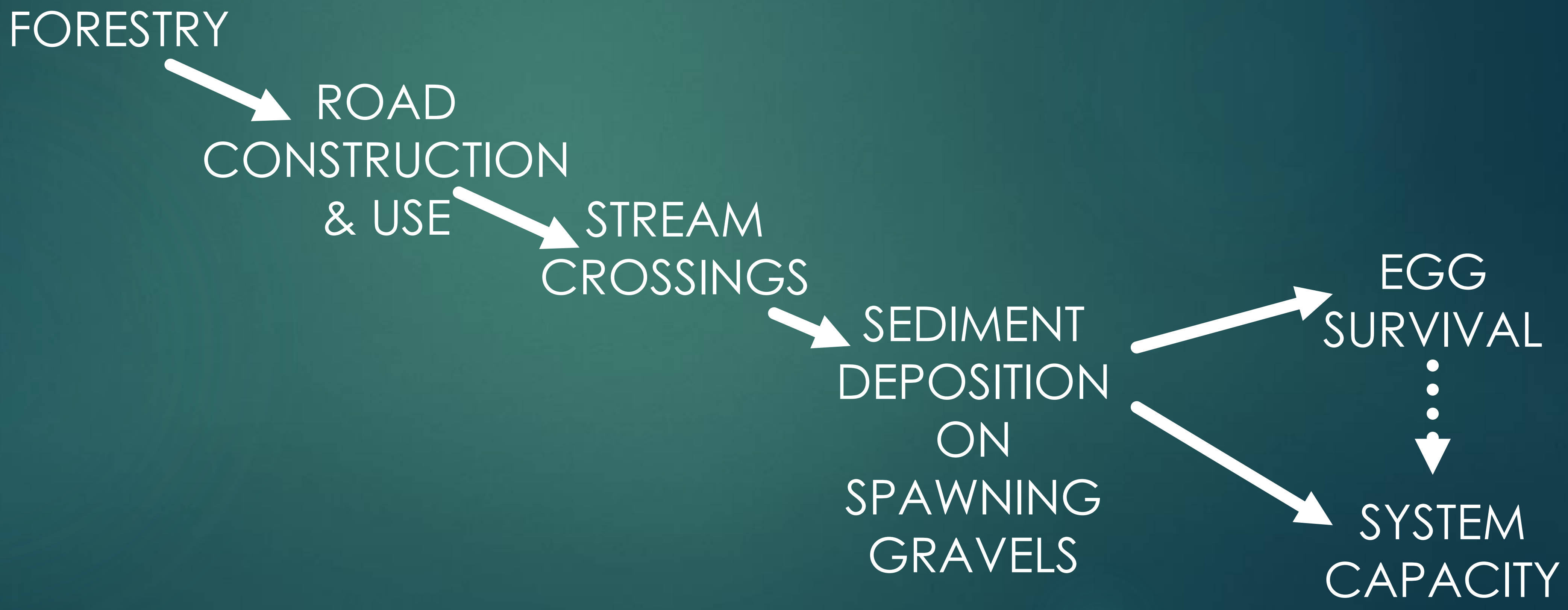
- Expert elicitation process conducted last week
- **Where are the BEST and WORST systems in BC?**
- **What stressors affect Coastal Cutthroat Trout populations there?**
- **What stressors are you MOST concerned about?**

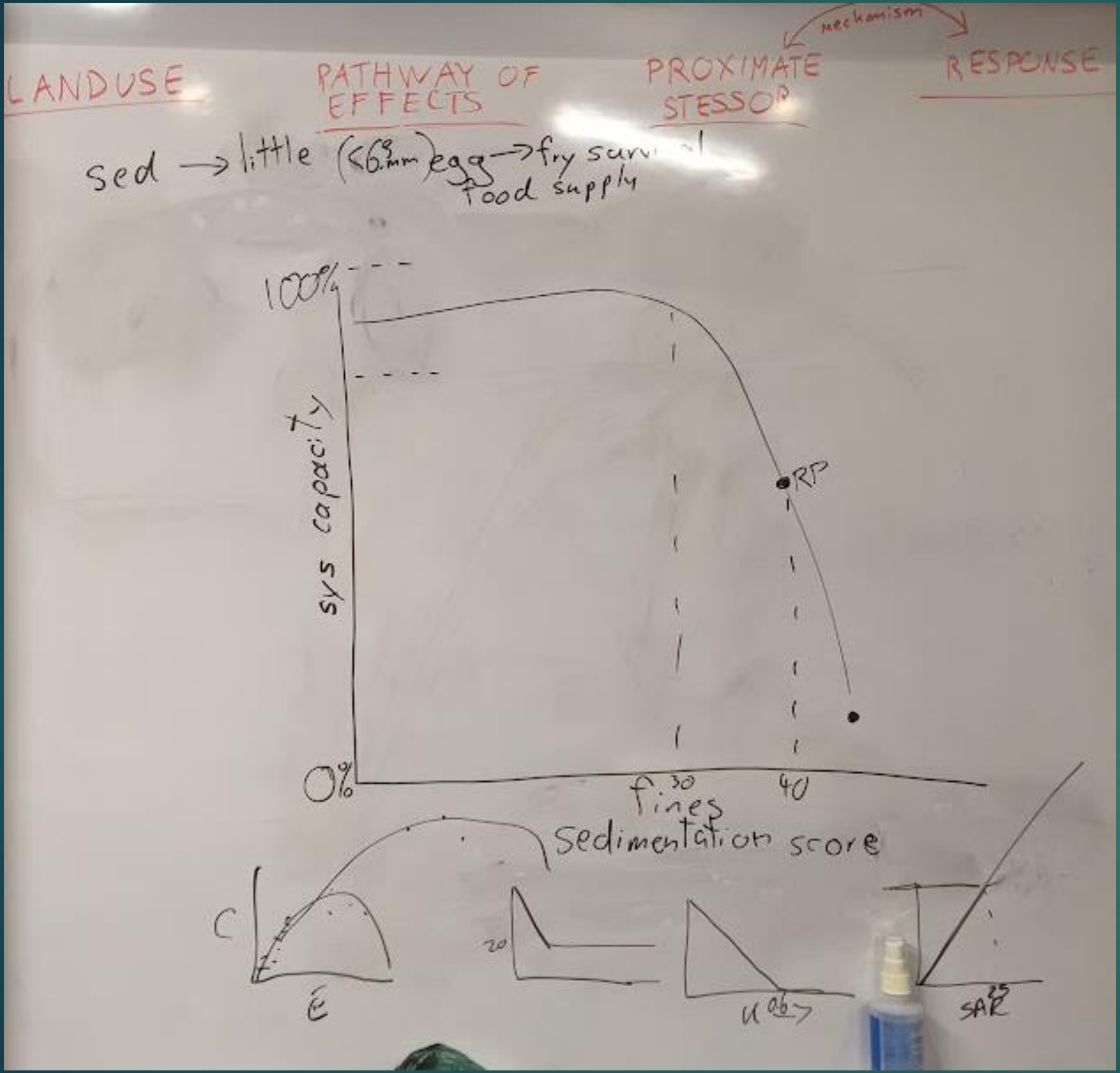
- Direct habitat loss (paved over)
- **Hybridization** (stocking rainbows, steelhead, coastal cutts)
- Toxins (pesticides, herbicides, swimming pools, de-icing, petroleum products, solvents, 6ppd-quinone)
- Temperature
- **Land use (forestry, urbanization, agriculture)**
- Culverts
- Peak flow hazards (scouring)
- Riparian degradation
- Pinniped & cormorant predation
- Sedimentation
- Nutrient input (phosphates, nitrates)
- Invasives (bass, etc.)
- Barrier dams
- Hypoxia
- Heat waves
- Competing management objectives (recreation vs management)
- Illegal harvest (non-compliance)
- Lack of spawning gravel (human induced via scour export, lack of input due to dams, bank armouring reduced erosion)
- Forage fish abundance (stickleback, etc)
- Dewatering of streams (full loss)
- Storm water drainage / runoff
- Channelization / diking
- Drought
- **Competition from stocking** of coho, cutts, steelhead, rainbow
- Recreational fresh/saltwater fishing
- Estuarine/foreshore development
- Lack of LWD in small streams (removal, emigration of rotten wood, no recruitment)
- Productivity driver (salmon subsidies)
- Climate change
- **Summer low flows** (water withdrawals, water use)
- Whirling disease
- 5-6 hatchery diseases, parasites
- Impervious surfaces (urban)
- Loss of wetlands/recharge areas (infiling)
- Loss of spawning and rearing areas (off-channel habitat loss or disconnection)
- Waste water releases (nutrients, pH – Cowichan, Stony Ck)
- Tanning chemical release (mink farms – Nathan Ck)
- Water temperature
- Invertebrate pop'n changes (food sources)
- Entrainment due to water withdrawals (hydro/irrigation)
- **Fragmentation** (culverts, old water infrastructure, seasonal disconnection of habitats)
- Acid rock drainage
- pH
- Heavy metals (zinc, demossers in Craigflower, Oliver Ck, Colquitz, aluminum in Kitimat)
- Too many salmon projects getting funded
- Paint/milk spills into storm drains
- Forest fire suppressants
- Barrier removal
- Nutrient enrichment programs
- Stewardship groups
- **Marine survival**
- Agriculture

a)

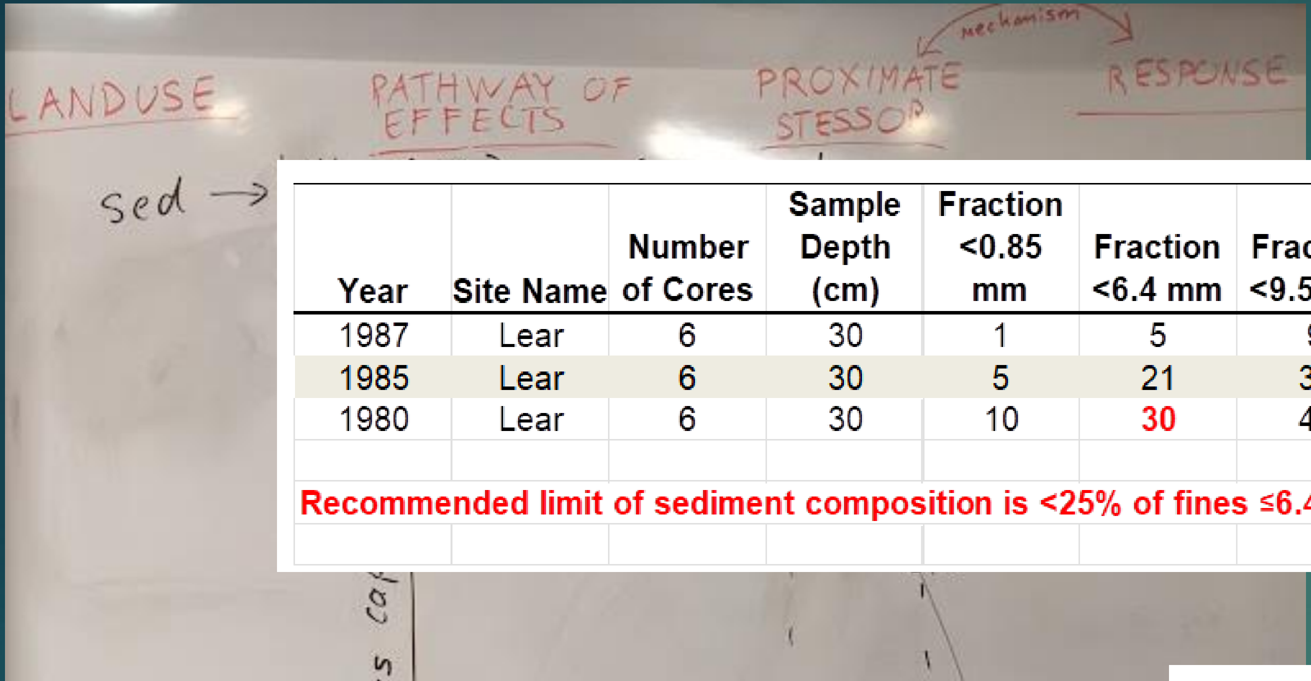

Ultimate Stressor
Intermeddiate Stressors
Proximate Stressor
Terminal Response
Stressor
(LANDUSE)
Response
(NUTRIENTS)
Stressor
Response
(1° Prod)
Stressor
Response
(HYPOXIA)
Stressor
Response
(FISH)


L. Jarvis et al.
Science of the Total Environment 906 (2024) 167456
a)
Ultimate Stressor
Intermeddiate Stressors
Proximate Stressor
Terminal Response
Stressor
(LANDUSE)
Response
(NUTRIENTS)
Stressor
Response
(1° Prod)
Stressor
Response
(HYPOXIA)
Stressor
Response
(FISH)


FORESTRY
ROAD CONSTRUCTION & USE
STREAM CROSSINGS
SEDIMENT DEPOSITION ON SPAWNING GRAVELS
EGG SURVIVAL
SYSTEM CAPACITY



mechanism
LANDUSE
PATHWAY OF EFFECTS
PROXIMATE STESSOR
RESPONSE
sed → little (<6.9mm) egg → fry survival
food supply
100%
sys capacity
RP
0%
30
40
fines
sedimentation score
C
20
SAR



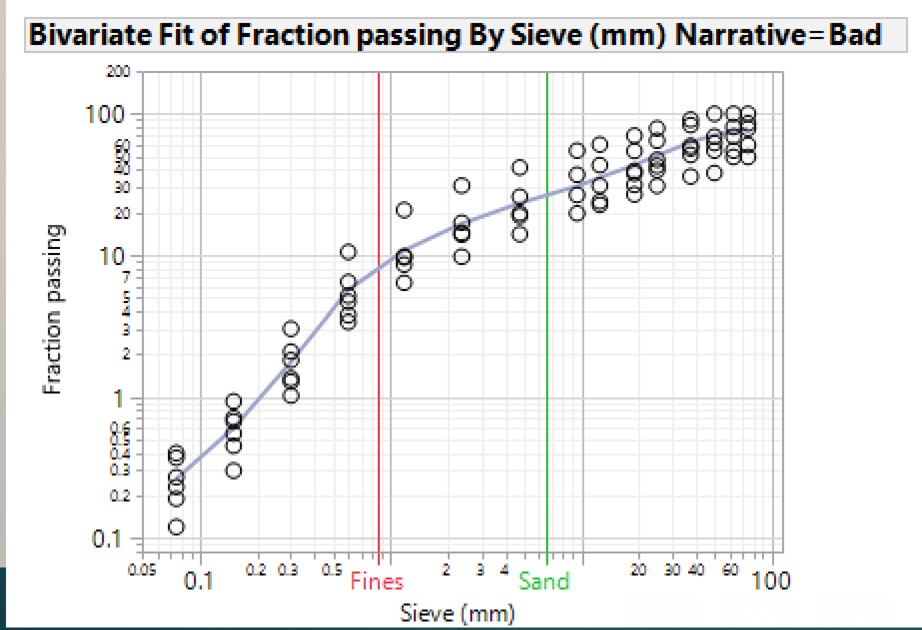
Year	Site Name	Number of Cores	Sample Depth (cm)	Fraction <0.85 mm	Fraction <6.4 mm	Fraction <9.5 mm	Narrative
1987	Lear	6	30	1	5	9	**Good**
1985	Lear	6	30	5	21	30	**Bad**
1980	Lear	6	30	10	30	40	**Ugly**

Recommended limit of sediment composition is <25% of fines ≤6.4 mm

EFFECTS OF HIGHWAY CONSTRUCTION AND MITIGATION ON SUMMER STEELHEAD IN THE COQUIHALLA RIVER, BRITISH COLUMBIA
VOLUME I

Prepared by:

RONALD A. PTOLEMY, RPBio.
Fisheries Biologist
Fisheries Assessment and Improvement Unit
Fisheries Management Section



Protocol for

Evaluating the Condition of Streams and Riparian Management Areas

(Riparian Management Routine Effectiveness Evaluation)

Progress // Coastal Cutthroat Modelling

- ✓ Delineate Conservation Units + Assessment Units

- ✓ Establish Stressor List

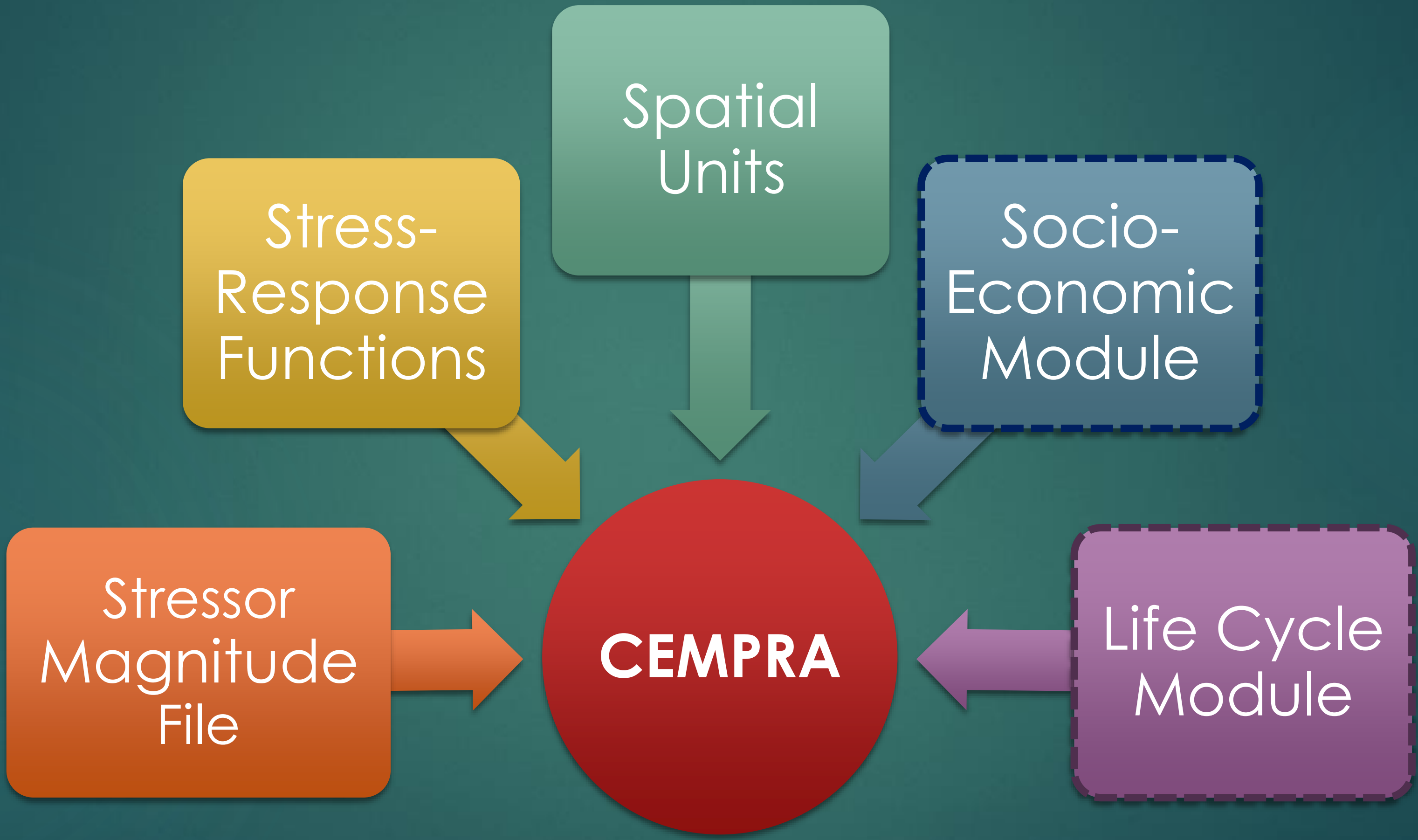
- ✓ (in progress) Develop/Find Stress-Response Functions

- Collect Stressor-Magnitude Data

- Run CEMPRA: Status Quo Scenario

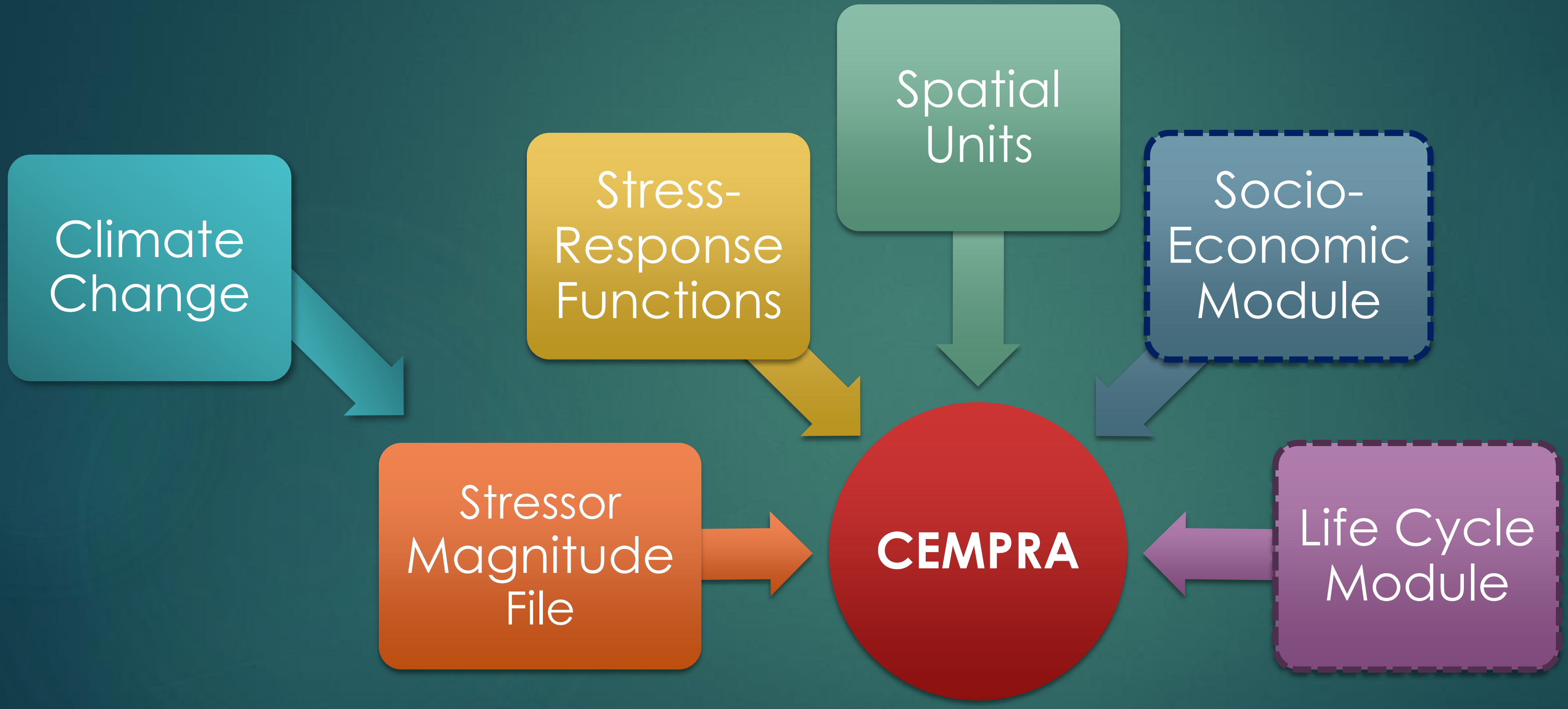
- Run CEMPRA: Alternative Future Scenarios

CEMPRA



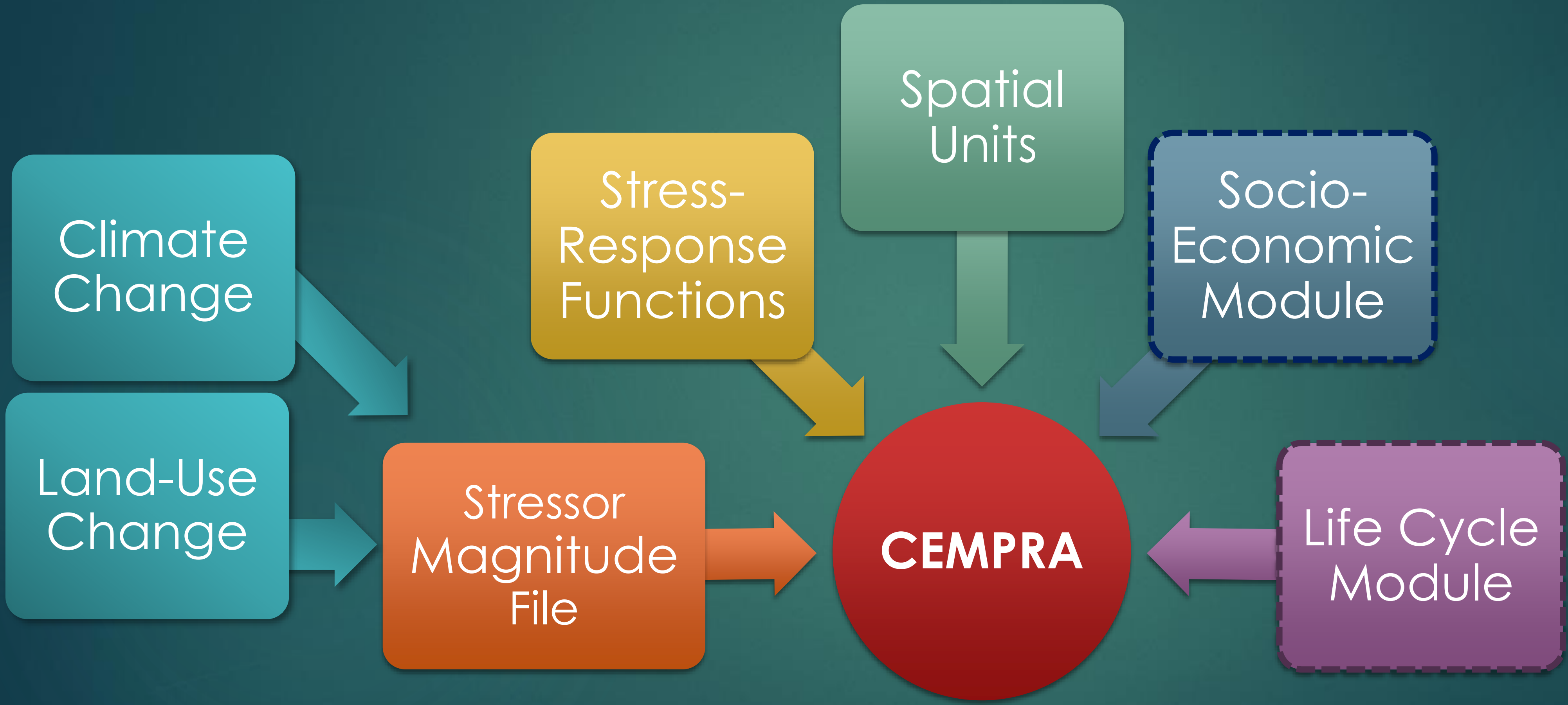
Spatial Units
Stress-Response Functions
Socio-Economic Module
Stressor Magnitude File
CEMPRA
Life Cycle Module

CEMPRA

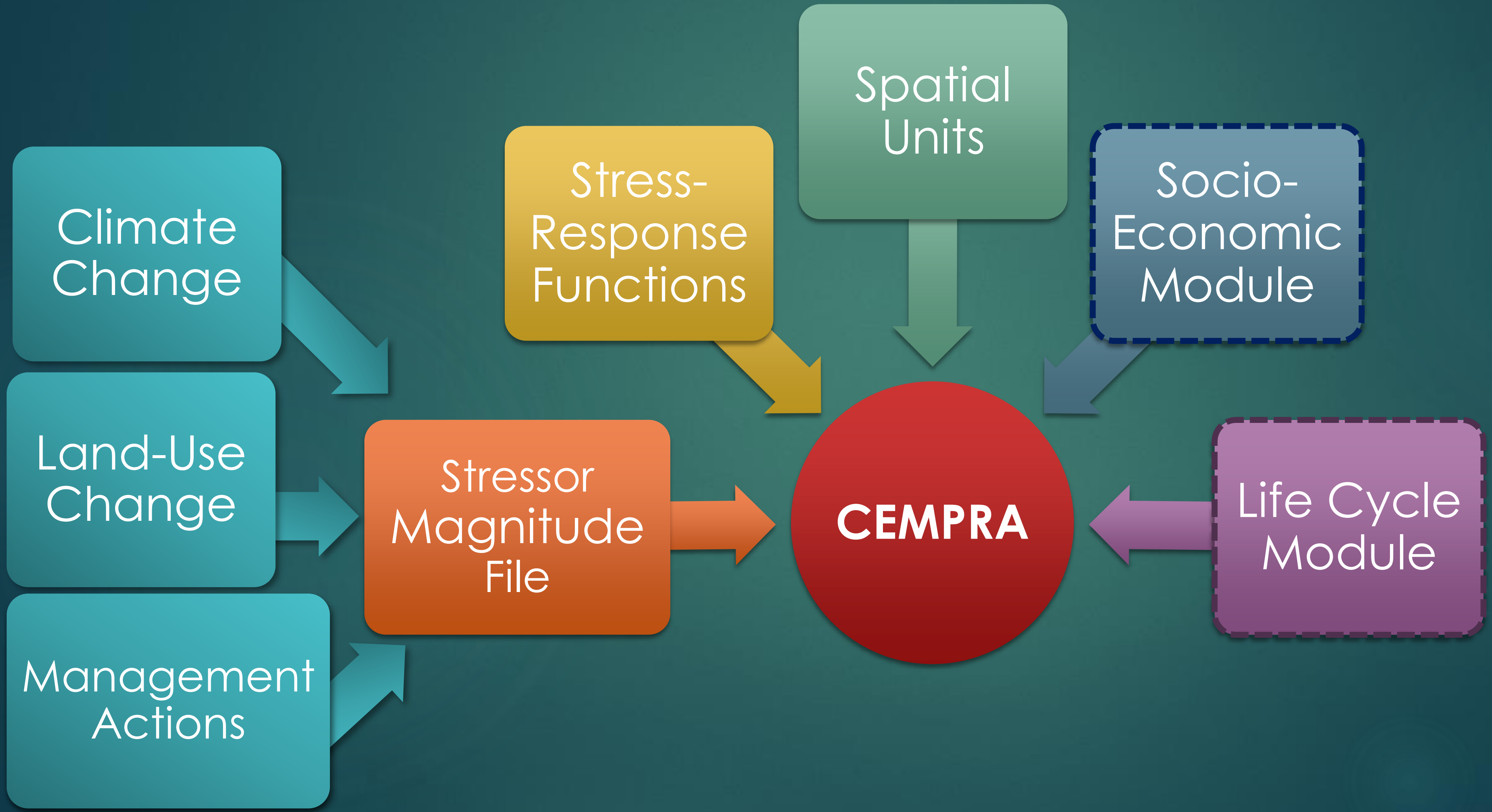


Climate Change
Stress-Response Functions
Spatial Units
Socio-Economic Module
Stressor Magnitude File
CEMPRA
Life Cycle Module

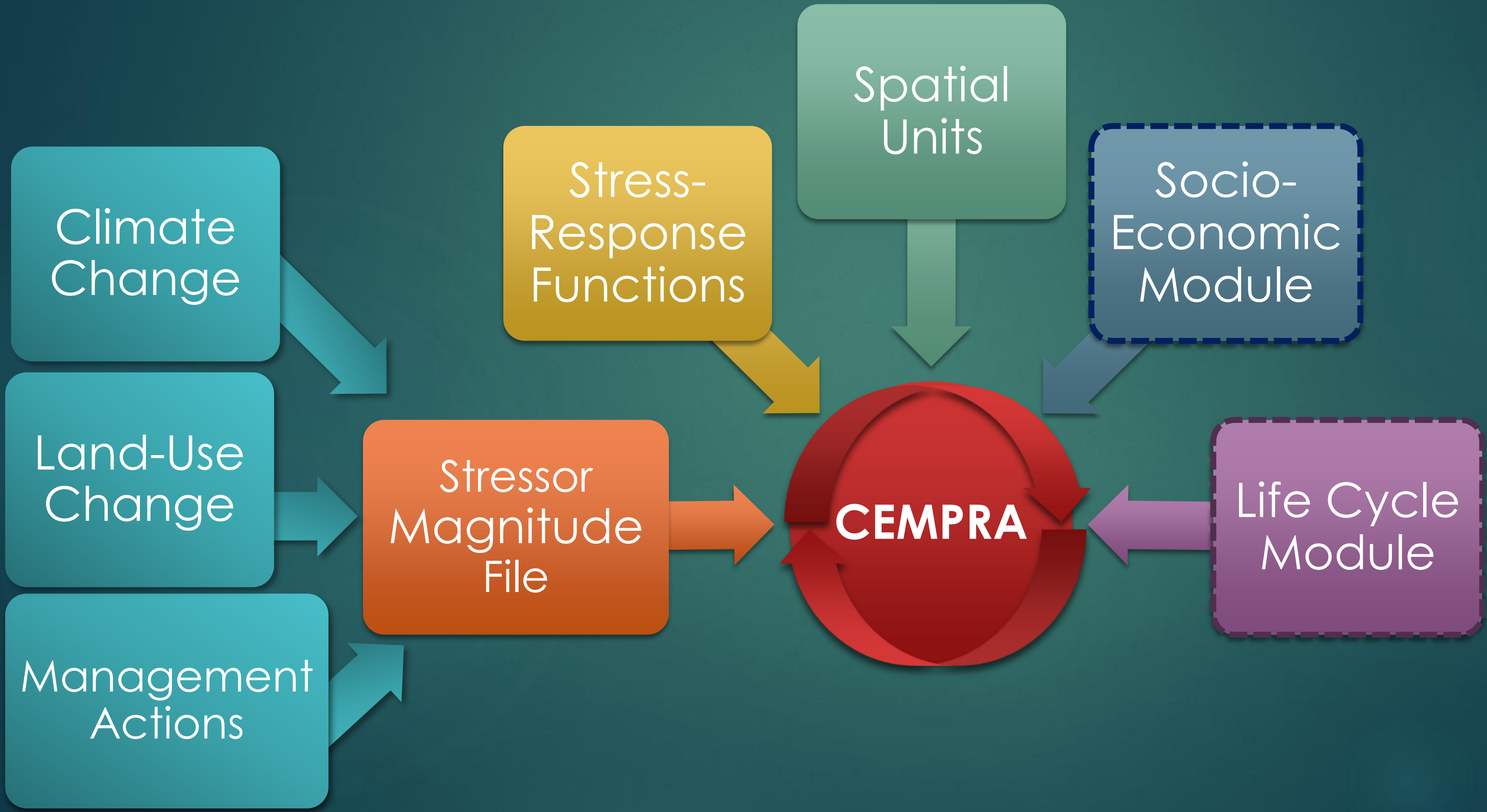
CEMPRA


Spatial Units
Stress-Response Functions
Socio-Economic Module
Climate Change
Land-Use Change
Stressor Magnitude File
CEMPRA
Life Cycle Module

CEMPRA


Climate Change
Land-Use Change
Management Actions
Stressor Magnitude File
Stress-Response Functions
Spatial Units
Socio-Economic Module
CEMPRA
Life Cycle Module

CEMPRA



Climate Change
Land-Use Change
Management Actions
Stressor Magnitude File
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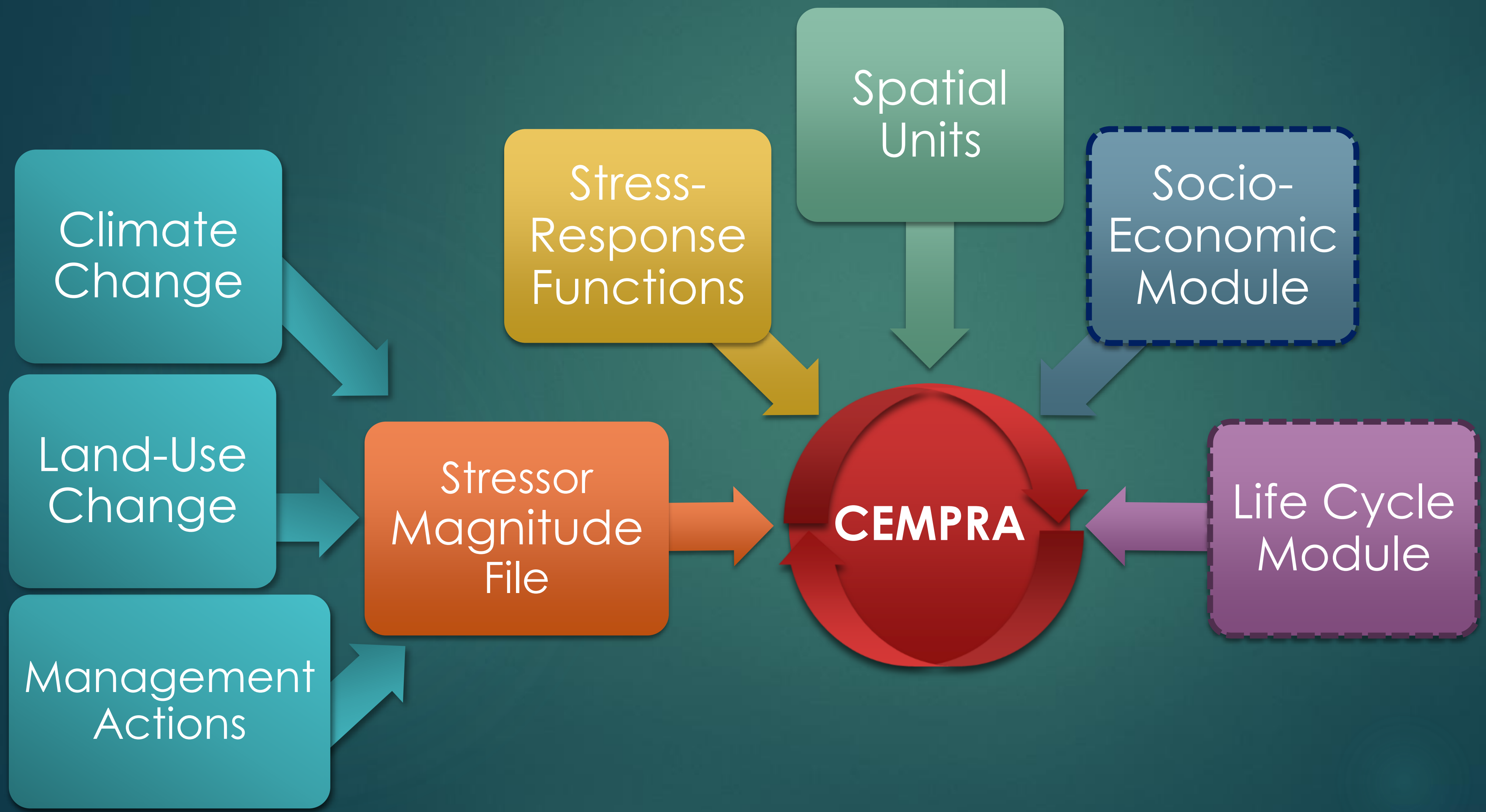
CEMPRA
Life Cycle Module

CEMPRA = Hypothesis Generator



Coastal Cutthroat Trout in BC

- Nearly 20 years since the last assessment
- No changes to legal protections and still data deficient
- CEMPRA framework allows for use to make hypotheses about threats on the landscape → where to prioritize efforts?
- Moving from risk descriptions to addressing risks on the landscape

Thank you!

John Hagen, *John Hagen and Associates, Prince George BC*
Brendan Anderson, *Ministry of Water, Land and Resource Stewardship, BC Provincial Government*
Sue Pollard, *Freshwater Fisheries Society of BC, Victoria BC*
Ron Ptolemy, *Ministry of Water, Land and Resource Stewardship, BC Provincial Government*
Jordan Rosenfeld, *UBC Institute for the Oceans and Fisheries*
Matthew Bayly, *MJBA, ESSA Technologies Ltd.*
Alexandra Tekatch, *ESSA Technologies Ltd.*
Eva Enders, *INRS*
Lauren Jarvis, *Department of Fisheries and Oceans*
Andrew Paul, *Alberta Environment and Protected Areas*
Kyle Wilson, *Central Coast Indigenous Resource Alliance*
Pedro Gonzalez, *University of British Columbia*
Laura MacPherson, *Alberta Environment and Protected Areas*
Jessica Reilly, *Alberta Environment and Protected Areas*
Michael Sullivan, *Alberta Environment and Protected Areas*