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Ecological Flows Tool

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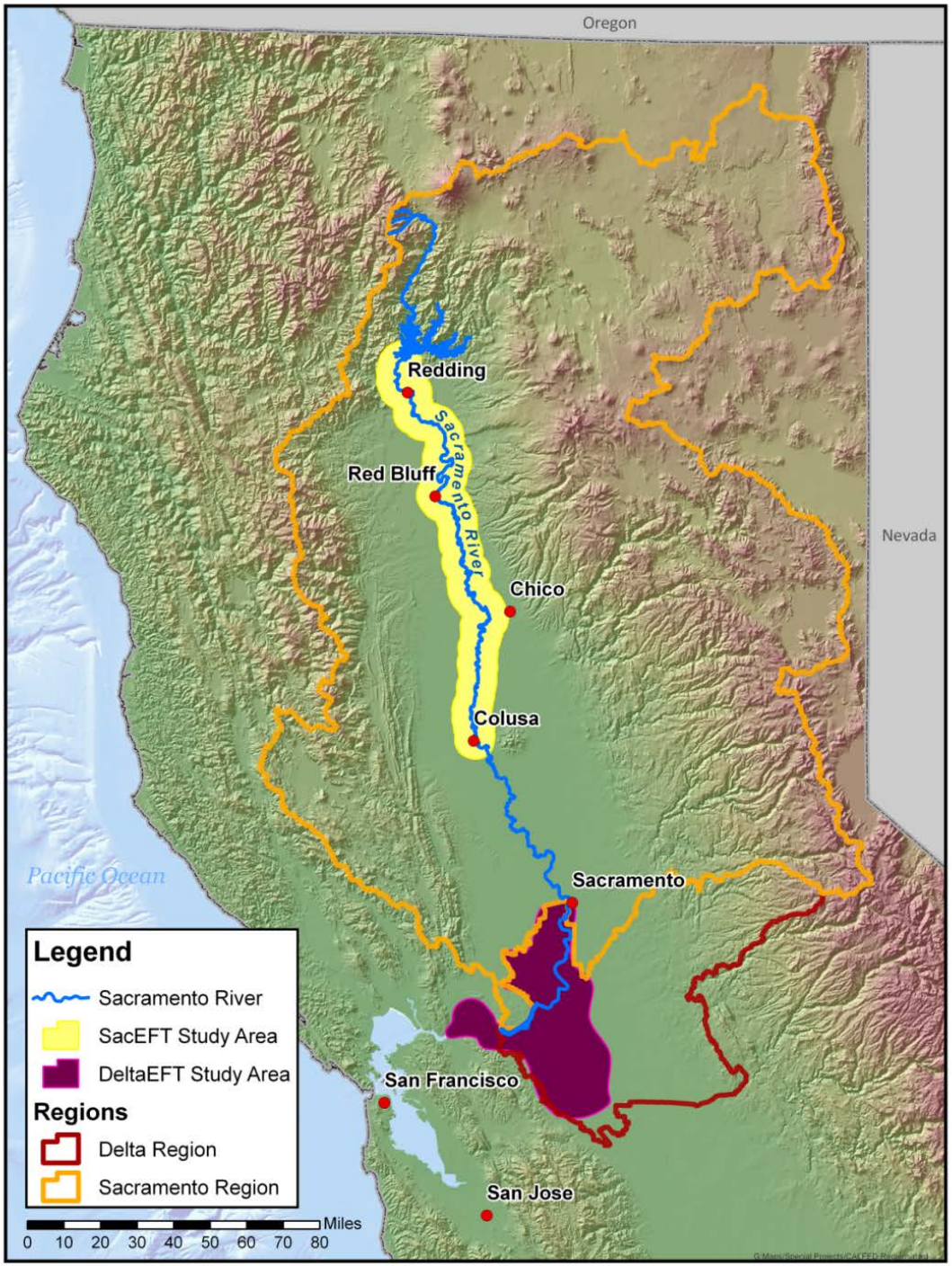

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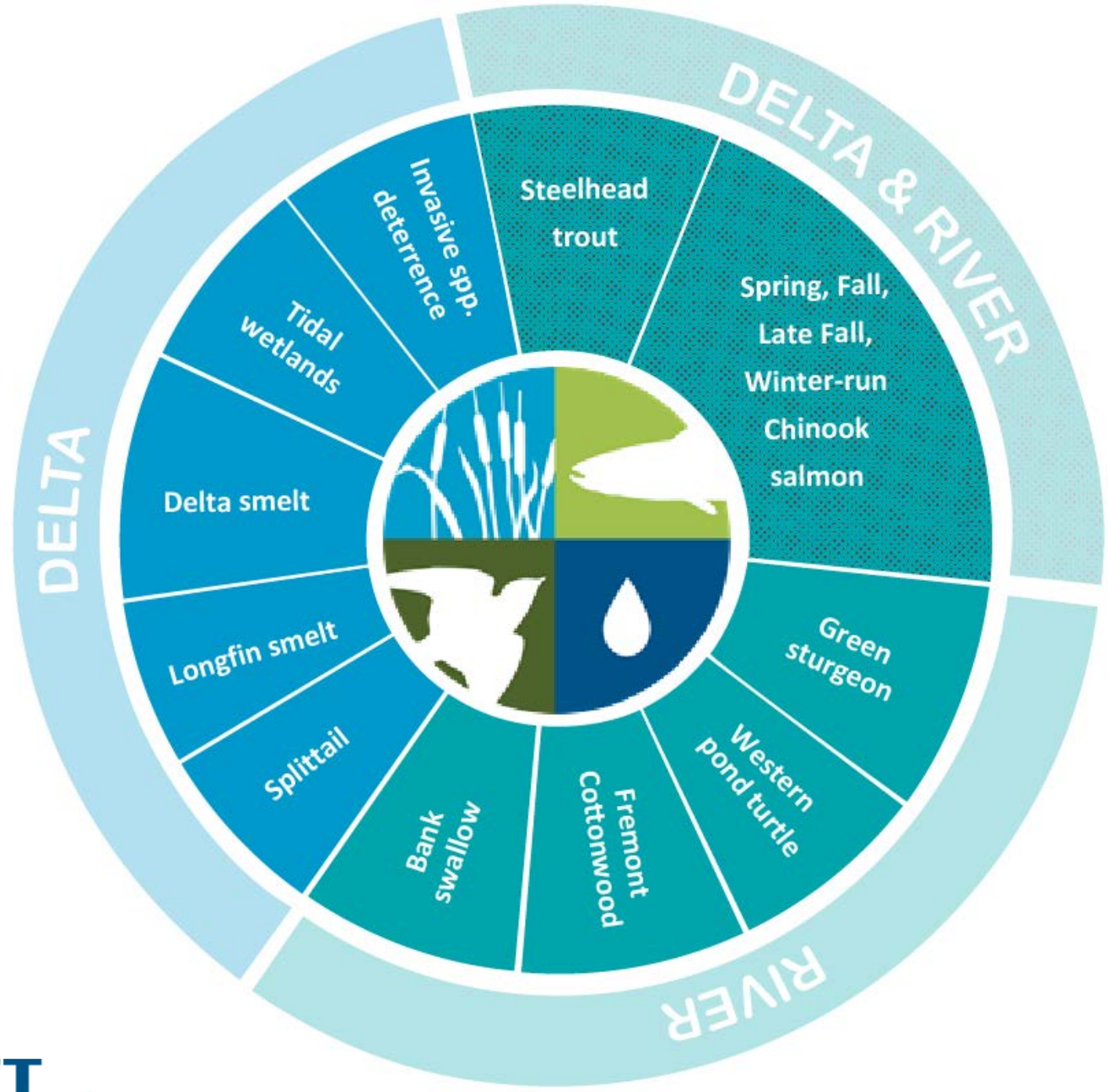

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Sacramento River

Sacramento River		
Focal Species & Habitats	**Performance Measures**	
Fremont cottonwood	FC1	Successful cottonwood initiation
	FC2	Cottonwood seedling scour
Bank swallow (BASW)	BASW1	Habitat potential/suitability
	BASW2	Risk of nest inundation and bank sloughing during nesting
Western pond turtle	LWD1	Index of old vegetation recruited to the Sacramento River mainstem
Green sturgeon (GS)	GS1	Egg-to-larvae survival
Chinook salmon, Steelhead trout (CS)	CS1	Area of suitable spawning habitat (ft2)
	CS3	Egg-to-fry survival (proportion)
	CS5	Redd scour
	CS6	Redd dewatering (proportion)
	CS2	Area of suitable rearing habitat (ft2)
	CS4	Juvenile stranding (index)

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Delta

Delta Ecoregion		
Focal Species & Habitats	**Performance Measures**	
Chinook & Steelhead (CS)	CS7	Smolt weight gain in alt. migration corridors
	CS9	Smolt mortality index as a funtion of passage time (negatively correlated with CS7)
	CS10	Smolt temperature preference index (departures from optimum v. weight gain)
Delta smelt (DS)	DS1	Spawning success index
	DS2	Index of habitat suitability
	DS4	Entrainment risk (index)
Splittail (SS)	SS1	Proportion of maximum potential spawning habitat (index)
Fresh/brackish tidal wetlands (TW)	TW1	Brackish wetland area
	TW2	Freshwater wetland area
Invasive species deterrence (ID)	ID1	Brazilian waterweed suppression
	ID2	(Corbula) Invasive clam larvae and recruit suppression
	ID3	(Corbicula) Invasive clam larvae and recruit suppression

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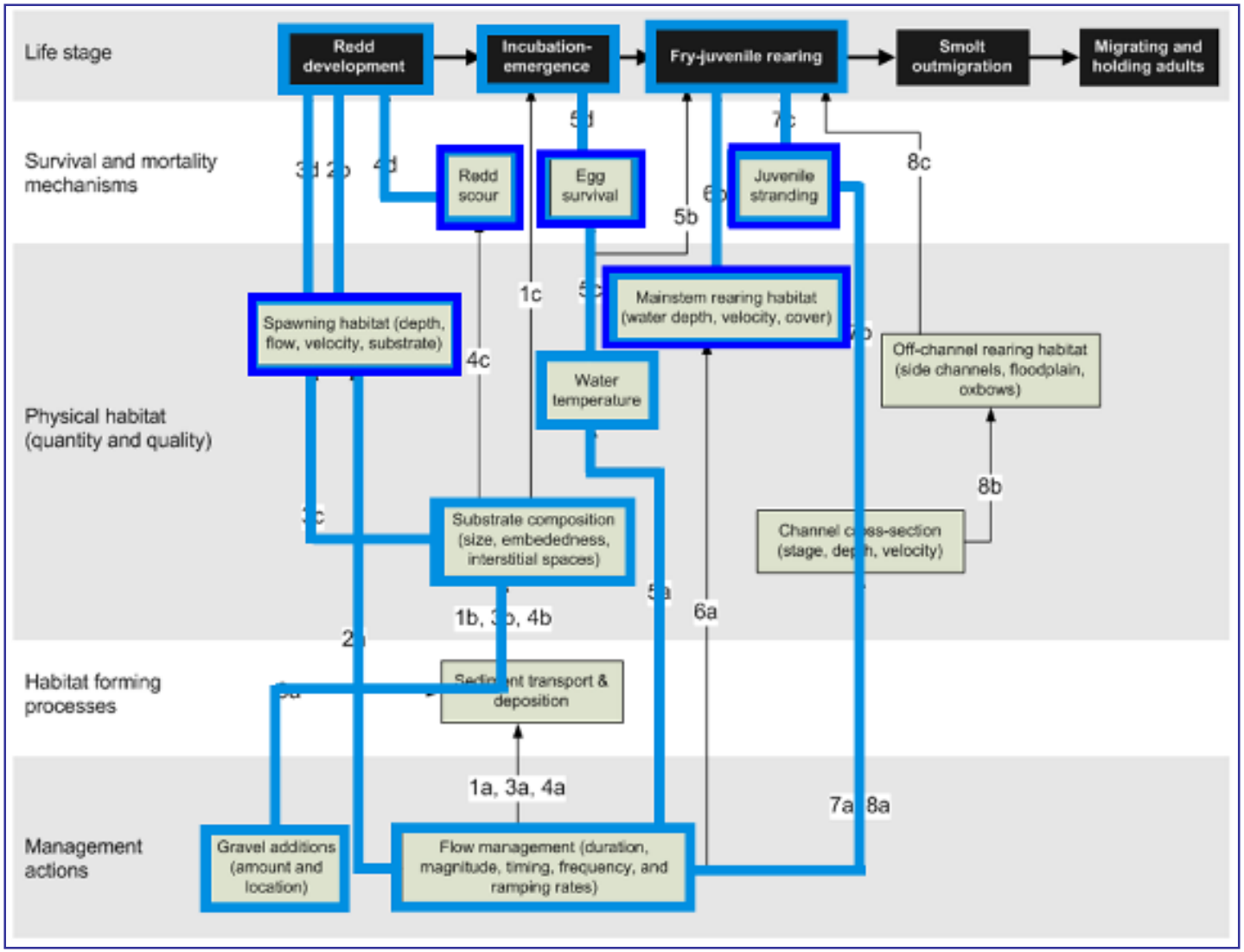
Conceptual models & functional relationships



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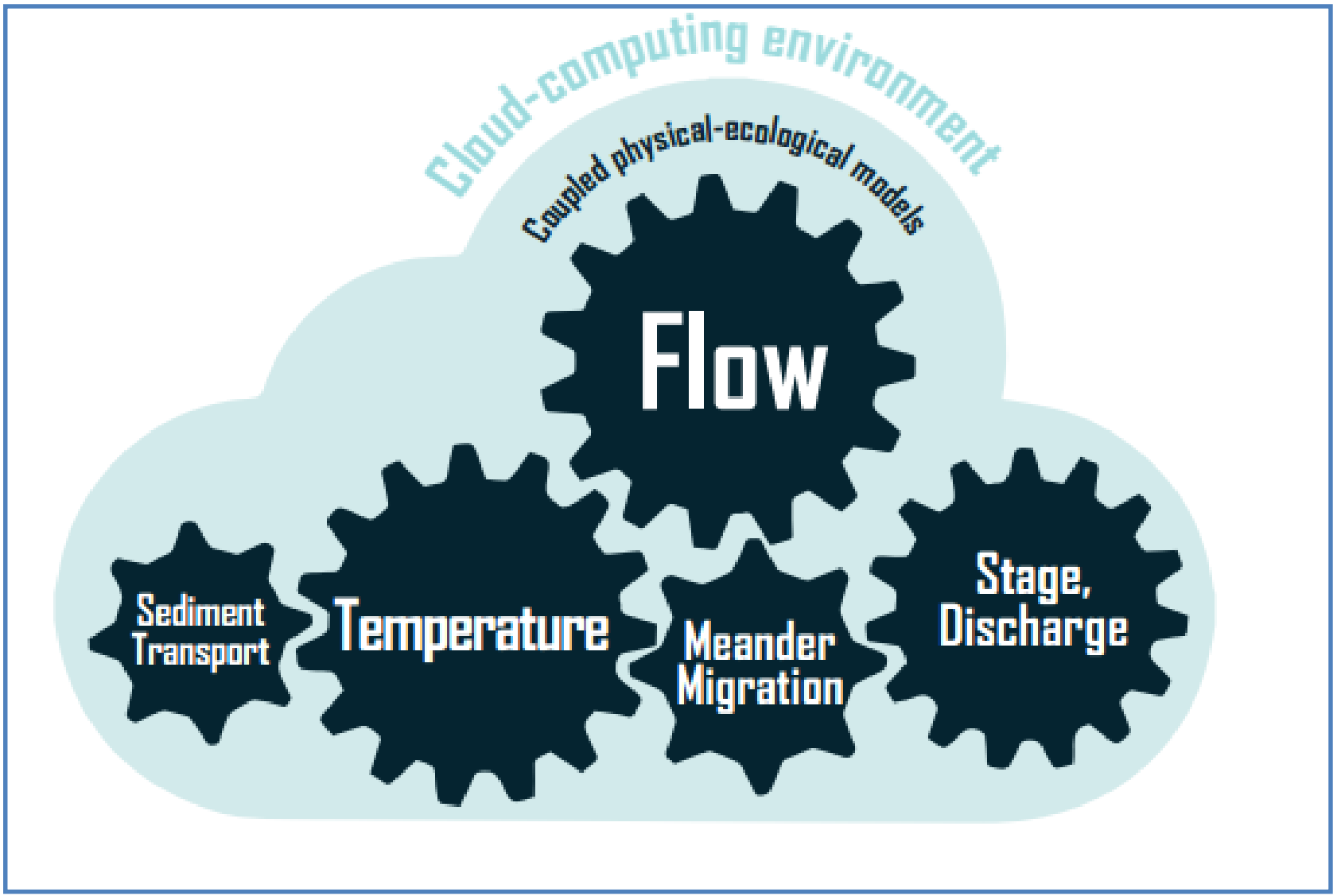
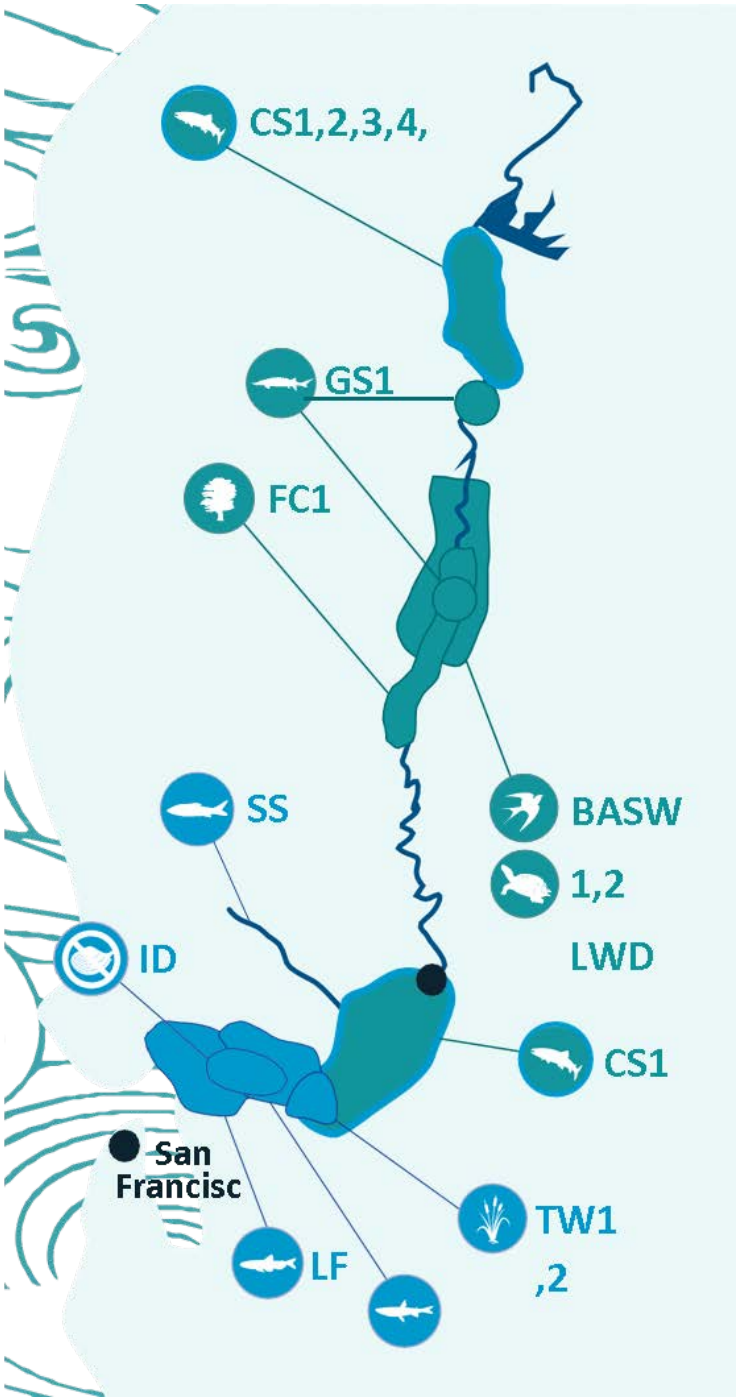
Coupled modelling



Spatially explicit analyses



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Multiple EFT outputs

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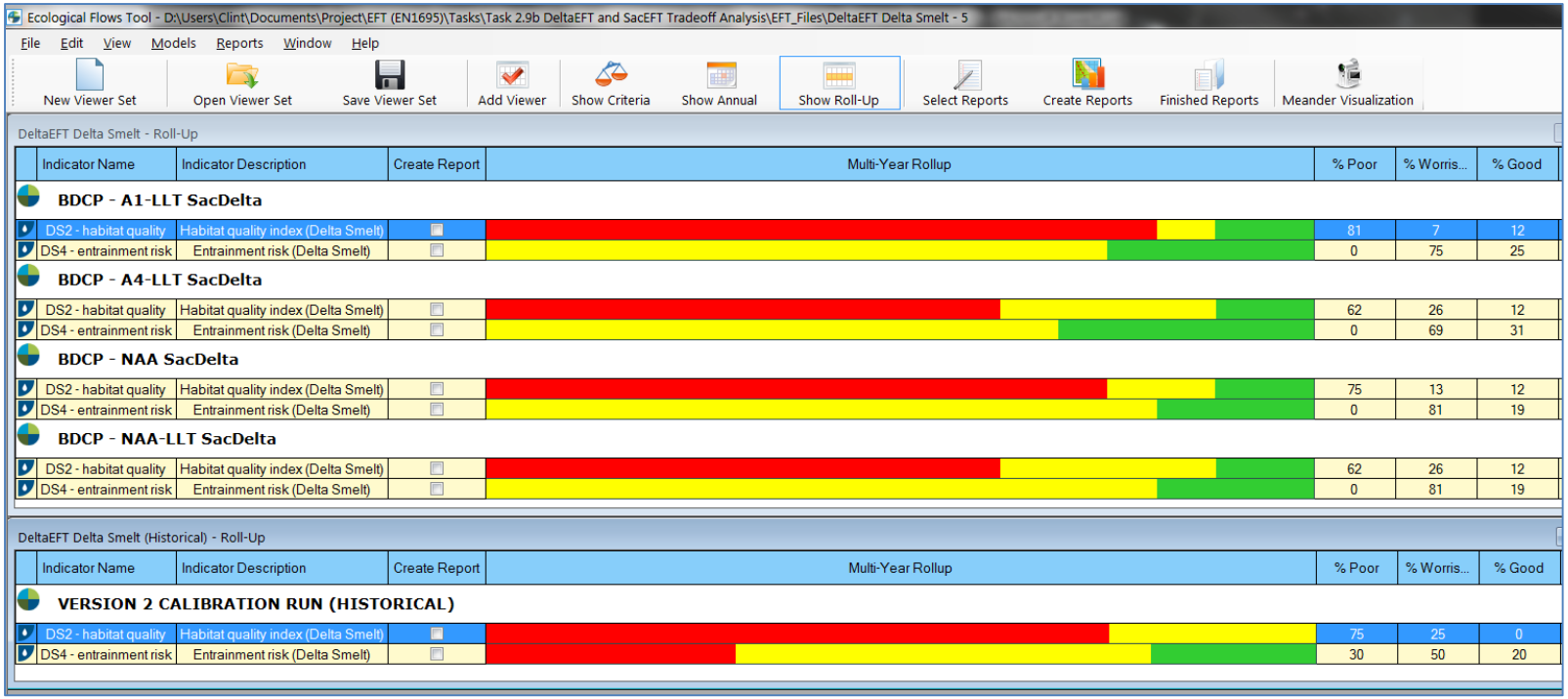
Relative suitability



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Absolute effect size

Focal species	Performance indicator (incomplete listing)	Reference case	Alt. 1	Alt. 2	Alt. *n*
Upper and Middle Sacramento River Indicators					
Fall Chinook	Suitable spawning habitat (CS1; 000s ft^2)	3,738	4,081 (9.2%)	4,069 (8.9%)	3,998 (6.9%)
Late Fall Chinook	Suitable spawning habitat (CS1; 000s ft^2)	1,272	1,195 (-6.0%)	1,187 (-6.7%)	1,232 (-3.1%)
Winter Chinook	Juvenile stranding index (CS4)	0.085	0.106 (-2.1%)	0.094 (-0.9%)	0.101 (-1.6%)
	Suitable rearing habitat (CS2; 000s ft^2)	37,153	37,602 (1.2%)	37,804 (1.8%)	37,101 (-0.1%)

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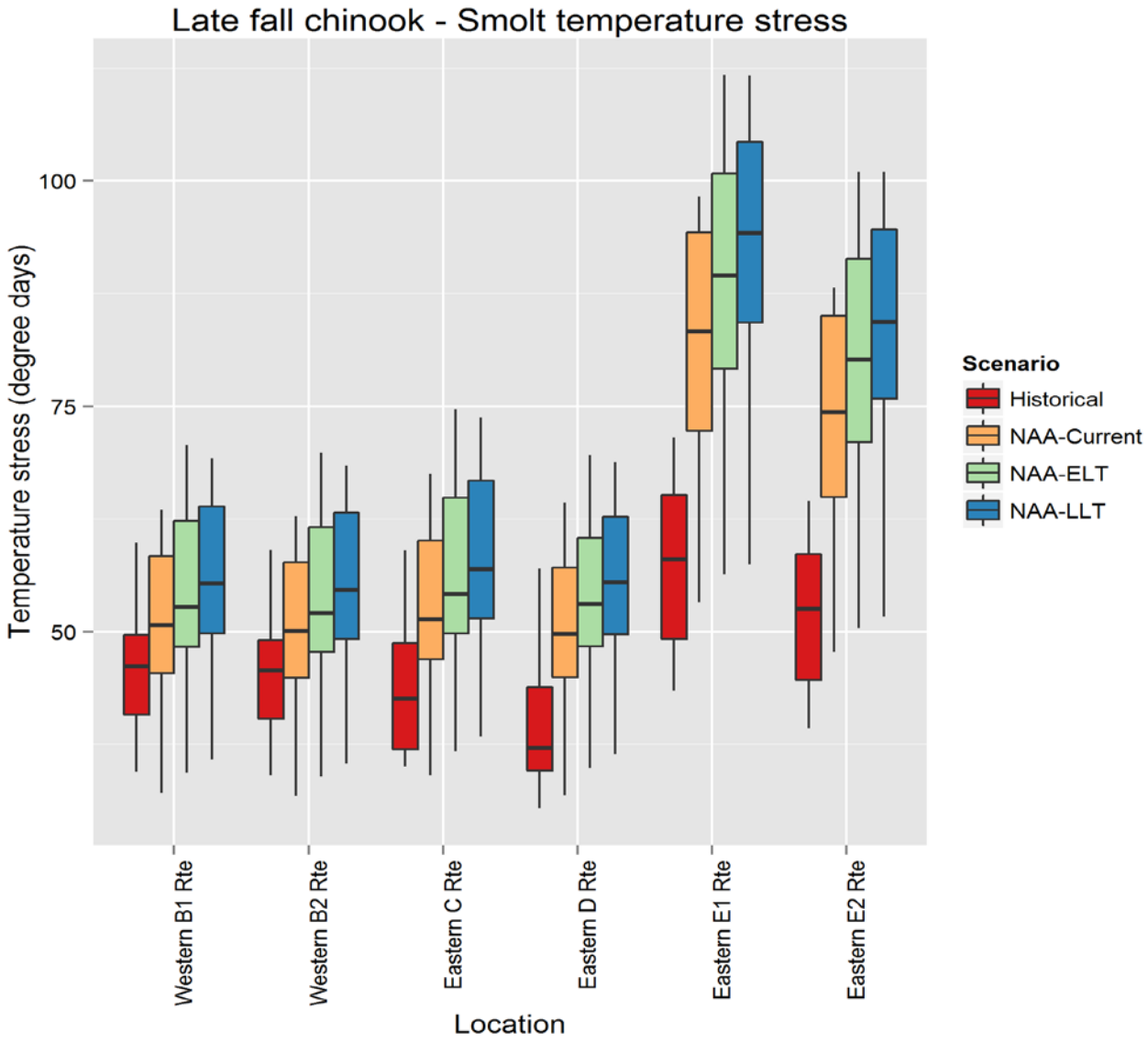
Effect size box plots



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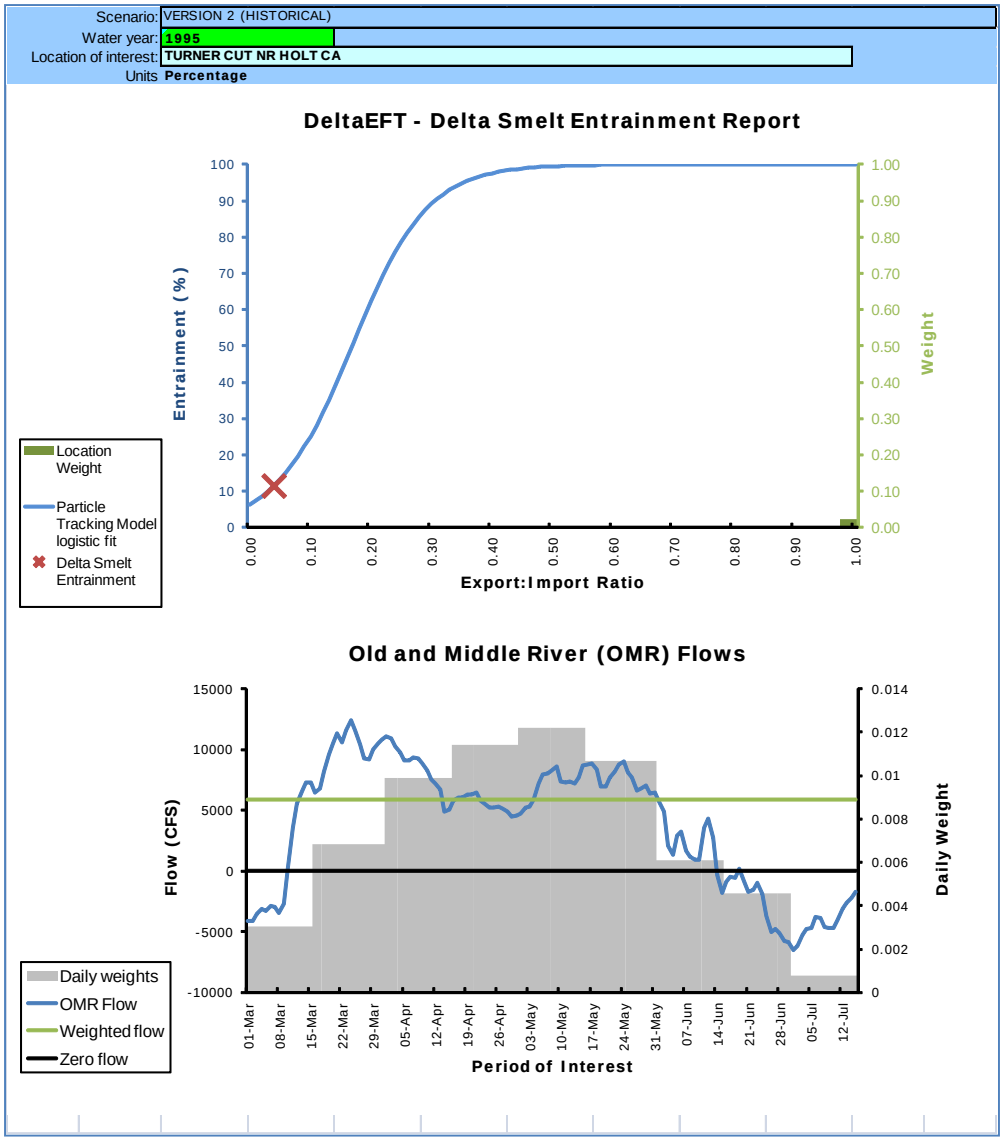
Yearly, monthly, daily, hourly results



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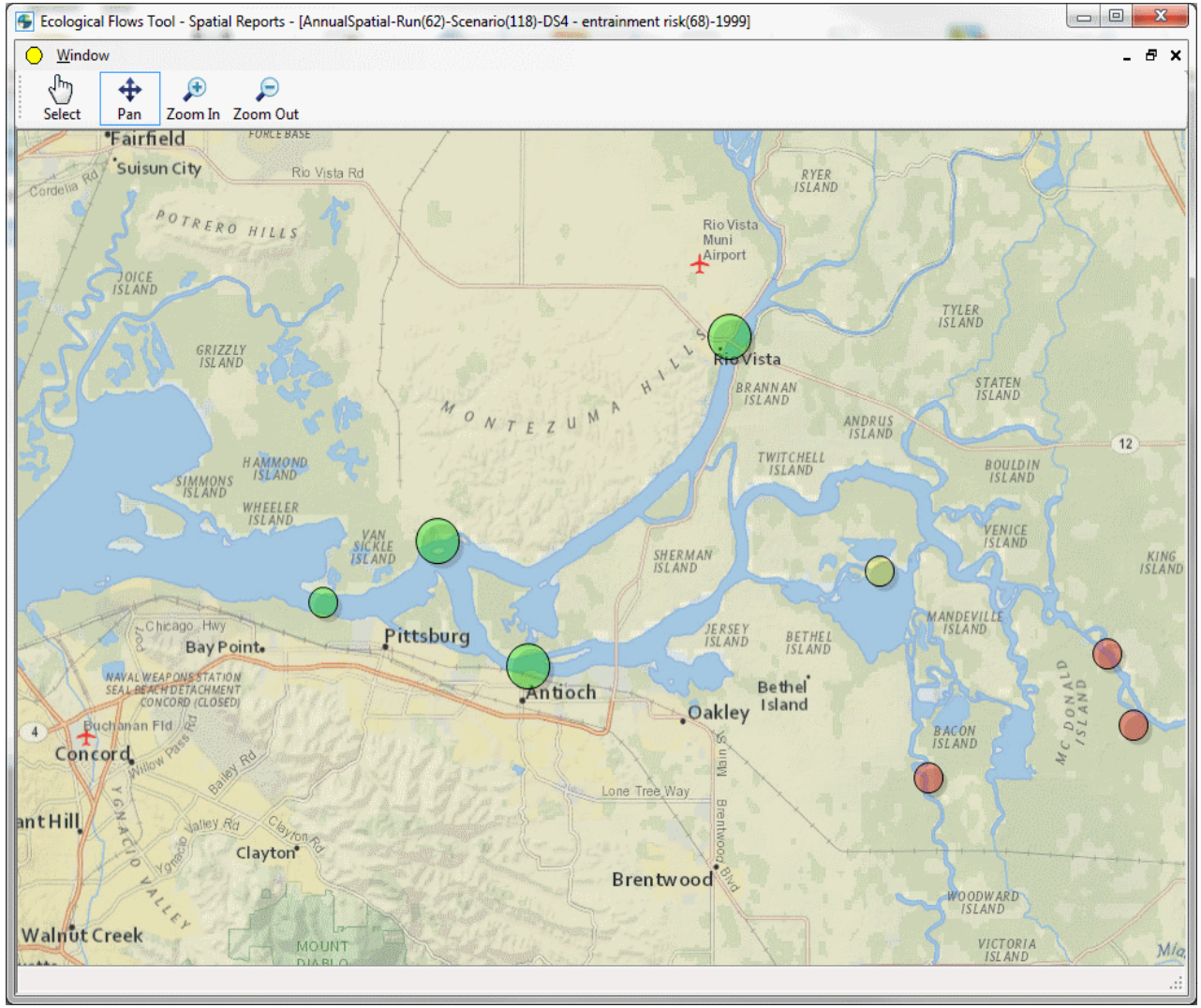
Spatial visualizations



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Net effect scores

	Upper & Middle Sacramento River Ecoregion					
	ESO		LOS		HOS	
	+	–	+	–	+	–
Fall	5		5		5	
Late Fall	1-ES		1-ES			
Spring	3-ES		5		3-RS	
Winter	1-RS					
Steelhead						
Bank swallow						
Green Sturgeon		3-RS		3-RS		3-RS
Cottonwood	1-ES		1-ES			
Woody Debris	1-RS					
	Delta Ecoregion					
Fall	+/–		+/–			
Late Fall		3-ES		3-ES		2-ES
Spring	+/–		+/–			
Winter		3-ES		3-ES		2-ES
Steelhead		3-ES		3-ES		2-ES
Splittail	6		6		6	
Delta smelt				6		
Longfin smelt					6	
Invasives		3-ES		4		3-ES
Tidal wetlands		3-RS		3-RS		3-RS

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EFT applications to date

1. Shasta Lake Water Resources Investigation
2. Sites Reservoir analysis
3. BDCP upstream effects analyses
4. BDCP alternatives analyses

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Target flow guidelines

Splittail		
Indicator	**SS1**	**Spawning habitat extent (Yolo)**
Objective & Rationale	Maintaining flow regimes that result in periodic inundation of riparian and floodplain habitat during winter and spring is important for splittail viability. When flooded, the majority of splittail spawning habitat is located in Yolo bypass, consequently inundation of the floodplain plays a large role in determining the extent of available spawning habitat. (DeltaEFT Design Document Section 2.2.3, pp. 100-105).	
Timing	O N D J F M A M J J A S (Feb 21)	
Location	Fremont Weir (FREMONT WEIR SPILL TO YOLO BYPASS NR VERONA CA, RSAC155, 11391021)	
Variable & Condition	100 < Q_{avg} < 2000 cfs for at least 75% of the period shown (approx. four weeks within this period)	
Recurrence	4 out of 10 years	
Potential conflicts & trade-offs	Notching Fremont Weir should provide habitat	
References	Moyle et al. (2004); Sommer *et al.* (2002), Feyrer *et al.* (2006)	
Delta Smelt		
Indicator	**DS4**	**Entrainment index**
Objective & Rationale	The indicator simulates entrainment risk from the CVP and SWP export operations. The indicator applies only to the larval and juvenile life stages. Low flow years historically have higher incidences of entrainment than high flow years because fish are distributed closer to the points of diversion. The indicator is based on the results of a Particle Tracking Model (PTM) experiment (Kimmerer and Nobriga 2008). (Design Document Section 2.2.2, pp. 89-100).	
Timing	O N D J F M A M J J A S	
Locations	Combined Old + Middle River (OLD R A BACON ISLAND CA, ROLD024, 11313405) + (MIDDLE R AT MIDDLE RIVER CA, RMID015, 11312676)	
Variable & Condition	≤ Normal WYT: Q_{avg} > −2,000cfs > Normal WYT: Q_{avg} > 0cfs	
Other Triggers	Juvenile smelt detected through trawls	
Recurrence	Annually	
Potential conflicts & trade-offs	May conflict with export objectives	
References	Kimmerer and Nobriga (2008); Moyle (1992); Sommer *et al.* (1997); Nobriga *et al.* (2001).	

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Persistent conflicting trade-offs…

Fall Chinook	Spawning WUA (CS1)	-14
	Thermal egg mortality (CS3)	4
	Redd Dewatering (CS6)	-1
	Redd Scour (CS5)	0
	Juvenile Stranding (CS4)	0
	Rearing WUA (CS2)	-5
Late Fall Chinook	Spawning WUA (CS1)	-2
	Thermal egg mortality (CS3)	0
	Redd Dewatering (CS6)	1
	Redd Scour (CS5)	0
	Juvenile Stranding (CS4)	0
	Rearing WUA (CS2)	3
Spring Chinook	Spawning WUA (CS1)	-15
	Thermal egg mortality (CS3)	11
	Redd Dewatering (CS6)	36
	Redd Scour (CS5)	2
	Juvenile Stranding (CS4)	5
	Rearing WUA (CS2)	-12
Winter Chinook	Spawning WUA (CS1)	35
	Thermal egg mortality (CS3)	2
	Redd Dewatering (CS6)	21
	Redd Scour (CS5)	0
	Juvenile Stranding (CS4)	34
	Rearing WUA (CS2)	-10
Steelhead	Spawning WUA (CS1)	-1
	Thermal egg mortality (CS3)	0
	Redd Dewatering (CS6)	-2
	Redd Scour (CS5)	3
	Juvenile Stranding (CS4)	2
	Rearing WUA (CS2)	-13
Bank Swallow	Habitat Potential (BASW1)	0
	Flow Suitability (BASW2)	0
Green Sturgeon	Egg Temperature Preference (GS1)	-7
Fremont Cottonwood	Seedling Initiation (FC1)	NULL
	Scour Risk (FC2)	7
Large Woody Debris	LWD Recruitment (LWD)	-

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The problem

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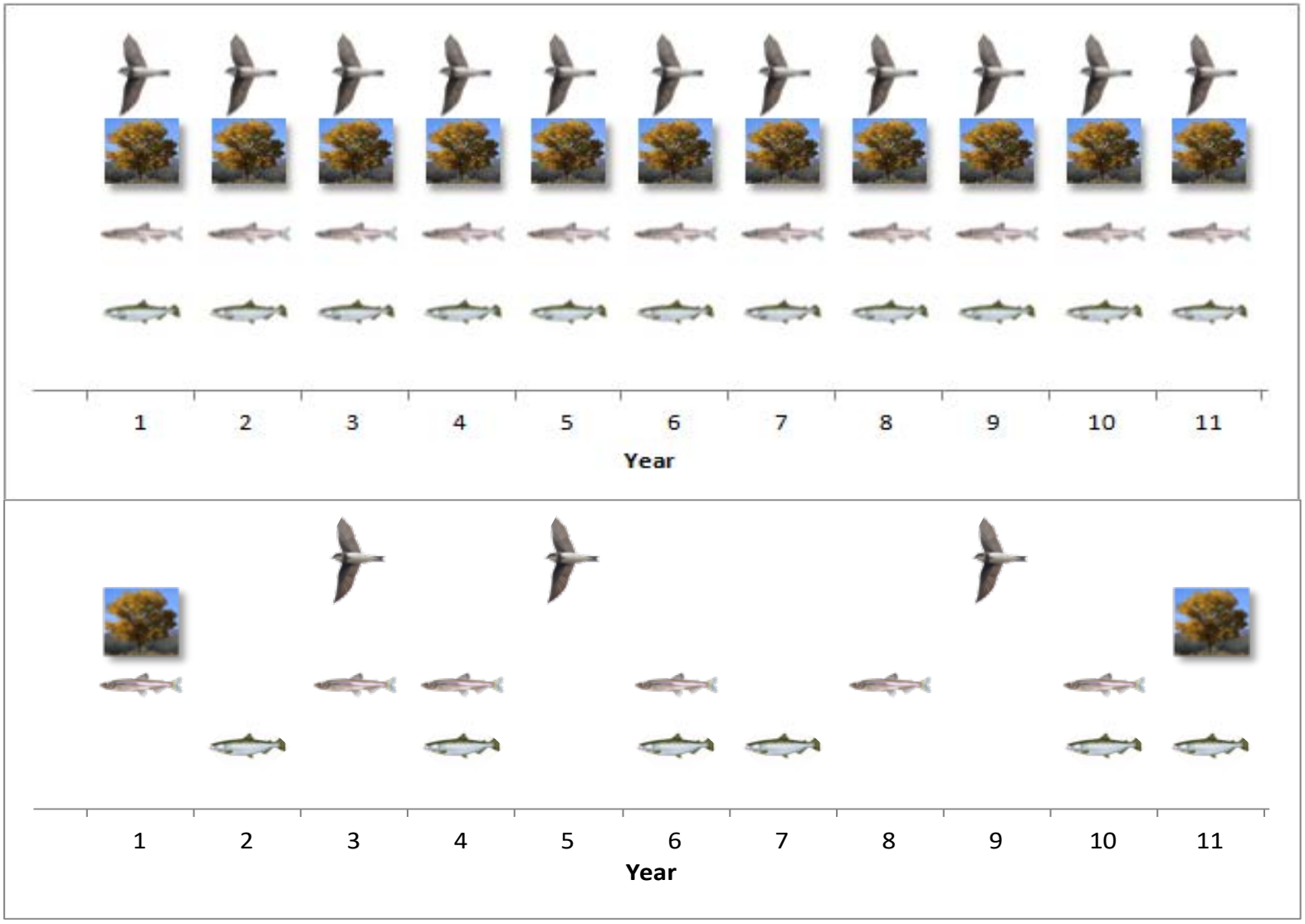
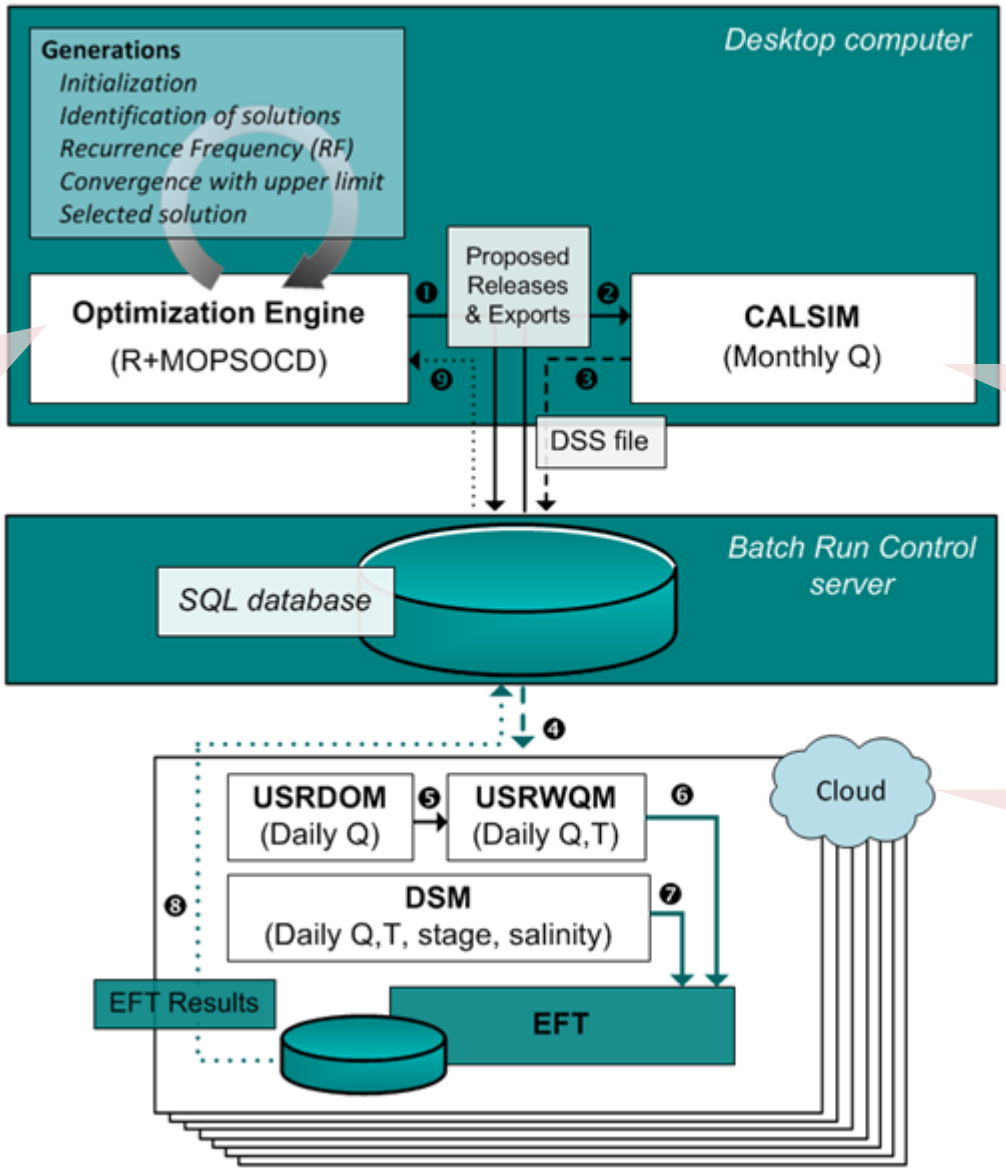
An alternative paradigm: turn taking optimization



Turn-taking optimization

Search uses Particle Swarm Optimization algorithm



Reconfigured CALSIM modeling suite to run in *single year mode*

Uses *cloud computing* for fast processing

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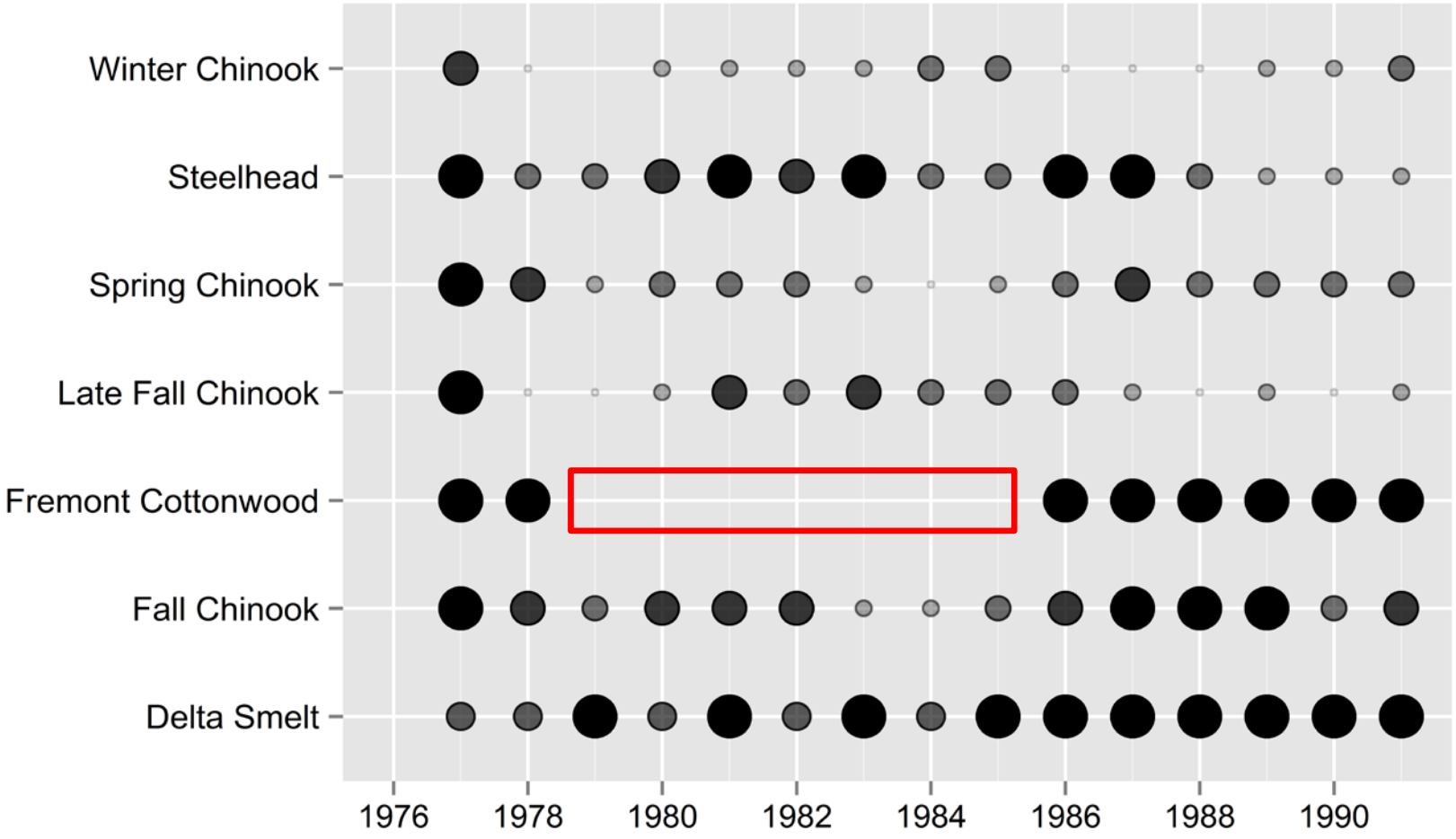
State-dependent piorities increase potential solutions



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Ecological results of turn-taking

Indicator	Number	Improved	Same	Worse
Fall Chinook	5	2	1	2
Late Fall Chinook	5	1	4	
Winter Chinook	5	5		
Spring Chinook	5	2	2	1
Steelhead	5	1	2	2
Fremont cottonwood	1	1		
Delta smelt	3		3	
Splittail	1		1	
Longfin smelt	1		1	
Total	**31**	**12**	**14**	**5**

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Key messages

1. No single best way to operate the water system.
2. EFT's turn taking optimization allows for more flexibility and solutions for more species.
3. Water managers need real-time operational tools paired with adaptive management to move beyond the status quo.

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Thank you!

Improving multi-objective ecological flow management with flexible priorities and turn-taking: a case study from the Sacramento River and Sacramento-San Joaquin Delta. - San Francisco Estuary & Watershed Science, March 2018.

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rluster@tnc.org

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