



# Improving multi-objective ecological flow management with flexible priorities and turn-taking

Clint Alexander

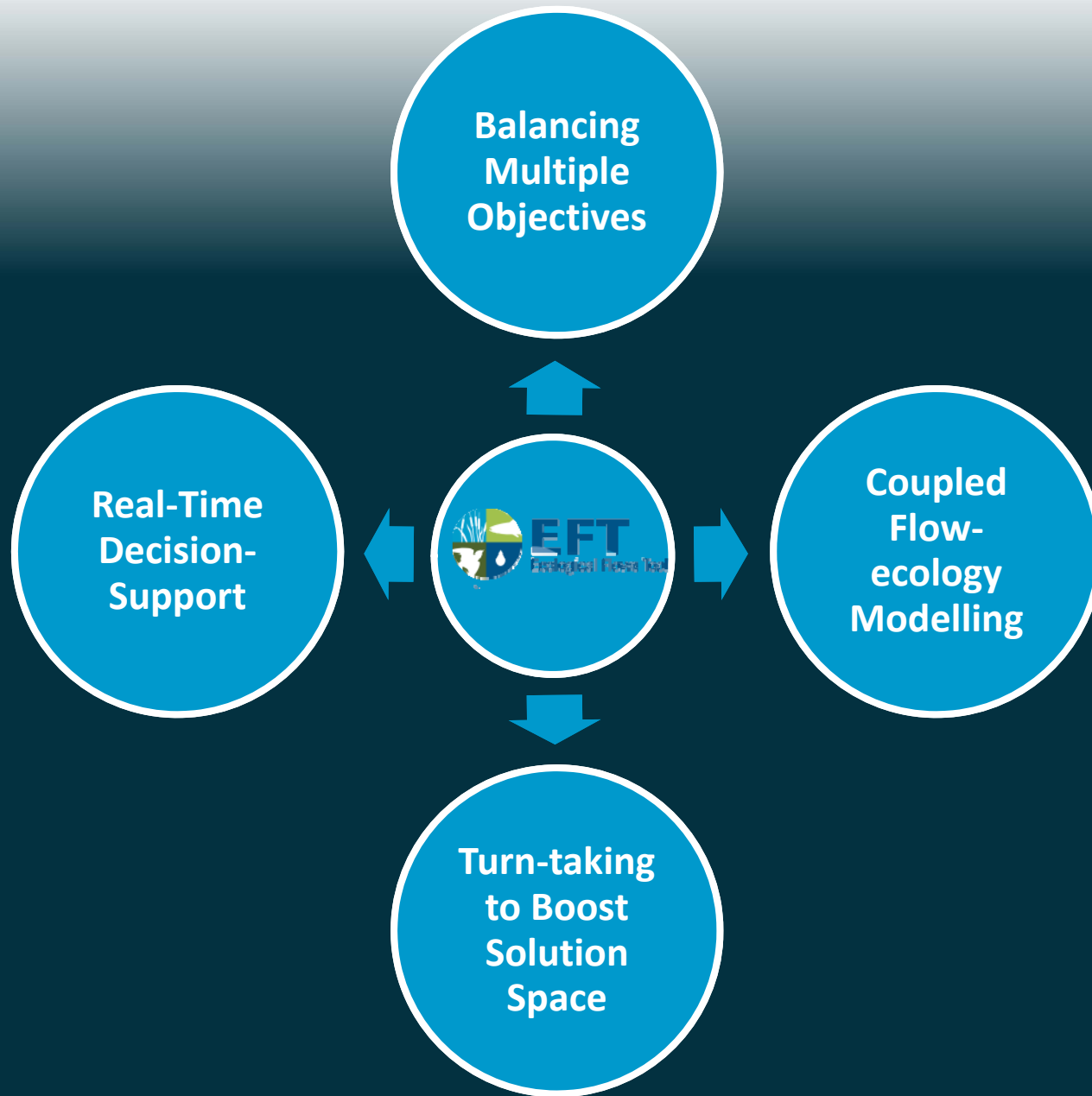


**ESSA**  
Technologies

The Nature  
Conservancy   
Protecting nature. Preserving life.



February 9, 2017







You can't  
always get  
what you want!



# Sacramento River Basin & San Francisco Bay-Delta "Family"



Steelhead trout



Chinook salmon



Green sturgeon



Invasive species deterrence



Bank swallow



Western pond turtle



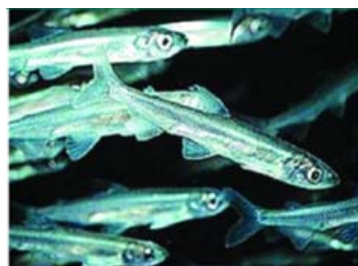
Fremont cottonwood



Tidal wetlands



Longfin smelt



Delta smelt



Splittail

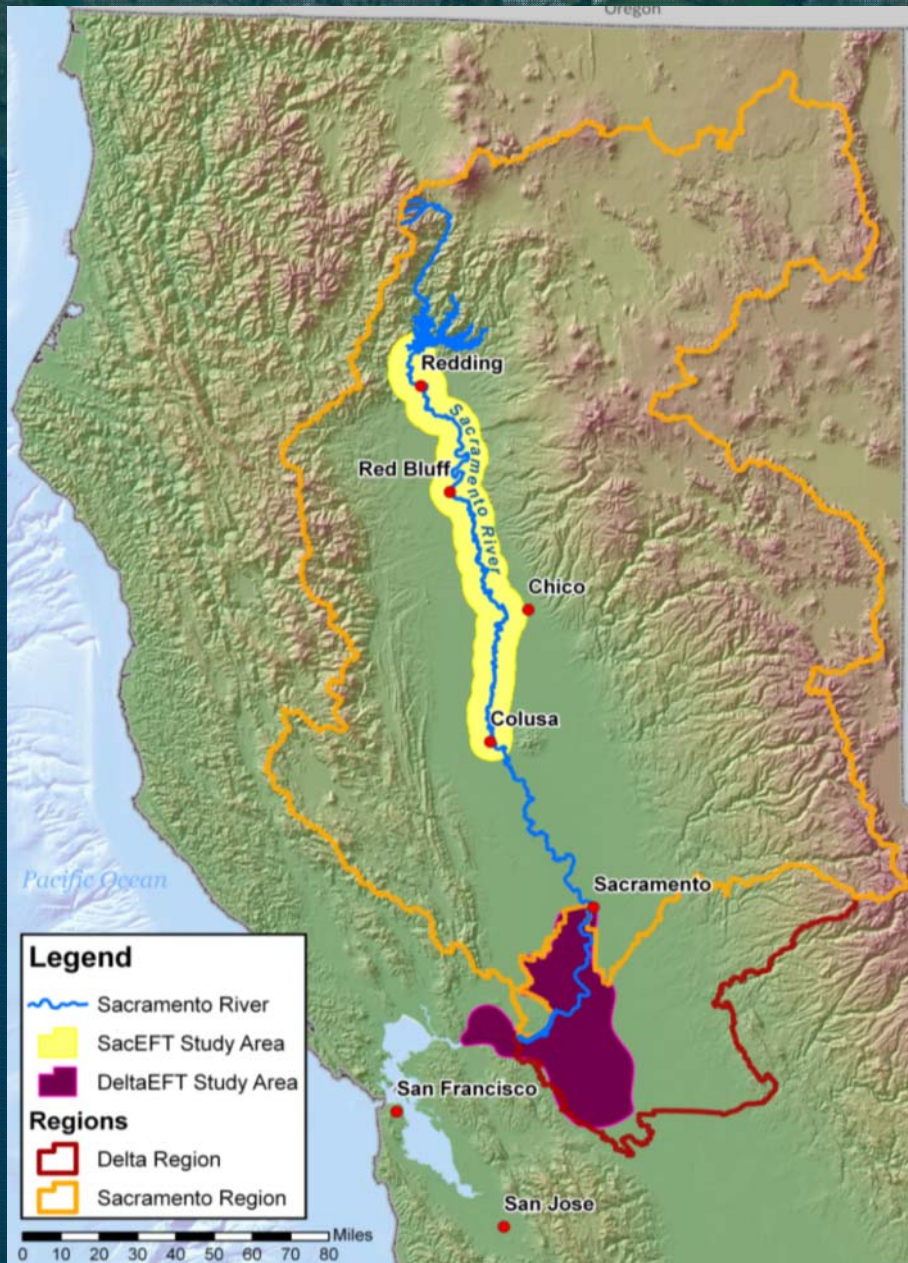


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**EFT**  
Ecological Flows Tool

# Sacramento River Basin and San Francisco Bay-Delta estuary

# California





# The Problem: **Rigid Water Management Regimes**

- **Limited flexibility**

- Complex layers of rules and regulations
- ESA & BiOps generate “winners and losers”

- **Sacramento River - simplistic flow targets**

- Min. flow targets; no high flow targets
- Few ramping rate targets
- Flow as proxy for desired outcome (e.g. spawning habitat)

- **Considers only a few solutions**

- Effects analysis modelling, State Water Board hearings, law suits
- Establishes set of relatively static priorities, decided in advance
- No one really evaluating larger number of alternative flow mgmt. regimes
- Disconnected tools brought together in somewhat ‘Rube Goldberg’ fashion
- Many trade-offs are poorly balanced through time






# Coupled Flow-Ecology Modelling – The Ecological Flows Tool



# 1 decision support platform

# 13 Species 25 indicators

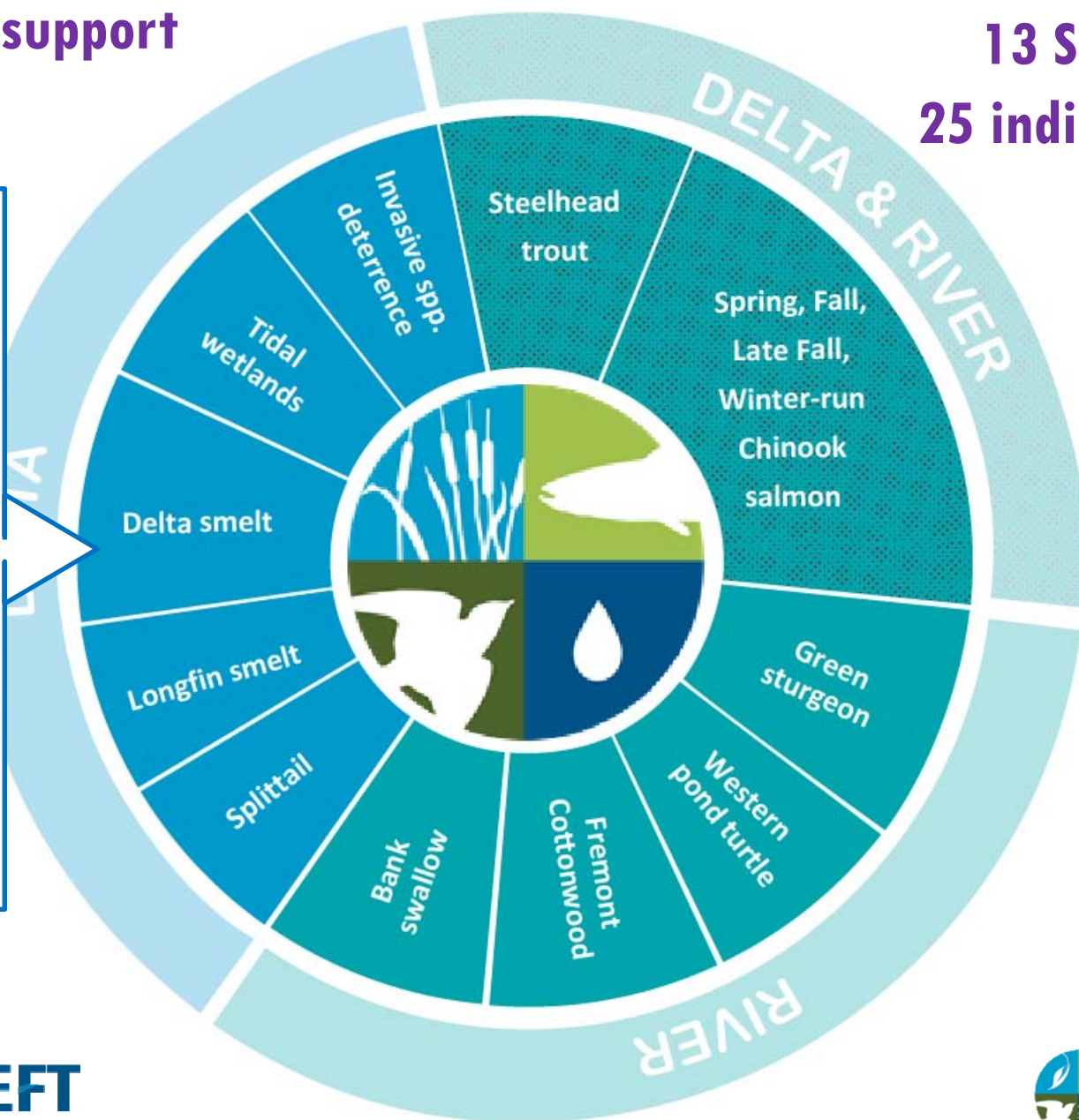
**Delta Smelt**



Spawning Success Index

Habitat Suitability Index

Entrainment Risk Index





# EFT

Ecological Flows Tool

**Application of the Ecological Flows Tool  
to Complement Water Planning Efforts  
in the Delta & Sacramento River**  
*Multi-Species Effects Analysis &  
Ecological Flow Criteria*

Ecosystem Restoration Program  
Agreement E0720044

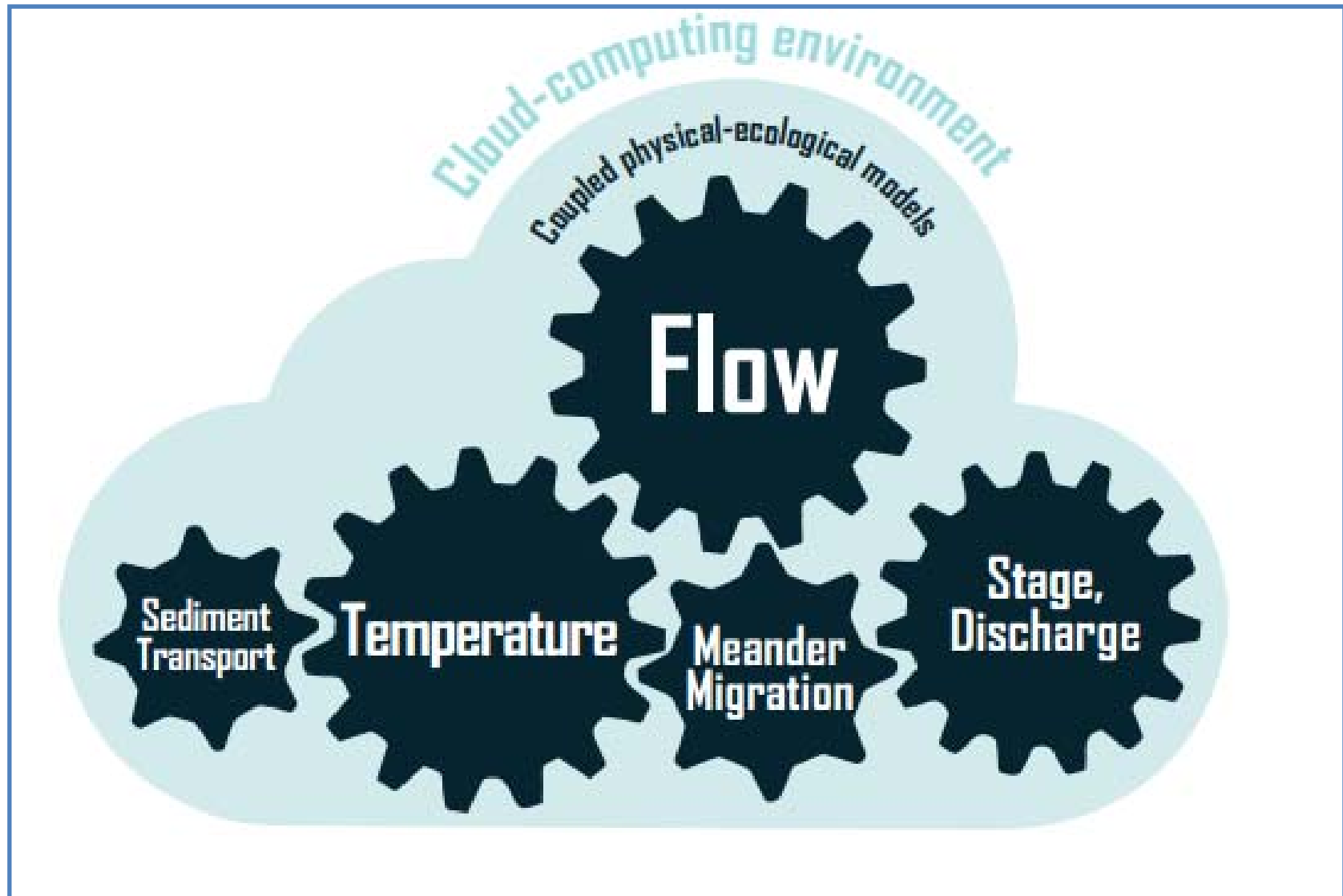
Final Report  
April 30, 2014

“EFT captures current knowledge in one place, builds community knowledge and is a great example of a decision support tool to reflect trade-offs in a very transparent manner. EFT is a great example tool for collaborative science”

~ Dr. Peter Goodwin, former  
Lead Scientist of the Delta  
Science Program

Google 'Research Gate Clint Alexander'

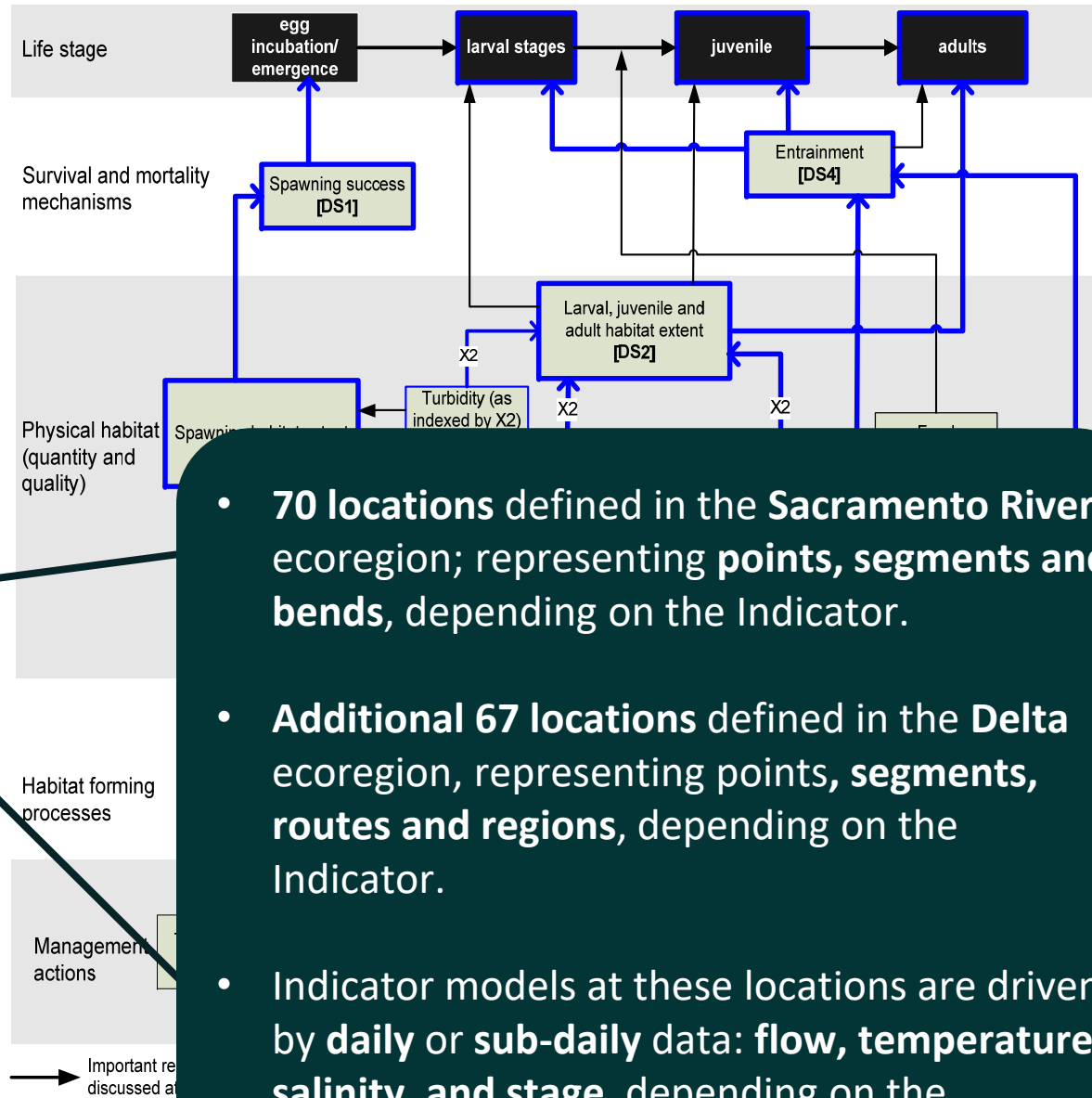
# Coupled modelling



# Conceptual Models linked to driving variables

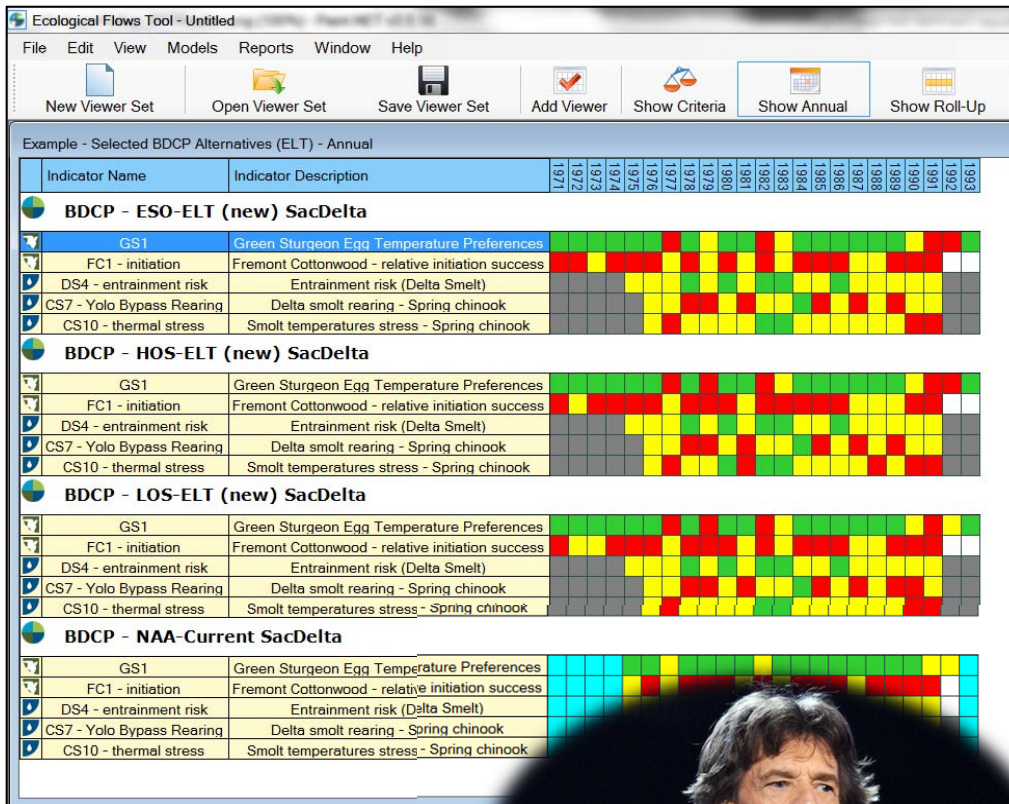
Input data (e.g. **temperature, salinity**) drive models at representative **locations and daily** timescale

Model **content** and **complexity** depend on state of scientific **knowledge** (e.g. peer literature, expert input)



- **70 locations** defined in the **Sacramento River** ecoregion; representing **points, segments and bends**, depending on the Indicator.
- **Additional 67 locations** defined in the **Delta** ecoregion, representing **points, segments, routes and regions**, depending on the Indicator.
- Indicator models at these locations are driven by **daily or sub-daily data: flow, temperature, salinity, and stage**, depending on the Indicator.

# Persistent conflicting trade-offs...



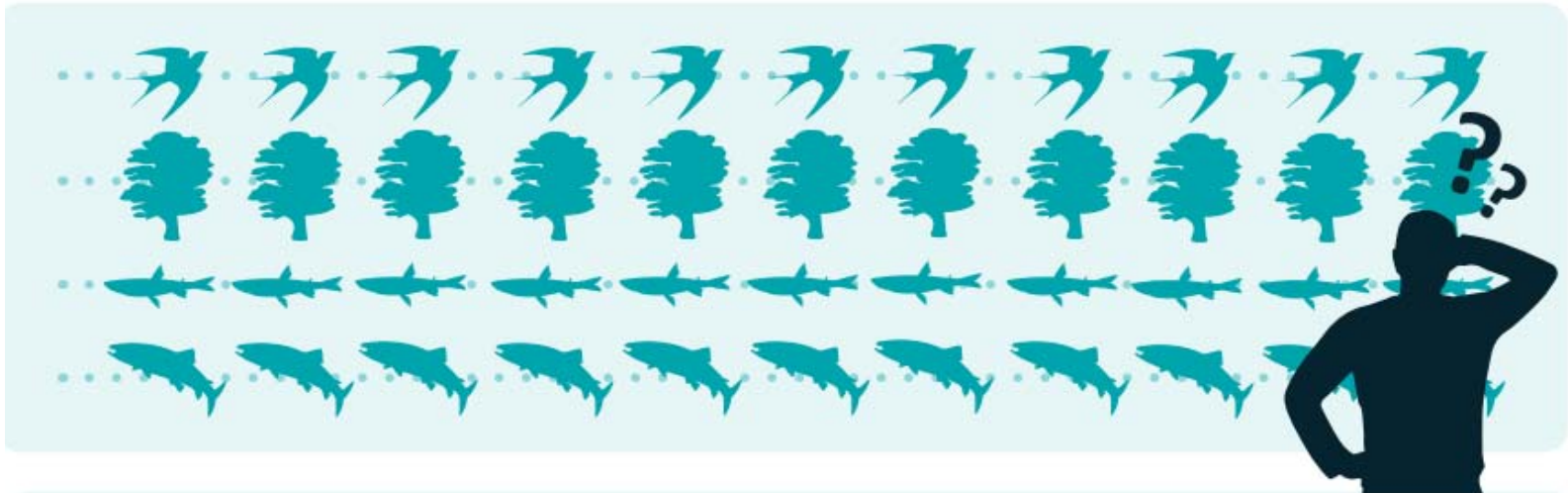
Fall Chinook	Spawning WUA (CS1)	-14
	Thermal egg mortality (CS3)	4
	Redd Dewatering (CS6)	-1
	Redd Scour (CS5)	0
	Juvenile Stranding (CS4)	0
	Rearing WUA (CS2)	-5
Late Fall Chinook	Spawning WUA (CS1)	-2
	Thermal egg mortality (CS3)	0
	Redd Dewatering (CS6)	1
	Redd Scour (CS5)	0
	Juvenile Stranding (CS4)	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)	-



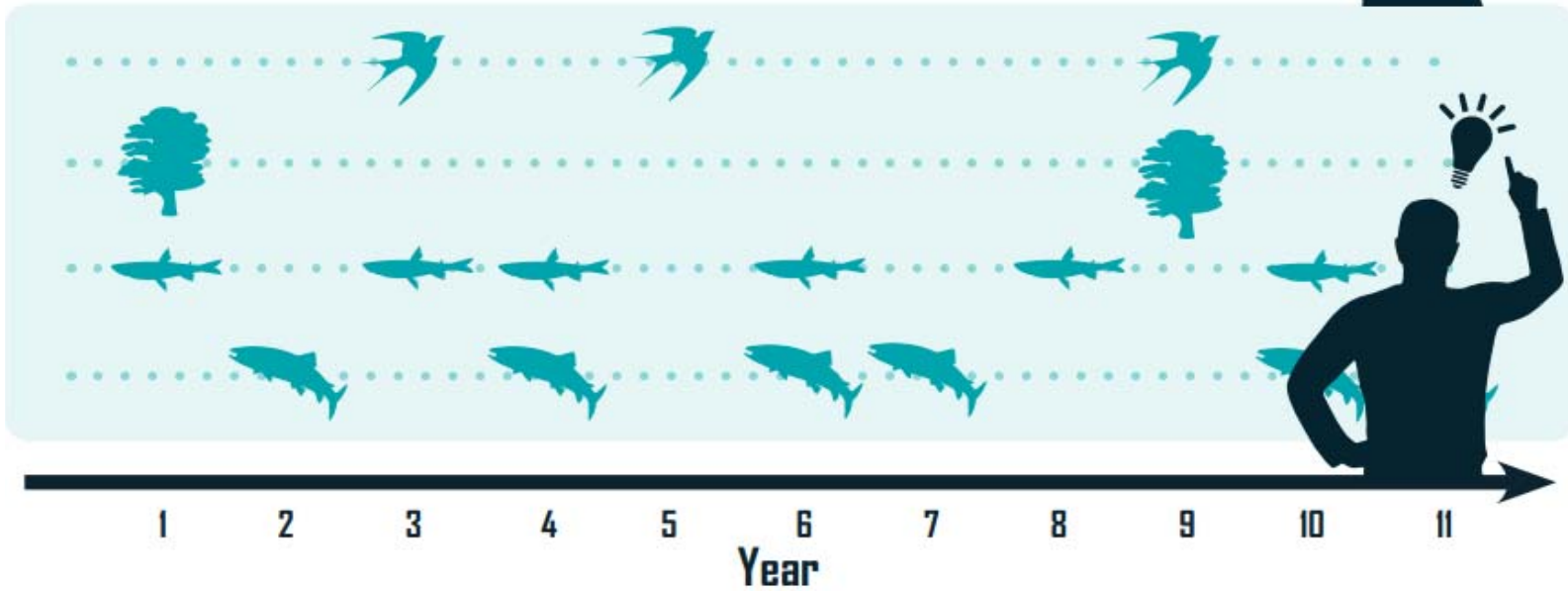
From “What-if” to Turn-Taking  
Optimization (TTO)  
*Boosting solution space*

# What Does Turn-Taking Look Like?

Business As Usual



Turn-Taking Optimization






# Business As Usual



Management Priority

Species Status

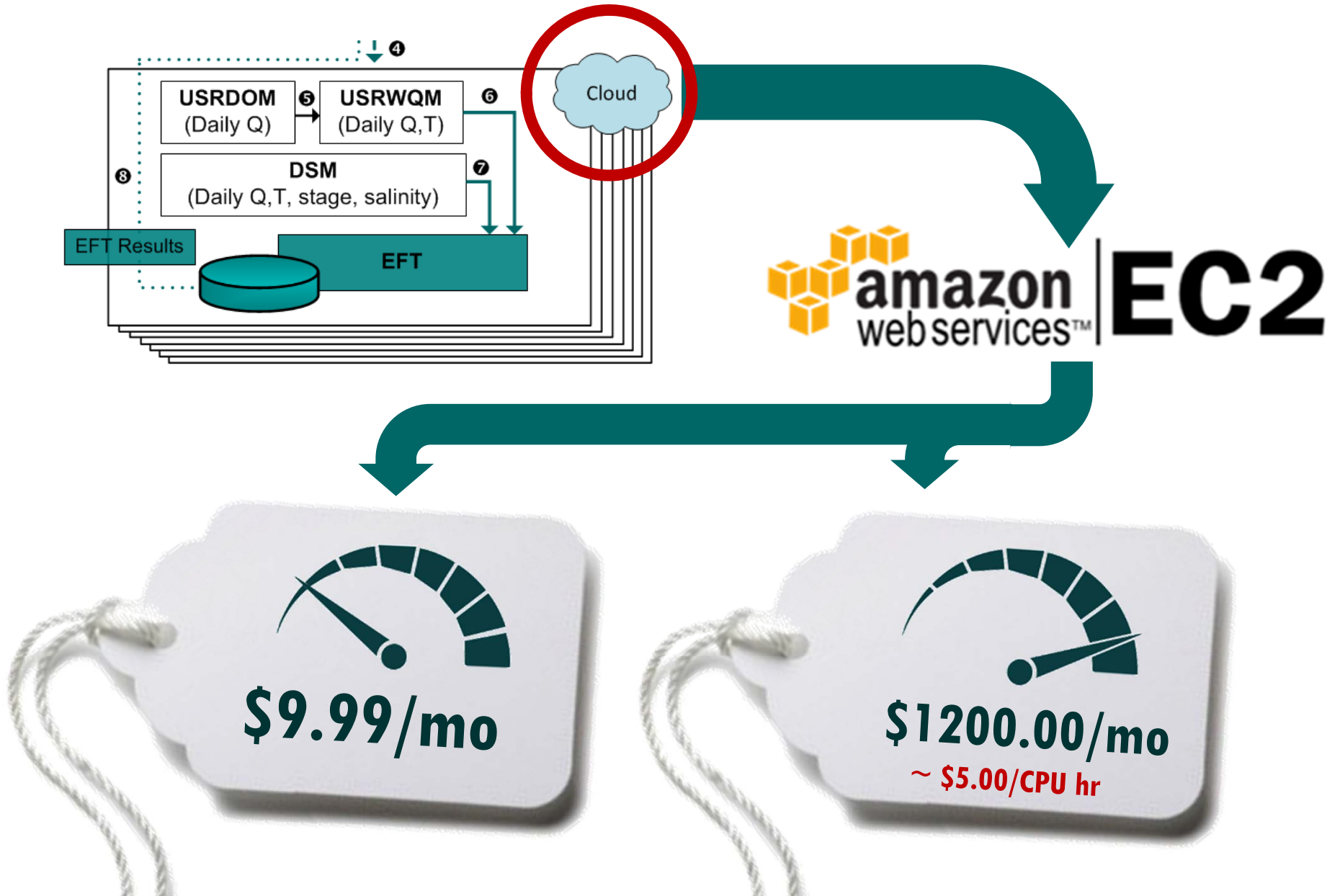
- Delta Smelt 
- Chinook Salmon 
- Steelhead 
- Fremont Cottonwood 



Year



# Commercial Cloud Cost-Effective



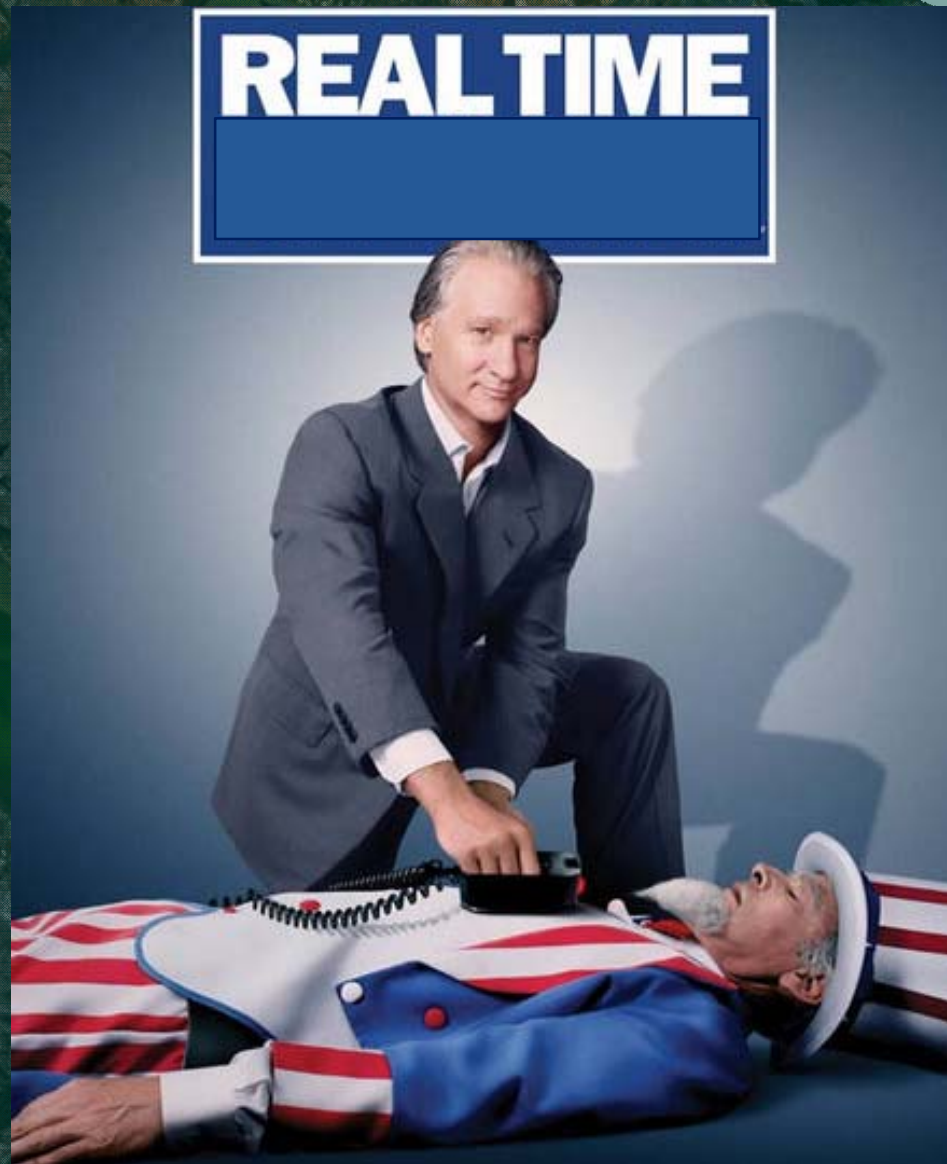
# Ecological Results of Turn-Taking

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	
<b>Total</b>	<b>31</b>	<b>12</b>	<b>14</b>	<b>5</b>





**Insufficient  
emphasis on real-  
time decision  
support tools for  
ecosystems**





# Real-time Decision Making Required to Achieve these Benefits

- **Multi-species benefits requires real-time decision support**
  - **Mental arithmetic too tough**
  - Need ***automated* real-time** tools
    - ...that **track recent history** & conditions
    - ...w **automated TTO computation to narrow solutions**
    - ...w data visualizations that **clearly present equally 'optimal' trade-offs**
- **Pair with adaptive management experiments to continuously learn**





# Take Home Points



No single best way to operate a water system



New TTO approach brings more flexibility, *more solutions*



Move away from winners/losers approach



Need greater emphasis on real-time operational tools

# More Information

- Publication coming soon!

Improving multi-objective ecological flow management with flexible priorities and turn-taking: a case study from the Sacramento River Basin and San Francisco Bay–Delta estuary, [San Francisco Estuary and Watershed Science](#), *in prep.*

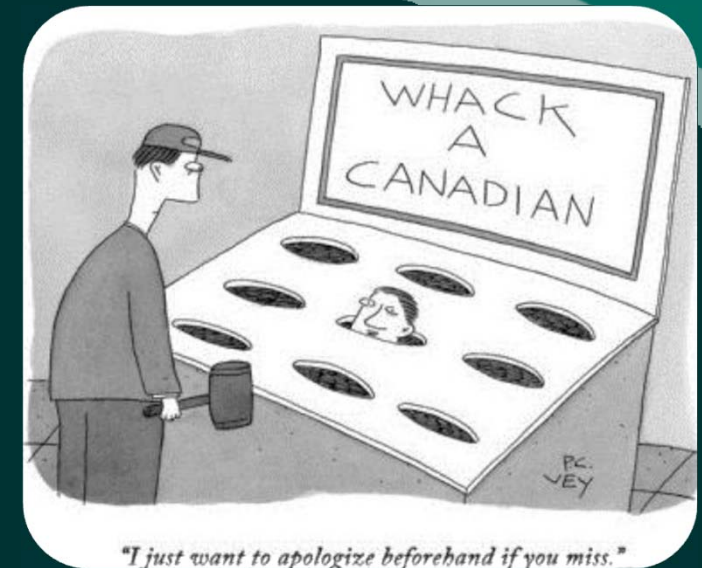
- EFT tech. report & software:

[essa.com/tools/ecological-flows-tool/](http://essa.com/tools/ecological-flows-tool/)

**Clint Alexander**

calexander@essa.com

(250) 808-2654



**Ryan Luster**

rluster@tnc.org

(530) 518-4490



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