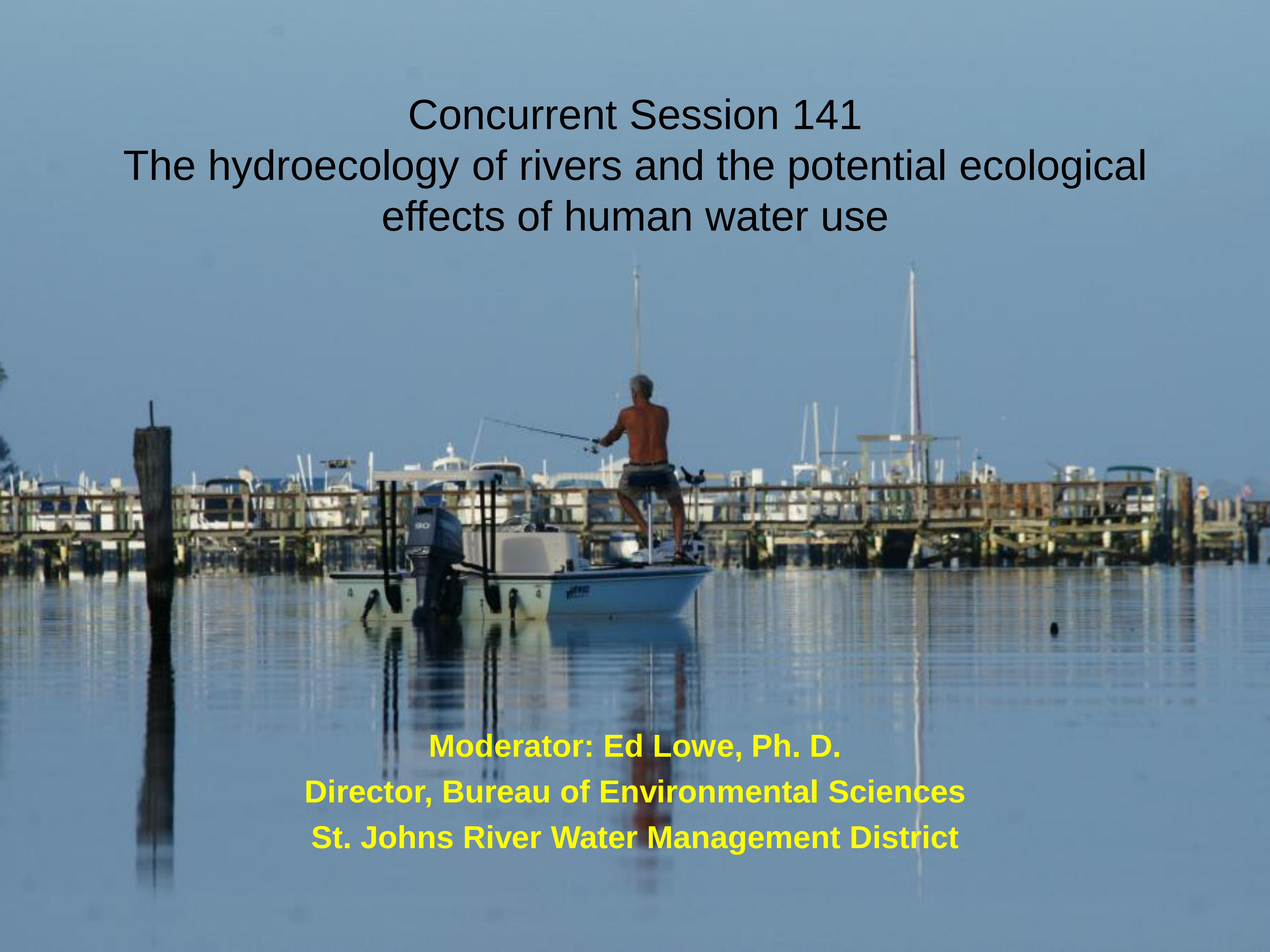
Concurrent Session 141
The hydroecology of rivers and the potential ecological effects of human water use



Moderator: Ed Lowe, Ph. D.

Director, Bureau of Environmental Sciences
St. Johns River Water Management District

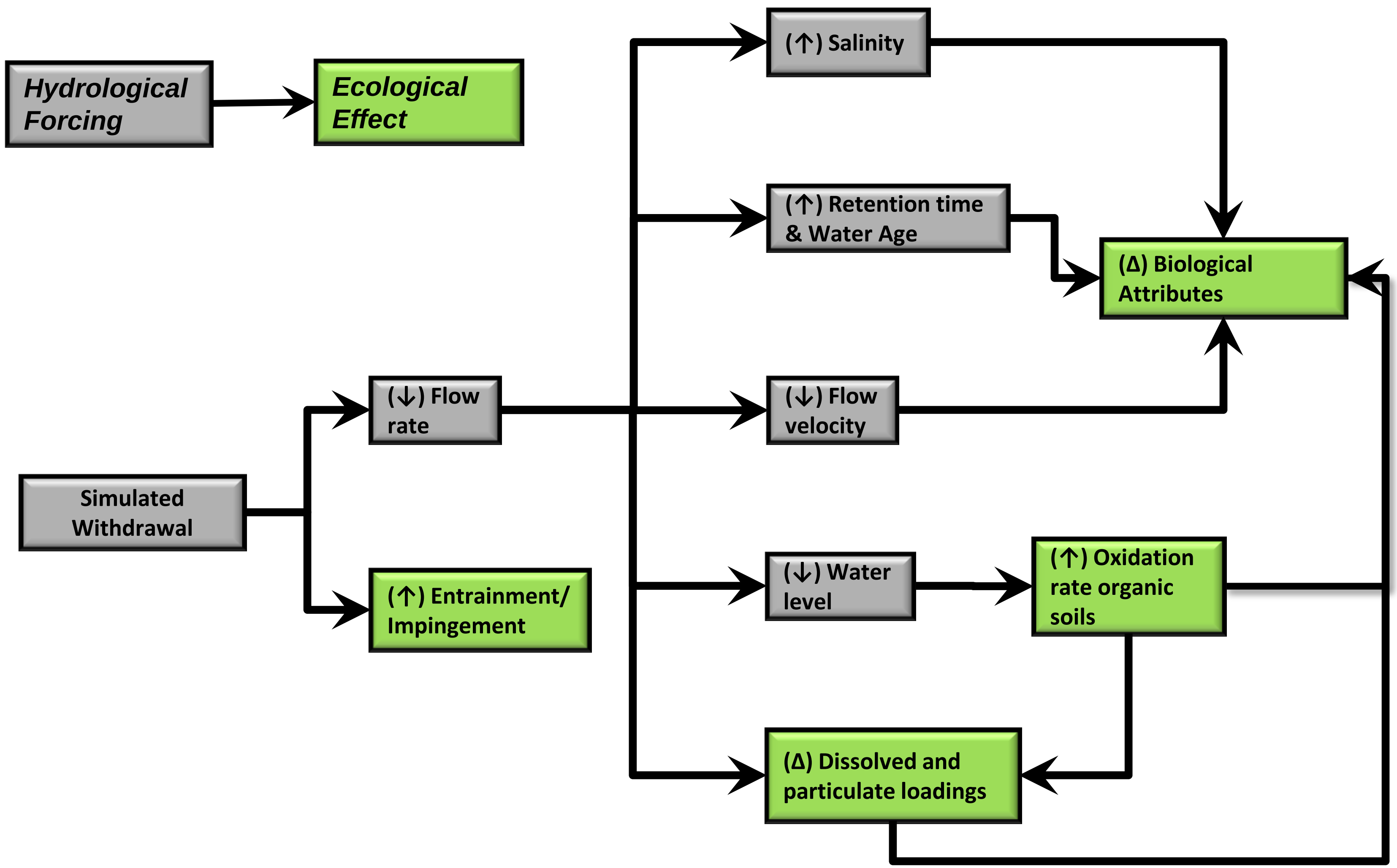
Session Overview

Photograph: Dean Campbell

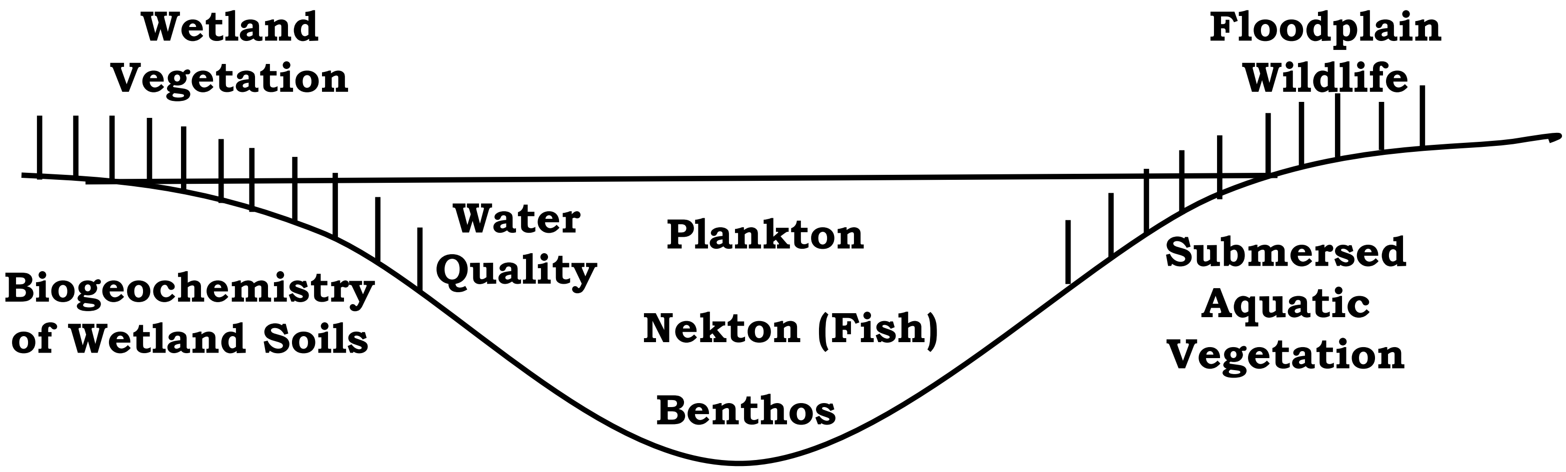
Primary Hydroecological Drivers

Driver	Definition	Key Ecological Attributes Potentially Affected
Discharge	Flow rate as volume per unit time (m^3/s or mgd)	Populations of fish, benthic macroinvertebrates, and wildlife in the estuary
Residence Time	Days required for a parcel of water to traverse a portion of the river – we used water age as a more specific metric for residence time (days)	Phytoplankton blooms – longer residence time increases blooms by increasing the growing time
Water Level	Elevation of the water surface above sea level (m) – important derivatives of water level are hydroperiod (days), depth (m), frequency of inundation	Wetland vegetation and wildlife, submersed aquatic vegetation, benthic macroinvertebrates, nutrient releases from floodplain soils
Salinity	Concentration of dissolved salts as practical salinity units (psu) – roughly, parts per thousand	Populations of fish, benthic macroinvertebrates, and wildlife in the estuary; submersed aquatic vegetation in the estuary

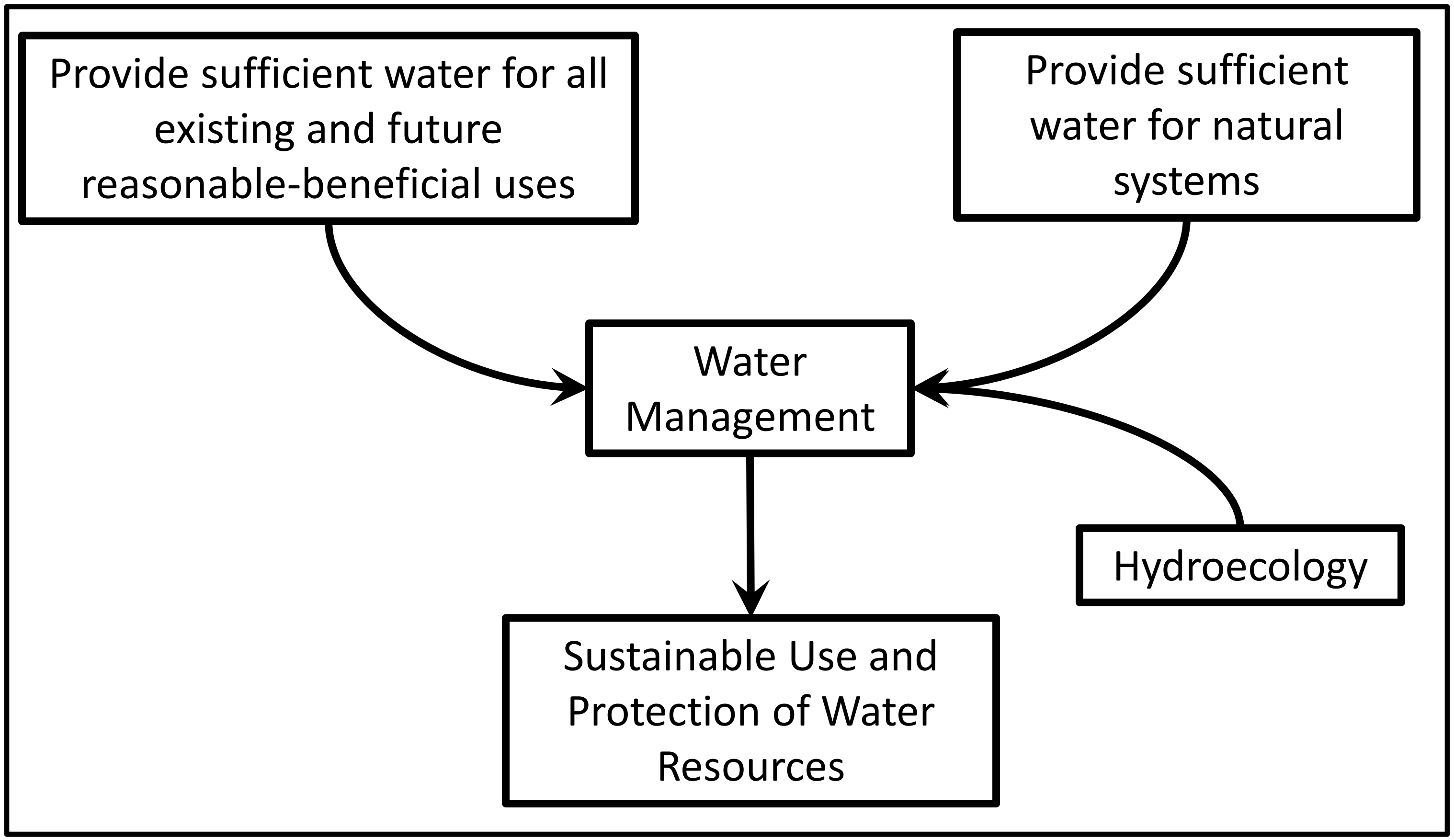
Withdrawal of surface water for human use affects a suite of hydrologic and hydrodynamic drivers and elicit changes in other abiotic drivers. These changes, in turn, influence the states of biological attributes.



Hydrologic and hydrodynamic changes can influence of the state of ecological attributes of all major ecosystem components. The effects will vary among attributes and along a river's length.



Hydroecology is the discipline that can guide the sustainable use of water resources to balance direct benefits (consumptive uses) and indirect benefits (goods and services of provided by natural systems) of water resources.



The hydroecology of rivers and the potential ecological effects of human water use

- **Ed Lowe**, St. Johns River Water Management District, Palatka, Florida – *Variable responses of ecological attributes and drivers to hydrologic alteration in the St. Johns River, Florida*
- **John White**, Louisiana State University, Baton Rouge – *Diverted Mississippi River sediment as a potential phosphorus source to Louisiana coastal wetland systems*
- **Eduardo Patino**, USGS, Ft. Meyers – *Water quality mapping and monitoring efforts in the tidal Caloosahatchee River and downstream estuaries*
- **Eric Roy**, Louisiana State University, Baton Rouge – *Nutrient dynamics at the estuarine sediment-water interface during large pulses of high nitrate Mississippi River water*

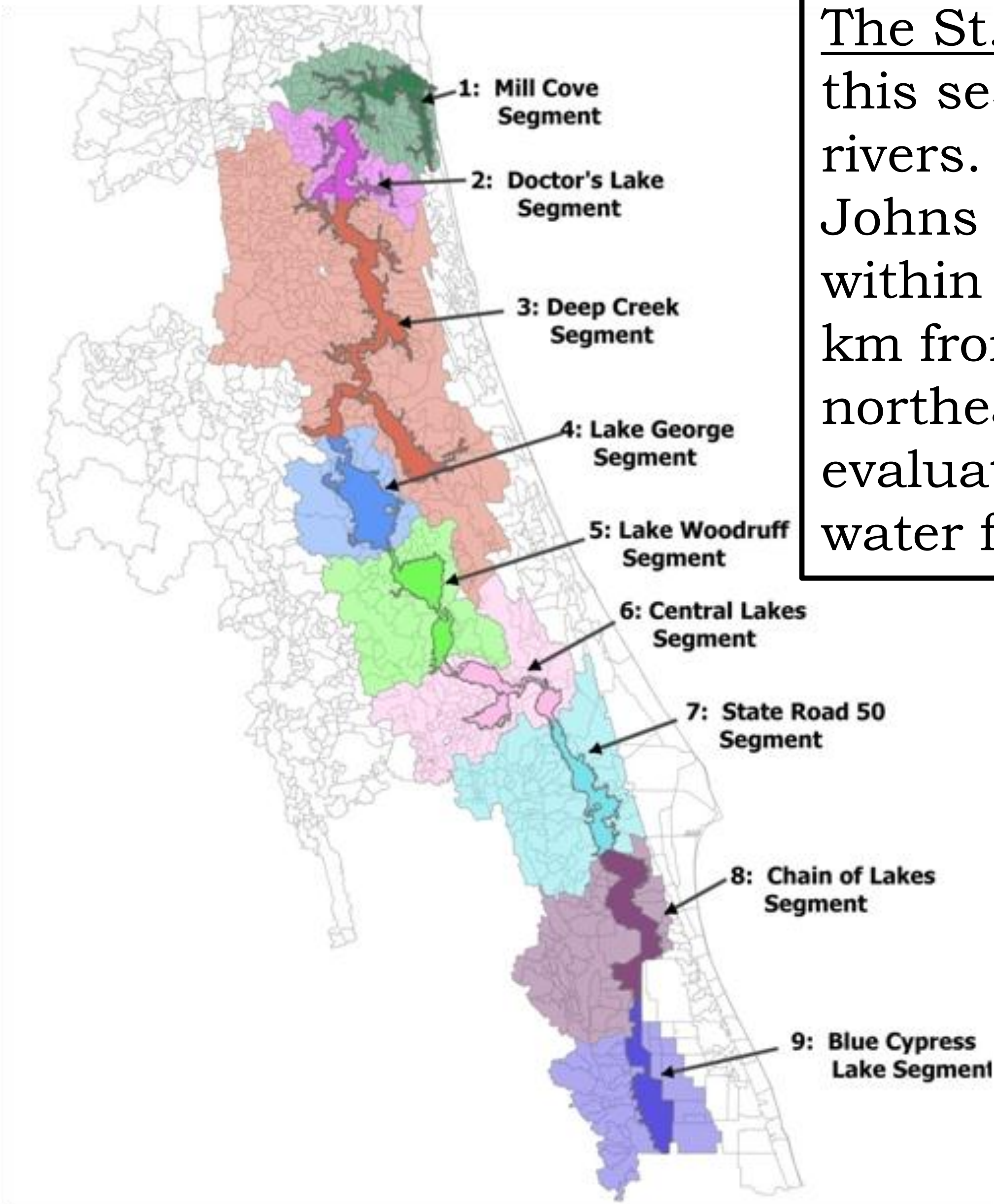
Variable Responses of Ecological Attributes and Drivers to Hydrologic Alteration in the St. Johns River, Florida

Ed Lowe, Larry Battoe, Dean Dobberfuhl, Mike Cullum, Pete Sucsy, Tim Cera, John Higman, Mike Coveney, Donna Curtis, Lawrence Keenan, Palmer Kinser, Rob Mattson, and Steve Miller

St. Johns River Water Management District

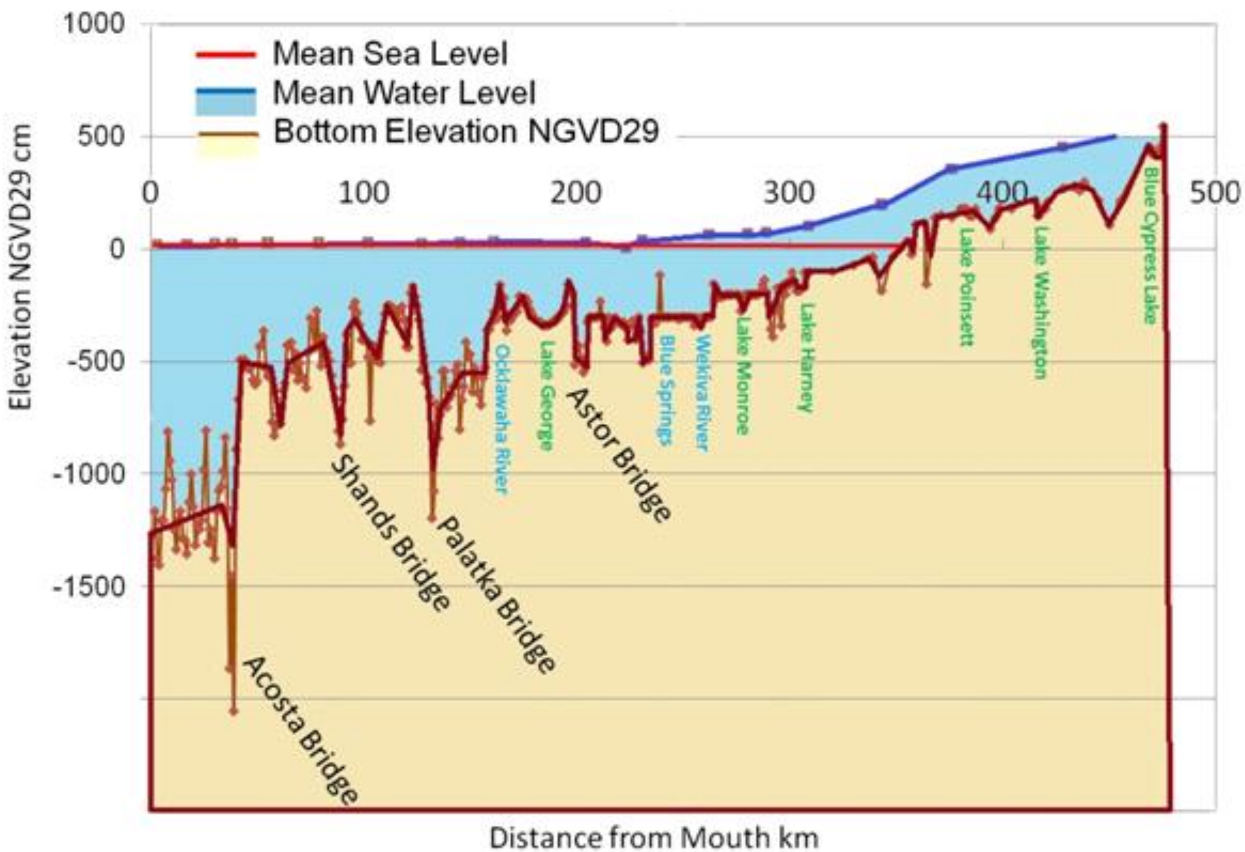
Photograph: Dean Campbell

Background



The St. Johns River - The subject of this session is the hydroecology of rivers. One example, is the St. Johns River, the longest river wholly within Florida, stretching over 500 km from headwaters to mouth in northeast Florida. It is being evaluated as a potential source of water for public supply.

The St. Johns River is a low-gradient system with a fall in mean water level of only about 7 m over its 500 km length. It is tidally influenced far upstream.

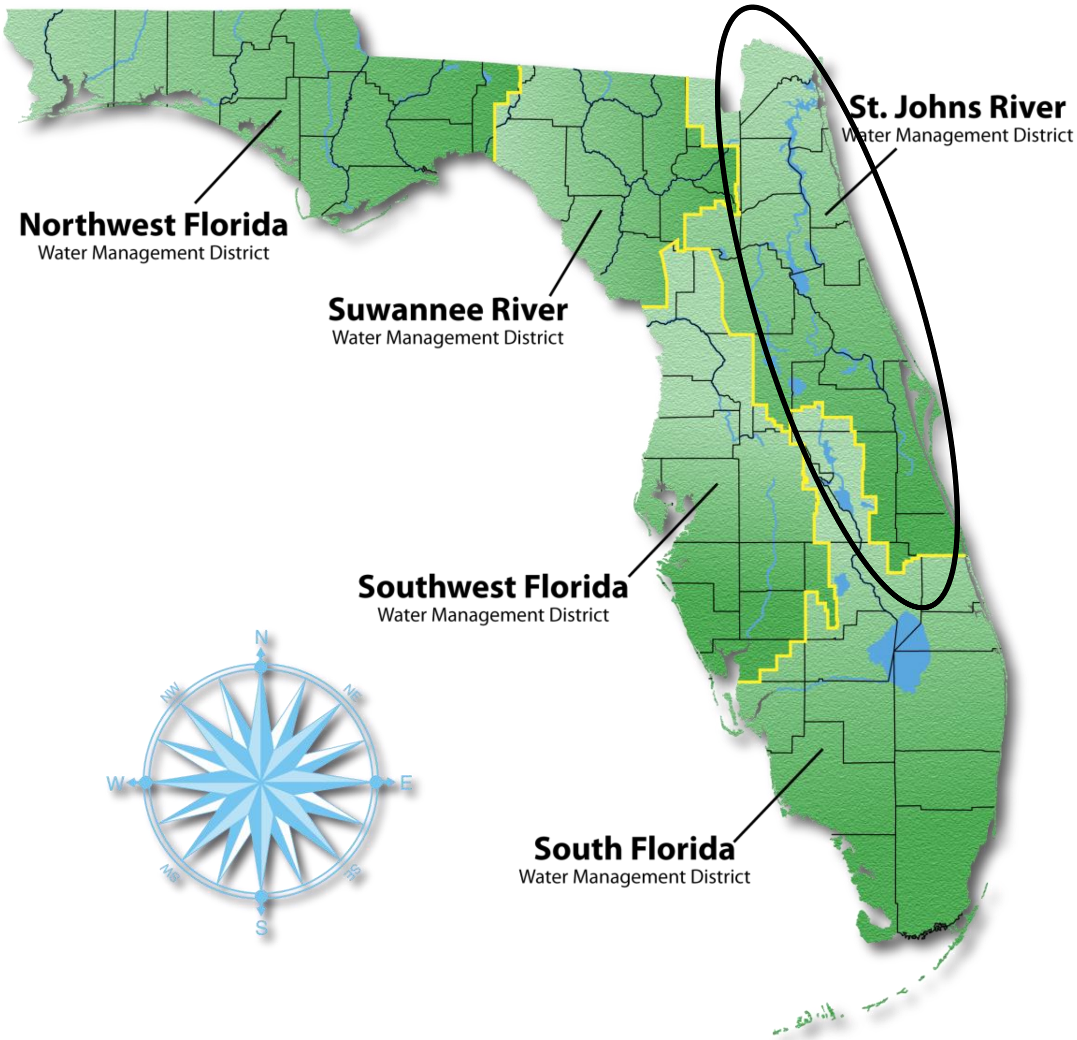


St. Johns River Bottom Elevation NGVD29 cm

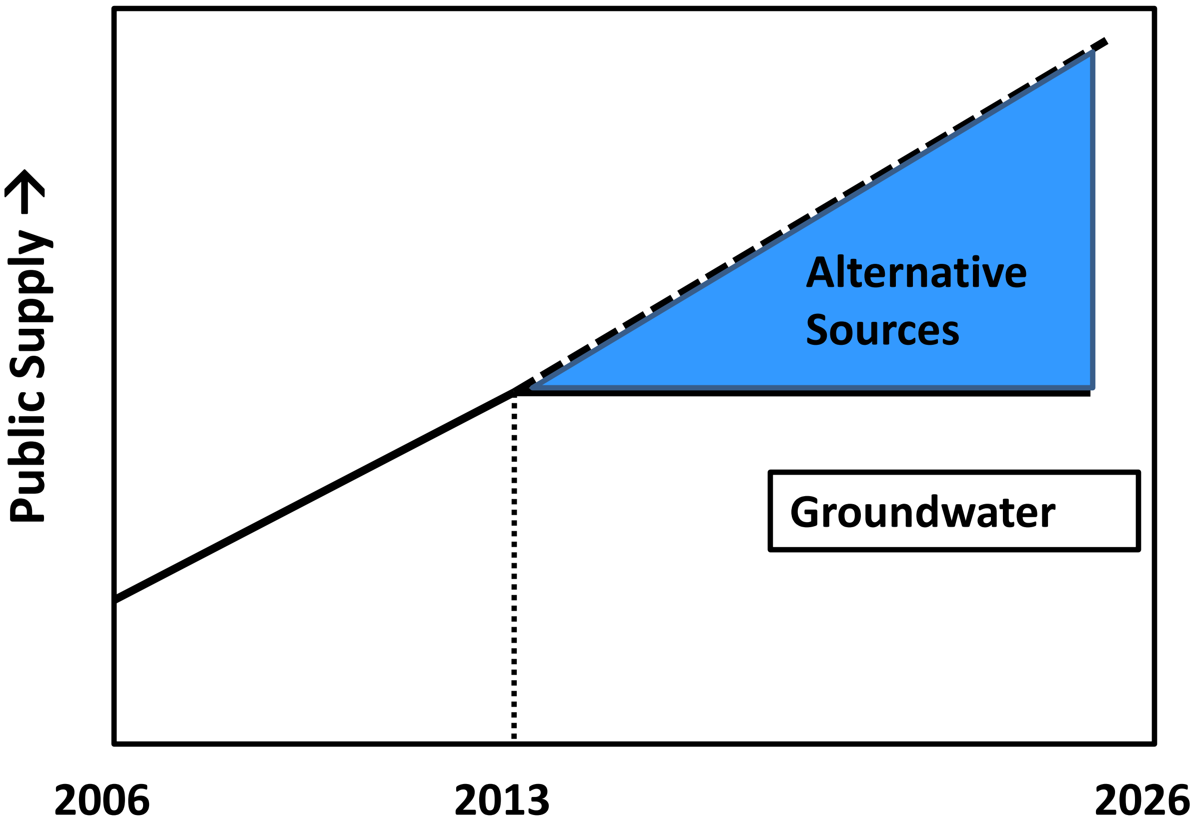
<u>Water Management in Florida</u> - The St. Johns River Water Management District (SJRWMD) is one of five WMDs in Florida, each delineated by a major drainage basin. It has primary responsibility for management of the water resources of the St. Johns River.

SJRWMD

- 12,283 square miles
- Covers all or part of 18 counties in northeast and east-central Florida



Fresh groundwater has been the major source of water for Florida but this source is reaching its sustainable limit. In central Florida, the water management districts agreed that in the near future alternative water sources would be needed to avoid harm to wetlands, lakes, and springs.



The Districts agreed that groundwater use would be capped at the 2013 demand. Alternative sources would be needed.

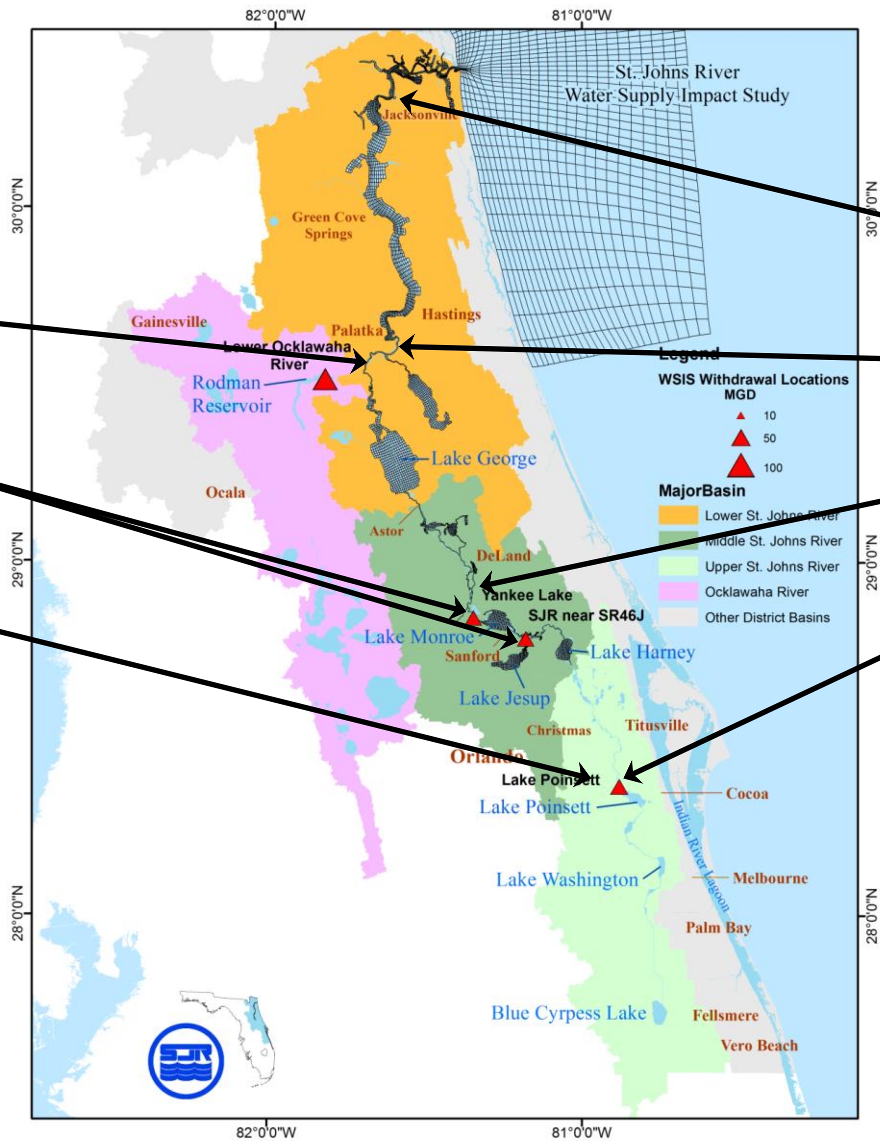
The work reported here stems from a comprehensive study to assess the potential ecological effects of increased use of surface water from the St. Johns River system. We examined the potential effects of withdrawals from four points totaling up to 11.48 $m^3\ s^{-1}$.

Modeled Annual Average Withdrawal

≤4.69 $m^3\ s^{-1}$
≈ 3 %

≤ 4.38 $m^3\ s^{-1}$
≈ 11 %

≤ 2.41 $m^3\ s^{-1}$
≈ 20 %



Average Discharge

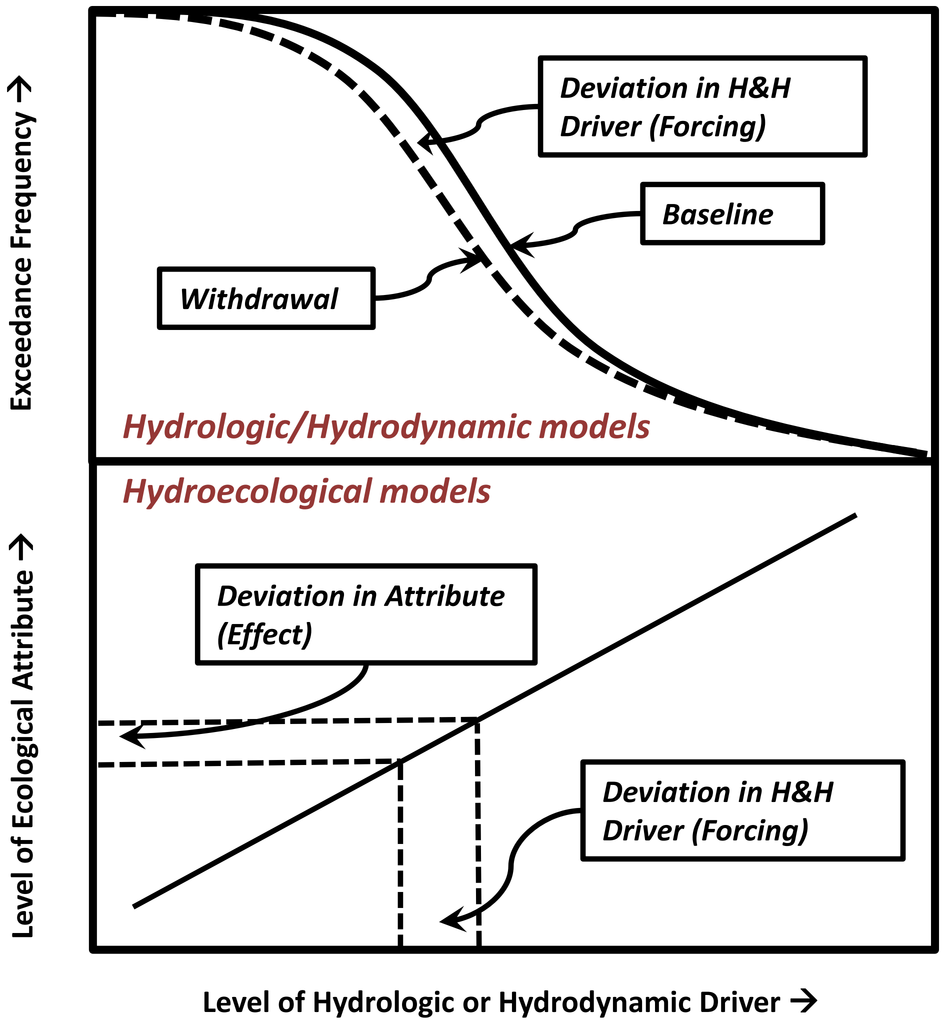
241.5 $m^3\ s^{-1}$

146.1 $m^3\ s^{-1}$

40.3 $m^3\ s^{-1}$

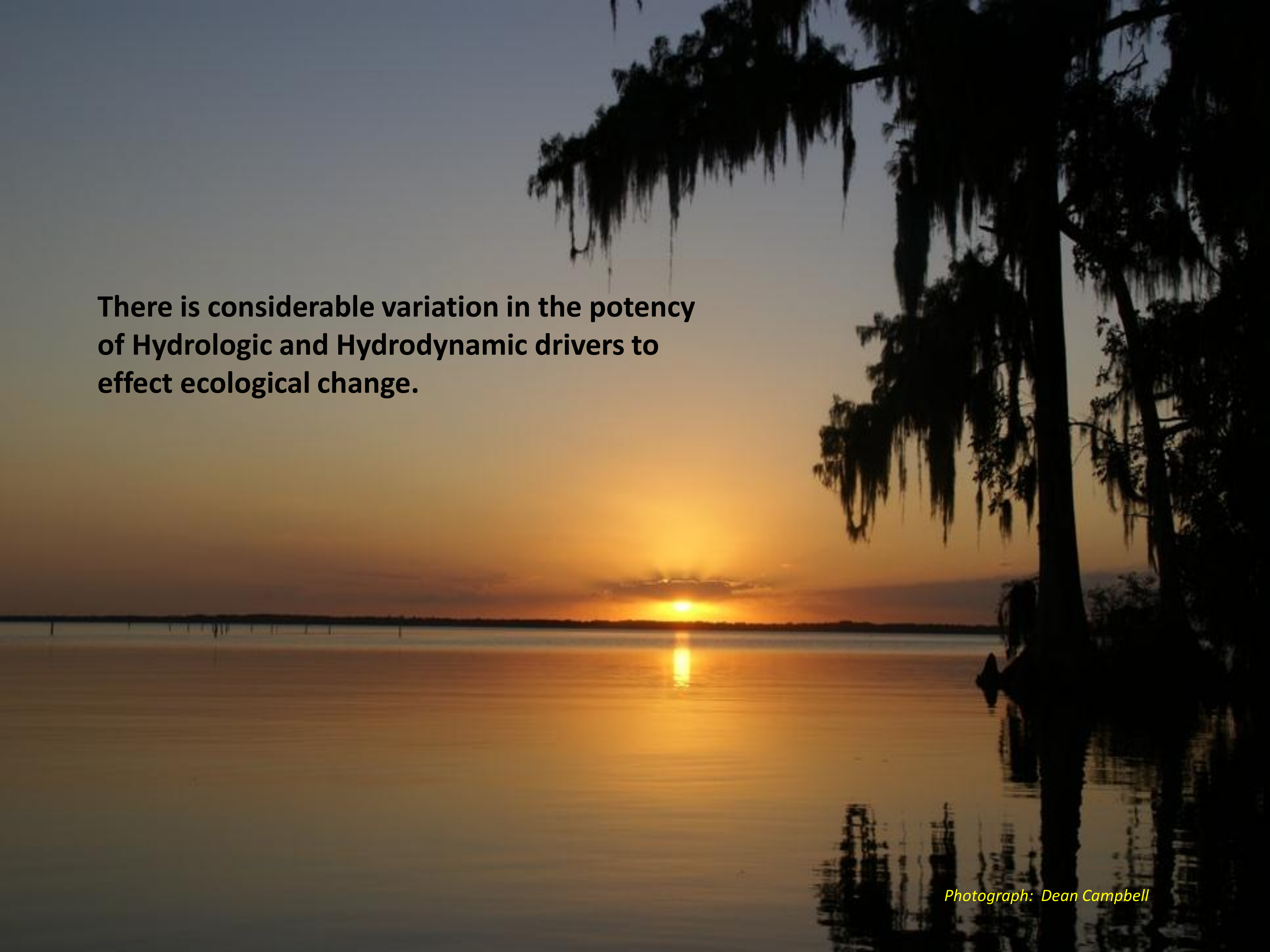
12.0 $m^3\ s^{-1}$

General Method: Estimate forcings as deviations in hydrologic and hydrodynamic (H&H) drivers from the baseline condition caused by a water withdrawal (top panel). Use forcings as inputs to hydroecological (HE) models that predict the potential ecological effects as deviations in ecological attributes from the baseline condition (bottom panel).



Forcings – deviations from the baseline condition in hydrologic and hydrodynamic (H&H) drivers

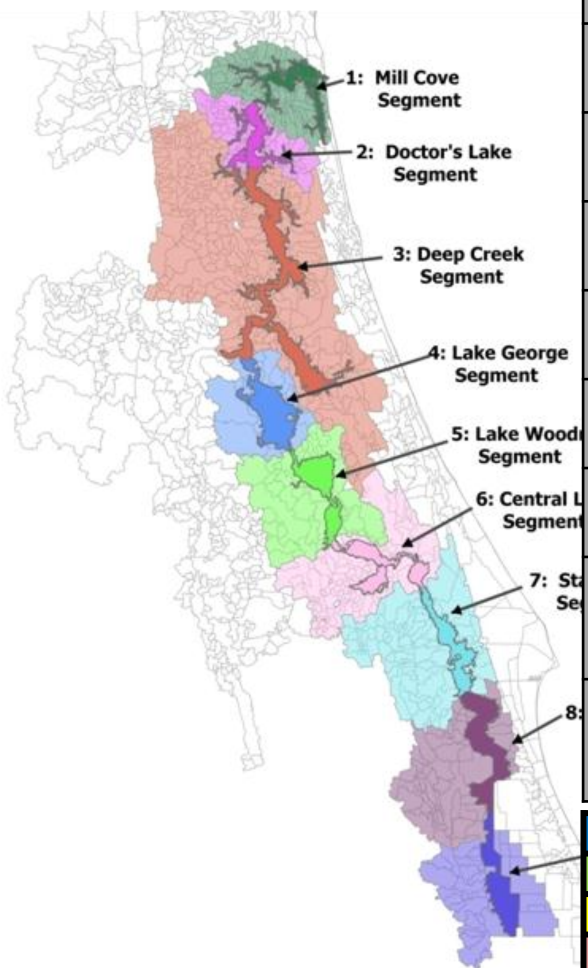
Effects – deviations from the baseline condition in ecological attributes



There is considerable variation in the potency of Hydrologic and Hydrodynamic drivers to effect ecological change.

Photograph: Dean Campbell

There was considerable variation in the potency of drivers to effect ecological change. This table shows findings for the extreme scenarios for each location.



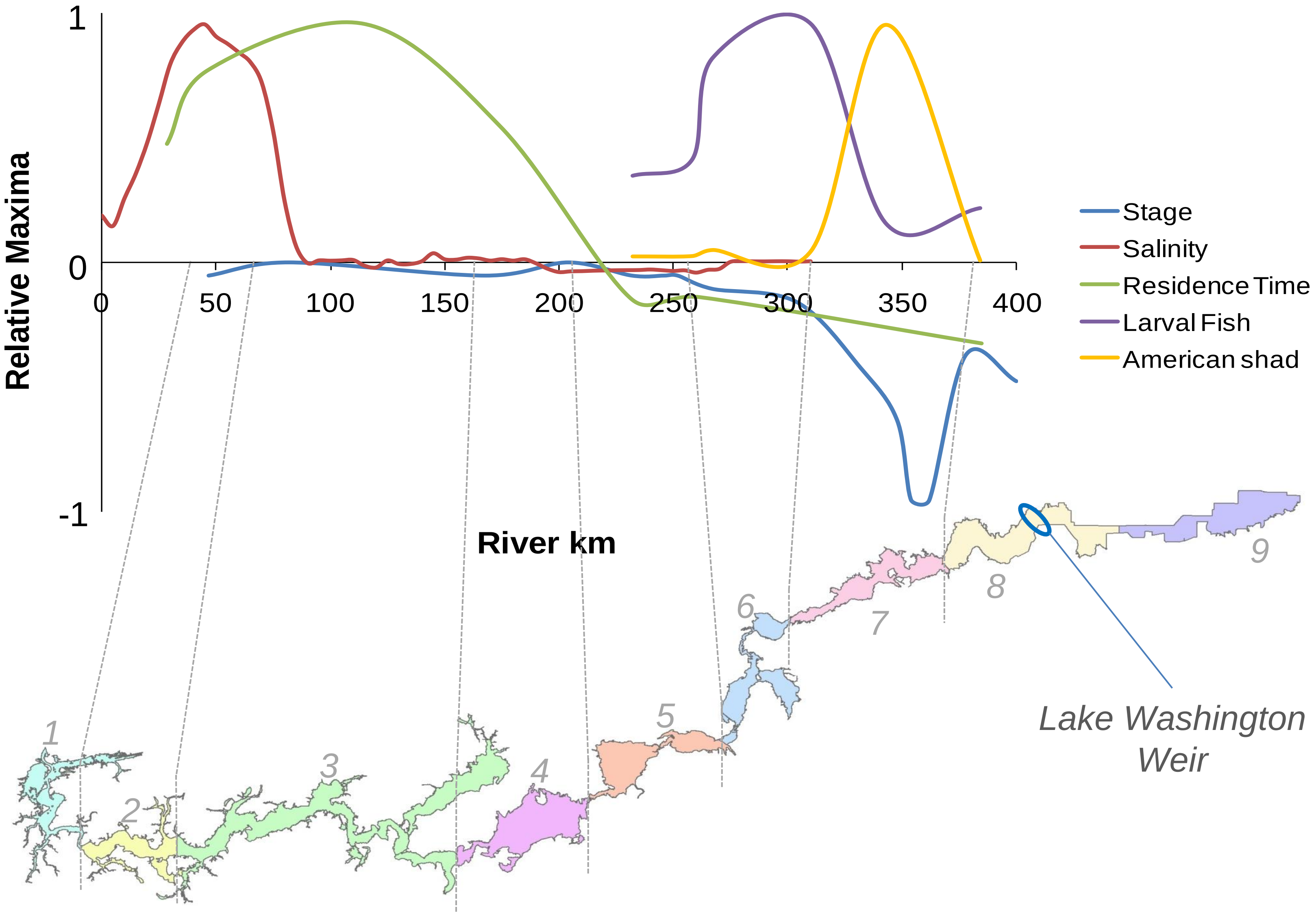
River Segment	Flow Rate	Salinity	Water Age	Water Level
1	**Fish		NA	
2	**Fish	*Wetlands	**Plankton	
3	**Fish	***Benthos	**Plankton	
4	***Fish	NA	**Plankton	
5	NA	NA	NA	***Wetlands
6	NA	NA		***Fish
7	NA	NA	NA	***Fish, Wetlands
8	NA	NA		***Fish, Wetlands

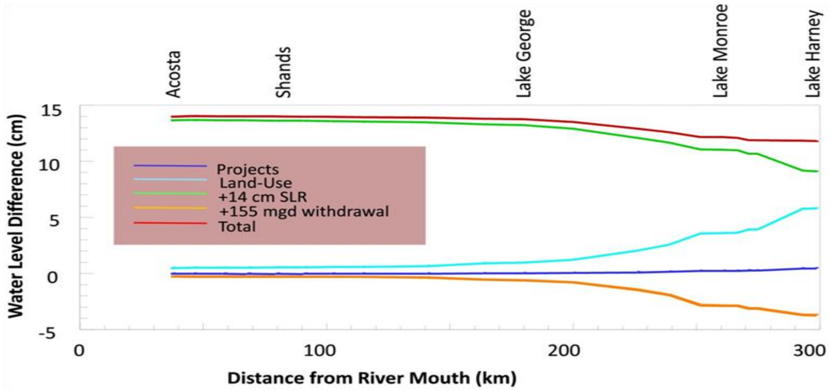
(blue)	Negligible effect
(green)	Minor effect
(yellow)	Moderate effect
(pink)	Major effect
(dark red)	Extreme effect

*	Very low uncertainty
**	Low uncertainty
***	Medium uncertainty
****	High uncertainty
*****	Very high uncertainty


The potential for ecological effects varies significantly along the river’s length.
Photograph: Dean Campbell

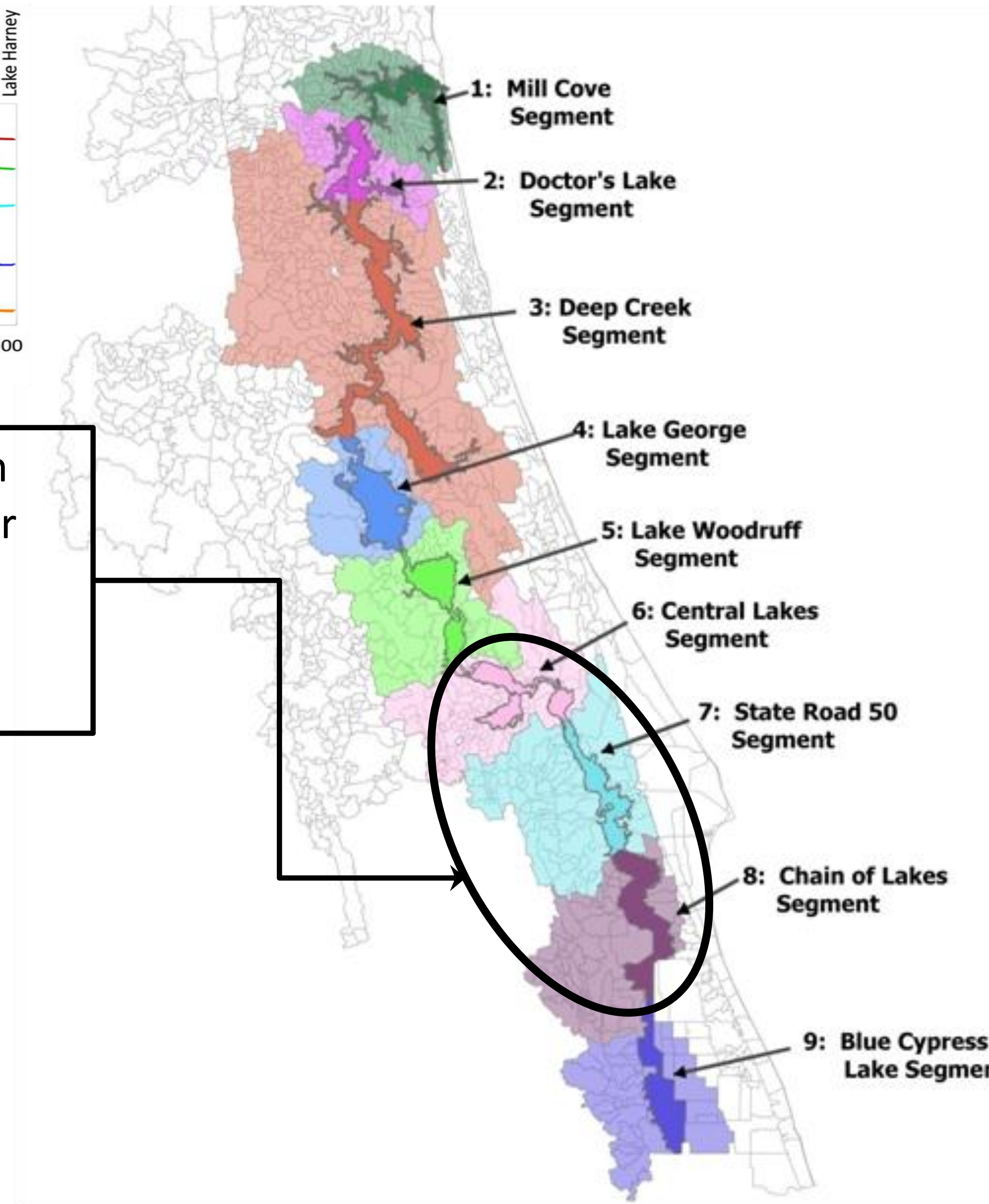
Results – Drivers - Longitudinal variation in the simulated, relative responses of H&H drivers to modeled water withdrawals.



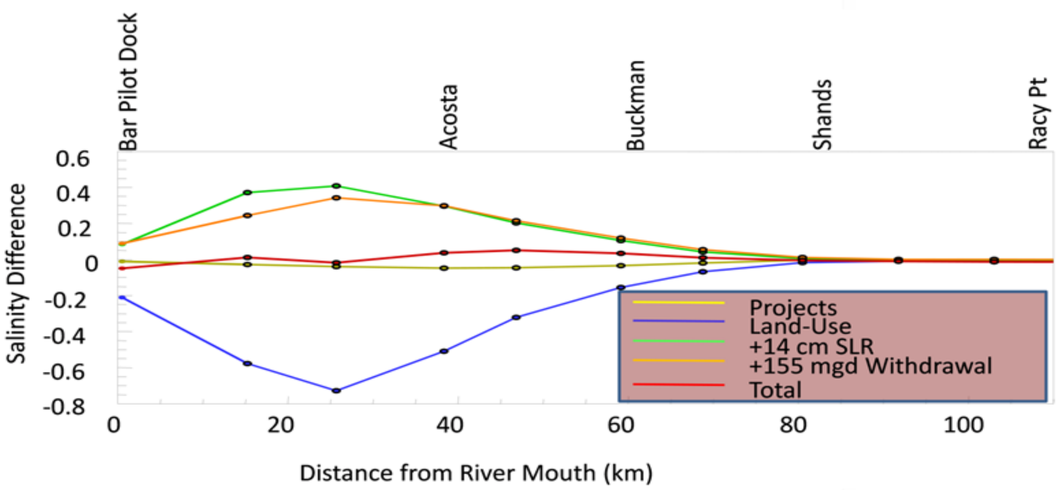


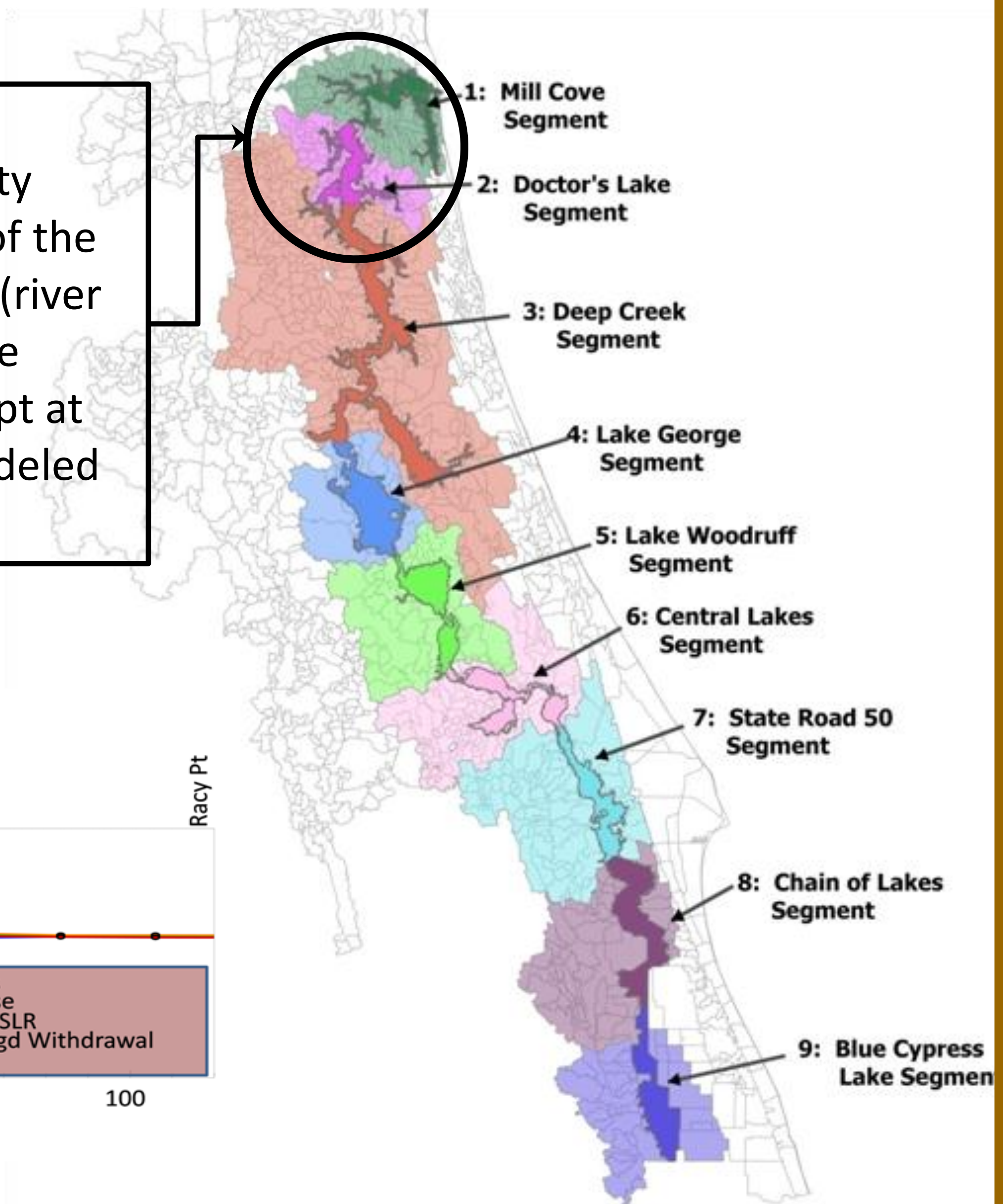
Hydroecological effects due to changes in water levels could only occur in the upper segments of the river. Under forecast conditions, water level effects in these segments would be negligible or minor.

Residence time effects would be negligible or minor in all areas.

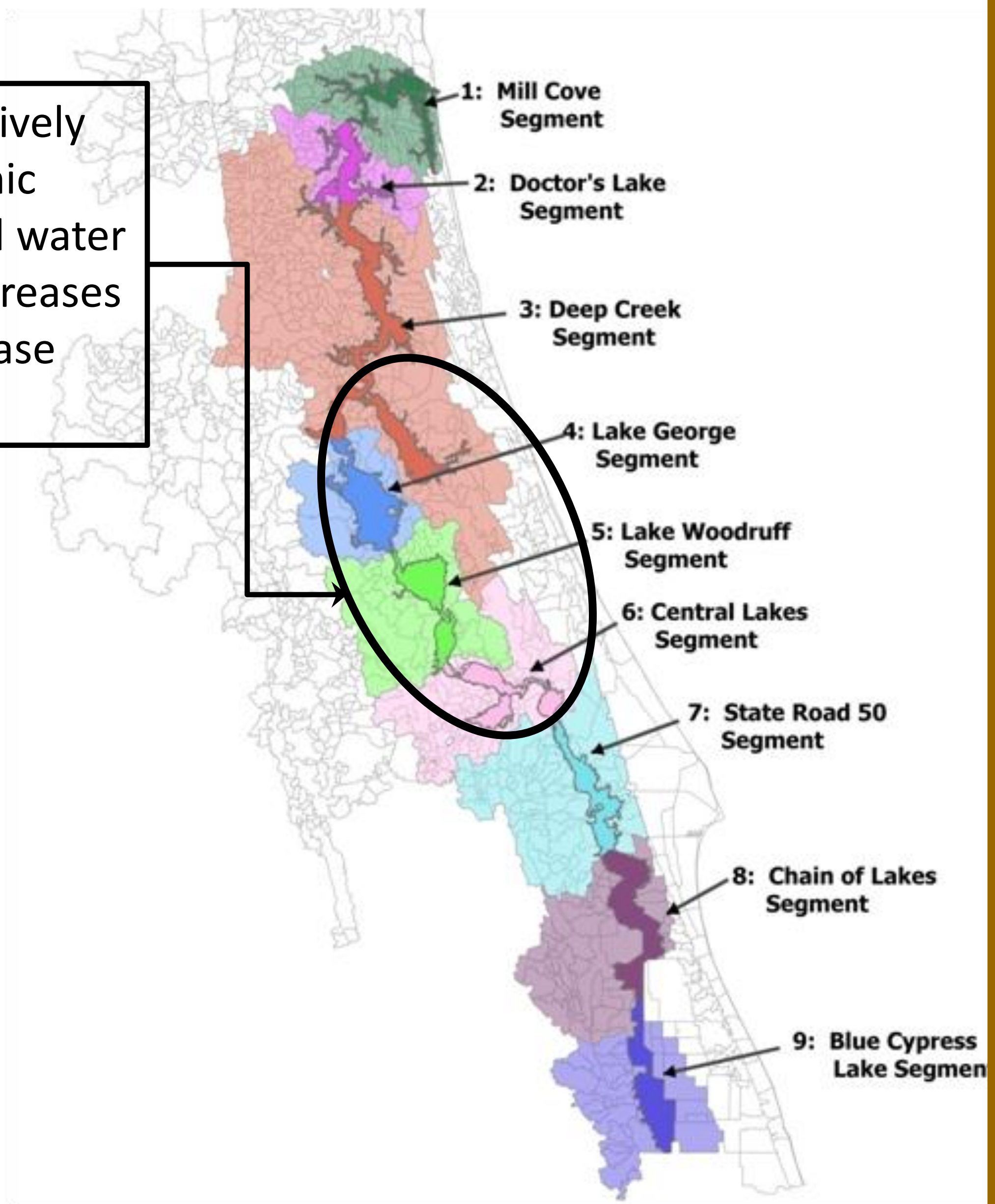


Hydroecological effects due to reduced freshwater discharge and increased salinity would only occur in the lower segments of the river to approximately the Shands Bridge (river mile 50). Under forecast conditions, these effects would be negligible or minor except at the highest level of water withdrawal modeled (262 mgd).

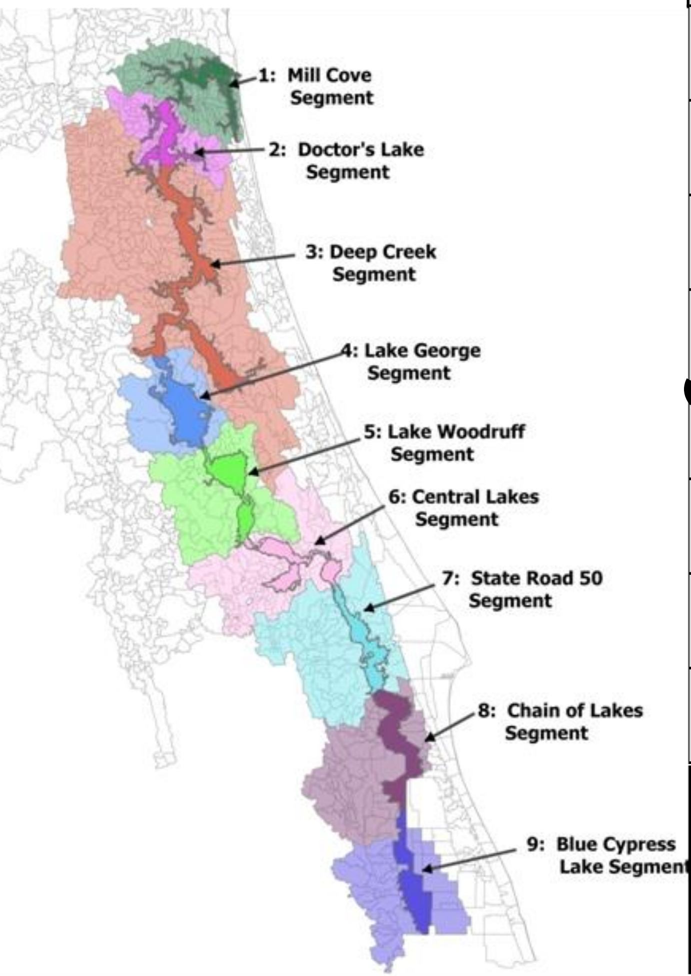


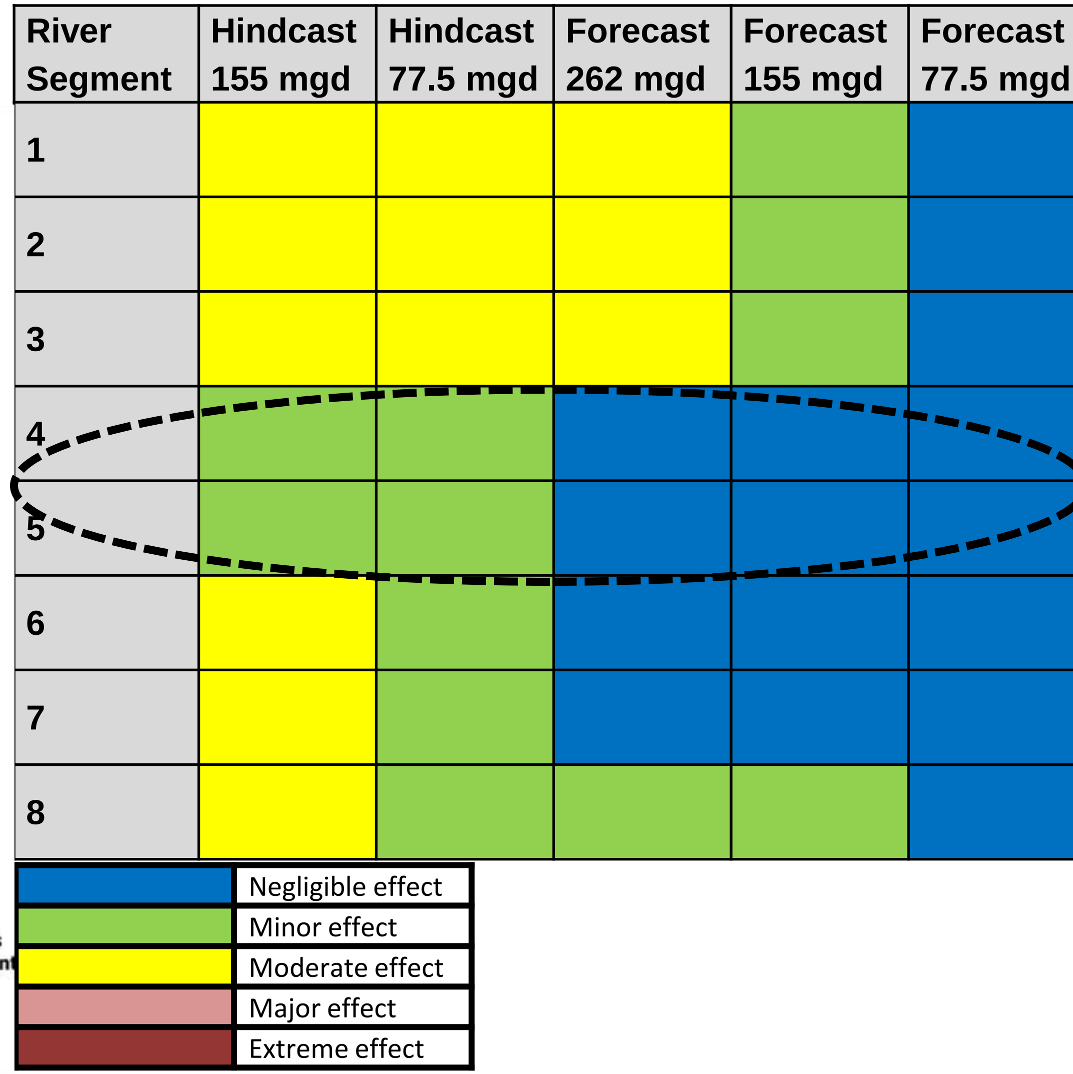


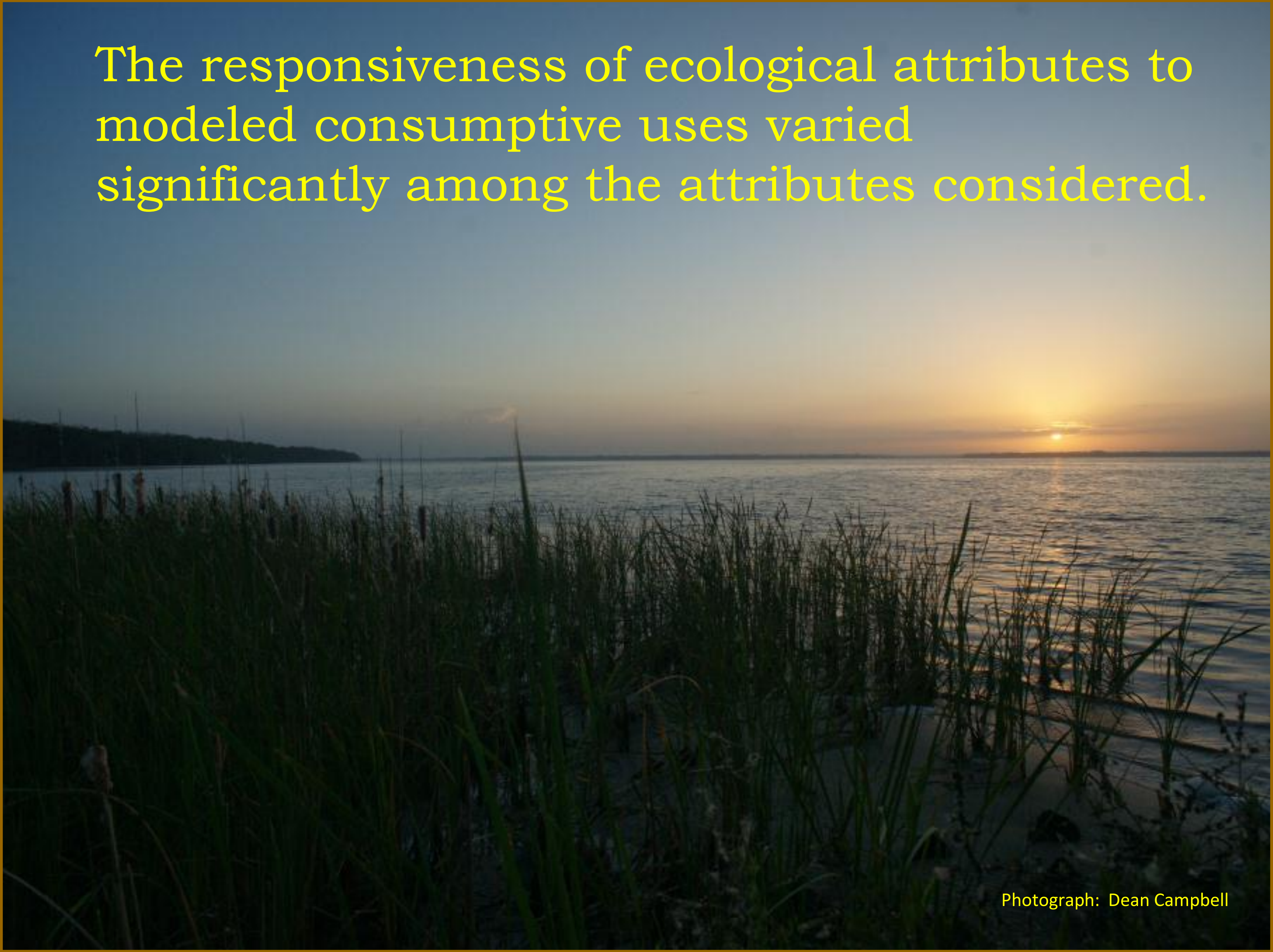
The middle reach of the river will be relatively insensitive to hydrologic and hydrodynamic effects of water withdrawals. Salinity and water level will not be appreciably affected. Increases in retention time will not materially increase the potential for phytoplankton blooms.



The middle reaches of the river (segments 4&5) were relatively insensitive to all potential changes in H&H drivers.



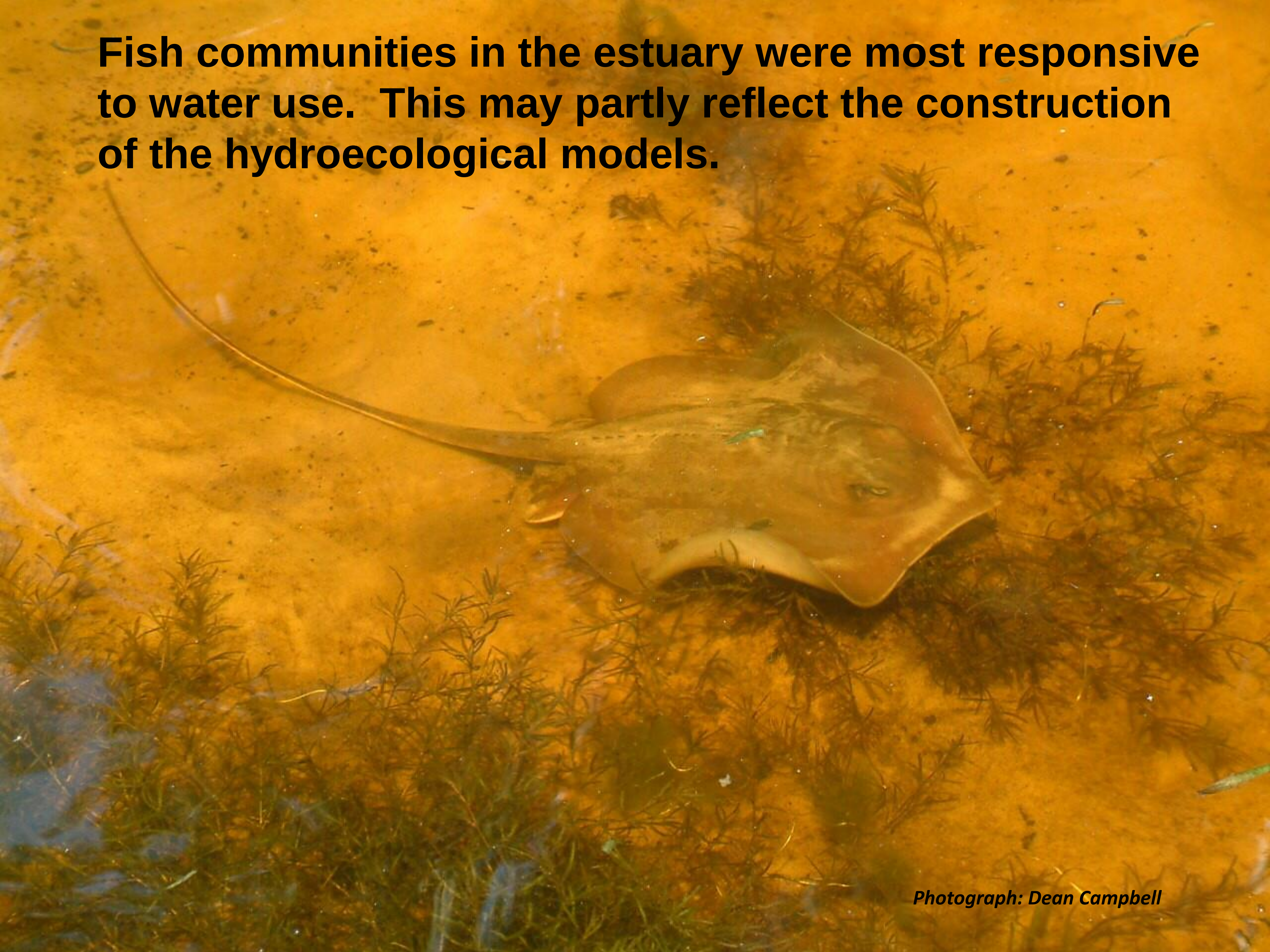



The responsiveness of ecological attributes to modeled consumptive uses varied significantly among the attributes considered.
Photograph: Dean Campbell

For three ecosystem components all hydroecological effects were negligible or minor for all conditions and areas examined.

- Water quality
  - Loading rates and concentrations of carbon, nitrogen, and phosphorus
  - Dissolved oxygen concentrations
- Submersed Aquatic Vegetation
  - Levels of salinity stress
  - Depth distributions
- Plankton
  - Intensity and duration of phytoplankton blooms
  - Species structure of zooplankton communities

Fish communities in the estuary were most responsive to water use. This may partly reflect the construction of the hydroecological models.



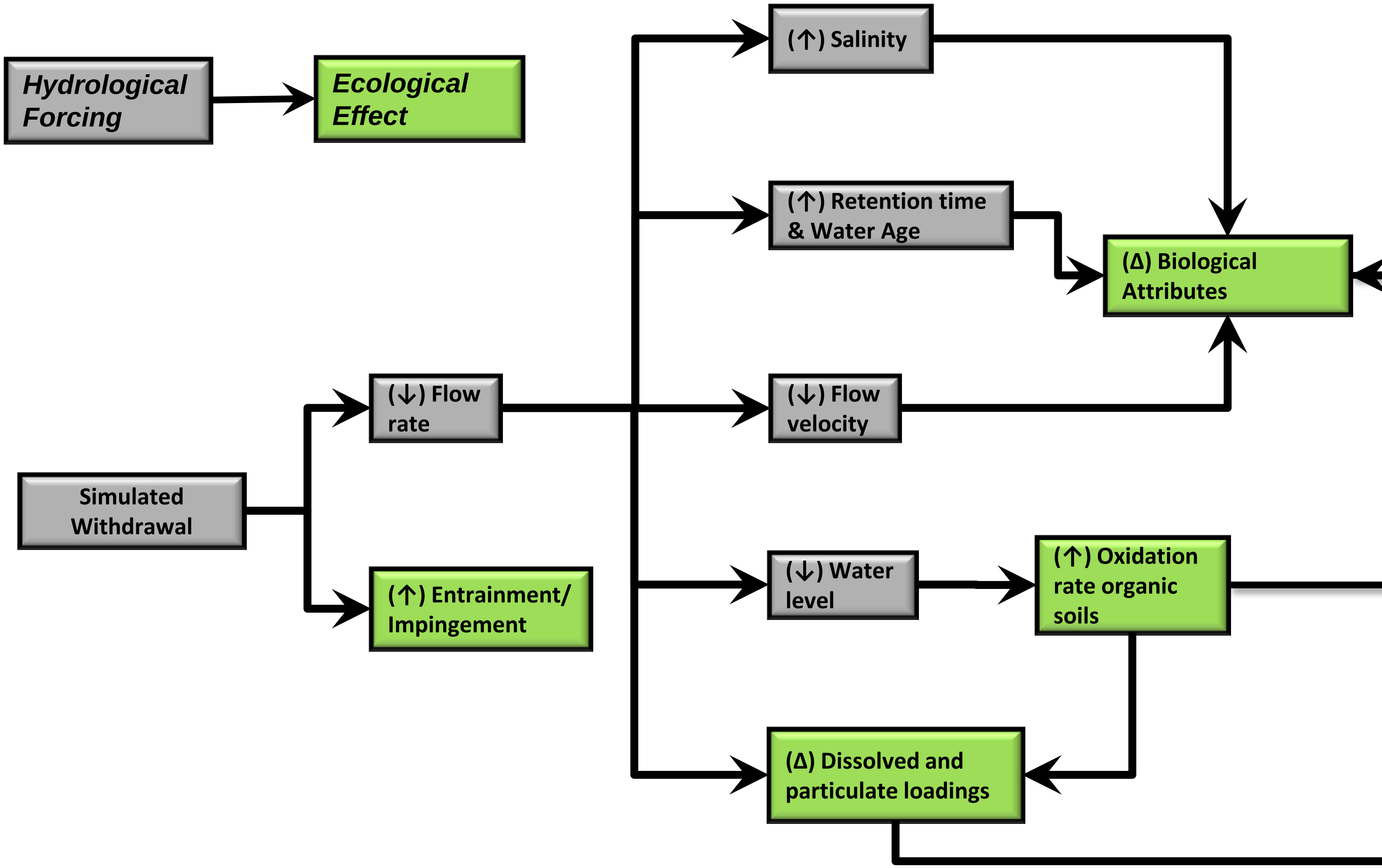
Photograph: Dean Campbell

Example: Percent change in relative abundance in the estuary for size classes of select species with strong flow response. Flow reduction effects in red, flow augmentation effects in black.

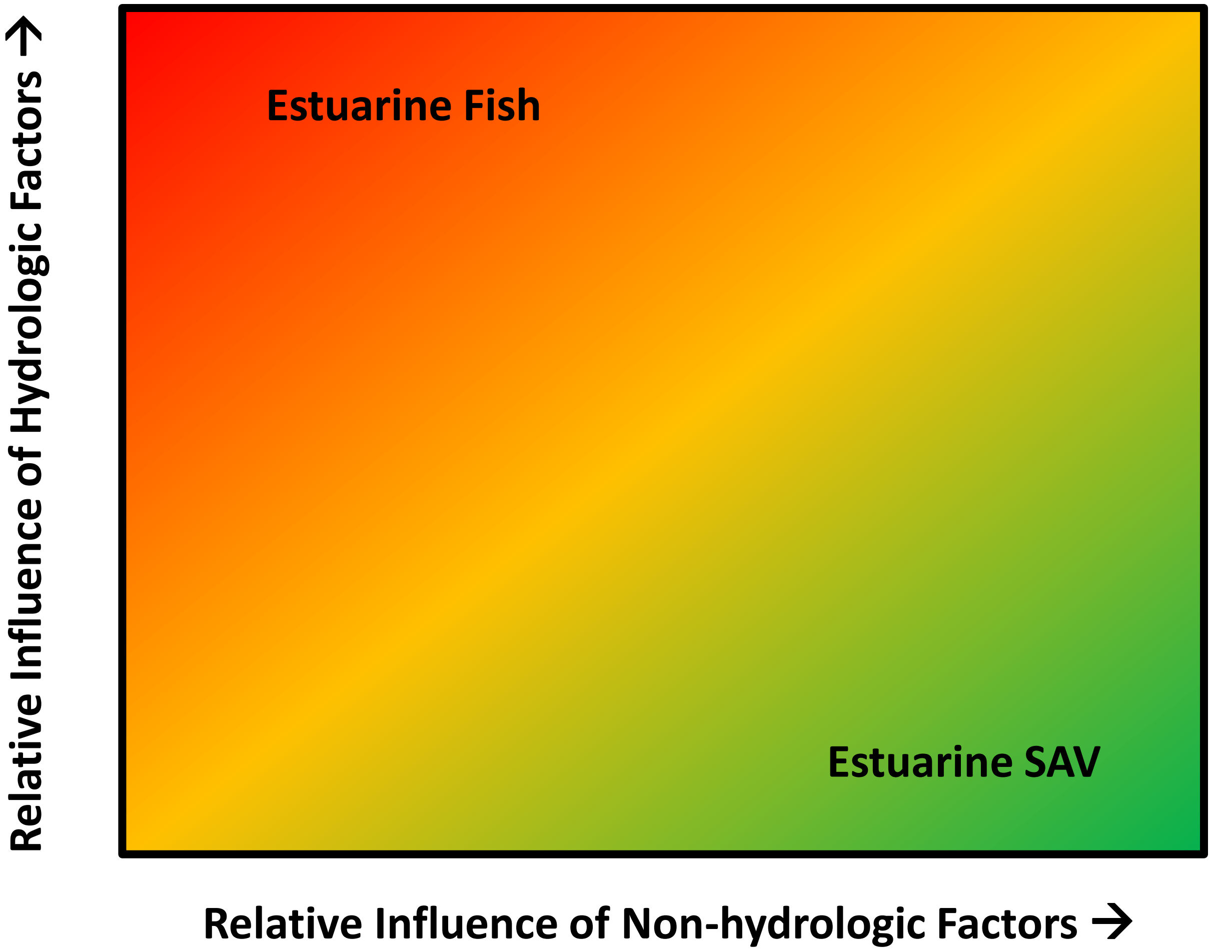
Species	Length (mm)	Spatial Extent of Effect	Hindcast 77.5 mgd	Hindcast 155 mgd	Forecast 77.5 mgd	Forecast 155 mgd	Forecast 262 mgd
Channel catfish	*50-100*	Broad	**-7.8**	**-17.4**	**29.9**	**17.2**	**-0.9**
Channel catfish	*150-275*	Narrow	**-28.5**	**-52.1**	**7.0**	**-21.9**	**-63.8**
Spotted seatrout	*31-50*	Broad	**10.7**	**42.4**	**-34.3**	**-14.9**	**23.1**
Spotted seatrout	*51-110*	Broad	**16.5**	**36.9**	**-27.6**	**-12.5**	**17.3**
Spotted seatrout	*201-325*	Narrow	**-1.8**	**-3.0**	**4.7**	**4.2**	**1.7**
Striped mullet	*31-45*	Broad	**11.5**	**25.3**	**-19.9**	**-9.1**	**8.6**

Narrow- effect confined to area of shifting salinity isopleths (≤ 2/8 sampling zones)
Broad - effect predicted for > 50% of the entire estuary (≥ 4/8 sampling zones)

The hydroecological models for fish in the estuary were developed using flow rate as the driver. Because flow rate affects all other hydrodynamic and hydrologic drivers, this approach may lead to the strongest and most predictive models. Thus, a general model may be more powerful than a specific model that uses a more proximate driver. The causal linkage, however, is less clear in such models.



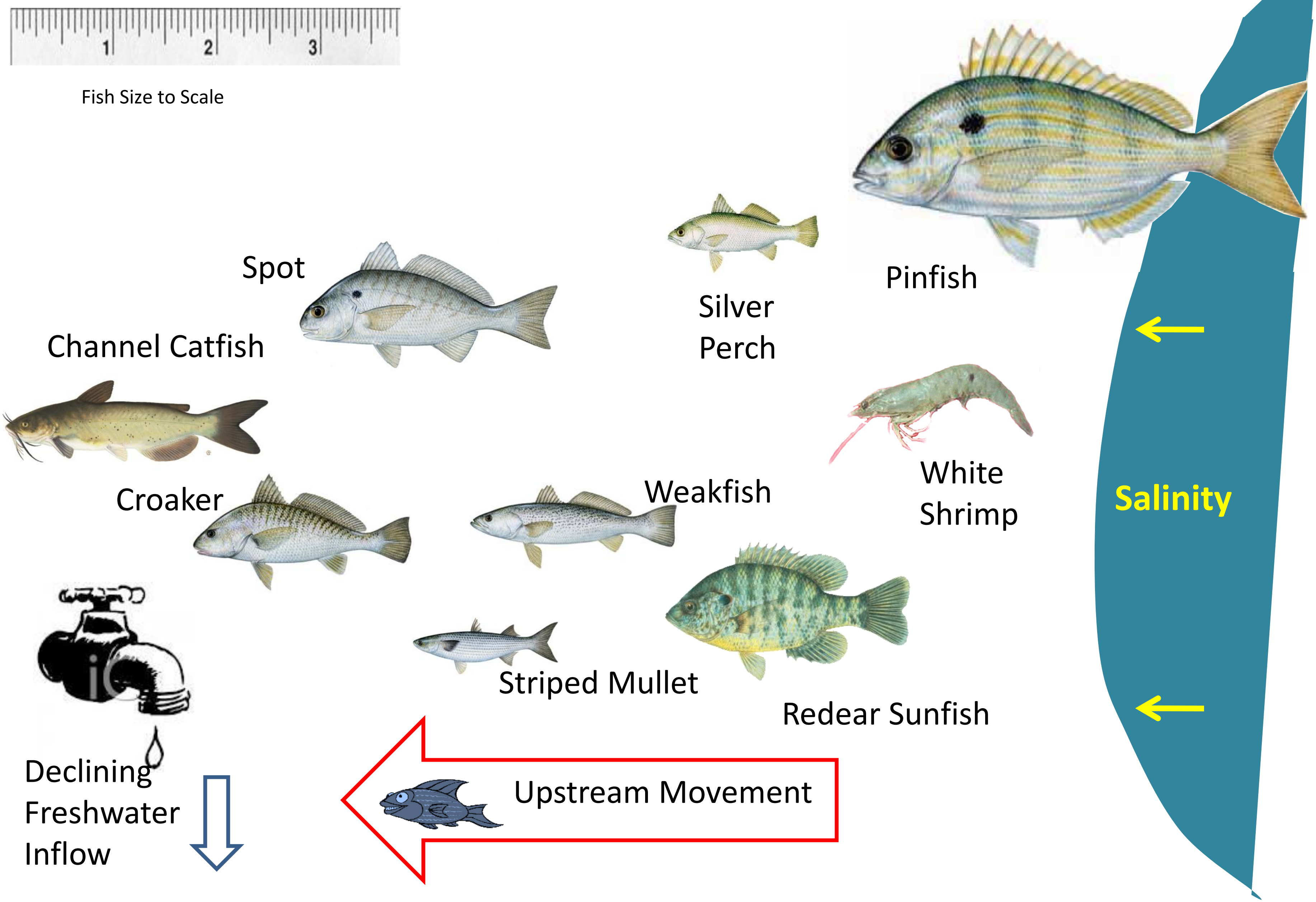
An important consideration in management actions is the relative influence of hydrologic and non-hydrologic drivers on ecological attributes. In this study, estuarine fish appeared to be affected more strongly affected by hydrologic drivers than estuarine SAV.



Responses to forcings were often mixed – i.e. positive, negative, and neutral.

Photograph: Dean Campbell

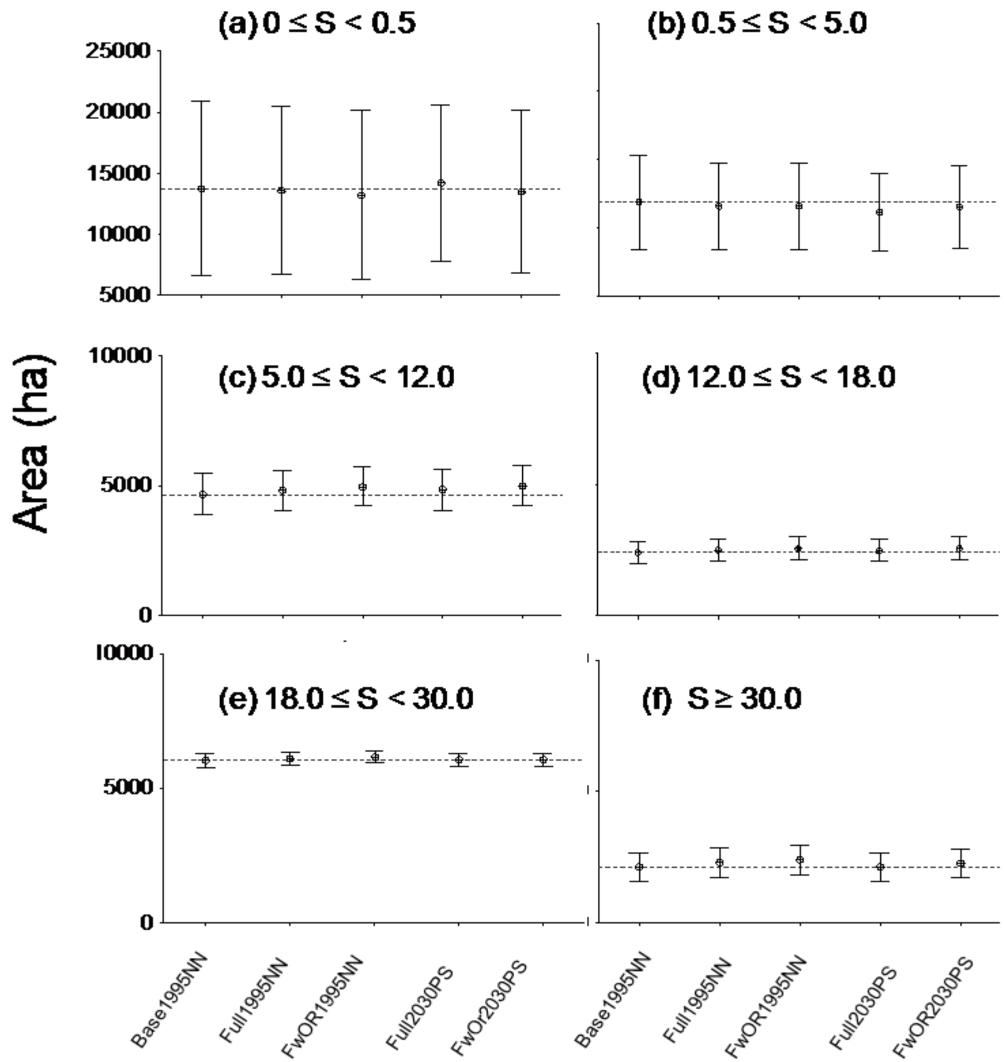
Juvenile Fish Movement in Response to Freshwater Inflow



Depending upon the species (and size), abundances of fish and invertebrates can be positively correlated, negatively correlated, or uncorrelated with freshwater inflow to the LSJR.

Species	Correlation	Size Range (mm)	Best Fit Inflow Lag Period (days)
Atlantic croaker	negative	130-170	120
Atlantic menhaden	uncorrelated	20-40	30-360
Atlantic weakfish	negative	70-110	60
Blue crab	negative	91-180	180
Southern flounder	positive	0-100	30, 210
Southern flounder	negative	126-325	150
Spotted seatrout	negative	31-110	150, 300
Spotted seatrout	positive	210-325	60
Channel catfish	positive	50-275	150, 180
Striped mullet	uncorrelated	0-30	30-360
Striped mullet	positive	31-45	210
White shrimp	uncorrelated	18-25	30 - 360

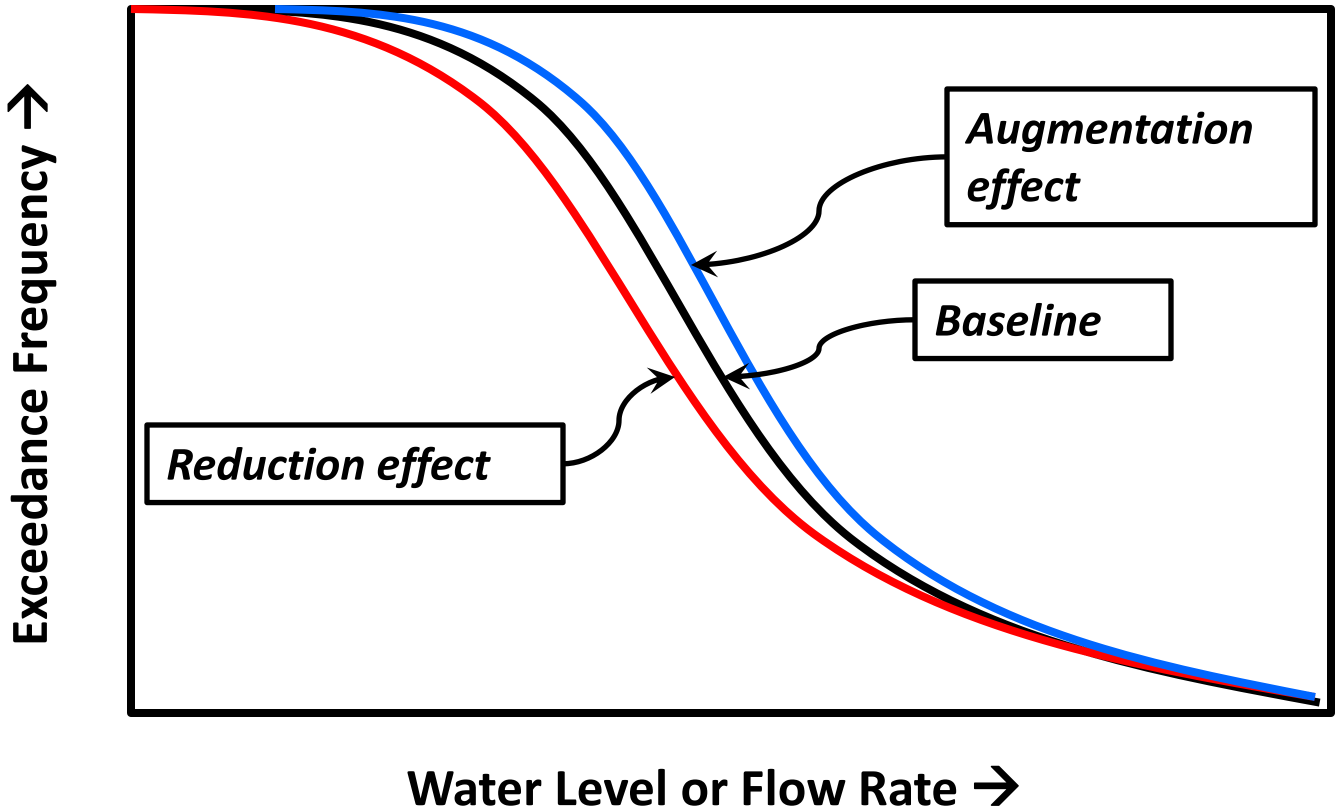
Although salinity isopleths move with variation in freshwater inflows, the mean annual areas of salinity zones varied little among withdrawal scenarios.



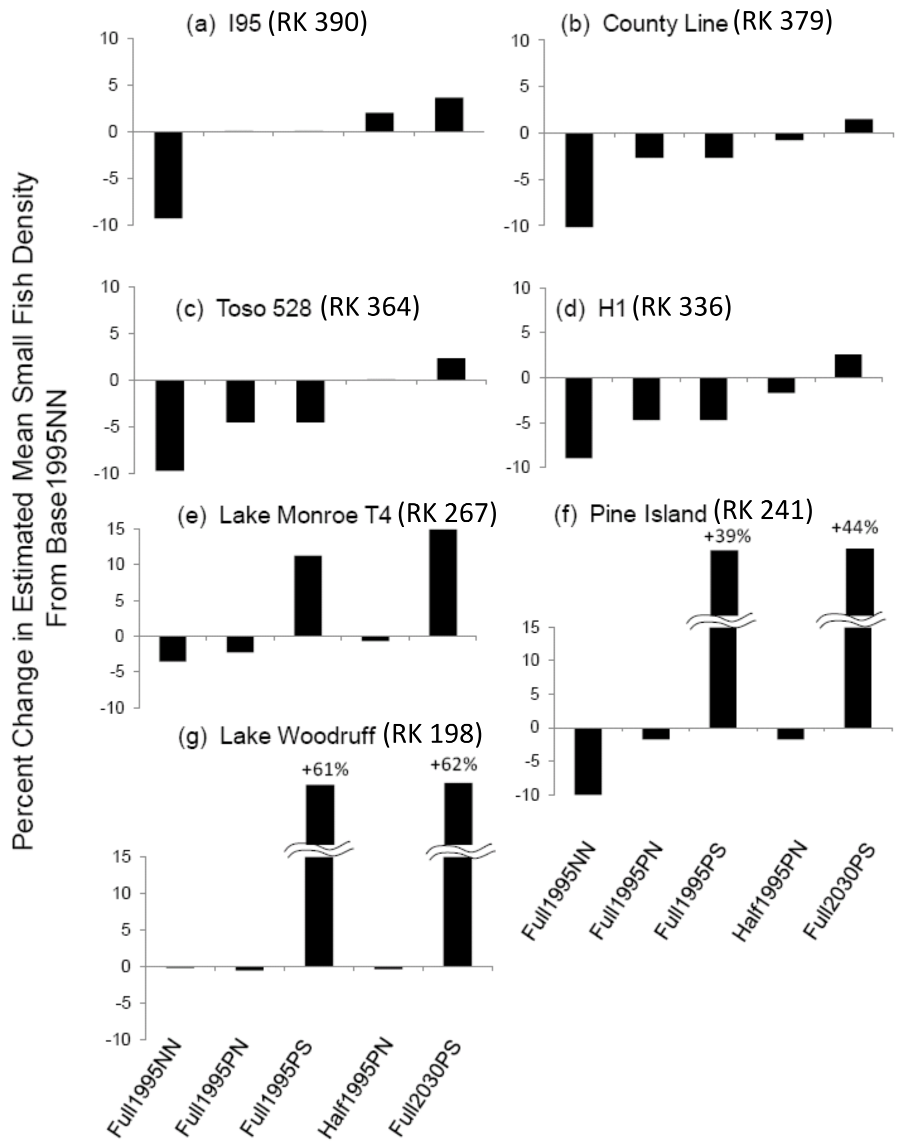
Projected changes in watersheds (land-uses, regional water projects) markedly affected the potential for ecological effects.

Photograph: Dean Campbell

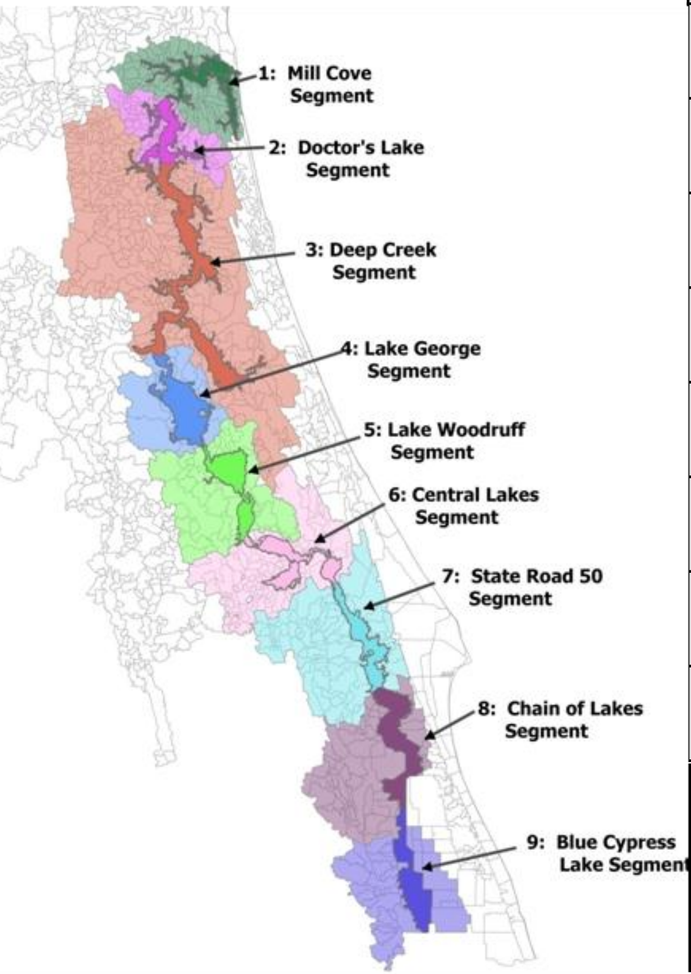
Under forecast conditions, H&H models predicted increases in river discharge – even when withdrawals were imposed. These augmentation effects cannot be attributed to withdrawals.



Results – <u>Attributes</u> **-** *Fish Abundance* - Deviations in small floodplain fish density under various scenarios.



Under the modeled conditions, hydroecological effects were no more than moderate in both hindcast and forecast scenarios and no more than minor in forecast scenarios with up to 155 mgd withdrawals.



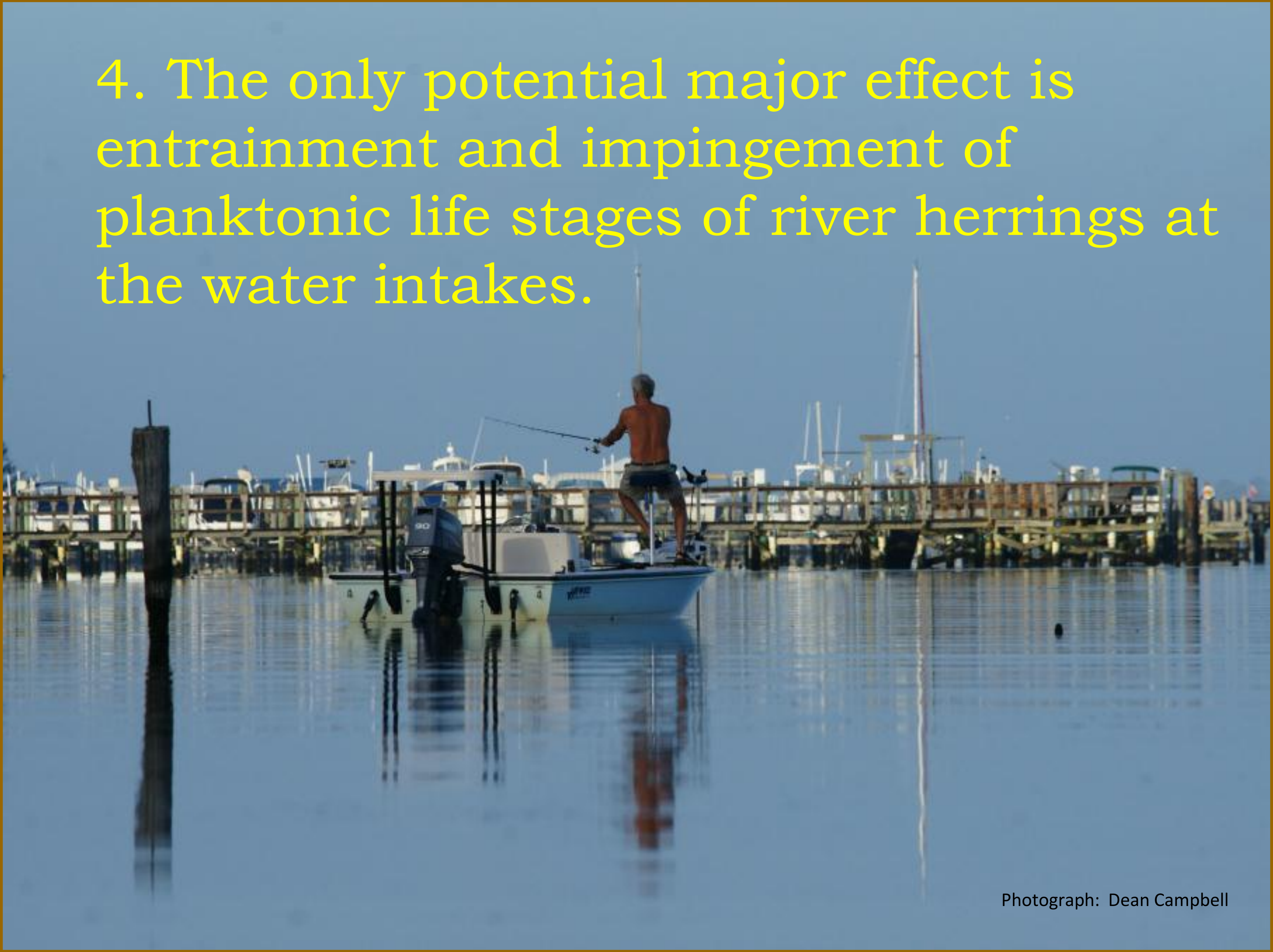
River Segment	Hindcast 155 mgd	Hindcast 77.5 mgd	Forecast 262 mgd	Forecast 155 mgd	Forecast 77.5 mgd
1					
2					
3					
4					
5					
6					
7					
8					

	Negligible effect
	Minor effect
	Moderate effect
	Major effect
	Extreme effect

Discussion

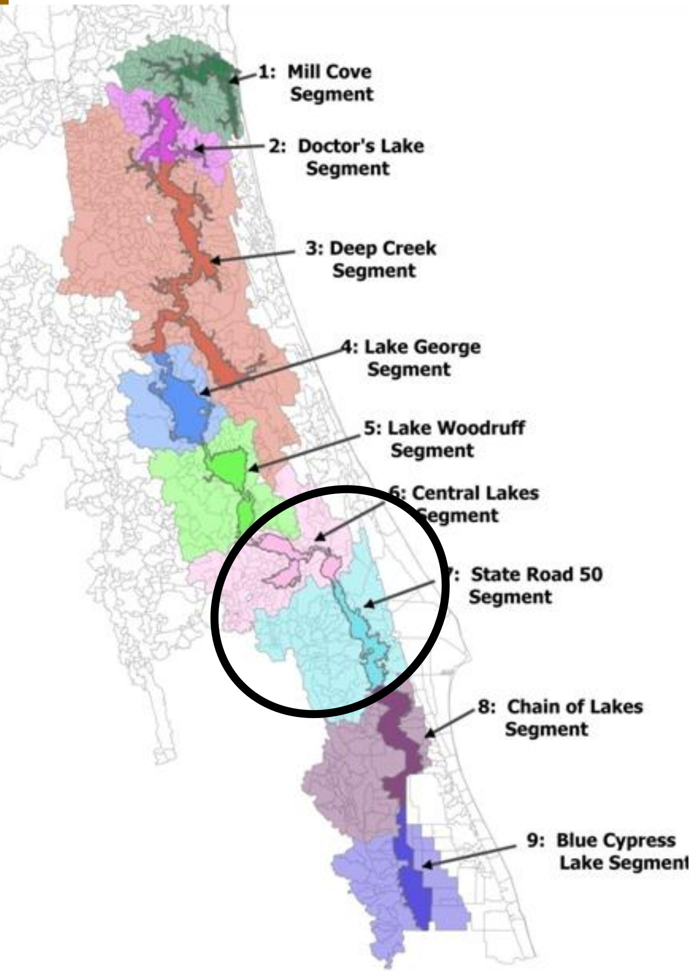
Photograph: R. S. Burks

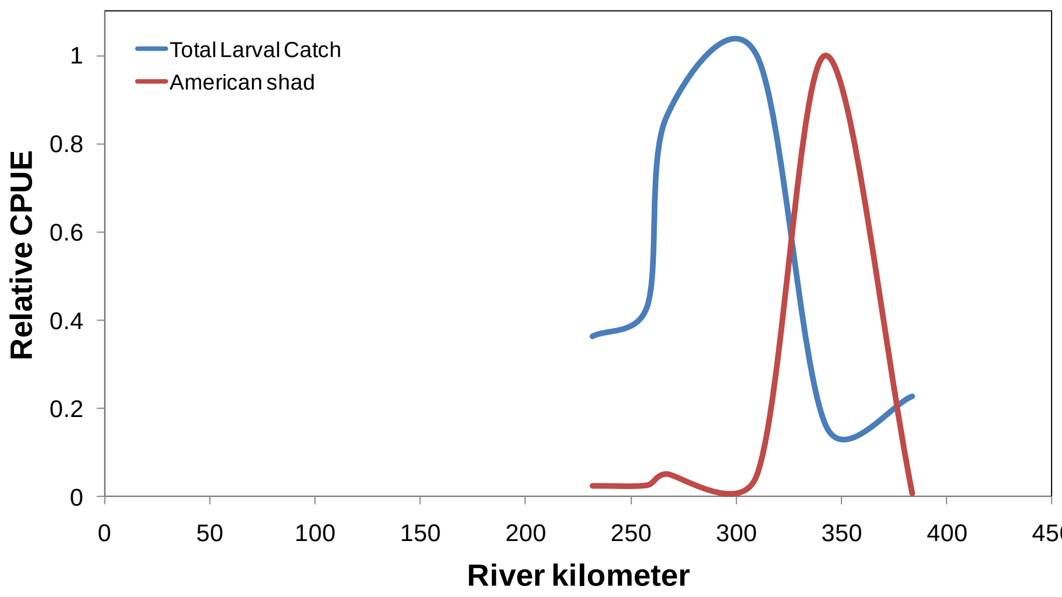
4. The only potential major effect is entrainment and impingement of planktonic life stages of river herrings at the water intakes.



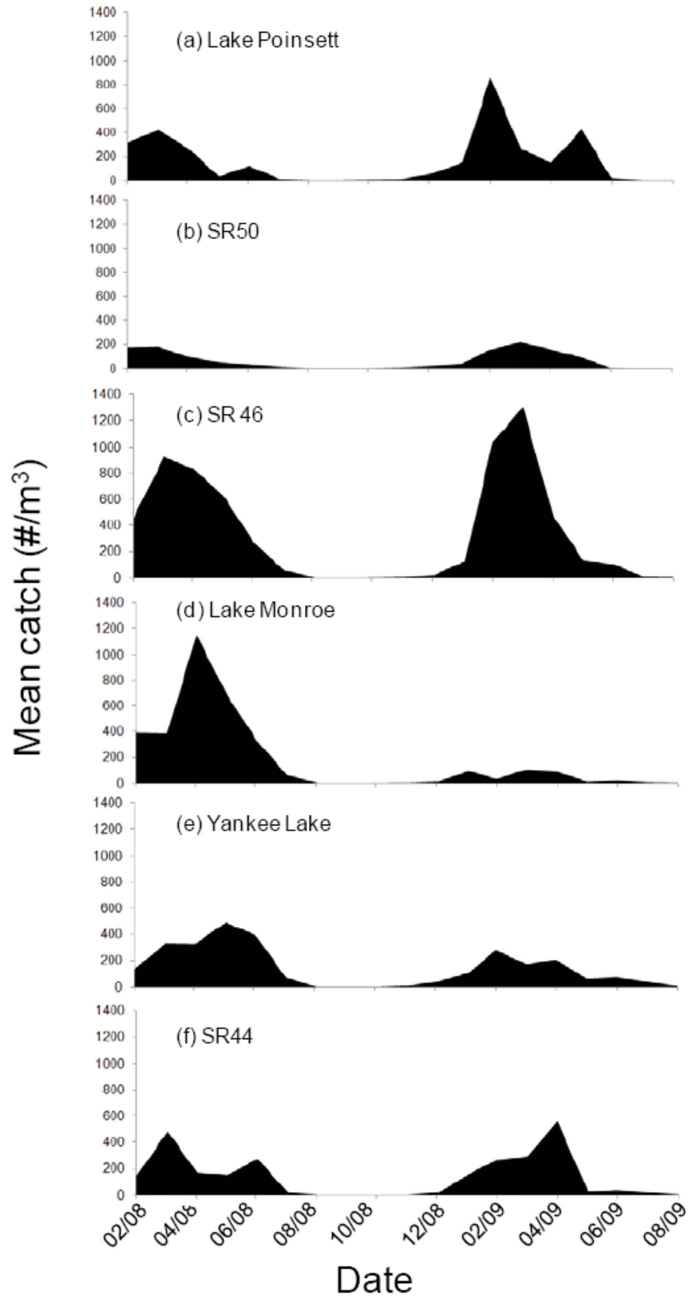
Photograph: Dean Campbell

The density of planktonic life stages of river herrings peaks in the upper segments (6& 7) near SR 46 and SR 50. Seasonally, the peak abundance is in winter and early spring. E&I can be avoided through suitable location, design, and operation of water intake structures.

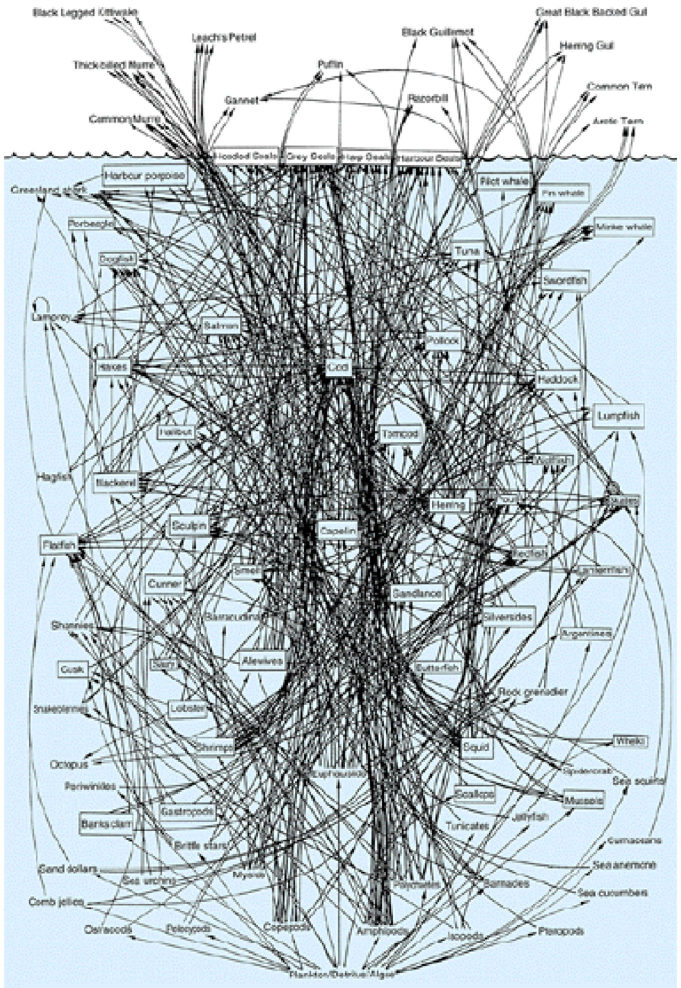




Results – Attributes **-** *Fishes* – Potential for E&I - Monthly variation in larval fish density at various locations in the St. Johns River.

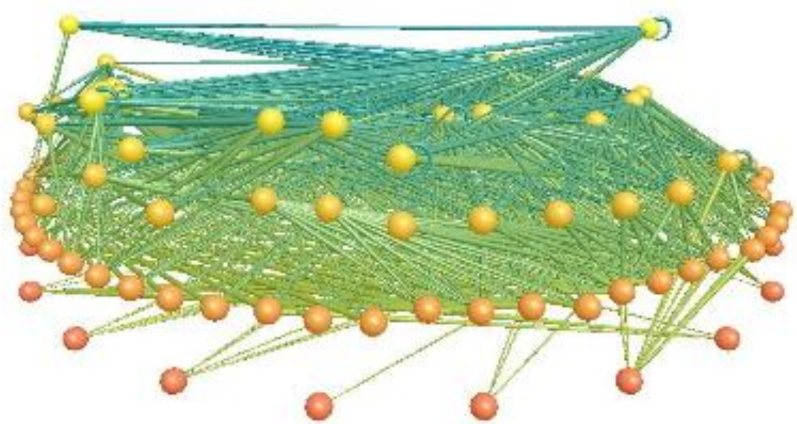


<u>Complexity and Scientific Uncertainty</u> - Ecosystems are extraordinarily complex. Predictions for such complex systems will always have an associated level of scientific uncertainty.



A simplified food web for the Northwest Atlantic

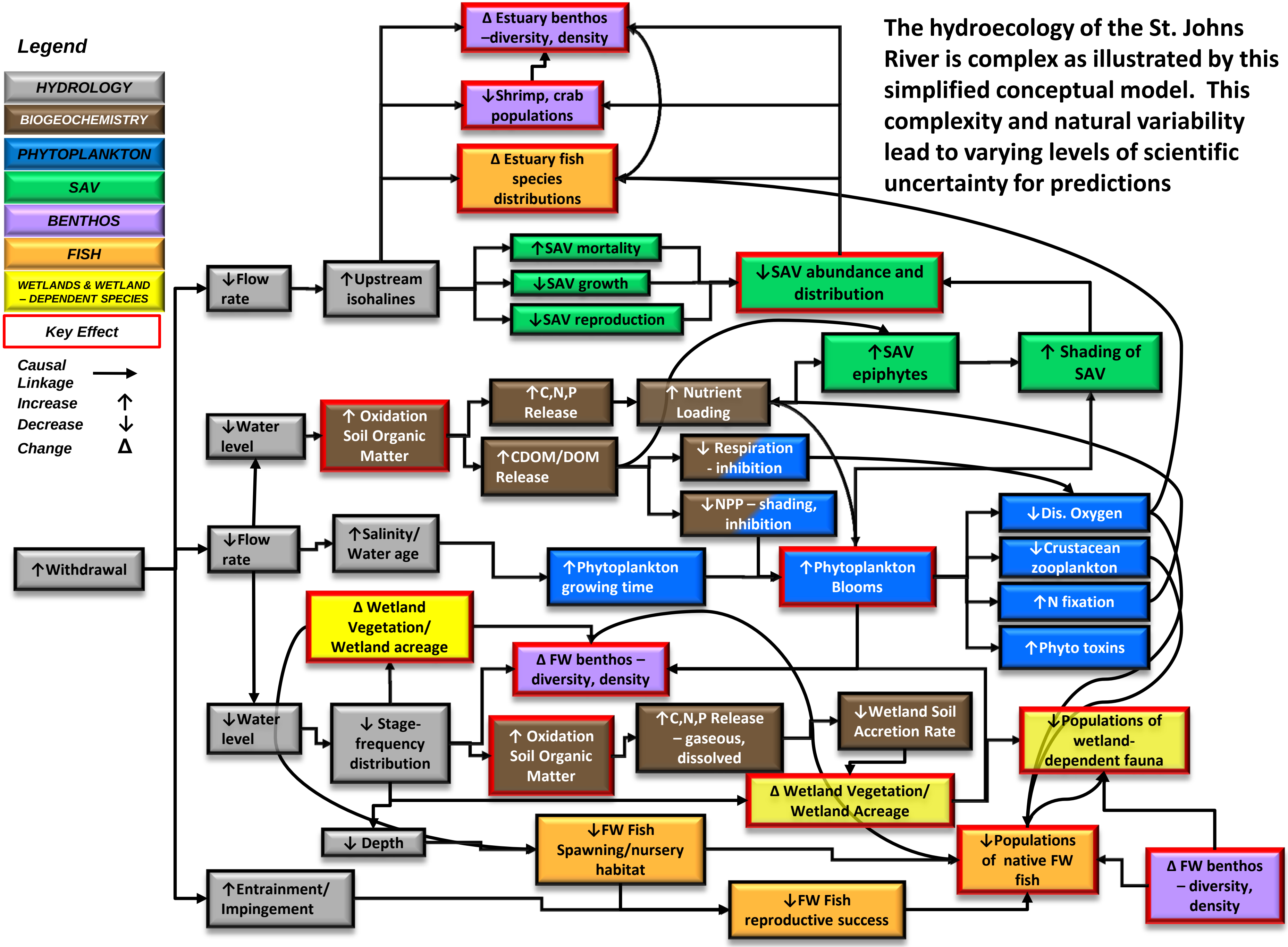
Lavigne & Fink, 2001.



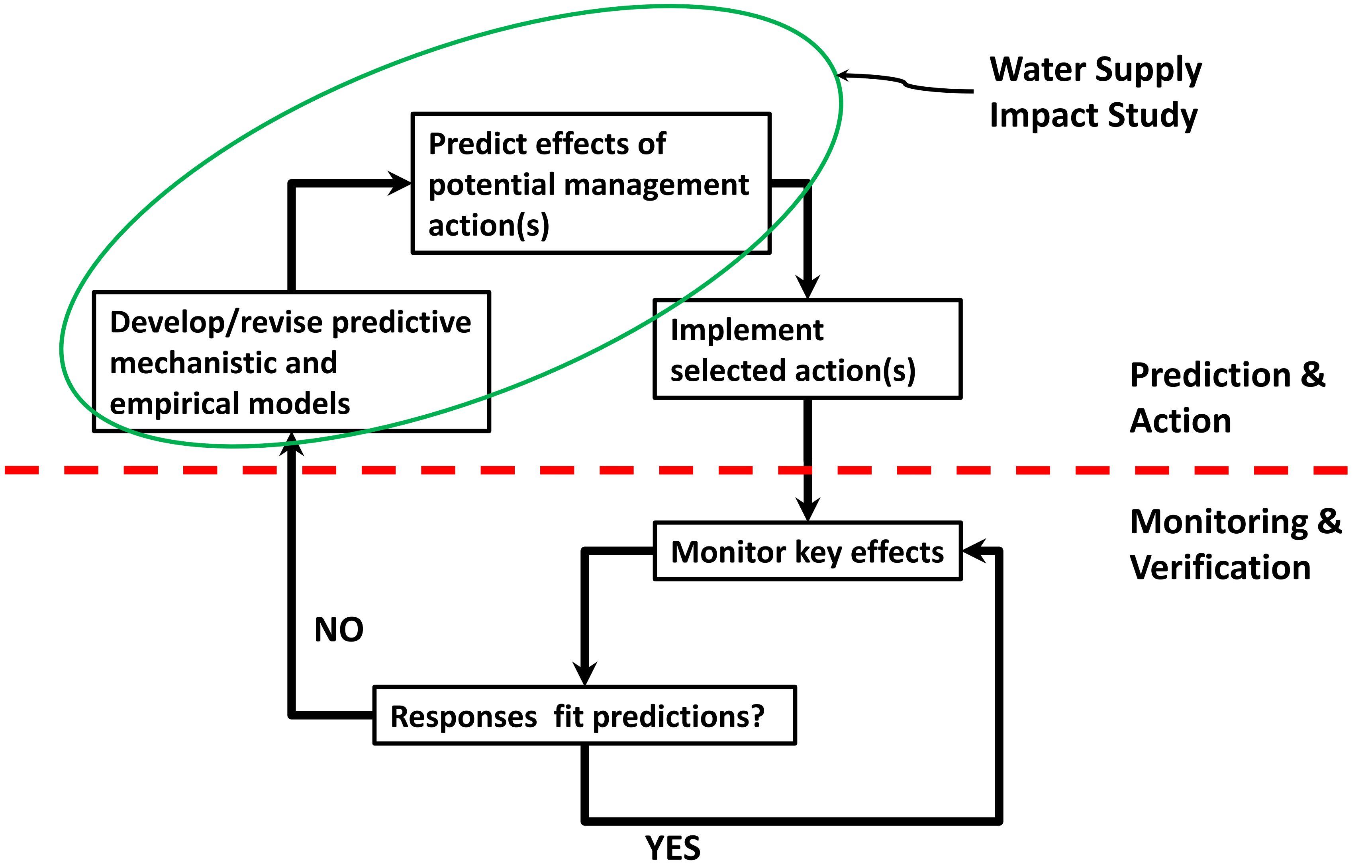
Food web of Little Rock Lake, Wisconsin
Yoon et al., 2005.

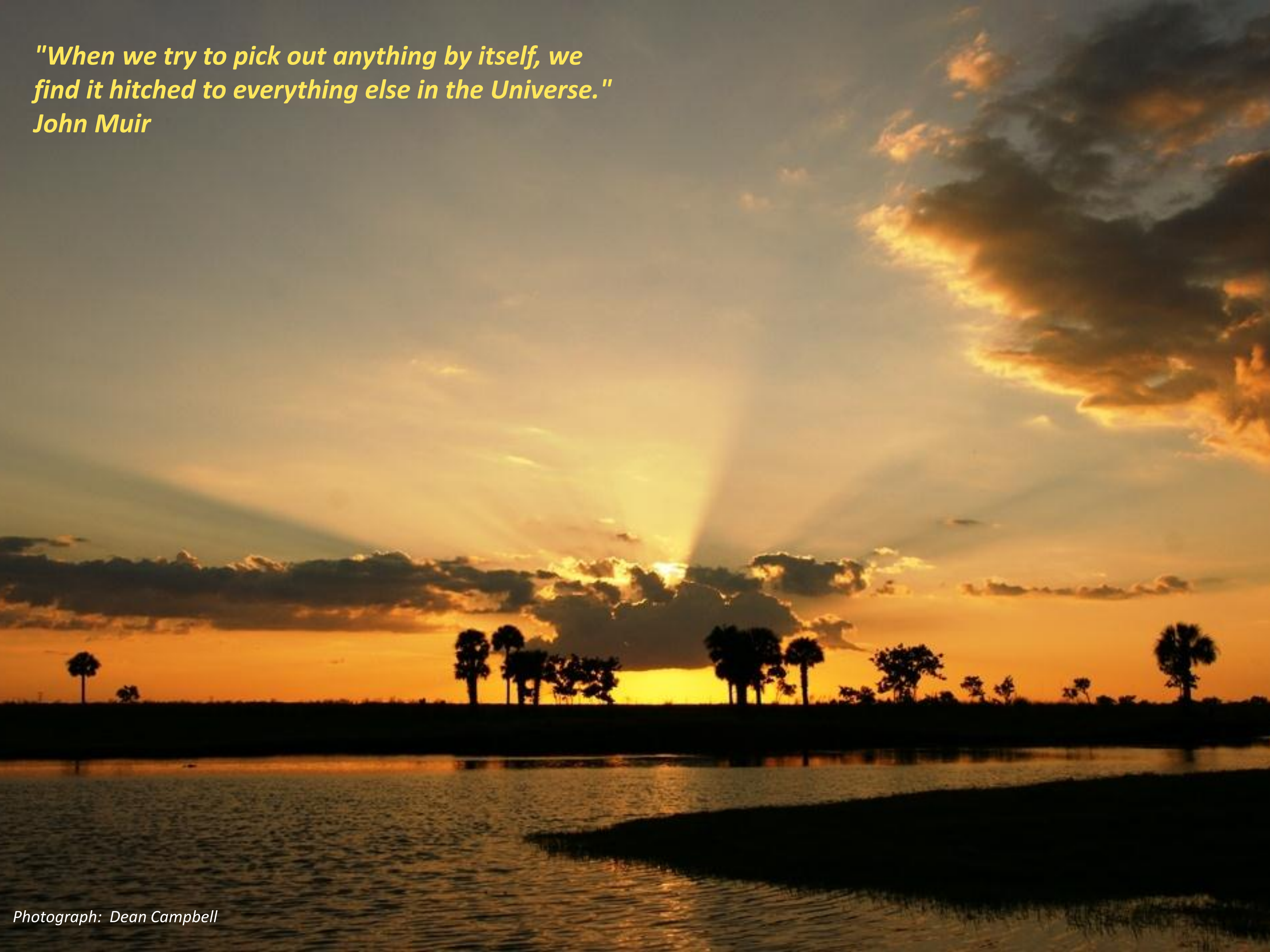
These food webs illustrate the trophic complexity of ecosystems. The complexity would increase considerably if interactions with physical and chemical variables were included.

The hydroecology of the St. Johns River is complex as illustrated by this simplified conceptual model. This complexity and natural variability lead to varying levels of scientific uncertainty for predictions



Managing Complexity- Perhaps, the most appropriate strategy for managing a complex system and scientific uncertainty is adaptive management.





Photograph: Dean Campbell