Modeling Hypoxia and Ecological Responses to Water Quality and Climate

1. Concept of Response to Habitat Change
2. Test of Concept
3. Predictive Model
4. Test of Model Assumptions
5. Application
6. Habitat Preference

Past and Future Predictions of Hypoxia and Climate Change

↓

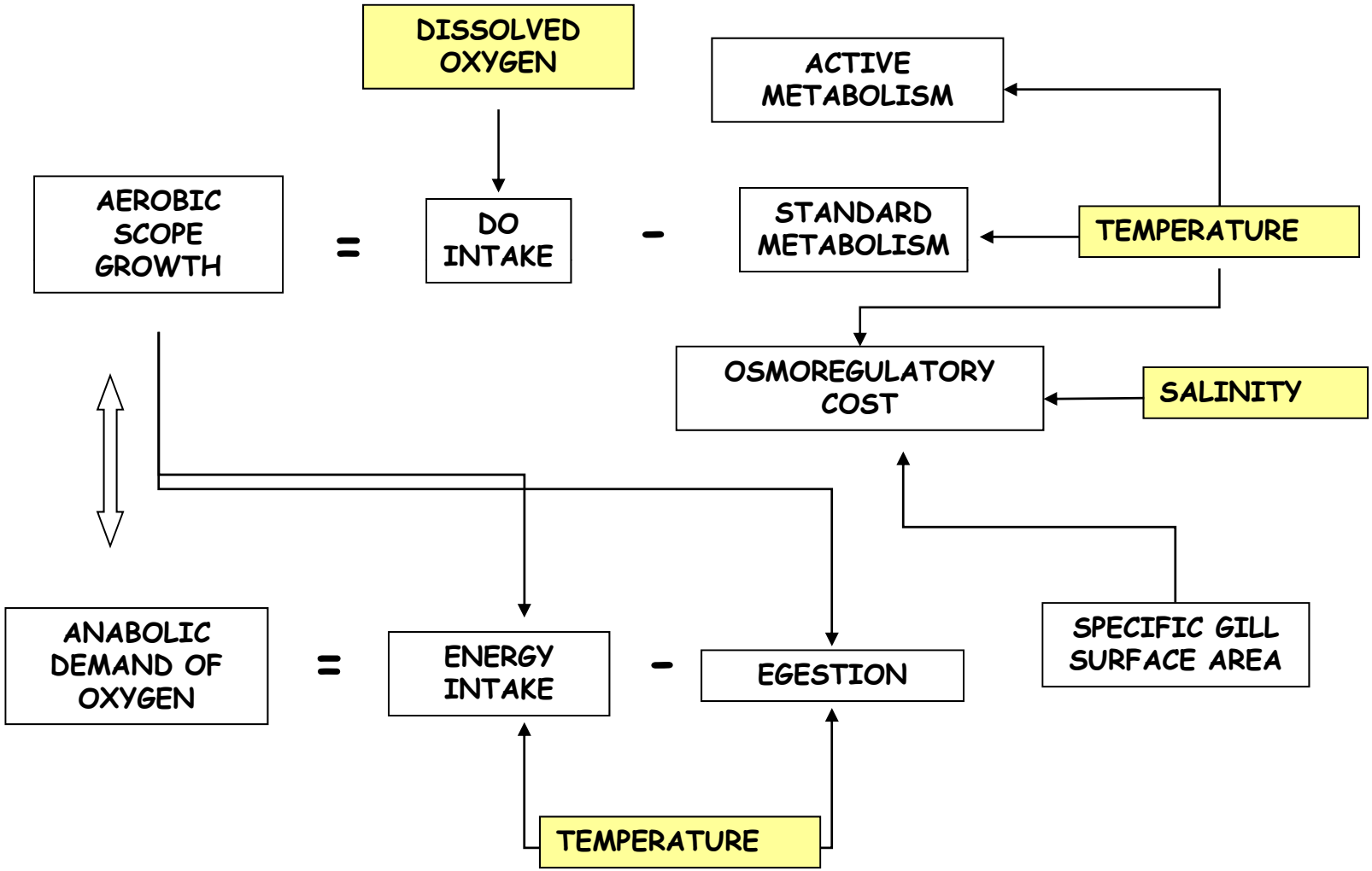
Essential Habitat Model: Sturgeon

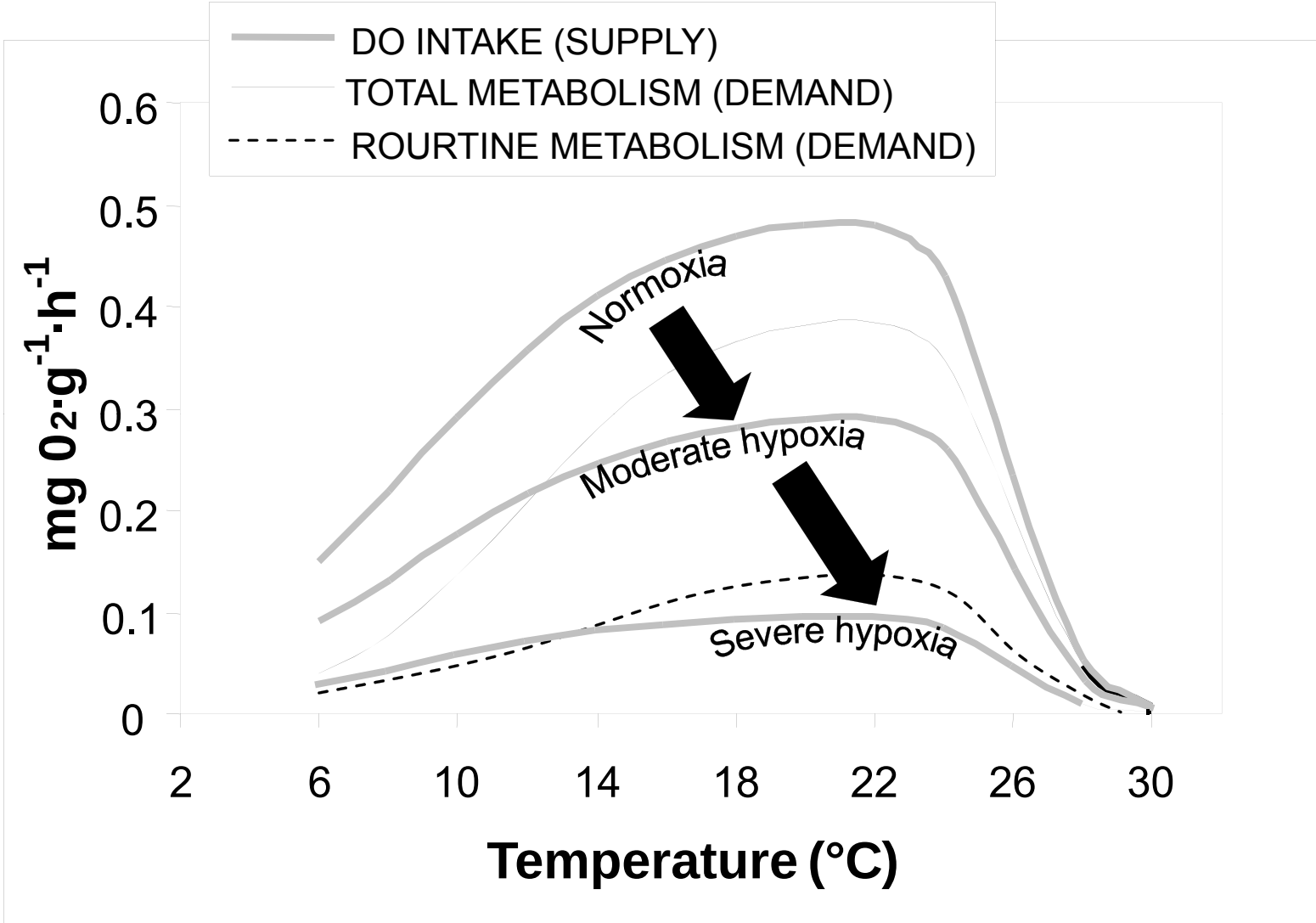
↓

Habitat Size and Quality

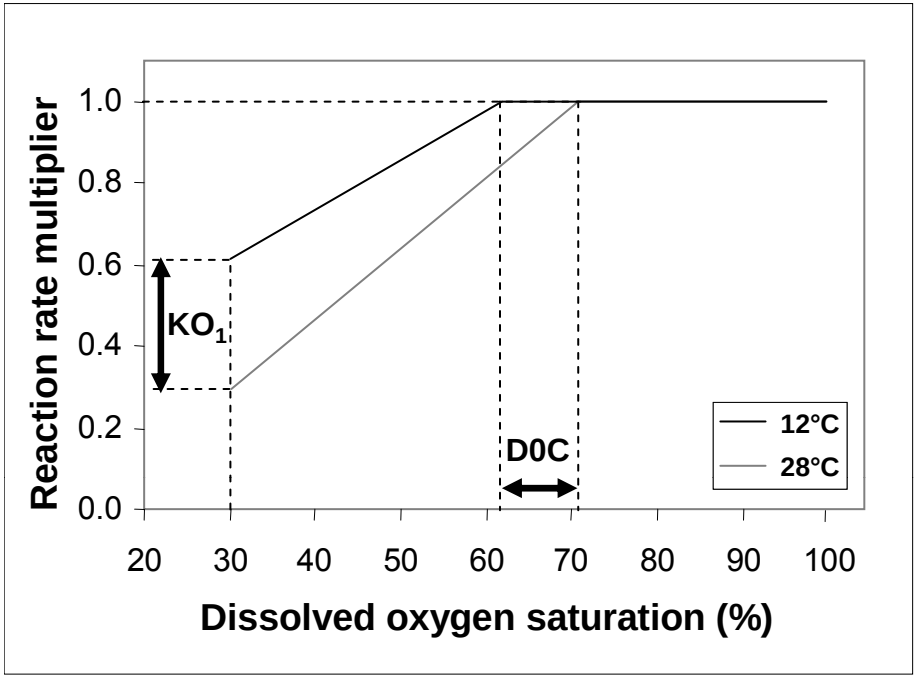
Concept:

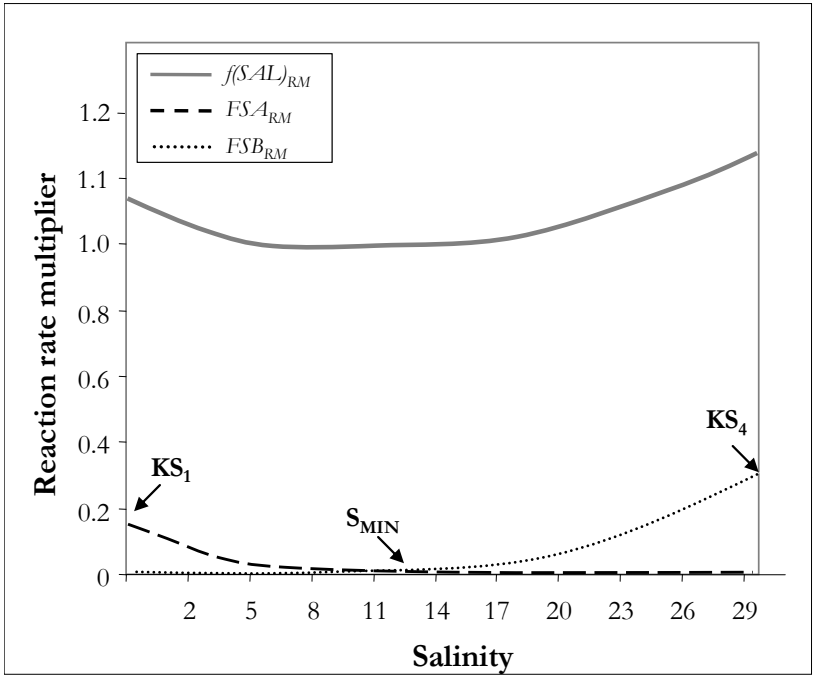
1. Budget: Growth = Food Consumption – (Metabolism + Wastes)
2. Oxygen Limits Budget in Ordered Way: $RM_{OD}+ACT_{OD}+SDA_{OD} \leq DO_{IN}$




DO INTAKE (SUPPLY)
TOTAL METABOLISM (DEMAND)
ROURTINE METABOLISM (DEMAND)
0.6
0.5
0.4
0.3
0.2
0.1
0
mg O2·g-1·h-1
Normoxia
Moderate hypoxia
Severe hypoxia
2
6
10
14
18
22
26
30
Temperature (°C)

Pauly's oxygen as limiting resource X Fry's classification scheme



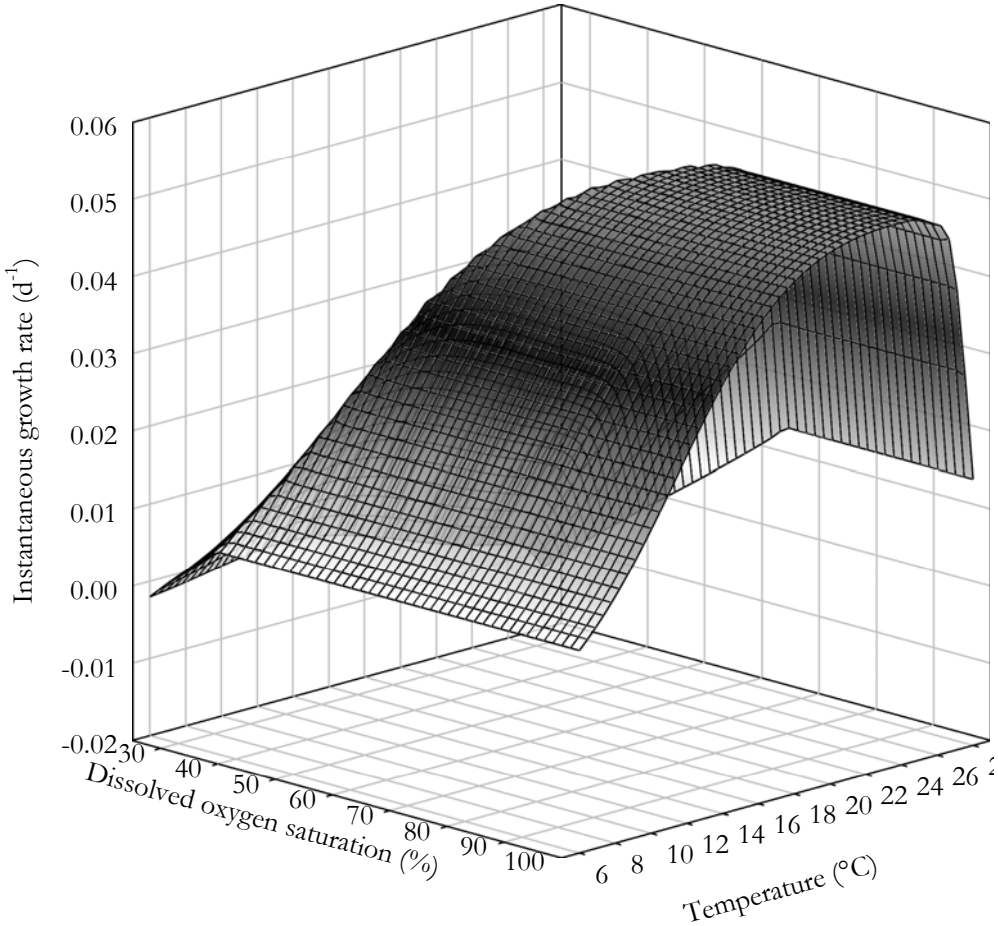


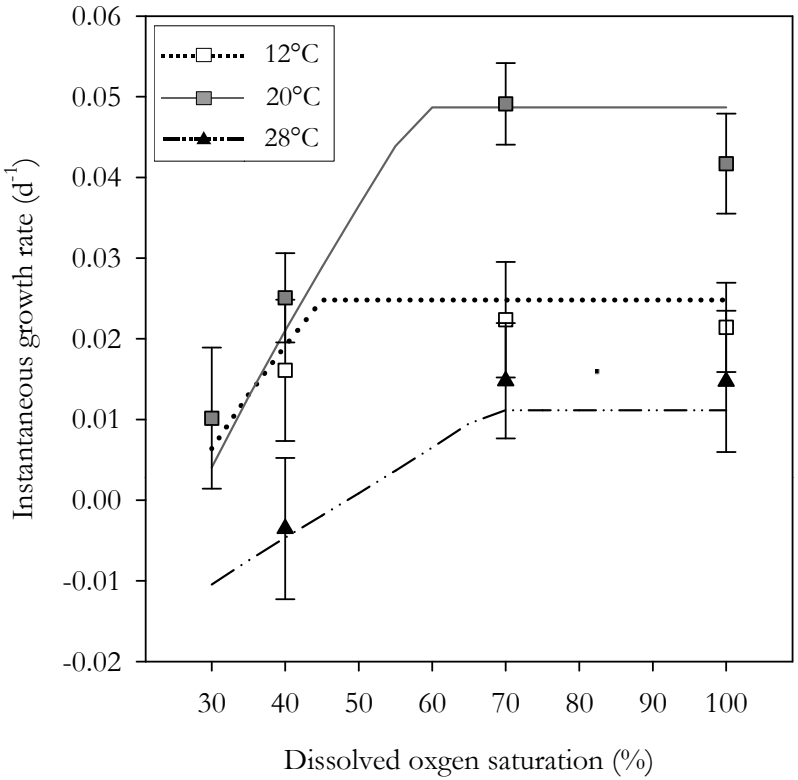
"Limiting" Effect on RM

"Masking" Effect on RM

Niklitschek, E.S. and D.H. Secor. 2010. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. Laboratory Results. J. Exp. Mar. Biol. Ecol. . J. Exp. Mar. Biol. Ecol. 381, Suppl. 1: 150-160.

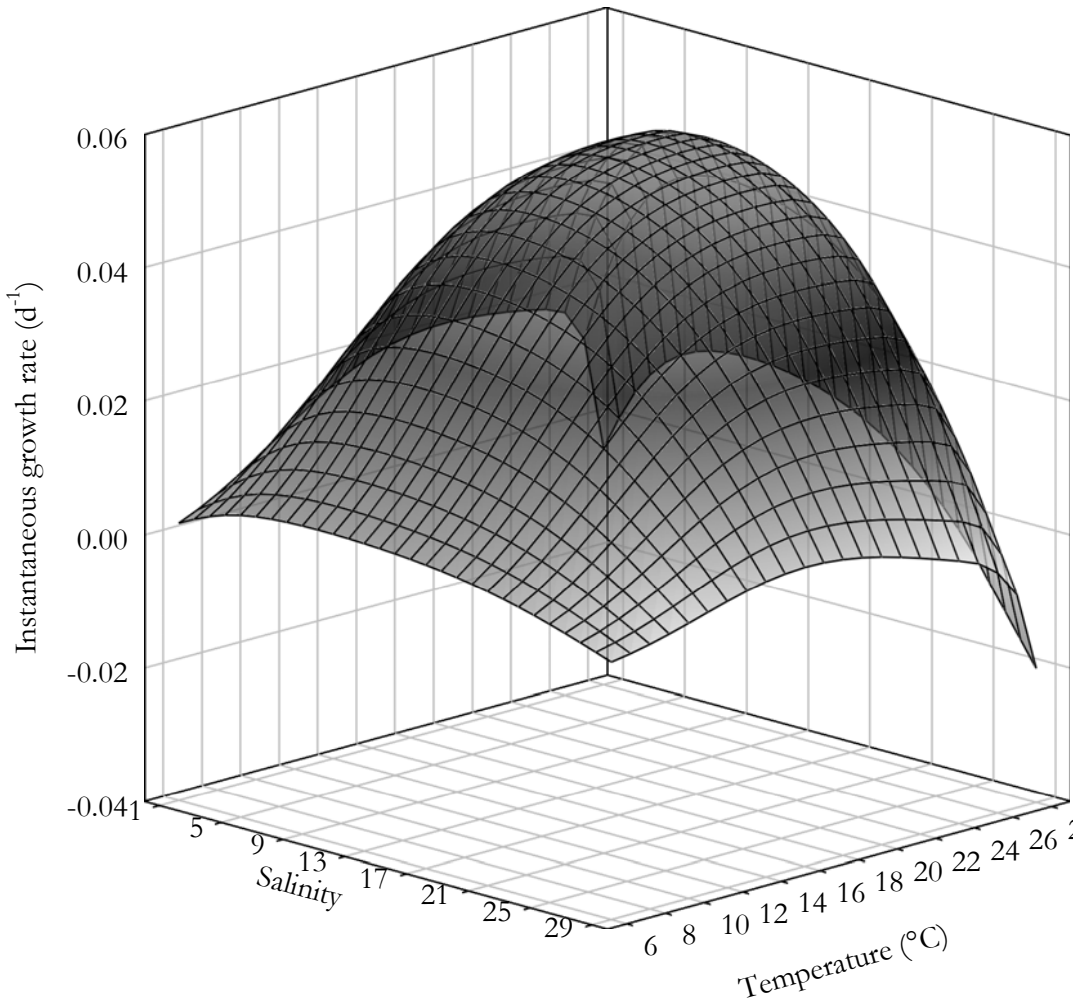
Niklitschek, E.S. and D.H. Secor. 2010. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: II. Model development and testing. J. Exp. Mar. Biol. Ecol. J. Exp. Mar. Biol. Ecol. 381, Suppl. 1: 161-172.

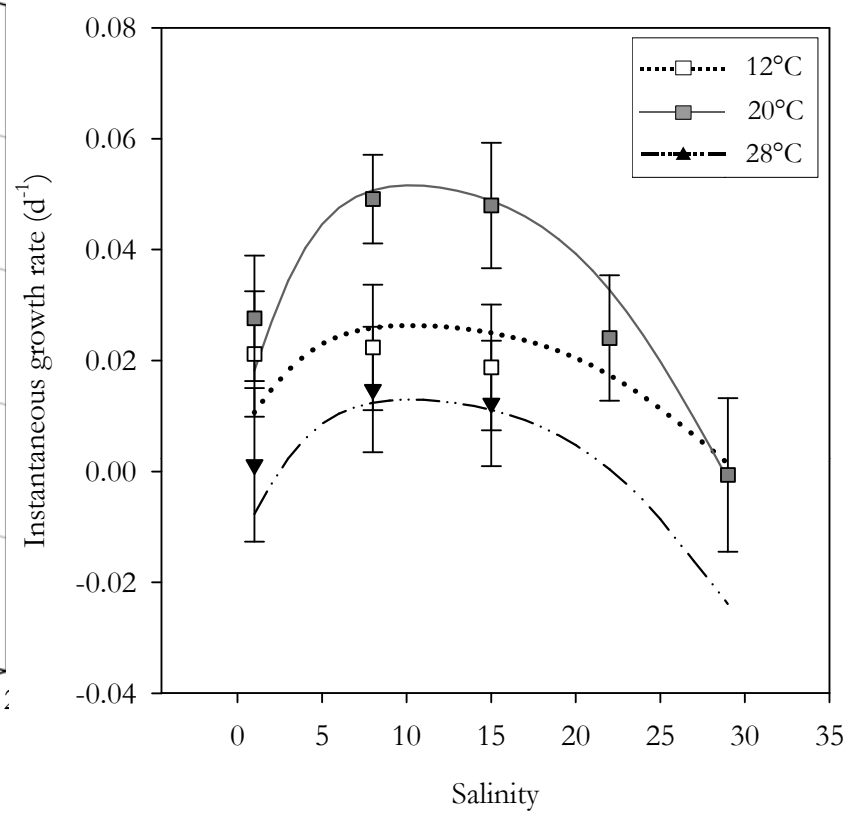




Dr. Edwin Niklitschek

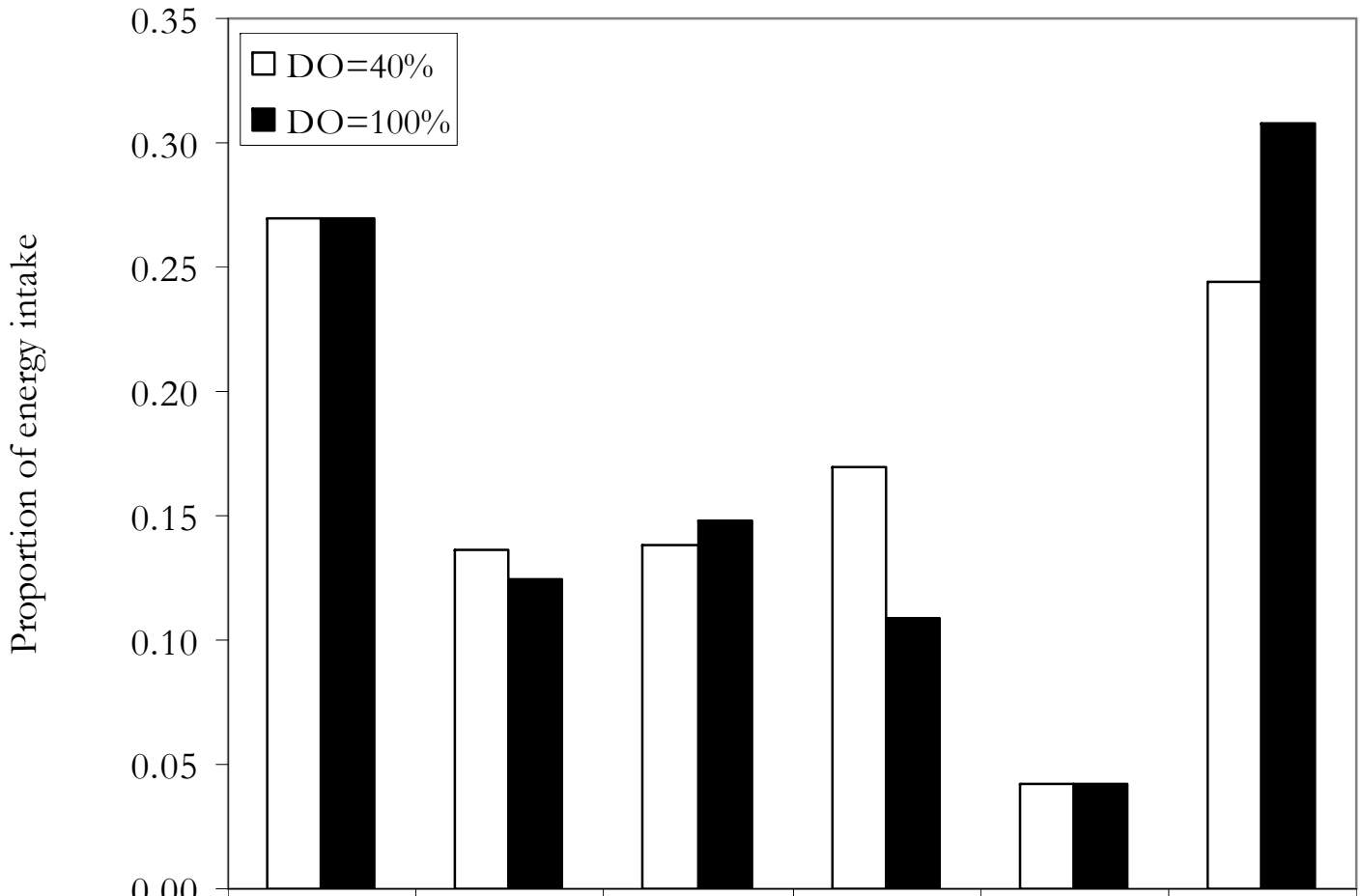
DO x Temperature





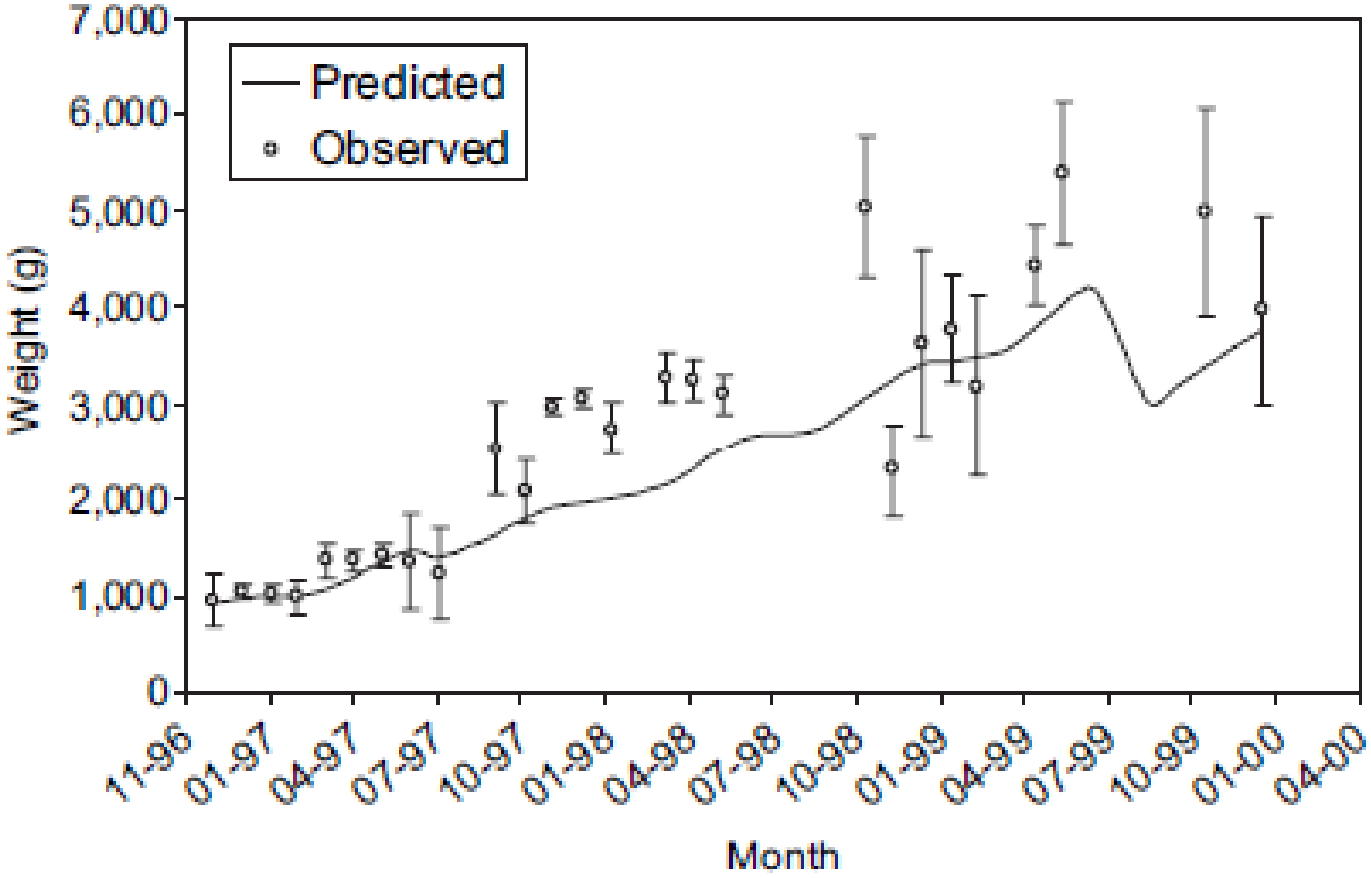
Salinity x Temperature

Hypoxia: Adaptive Response



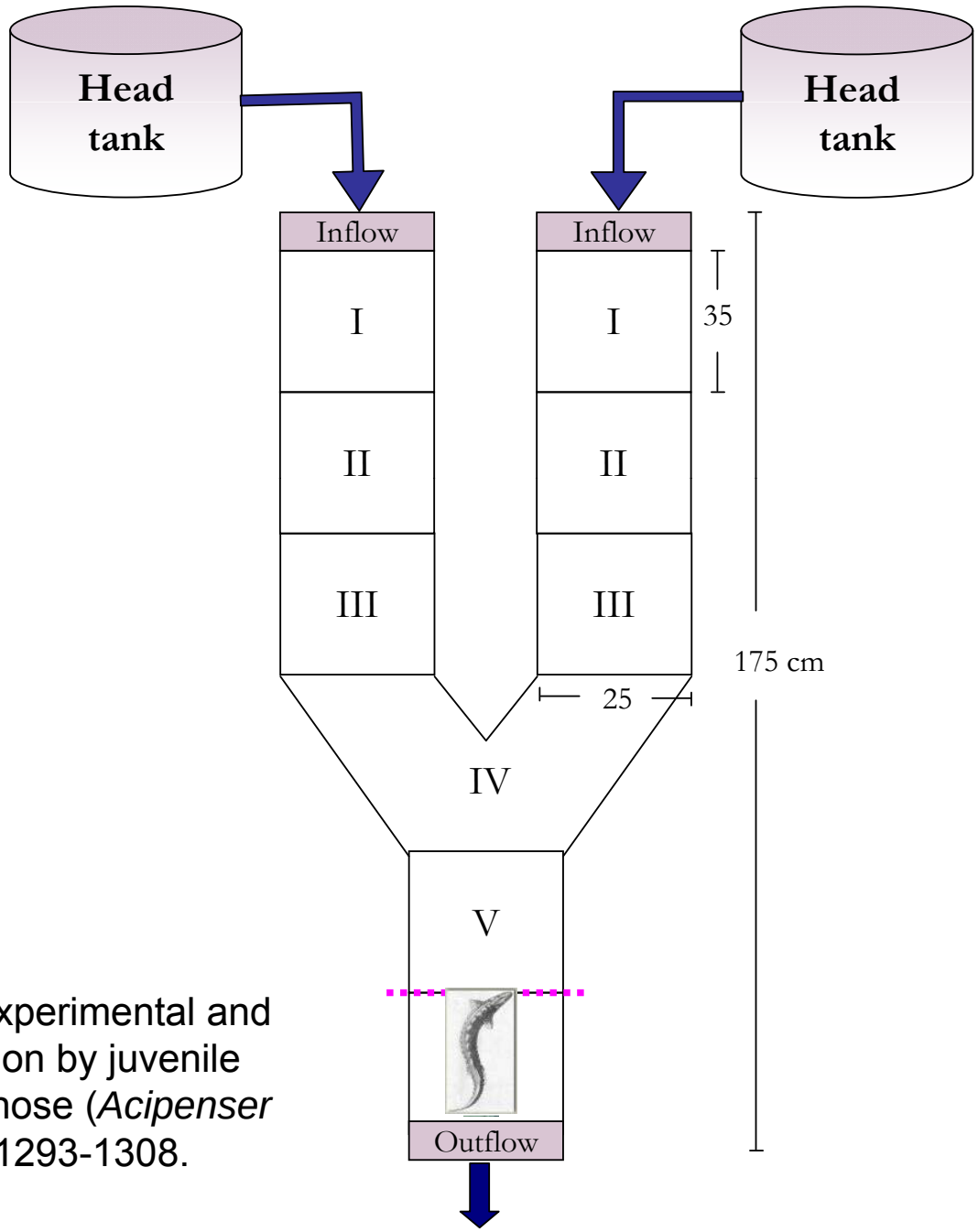
	ACT	RM	SDA	EG	U	G
DO=40%	27%	14%	14%	17%	4%	24%
DO=100%	27%	12%	15%	11%	4%	31%

Corroboration: Mesocosm Trials



Corroboration: Preference

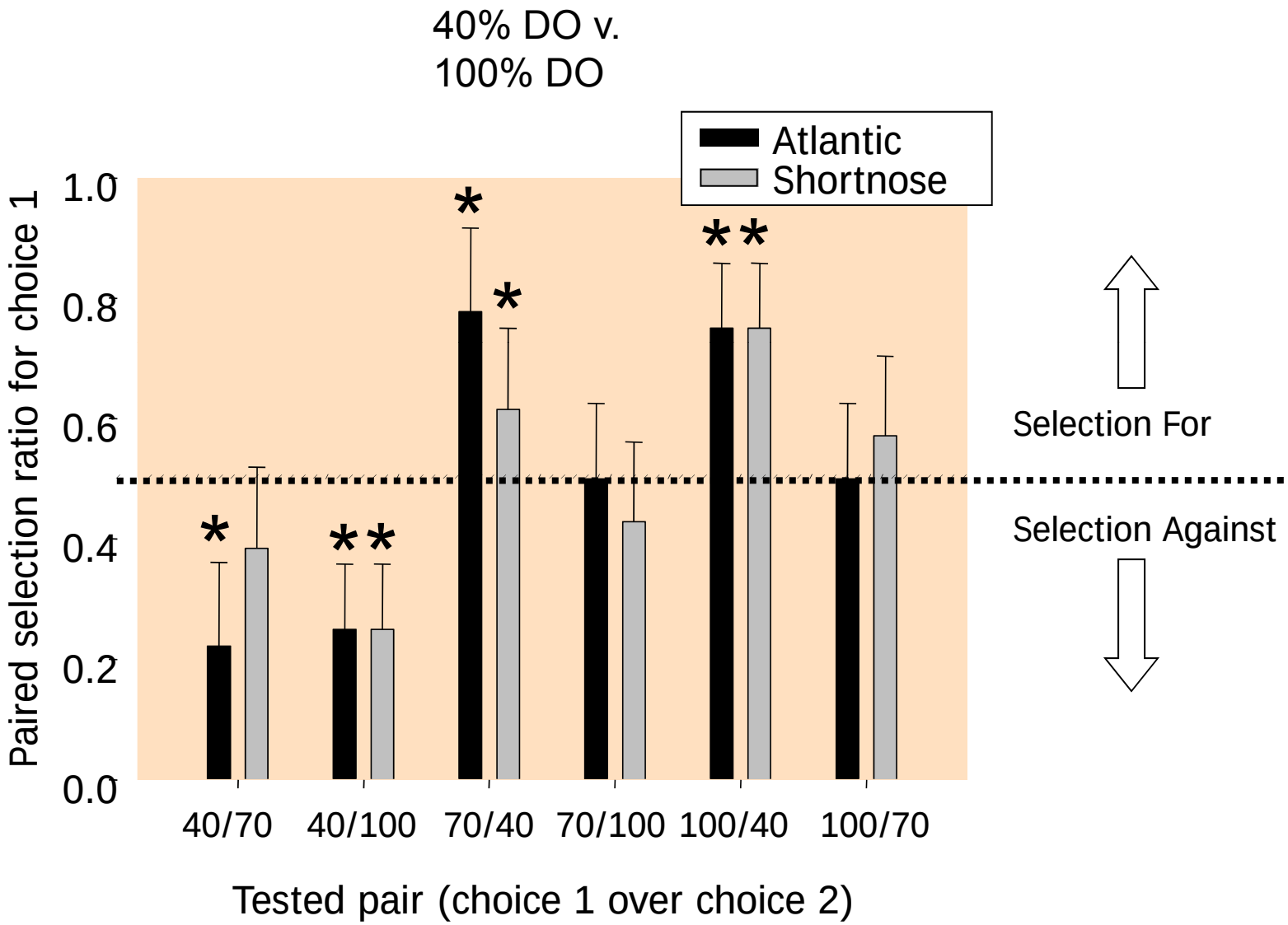
- Y-shaped raceway divided in two confluent legs and 6 sections
- Fish allowed to acclimate to the raceway for 30 min and then released to swim against the current
- Selected branch and section recorded after 20 min
- Water quality monitored at each branch and section before/after each experiment



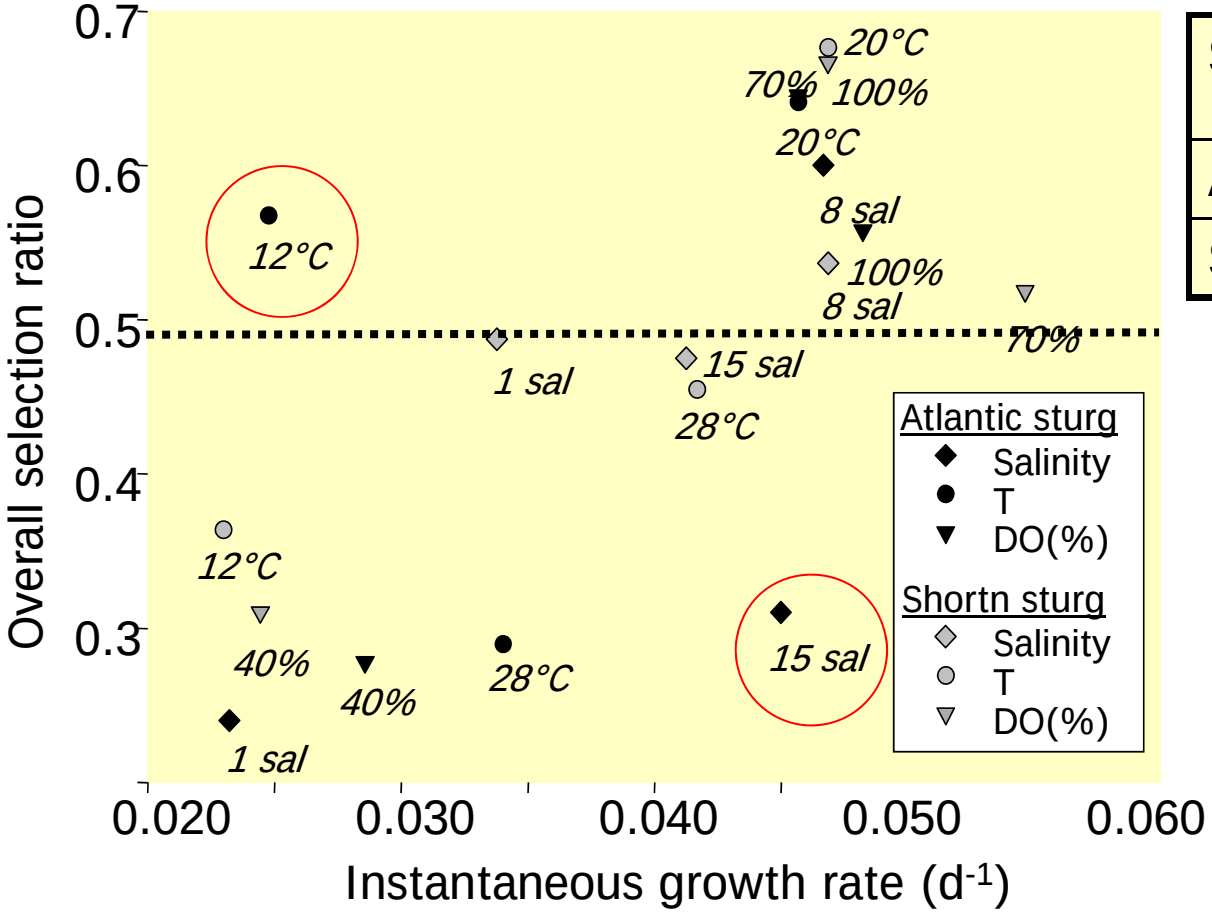
Niklitschek, E.S. and D.H. Secor. 2010. Experimental and field evidence of behavioral habitat selection by juvenile Atlantic (*Acipenser oxyrinchus*) and shortnose (*Acipenser brevirostrum*) sturgeons. J. Fish Biol. 77: 1293-1308.

Corroboration: Preference

Results: dissolved oxygen experiments



Corroboration: Preference



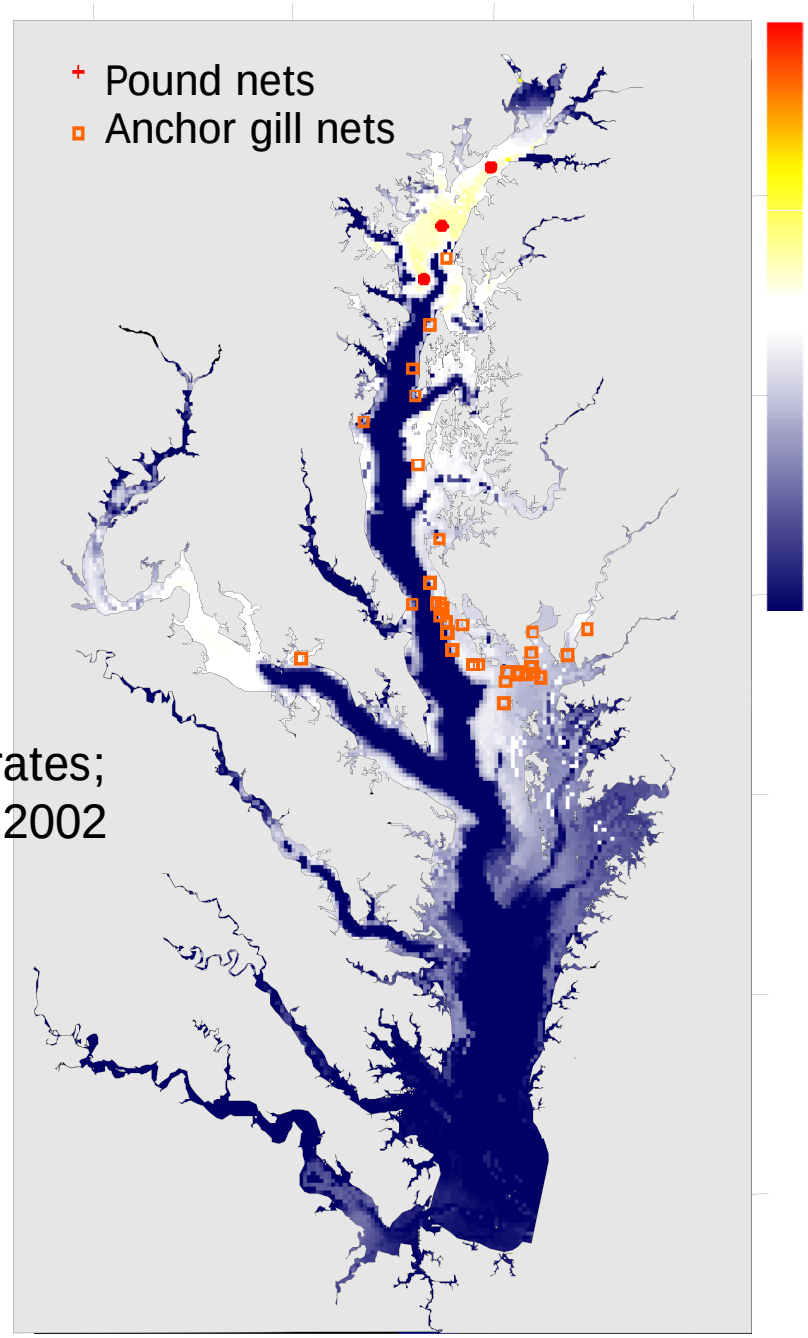
Species	r	P
Atlantic	0.63	0.07
Shortnose	0.80	0.01

Niklitschek, E.S. and D.H. Secor. 2010. Experimental and field evidence of behavioral habitat selection by juvenile Atlantic (*Acipenser oxyrinchus*) and shortnose (*Acipenser brevirostrum*) sturgeons. J. Fish Biol. 77: 1293-1308.

Field evidence for Atlantic sturgeon habitat selection in the Chesapeake Bay

- 15 to 90% of the bay unsuitable for juvenile Atlantic sturgeon, worst in summer
- 85% of 619 captures recorded in 1997-1999 occurred in sites where positive production was expected
- Growth rates in recaptured individuals matched maximum growth expectations

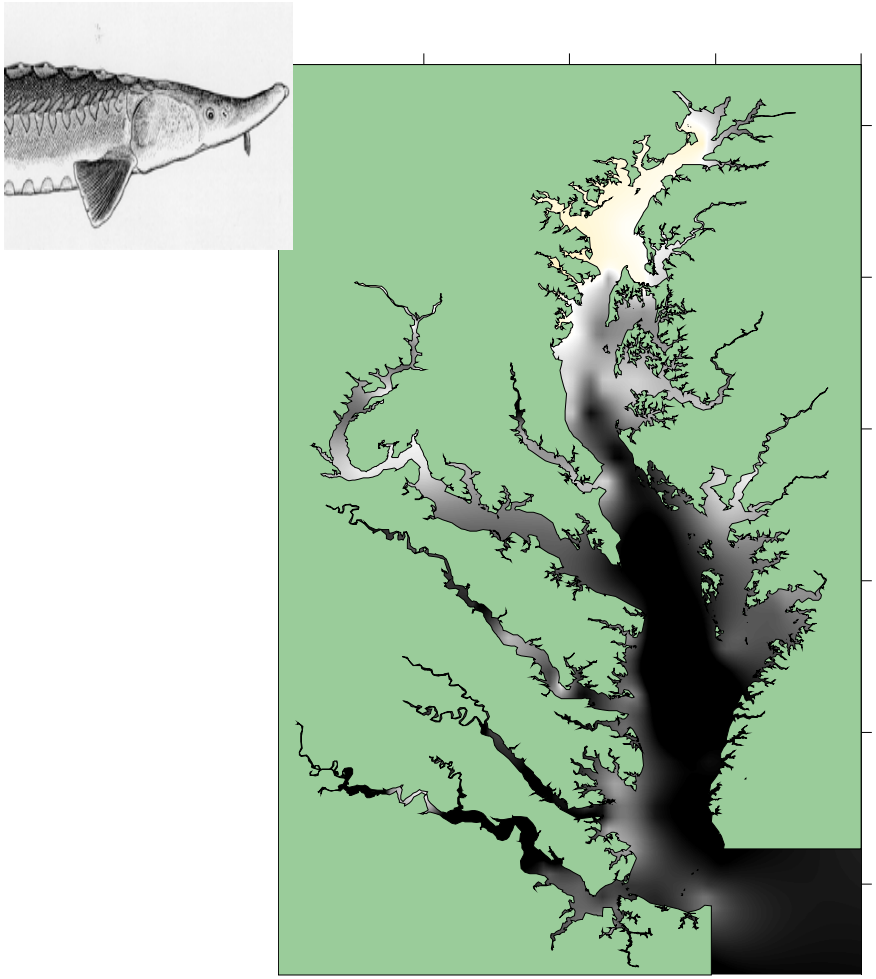
Average growth rates;
July 1993-2002



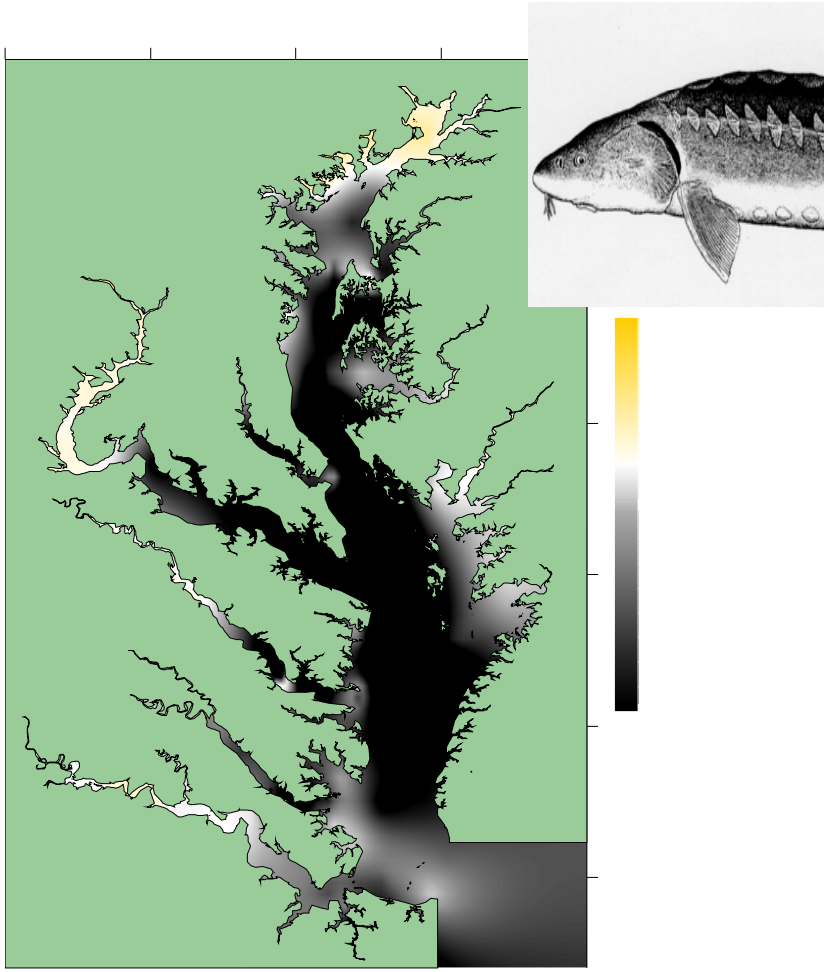
Niklitschek, E.J. and Secor, D.H. 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine and Coastal Shelf Science 64: 135-148.

Application

Summer habitat reduced by temperature, hypoxia and salinity interactions



Atlantic sturgeon

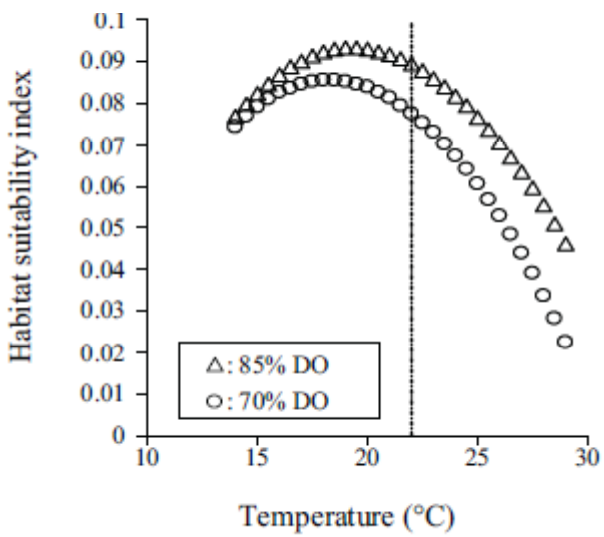


Shortnose sturgeon

Application – Hudson River

Table 4.—Summary table of bioenergetic modeling simulations of habitat suitability for a 5-g juvenile shortnose surgeon in the upper Hudson River estuary. Temperature indicates range of years used for simulation and simulated change (e.g., +1°C), Salinity was held constant at 0 for all model runs. DO = dissolved oxygen.

		Model input	
Simulation	Scenario	DO (% sat)	Temperature
Historical: Albany Pool	Baseline run (current conditions)	85	1987–2005
	Moderate hypoxia	40	1987–2005
	Severe hyopoxia	20	1987–2005
Forecast: Climate change	Baseline run (85% DO)	85	1988
	1°C increase	85	1988 + 1°C
	3°C increase	85	1988 + 3°C
	Baseline run (70% DO)	70	1988
	1°C increase	70	1988 + 1°C
	3°C increase	70	1988 + 3°C



Woodland, R.J., D.H. Secor, and E.J. Niklitschek. 2009. Past and future habitat suitability for the Hudson River population of shortnose sturgeon: a bioenergetic approach to modeling habitat suitability for an endangered species. Am. Fish. Soc. Symp. 69: 589-604.

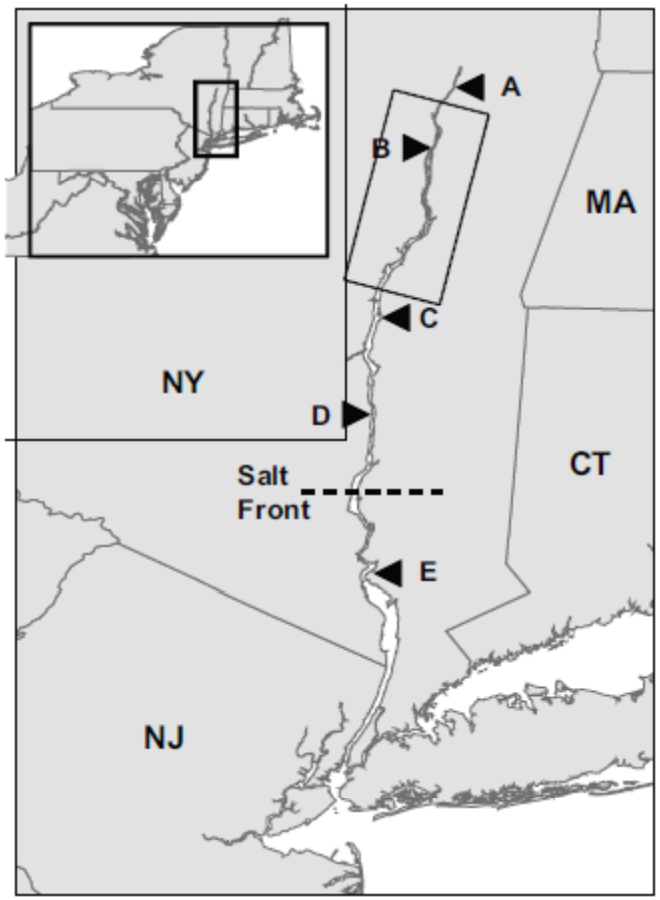
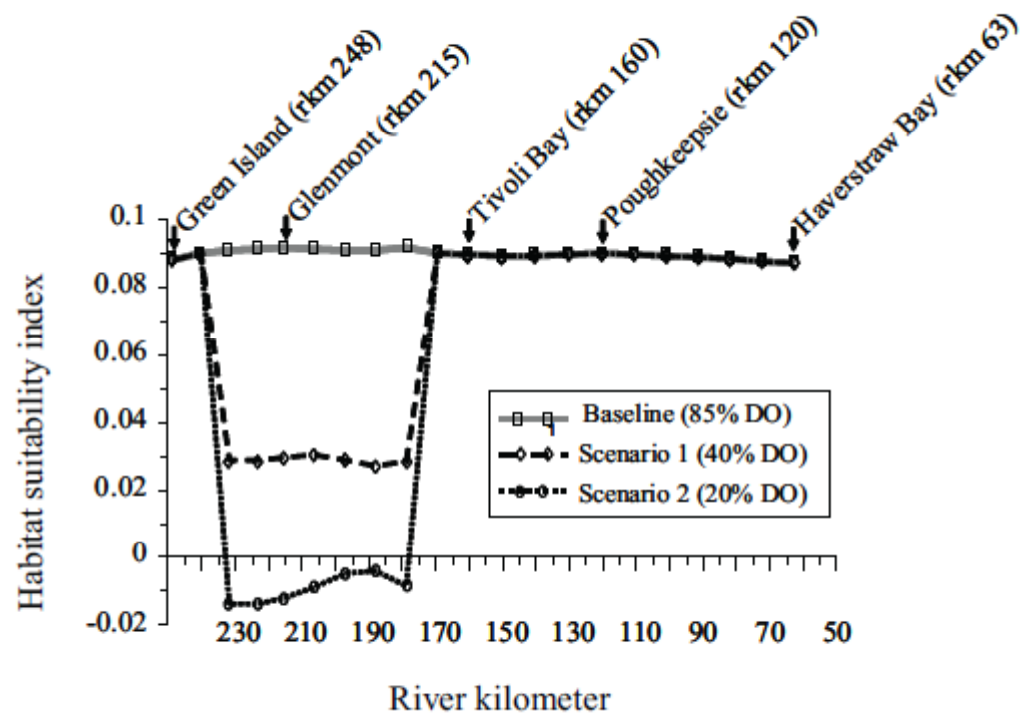


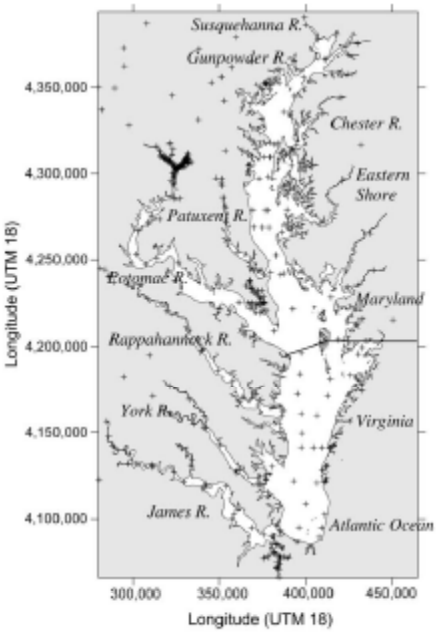
Table 1.—Sampling station site name, location (river kilometer), data attributes (datum collection frequency, total data included, data range [years]), and source of historical water temperature data from the Hudson River. Sources include the U.S. Geological Survey (USGS, www.usgs.gov), New York Department of Environmental Conservation (NYDEC), National Estuarine Research Reserve System (NERRS, www.nerrs.gov), Poughkeepsie water treatment facility (PWTF), and SUNY Marine Science Research Center (MSRC, Drisco et al. 2003).

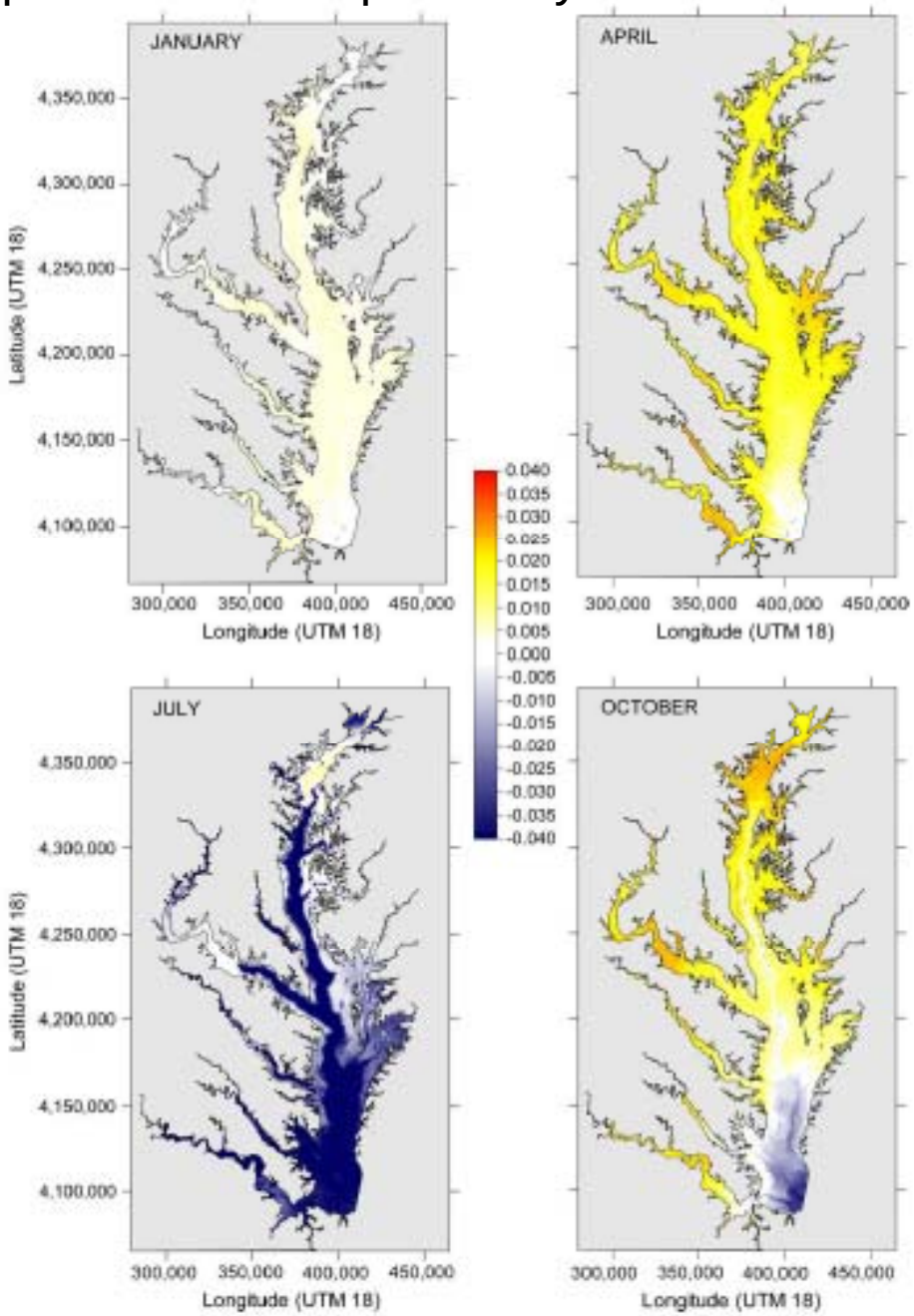
		Temperature data			
Site	River km	Sampling frequency	Total data (*N*)	Data range	Source
Green Island	248	~monthly	73	1970–1985, 1988–1994	USGS
Glenmont	215	monthly	18	1993–2002	NYDEC
Tivoli Bay	160	0.5 h	7,616	1995–2000	NERRS
Poughkeepsie	120	daily	1,448	1987–2005	PWTF
Haverstraw Bay	37–63	biweekly	52[a]	1985–2002	MSRC

[a] Each Haverstraw Bay datum used in this analysis represents a biweekly mean calculated from 25 individual temperature measurements collected from the Haverstraw–Tappan Zee region of the Hudson River (see Drisco et al. 2003).

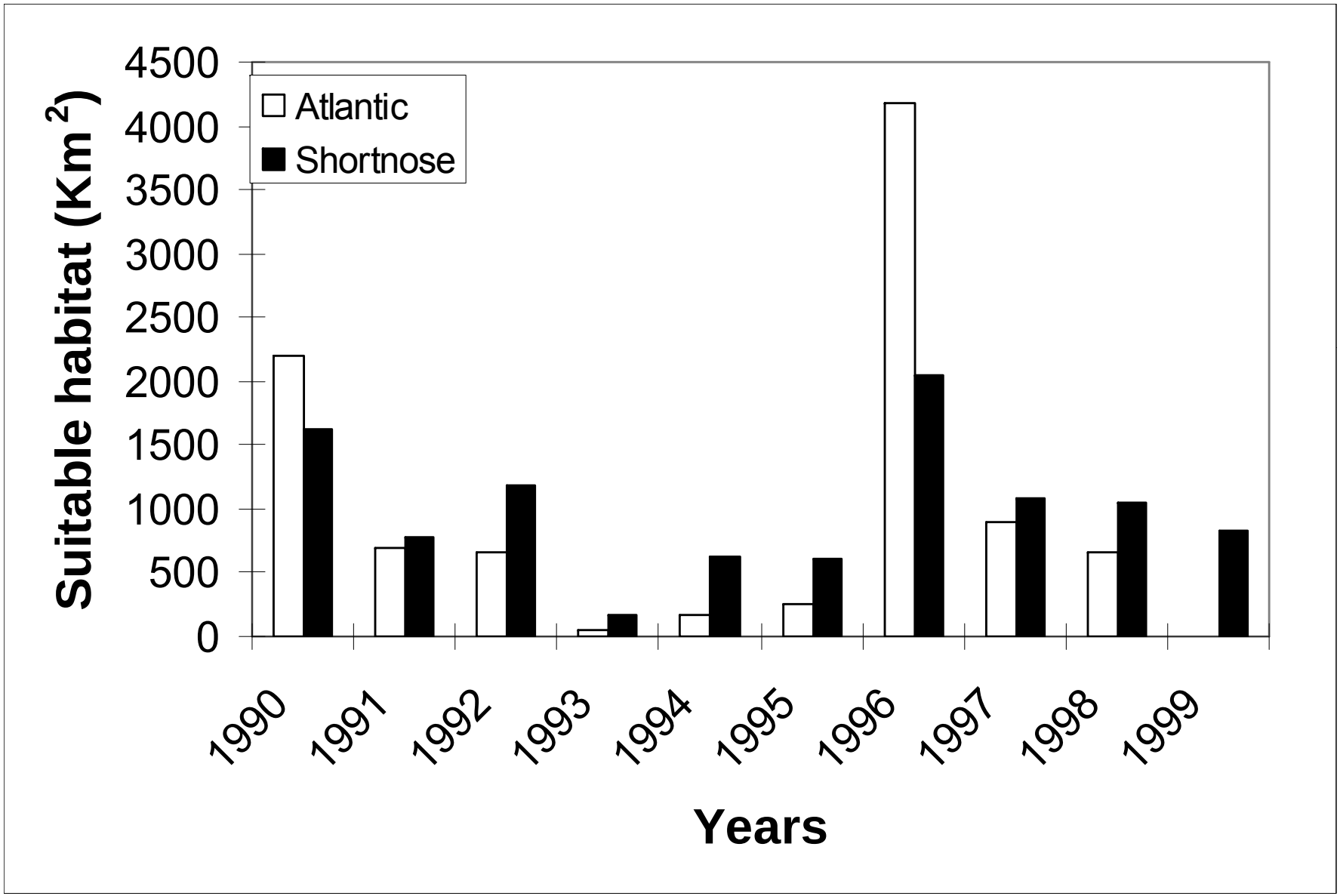


Application – Chesapeake Bay

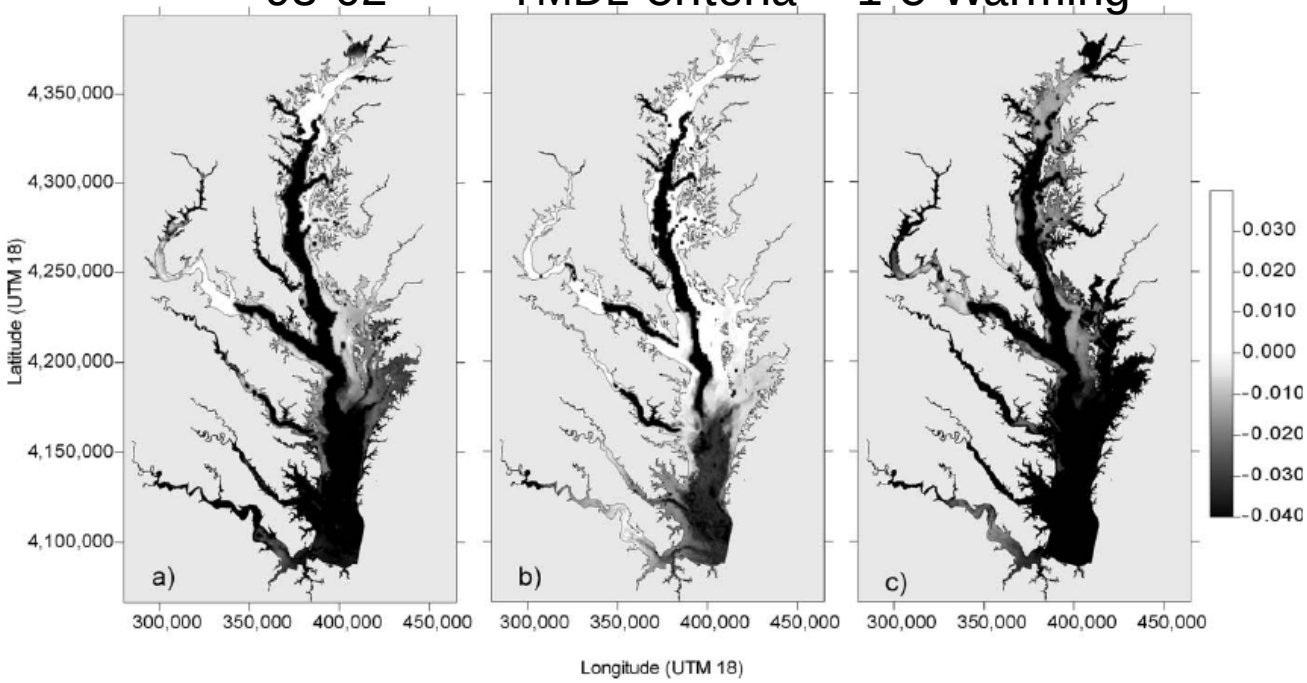


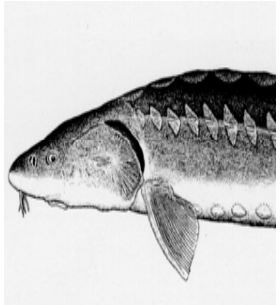


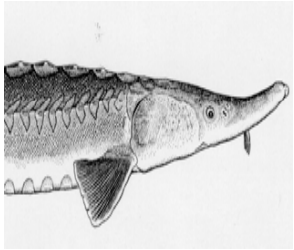
Niklitschek, E.J. and Secor, D.H. 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine and Coastal Shelf Science 64: 135-148.

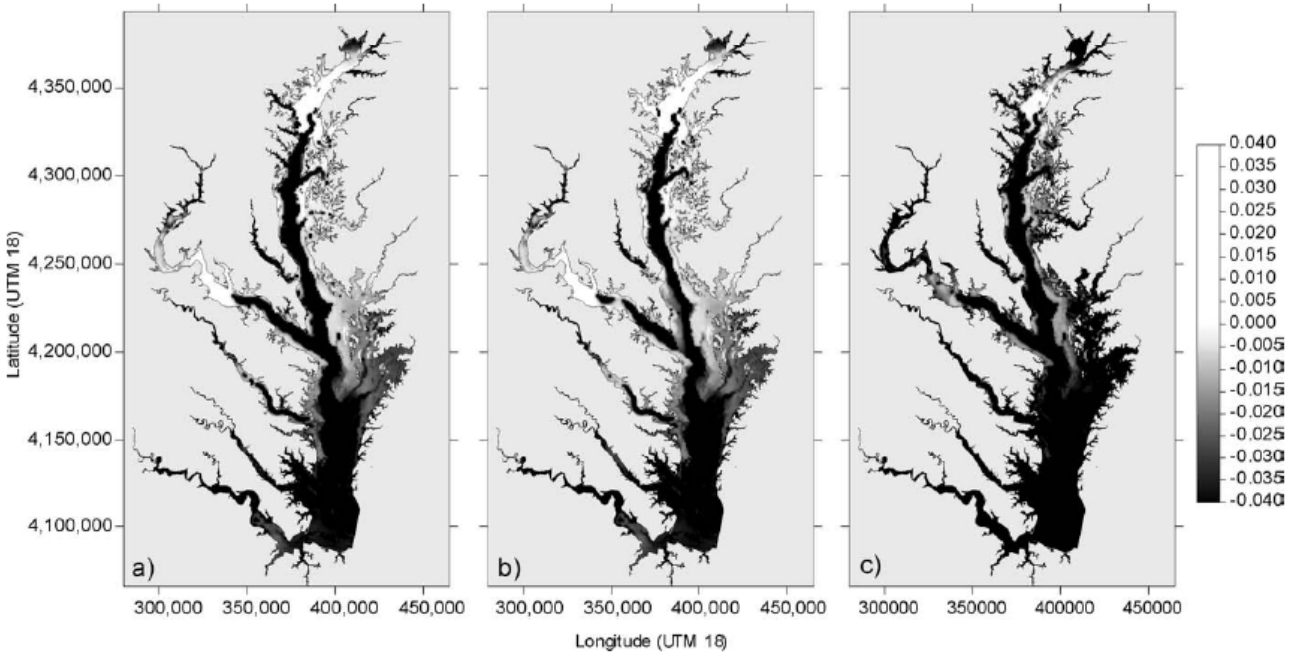

Suitable habitat (Km2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Atlantic
Shortnose
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Years

‘93-02 TMDL Criteria 1 C Warming

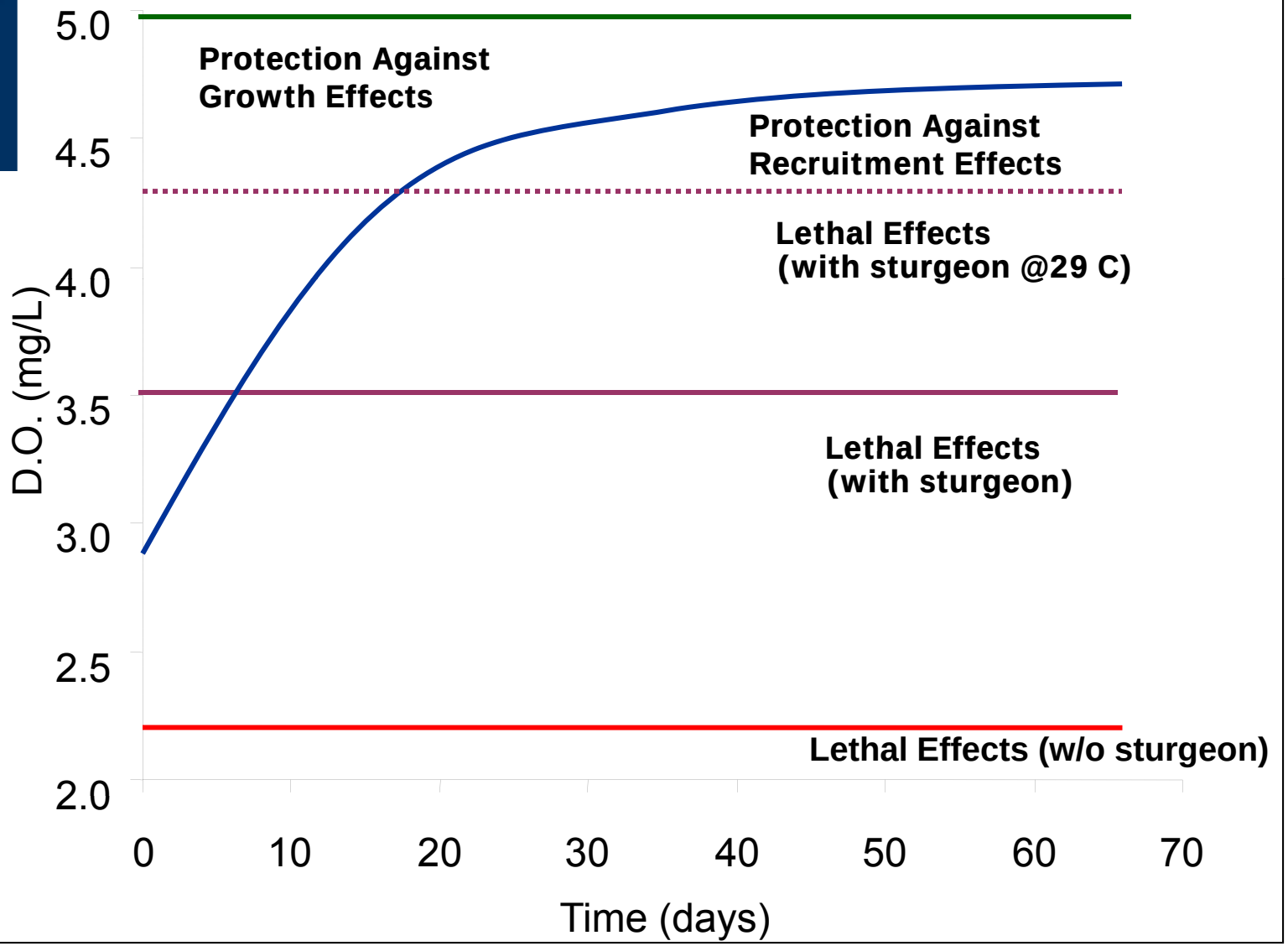








EPA Chesapeake Bay Program
Proposed Open water & Spawning/Nursery Habitat Criteria



Next Steps:

- Supply models with retrospective and simulated environmental data
    - Ongoing NOAA Coastal Program Award (CHRP)
- Supply managers with data visualization tools
- Diagnose performance of habitat model with telemetry data (habitat preference)
    - Strategic tagging/release of sturgeons
    - Intensive water quality mapping
- If experimental fish available, test other strains