Using real-time satellite ocean color and robotics to test ecological hypotheses that lead to conservation plans

Matthew Oliver, Matthew Breece, Dewayne Fox, Danielle Haulsee,
Steven Bograd, Elliot Hazen, Heather Welch, Ed Hale

University of Delaware

University of Delaware

Aquatic Sciences
Delaware State University

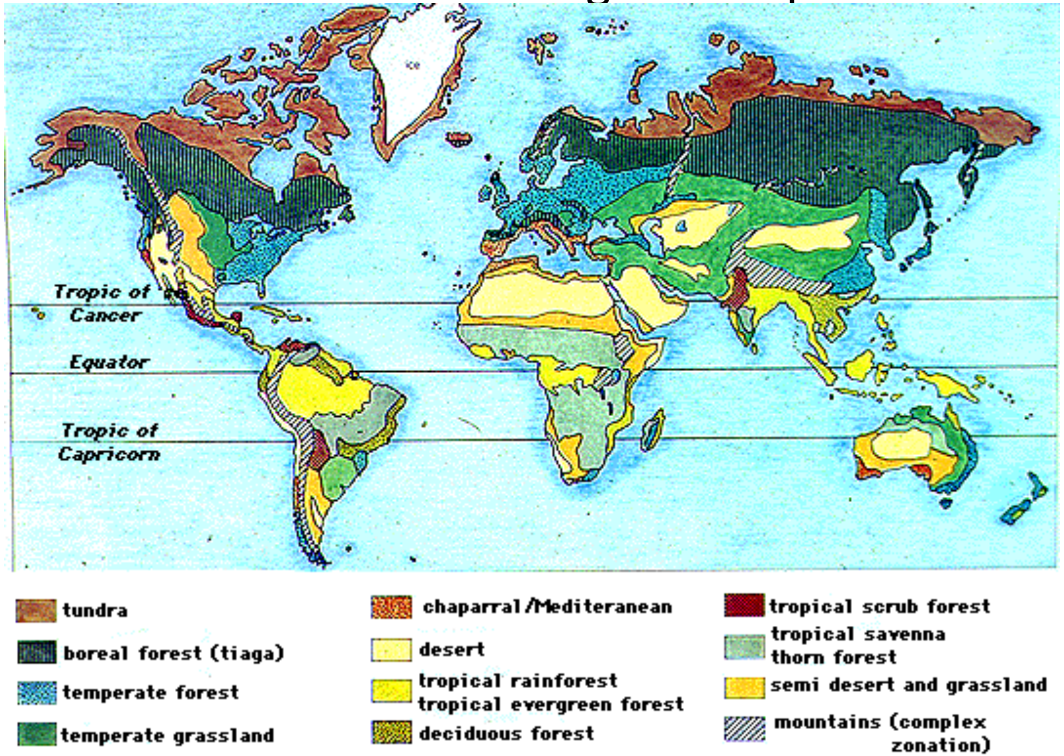
Delaware Division Fish & Wildlife

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MARACOOS
Ocean Information for a Changing World

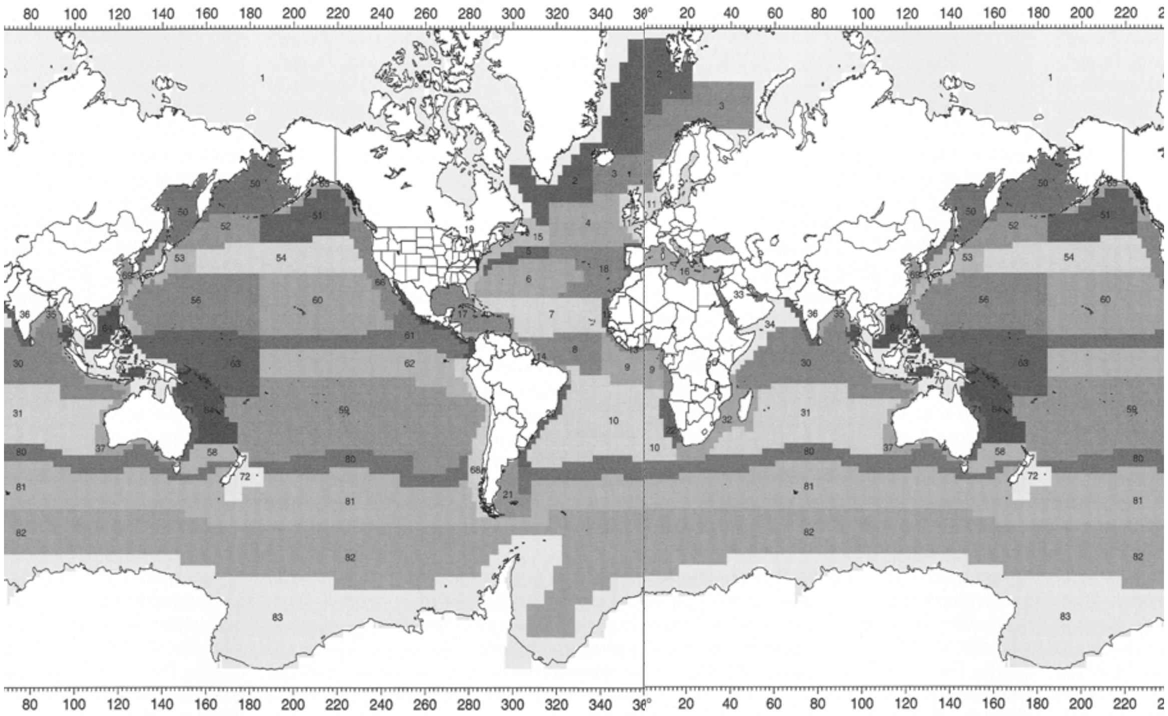
NASA
Applied Sciences Program
NASA Earth Science

Characteristics of the primary producers are primary drivers in defining landscapes.



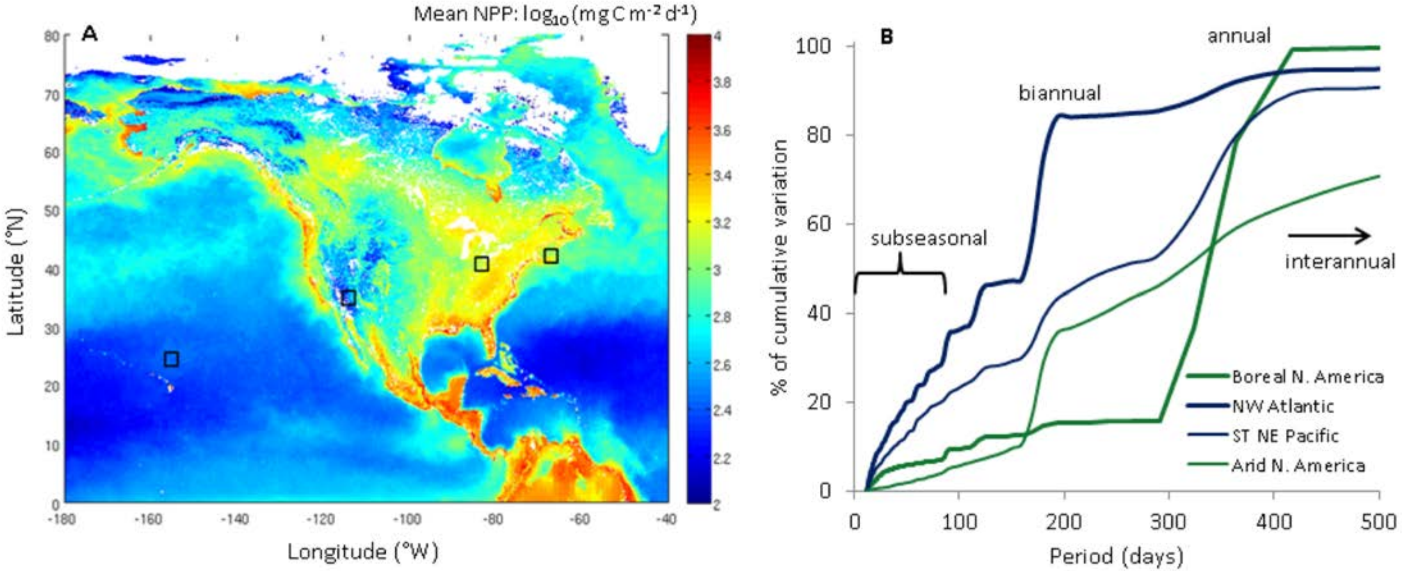
Quasi-state like outcomes

Biomes/Provinces/Seascapes



Longhurst, 1998

Primary Producer turnover rates are fast in the ocean



ICES Journal of Marine Science

ICES Journal of Marine Science (2016), 73(7), 1839–1850. doi:10.1093/icesjms/fsw086

Contribution to the Themed Section: '*Seascape Ecology*'

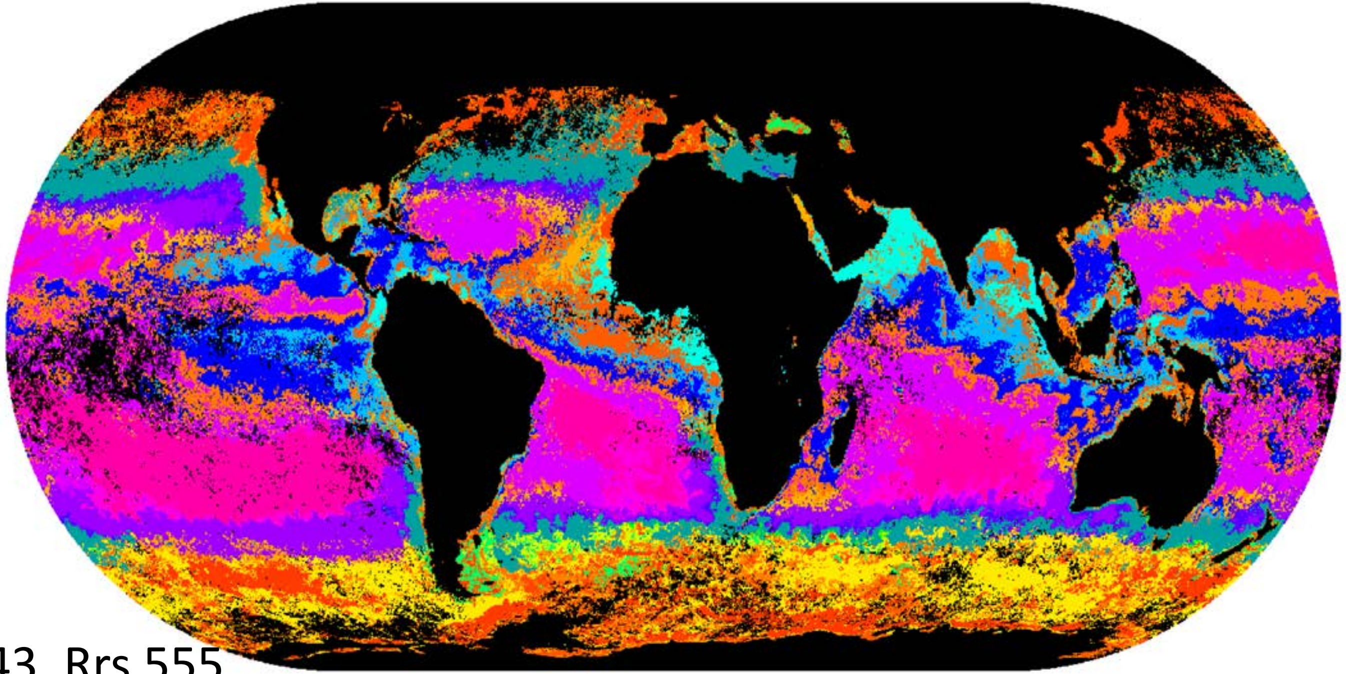
Quo Vadimus

Seascapes as a new vernacular for pelagic ocean monitoring, management and conservation

Maria T. Kavanaugh[1*‡], Matthew J. Oliver[2‡], Francisco P. Chavez[3], Ricardo M. Letelier[4], Frank E. Muller-Karger[5], and Scott C. Doney[1]

Dynamic Seascapes/Provinces

http://basin.ceoe.udel.edu/erddap/griddap/aqua_global_water_mass_province.graph



- SST, Rrs 443, Rrs 555
- These are conservation hypotheses to be tested

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L15601, doi:10.1029/2008GL034238, 2008

Objective global ocean biogeographic provinces

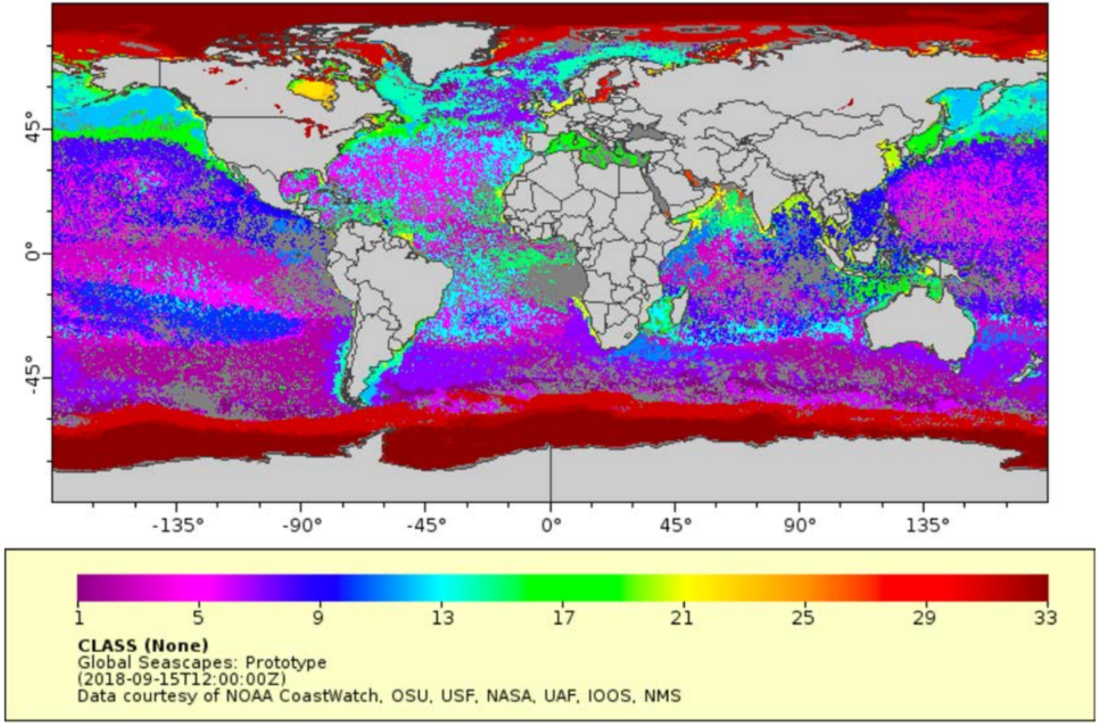
Matthew J. Oliver[1,2] and Andrew J. Irwin[3]

Received 4 April 2008; revised 5 June 2008; accepted 25 June 2008; published 2 August 2008.

Dynamic Seascapes/Provinces

https://cwcgom.aoml.noaa.gov/erddap/griddap/noaa_aoml_4729_9ee6_ab54.graph

Maria Kavanaugh, OSU



Case 1

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2016 doi: 10.1111/2041-210X.12532

Dynamic seascapes predict the marine occurrence of an endangered species: Atlantic Sturgeon *Acipenser oxyrinchus oxyrinchus*

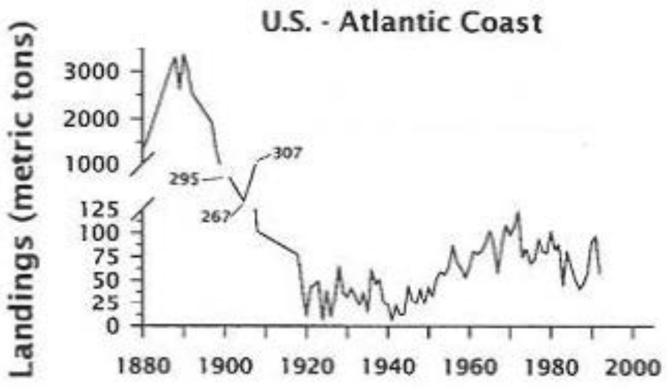
Matthew W. Breece[1]*, Dewayne A. Fox[2], Keith J. Dunton[3], Mike G. Frisk[3], Adrian Jordaan[4] and Matthew J. Oliver[1]

[1]Oceanography, University of Delaware, 700 Pilottown Road, Lewes, DE 19958, USA; [2]Natural Resources, Delaware State University, 1200 N. DuPont Hwy, Dover, DE 19901, USA; [3]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794-5000, USA; and [4]Department of Environmental Conservation, University of Massachusetts Amherst, 160 Holdsworth Way, Amherst 01003, MA, USA

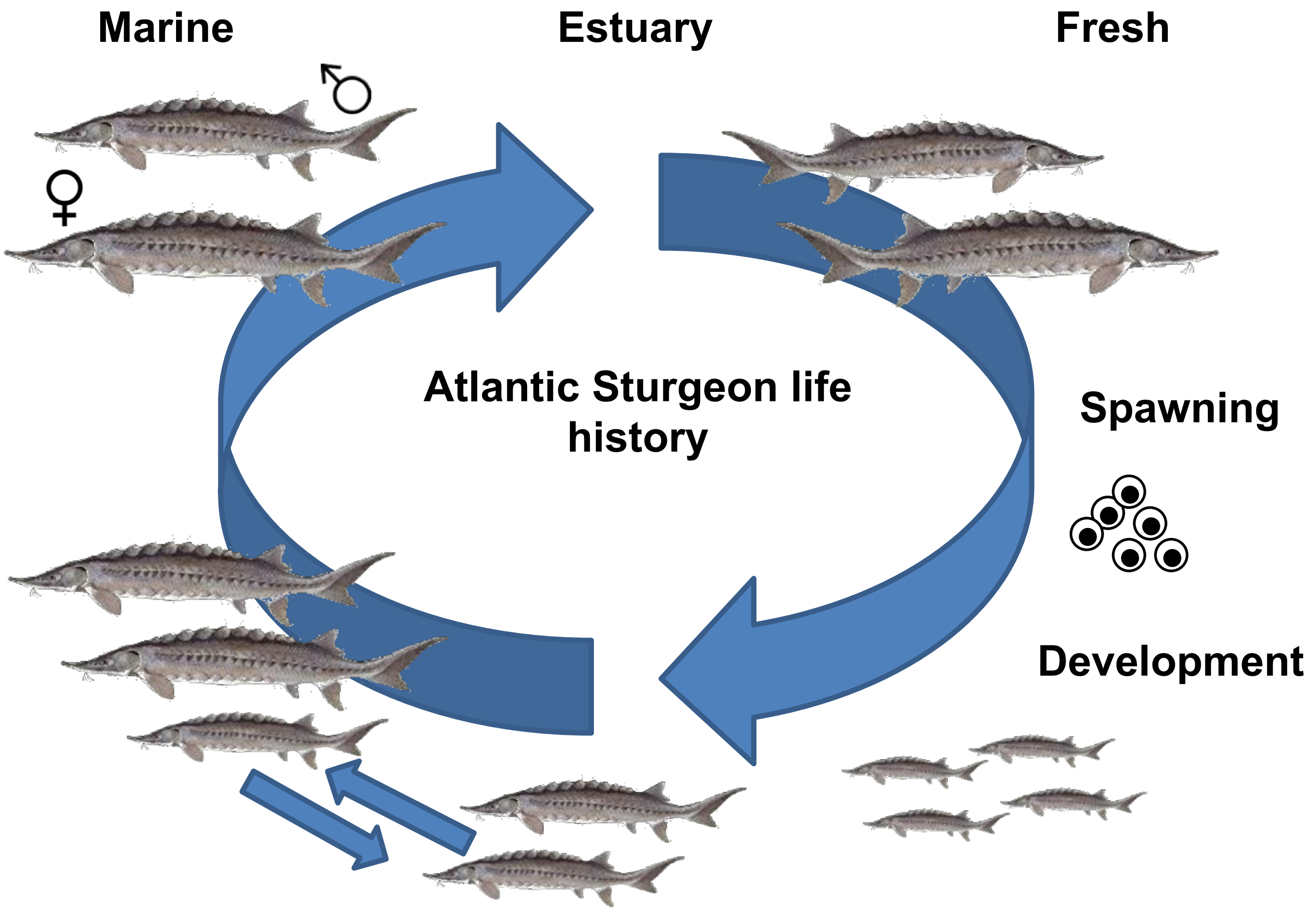
Historic Fisheries

Case 1

- Delaware River Fishery
  - Peak of 2700mt harvest 1888
  - Largest sturgeon fishery in the United States (75% of landings)
  - Collapsed ~1900
- Minimal take, no recovery
  - Coast wide moratorium since 1998
  - Listed under the ESA in 2012

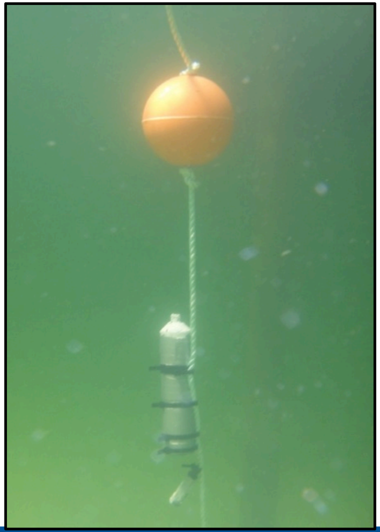


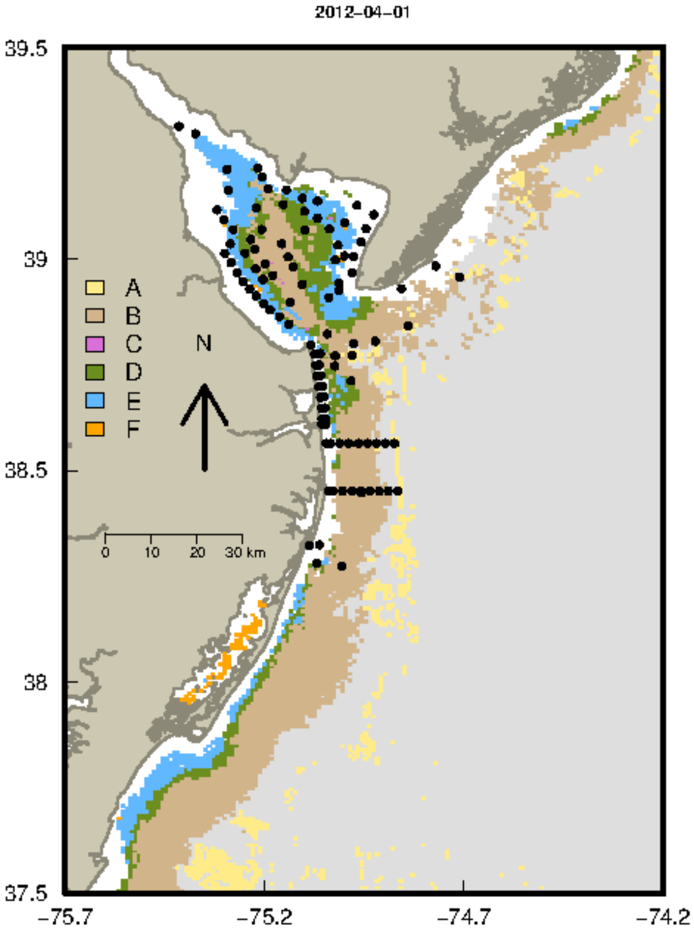
Case 1


Marine
Estuary
Fresh
♂
♀
Atlantic Sturgeon life history
Spawning
Development

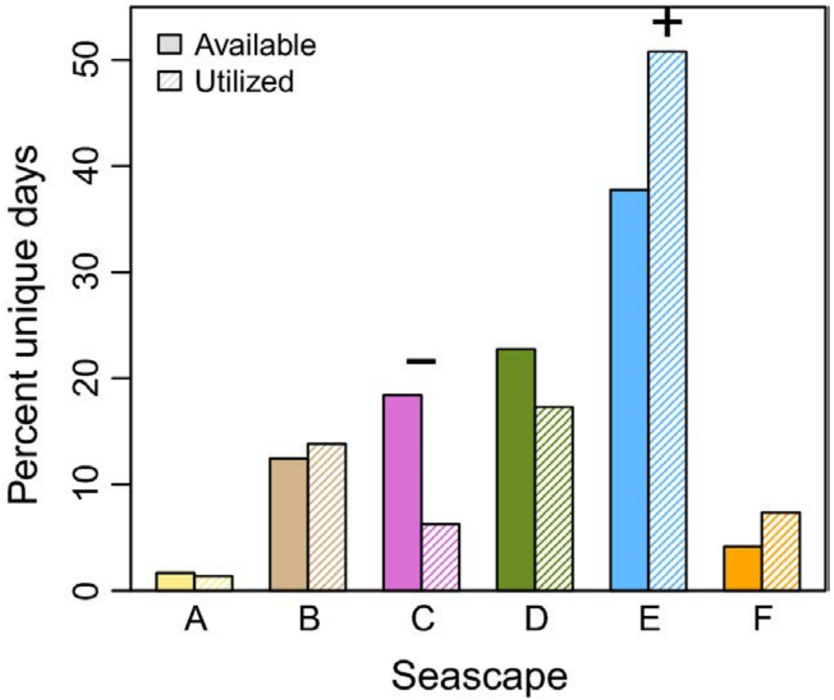
Ocean Color Seascape Classes

- Match Seascapes to receiver stations
- 260 tagged sturgeon

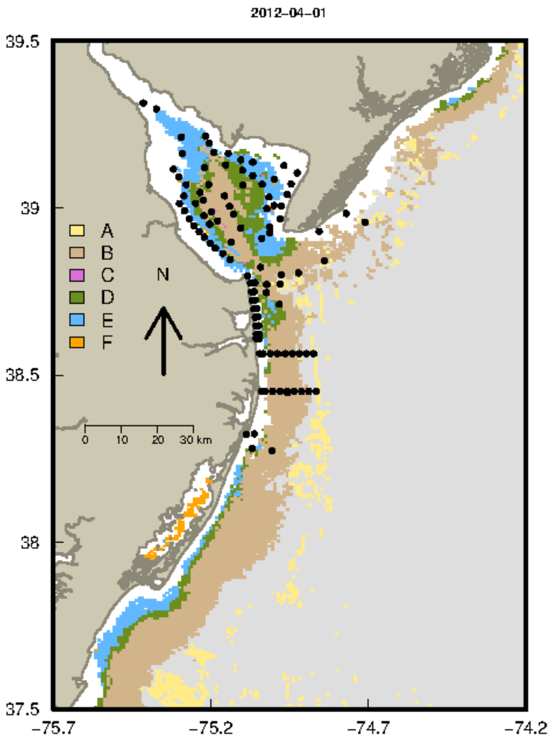




Case 1



Available
Utilized
Percent unique days
0
10
20
30
40
50
+
−
A
B
C
D
E
F
Seascape



2012−04−01
39.5
39
38.5
38
37.5
−75.7
−75.2
−74.7
−74.2
A
B
C
D
E
F
N
0 10 20 30 km

Do Atlantic Sturgeon prefer a specific Seascape?

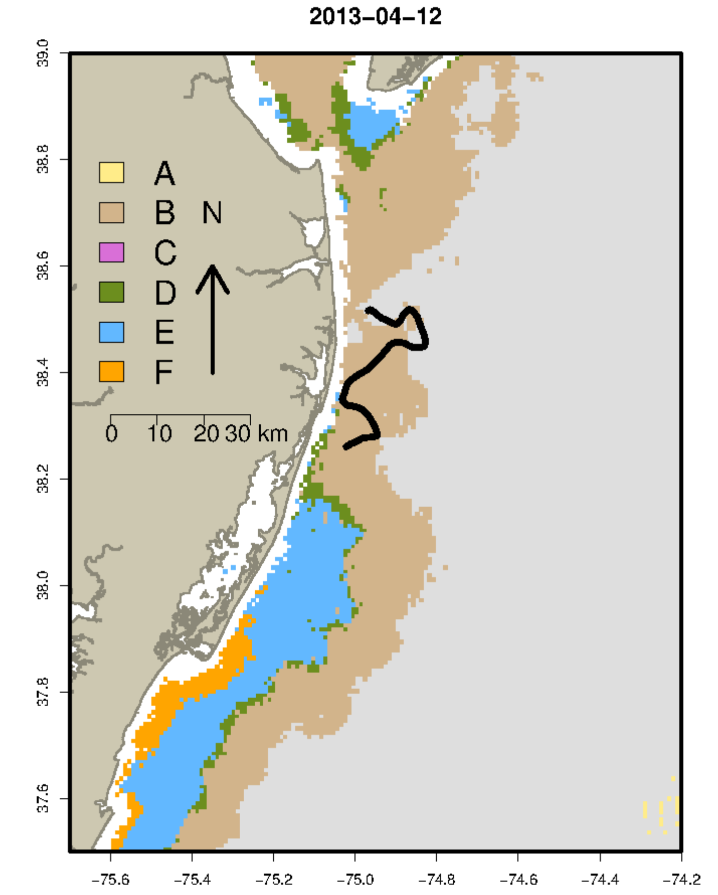
Case 1

Help from Commercial Fishermen

Case 1

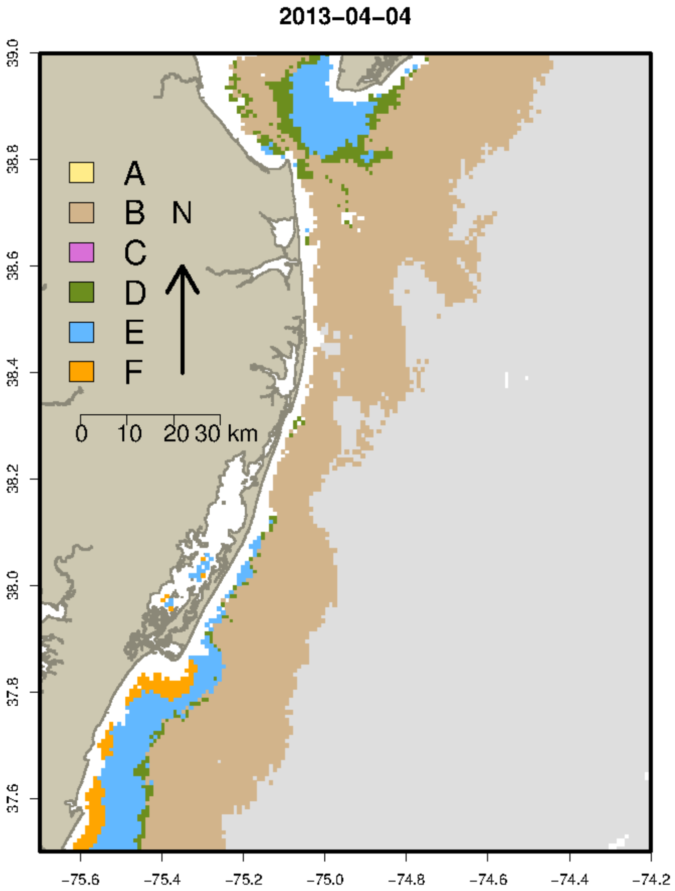
Glider Detections by Seascape

Case 1



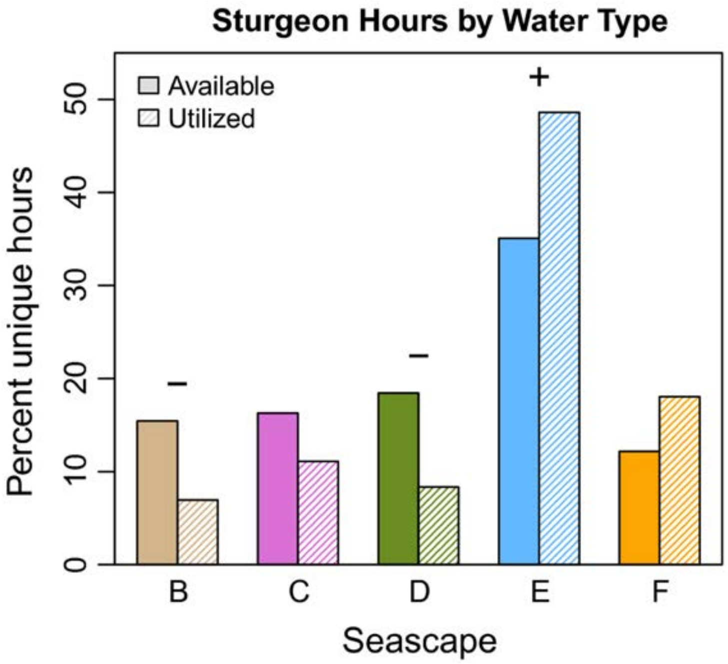
Glider Detections by Seascape

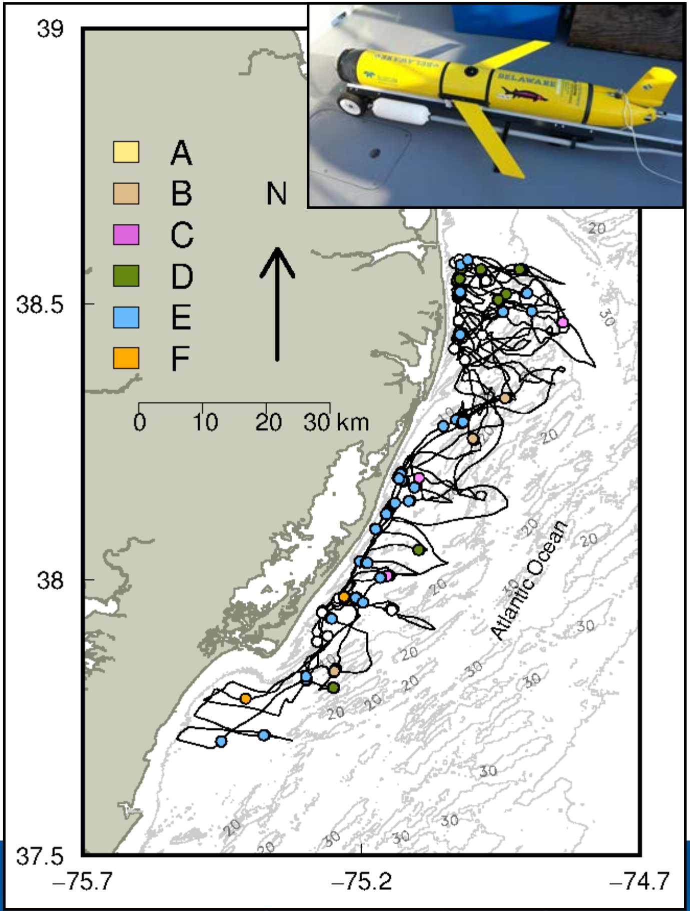
Case 1



Glider Detections by Seascape

Case 1



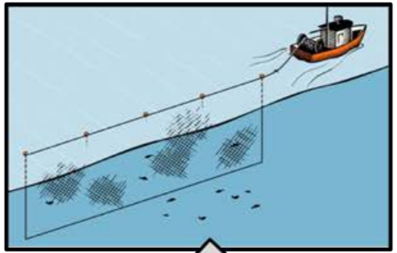


Atlantic Sturgeon Risk Model

- Predict where and when habitats occur
- Identify how changing conditions shift habitats
- Link conditions and occurrence
- Give the fishery the tools to reduce Atlantic Sturgeon bycatch through behavioral changes
- Make it applicable to other ecosystems and industries

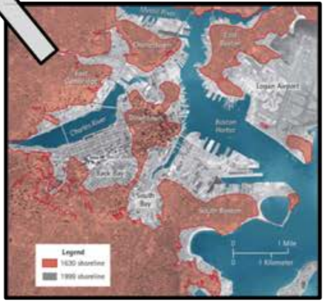
The Atlantic Sturgeon Risk Model

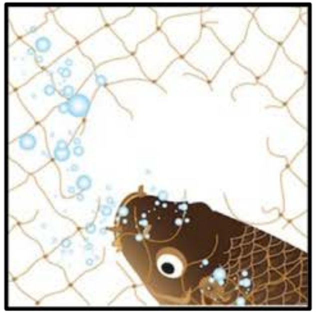
Project motivation



Proposed bycatch take limits

Regulatory and economic incentive to avoid sturgeon bycatch





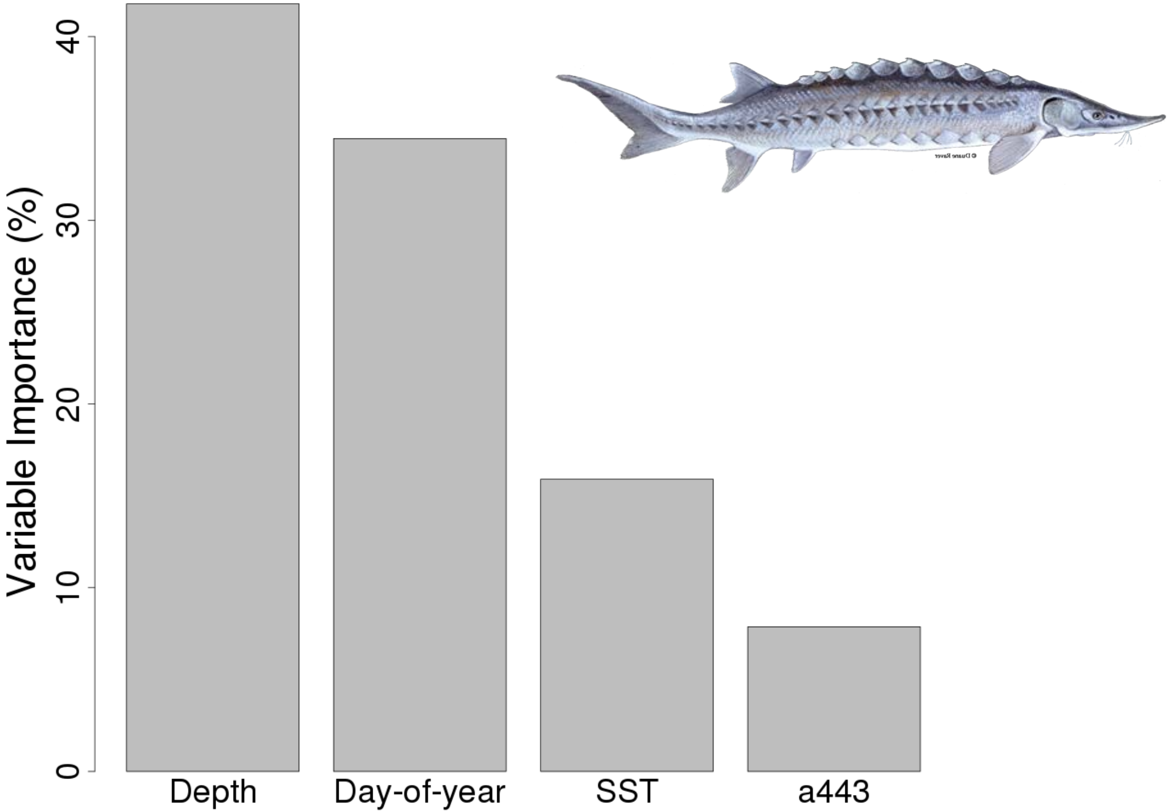
Gear damage and missed fishing days

@Heather_M_Welch

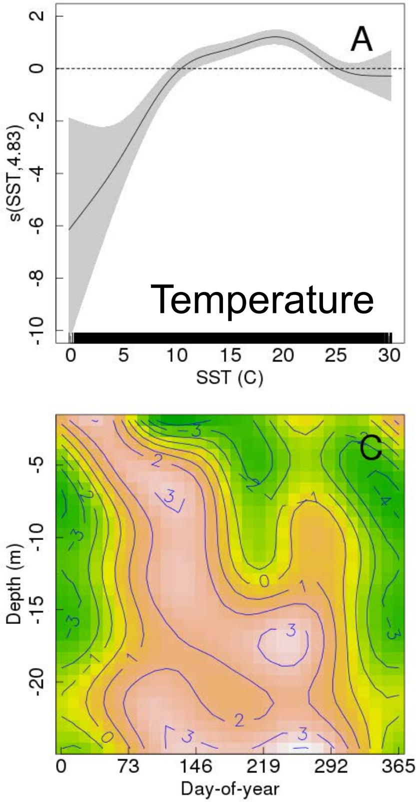
Response - Presence/Absence

- Atlantic Sturgeon
  - 301 individuals
  - 19,069 unique observations
  - 1,900 presences matched to 1 day Satellite data
  - 1,387,197 absences matched to daily satellite data

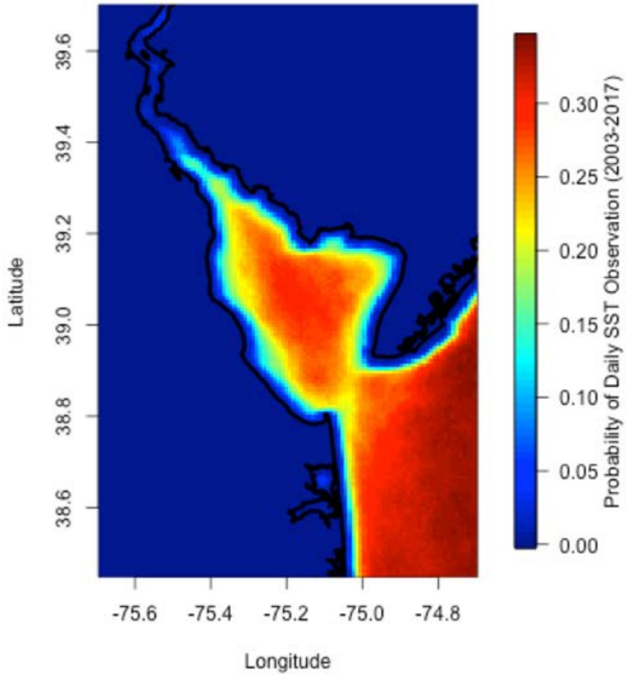
Model <- GAMM4(P_A ~ s(sst) + s(a_443nm) + t2(depth x day of year))


Variable Importance (%)
0
10
20
30
40
Depth
Day-of-year
SST
a443

Response Functions

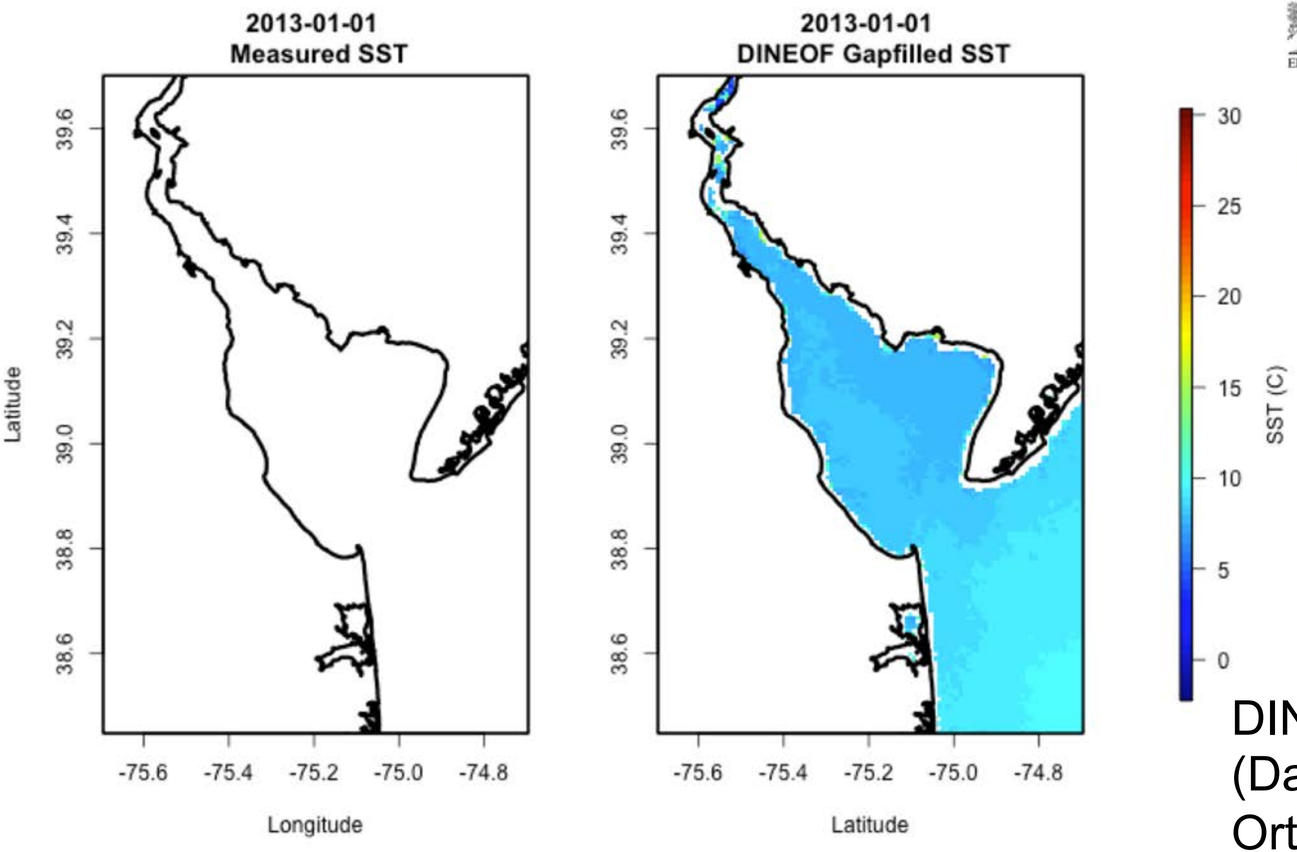


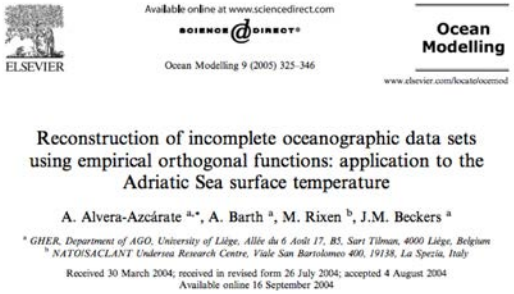
Daily observations from satellites are rare



Clouds are not random

Case 2





ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT
Ocean Modelling 9 (2005) 325–346
Ocean Modelling
www.elsevier.com/locate/ocemod

Reconstruction of incomplete oceanographic data sets using empirical orthogonal functions: application to the Adriatic Sea surface temperature

A. Alvera-Azcárate [a,*], A. Barth [a], M. Rixen [b], J.M. Beckers [a]

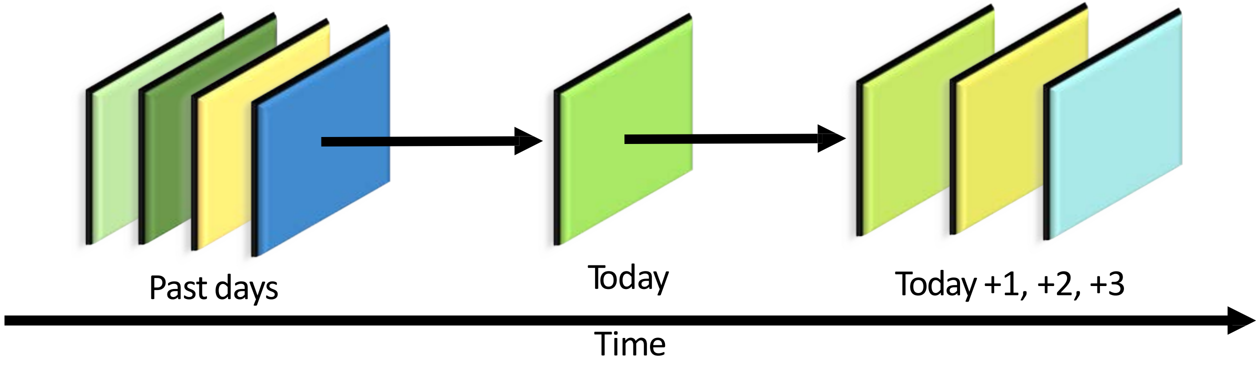
[a] GHER, Department of AGO, University of Liège, Allée du 6 Août 17, B5, Sart Tilman, 4000 Liège, Belgium
[b] NATO/SACLANT Undersea Research Centre, Viale San Bartolomeo 400, 19138, La Spezia, Italy

Received 30 March 2004; received in revised form 26 July 2004; accepted 4 August 2004
Available online 16 September 2004

DINEOF to gap-fill data (Data INterpolating Empirical Orthogonal Functions)

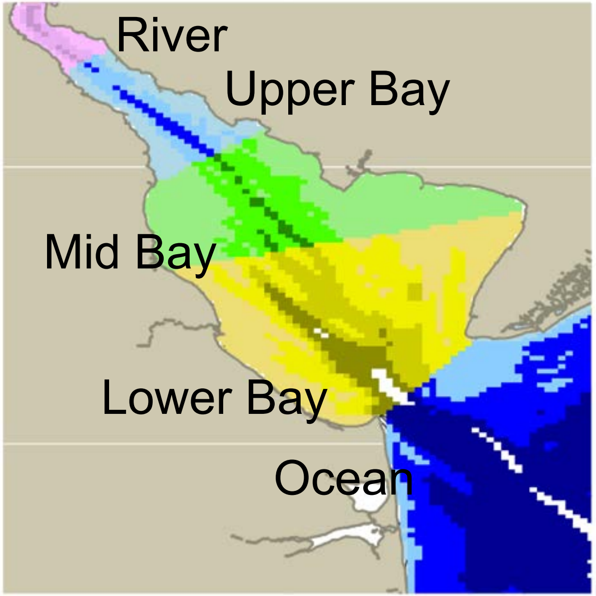
Case 2

DINEOF Predictions



RMS errors between measured SST and A443 with greater than 50% coverage over the study region for gap filled nowcast, forecasts, and climatology.

	G. F. Nowcast	G. F. 1-Day Forecast	G. F. 2-Day Forecast	G. F. 3-Day Forecast	G. F. MODIS - Aqua Climatology
MODIS-Aqua SST (C)	0.28	0.76	0.82	0.98	1.02
VIIRS SST (C)	0.25	0.93	1.18	1.41	1.15
MODIS-Aqua A443 (m^{-1})	0.57	1.28	1.34	1.49	0.78
VIIRS A443 (m^{-1})	0.32	0.58	0.65	0.66	0.38



Atlantic Sturgeon alert zones based on the 2016 ASMFC Delaware River Sustainable Fishing Plan for American Shad. River (pink), Upper Bay (blue), Mid Bay (green), Lower Bay (yellow), Ocean (blue). The regions are divided further by depth bins to make the 17 zones, <5m, 5-10m, 10-15m, >15m (> 15m does not occur in the Mid Bay, Upper Bay and River).

Based on ASMFC SFP for American Shad

- River – north of Collins Beach
- Upper Bay – Collins Beach to Port Mahon
- Mid Bay – Port Mahon to Bowers Beach
- Lower Bay – South of Bowers Beach to Cape Henlopen
- Ocean – East of Cape Henlopen

Depths

- 0-5 meters
- 5-10 meters
- 10-15 meters
- Above 15 meters

If you know generally where you are on the bay and the depth, you know your risk.

Delivery of Products (SMS Text)

Case 2

53291

Mon, Apr 22, 2019 09:25

Atlantic Sturgeon Forecast Warning
Apr 22 2019
Medium Risk: River 16-33ft, LowBay more than 33ft

Apr 23 2019
Medium Risk: River 16-33ft, LowBay more than 33ft

Apr 24 2019
Medium Risk: River 16-33ft, LowBay more than 33ft

Web App http://bit.ly/2l3zpxb
Forecast Flyer http://bit.ly/2oN6fKW

Txt STOP to cancel

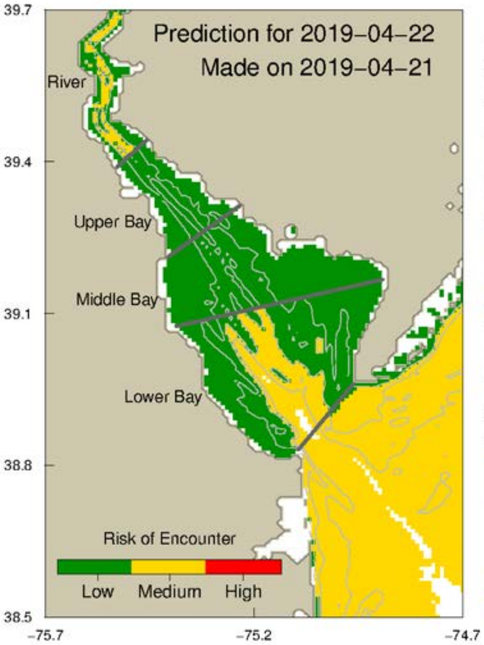
If you know generally where you are on the bay and the depth, you know your risk.

Atlantic Sturgeon Predicted Occurrence

Green indicates low risk of encountering Atlantic Sturgeon

Yellow indicates medium risk of encountering Atlantic Sturgeon

Red indicates high risk of encountering Atlantic Sturgeon



This product is developed for mature Atlantic Sturgeon using historic telemetry observations matched to date, bathymetry, and sea surface temperature and ocean color from NASA's MODIS AQUA satellite. The five regions (Delaware River, Upper Delaware Bay, Middle Delaware Bay, Lower Delaware Bay, and Atlantic Ocean) are divided into 5 meter depth bins.

Contact:
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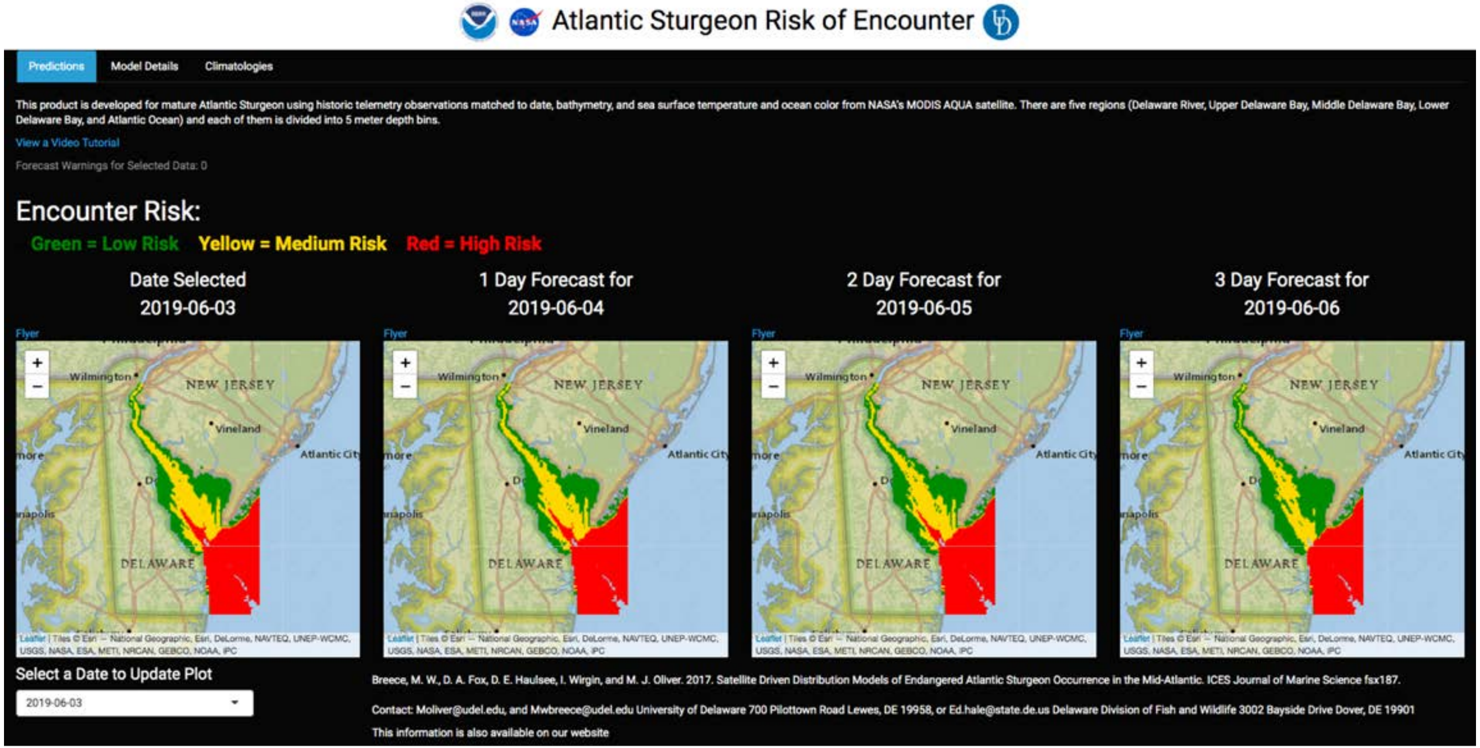
Lewes, DE 19958
Ed.hale@state.de.us Delaware Division of Fish and Wildlife 3002 Bayside Drive Dover, DE 19901

Breece, M. W., D. A. Fox, D. E. Haulsee, I. Wirgin, and M. J. Oliver. 2017. Satellite Driven Distribution Models of Endangered Atlantic Sturgeon Occurrence in the Mid-Atlantic. ICES Journal of Marine Science fsx187.

Delivery of Products (Web Application)

Case 2



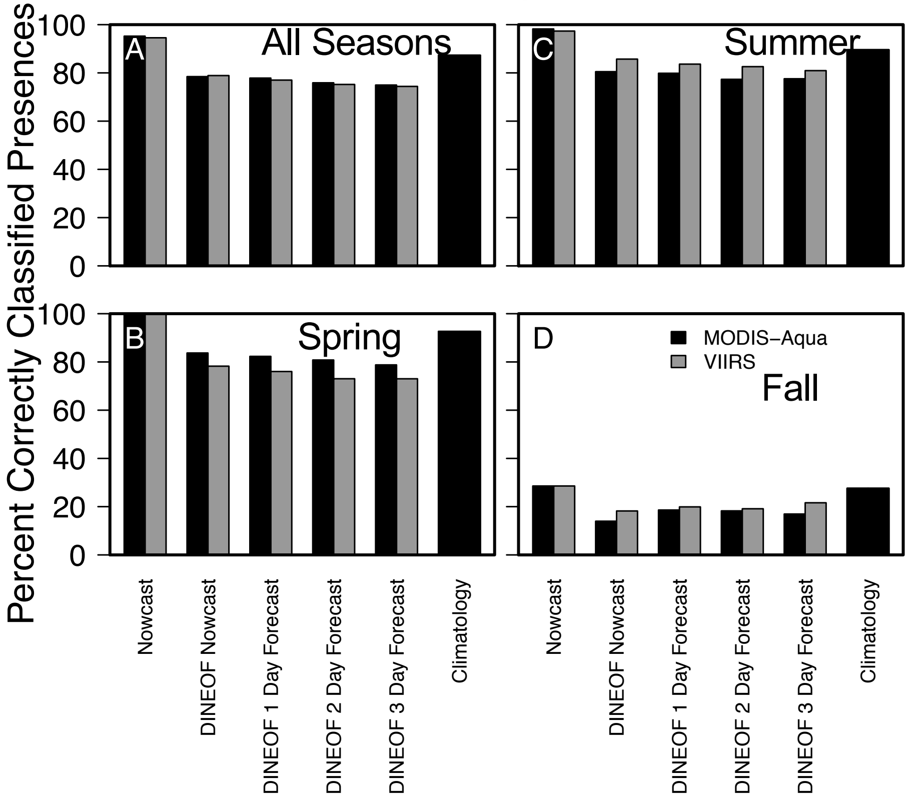
http://basin.ceoe.udel.edu/shiny/sample-apps/sturgeon/

http://basin.ceoe.udel.edu/shiny/sample-apps/sturgeon-viirs/

University of Delaware

Uncertainty of Products (Temporally, by pixel)

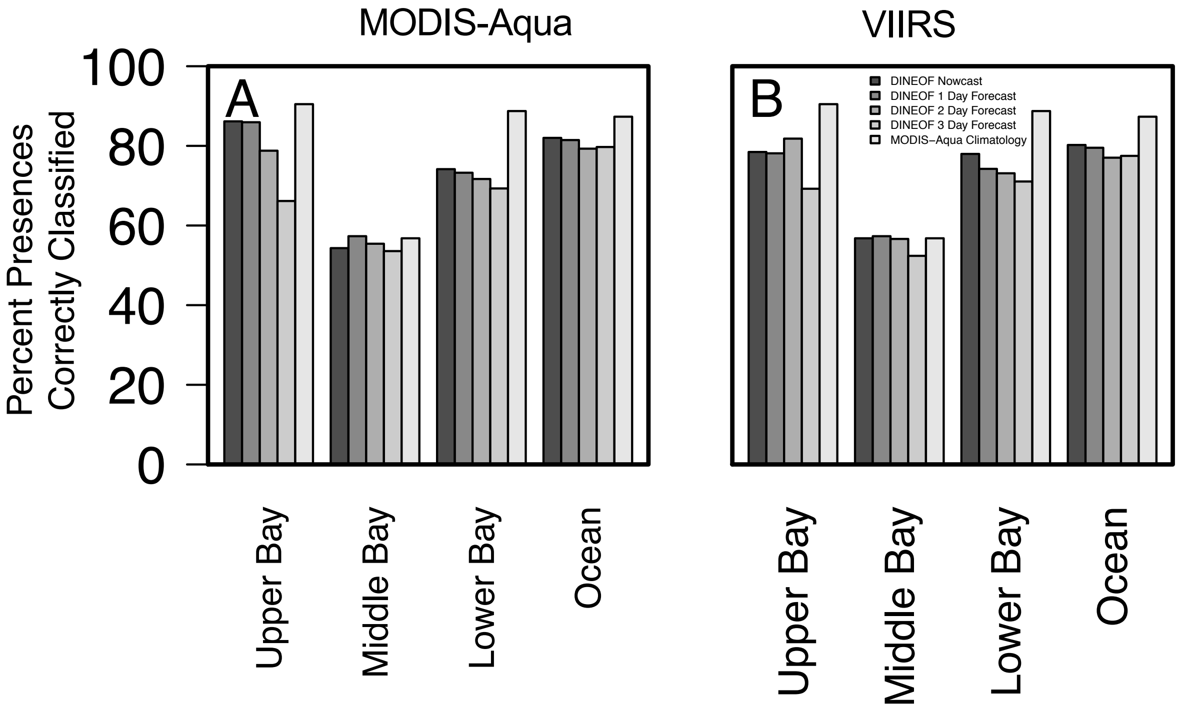
Case 2



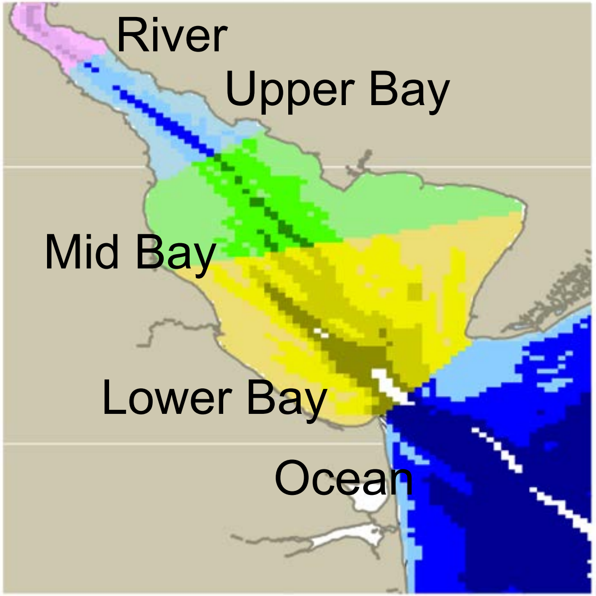
Spring = Mar 21 – Jun 21 Summer = Jun 21– Sep 21 Fall = Sep 21-Dec 21

Uncertainty of Products (Spatially, by pixel)

Case 2



Delivery of Products



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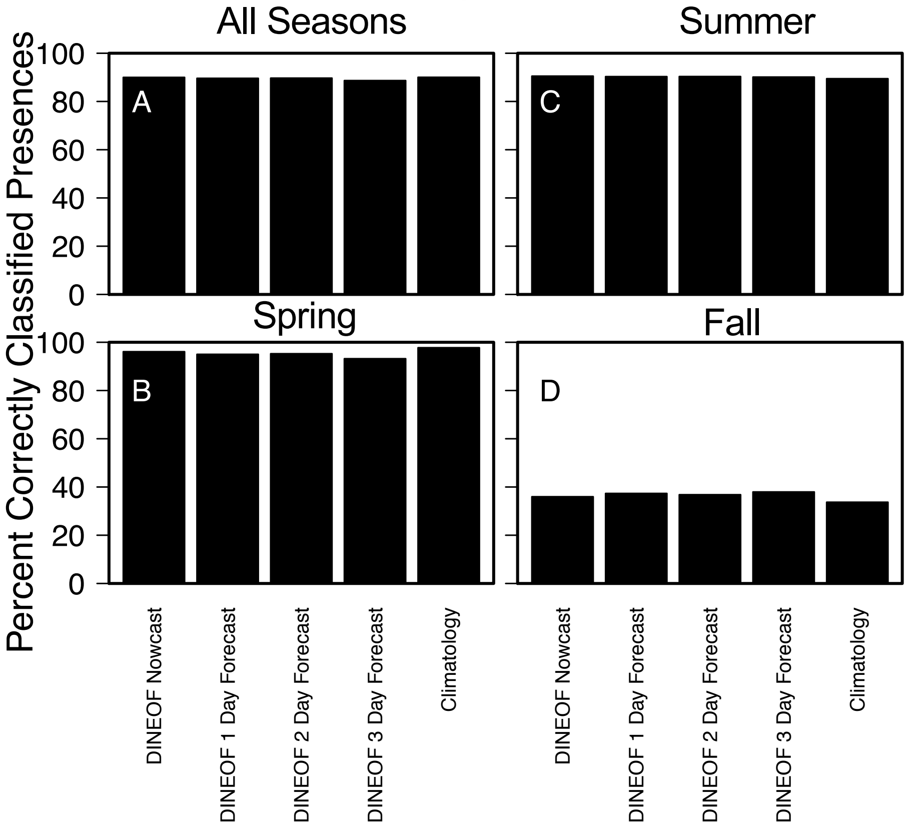
Uncertainty of Products (Temporally, by region)

Case 2



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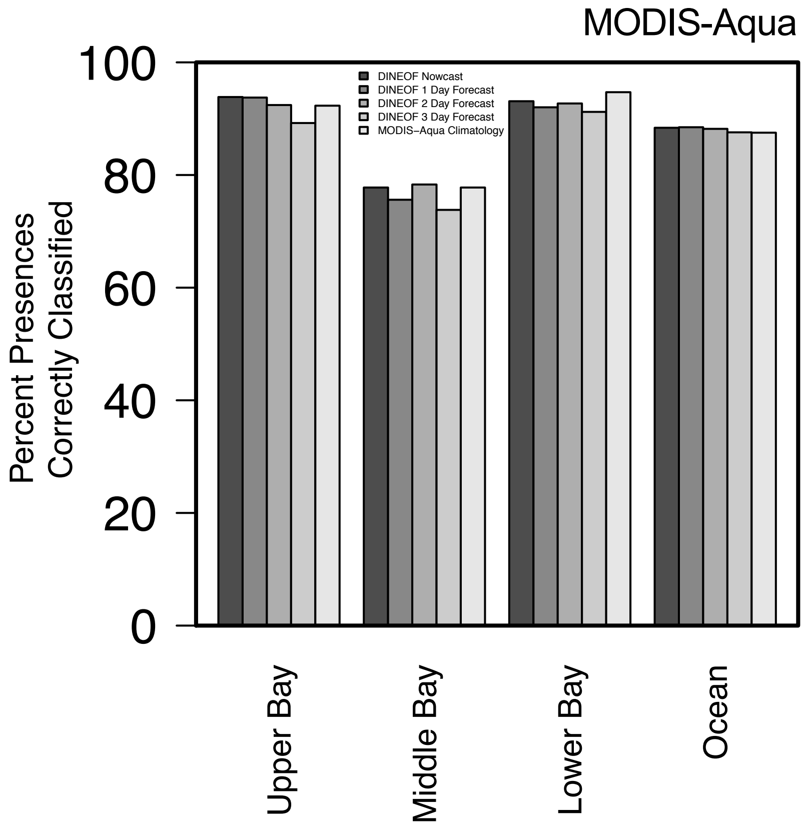
Uncertainty of Products (Spatially, by region)

Case 2



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Each requires access to either cell/internet

High information to low information

What are we asking of the users to understand this?