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
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.
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
Dynamic Seascapes/Provinces

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

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

Matthew W. Breeze¹, Dewayne A. Fox², Keith J. Dunton³, Mike G. Frisk³, Adrian Jordaan⁴, and Matthew J. Oliver⁵

¹Oceanography, University of Delaware, 700 Pilottown Road, Lewes, DE 19958, USA; ²Natural Resources, Delaware State University, 1200 N. DuPont Hwy, Dover, DE 19901, USA; ³School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794-5000, USA; and ⁴Department of Environmental Conservation, University of Massachusetts Amherst, 166 Holdsworth Way, Amherst 01003, MA, USA
Historic Fisheries

- 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
Atlantic Sturgeon life history

Marine

Estuary

Fresh

Spawning

Development

Case 1
Ocean Color Seascape Classes

- Match Seascapes to receiver stations
- 260 tagged sturgeon
Case 1
Do Atlantic Sturgeon prefer a specific Seascape?
Help from Commercial Fishermen

Case 1
Glider Detections by Seascape

Case 1
Glider Detections by Seascape

Case 1
Glider Detections by Seascape

Sturgeon Hours by Water Type

Percent unique hours

- Available
- Utilized

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

Case 2

Project motivation

Regulatory and economic incentive to avoid sturgeon bycatch

Proposed bycatch take limits

ESA listed in 2012

Gear damage and missed fishing days

@Heather_M_Welch
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))
Case 2

Variable Importance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Importance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>40</td>
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<tr>
<td>Day-of-year</td>
<td>30</td>
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<tr>
<td>SST</td>
<td>20</td>
</tr>
<tr>
<td>a443</td>
<td>10</td>
</tr>
</tbody>
</table>
Response Functions

Case 2

Temperature

A

a_443n

B

C

Day-of-year

Depth (m)

0 73 146 219 292 365

0 15 30

0 10 -10

20 10 -20

0 1 2 3 4 5 6

-10 10 -4 6

2 0 2

0 2 4 6
Daily observations from satellites are rare

Clouds are not random
DINEOF to gap-fill data
(Data INterpolating Empirical Orthogonal Functions)
RMS errors between measured SST and A443 with greater than 50% coverage over the study region for gap filled nowcast, forecasts, and climatology.

<table>
<thead>
<tr>
<th></th>
<th>G. F. Nowcast</th>
<th>G. F. 1-Day Forecast</th>
<th>G. F. 2-Day Forecast</th>
<th>G. F. 3-Day Forecast</th>
<th>G. F. MODIS - Aqua Climatology</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS-Aqua SST (C)</td>
<td>0.28</td>
<td>0.76</td>
<td>0.82</td>
<td>0.98</td>
<td>1.02</td>
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<tr>
<td>VIIRS SST (C)</td>
<td>0.25</td>
<td>0.93</td>
<td>1.18</td>
<td>1.41</td>
<td>1.15</td>
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<tr>
<td>MODIS-Aqua A443 (m⁻¹)</td>
<td>0.57</td>
<td>1.28</td>
<td>1.34</td>
<td>1.49</td>
<td>0.78</td>
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<tr>
<td>VIIRS A443 (m⁻¹)</td>
<td>0.32</td>
<td>0.58</td>
<td>0.65</td>
<td>0.66</td>
<td>0.38</td>
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</tbody>
</table>
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.
If you know generally where you are on the bay and the depth, you know your risk.
Delivery of Products (Web Application)

http://basin.ceoe.udel.edu/shiny/sample-apps/sturgeon/
http://basin.ceoe.udel.edu/shiny/sample-apps/sturgeon-viirs/
Uncertainty of Products (Temporally, by pixel)

Spring = Mar 21 – Jun 21
Summer = Jun 21– Sep 21
Fall = Sep 21-Dec 21
Uncertainty of Products (Spatially, by pixel)

Case 2

MODIS-Aqua

Percent Presences Correctly Classified

0 20 40 60 80 100

Upper Bay Middle Bay Lower Bay Ocean

A

VIIRS

Upper Bay Middle Bay Lower Bay Ocean

B

DINEOF Nowcast DINEOF 1 Day Forecast DINEOF 2 Day Forecast DINEOF 3 Day Forecast MODIS-Aqua Climatology
Based on ASMFC SFP for American Shad

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If you know generally where you are on the bay and the depth, you know your risk.
Uncertainty of Products (Temporally, by region)

All Seasons

Spring

Summer

Fall

Percent Correctly Classified Presences

DINEOF Nowcast  DINEOF 1 Day Forecast  DINEOF 2 Day Forecast  DINEOF 3 Day Forecast  Climatology

Spring = Mar 21 – Jun 21  Summer = Jun 21– Sep 21  Fall = Sep 21-Dec 21
Uncertainty of Products (Spatially, by region)

MODIS-Aqua

Percent Presences Correctly Classified

Upper Bay | Middle Bay | Lower Bay | Ocean

Case 2
Equity for Users

We have a diversity of content outlets
Each requires access to either cell/internet
High information to low information
What are we asking of the users to understand this?