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Integrating Marine Mammal Observations with Real-Time Vessel Tracking

Erin Murnane
Naval Research Laboratory
Code 8114, Space Systems Development

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Outline

- Who am I?
  - NRL Karle's Fellowship
- NRL’s real-time vessel tracking system
  - What is S2A?
- Track reconstruction and applying a hidden-state model
  - Explanation of parameters that go into EM algorithm
- Future track integration implications into S2A

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Sea-Link Advanced Analysis (S2A)

NRL's Marine Domain Awareness platform

- S2A is a multiple intelligence (multi-INT) fusion engine, track database, and web-browser accessible map
- Maintains 150K active tracks daily.
- S2A applies core fusion capabilities that de-clutters the intelligence analyst's workspace by providing:
  - Tasking analytics (query widgets)
  - Data aggregation
    - Over 1,000 data sources (AIS, MLEIN, open-source internet, etc.)
    - Major data categories: vessel positions, schedules, and metadata
  - Automated track fusion and database
  - Alerting (Latency test in Kent Island, MD reported 4 - 4.5 minutes to report alerts on new data)
- S2A Users
  - Unclassified S2A will be fully accessible end of FY18.
  - Pilot projects currently tested with US Coast Guard and MD/DE State police

Figure 1: List of current widgets available for Unclassified S2A

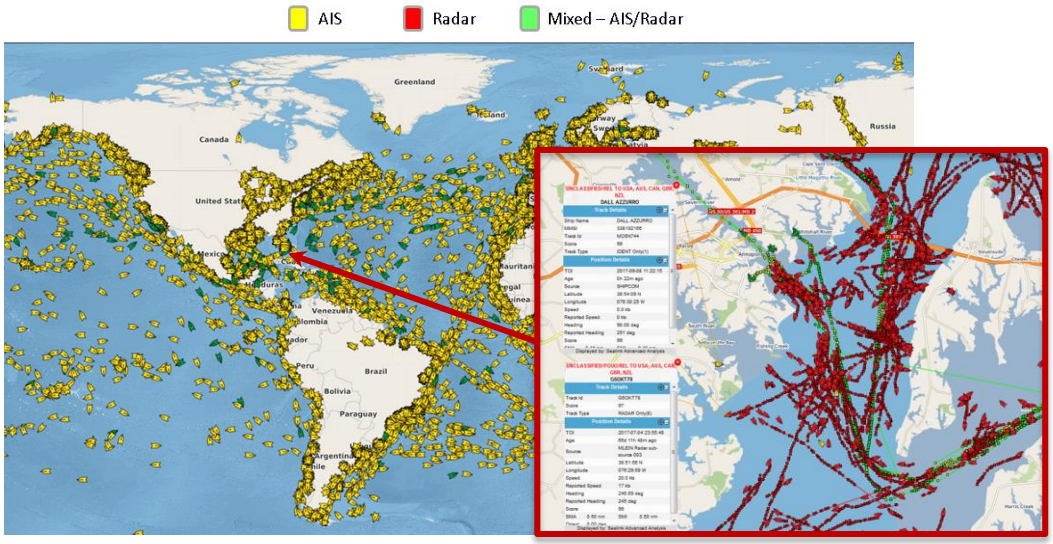

Figure 2: Word view map of active tracks, highlighting the Chesapeake Bay tracks incorporating radar data and AIS

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S2A Capabilities

Example Demo Scenarios

Create an automatic alert for active "bad actor" vessels in user defined area of interest (AOI) in last 12 hours

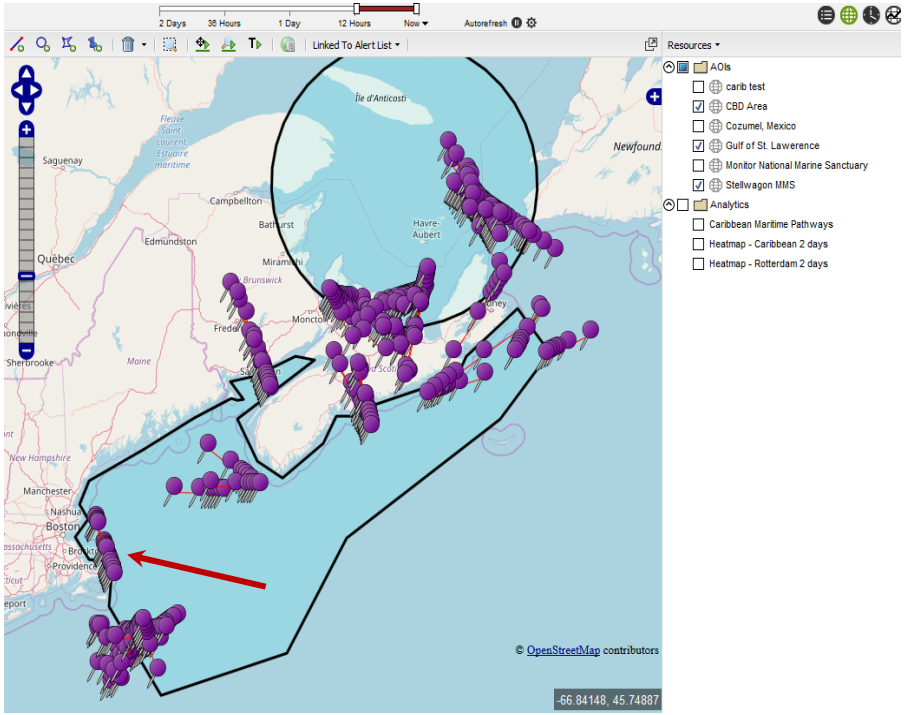

Figure 3: Vessels exceeding 12 knots in the last 12 hours in the Gulf of Maine, George's Bank, Bay of Fundy, and Gulf f St. Lawrence.

Discover and verify potential "bad actors" operating in the AOI with 'ICED' widget in a user defined AOI. Later add vessels of interest (VOI) to 'Briefcase' widget for sharing.

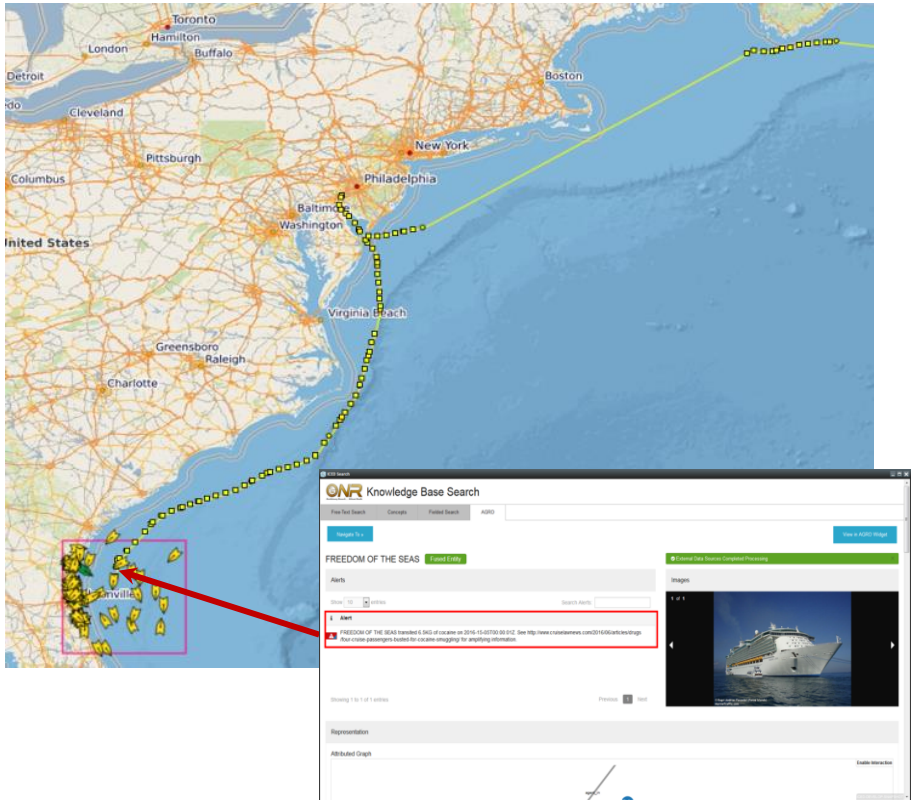

Figure 4: ICED widget alert on FREEDOM OF THE SEAS flagged for transiting 6.5 KG of cocaine on 5/15/2016.

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Marine Mammal Track Reconstruction and Integration

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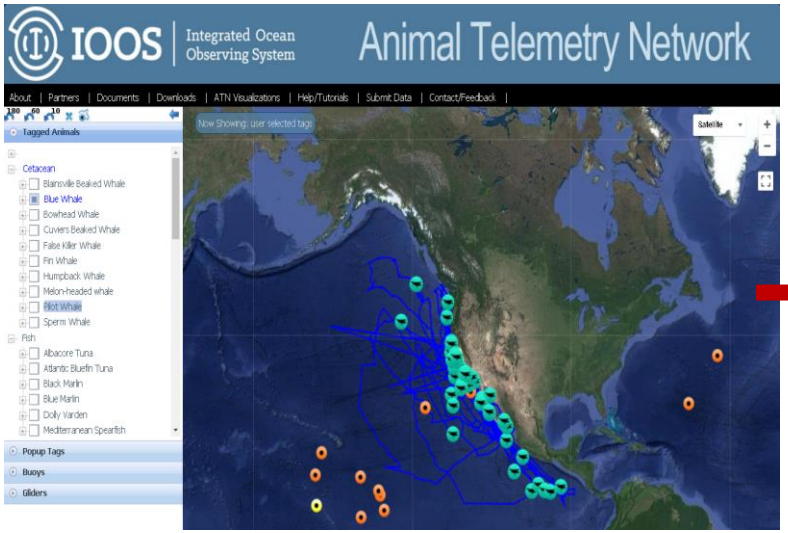
Marine Mammal Tracks in S2A

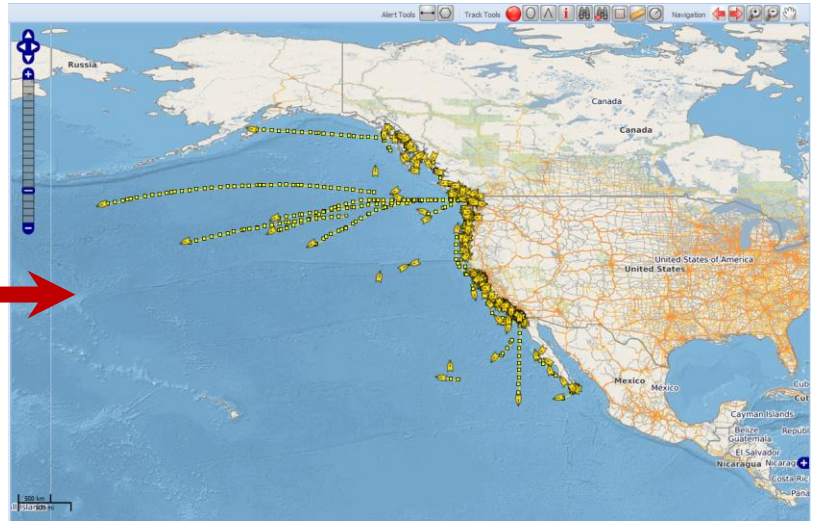
Karle's Fellowship Project FY18/19 Overview

Project aim: Develop detection, fusion, and tracking algorithms based on available marine mammal sensor data. This will enhance the detection of marine mammal locations and patterns, and provide tracking of marine mammals in S2A along with maritime objects

Purpose: To provide a merged operational picture between mammals and vessels in order to predict interactions. Future applications may include ship strike mitigation and provide automatic reporting of illegal, unreported, and unregulated (IUU) vessels suspected of bycatch.

Technical approach: Explore fusion methods of poorly conditioned, time out-of-phase data into a fused product, and attempt to provide accurate prediction of marine mammals. This entails drawing on areas of deep learning.





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Results

Initial Optimization

Applied *circular linear process models* to direction and distance between observed points. An *Expectation Maximization (EM) algo*rithm is then applied to predict hidden state and projected direction. (Nicosia, 2017)

Originality of approach: Algorithm is flexible to *multiple hidden movement states* (“encamped” or “exploratory”) dependent on *multiple external influences* (distance to last cluster, distance to shore, shipping lanes, etc.)

Marine mammal application: *two* state model featuring directional persistence with *one* external influence: direction to closest cluster, x_{center}

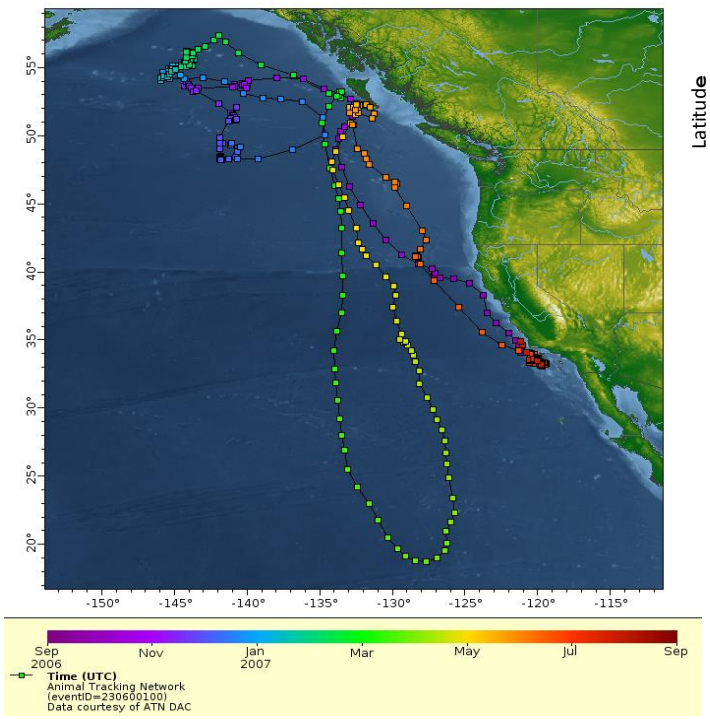
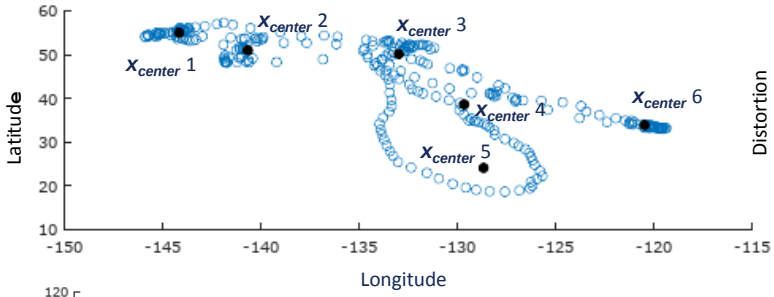
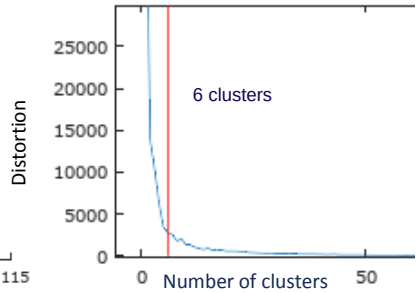
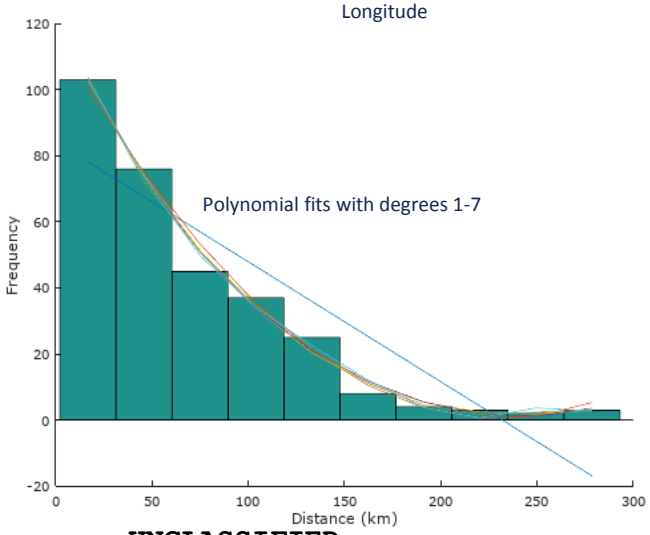


Figure 6: Fin Whale ID: 230600100 from Animal Telemetry Network provided by Bruce Mate







Optimal polynomial fit:
5th degree

Optimal number of clusters
6 clusters

Number of locations:
306

Rate:
1 location/day

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Results

Unsupervised Learning Parameters

Model:
Exponential distribution

Observation variable, distance:
d_t

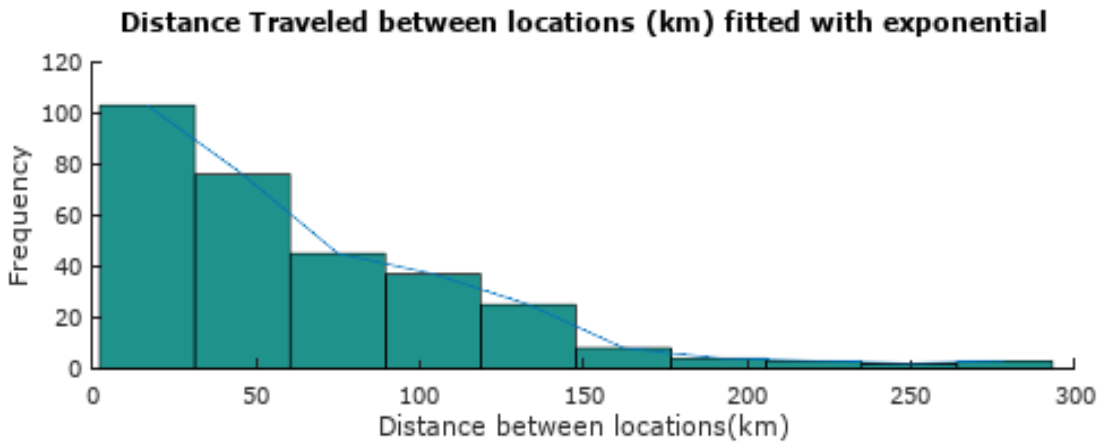
Parameters:
π^i weight and λ^i mean of respective exponential distributions given,
i, animal movement state

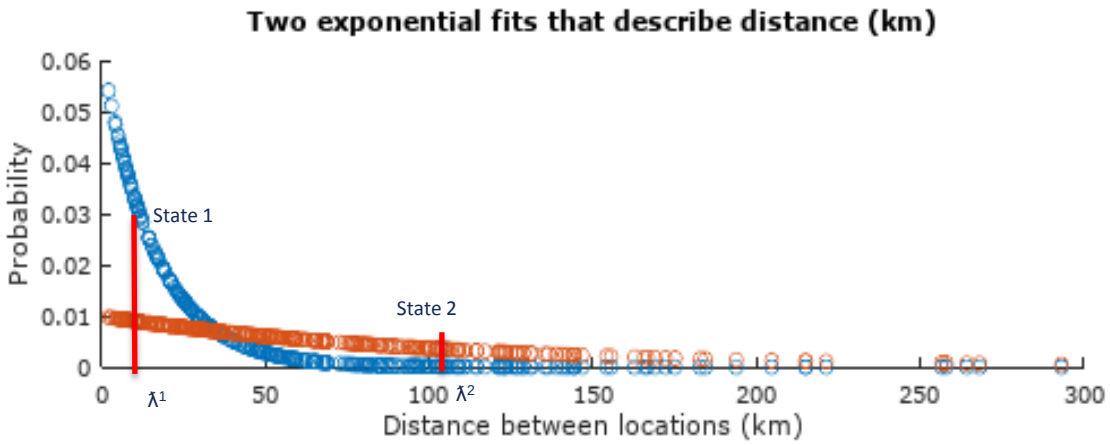
	λ^1		λ^2
0.386	16.139 km	0.614	100.30 km

$D_{critical}$: 67.847 km

State 1: "encamped"
Number of Locations: 118

State 2 :"exploratory"
Number of Locations: 188





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Results

Unsupervised Learning Parameters

Model:
von Mises distribution

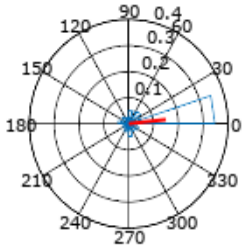
Observation variable, direction:
y_t

Parameter:
κ^i directional persistence of y_t,
the direction between animal's locations,
in state ***i*** given an external influence.

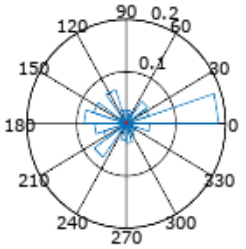
State 1: "encamped"
Number of Locations: 118
Mean direction (rads): 0.192
Resultant length: 0.185
κ_y = 0.740
$\kappa_{xcenter}$ = 0.758

State 2 :"exploratory"
Number of Locations: 188
Mean direction (rads): 2.72
Resultant length: 0.104
κ_y = 0.054
$\kappa_{xcenter}$ = 0.039

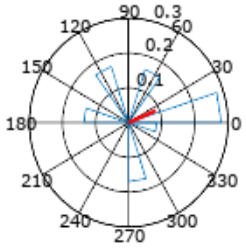
Directional persistance, y(t) as animal is in State 1



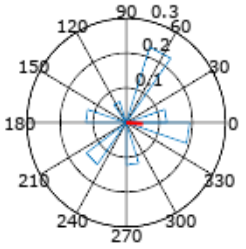
Directional persistance, y(t) as animal is in State 2



Directional persistance, xcenter as animal is in State 1



Directional persistance, xcenter as animal is in State 2



If a external influence is **highly attractive, then** κ **is large**. Similarly, a strong **negative value of** κ means the external influence has a **repulsive effect** and the animal tends to move away from it .

The more uniformed the distribution of turning angles in polar plots implies animal tends to turn around and **does not have a preferred direction.**

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Future Expectations

- Include other external influence and examine parameters
  - Distance to nearest vessel (from S2A)
  - Distance to shelf
  - Distance to shipping lanes
  - Sea Surface Temperature (SST)
- Model fit for optimal behavioral states

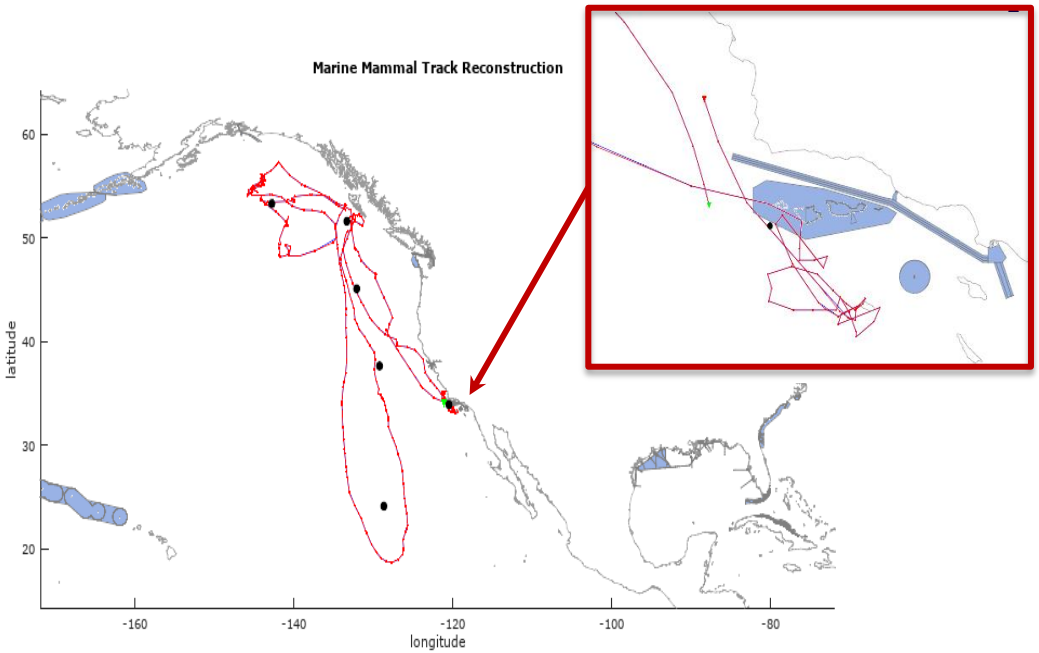

Figure 6: Current view of a Fin Whale 230600100 track in OCTAVE depicted with centroid cluster points and shipping lanes/large vessel anchorage areas plotted

- Implement and utilize real-time data
  - SPOT-258E tag at Chesapeake Beach MD
- Fuse other data sources into track
  - REAL-TIME current satellite tag data
  - Acoustic localizations
  - Manual inputs from vessel/aircraft surveys
  - Satellite imagery
- Establish marine mammal/vessel alert criterion

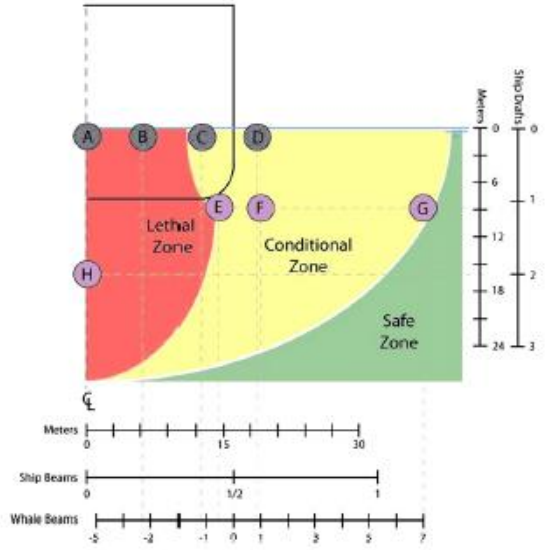

Figure 7: Silber G., Slutsky, J. & Bettridge, S. (2009), "Hydrodynamics of ship/whale collision". *Journal of Experimental Marine Biology.* Accepted 31 May 2010

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Questions?