Developing and validating geolocation methods for groundfish species off New England

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Rationale

Understanding fish movement is critical for describing spatial processes and population dynamics. Such information can improve stock assessments and fishery management plans that account for population structure, including movements across stock boundaries. Archival data storage tags (DSTs) present the opportunity to acquire higher resolution data on fish movements. Development and validation of geolocation methods to estimate daily positions of demersal fish off New England using tidal, temperature, and depth data are required.

Methodology

Fig. 1: Data storage tags attached to an Atlantic cod (left) and a yellowtail flounder (right).

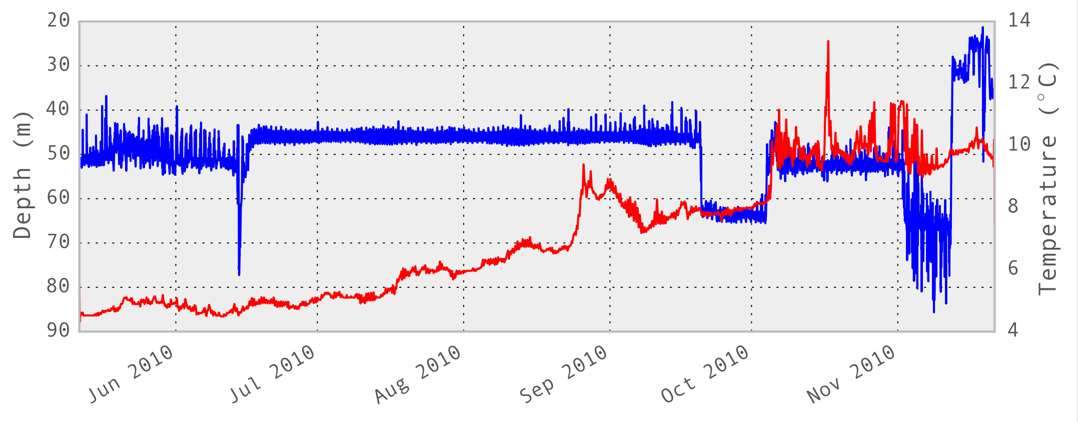


Fig. 2: Example of the depth (blue) and temperature (red) data from a DST attached to an Atlantic cod.

- We tagged cod with Star-Oddi DSTs that record time series of temperature and pressure data and recaptured 45.
- The most advanced tidal-based geolocation tool is a MATLAB geolocation toolbox developed by M.W. Pedersen for the North Sea based on Hidden Markov Models (HMMs) [1].
- These models need modification and calibration for our region- and species-specific geolocation application.

Revised likelihood model

- The likelihood model constructs daily probability distribution of the observational data
- Likelihood is calculated by matching depth and temperature from the tag and the ocean model with tolerance intervals accounting for errors in both data[2].
- We used high-resolution bottom temperature and tidal data from the Northeast Coastal Ocean Forecasting System (NeCOFS) as oceanographic data.
- Tidal characteristics extracted from tag-recorded depth signals were compared with that reconstructed from the ocean model to rule out unlikely locations.
- We implemented activity level characterization to a) utilize more information from the tag-recorded data, and b) assess the daily activity level of the tagged fish:
  - ★ **High**: depth-temperature from max daily depth
  - ★ **Moderate**: depth-temperature from 5-h tidal fitting
  - ★ **Low**: depth-temperature from 5-h tidal fitting + tidal characteristics from 13-h tidal fitting to remove unlikely locations.

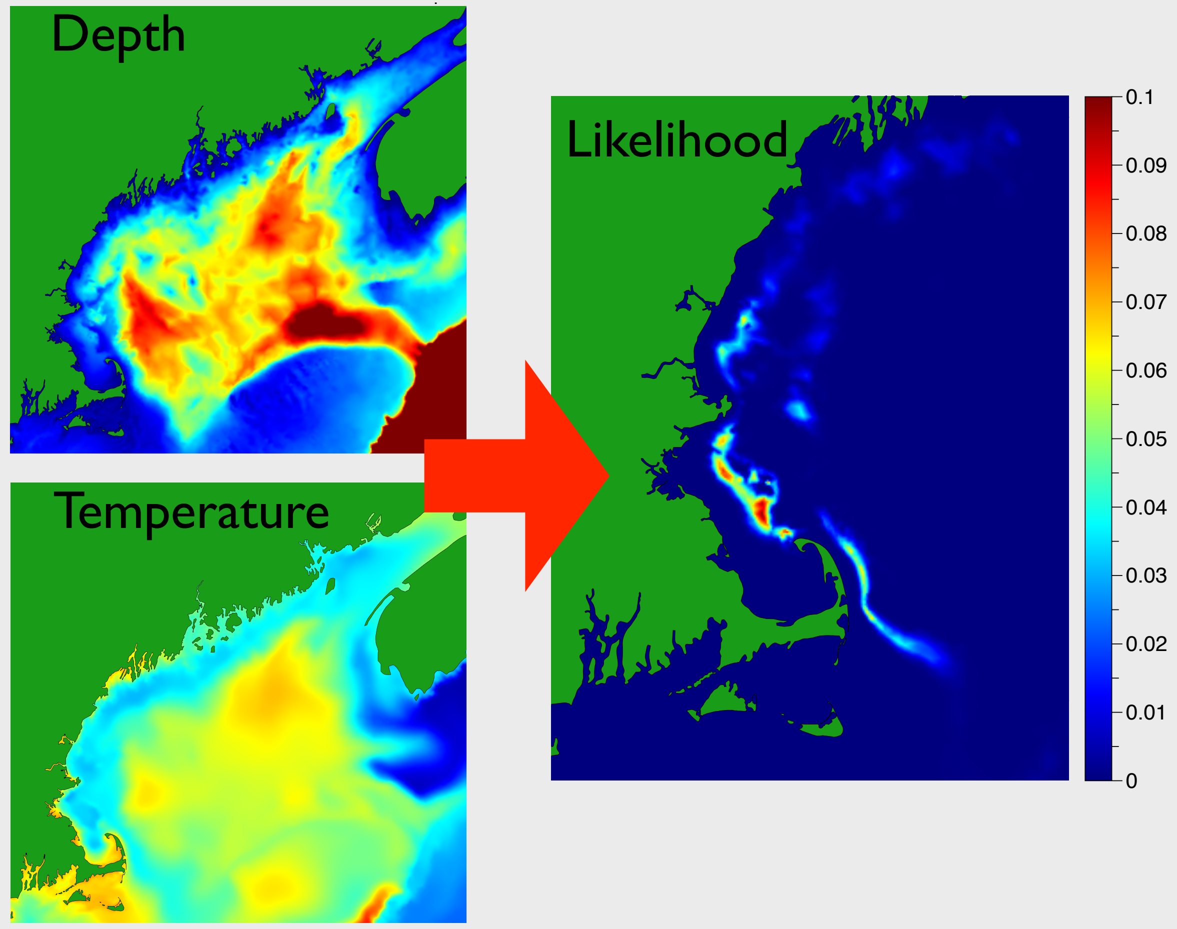
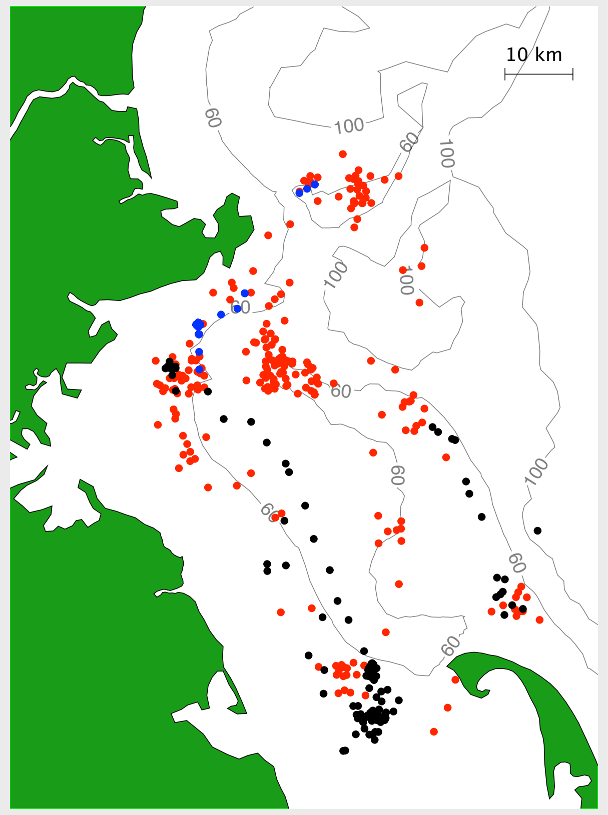


Fig. 3: Example of a daily likelihood distribution (right) constructed from comparing NeCOFS depth (upper left) and temperature (upper right) with those recorded by the DST.

Validation

A subsample (n=10) of the 45 DST recaptures were also tagged with acoustic transmitters. High resolution locations were measured by an acoustic telemetry positioning system[3]. Fish locations detected by the acoustic receivers (**blue dots**) were compared to same-day estimate of fish locations from the most probable tracks (**red dots**) constructed by the modified HMM. The standard error of the modified HMM and acoustic locations is 30.8 km, an improvement over 57.9 km for the baseline HMM with unmodified likelihood model (**black dots**).

Fig. 4: Fish locations detected by the acoustic receivers (blue dots) and same-day estimate of fish locations constructed by the modified HMM (red dots). Black dots are locations constructed by the baseline HMM with unmodified likelihood model.



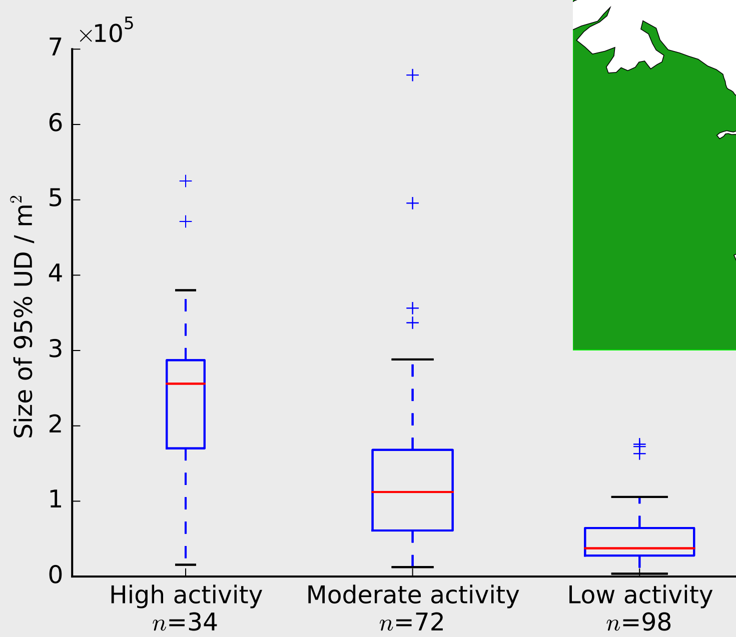
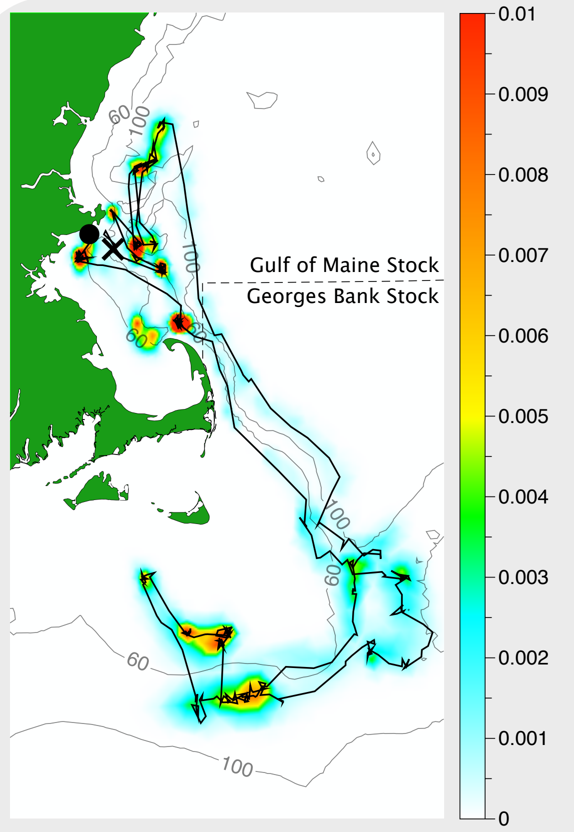


Fig. 5: Box plot of the size of daily 95% utilization distribution determined from acoustic array detection of the high, moderate, and low activity levels determined by the likelihood model.

To validate the activity level characterization approach of the likelihood model, we compared the size of daily 95% utilization distribution determined from acoustic array detection[3] with the activity levels determined by the likelihood model. The results indicate that the fish were utilizing smaller areas during low activity periods.

Preliminary Results



We ran the modified HMM geolocation model on all 45 recaptured cod. The geolocation output of each tagged fish include the most probable track, the behavior state sequence, and quantified uncertainties.

Fig. 6: Example of the most probable track of fish #56 (solid line) with spatial uncertainty represented by estimated utilization distribution (color code).

We aggregated the HMM-estimated utilization distribution for all 45 DST-tagged fish. The overall distribution indicated core-use areas in Massachusetts Bay, between Cape Ann and Cape Cod.

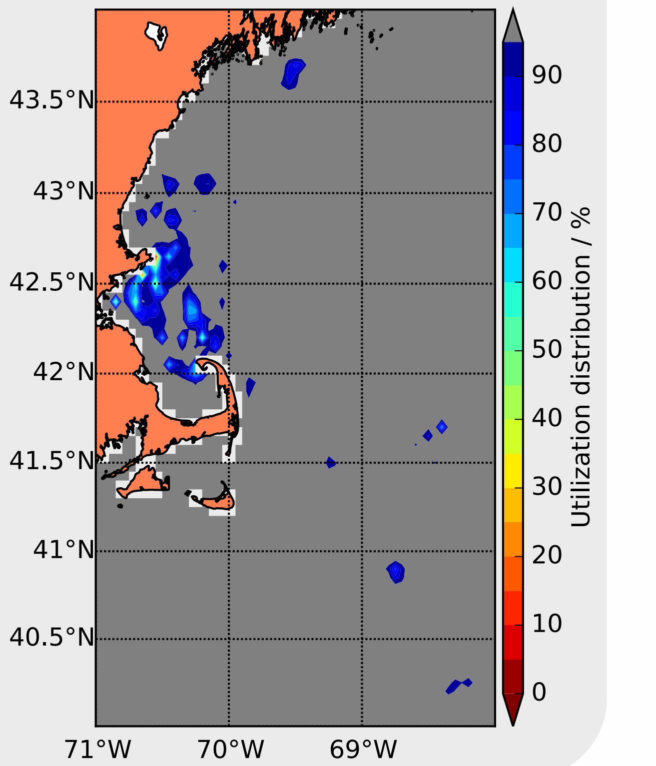


Fig. 7: Aggregated utilization distribution of the 45 fish tagged with Star-Oddi DSTs.

Future work

- Further validation with simulated tracks
- Geolocate all cod, yellowtail flounder, and monkfish tags.
- Develop a web-based geolocation service

References

[1] Pedersen et al. 2008. *Can J Fish Aquat Sci* **65**: 2367. [2] Le Bris et al. 2013. *Fish Res* **148**: 106. [3] Dean et al. 2014. *ICES J Mar Sci* **71**: 1474.

Acknowledgements

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