AED Peer Review '07

Stressor-Response Relationships for Habitat Alteration: Habitat Quality and Response of Juvenile Winter Flounder (WQ MYP)

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Agency Problem:

EPA's Aquatic Stressors Framework and Habitat Alteration Research Program call for development of stressor-response relationships between habitat alteration and valued populations of fish, shellfish, and wildlife. Historically, winter flounder have supported important fisheries along the coast of New England, but in recent years winter flounder numbers have declined precipitously – leading to considerable public awareness of these fish and concern for their sustainability. AED winter flounder studies are proceeding in three directions in collaborations involving EPA's Office of Water, NOAA (NMFS), RI Department of Environmental Management, MA Division of Marine Fisheries, and the University of Rhode Island. These efforts support the Clean Water Act by identifying critical nursery areas and informing regulation of shoreline habitat alteration and dredging.

Background:

Winter flounder are a commercially and recreationally valued species. These fish spawn in estuaries and embayments in late winter, producing demersal adhesive eggs. Larvae emerge during the spring, then metamorphose into juveniles and settle in shallow nearshore nursery habitats (e.g., vegetated, unvegetated, eelgrass). Once fish settle, they exhibit strong site fidelity to these nearshore habitats during their first summer. This early life history exposes juvenile flounder to habitat alteration from a variety of anthropogenic activities including dredging, wetland alteration, and eutrophication. Their site fidelity makes these fish a good candidate for habitat studies and allows possible identification of distinct natal fingerprints through otolith microchemistry.

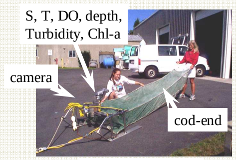
Research Goals:

- Relate densities of juvenile winter flounder to multiple scales of habitat variation and habitat alteration in western Rhode Island. **(Study I)**
- Determine which nearshore juvenile habitats are most important for recruitment to adult offshore winter flounder populations. **(Study II)**
- Determine the effects of sediment burial on hatching success of winter flounder. **(Study III)**

Study I

Methods & Approach:

We used random survey methods to relate densities of juvenile winter flounder to multiple scales of habitat variation in Narragansett Bay and nearby coastal lagoons. We sampled 163 sites in 2002 and 2003 using a 1-m beam trawl with attached video camera, GPS track overlay, and continuous-recording water quality sonde. Habitat patterns at larger spatial scales were also assessed, using aerial imagery, depth data, and other information. We used step-wise multiple regression to look for correlations between fish abundance and: year, waterbody geomorphology, date, tide, latitude, tow speed, temperature, salinity, DO, depth, turbidity, chlorophyll a, algal cover, mud, muddy sand, sand, shell, human population density, distance to nearest sewer outfall, habitat type, habitat diversity within a tow, number of nearby human structures, percent of unaltered shoreline, distance to nearest marsh or SAV bed, and more.



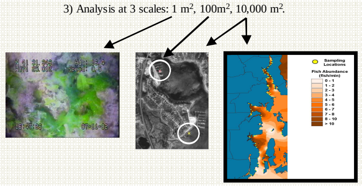
1 meter beam trawl

"Multiple Habitats at Multiple Scales"

1) Random transects with instrument sled.

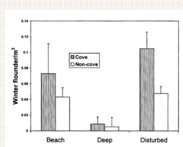
2) Characterization of shoreline from aerial images.

3) Analysis at 3 scales: 1 m^2, 100m^2, 10,000 m^2.



Results and Conclusions:

We caught 25 species and 977 fishes, and winter flounder was the most common species in both years of the study. Results of our step-wise multiple regression showed that, while habitat explained only about 25% of the variability in fish abundance, juvenile flounder were most abundant in coves and upper estuaries at sites with shallow marsh or beach edges and high human disturbance. Further, flounder densities increased with human population density, algal cover, and mud. Our data suggest that many areas in highly altered upper estuaries may provide beneficial nursery habitat for winter flounder despite apparent human disturbance.



Flounder density captured in cove and non-cove sites in three habitats: beach or marsh shorelines, deep water (> 4m), and human-altered (disturbed) sites, which include industrial areas, artificially hardened shorelines, and marinas (Meng et al. 2005).

Study II

Methods & Approach:

We are using otolith microchemistry to delineate important nursery areas that supply recruitment to the adult offshore winter flounder population. In 2002, 2003, and 2004, we measured chemical signatures in juvenile otoliths from important inshore habitats and locations. Adult offshore winter flounder from the same cohort of juveniles are now being collected and chemically analyzed to identify corresponding chemical signatures.

Phase I: Juveniles

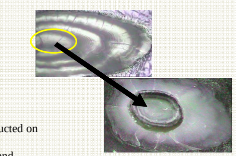
Juveniles were collected from nursery habitats in Narragansett Bay, coastal lagoons, and an estuarine river.

Sagittal otoliths were removed for the analysis of trace elements (Ca, Ba, K, Li, Mg, Mn, Na, Ru, and Sr) and stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) to identify signatures characteristic of nursery areas and habitats.

Phase II: Adults

Adult winter flounder corresponding to the sampled juvenile cohort were collected from the offshore fishery in 2006 and 2007.

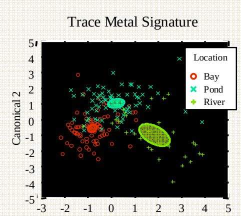
Juvenile otolith cores (the portion of the otolith formed during the inshore juvenile life history stage) were removed from adult fish using a Micromill.

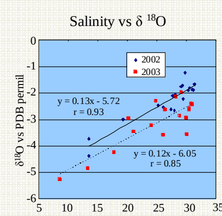


Elemental and isotopic analyses were conducted on the juvenile cores to look for signatures characteristic of specific inshore locations and habitats.

Results:

Trace metal signatures of winter flounder otoliths collected from Narragansett Bay, coastal lagoons (ponds), and Narrow River showed a Linear Discriminant Functional Analysis (LDFA) classification success of 76%.





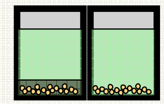
There was good correlation between salinity and $\delta^{18}O$ at each of the stations for both of the years. Stations with more freshwater inputs showed depleted values relative to locations with higher salinity. Therefore, $\delta^{18}O$ may further differentiate nursery habitats based on salinity.

Study III

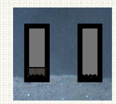
Methods & Approach:

We used experimental methods to determine the effects of sediment burial on hatching success of winter flounder. We coordinated a series of laboratory and field experiments with winter flounder eggs and clean sediment so as to provide data for regulatory applications and for sediment effects modeling.

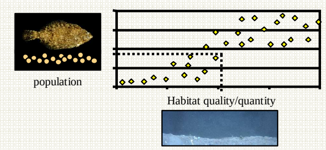
1) Lab: Egg hatching was determined at various burial levels in the laboratory.



2) Field: In-situ egg survival was studied during a dredging event in Narragansett Bay as a collaboration with URI.

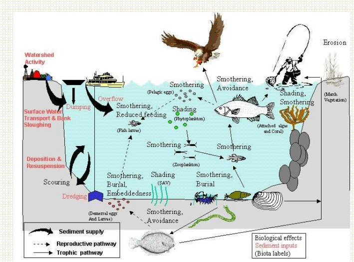


3) Application: Results can be applied to modeling that incorporates sediment deposition data from dredging projects and other alterations.



Results and Conclusions:

In the laboratory experiment, percent total hatch was variable in eggs buried in less than 3 mm of sediment, while there was little or no hatch in eggs buried in greater than 3 mm of sediment. Results from the in-situ field experiment were somewhat ambiguous. Overall, these findings are important whenever proposed anthropogenic activities (such as dredging) might result in increased sediment deposition in winter flounder spawning areas during the spawning season.



Conceptual model of the biological effects of suspended and bedded sediment (SABS) in aquatic systems (Berry et al. 2002).

Impact and Outcomes:

Our work supports attainment of the objectives of the Clean Water Act by improving the understanding of habitat needs of a societally valued fish species. This has led to more informed management decisions involving habitat alteration and restoration, and dredging in critical flounder nursery areas. The knowledge gained through the juvenile distribution component of this effort (**Study I**) is being used by RI DEM in reviewing permit applications and has given state managers a more realistic perspective on the value of anthropogenically altered coves in upper Narragansett Bay, leading to more informed decision-making. Identification, conservation, and management of nursery habitats is critical to adult fish populations. The technical approaches and tools we are developing to identify nursery habitats (**Study II**) will benefit the Office of Water, National Marine Fisheries Service, and RI Department of Environmental Management in delineating critical nursery areas for winter flounder in Narragansett Bay, Rhode Island's coastal lagoons (ponds), and elsewhere. The effect of clean sediment on winter flounder egg survival (**Study III**) has particular implications for the regulation of dredging, and the sensitivity of winter flounder eggs to burial has resulted in seasonal banning of dredging in several northeastern U.S. estuaries. Application of the knowledge gained by our research enhances the sustainability of valued aquatic resources.

Future Directions:

Studies I and III of this research program are essentially complete. Study II is at a stage where results linking juvenile nurseries to offshore adult populations are now being produced. Future work for Study II will include additional collections of adult winter flounder and juvenile tautog to examine year-to-year variability in chemical signatures.

Related Publications:

Berry, W. J., N. I. Rubinstein, B. Melzian, and B. Hill. 2002. The Biological Effects of Suspended and Bedded Sediment (SABS) in Aquatic Systems: A Review of the "State of the Science." September 30, 2002

Cicchetti, G. 2006. Fisheries in Mount Hope Bay: notes on a special symposium from a session moderator. Northeastern Naturalist 13:27-30.

Meng, L., G. Cicchetti and M. Chintala. 2004. Nekton habitat quality at shallow water sites in two Rhode Island coastal systems. Estuaries 27:740-751.

Meng, L., G. Cicchetti and S. Raciti. 2005. Relationships between juvenile winter flounder and multiple-scale habitat variation in Narragansett Bay, Rhode Island. Transactions of the American Fisheries Society 134:1509-1519.

Meng, L., C.D. Orphanides and J.C. Powell. 2002. Use of a fish index to assess habitat quality in Narragansett Bay, Rhode Island. Transactions of the American Fisheries Society 131:731-742.

Pruell, R.J., B.K. Taplin and K. Cicchelli. 2003. Stable isotope ratios in archived striped bass scales suggest changes in trophic structure. Fisheries Management and Ecology 10:329-336.

Pruell, R.J., B.K. Taplin, J.L. Lake and S. Jayaraman. 2006. Nitrogen isotope ratios in estuarine biota collected along a nutrient gradient in Narragansett Bay, Rhode Island, USA. Marine Pollution Bulletin 52:612-620.

EPA Atlantic Ecology Division Narragansett, Rhode Island