

Temperature and Salinity Effects on the Growth and Survival of Juvenile Penaeid Shrimps: Implications for the Influence of River Diversions on Production

Primary Investigator: Doran Mason - NOAA GLERL

Co-Investigators: Lawrence Rozas - NMFS Lafayette, LA, Thomas Minello - NOAA Fisheries Service Galveston Laboratory, Craig Stow - NOAA GLERL

Overview

Water-control structures are currently being used, and additional structures are being planned, on the northern Gulf of Mexico to divert river water into nearby estuaries for wetland restoration. These freshwater flows directly alter the temperature and salinity of estuarine waters, which can influence the distribution and productivity of penaeid shrimps and other fishery species. Currently, too little is known about the environmental requirements of penaeid shrimps to design and operate diversions to both restore wetlands and minimize impacts to penaeid shrimps. We propose to use a series of controlled laboratory experiments to establish the relationships between the distribution, growth, and survival of juvenile white shrimp and brown shrimp and two key environmental variables (water temperature and salinity) affected by freshwater inflows. We also will test the validity of these relationships using continuously recorded environmental data and growth and survival data from shrimp caged along a salinity gradient in an estuary. In addition, we will look for a relationship between shrimp growth rates in the field and the availability of potential prey. Experiments also will be conducted in the laboratory to examine salinity selection by shrimp. The results from these experiments would be incorporated into simulation models to predict effects of temperature and salinity on shrimp growth and survival. These models can be linked to a hydrology-hydrodynamic model and used in conjunction with different river diversion scenarios to assist managers in minimizing the impacts of freshwater releases to shrimp production when restoring coastal systems.

Proposed Work

The research performed at GLERL will focus on developing predictive models for brown and white shrimp. Initial versions of the white and brown shrimp bioenergetics models have been developed. To parameterize the models, we have made extensive use of data from other species of penaeid shrimp, as bioenergetics data for white and brown shrimp were somewhat sparse. In order to quantify the uncertainty in our parameter estimates, we used Bayesian parameter estimation techniques to quantify parameter uncertainty. For this year, model simulations will be performed to predict growth and survival of brown shrimp and white shrimp based on various freshwater discharge scenarios as determined from historical data on salinity and temperature from the bay, and assuming realistic (but extreme) cases.

Scientific Rationale

Water-control structures are currently being used in Louisiana to divert freshwater from the Mississippi River into nearby estuaries. Many additional large capacity structures are being planned in the state to divert Mississippi River water into coastal areas for wetland restoration. Water diversions are also one part of a large comprehensive plan in Mississippi to rebuild impacted coastal marshes after Hurricane Katrina.

River diversions increase the inflow of freshwater to estuaries, and in doing so influence numerous estuarine characteristics that affect primary and secondary productivity (Alber 2002). These freshwater inflows directly alter the water temperature and salinity of estuarine waters, which can influence the distribution and productivity of estuarine animals. For example, in coastal Louisiana, brown shrimp *Farfantepenaeus aztecus* production has been related to the salinity and temperature of estuarine nursery areas (Barrett and Gillespie 1973).

Data from the scientific literature that would inform management decisions for operating diversion structures to minimize impacts to the shrimp fisheries are inadequate. Only a few studies have examined the effect of salinity and water temperature on growth and survival of brown shrimp and white shrimp *Litopenaeus setiferus*. Penaeid (both brown shrimp and white shrimp) postlarvae survived and grew equally well in salinities of 2-40‰ in a laboratory study where water temperatures were held between 24.5 and 26.0°C (Zein-Eldin 1963). Survival of brown shrimp postlarvae decreased in salinities <5‰, however, when temperatures were <15°C (Zein-Eldin and Aldrich 1965), but brown shrimp were more tolerant than white shrimp of temperatures <15 °C (Zein-Eldin and Griffith 1969). Keiser and Aldrich (1973) reported that postlarval brown shrimp selected for salinities mainly between 5 and 20‰ in a laboratory salinity gradient; subsequent experiments suggested that the range of salinity selection for brown shrimp may be larger and variable and that postlarval white shrimp and brown shrimp select for similar salinities (Keiser and Aldrich 1976). Relatively little work has been conducted on the effects of temperature and salinity on larger juveniles. In laboratory experiments on juveniles, Saoud and Davis (2003) reported growth of brown shrimp to be significantly higher at salinities of 8 and 12‰ than 2 and 4‰, but water temperature was not varied and white shrimp were not examined. Survival and growth rates of juvenile penaeid shrimps have not been documented for the range of different combinations of water temperature, salinity and shrimp size that commonly occur in an estuarine environment.

The uncertainty surrounding the environmental requirements of brown shrimp and white shrimp is surprising given the importance of the fisheries for these species. Development of a better understanding of the relationship between water temperature, salinity and growth and survival of juvenile brown shrimp and white shrimp is needed in order to adaptively manage large water diversion structures. In this collaborative project, we will bring together the expertise of NOAA and a Cooperative Institute (CI) consortium member in field and laboratory ecological studies with the simulation modeling capabilities at NOAA.

Governmental/Societal Relevance

This project contributes to the NOAA mission goal to protect, restore, and manage the use of coastal and ocean resources through an Ecosystem approach to management and to the NOAA ecosystem goal outcome of healthy and productive coastal and marine ecosystems that benefit society, and to the NOAA performance objective to increase the number of habitat acres conserved or restored. Robust coastal economies are dependent on a productive coastal environment. In the northern Gulf of Mexico, coastal economies are built around sustainable fisheries. Brown shrimp and white shrimp support two of the most important fisheries of the region, and these fisheries are sustained by coastal wetlands. In response to continuing degradation of coastal wetlands and potential negative economic impacts, river diversions are currently being used, and additional diversions are being planned, to restore coastal wetlands. A better understanding of the environmental requirements of brown shrimp and white shrimp may make it possible to design and operate these freshwater diversions in a manner that would both restore estuarine areas and benefit the shrimp fisheries. The results of our study would be used to develop relationships between shrimp growth and survival and two primary environmental variables (temperature and salinity) affected by freshwater inflows. These relationships can be used in a model linked to a hydrology-hydrodynamic model to predict the spatial distribution, growth and mortality, and production of shrimp in coastal areas. These models could be used in conjunction with different river diversion scenarios to assist managers in minimizing the impacts of freshwater releases to shrimp production when restoring coastal systems.

Relevance to Ecosystem Forecasting

As a part of wetland restoration in coastal Louisiana, several freshwater diversions are being planned or are in the process of being developed. These diversions are being built to help deliver sediments and freshwater needed for coastal restoration. The addition of cold, river water to coastal marshes will result in the alteration of the spatial patterns of salinity and temperature in these marshes. Development of shrimp bioenergetics models will help to predict the potential effects of changes in temperature and salinity patterns on shrimp production and will aid managers in developing operation plans which minimize these effects.

References

- Alber, M. 2002. A conceptual model of estuarine freshwater inflow management. **Estuaries** 25:1246-1261.
- Barrett, B.B. and M.C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. *Louisiana Wildlife and Fisheries Commission Technical Bulletin No. 9*, New Orleans, LA, 28 pp.
- Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish Bioenergetics 3.0 for windows. *University of Wisconsin Sea Grant Technical Report No. WISCU-T-97-001*.
- Keiser, R.K. and D.V. Aldrich. 1973. A gradient apparatus for the study of salinity preference of small benthic and free swimming organisms. *Contributions in Marine Science* 17:153-162.

- Keiser, R.K. and D.V. Aldrich. 1976. Salinity preference of postlarval brown and white shrimp (*Penaeus aztecus* and *P. setiferus*) in gradient tanks. *Texas Sea Grant Publication TAMUSG-75-208*, 260 p.
- Lane, R.R., J.W. Day, D. Justic, E. Reyes, B. Marx, J.N. Day and E. Hyfield. 2004. Changes in stoichiometric Si, N and P ratios of Mississippi River water diverted through coastal wetlands to the Gulf of Mexico. *Est., Coast. Shelf Sci.* 60:1-10.
- McTigue, T. and R.J. Zimmerman. 1998. The use of infauna by juvenile *Penaeus aztecus* Ives and *Penaeus setiferus* (Linnaeus). *Estuaries* 21: 160-175.
- Minello, T. J. and R. J. Zimmerman. 1991. The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. In: DeLoach, P., W. J. Dougherty, and M. A. Davidson (eds.) *Frontiers in Shrimp Research*. Elsevier Science Publishers, Amsterdam, p. 1-16.
- Minello, T.J., K.W. Able, M.P. Weinstein, and C.G. Hays. 2003. Salt marshes as nurseries for nekton: testing hypotheses on density, growth and survival through meta-analysis. *Marine Ecology Progress Series* 246:39-59.
- Peterson, M.S., B.H. Comyns, C.F. Rakocinski and G.L. Fulling. 2004. Defining the fundamental physiological niche of young estuarine fishes and its relationship to understanding distribution, vital metrics, and optimal nursery conditions. *Environmental Biology of Fishes* 71(2):143-149.
- Rozas, L. P., T. J. Minello, I. Munyera-Fernandez, B. Fry, and B. Wissel. 2005. Macrofaunal distributions and habitat change following winter-spring releases of freshwater into the Breton Sound Estuary, Louisiana (USA). *Estuarine, Coastal and Shelf Science* 65:319-336.
- Saoud, I.P. and D.A. Davis. 2003. Salinity tolerance of brown shrimp *Farfantepenaeus aztecus* as it relates to postlarval and juvenile survival, distribution, and growth in estuaries. *Estuaries* 26:970-974.
- Tate, M. W. and R. C. Clelland 1957. *Nonparametric and shortcut statistics*. Interstate Printers and Publ., Inc, Danville, IL. 1-171 p.
- Underwood, A.J. 1997. *Experiments in ecology. Their logical design and interpretation using analysis of variance*. Cambridge University Press, United Kingdom. 504p.
- Zein-Eldin, Z.P. 1963. Effect of salinity on growth of postlarval penaeid shrimp. *Biological Bulletin* 125:188-196.
- Zein-Eldin, Z.P. and D.V. Aldrich. 1965. Growth and survival of postlarval *Penaeus aztecus* under controlled conditions of temperature and salinity. *Biological Bulletin* 129:199-218
- Zein-Eldin, Z. P., and G. W. Griffith. 1969. An appraisal of the effects of salinity and temperature on growth and survival of postlarval Penaeids. *Food and Agricultural Organization Fisheries Report No. 57* 3:1015- 1026.