

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

Lawrence P. Rozas¹, Thomas J. Minello², and Doran M. Mason³

^{1,2}NOAA Fisheries Service, ¹SEFSC EHCFC, Lafayette, LA; ²SEFSC Galveston Laboratory, Galveston, TX; ³NOAA GLERL, Ann Arbor, MI

ABSTRACT

We are using a series of controlled laboratory experiments to establish the relationships between the distribution, growth, and survival of juvenile white shrimp *Litopenaeus setiferus* and brown shrimp *Farfantepenaeus aztecus* and two key environmental variables (water temperature and salinity) affected by freshwater inflows. We also are testing 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. The results from these experiments will 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.

INTRODUCTION

Coastal landloss is a major source of environmental change along the Northern Gulf of Mexico today. Landloss rates in Louisiana are higher than anywhere in the U.S., and the 2005 hurricanes alone may have converted > 55,000 ha of coastal wetlands to open water (Barras 2007). The loss of coastal wetlands poses a serious threat to the fisheries that depend on these areas for habitat.

Water-control structures are currently being used, and more are being planned, in Louisiana to divert freshwater from the Mississippi River into nearby estuaries for wetland restoration. The effect of these large-scale diversions on coastal fisheries is uncertain (Rozas et al. 2005).

The concern is that estuarine temperatures and salinity will be reduced by river diversions, and that this will negatively impact recruitment, growth, and productivity of fishery species. The potential conflict between use of diversions and fisheries is particularly high for brown shrimp because their young enter estuary nursery areas as postlarvae in the early spring, at the same time that freshwater and sediment are most available in the Mississippi River for use in diversions.

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. 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 consortium member in field and laboratory ecological studies with the simulation modeling capabilities at NOAA.

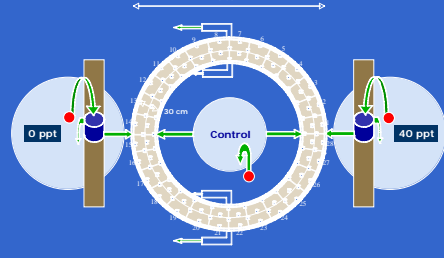
Our study was designed with four objectives: (1) Establish the relationships between the distribution, growth, and survival of juvenile brown shrimp and white shrimp and two key environmental variables (water temperature and salinity) affected by freshwater inflows using a series of controlled lab experiments; (2) Test the validity of these relationships using field experiments; (3) Examine the relationship between shrimp growth rates in the field and the availability of potential prey; and (4) Incorporate experimental results into simulation models to predict the effects of temperature and salinity on shrimp growth and survival.

METHODOLOGY

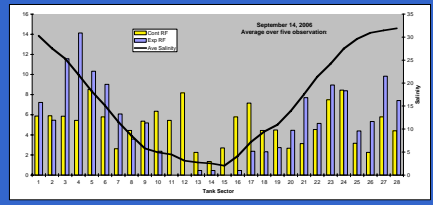
We are initiating this research by developing simulation models describing the effects of temperature and salinity on shrimp growth. These models (for brown shrimp and white shrimp) will be based on existing information in the literature and unpublished experimental data. Laboratory and field experiments will then be conducted for comparison with model predictions, and the models will be adjusted as needed. Field experiments on growth and survival will be conducted in the Barataria Bay estuary of Louisiana. Experiments on salinity selection in a gradient tank will be conducted at the NMFS Laboratory in Galveston, Texas.

Gradient Tank Experiments

Laboratory experiments are being conducted to examine how salinity may affect the distribution of shrimp. Circular raceways (diagram below) are used. A salinity gradient of slowly flowing water is



Experimental raceway dimensions: Width: 15 cm, Length: 6.36 cm, Water depth: 10 cm. At Inflow Rate of 2.0 L/min (x2) Current is 4.0 cm/min, 4% exchange per min, 2.4 min turnover



Laboratory Growth Experiments

Growth experiments to establish relationships between growth and survival of penaeid shrimps and water temperature and salinity are to be conducted in the laboratory by our university partner. These experiments will incorporate a 3 by 5 by 2 factorial design with three levels of temperature, five levels of salinity, and using two size classes of juvenile shrimp (Peterson et al. 2004). Each experiment will be replicated five times. Shrimp will be held at a 14:10 photoperiod cycle under

flow-throw conditions and fed *ad libitum* twice each day.

Field Growth Experiments

Growth and survival rates of young shrimp also are being measured in the field by caging animals in shallow water along an estuarine salinity gradient. Individually marked animals are measured and placed into 1 m² cages (foreground in image on left) to initiate experiments. After 7 d, animals are captured, weighed, and measured to determine growth rates. Growth rates of 1 mm d⁻¹ have been measured in experiments similar to those we are conducting (Minello et al. 2003). Availability of potential prey will be determined from samples collected with benthic cores.



Model Development and Application

Bioenergetics growth, survival, and spatial distribution models are being developed and parameterized from existing information in the literature (e.g., Zein-Eldin and Griffith 1969, Saoud and Davis 2003) and will be modified from the results of the laboratory experiments in our study. Growth and survival models will be tested against the results of our field experiments and adjusted accordingly. Model simulations will then 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, and assuming realistic (but extreme) cases.

PROGRESS TO DATE

Models currently are being developed from existing literature. Initial laboratory gradient experiments were conducted using white shrimp, and experiments using brown shrimp are underway. The enclosures and protocol for field growth experiments were tested last fall, and the first experiments using brown shrimp will be conducted in May 2007.

LITERATURE CITED

Barras, J. A. 2007. Land area changes in Louisiana after Hurricanes Katrina and Rita. U.S. Geological Survey Report (approved draft).
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 TAMU-SG-75-208, 260 p.
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.
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 129:199-211.
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.