Project **Number** 3

# Effect of Shoreline **and Shallow** Sublittoral Habitat Contamination and Loss on Dominant **Infaunal** Invertebrates

Principal Investigator:
Dr. Darryl L. **Felder**

Associate Investigator
Mr. Roger **Griffis**
Dr. Robert **Twilley**

Department of Biology
University of Southwestern Louisiana
Lafayette, LA 70504

## Figures

## ABSTRACT

Oil contamination and physical perturbation of intertidal and shallow subtidal substrates threaten future mass mortalities in the extensive populations of ghost shrimp that dominate many coastal habitats of the northern Gulf of Mexico. Evidence from studies elsewhere suggests that these species play key ecological roles in determining g coastal habitat quality, and that reductions in their population densities may substantially alter physical, chemical and biological characteristics of the infaunal habitat. The present study seeks to quantify the ecological significance of ghost shrimp communities by a combination of empirical field studies and laboratory mesocosm experiments. We hypothesize that: 1) ghost shrimp galleries provide substantial traps for entrainment and accumulation of oil deep into substrates of intertidal and shallow subtidal habitats; 2) reductions in population densities of ghost shrimp alter rates of sediment bioturbation, sediment redox potential, and nutrient flux across the sediment-water interface; 3) reduction in density of ghost shrimp alters community structure in the macrobenthic infaunal assemblage; 4) ghost shrimp populations undergo defined seasonal breeding peaks of particular vulnerability; 5) recovery of diminished ghost shrimp populations occurs both by planktonic recruitment of larvae and by recruitment from burrowed postlarval populations.

## PROJECT GOALS AND OBJECTIVES

1. Determine relative densities of *Callichirus islagrande*, *Callichirus major*, and *Lepidophthalmus louisianensis* in selected coastal habitats.

2. Determine burrow depths and volumes, equated to surface openings.

3. Seasonally compare density and biomass in populations.

4. Quantify sediment bioturbation and irrigation in populations.

5. Measure laboratory and field effects of burrows and irrigation on interstitial oxygen, redox potential, nutrient flux, and associated macrofauna.

## Scientific Approach

Year *1*

1. Identify study habitats:
    - a. Barrier Island Seaward Margin
    - b. Barrier Island Bayward Margin
    - c. Tidally Flushed Coastal Flats
2. Field collections and density determinations:
    - a. Transect and Quadrat Studies
    - b. Burrow Counts and Excavations
    - c. Recoveries by Hydraulic Jet and Yabby Pump
        - i. Animals for Mesocosm Studies
        - ii. Animals for Reproduction/Growth Analyses
    - d. Core Samples for Analysis of Faunal Associates

Year 2

1. Continue and complete elements listed above.
2. Field measurements:
    - a. Burrow Volumes
    - b. Rates of Sediment Redeposition and Ventilation
    - c. Oxygen and Eh in:
        - i. Ambient Water
        - ii. Interstitial Water (burrow wall vs. interburrow)
        - iii. Sediment Profiles Over Depth

Year 3

1. **Mesocosm measurements** - Rates of Sediment Redeposition and Ventilation
2. Nutrient Flux Experiments - **Nitrification and Denitrification**

## ACCOMPLISHMENTS TO DATE

Primary **monitoring** sites have been established for three species of mud shrimp. ***Lepidophthalmus louisianensis*** (formerly ***Callianassa)*** populations are being studied along **the** western shores of Bay St. Louis, Mississippi, while populations of ***Callichirus islagrande*** **and** ***Callichirus** major are* being studied *along the* **Gulf** beach and bayward shores (respectively) of Isles **Dernieres,** Louisiana. In addition to these primary sites, comparative populations have been examined ad **libitum** in western **Louisiana, Alabama,** and western **Florida. In primary** monitoring sites, burrow numbers (surface and subsurface) and biomass have been documented during each quarterly sampling trip. **Transects** have been established and excavations have been conducted to develop coefficients between burrow density and population counts. Population samples have been taken from beach crests onto seaward bars and bay flats. Representative **faunal** associates have been documented. Representative samples of **mudshrimp** populations have been recovered by use of **yabby** pumps and hydraulic **jets;** growth **meristics,** wet weights, dry weights, and AFDW have been determined for those samples.

*Densities* of ***Lepidophthalmus louisianensis*** *in the* Bay St. Louis study area have been found to average between 100 and **300/m$^2$** in the **areas** of peak concentration. These areas have been found to extend from shoreline to an excess of 200m bayward, and well onto the sublittoral bay floor with identifiable food items dominated by shallow **benthic** diatoms **(Fig.1).** Thus, the density and **areal** expanse of these populations grossly exceeds our previous estimates, and suggests a phenomenal dominance of the benthic **infaunal** community. By the same token, the populations take on a larger than expected role as the primary agents of overturn, **bioturbation** and nutrient mixing in sediments of **oligohaline** embayments. On **beachfront** habitats of Isles **Dernieres, Louisiana,** C. ***islagrande*** *occurs in* concentrations of up *to* **40/m$^2$** in areas of *greatest* density, just inshore of **the** inner sand bar. However, populations are not distributed homogeneously from the longshore perspective, even in the beachfront zone of greatest concentration for **100m** to either side of the primary study site on the Gulf beach, mean population densities in optimal habitat range from O to 42/m$^2$. General distribution of the **population** extends **from** the mean high tide mark **(12m below** the summer beach **berm;** 8m below winter berm) to well beyond the **subtidal second sandbar,** and occasionally onto a third bar (where developed). ***Callichirus major*** *occurs* **infrequently** in the seaward extreme of these beachfront populations, but dominates subtidal sediments on the bayward **shorelines** of the barrier island (Fig. 2). Here, ***Callichirus islagrande*** *occurs* almost exclusively in densities averaging **24-35/m$^2$** on the sandy flats from about 5m below the beach crest to about 40m **bayward;** beyond this flat (roughly from lowest low-water to hayward), C. ***islagrande*** *is* replaced by C. *major* which occurs in densities of 8- **12/m$^2$.** These populations extend bayward into depths (low tide) exceeding lm, over a distance **exceeding 50m** from the bayward extreme of the C. ***islagrande*** population.

Onset of the annual breeding cycle has been documented in population of all three species, as have **quarterly** changes and spatial variations in population structure. Population size frequencies have been shown to vary seasonally between inner and outer flat components of the ***Lepidophthalmus louisianensis*** populations in Bay St. Louis (Figs. 3 and 4).

**Figure 1.** *Lepidopthalmus Louisianaensis* Gut Contents.

Bacillariophyceae (Diatoms)

Centric: *Cyclotella, Actinoptychus*

*Pennate:* *Amphora, Achnan thes, Nitzchia, Pinnularia, Gomphonema*

Euglenophyceae

*Trachelomonas hispida* var. *punctata*

Sarcomastigophora

Granuloreticulosea: *Streblus* and others

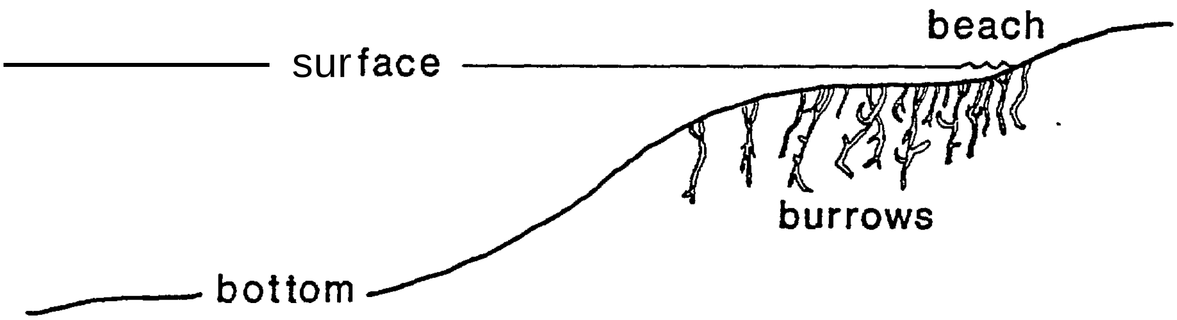


**Figure** 2. *Lepidopthalmus Louisianaensis, Callichirus* major, *Callichirus islagrande* on Isle Dernieres, Louisiana.

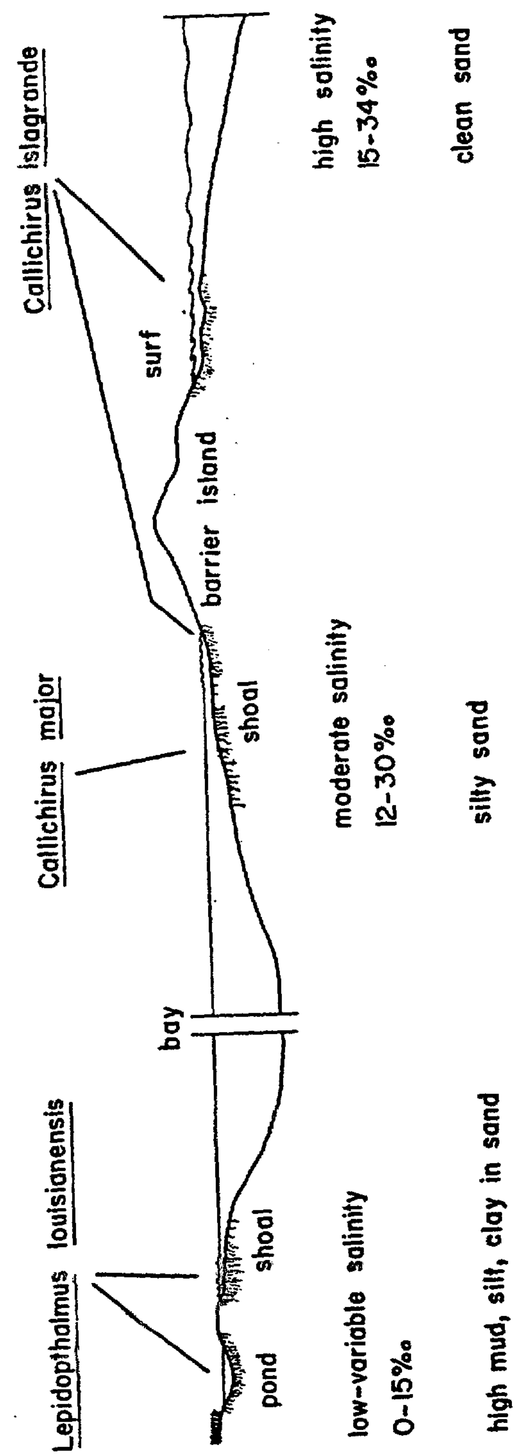


**Figure 3.** Population size frequencies of *Lepidophthalmus*, **Bay St. Louis, MS,** July 1990.

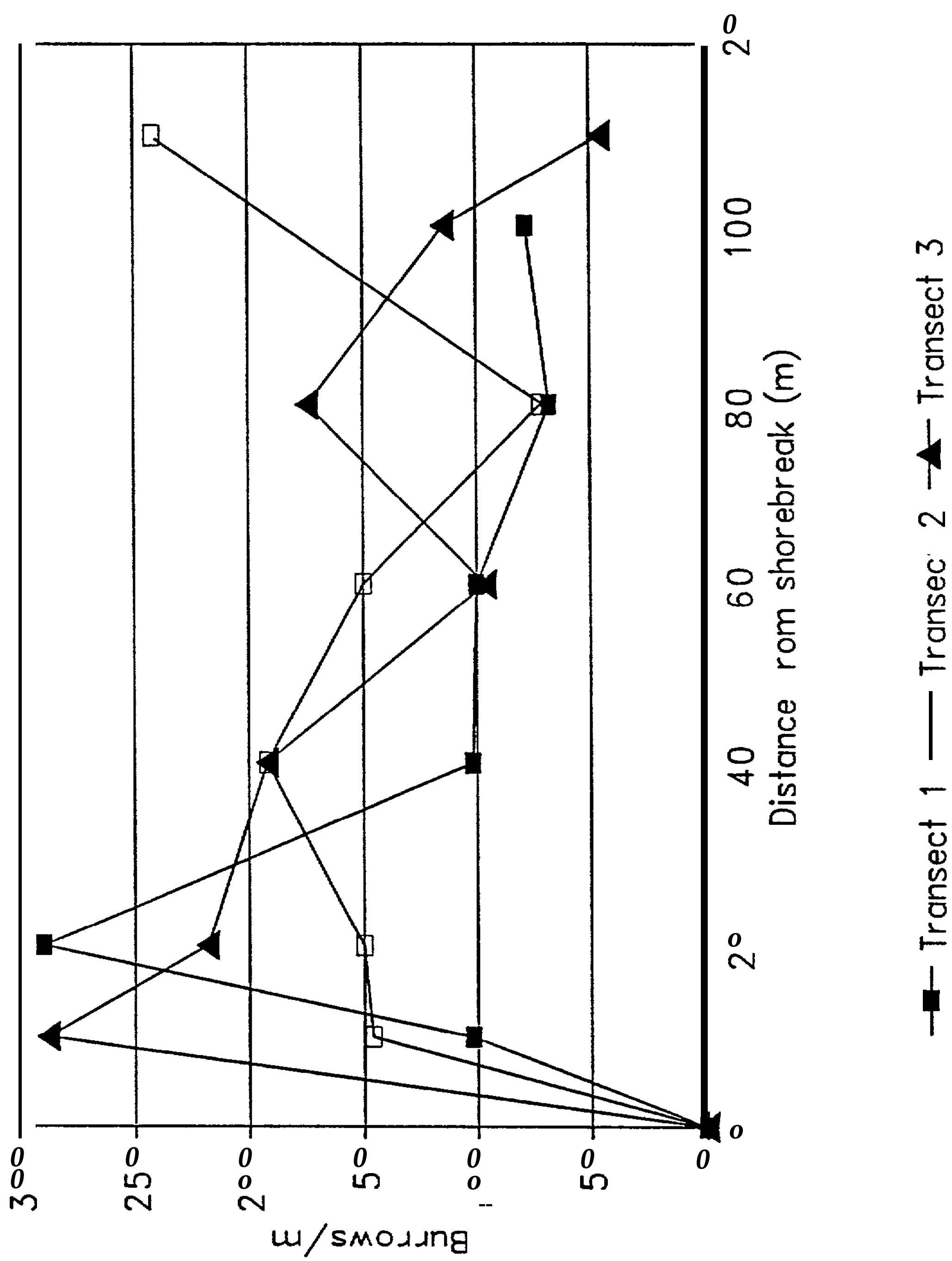
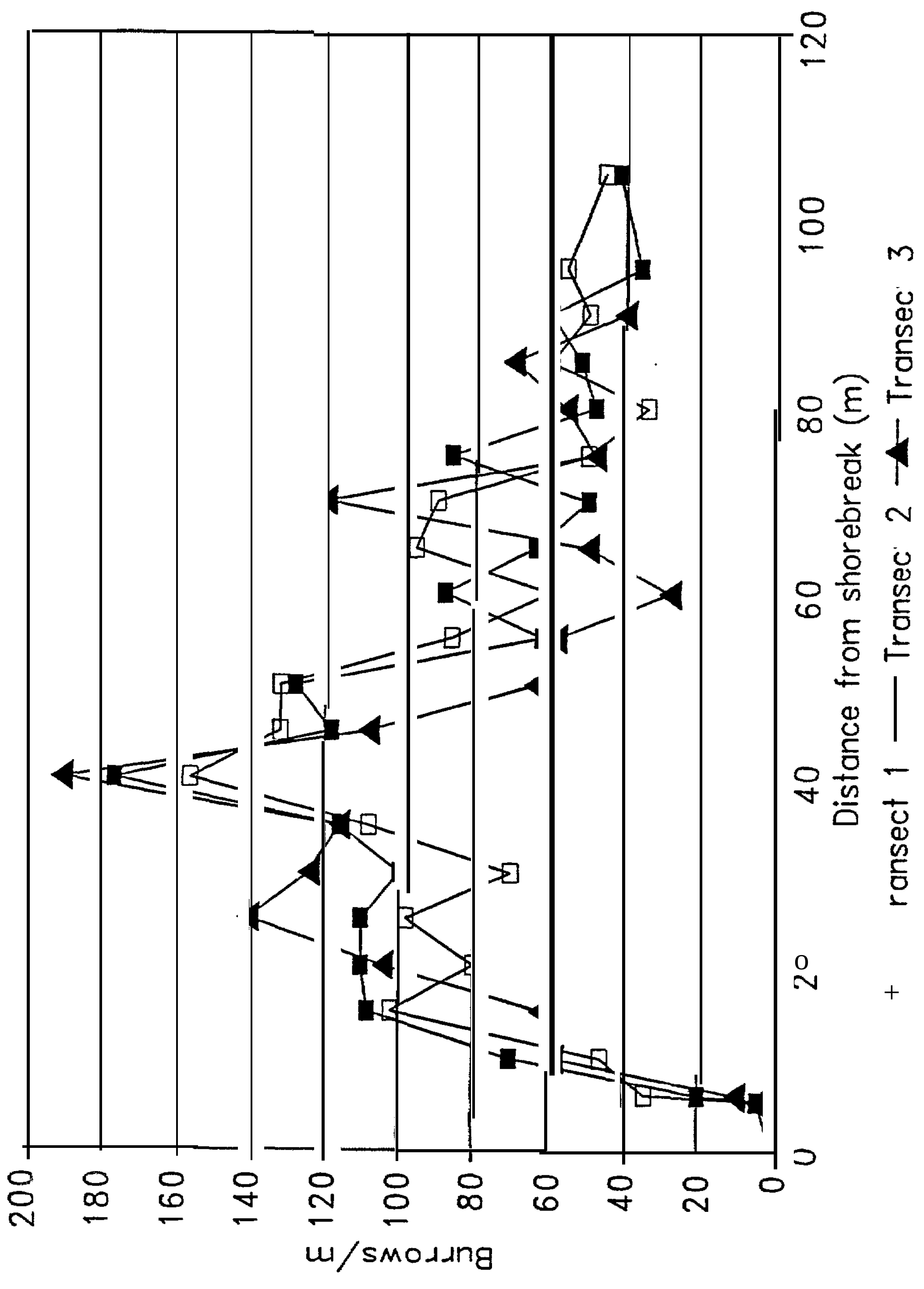


**Figure 4.** Population size frequencies of *Lepidophthalmus*, Bay St. Louis, MS, Dec 1990.



Surface burrow counts have been shown to vary consistently with subsurface counts and population samples, lending promise to the development of reliable coefficients for these relationships. Analyses of growth **meristics** and biomass is well underway for both genera under study, as exemplified in Figs. 5 and 6 for ***Lepidophthalmus louisianensis****. The* biomass represented attests **to** both the dominance of these animals in the intertidal habitat and to the remarkable **monospecific** standing crop represented by them in subsurface sediments. In addition, physical characteristics of the burrow have been **quantified,** both in terms of burrow surface areas (Fig. 7) and burrow volumes (Fig. 8) for populations of ***Lepidophthalmus****, with similar analyses in progress* for ***Callichirus****. These analyses* provide evidence that the burrows increase surface area in these habitats by up to **7-fold,** affording a substantial enhancement of the interface between oxygenated waters and reduced substrates. Two papers, both concerning growth and population structure in ***Lepidophthalmus louisianensis*** (referred to under ***Callianassa***) **were** accepted in late summer of 1989 for publication in the *Journal of Crustacean **Biology***. Both are based on analyses of growth data that were completed under current support. These analyses provide departure points and comparative data sets for field studies that are now underway. A symposium concerning the biology of mudshrimp was conducted **in** conjunction with the American Society of Zoologists annual meetings in Boston during December 1989. Preliminary results of the current studies were presented at those meetings. Additional results were presented at the American Society of Zoologists meetings in San Antonio during December 1990.

## SIGNIFICANT FINDINGS

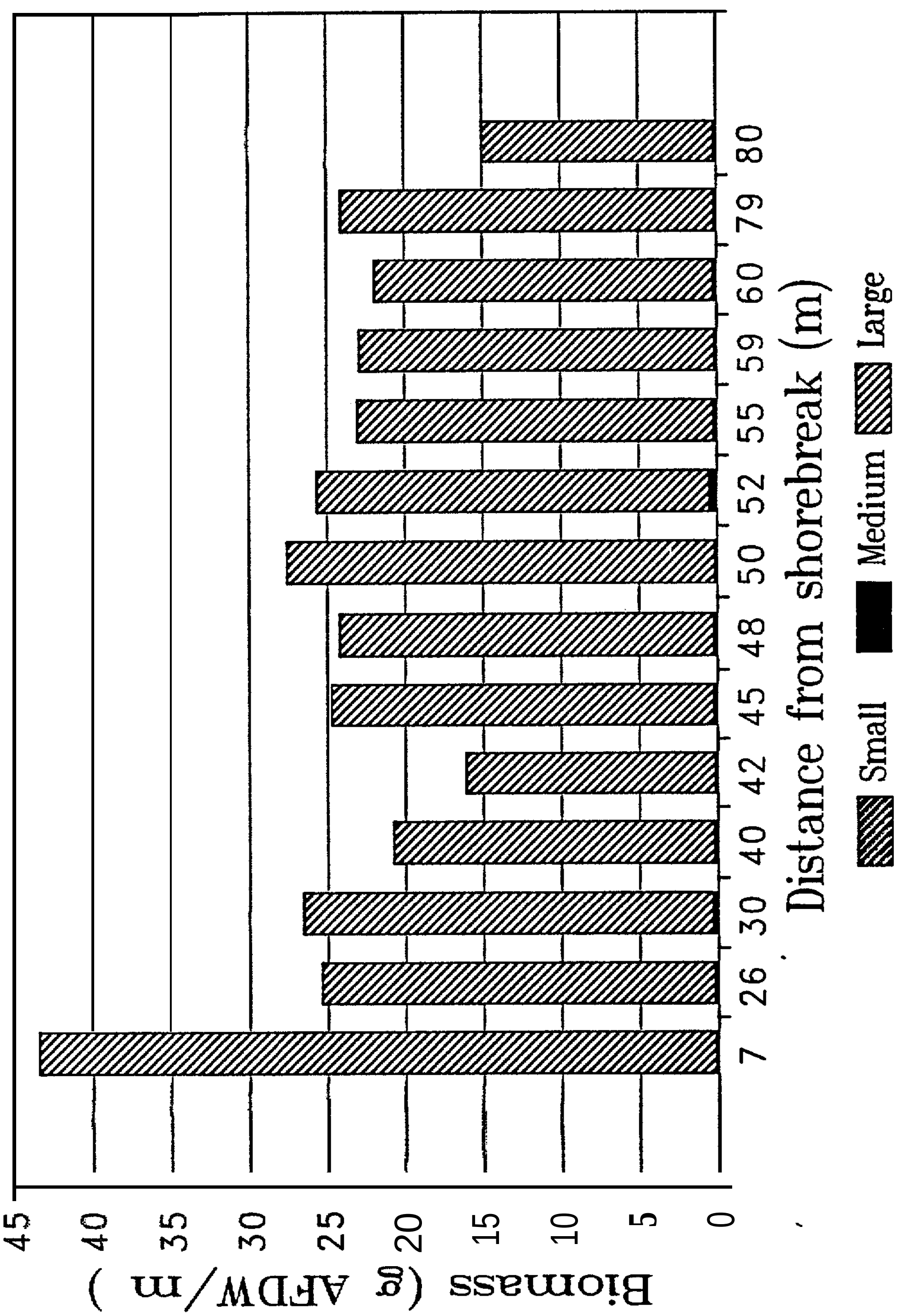
1. Density and biomass of ***Lepidophthalmus louisianensis*** *can* far exceed expectations, and the populations can extend well into the **subtidal;** the species dramatically dominates the **benthic estuarine** infauna in many localities this portends a larger than expected role for this species in sediment overturn and nutrient cycling. Importance of the burrow itself cannot be underestimated in this capacity. The burrows alone may contribute a seven-fold increase in the interface between reduced and oxygenated environments. This, coupled with water movement through the **burrow,** as accomplished while the animal ventilates, greatly magnifies the potential for microbial production and cycling of nutrients.

2. The life cycle and standing population structure of ***Lepidophthalmus louisianensis*** *can vary* strikingly between **localities;** cycles in population structure observed by **Felder** and **Lovett** (1989) on Grand Terre Island, Louisiana, vary somewhat **from** localities in Bay St. Louis, Mississippi; a more subtle variation also occurs between sites in Bay St. Louis (where proximity to shoreline accounts for some variation); population structure suggests **that period emigration** and immigration may occur among juvenile stages.

3. Striking variation in population density occurs along shores of the Isle **Dernieres** barrier island Gulf beach; this is not readily explained by physical structure or sedimentary characteristic density distributions suggest gregarious behavior of larval (and/or **postlarval) recruits;** dense accumulations of fecal materials in well-populated habitats may provide a cue to trigger settlement and burrowing.

4. Contrary to Atlantic coast populations, populations of ***Callichirus*** *major* on Isles Dernieres, **Louisiana,** do not appear to dominate **intertidal** open sandy seaward beaches (the C. ***islagrande*** habitat) but rather are **concentrated from** the lower intertidal into the upper subtidal, primarily on the bayward side of the barrier **islands;** this difference between Gulf and Atlantic populations further supports **our theory** that these populations are genetically **distinct;** our **preliminary** genetic comparisons of isozymes between these two populations suggests that they may deserve recognition as separate species.

**Figure 5.** Growth meristics *Lepidophthalmus* *nensi* Bay St. Louis, MS, Dec.1990.



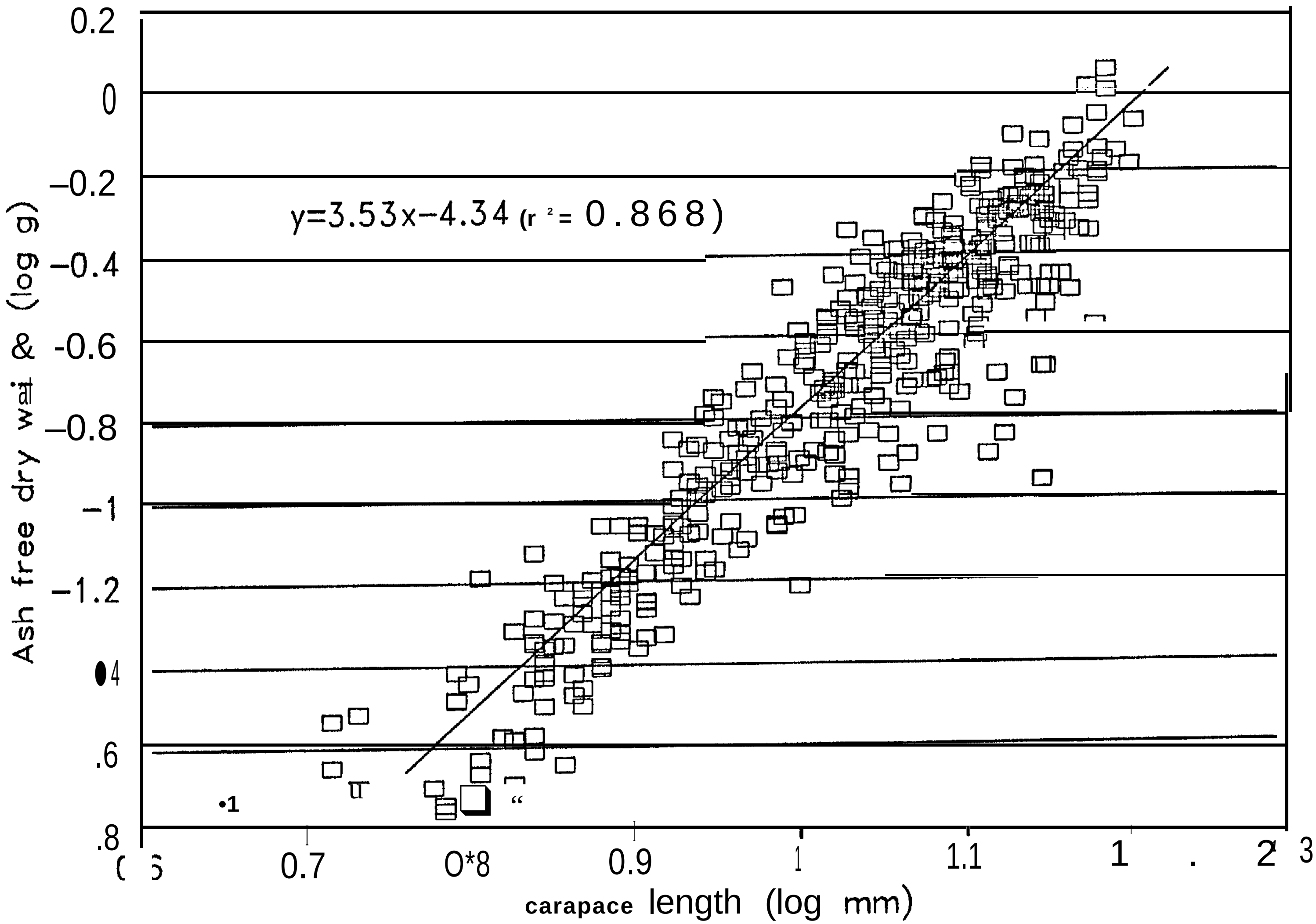



Figure 6. Biomass of *Lepidophthalmus louisianensis* through 1990.

**Figure 7.** Burrow surface area of *Lepidophthalmus louisianensis*, Bay St. Louis, MS, Dec. 1990.

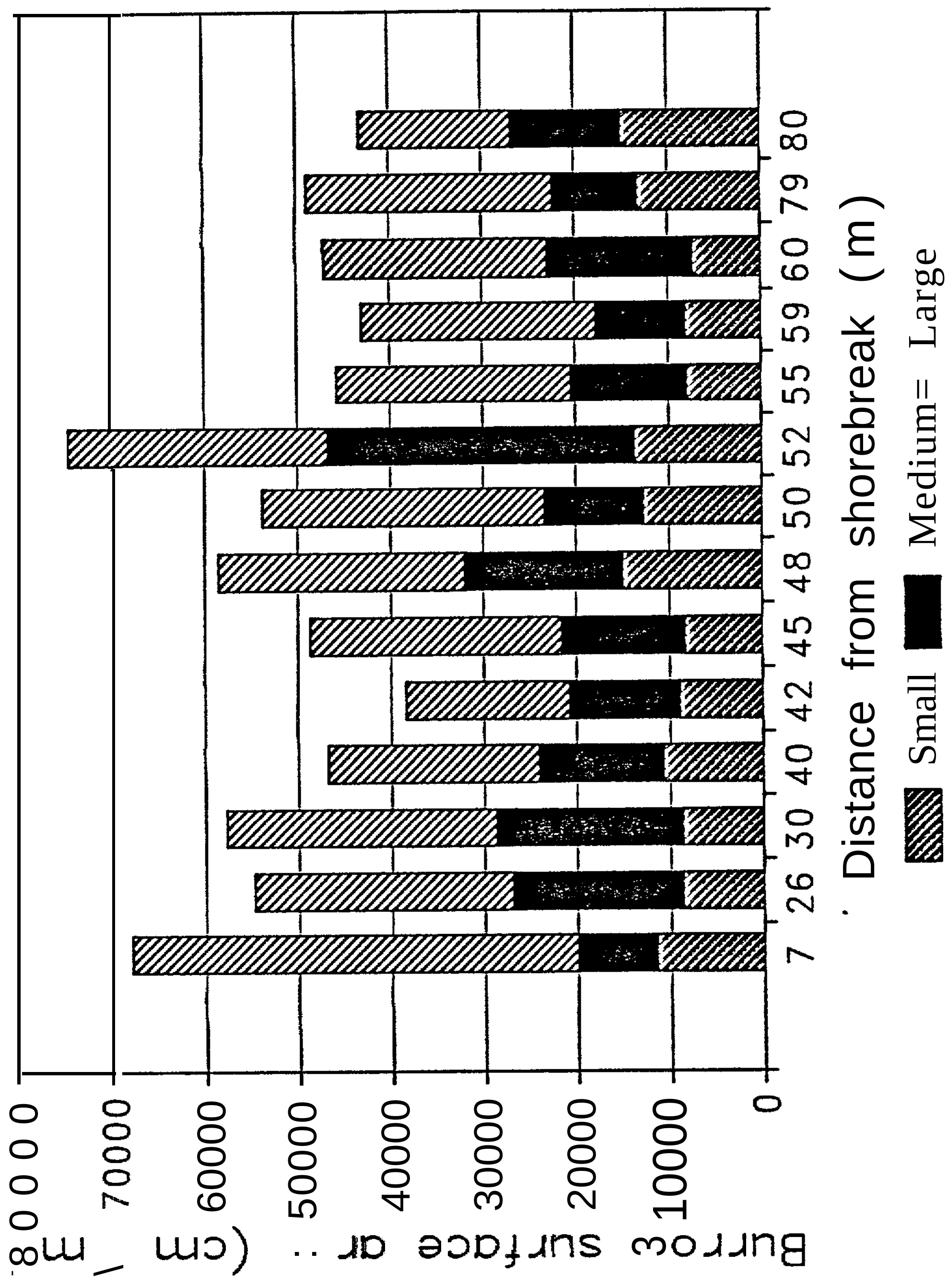
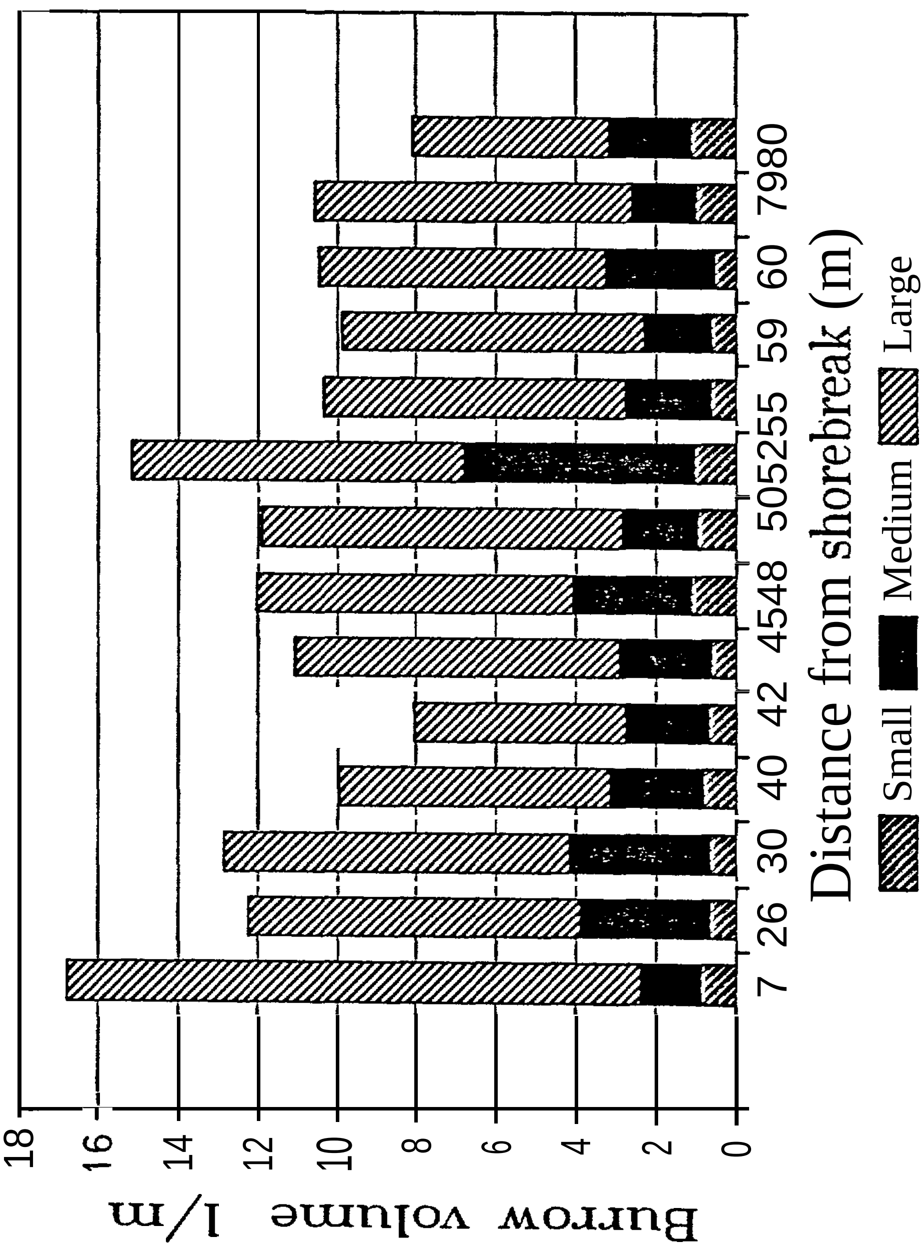


**Figure 8.** Burrow volume of *Lepidophthalmus louisianensis*, Bay St. Louis, MS, Dec. 1990.



5. *In the* habitats occupied by ***Callichirus islagrande*****, small** individuals appear to be recruited selectively into the lower intertidal and shallow **subtidal** environments, rather than throughout the densely populated intertidal swash zone. This suggests that there is some redistribution into the upper tidal environs with maturation, and that recruitment to those areas is not dependent solely upon direct settlement of larvae. Hence, repopulation of **defaunated** areas may **occur** by a variety of pathways.

**6. Populations** of ***Lepidophthalmus*** *in the* Northern Gulf of Mexico are morphologically and genetically distinct from those in the **Mesoamerica** and the Caribbean. Hence, literature concerning **reproduction,** recruitment and population ecology of remote populations does not **apply to** the same species as presently under study. Genetic identity is however uniform for populations ranging **from** northern **Tamaulipas,** Mexico, to northwestern Florida. These will remain recognized within a redefined description of ***L. louisianensis*** *(Schmitt)* ***sensu stricto****, while* related populations in the lower Southwestern Gulf of Mexico. Yucatan, Belize, **Columbia,** and Brazil will be recognized as separate species, new to science.

## PROBLEMS OR DELAYS ENCOUNTERED AND PROPOSED SOLUTIONS

Late award of **funding** in the first year necessitated that available student and technician workers originally **identified** for this project commit to other funded studies. This caused a delay in the initiation of the originally planned monthly to bimonthly sampling scheme in time to encompass the breeding peaks during 1989. Thus, technical support during the summer of 1989 was limited to a summer technician, and involvement of a doctoral student in the project was postponed, as were some phases of the field sampling program.

The above **problems** have been solved by shifting of the sampling schedule, altering some task **responsibilities** of project personnel, and identification of alternative study sites. The schedule for field monitoring of populations has been shifted to emphasis on the spring and summer reproductive periods in 1990-91, and this is reflected in the carryover of some year 1 funds to year 2. This requires an overall project extension of 6-12 months. A **doctoral-**level student, Mr. Roger Griffis, has been involved in the project since September, 1990. Prior to that time, larger than planned components of **the** summer sampling and analysis duties were undertaken by the summer field technician (supported under institutional match) and **by** the **PI/PD.** in addition to a portion of the **PI/PD** salary that is provided as institutional **match, 1/2** month of summer salary will be billed to the project to cover the additional time commitment (applying funds that had been originally earmarked to support the **primary** technician during the summer).

*The originally* proposed sites for studies of ***Callichirus*** *major* and L. ***louisianensis*** did not prove workable. However, alternative study sites have now been located for both species. In the ease of C. *major, the* populations have been found to center on **subtidal** bayward flats of barrier islands, rather than on the mid-intertidal as originally **surmised.** The **mid-**intertidal and upper intertidal of the hayward **shores** are instead populated by C. ***islagrande*** *in the* study **area,** or are sometimes populated **by** a mix of the two ***Callichirus*** *species.* Because **of its** concentration **in** the **subtidal,** the population of ***C.*** *major* **cannot be** monitored by the same methods **of** counting and collecting that are employed for the other two species (populations **of** which are largely exposed at low tide). A suction dredge is being **developed** as a sampling tool for possible use on those populations. Meanwhile, a very suitable study site for ***Lepidophthalmus louisianensis*** has been identified along the **estuarine** shoreline of western Bay St. **Louis,and** work with that species is well underway.

## REVISED SCHEDULE FOR REMAINDER OF PROJECT

As detailed in the previous annual report, delayed start on the project moved a number of year 1 activities into year 2 and year 2 activities into year 3. No further budget changes are presently requested, beyond those requested in the June 1990 annual report. However, it is requested that the final completion date for the overall project be extended for between 6 and 12 months. This will allow adequate time for mesocosm and nutrient flux experiments that are beginning at present. It will also allow an additional spring season for field monitoring of populations; poor weather conditions and abnormal tides have greatly limited field sampling in the March-May periods of both 1990 and 1991.

## PROJECT PARTICIPANTS

| | |
|---|---|
| Principal Investigator: | Dr. Darryl L. Felder |
| Collaborators: | Mr. Robert Griffis and Dr. Robert R. Twilley |
| Summer Technicians: | 1989--Mr. John Matese<br>1990--Ms Lisa Bennett<br>199 1--Mr. Philip Thevenet<br>1991 --Mr. James Powers |

## RELATED PUBLICATIONS AND PRESENTATIONS

### Publications

Felder, D.L., and D.L. Lovett. 1989. Relative growth and sexual maturation in the estuarine ghost *Callianassa louisianensis* Schmitt, *1935. Journal of Crustacean Biology,* 9(4):540-553.

Lovett, D.L., and D.L. Felder. 1989. Application of regression techniques to studies of relative growth in crustaceans. *Journal of Crustacean Biology,* 9(4):529-539.

Manning, R.B., and D.L. Felder. (In press). *"Revision of the American Callianassidae (Crustacean, Decapoda, Thalassinidea)". Proceedings* of the Biological Society of Washington, 56 ms. pages.

Griffis, R.B., and T.H. Suchanek. (In press) A model of relationships between burrow architecture and trophic mode in thalassinidean shrimp *(Decapoda: Thalassinidea).* Marine Ecology Progress Series, 24 ms. pages.

### Presentations

Manning, R.B., and D.L. Felder. "Re-evaluation of *callianassid genera". Invited* Paper: Biology of the *Thalassinoidea,* Special Symposium, American Society of Zoologists annual meeting, Boston, December, 1989.

Felgenhauer, B.E., and D.L. Felder. "Morphological studies of the *thalassinidean digestive* tract". Invited Paper: Biology of the *Thalassinoidea,* Special Symposium, American Society of Zoologists, annual meeting, Boston, December, 1989.

Staton, J., and D.L. Felder. "Genetic differentiation in coastal callianassid populations of the Gulf of Mexico and the Carolinian Atlantic". Invited Paper: Biology of the

***Thalassinoidea***, *Special* **Symposium**, *American Society* of Zoologists, annual meeting, Boston, December, 1989.

**Felder**, D.L., J. Staton, and **R.B. Griffis.** "Relationship of burrow morphology to population structure in the **estuarine** ghost shrimp ***Lepidophthalmus louisianensis (Decapoda, Thalassinoidea)*".** Contributed **paper:** The Crustacean Society and The American Society of Zoologists, annual meeting, San Antonio, December, 1990.

Zimmerman, T.L., and **D.L. Felder.** "Reproductive cycling in a newly recognized Gulf coast species, ***Sesarma (Decapoda, Brachyura)*".** Contributed **paper:** The Crustacean Society and The American Society of Zoologists, annual meeting, San Antonio, December, 1990.

## PROPOSALS SUBMITTED AND GRANTS RESULTING

**Felder, D.L. (PI/PD)** and **R.G. Griffis** (Collaborating Investigator). "Burrowing **Thalassinoid** Shrimp as Determinants of Tropic Production and **Microbially** Mediated Nutrient Cycling in **Estuarine Benthic** Communities". Louisiana Sea Grant College Program, $77,100, (pending).