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STUDY TITLE: Stability and Change in Gulf of Mexico Chemosynthetic Communities

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KEYWORDS: Chemosynthetic fauna, seep, continental slope, geochemistry, biogeochemistry, molecular ecology, age and growth, Lamellibrachia, Bathymodiolus, Beggiatoa, parasitology, marine GIS

BACKGROUND: The program was fundamentally concerned with the effect that development of offshore energy reserves might have upon dense assemblages of deep-sea organisms, particularly chemosynthetic tubeworms, mussels, and clams, as well as fish and crustaceans, which live in association with them. Hydrocarbons from commercial oil and gas reserves escape into the sea bottom at natural seeps found commonly across the Gulf of Mexico's northern continental slope. Chemosynthetic animals utilize chemical energy from hydrocarbons to maintain colonies that have unusually high biomass compared with the sea bottom elsewhere. Chemosynthetic communities at hydrocarbon seeps were discovered in 1984 and have been previously

investigated in studies funded by MMS. However, more knowledge was needed about the life history and ecology of chemosynthetic communities in the Gulf of Mexico.

OBJECTIVES: The objectives of this project were as follows: Review biotic and abiotic features of existing conceptual models of chemosynthetic communities which explain observed patterns of distribution and abundance, in order to develop an effective, refined plan for continued research. Further evaluate the physical-chemical factors (e.g., depth, temperature, water chemistry, sediment types, and dissolved gasses) which influence, limit, enhance, or control the distribution, abundance, and growth of chemosynthetic communities. Further investigate the sources (e.g., deep versus shallow or petrogenic versus biogenic) of any necessary dissolved gasses and the likelihood that petroleum production may ultimately deprive the animals of an energy source. Further determine if chemosynthetic communities are robust or fragile, and whether they are essentially permanent or ephemeral; characterize age, growth rate, turnover rates, reproduction and recruitment, and patterns of senescence and death in the dominant chemosynthetic animals; further examine recovery rates of communities damaged by physical disturbance. Further determine the reliability of methods for detecting chemosynthetic communities using remote acoustic and/or geophysical devices, imaging instrumentation, hydrocarbon measurements, and/or other available technologies.

DESCRIPTION: A highly integrated program of sample collection and site description was conducted during two cruises with the submersible Johnson Sea Link. All collections and stations were carefully documented with video and still photography and an exhaustive and carefully controlled list of collection, stations, and observations was made to ensure accurate sample identification and tracking. Principal sampling methods included sediment collection, water and gas collection, animal collections and manipulations, and photographic documentation. Additional sampling was conducted from other surface ships and from the Navy submarine NR-1. Analysis and reporting on samples was carried out in laboratories at Texas A&M University and five other institutions.

SIGNIFICANT CONCLUSIONS: At four representative study areas, tube worms (*Lamellibrachia* c.f. *barhami*) and mussels (*Bathymodiolus childressi*) and bacteria (*Beggiatoa*) were found to derive their food supply from the organic enrichment at the sea bottom caused by the oil and gas. Seawater sulfate in sediment pore fluids is chemically reduced to hydrogen sulfide at exceptionally high rates. The chemosynthetic organisms in turn support an abundant food chain of associated fish, crustaceans, and other invertebrates. Water circulation provides the mechanism by which larvae can be transported across the slope. Genetic fingerprinting of the fauna confirmed that gene pool of the chemosynthetic species is well mixed. Distinctive geological and geophysical signatures indicate active oil and gas seepage and presence of shallow deposits of gas hydrates. Tubeworm longevity appears to exceed 200 years for the larger specimens. Mussels, also comparatively long-lived, showed differing levels of health among the study sites, partly because of parasitic infestations. Distribution of sessile animals at the seeps is highly patchy, probably due to multiple settlement events

of transient vents. Communities require many generations to develop their present form. Chemosynthetic communities in the northern Gulf of Mexico appear to be locally fragile, but regionally robust.

STUDY RESULTS: Samples were collected and analyzed from four chemosynthetic communities located at water depths from 550 to 620 m in the central Gulf of Mexico. Side scan sonar images and other geophysical products were examined to determine the characteristic signature of chemosynthetic communities. Individual tube worms and mussels were marked and released to determine age and growth characteristics. Stable isotopes were used to examine trophic interactions between chemosynthetic animals and heterotrophic fauna. Geochemical characteristics and processes of inorganic and organic components of the surface sediments were detailed. Parasites of mussels were identified. Molecular techniques were used to examine the degree of isolation among separate chemosynthetic communities.

STUDY PRODUCTS: MacDonald, I.R., ed. 2002. Stability and Change in Gulf of Mexico Chemosynthetic Communities. Volume I: Executive Summary and Volume II: Technical Report. Prepared by the Geochemical and Environmental Research Group, Texas A&M University. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2002-035 and 036 483 pp.

The following peer-reviewed publications (published or in press) were written by principal investigators and their students or collaborators based on collections and analyses performed under the auspices of this program:

Bergquist, D. C., F. M. Williams, and C. R. Fisher. 2000. Longevity record for deep-sea invertebrate. Nature 403: 499-500.

Callender W. R. and Powell, E. N. 1999. Why did ancient chemosynthetic seep and vent assemblages occur in shallower water than they do today? Intl. Jnl. of Earth Sci. 88 (3): 377-391.

Callender R, Powell E.N. 2000. Long-term history of chemoautotrophic clam-dominated faunas of petroleum seeps in the northwestern Gulf of Mexico. FACIES. 43: 177-204.

Fisher, C. R., I. R. MacDonald, R. Sassen, C. M. Young, S. Macko, S. Hourdez, R. Carney, S. Joy, and E. McMullin. 2000. Methane ice worms: *Hesiocaeca methanicola* colonizing fossil fuel reserves. Naturwissenschaften 87 (4): 184-187.

Freytag, J.K., Girguis, P.R., Bergquist, D.C., Andras, J.P., Childress, J.J., Fisher, C.R. 2001. A paradox resolved: Sulfide acquisition by roots of seep tubeworms sustains net chemoautotrophy. PNAS. 98(23): 13408-13413.

Gardiner, S.L., McMullin, E., Fisher, C.R. 2001. *Seepiophila jonesi*, a new genus and species of vestimentiferan tube worm (Annelida : Pogonophora) from hydrocarbon seep communities in the Gulf of Mexico. Proc. of the Biol. Soc. of Wash. 114(3): 694-707.

Hourdez, S., L. A. Frederick, A. Schernecke, and C. R. Fisher. 2001. Functional respiratory anatomy of a deep sea orbiniid polychaete from the Brine Pool NR-1 in the Gulf of Mexico. Invertebrate Biology. 120(1): 29-40.

Julian, D., F. Gaill, E. Wood, A. J. Arp, and C. R. Fisher. 1999. Roots as a site of hydrogen sulfide uptake in the hydrocarbon seep vestimentiferan *Lamellibrachia* sp. J. Exp. Biol. 202; 2245-2257.

Lanoil BD, Sassen R, La Duc MT, Sweet ST, Nealson KH. 2001. Bacteria and Archaea physically associated with Gulf of Mexico gas hydrates. Applied and Env. Microbiol. 67 (11): 5143-5153.

Macavoy, S.E., Carney, R.S., Fisher, C.R., and Macko, S.A. 2002. Use of chemosynthetic biomass by large, mobile, benthic predators in the Gulf of Mexico. Mar. Ecol. Prog. Ser. 225: 65-78.

MacDonald, I.R. 1998. Habitat formation at Gulf of Mexico hydrocarbon seeps. Cahiers de Biologie Marine. 39 (3-4): 337-340.

MacDonald, I. R., D. Buthman, W. W. Sager, M. B. Peccini, and N. L. Guinasso Jr. 2000. Pulsed flow of hydrocarbons from a mud volcano. Geology. 28(10): 907-910.

McMullin, E., D. C. Bergquist, and C. R. Fisher. 2000. X-metazoans: Real animals in extreme environments. Space Biol. Bull. 13: 1-12.

Nelson, K. and C. R. Fisher. 2000. Absence of cospeciation in deep-sea vestimentiferan tubeworms and their bacterial endosymbionts. Symbiosis. 28(1): 1-15.

Powell, E.N., R.D. Barber, M.C. Kennicutt, and S.E. Ford. 1999. Influence of parasitism in controlling the health, reproduction and PAH body burden of petroleum seep mussels. Deep Sea Research. 46. 2053-2078.

Pruski, A. M., A. Fiala-Médioni, C. R. Fisher, and J. C. Colomines. 2000. Free amino compound composition of symbiotic invertebrates from the Gulf of Mexico hydrocarbon seeps. Mar. Biol . 136: 411-420.

Sager, W. W., C. S. Lee, I. R. Macdonald, and W. W. Schroeder. 1999. High-frequency near-bottom acoustic reflection signatures of hydrocarbon seeps on the northern Gulf of Mexico continental slope. Geo Marine Letters. 18 (4). 267-276.

Sager, W. W., I. R. MacDonald, W. R. Bryant, R. L. Carlson, and D. B. Prior, TAMU2 digital side-scan sonar survey of Louisiana Slope areas containing active oil seeps and

halokinetic sediment modification, paper 8595, Proceedings of the 1998 Offshore Technology Conference, Houston, 4-7 May 1998, 57-69, 1998.

Sager, W. W., M. C. Kennicutt II and Gas Hydrate Science Team, Proposal to the Ocean Drilling Program for Drilling Gas Hydrate in the Gulf of Mexico, paper 12111, Proceedings of the 2000 Offshore Technology Conference, Houston, 1-4 May 2000.

Sassen R, Sweet ST, Milkov AV, DeFreitas DA, Kennicutt MC. 2001. Thermogenic vent gas and gas hydrate in the Gulf of Mexico slope: Is gas hydrate decomposition significant? Geology. 29(2): 107-110.

Scott, K. M., M. Bright, and C. R. Fisher. 1998. The burden of independence: Inorganic carbon utilization strategies of the sulfur chemoautotrophic hydrothermal vent isolate *Thiomicrospira crunogena* and the symbionts of hydrothermal vent and cold seep vestimentiferans. Cah. Biol. Mar. 39: 379-382.

Smith, E. B., K. M. Scott, E. R. Nix, C. Korte, and C. R. Fisher. 2000. Growth and condition of seep mussels at a Gulf of Mexico Brine Pool. Ecology 81:2392-2403.

Urcuyo, I.A., Massoth, G.J., MacDonald, I. R., Fisher, C.R. 1998. In situ growth of the vestimentiferan Ridgeia piscesae living in highly diffuse flow environments in the main Endeavour Segment of the Juan de Fuca Ridge. Cahiers De Biologie Marine 39(3-4):267-270.