Challenges in Adaptive Management: Chemosynthetic Communities in the Gulf of Mexico

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Abstract: Gregory Boland examines the challenges in adaptive management through the lens of the Offshore Minerals Management Program. He describes environmental laws affecting the program and discusses how an adaptive approach to management is possible within that framework. Boland describes how an adaptive management process was used by the Minerals Management Service (recently reorganized as the Bureau of Ocean Energy Management, Regulation and Enforcement) to provide a consistent and comprehensive approach to protect high-density chemosynthetic communities of the Gulf of Mexico.

I. Introduction

This paper describes adaptive management practices applied by a bureau of the Department of Interior, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), for the protection of a recently discovered and unique type of deep sea community known generally as chemosynthetic communities. The role of BOEMRE in managing offshore U.S. energy and mineral development and authorizing legislation is addressed in opening segments, followed by some brief background on deep sea communities, and an overview of chemosynthetic communities in the Gulf of Mexico (GOM). Management of the subject biological communities has presented numerous challenges inherent in adaptive management due to the extreme environment in which they occur and their initially unknown basic biology.

The BOEMRE, a bureau of the Department of the Interior with about 1,700 people in 20 cities across the United States, has two primary programs: Minerals Revenue Management, and Offshore Energy and Minerals Management.[2] The BOEMRE manages energy development in over 1.76 billion offshore acres of federal land called the Outer Continental

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[2] A reorganization of this program structure was announced at the time of writing.

Shelf (OCS)[3] and annually disburses more than $8 billion in minerals revenue. Major regulating policy primarily originates from the Outer Continental Shelf Lands Act.[4] Other regulatory sources include the National Environmental Policy Act (NEPA) and numerous other laws such as the Marine Mammal Protection Act, Clean Air Act, Coastal Zone Management Act, and the Magnuson-Stevens Fishery Management Act. With passage of the Energy Policy Act of 2005,[5] the Minerals Management Service (MMS) was named lead authority for renewable energy projects, such as wave, wind, and current energy, on federal offshore lands. The BOEMRE also extensively funds environmental studies to obtain information necessary for NEPA analysis and decision-making by management. Since it was founded in 1982, the MMS has funded over $800 million in environmental studies. MMS is now BOEMRE.

II. Chemosynthetic Communities in the Gulf of Mexico

Deep sea exploration and study are very difficult, not unlike space exploration. The northern GOM is a geologically complex basin with a maximum depth of 3800 m (12,464 ft). It has been described as the most complex continental slope region in the world. Regional topography of the slope consists of basins, knolls, ridges, and mounds derived from the dynamic adjustments of salt to the introduction of large volumes of sediment over long time scales. This complex structure has resulted in widespread seabed structural faulting and the migration of hydrocarbons that become the key factor for the presence of significant biological communities in the deep GOM.

A. Gulf of Mexico Deep Sea Biological Communities

More than 99% of the sea floor in the GOM consists of soft sediment made up of various mixtures of primarily silt and clay. These wide-spread soft bottom communities are well described in the final reports from two major MMS studies, the Northern Gulf of Mexico Continental Slope Study (1988)[6] and the Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology Study (2009).[7] There are two other major habitat types considered significant in the GOM. These are deep-water or cold-water coral habitats and chemosynthetic communities. Although known for a longer period, cold-water coral communities have only recently been investigated in the GOM and are not a major part of

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[3] The term "Outer Continental Shelf" is a legal term created by federal law and is distinct from the geographic term "continental shelf." There is no scientific definition of the OCS. Legally, the OCS comprises that part of the submerged lands, subsoil, and seabed, lying between the seaward extent of the states' jurisdiction and the seaward extent of federal jurisdiction (generally 200 nautical miles offshore).

[4] Outer Continental Shelf Lands Act, 43 U.S.C. §§ 1331 – 1356a (2005).

[5] Energy Policy Act of 2005, Pub. L. No. 109–58, 119 Stat. 594 (Aug. 8, 2005), *available at* http://www.epa.gov/oust/fedlaws/publ_109-058.pdf.

[6] MINERAL MANAGEMENT SERVICE, NORTHERN GULF OF MEXICO CONTINENTAL SLOPE STUDY, FINAL REPORT: YEAR 4, VOLUME II: SYNTHESIS REPORT, OCS Study/MMS 88-0053 (Benny J. Gallaway ed., 1988), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/3/3696.pdf [hereinafter *Gallaway*].

[7] MINERAL MANAGEMENT SERVICE, NORTHERN GULF OF MEXICO CONTINENTAL SLOPE HABITATS AND BENTHIC ECOLOGY STUDY: FINAL REPORT, OCS Study/MMS 2009-039 (Gilbert T. Rowe & Mahlon C. Kennicutt II eds., 2009), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/4/4842.pdf [hereinafter *Rowe & Kennicutt*].

this discussion.[8] Ironically, these important deep coral communities in the GOM rely on the hard substrate created by the principal subject, chemosynthetic communities.

B. Gulf of Mexico Chemosynthetic Communities

Chemosynthetic communities are groups of animals living in the deep sea (deeper than 300 m (984 ft)) that live on dissolved gases through a symbiotic association with bacteria living inside their tissues. They are remarkable because these are the only large animals that utilize a food source independent of the photosynthesis that supports all other life on earth. There are four general community types in the GOM. These are: (1) communities dominated by tube worms (Figure 1), (2) mussels (Figure 2), (3) clams living on the sediment surface, and (4) a different group of clams that live within the sediments of the seabed. Bacterial mats are present at all sites visited to date. These faunal groups tend to display distinctive characteristics in terms of how they aggregate, the size of aggregations, the chemical properties of the habitats in which they occur and, to some degree, the other non-chemosynthetic fauna that occur with them. The necessary conditions for their growth exist only in relatively small, widely scattered habitats. Many of the species found at these cold seep communities in the Gulf are new to science and remain undescribed.

Fig. 1. The gill plume of a chemosynthetic tube worm. These animals still need oxygen for respiration, but have no digestive tract. Symbiotic bacteria living in their tubes obtain sulfides from the sediment bottom and provide energy to the tube worm. They can live up to 450 years. The green band was stained in previous years to measure growth rate. Image courtesy of MMS and NOAA OER, Expedition to the Deep Slope.

Fig. 2. Chemosynthetic mussel community (different species can live off methane, hydrogen sulfide or both) and associated sea cucumbers at a depth of 2,200 m (7,218 ft). Image courtesy of MMS and NOAA OER, Expedition to the Deep Slope.

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[8] For more information on these coral communities, *see* CSA INTERNATIONAL, INC., CHARACTERIZATION OF NORTHERN GULF OF MEXICO DEEPWATER HARD BOTTOM COMMUNITIES WITH EMPHASIS ON *LOPHELIA* CORAL, OCS Study/MMS 2007-044 (2007), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/4/4264.pdf [hereinafter *CSA International 2007*]; W.W. SCHROEDER, SEAFLOOR CHARACTERISTICS AND DISTRIBUTION PATTERNS OF *LOPHELIA PERTUSA* AND OTHER SESSILE MEGAFAUNA AT TWO UPPER-SLOPE SITES IN NORTHEASTERN GULF OF MEXICO, OCS Study/MMS 007-035 (2007), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/4/4256.pdf.

C. Discovery

This new type of large invertebrate, one that derives its food source from chemosynthesis, was not discovered anywhere on earth until 1977. The first discovery was made unexpectedly at hydrothermal vents in the eastern Pacific Ocean during geological explorations of a mid-Atlantic spreading center.[9] Two scientists, John B. Corliss and Jerry van Andel first witnessed dense chemosynthetic tube worms from the submersible *Alvin* on February 17, 1977.[10] This expedition followed the unanticipated discovery of large clams associated with the Galapagos Rift hydrothermal vents using a remote camera sled the previous year.[11] Similar communities were first discovered in the Eastern Gulf of Mexico in 1983 on another *Alvin* submersible dive. This expedition was investigating the bottom of the Florida Escarpment in areas of "cold" brine seepage where they unexpectedly discovered tube worms and mussels.[12]

Two groups discovered chemosynthetic communities in the Central GOM essentially concurrently in November 1984. During investigations by Texas A&M University to determine the effects of oil seepage on benthic ecology (until this investigation, all effects of oil seepage were assumed to be detrimental), bottom trawls unexpectedly recovered extensive collections of chemosynthetic organisms including tube worms and clams.[13] Just prior to this, LGL Ecological Research Associates[14] was conducting a research cruise as part of the multiyear MMS Northern GOM Continental Slope Study.[15] Bottom photography (processed on board the vessel) resulted in clear images of vesicomyid clam communities later realized to be chemosynthetic-based (Figure 3), coincidentally in the same manner as the first discovery of clam communities by camera sled in the Pacific in 1976.[16] The first images of tube worm communities *in situ* in the Northern GOM were obtained during this same LGL/MMS 1984 cruise[17] (Figure 4), which occurred prior to the initial submersible

[9] J.B. Corliss et al., *Submarine Thermal Springs on the Galapagos Rift*, 203 SCIENCE 1073-1083 (1979).

[10] Woods Hole Oceanographic Institute, Alvin Dive Information, Dive Number 713, http://www.marine.whoi.edu/divelog.nsf/7d6ced7cbf2c43a285256812005446a6/fee12bd002bd79908525620b006c94b0?OpenDocument (last visited June 16, 2010).

[11] The first photographs of new chemosynthetic life forms were taken remotely in 1976 by Dr. Peter Lonsdale from Scripps aboard the Scripps vessel R/V *Melville* using DeepTow, a towed camera platform.

[12] C.K. Paull et al., *Biological Communities at the Florida Escarpment Resemble Hydrothermal Vent Taxa*, 226 SCIENCE 965-967 (1984).

[13] Mahlon C. Kennicutt et al., *Vent-type Taxa in a Hydrocarbon Seep Region on the Louisiana Slope*, 317 NATURE 351-353 (1985).

[14] LGL Ecological Research Associates, Inc. is an independently owned environmental service company located in Bryan, Texas. LGL, Corporate Resume and Recent Experience, http://www.lgltex.com/corp_experience.htm (last visited June 16, 2010).

[15] *See* Gallaway, *supra* note 6.

[16] An analysis of these images was published in 1987. *See*, I. Rosman, G.S. Boland, and J.S. Baker, *Aggregations of* Vesicomyidae *on the Continental Slope off Louisiana*, 34 DEEP SEA RESEARCH PART A. OCEANOGRAPHIC RESEARCH PAPERS 1811-1820 (1987).

[17] These images were not processed until after the cruise. *See*, G.S. Boland, *Discovery of Co-occurring Bivalve* Acesta *sp. and Chemosynthetic Tube Worms Lamellibrachia*, 323 NATURE 759 (1986).

investigations and firsthand descriptions of Bush Hill, the name given to the first chemosynthetic community discovered in the GOM, in 1986.

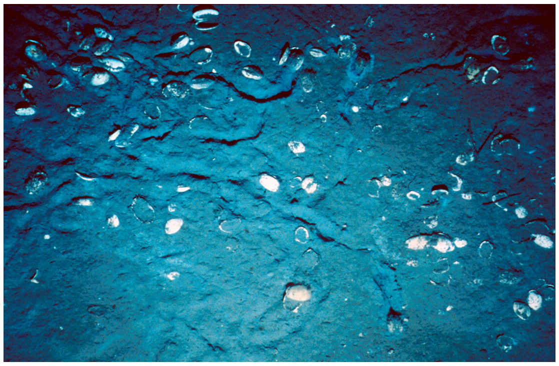

Fig. 3. The first evidence of a chemosynthetic community in northern Gulf of Mexico; image taken November 14, 1984, depth 950 m (3,116 ft). Note living clams plowing through sediment exposing their tissues to sulfides that support their symbiotic chemosynthetic bacteria. Image courtesy Gregory S. Boland/LGL Ecological Research Associates.

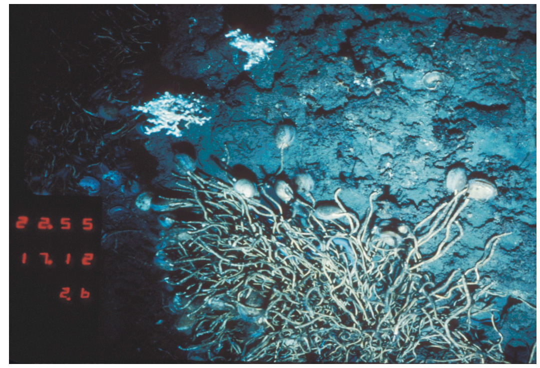

Fig. 4. This is the first image of a chemosynthetic tube worm community in the northern GOM taken November 12, 1984. Also present are two "cold-water" coral colonies (*Lophelia pertusa*), hagfish among the tube worms, and an unusual commensal relationship between the tube worms and numerous bivalves attached only to the ends of the living tube worms. Image courtesy Gregory S. Boland/LGL Ecological Research Associates.

III. Challenges of Adaptive Management

Beginning in 1985, there was recognition of a completely new kind of life form living in the deep GOM, not just at the bottom of the Florida Escarpment, but also distributed throughout an extensive area of the northern GOM slope in one of the richest oil and gas regions of the world. Exploration and development of these energy sources was also beginning to enter deeper and deeper water depths. It was the responsibility of MMS to investigate these new and unique communities to enable informed decisions for the management of the oil and gas industry and related potential impacting activities.

The use of the term adaptive management in this paper does not imply a strict application of the process. Not all the criteria for a classic adaptive management regime, such as the use of models to evaluate management decisions, are met. Rather, this is an adaptive approach where new information and learning is occurring and that knowledge is being used to revise management decisions on an ongoing basis.

A. The First Step

An appropriate first step was to take a close look at these new chemosynthetic communities. To do that, a submersible or camera system is required to descend to at least 500 m (1,640 ft) underwater. At the time, there were limited facilities that could accomplish this. Only three research submersibles were available (the *Alvin* from Woods Hole Oceanographic Institution and the two *Johnson Sea Link* submersibles (Figure 5) at the Harbor Branch Oceanographic Institution) and a limited number of remotely operated vehicles (ROVs) were available for research purposes.

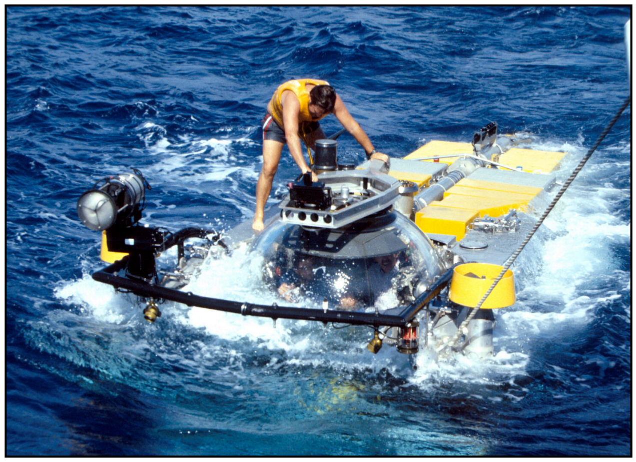

Fig. 5. One of the two *Johnson Sea Link* submersibles operated by the Harbor Branch Oceanographic Institution. Forward acrylic sphere holds one pilot and principal science observer, aft metal sphere holds a sub crew member and one additional science observer. Maximum diving depth 1,000 m (3,280 ft). Image courtesy of Gregory S. Boland.

The first manned mission to observe chemosynthetic communities in the Northern GOM was initiated through a contract modification and extension of an ongoing study funded by MMS studying the soft bottom habitats of most of the entire northern GOM continental slope. This study, the *Northern Gulf of Mexico Continental Slope Study*[18] was modified to extend its contract period to include this new mission using the *Johnson Sea Link* submersible to study these new habitats. From a brief seven-day mission in September 1986 on the vessel R/V *Edwin Link,* one of the most extensive chemosynthetic communities in the GOM was discovered on the first dive at a depth of 543 m (1,781 ft). It was nicknamed "Bush Hill" due to abundant tube worm colonies or "bushes" observed as the submersible cruised over it for the first time.[19]

A good deal of understanding was obtained from this first submersible mission with regard to the correlation between these habitats and geophysical characteristics, *i.e.*, seabed faulting, gas and oil seeps, and gassy sediments. This knowledge was critical for developing a mechanism to predict the location of these communities using some kind of remote sensing as opposed to being required to visually look at every square foot of the seabed to demonstrate the presence or absence of these newly discovered communities.

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[18] Gallaway, *supra* note 6.

[19] Author was the first submersible dive sphere observer.

B. Initial Protection

Immediately after discovery of chemosynthetic communities, MMS recognized their significance and created initial protective measures designed to prevent direct impact on these habitats by the placement of offshore structures on the seabed. An avoidance policy was implemented early on, but the first written regulatory policy was not completed until 1988. The instrument used is termed a Notice to Lessees or NTL. The NTLs supplement regulations that govern operations on the OCS and provide clarification or interpretation of regulations and further guidance to lessees and operators in the conduct of their operations. These guidance documents can be implemented much more efficiently than MMS's overarching regulations broadly regulating offshore operations.[20] The first Notice to Lessees, entitled NTL 88-11: *Implementation of Measures to Detect and Protect Deepwater Chemosynthetic Communities*, required mandatory identification and avoidance of chemosynthetic communities and avoidance of damage from anchors and platform structure components.

C. Understanding

After the first MMS-funded exploration expedition in 1986, a door was opened, but as with any major new discovery, it was obvious there was still very little known about these incredible communities spread across the northern Gulf. The MMS initiated the first of three major studies dedicated to the study of Gulf chemosynthetic communities beginning in 1991. With some additional support from the National Oceanic and Atmospheric Administration (NOAA), two major field sampling cruises were launched in 1991 and 1992 by Texas A&M University, the MMS-funded contractor. A total of 6 sites of the approximately 43 known locations at the time were intensively studied, again using the *Johnson Sea Link* submersibles from Harbor Branch Oceanographic Institution. This four-year effort, later to be known as Chemo I, resulted in the keystone publication final report, *Chemosynthetic Ecosystems Study*.[21]

This large multidisciplinary Chemo I study was just the beginning of the learning process. A more comprehensive study was necessary to begin to understand the ecosystem-based processes that regulated both the distribution and health of these chemosynthetic communities, and to begin to approach an understanding of their natural stability and how they change over time.

A second major study, *Stability and Change in Gulf of Mexico Chemosynthetic Communities*, which came to be known as Chemo II, was funded by MMS in 1996.[22] The

[20] These regulations can be found in the Code of Federal Regulations Title 30, Mineral Resources, and Title 40, Protection of the Environment.

[21] MINERAL MANAGEMENT SERVICE, CHEMOSYNTHETIC ECOSYSTEMS STUDY FINAL REPORT, OCS Study/MMS 95-0023 (I. R. MacDonald, W. W. Schroeder, & J. M. Brooks eds., 1995) *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/3/3323.pdf [hereinafter *Chemo I*].

[22] MINERAL MANAGEMENT SERVICE, STABILITY AND CHANGE IN GULF OF MEXICO CHEMOSYNTHETIC COMMUNITIES, VOLUME II: TECHNICAL REPORT, OCS Study MMS 2002-036 (I. R. MacDonald ed., 2002), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/3/3072.pdf [hereinafter *Chemo II*].

MMS contract required that the researchers take an integrated, multi-disciplinary approach to address the complex issues associated with the protection of these biological assemblages. This study encompassed ecological studies at both regional and local scales, as well as an evaluation of temporal changes in these communities. An understanding of the stability and change within these communities was addressed in the context of their interactions within the geological, chemical, and oceanographic setting. Knowledge of the processes that control the distribution, health, and succession of communities in these environments is necessary to forecast potential impacts. Integrated studies were designed to collect ecological, geological, chemical, and oceanographic information related to the longevity, robustness, and recovery of chemosynthetic communities.

D. Adaptation of Management Policy: New Avoidance Criteria

Information gained through the Chemo I and Chemo II studies allowed MMS, through an adaptive approach, to develop more specific requirements and further refine its mitigation measures. Avoidance buffer distances between impacting activities and potential chemosynthetic communities were introduced in NTL 2000-20, which set specific, minimum separation distances from features, or areas, that "could" support high-density chemosynthetic communities. These included an avoidance distance of 305 m (1,000 ft) for the platform location and associated discharges and 76 m (250 ft) for anchoring and other physical impacts.

An important aspect of this policy is that avoidance was required for the "potential" presence of communities. Part of the increasing knowledge gained about these habitats included a better understanding of the geophysical signatures that were very strong indicators for the likely presence of living communities. The presence of these geophysical signatures (faults, hard bottom reflectivity, etc.) were used to define specific avoidance distances for the discharge locations of drilling muds[23] and cuttings and for all other proposed seafloor disturbances including anchors, anchor chains, wire ropes, seafloor template installations, and pipeline construction. Only submission of *in situ* imagery that demonstrated the absence of suspected chemosynthetic habitats would allow reconsideration of this risk-averse approach.

E. Monitoring of Impacts

Informed management and protection of this previously unknown resource is challenging without sufficient knowledge about all sources of potential impacts to these communities from energy development. In addition to the straightforward physical impacts of placing a structure or anchor on the seabed, additional potential impacts come from the discharge of cuttings and associated drilling fluids resulting from the drilling of wells. Several studies[24]

[23] Drilling fluids or "mud" is a fluid mixture composed primarily of the heavy natural mineral barite and is used in the drill pipe for the purpose of lubricating the drill bit and counter-weighting against internal pressure in the drilled hole.

[24] MINERAL MANAGEMENT SERVICE, GULF OF MEXICO OFFSHORE OPERATIONS MONITORING EXPERIMENT, PHASE I: SUBLETHAL RESPONSES TO CONTAMINANT EXPOSURE, FINAL REPORT, OCS Study/MMS 95-0045 (M. C. Kennicutt, II ed., 1995); CONTINENTAL SHELF ASSOCIATES, FINAL REPORT: GULF OF MEXICO COMPREHENSIVE SYNTHETIC BASED MUDS MONITORING PROGRAM (2004), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/2/3050.pdf (Volume 1) and

have investigated drilling discharge impact sources in the past. However, these studies were located in shallower water than the habitat of chemosynthetic communities, which is generally deeper than 300 m (984 ft).

To monitor potential impacts from deepwater oil and gas drilling activities on chemosynthetic communities without harming them, MMS examined the direct effects of deepwater drilling on the sea floor in a number of areas uninhabited by chemosynthetic organisms. Contemporary with chemosynthetic habitat studies, a separate deepwater project was funded by MMS that specifically addressed the impacts of drilling in deepwater. This project, *Effects of Oil and Gas Exploration and Development at Selected Continental Slope Sites in the Gulf of Mexico,*[25] was awarded in June 2000. The objectives of this study were to assess the physical, chemical, and biological impacts of oil and gas development at selected exploration and development well sites on the GOM continental slope. Major objectives included documentation of drilling mud and cuttings accumulations, and physical modification/disturbance of the seabed due to anchors and mooring systems. All sites were at a water depth of approximately 1,100 m (3,609 ft).

Results showed drill cuttings and drilling fluid accumulations were evident mainly within a 500-m (1640-ft) radius near-field zone at all four sites (Figure 6), though there was geophysical and chemical evidence for deposits extending beyond this area. Physical impacts from anchoring were detected through side-scan sonar surveys. Individual anchoring-related scars ranged in length from less than 100 m (328 ft) to over 3 km (1.8 miles) and these extended from anchor locations toward the direction where the platform would have been located on the sea surface (Figure 7).

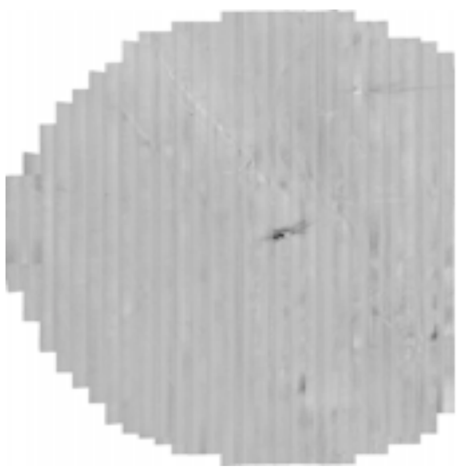

Fig. 6. Side-scan sonar mosaic at lease block Viosca Knoll 916 showing highly reflective bottom sediments representing drill cuttings discharge accumulations in the darker center area. The full figure has a diameter of about 6 km (3.7 miles). Cuttings discharge from a single exploratory well lies within a radius of 500 m (1,640 ft) in the center of the figure. Image from MMS-2006-045.

http://www.gomr.mms.gov/PI/PDFImages/ESPIS/2/3051.pdf (Volume II).

[25] CONTINENTAL SHELF ASSOCIATES, EFFECTS OF OIL AND GAS EXPLORATION AND DEVELOPMENT AT SELECTED CONTINENTAL SLOPE SITES IN THE GULF OF MEXICO, VOLUME II: TECHNICAL REPORT, OCS Study/MMS 2006-045 (2006), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/3/3875.pdf.

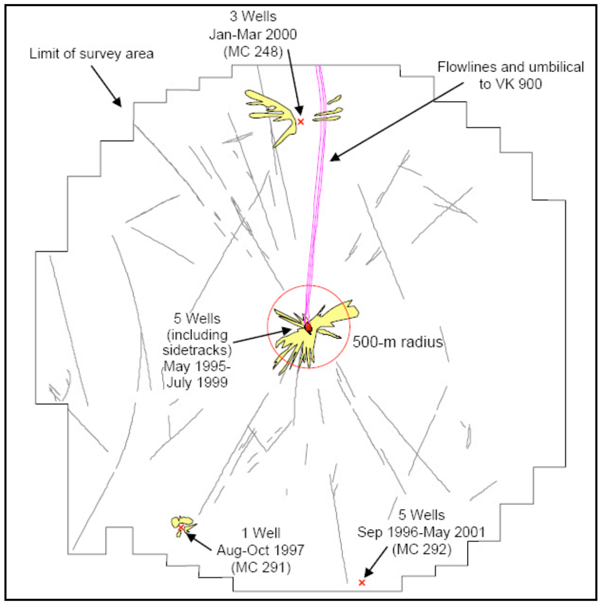

Fig. 7. This is the interpreted diagram using the side-scan sonar mosaic for a production drilling site at block Mississippi Canyon 292. High reflectance from side scan data at well sites is interpreted as drilling discharge accumulations. Linear marks represent impacts from anchor chains/rope. Image from MMS-2006-045.

Results from this study were utilized immediately in consideration of the evidence for more extensive impacts from anchor chains or wire ropes. Rather than limiting consideration of impacts from only the anchor location and lengths of chain/rope expected to be in contact with the bottom after installation, the full distance from the anchor point to the platform location was included in the bottom area evaluated for potential impacts. From the study of the distances reached by sinking muds and cuttings discharges, the avoidance policy was adapted once again, although delays were encountered with respect to the release of the official NTL (see Section IV below).

F. Additional Study: The Deep Missing Piece

Yet another challenge for fully understanding the distribution and ecology of chemosynthetic communities throughout the full depth range of the GOM has been the difficulty in studying the deepest parts of their environment. Throughout the initial two studies, Chemo I and Chemo II, research was largely restricted to the depth capabilities of the available facilities, the *Johnson Sea Link* submersibles and the Navy's *NR 1* research submarine used for a portion of Chemo II. All of these submarines are limited to a maximum depth of about 1,000 m (3,280 ft) while the deepest part of the GOM continental slope with visual evidence of the presence of chemosynthetic communities reaches a depth of at least 2,743 m (9,000 ft). A third major study was therefore necessary to investigate this missing piece. This new study, to be completed in mid-2010, is specifically targeted for water depths greater than 1,000 m (3,280 ft). Funding for the study, *Investigations of*

Chemosynthetic Communities on the Lower Continental Slope of the Gulf of Mexico (Chemo III), was awarded in 2005.[26]

This new project had an additional advantage of full partnership with other Federal agencies. Through sponsorship of the National Oceanographic Partnership Program,[27] NOAA's Office of Ocean Exploration and Research (OER) was a partner in this large study, providing research vessel and submergence facility support over the two field years of the four-year project. Scientists with the U.S. Geological Survey also conducted companion studies directly tied to the overall objectives of MMS. For the MMS/NOAA OER field work, the submersible *Alvin* was used in 2006 and the premiere research ROV, *Jason II* from Woods Hole Oceanographic Institution, was used in 2007. Both of these expeditions lasted nearly a month each. These two cruises were designated "signature expeditions" by NOAA and are extensively documented with daily logs, outreach materials, and images on NOAA's Ocean Explorer website.[28]

Basic discoveries during this study demonstrated that chemosynthetic communities can be present throughout the deep GOM anywhere characteristic geophysical signatures exist. Results indicated that species composition at these much deeper sites was generally completely different than the shallower slope communities. The most important aspect of these studies was the development of the essential knowledge BOEMRE needs to fully understand the entire habitat range for these communities throughout the GOM.

IV. Additional and Ongoing Adaption of Management Policy

With new information derived from MMS-funded studies including direct field measurements of the distances that deepwater drilling discharges are deposited over the seabed, additional modifications to avoidance policy for the protection of chemosynthetic communities was indicated. Other contemporary studies were also investigating cold-water coral habitats that are closely associated with the same habitat areas as chemosynthetic communities.[29] These studies were also utilized in this most recent adaptive management phase.

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[26] Two interim reports are currently available. JAMES M. BROOKS ET AL., INVESTIGATIONS OF CHEMOSYNTHETIC COMMUNITIES ON THE LOWER CONTINENTAL SLOPE OF THE GULF OF MEXICO: INTERIM REPORT 1, OCS Study/MMS 2008-009 (2008), *available at* http://www.gomr.mms.gov/PI/PDFImages/ESPIS/4/4320.pdf; JAMES M. BROOKS ET AL., INVESTIGATIONS OF CHEMOSYNTHETIC COMMUNITIES ON THE LOWER CONTINENTAL SLOPE OF THE GULF OF MEXICO: INTERIM REPORT 2, OCS Study/MMS 2009-046 (2009), *available at* http://www.gomr.mms.gov/ PI/PDFImages/ESPIS/4/4877.pdf .

[27] The National Oceanographic Partnership Program (NOPP), http://www.nopp.org/, is a collaboration of federal agencies to provide leadership and coordination of national oceanographic research and education initiatives.

[28] *See*, NOAA Ocean Explorer, Expedition to the Deep Slope, May 7 – June 2, 2006, http://oceanexplorer.noaa.gov/explorations/06mexico/welcome.html; NOAA Ocean Explorer, Expedition to the Deep Slope 2007, June 4 – July 6, 2007, http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html (last visited June 17, 2010).

[29] CSA International 2007, *supra* note 8; Ongoing BOEM/NOAA collaboration study, Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard Bottom Habitats with Emphasis on Coral Communities: Reefs, Rigs and Wrecks (*Lophelia* II) (GM 08-03),

Several significant components of the previous NTL 2000-G20 were modified based on new information including: (1) the minimum depth of activity requiring individual action reviews, (2) the buffer distances required for separation from surface discharges from potential community locations, and (3) the buffer distance required for separation from other physical impacts such as anchoring.

Deep coral habitat research influenced the adaptive change that decreased the minimum depth for site-specific biological reviews required for all drilling plans or pipeline installation applications submitted to MMS from 400 m (1,313 ft) up to 300 m (984 ft). This was largely due to one of the most remarkable deep coral habitats discovered at a depth of 305 m (1,000 ft) in lease block Viosca Knoll 906.[30] The most recent adaption of policy as of this writing was finalized in NTL 2010-G40, *Deepwater Benthic Communities.*[31] Buffer distances for discharges were increased from 305 m (1,000 ft) to 610 m (2,000 ft), as a direct result of research findings. Avoidance distances were also increased from 76 m (250 ft) to 152 m (500 ft) for other physical impacting activities such as anchors. An additional 305-m (1,000-ft) buffer radius is added to anchor patterns when in the vicinity of probable chemosynthetic communities to prevent possible inadvertent contact with the communities.

The adaptation of management policy for the protection of deep GOM biological communities will continue in the future. To date, it appears that existing protective measures have been effective. Several chemosynthetic communities have been studied on a regular basis for many years and no detectable degradation has occurred that could be attributed to man's activities.

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http://www.gomr.mms.gov/homepg/regulate/environ/ongoing_studies/gm/GM-08-03.html (last visited June 17, 2010).

[30] This site was "rediscovered" through direct participation of MMS and use of archived seismic data guiding a mission using the Navy's *NR 1* submarine to an area thought to be the same as the area described by Donald R. Moore and Harvey R. Bullis Jr. in *A Deep-water Coral Reef in the Gulf of Mexico,* BULL. MAR. SCI. 10(1): 125-128 (1960) and reported by William Schroeder in *Seafloor Characteristics and Distribution Patterns of* Lophelia pertusa *and other Sessile Megafauna at Two Upper-slope Sites in Northeastern Gulf of Mexico*, *supra* note 8.

[31] NTL 2010-G40, Deepwater Benthic Communities NTL implemented January 27, 2010, *available at* http://www.gomr.mms.gov/homepg/regulate/regs/ntls/2009NTLs/09-G40.pdf .