

STUDY TITLE: Explosive Removal of Offshore Structures - Information Search and Synthesis

REPORT TITLE: Explosive Removal of Offshore Structures - Information Synthesis Report

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KEY WORDS: explosive structure removal; marine fishes; marine turtles; marine mammals; acoustics; impact assessment; platform; endangered species; protected species; synthesis; mitigation; monitoring; data gaps

BACKGROUND: MMS requires that offshore oil and gas structures be removed from the U.S. outer continental shelf (OCS) within 1 year of lease termination. MMS regulations require that structures must be severed at least 5 m (15 ft) below the surface of the seafloor. Offshore structure (e.g., platform) removal typically involves the use of explosives to sever structure-associated components – wellheads, piles, etc. Historically, offshore development and production of oil and gas reserves (and most platform removals conducted to date) have occurred in waters of the continental shelf (at depths of 200 m or less). Recent interest in deepwater development, however, has raised the issue of future platform removals in deeper OCS waters over the continental slope. The presence of listed (i.e., endangered or threatened species listed or proposed for listing under the Endangered Species Act [ESA]) and/or protected species (i.e., marine mammals protected under the Marine Mammal Protection Act [MMPA]) in

marine waters, coupled with the mandate to minimize or eliminate the potential for impact to these species, underscores the need to fully understand the environmental impacts associated with explosive removal. Topics of interest in this regard include a thorough characterization of explosive removal technologies and techniques, a description of the physics of underwater explosions, and environmental impacts resulting from these underwater demolitions. While the expected application of this knowledge may include U.S. waters (e.g., Gulf of Mexico, California, and Alaska OCS), the scope of this effort is worldwide.

OBJECTIVES: (1) To provide a summary of available information on the explosive removal of offshore structures by topic; (2) To identify information and data gaps that could be filled by subsequent research activities; and (3) To recommend areas of research to meet MMS information needs.

DESCRIPTION: This project focuses on the collection and summarization of existing information on four topics associated with the explosive removal of offshore structures: explosive structure removal methods; the physics of underwater explosions; the effects of underwater explosions on three faunal groups: marine fishes, turtles, and mammals; and mitigation and monitoring of these effects. The goal was to assemble published and unpublished literature and compile these into a preliminary bibliography database in an electronic and searchable format (ProCite, Access). Collected information was then reviewed and summarized in an information synthesis report.

SIGNIFICANT CONCLUSIONS: (1) The most commonly used technique for explosive cutting of piles and conductors is with bulk explosive charges; (2) Increased use of techniques that involve smaller charge sizes could reduce potential impacts on marine life; (3) The physical principles of underwater detonations and of the propagation of shock and sonic waves in the surrounding medium are well understood, but there are significant gaps in applying this knowledge to actual removal of offshore structures; (4) There are important differences among fishes, marine turtles, and marine mammals with respect to the types and adequacy of available data. In general, fishes are the best-studied group, and marine turtles the least studied. For predicting impacts on fishes, the empirical data from observations during actual structure removals would seem to be more useful than any attempt to calculate impacts based on experiments or mechanistic models. Years of experience using the 3,000 ft (914 m) "safety range" monitored under the "generic consultation" suggests it has been effective in preventing most deaths and serious injuries of marine turtles and marine mammals. In all three groups, there is relatively little information about sublethal impacts, particularly on the auditory system; and (5) While mitigation measures appear to be effective in preventing death or injury of mammals and turtles, it is uncertain to what extent sublethal effects may be occurring beyond the safety range.

STUDY RESULTS: The most common technique for explosive cutting of piles and conductors is with bulk explosive charges, which can be separated into two main categories: configured bulk charges and cutting charges. Configured bulk charges (including ring charges and focused charges) are designed to collide or "focus" the

detonation front to concentrate more energy along the fracture line, and thus reduce the size of the charge needed to cut a piling. Cutting charges include linear-shaped charges and "cutting tape." Linear-shaped charges and flexible cutting tape use high-velocity explosive energy to accelerate a v-shaped band of cutting material, usually copper, in a high velocity jet that penetrates through the steel of the piling. Potential future explosive cutting techniques include contact plaster charges, shock-wave focusing charges, and radial hollow charges. Generally, these techniques are designed to more effectively focus the explosive pressure wave against the piling or other structure to be cut, thus requiring smaller charge weights.

The explosive reaction is the chemical breakdown of oxygen within unstable molecules in the explosive material into more stable derivatives, a process accompanied by the release of large amounts of heat. Detonation is the term for the rapid movement of a pressure front ahead of the chemical transition front. In a detonating explosive, a physical shock front rapidly compresses the explosive material and advances significantly faster than the sonic velocity of the material. Beyond a short distance from the blast, the main sources of impact are the shock wave and the expanding gaseous reaction products. The original shock wave is the primary cause of harm to aquatic life at great distances from the shot point; the expanding gases, if they do break into the water column from the substrate where the explosion occurs, can set up a pulsating bubble whose recurring pressure waves may also contribute significantly to damage. The manner in which shock and acoustic waves propagate from the source into the ocean is strongly influenced by the ocean environment. Noise propagating in shallow water (i.e., depths less than a few hundred meters) can reflect many times from the sea surface and bottom. In these cases, sea surface roughness and sea bottom characteristics are often very important. Fewer surface and bottom interactions occur in deeper water. However, refractive effects due to differential temperature and salinity profiles can cause sound to be trapped in small depth channels and can lead to sound focusing. Sound level metrics are parameters that quantitatively describe the characteristics of sound pressure waves at a given spatial location, and their values are used to gauge the degree of impact that underwater sound signals have on marine life. Standard thresholds for the metrics have been established in reference to the minimum levels at which specific impacts have been observed to occur for given species. The most common metrics for impulsive sounds are peak pressure; peak-to-peak pressure; impulse; root-mean-square (rms); energy flux density; and sound exposure level. A modified version of the peak pressure metric, identified as $\text{dB}_{\text{ht}}(\text{Species})$, also has been developed that accounts for the frequency-dependent hearing sensitivities of specific species. This metric is based on the same principle as frequency weighting schemes used for determining impacts of noise on humans.

The lethal effects of underwater explosions on numerous species of fishes have been studied in laboratory and field experiments and have been modeled extensively. These data and models have been used to calculate effect ranges. In addition, there have been monitoring studies specifically designed to estimate fish kills associated with structure removals in the Gulf of Mexico. These studies have documented that most of the fishes recovered from explosive removal activities were found within 25 m of the

structures, with numbers decreasing with distance out to 100 m, the greatest extent to where divers searched for dead fishes. Therefore, it seems that most fishes associated with platforms are close enough to be killed or injured by a typical underwater detonation associated with structure removals. There are many variables affecting the fate of individual fishes, including their size, shape, vertical position in the water column, and orientation relative to the detonation source. For predicting impacts, empirical data from observations during actual structure removals may be more useful than any attempt to calculate impacts based on experiments and models. Huge variations in the fish population itself, including numbers, species, sizes, and orientation and range from the detonation, would make it very difficult to accurately predict mortalities at any specific site.

The effects of an underwater explosion on marine turtles are dependent upon several factors: the size, type, and depth of the explosive charge; the size and depth of the turtle in the water column; overall water column depth; and the standoff distance from the explosive charge to the turtle. Potential impacts to marine turtles include non-injurious effects (acoustic annoyance and mild tactile detection or physical discomfort), non-lethal injuries ("minor" injuries to the turtle's auditory system and certain internal organs), and lethal injuries. There have been no laboratory studies of explosive impacts on sea turtles, and only limited field observations and experiments. In several instances, turtle injuries and mortalities (and in some cases, strandings) have been noted following underwater detonations. Only one field experiment has been conducted in which sea turtles were exposed at known distances from a structure removal detonation; however, that study did not include concurrent pressure measurements to estimate the magnitude and duration of the shockwave received by the caged turtles. Further, there have been no mechanistic models developed specifically to estimate impacts on sea turtles. Rather, it has been assumed that models developed for other vertebrates are reasonable approximations. An equation developed for a turtle "safety range" was based on field observations of three turtles following an open-water detonation and on the criteria for platform removal established by the National Marine Fisheries Service (NMFS) – i.e., it was not independently derived from observations or experimental data. Data suggest the NMFS "generic consultation" has been effective in preventing most deaths or serious injuries of sea turtles.

For many years, the only data available for predicting blast impacts on marine mammals were extrapolations from experiments on terrestrial mammals submerged in ponds. Only recently have experimental studies of explosive impacts on marine mammals been conducted, using animal carcasses and opportunistic post-mortem examinations of stranded animals following detonations. There have been numerous attempts to model explosive impacts on marine mammals, mostly focused on larger explosions associated with military testing such as ship shock trials. There has also been considerable research into sublethal auditory effects such as temporary threshold shift (TTS) as well as behavioral responses to underwater noise, primarily from seismic surveys using airguns. As with marine turtles, the 3,000 ft (914 m) range monitored under the "generic consultation" suggests it has been effective in preventing most deaths or serious injuries of marine mammals. Auditory effects such as TTS and permanent threshold shift (PTS)

may occur beyond the “safety range” monitored during structure removals. These effects are of particular concern for marine mammals because of the regulatory implications of the MMPA, which prohibits “harassment.” The National Oceanic and Atmospheric Administration – Fisheries Division (previously NMFS) has accepted TTS as a criterion for marine mammal harassment.

STUDY PRODUCT(S): Continental Shelf Associates, Inc. 2003. Explosive Removal of Offshore Structures – Information Synthesis Report. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-070. 236 pp.