

## **Port of Miami Project – Protecting Marine Species During Underwater Blasting**

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**Abstract** - The Port of Miami, Miami-Dade County, Florida (Port) is the largest container port in the State of Florida. However, it is located in the center of a diverse ecosystem. Biscayne Bay surrounds the Port and portions of the bay have been designated as a National Park, a Florida Aquatic Preserve and a state Critical Wildlife Area. The bay is home to many protected, threatened and endangered species including the Florida manatee, five sea turtle species, American crocodile and bottlenose dolphin, in addition to important recreational and commercial fish species.

In 1990, Congress authorized the deepening and expansion of the Port including deepening of the Dodge Lummus Island Turning Basin and Fisherman's Channel to -42 feet. The Port previously attempted to complete the project without underwater blasting. The contractor and subsequent surety company were unable to successfully complete the authorized work primarily due to the limestone bedrock that was resistant to dredging. In 2000, the Port approached the Jacksonville District, U.S. Army Corps of Engineers (District) to complete this project. The District determined that blasting would be required as a construction technique and that Miami Harbor is occupied by a number of species that are protected under the Endangered Species Act (ESA) including the manatee, two species of sea turtles and the crocodile. As a result the District initiated consultation with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the ESA. The District also determined that bottlenose dolphins, a species protected under the Marine Mammal Protection Act (MMPA), had been documented transiting through the Port and could also be affected by the proposed blasting. The District submitted an application for an Incidental Harassment Authorization under the MMPA in June 2002, which was issued in 2004 and renewed in April 2005. Construction blasting began in June 2005 and was completed in August 2005. A key determination made by NMFS and the USFWS was that protected marine species were unlikely to be seriously harmed by the detonations due to the District's conservative monitoring and mitigation measures aimed to ensure that protected marine species would not be within a pre-determined safety zone when the detonations occurred. This paper reviews the results from protected species watch program; an overview of acoustic and pressure measurement data collected during construction; and potential implications for future work using blasting as a construction technique in Florida or elsewhere.

**Introduction** - The Port of Miami (Port), located on the southeast coast of Florida, is in the top 10 cargo container ports in the United States and is the largest container port in Florida. The Port carries the dual distinction of “Cruise Capital of the World” and “Cargo Gateway of the Americas.” In 2005, approximately 3.5 million passengers and more than one million tons of cargo transited through the Port of Miami from around the world (Port of Miami website, accessed September 2006). The Port is also located in the center of a unique and diverse ecosystem. Biscayne Bay surrounds the Port and portions of the Bay have been designated as a National Park, a Florida Aquatic Preserve, an Outstanding Florida Water, and a state Critical Wildlife Area (Figure 1).

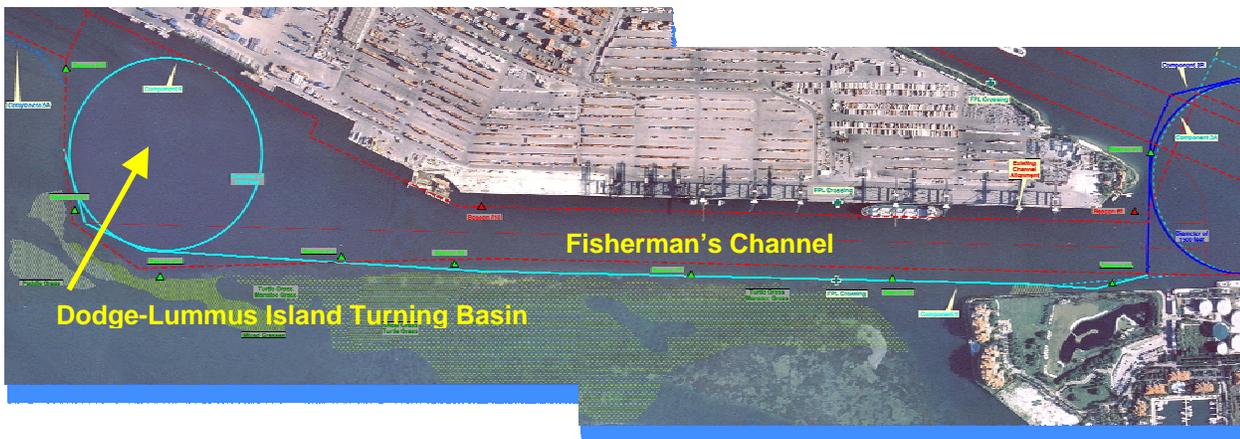


**Figure 1 – An aerial photograph of the Port of Miami, centrally located in Biscayne Bay**

Biscayne Bay is home to many protected, threatened and endangered species including the Florida manatee (*Trichechus manatus*), five sea turtle species (*Family Cheloniidae*), American crocodile (*Crocodylus acutus*) smalltooth sawfish (*Pristis pectinata*) and bottlenose dolphin (*Tursiops truncatus*), in addition to numerous important recreational and commercial fish species including, but not limited to various life stages of penaeid shrimp complex, red drum, reef fish, stone crab, spiny lobster, migratory/pelagic fish, and snapper/grouper complex. Terrestrial and marine habitats surrounding the Port include beaches, mangroves, seagrass beds, and hardbottom and reef communities. Due to the ecologically diverse and significant marine resources within the vicinity of the Port, any construction, maintenance, or operational activities are of primary interest to the Federal, State, and local natural resource and regulatory agencies (agencies). In addition, Miami-Dade County has many active non-profit organizations (NGOs) whose focus is on protecting natural resource and coastal development issues.

In 1990, in response to the need for continued growth of the Port to meet the demands of the passenger and commercial shipping industries, Congress authorized the deepening and expansion of the Port to 42 feet (12.8 m). Phase I, in which the Port deepened the entrance channel and Fisher Island turning basin,

was completed in 1993. Phase II, a \$40 million project to address the South Harbor, was initiated in the mid 1990s and was unable to be completed due to the hardness of the rock and the contractor's equipment. The Port's permits at the time did not allow them to utilize blasting as a construction technique. In 2000, the Port approached the Jacksonville District, U.S. Army Corps of Engineers (District) to complete the construction. The Corps' engineers determined that due to the hardness of the limestone rock, blasting would be required to pre-treat the rock before dredging. Construction began in June 2005 and was completed in July 2006. This work involved 38 days of blasting between June and August of 2005, in the Dodge-Lummus Island Turning basin and Fisherman's Channel on the south side of the Port.



**Figure 2 – Close up aerial photograph of the Dodge-Lummus Island Turning Basin and Fisherman's Channel**

One of the major concerns associated with the project was the potential effects of blasting on protected marine species inhabiting Biscayne Bay. Blasting effects on marine animals associated with open water blasts (i.e., military ordinance and oil rig removal operations) are well documented (Finneran, *et al.*, 2000) and can range from harassment to direct injury and mortality. Dolphins are a highly auditory species dependent upon vocalization and their sensitive and well-developed perception of sound for nearly all aspects of their behavior and survival. Temporary threshold shifts (TTS) in a dolphin's ability to perceive sound and direct injury to ear structures could have long-term negative consequences for individual dolphins as well as to group dynamics and behavior. TTS is well documented in the literature for dolphins (Ketten, 1996) as are some of the physical injuries to auditory structures (Ketten, 1996; Keevin and Hempen, 1997). Both dolphins and manatees are also highly susceptible to lethal and sub-lethal injuries by the reaction of air cavities within the body to the pressure waves produced from the blast. In particular, organs such as the lungs and intestines can be severely compromised even though outward injury may not be noticeable. Very little information is available on the effects of blasting on marine reptile species, including sea turtles and crocodile (Keevin *et al.*, 1999).

The focus of the proposed blasting work at the Port was to pre-treat bedrock prior to removal by a dredge utilizing confined blasting, meaning the shots would be "confined" in the rock. In confined blasting, the hole in which the explosive material is placed is capped with an inert material, such as crushed rock. This is referred to as "stemming the hole." Studies have shown that stemmed blasts have up to a 60-90% decrease in the strength of the pressure wave released, compared to open water blasts of the same charge weight (Nedwell and Thandavamoorthy, 1992; Hempen *et al.*, 2005). However, unlike

open water blasts, very little documentation exists on the effects that confined blasting can have on marine animals near the blast (Keevin *et al.*, 1999).

Regulatory Issues - As previously stated, the District had determined that the waters surrounding the Port were home to many endangered and threatened species. As required by the Section 7 of the Endangered Species Act of 1973 (ESA), the District initiated consultation with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) concerning the potential effect the deepening project could have on listed species under their purview. These consultations resulted in findings that the proposed blasting was likely to affect, but unlikely to adversely affect listed species in the project area (NOAA 2002, USFWS 2002).

The District also determined that a population of bottlenose dolphins, a species protected under the Marine Mammal Protection Act of 1972 (MMPA), had been documented transiting through the Port and could be affected by the proposed blasting. Under the MMPA, it is illegal to take marine mammals (in any manner) without a special authorization. The term “take” means to harass, hunt, capture, or kill or to attempt to harass, hunt, capture or kill any marine mammal. The District applied for and received an incidental harassment authorization (IHA) from NMFS in 2003 and renewed in 2005 with the knowledge that dolphins transit the project area and are likely to incur some incidental harassment as defined in the MMPA as a result of blasting activities (NOAA 2003, 2005a). When the IHA was issued, NMFS concluded that:

*“NMFS has determined that the Corps’ proposed action, including mitigation measures to protect marine mammals, should result, at worst, in the temporary modification in behavior by small numbers of bottlenose dolphins, including temporarily vacating the area to avoid the blasting activities and the potential for minor visual and acoustic disturbance from the detonations. This action is expected to have a negligible impact on the affected species or stocks of marine mammals. In addition, no take by injury and/or death is anticipated, and harassment takes will be at the lowest level practicable due to incorporation of the mitigation measures described”* (NOAA 2005b).

The Mitigation Plan (Protected Species Watch Plan) - As part of the development of the protected-species protection and observation protocols, which were incorporated into the plans and specifications, the Corps worked with the agencies and NGOs to address concerns and potential impacts. One challenge was the misconceptions and misinformation brought to the protocol development by the agencies, since none had any previous experience with confined underwater blasting as a construction technique. As a result, in an effort to educate the agencies and the public, the Corps and Port hosted a series of blasting “workshops” to provide information about blasting, and more specifically, confined blasting.

A danger zone radius was calculated to determine the maximum distance from the blast at which harassment or injury to protected marine species is likely to occur. This danger zone was determined by the amount of explosives used within each delay (which can contain multiple boreholes). These calculations are based on impacts to terrestrial animals in water when exposed to a detonation suspended in the water column (unconfined blast) as researched by the U.S. Navy in the 1970s (Yelverton *et al.*, 1973; Richmond *et al.*, 1973). The reduction of impact by confining the shots would more than compensate for the presumed higher sensitivity of marine species. The District believed that this danger zone radius was a conservative, but prudent, approach to the protection of marine wildlife species. The

zone calculations were done using a tiered approach based on level of impact and mitigative procedures. These zone calculations were included as part of the specifications package.

The calculations are as follows:

1) Danger Zone: The radius whose outer limit represents the minimum distance for no expected mortality. The danger zone (ft) = 260 [79.25 m] X the cube root of weight of explosives in lbs per delay.

2) The Safety zone (sometimes referred to as the exclusion zone) is a larger radius to insure species are beyond the minimum distance whereby harassment may occur, typically beyond the 180 dB isopleths. The safety zone (ft) = 520 [158.50 m] X cube root of weight of explosives in lbs per delay.

3) The Watch Zone is three times the radius of the Danger Zone to insure animals entering or traveling close to the safety zone are spotted and appropriate actions can be implemented before or as they enter any impact areas. Animals in the watch zone are closely monitored to insure they do not enter the safety zone.

The selected contractor, Great Lakes Dredge and Dock (GLDD) and their subcontractors, Contract Drilling and Blasting (CBD) and ECOES Consulting, Inc., submitted (as required per project specifications) an environmental protection plan that included a Protected Species Watch Plan to be utilized during blasting activities. This watch plan was forwarded to the resource agencies for review and in the cases of NMFS and USFWS, approval.

The blast plan that was developed between the Corps and GLDD maximized the efficiency of the rock removal while minimizing the impacts to the surrounding environment and species. All blasting was managed from the GLDD's Drill Barge, *Apache* (GLDD, 2005). The maximum poundage of explosives utilized for this project was not expected to exceed 375 lbs (107.10kg) per delay based on discussions with CDB's explosive's expert.

Using this explosive weight as the maximum expected during construction, the three radii would be:

Danger zone = 1,875 ft (572 m)

Safety zone = 3,750 ft (1,143 m)

Watch zone = 5,625 ft (1,715 m)

The Corps used these numbers as the worst case that would be encountered during construction.

Blasting began on 25 June and was completed on 12 August 2005 for a total of 38 days of blasting for 40 blasting events (3 days had 2 blasts). Explosive weights ranged from 17 lbs (7.7 kg) to 376 lbs (108 kg) per delay with the mean explosive weight per delay of 119lbs (54 kg) giving the mean zone distances of:

Danger zone = 1,278 ft (390 m)

Safety/Exclusion zone = 2,556 ft (779 m)

Watch zone = 3,834 ft (1,169 m)

The 119-lb charge distances were used for conducting the watch program during all blasts unless the watch coordinator was informed that the blast weight was over 120lbs (54 kg) (Figure 3).



**Figure 3 – Sample zone layout using the mean weight of explosives of 119lbs (53.98 kg).**

A watch plan was formulated based on the required safety zones and optimal observation locations. The watch plan consisted of six (6) observers which included at least one (1) aerial observer, two (2) boat-based observers, and two (2) observers stationed on the drill barge. The 6th observer was placed in the most optimal observation location (boat, barge or aircraft) on a day by day basis depending on the location of the blast and the placement of dredging equipment. This process helped to insure complete coverage of the three zones as well as any critical areas. The watch began at least 1 hour prior to each blast and continued for one-half hour after each blast.

The aerial observer flew in a turbine engine helicopter (bell jet ranger) with doors removed. This provided maximum visibility of the watch and safety zone as well as exceptional maneuverability and the needed flexibility for continual surveillance without fuel stops or down time, minimization of delays due to weather or visibility and the ability to deliver post-blast assistance. Boat-based observers were placed on one of two vessels, both of which had attached platforms that place the observer's eyes at least 10 feet (3 m) above the water surface enabling optimal visibility of the water from the vessels (Figure 5). The boat observers covered the safety zone where waters were deep enough to safely operate the boats without any impacts to seagrass resources. The shallow grass beds south of the project site relegated the observer boats mainly to the channel east and west of the blast zone (Figure 4). The pontoon boat was able to move up the small pipe channel to the south of the site and in some of the deeper portions of the grass beds. At no time were any of the observer boats allowed in shallow areas where props could potentially impact the fragile seagrass.

The restricted access of the boats did not adversely impact the watch program since the visibility through the water column in the shallow areas was excellent from the air and under normal conditions; the bottom was visible to the helicopter observer. Therefore, the important areas for boat coverage were

within the channel where animals were not as easily tracked from the air and thus boats could provide additional coverage. The only time this restrictive area became a concern was when the dredge *Texas*

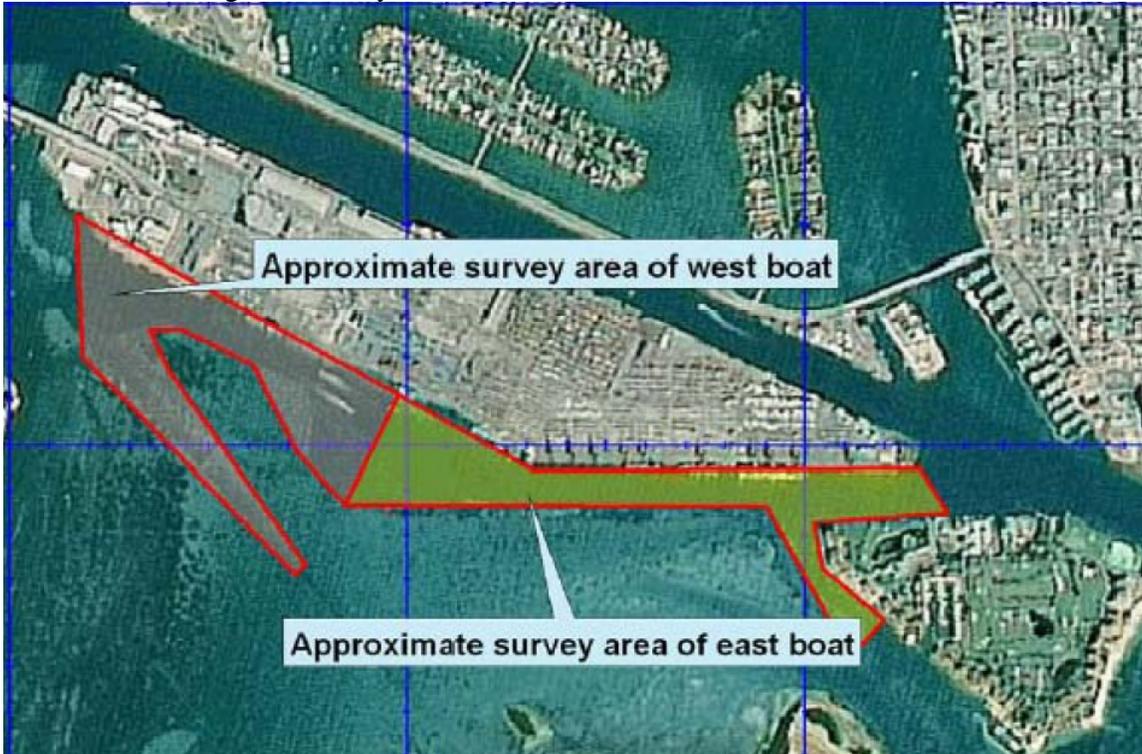


Figure 4 – Aerial photograph of the approximate survey area for each of the surface boats.



Figure 5 – Photographs of the two observer vessels, note the observation towers.

was operating and the tide was either flooding or switching from flood to ebb. At these times, apparent turbidity in the water was high and visibility through the water column was reduced so that animals were not seen below the surface as they would be under normal conditions in this area. However, animals surfacing in these conditions were still routinely spotted from the air and from the boats, thus the overall observer program was not compromised, only the degree to which animals were tracked below the surface. Adjustments to the program were made accordingly so that all protected species were confirmed out of the safety zone prior to T-minus 5 minutes, just as they would have been under normal visual conditions. It is important to note that the waters within the project area are exceptional for observation so that the decreased visibility below the surface during turbid conditions made the waters more typical of other manatee habitats and port facilities where observer programs are also effective.

All observers were equipped with marine-band VHF radios, maps of the blast zone, polarized sunglasses, and appropriate data sheets. In addition to this observation gear, all required personal protective equipment (hard hat, steel toed boots, life vest) was worn by observers at all times with the exception of the aerial observer.

Communications among observers and with the blaster was of critical importance to the success of the watch plan. The aerial observer was in contact with vessel and drill-barge based the observers and the drill barge with regular 15-minute radio checks throughout the watch period. Constant tracking of animals spotted by any observer was possible due to the amount and type of observer coverage and the excellent communications plan.

Watch hours were restricted to between two hours after sunrise and one hour before sunset. The watch began at least one hour prior to the scheduled blast and was continuous throughout the blast. Watch continued for at least 30 minutes post blast at which time any animals that were seen prior to the blast were visually re-located whenever possible and all observers in boats and in the aircraft assisted in cleaning up any blast debris.

If any protected species were spotted during the watch, the observer notified the aerial observer and/or the other observers via radio. The animal was located by the aerial observer to determine its range and bearing from the blast array. Initial locations and all subsequent re-acquisitions were plotted on maps. Animals within or approaching the safety zone were tracked by the aerial and boat based observers until they exited the safety zone. Anytime animals were spotted near the safety zone, the drill barge was alerted as to the animal's proximity and some indication of any potential delays it might cause.

If an animal was spotted inside the safety zone and not re-acquired, no blasting was authorized until at least 30 minutes had elapsed since the last sighting of that animal. If manatees were spotted near any of the operations, all crew boats, tugs and other vessels were notified to go to slow speed. The watch continued its countdown up until the T-minus five (5) minute point. At this time, the aerial observer confirmed that all animals were outside the safety zone and that all holds have expired prior to clearing the drill barge for the T-minus five (5) minute notice. A fish scare charge was fired at T-minus five (5) minutes and T-minus one (1) minute to minimize effects of the blast on fish that may be in the area of the blast array by scaring them from the blast area.

An actual delay in blasting only occurs when a protected species was located within the exclusion zone at the point where the blast countdown reaches the T-minus five (5) minutes. At that time, if an animal is in or near the safety zone, the countdown is put on hold until the zone is completely clear of protected species and all 30-minute sighting holds have expired. Animal movements into the safety zone prior to that point are monitored closely but do not necessarily stop the countdown. The exception to this would be stationary animals that do not appear to be moving out of the area or animals that begin moving into the safety zone late in the countdown. For these cases, holds on the T-minus 15 minutes may be called for in order to keep the shipping channel open and minimize the impact on Port operations.

**Results** - During observations, the expected two species of marine mammals were spotted, manatees and bottlenose dolphin, as well as loggerhead turtles (*Caretta caretta*) and other unidentified sea turtles. A total of 186 individual animals were spotted, with approximately 60% of these observations being manatees. Protected species were spotted during watches for 36 of the blasts or 95% of the watches.

Dolphins were spotted inside the exclusion zone 12 times with a total of 30 individuals; turtles were spotted inside the exclusion six (6) times for a total of seven (7) individuals; and manatees were spotted inside the exclusion zone five (5) times with a total of 14 individuals. Not every sighting within the exclusion zone caused a delay in blasting and in fact, most sightings within the exclusion zone did not result in an actual hold in the countdown (Barkaszi, 2005).

Conclusion - Based on the monitoring data collected during the construction of the Miami Harbor Phase II project, the District and NMFS continue to believe that due to the conservative monitoring and mitigation requirements of the IHA and ESA consultations, protected marine species were unlikely to have been harmed by the blast detonations due to the size of the blasts, the stemming of the charges, the depth of the water and the required stand-off distances between the animals and the blast array. This project serves as an example of cooperation, management and action to prevent impacts to protected marine species during channel-deepening blasting. Other projects may use the success of this program to tailor their projects' needs to avoiding harm to both protected species and the native marine biota, as a whole.

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