

Results and evaluation of US Navy shock trial environmental mitigation of marine mammals and sea turtles

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ABSTRACT

A shock trial of a US Navy Destroyer, the USS *Winston S. Churchill*, was conducted offshore of northern Florida in May and June 2001. The shock trial consisted of three underwater detonation tests, spaced approximately one week apart. Environmental mitigation to minimise the impact of the shock trial on marine mammals and sea turtles was based on a Safety Range of 3.7km (2 n.miles) radius around the detonation site, and a Buffer Zone of an additional 1.85km (1 n.mile) radius beyond the Safety Range. Mitigation included site selection surveys, pre-detonation aerial, vessel and bio-acoustic monitoring, and post-detonation aerial and vessel monitoring. Six species of odontocete and two species of sea turtle were identified during mitigation monitoring, as well as several sightings that could not be identified by species. Site selection aerial surveys were implemented to select a test site with the lowest abundance of marine mammals and sea turtles. Nearly 300 animals were seen during site selection surveys. Pre-detonation aerial and vessel monitoring was implemented to sight any marine mammal and sea turtle within the Safety Range on designated test days, and track the animals until they could be verified to be outside the Safety Range. Approximately 1,200 marine mammals and 32 sea turtles were sighted during pre-detonation monitoring. Pre-detonation bio-acoustic monitoring was implemented to detect large cetaceans within the Safety Range and Buffer Zone; the only calls heard were from dolphins that could not be localised. Post-detonation monitoring was implemented to determine the effectiveness of mitigation procedures. No injured or dead marine mammals or turtles were detected during approximately 185 hours of post-detonation aerial and vessel visual monitoring. Post-detonation monitoring resulted in observations of 767 marine mammals and 42 sea turtles. With only two exceptions, the same marine mammal and sea turtle species were observed prior to, during and after the shock trial test time period. Factors leading to the success of this environmental mitigation effort are summarised, and recommendations for improvements to mitigation efforts of this size and scope are suggested. These recommendations include the use of a simultaneous second aircraft for improved coverage during pre-detonation surveys, increased post-detonation aerial monitoring, equitable survey data for all test sites under consideration during planning stages, and reassessment of bio-acoustic monitoring need and purpose.

KEYWORDS: ACOUSTICS; ATLANTIC OCEAN; SURVEY-AERIAL; ODONTOCETE; SEA TURTLE; NOISE

INTRODUCTION

Each new class of ship (or major upgrade) constructed for the United States Navy must undergo US Live Fire Test and Evaluation (LFT&E) based on congressional legislation (10 USC 2366). A shock trial is one means of addressing the requirements of LFT&E and the Navy's ship shock hardening requirements. A shock trial is a series of tests consisting of underwater detonations, each separated by approximately one week, that send a shock wave through the ship's hull to simulate explosive near-misses during combat. A shock trial allows the Navy to assess the survivability of the hull, the ship's systems, and the capability of the ship to protect the crew. The USS *Winston S. Churchill* (DDG 81), a Flight IIA guided missile destroyer of the *Arleigh Burke* class, was selected as the shock trial ship for this class.

Operational requirements, including water depth, ship traffic, proximity to Naval Stations for ship and air support, and proximity to ship repair facilities and an ordnance loading station, were used to identify potential test areas. Three test areas met the operational requirements: Norfolk, Virginia; Pascagoula, Mississippi; and Mayport, Florida. The Navy prepared an Environmental Impact Statement (EIS) to assess the potential environmental impacts associated with conducting the shock trial in accordance with the National Environmental Policy Act and Executive Order 12114 (Department of the Navy, 2001). The EIS was prepared with the cooperation of the US National Marine Fisheries Service (NMFS). The EIS assessed the three potential test areas and concluded that the Mayport test area

represented the area least likely to negatively impact (via mortality, injury and harassment) marine mammals and sea turtles. The Mayport test area was 120km (65 n.miles) offshore of Jacksonville, Florida (Fig. 1). The overall configuration of the test area was based on operational restrictions, including minimum 600ft depth, within 100 n.miles of shore support and avoidance of offshore ordnance dumping areas. The Mayport test area was within the Gulf Stream current that runs offshore of the east coast of North America (Schmitz *et al.*, 1987). The Navy requested and received a Letter of Authorisation (LOA) from the NMFS for the incidental taking of a small number of marine mammals during the shock trial, in accordance with the US Marine Mammal Protection Act (MMPA). Additionally, incidental sea turtle takes under the US Endangered Species Act (ESA) were specified in the terms and conditions of a Biological Opinion written by NMFS.

A critical element of the EIS and the request for the LOA was the planning of environmental mitigation procedures to minimise the impact of the shock trial on marine mammals and sea turtles. The mitigation plan provided the overall approach to environmental mitigation and monitoring procedures, mitigation team and individual responsibilities and support requirements. The overall objectives of the Environmental Mitigation and Monitoring Plan were to:

- (1) assist in the selection of a test site within the Mayport test area that posed the least risk to the marine environment, specifically marine mammals and sea turtles, by conducting site selection surveys;

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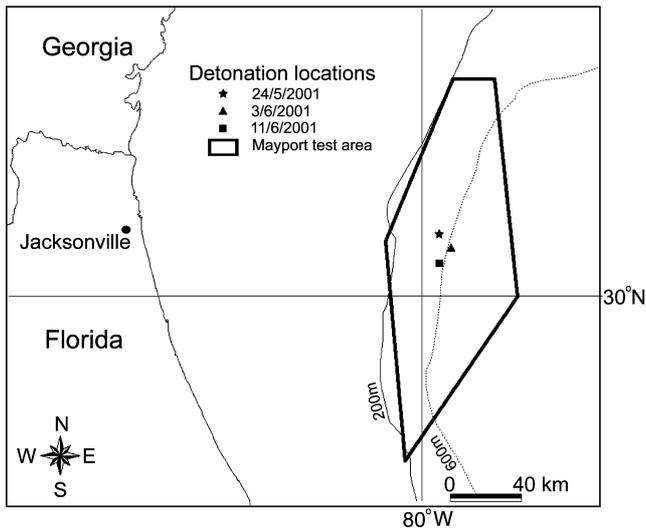


Fig. 1. Mayport, Florida, test area and locations of three shock trial tests, Spring 2001.

- (2) conduct pre-detonation monitoring on the day of the test prior to each detonation in an effort to ensure it was free of detectable marine mammals, sea turtles, large *Sargassum* rafts, large schools of fish and flocks of seabirds (the latter three were considered potential indicators of marine mammal or sea turtle occurrence); and
- (3) conduct post-detonation monitoring of the test site to measure the effectiveness of mitigation procedures and, when appropriate, recommend changes to the plan prior to the next test.

Environmental mitigation was based on a Safety Range of 3.7km (2 n.miles) radius around the detonation site and a Buffer Zone of an additional 1.85km (1 n.mile) radius beyond the Safety Range. The Safety Range was based on conservative calculations of the distance at which marine mammals and sea turtles would be killed or injured (Level A harassment under the MMPA) by the shock wave (Department of the Navy, 2001). The actual maximum distances at which mortality (1.35km [0.73 n.miles]) and injury (2.25km [1.22 n.miles]) were estimated to occur were well within the Safety Range. Beyond this range, impacts to marine mammals and sea turtles were expected to result only in Level B harassment, or temporary disruption of behavioural patterns, which were not mitigated because any observable disruptions were expected to be short-lived and not repetitive. The Safety Range and Buffer Zone provided one of the bases for test postponement, such that any marine mammal or sea turtle detected within the Safety Range would automatically lead to a postponement of the detonation until that animal could be verified clear of the Safety Range. Any animal seen within the Buffer Zone swimming towards the Safety Range also led to a postponement, until that animal could be verified to be swimming away from the Safety Range. Postponement would also occur if sea state conditions were unacceptable (greater than sea state 3 or Beaufort scale 4) or if visibility was not adequate for observations.

MATERIALS AND METHODS

Environmental mitigation components consisted of site selection surveys (aerial only), pre-detonation visual monitoring (aerial and shipboard), pre-detonation bio-

acoustic monitoring and post-detonation visual monitoring (aerial and shipboard). The mitigation team leader coordinated all aspects of the mitigation effort and served as liaison to the rest of the shock trial operations team. The lead scientist directed the activities of the mitigation team, tracked all marine mammal and sea turtle sightings and provided recommendations to the shock trial test director. All observers involved had a minimum of two years of experience as a marine mammal/sea turtle observer, veterinary assistant and/or bio-acoustician. On average observers had greater than 10 years experience. A representative from NMFS was part of the pre-detonation shipboard monitoring team, to verify that the mitigation plan was implemented adequately.

All aerial surveys/monitoring were flown in high wing aircraft (O2 SkyMaster) at an altitude of 229m (750ft) and a speed of 110 knots. Observed marine mammals and sea turtles were identified by species where possible, and location, group size and swim direction were noted.

Site selection surveys were conducted 1-2 days prior to the planned test day, and were designed to select a test site within the test area, with the lowest relative abundance of marine mammals and sea turtles. Survey lines were spaced 9.3km (5 n.miles) apart and the entire test area could be surveyed during a 5.5 hour flight. The lead scientist assessed the site selection survey results and recommended the best area in which to conduct the test to the shock trial test director. Site selection surveys were also used to monitor environmental conditions in the test area, such as sea state and visibility, and provided the shock trial test director with valuable information on the feasibility of successfully conducting the test. If site selection monitoring of the test area could not be conducted adequately due to inclement weather or high sea states, the test was postponed for at least a day or until an adequate site selection survey could be completed. Site selection surveys occurring after the first test also served as supplementary post-detonation monitoring because the area surveyed often overlapped with the previous test site(s). However, effort and sightings recorded during site selection surveys were not double-counted as post-detonation data.

All monitoring conducted prior to the detonation on designated test days was 'pre-detonation' even if the test was delayed and no detonation occurred on that day. Pre-detonation aerial visual monitoring was designed to locate any animals within the Safety Range and track the animals until they could be verified to be outside the Safety Range. Aerial monitoring consisted of broad scale survey lines that were spaced 1.85km (1 n.mile) apart, followed by finer scale survey lines in the immediate area of the detonation site spaced at 0.93km (0.5 n.miles). All animal positions and swim directions were plotted relative to the detonation site using a marine animal tracking and sighting software program (MATS). The MATS software also depicted the Safety Range and Buffer Zone, which allowed the lead scientist to immediately determine whether or not a sighting was within the Safety Range. Visual monitoring from the aircraft commenced approximately 1.5 hours prior to the planned detonation and continued until detonation occurred. A second aircraft was on-call if the original aircraft had to leave the test area to refuel so that aerial monitoring was continuous.

Pre-detonation shipboard visual monitoring occurred on designated test days and was designed to locate marine mammals and sea turtles within the Safety Range and Buffer Zone, and to track the animals until they could be verified to be outside the Safety Range. Observers were based onboard

the *Winston S. Churchill*, located in the centre of the Safety Range, and positioned on each bridge wing. Two observers monitored the test site with mounted 25× power binoculars (*Bigeyes*), while four additional observers monitored the site with handheld binoculars. This allowed for 360° overlapping coverage. Sighting locations were based on bearing and distance; bearing was measured relative to the bow of the vessel using a calibrated collar at the base of the yoke of the *Bigeyes*; distance was measured using a calibrated reticle in the oculars of the *Bigeyes*. All marine mammal and sea turtle positions and swim directions were immediately plotted relative to the detonation site using the MATS software. Shipboard monitoring commenced at least one hour prior to the planned detonation. Monitoring via the *Bigeyes* continued until three minutes prior to detonation, when the *Bigeyes* were stowed for safety. Monitoring via handheld binoculars continued until one minute prior to detonation, when all observers were positioned inside the bridge for safety considerations. Pre-detonation shipboard visual monitoring on designated test days also took place from the Marine Animal Recovery Team (MART) vessel. Sighting information reported by the MART was included in the pre-detonation sighting database and entered via the MATS software. The MART vessel was generally positioned about 5 n.miles from the detonation point during pre-detonation monitoring, so most sightings were well outside of the Safety Range and Buffer Zone. However, MART pre-detonation sighting information did provide an indication of animals moving towards the detonation point that could then be tracked by vessel observers onboard the *Winston S. Churchill*, or by aerial observers.

Aerial and shipboard observers tracked any marine mammals located within the Safety Range (often in tandem with each other) until the animals were verified clear of and swimming away from the Safety Range. Sea turtles were assumed to be moving north with the Gulf Stream current, which could be measured on a daily basis from the *Winston S. Churchill*; clearance of the Safety Range by sea turtles was calculated based on the original position and time of the sighting. For example, on a day when the current was measured as 3 knots, a sea turtle observed three miles from the northern edge of the Safety Range would be estimated to be clear of the area in one hour.

Pre-detonation bio-acoustic monitoring occurred on designated test days, and was designed to acoustically detect mysticetes and sperm whales (*Physeter macrocephalus*) within the Safety Range and Buffer Zone via localisation of lower-frequency (10Hz – 4kHz) calls. These species were monitored bio-acoustically in addition to visually because they are generally more difficult to detect at the surface than other marine mammals, due to their relatively solitary nature (mysticetes), or their tendency to dive deeply and remain submerged (sperm whales). A DIFAR-based Acoustic Monitoring System (D-AMS) was specifically designed for this test (Department of the Navy, 2002). The D-AMS was also capable of detecting some higher frequency calls from other marine mammals, but was not able to determine the call location. Prior to deploying the D-AMS, an ambient noise buoy and an AXBT (airborne expendable bathythermograph) were deployed for obtaining a sound-speed profile. Passive DIFAR sonobuoys, with 8 hour duration, were deployed from an Orion P-3 aircraft at least one hour prior to the planned detonation time, and continuously monitored. DIFAR buoys allowed for a radio frequency (RF) channel to be selected from 99 available, extending from 136.000 to 173.125MHz with 375kHz between channels. The radio frequency power was 1W. The

acoustic coverage was from 5Hz to almost 5kHz, with maximum sensitivity at about 1.5kHz.

The sonobuoy array was a regular hexagon, formed by two rows of three buoys, each sandwiching a row of four buoys. The hexagon had 2 n.mile sides and one sonobuoy at the centre. The array spanned 4 n.miles. Based on the known ranges of source levels for large whales and expected background sounds for sea state three or less, animals could be expected to be heard from at least 5 n.miles, assuring coverage of the Safety Range and Buffer Zone. The centre of the hexagonal array was selected so that the centre buoy would cross the planned shot point at the expected detonation time. For localisation, a minimum of two buoys were required to detect the whale call, thus providing two bearings whose intersection defined the whale location. Additional buoys were deployed to replace those lost to drift over time; buoy location was monitored via frequent overflights of the P-3, and calculation of drift based on current. Acoustic data received from the buoys was monitored by four bio-acousticians based on the P-3. Data were displayed as strip spectrograms showing frequency and duration of the call and as polar displays of bearing-time and bearing-frequency. Processing of mysticete and sperm whale call location was based on bearing and range, and locations could be ascertained in real-time. Calling animals could also be tracked acoustically until they were outside of the Safety Range. Because the bio-acoustic component was designed to provide real-time detections, the data were recorded in a continuous 30 minute loop only, such that data older than 30 minutes were replaced by new data. There was no long-term archiving of bio-acoustic data. All bio-acoustic data were immediately radioed to the lead scientist and entered into the MATS software. Bio-acoustic monitoring was continuous until the time of detonation.

Monitoring that occurred after each detonation was termed 'post-detonation', until the next site selection survey commenced. Each test was separated by at least one week to allow enough time to prepare the ship, and so there was usually a 2-3 day gap when no surveys or monitoring were conducted. The objective of post-detonation monitoring was to detect any marine mammals or sea turtles killed or injured by the test. Animals killed by the blast would likely suffer lung rupture, which would cause them to float to the surface due to air in the blood stream (Department of the Navy, 2001). Animals that were mortally wounded and whose carcasses sunk, would likely resurface within a few days although this would depend on size and type of animal, fat stores, currents, depth and temperature of the water and other variables. Post-detonation visual monitoring commenced immediately following each detonation. Aerial monitoring was assisted by the MART. Aerial and vessel monitoring continued in the area of the detonation and progressively down current for two days after the first two tests and seven days after the final test. Aerial monitoring via transect lines spaced 0.93km (0.5 n.miles) apart were flown centred around and down current of the detonation site immediately following the test. During aerial monitoring on the days following the test, aerial observers first monitored the area immediately surrounding the detonation site, then focused on areas down current from the test site; the exact area monitored depended on the speed and direction of the Gulf Stream.

The primary responsibility of the MART was to be on-site should any injured or dead marine mammals or sea turtles be detected in the area after the detonation and, secondarily, provide continuous on-site visual post-detonation monitoring. The MART included a marine mammal

veterinarian, sea turtle veterinarian, marine mammal observer and two sea turtle specialists. The MART was based onboard the R/V *Athena*, a 50.3m (165ft) research vessel owned and operated by NSWC (Naval Systems Weapon Center), based in Panama City, Florida. This vessel was chosen specifically for the MART because it was: (1) capable of lifting injured or dead marine mammals or sea turtles up to 4,536kg (10,000lb) onto a rear deck work area; (2) outfitted with an aft dive platform for investigating larger animals; (3) capable of high speeds to transport injured animals quickly to shore; and (4) fitted with adequate deck work space, storage and freezer space. Primary visual searching aboard the MART vessel was by naked eye, and handheld 7× binoculars were used to confirm initial sightings, and to determine species identification, group size and swimming direction. Post-detonation MART monitoring commenced immediately after detonation, with a search of the detonation site, and then progressed down current. Track lines were in a zigzag pattern, with lines spaced approximately 1.85km (1 n.mile) apart and 9.3-11.1km (5-6 n.miles) long. Vessel speed ranged from 1.5-3.5 knots, depending on the speed of the Gulf Stream current pushing the vessel. A long-line high flyer was fashioned out of a buoy with a strobe light attached as a way to help the vessel maintain consistent speed with the Gulf Stream and allow the vessel to pick up a track line after diverting away for animal sightings. Environmental conditions such as sea state, wind speed and direction, swells and sea surface temperature were recorded every hour by the ship's captain. Visual observations started in the early morning when sunlight was sufficient for viewing, and ended 30 minutes prior to sunset, or when lighting conditions precluded adequate visualisation of the horizon.

RESULTS

The shock trial, consisting of three tests, was conducted in May and June 2001 (Department of the Navy, 2002). Mitigation activities in support of the test commenced 29 April and ended 18 June. For each test, a 4,536kg (10,000lb) charge was detonated, one on each of 24 May, 3 June and 11 June; there was also one mis-fire on 10 May. Environmental mitigation led to the postponement of tests on six occasions:

- (1) 10 May: Sea turtle sighting and subsequent Risso's dolphin (*Grampus griseus*) sighting delayed testing by approximately 1.3 hours until both were confirmed clear of the Safety Range. No detonation occurred due to mis-fire.
- (2) 31 May: Numerous marine mammal and sea turtle sightings delayed testing by one day.
- (3) 1 June: Lack of bio-acoustic monitoring support delayed testing by approximately three hours, until a waiver of use was received from NMFS; thunderstorms in the area and a subsequent lack of aerial monitoring support delayed testing by one day.
- (4) 2 June: Unacceptable sea state (4 and above) delayed testing by one day.
- (5) 3 June: Dolphin sighting delayed testing by approximately 1.5 hours, until it was confirmed to be clear of Safety Range. Detonation occurred after the Safety Range was confirmed clear of detectable marine mammals and sea turtles.
- (6) 11 June: As (5) above.

Approximately 54 hours were flown during site selection surveys (Department of the Navy, 2002). A total of 231 marine mammals and 67 sea turtles were seen (Table 1, Fig.

2). Several surveys were flown in less than optimal conditions (sea state >3, low visibility), which precluded effective surveying. Under those circumstances, an additional day of site selection surveying was completed before the test was undertaken. Marine mammals identified by species included bottlenose dolphins (*Tursiops truncatus*), pilot whales (most likely short-finned pilot whales, *Globicephala macrorhynchus*), Risso's dolphins and *Stenella* spp., in addition to loggerhead sea turtles (*Caretta caretta*). Several sightings were recorded that could not be identified by species due to the greater emphasis placed on determining relative abundance of all animals in the test area.

Approximately 45 hours of aerial surveys were flown during pre-detonation activities. A total of 694 marine mammals and 24 sea turtles were seen (Table 1, Fig. 3). Marine mammals identified by species during pre-detonation aerial monitoring included bottlenose dolphins, pilot whales, Risso's dolphins and *Stenella* spp., in addition to loggerhead sea turtles. Several sightings were recorded that could not be identified by species due to the greater emphasis placed on detection of animals relative to the detonation point during pre-detonation monitoring. This limited the effort (e.g. aerial circling) available for identifying sightings by species, and obtaining detailed information on group sizes and behaviour. The majority of sightings (448 marine mammals and 4 turtles) were observed on 31 May, when nearly 800 animals (794 marine mammals and 4 turtles) were observed by aerial and vessel observers. The number and consistency of sightings resulted in the postponement of testing on that day.

Approximately 24 hours of pre-detonation shipboard observations were carried out from the *Winston S. Churchill*, and a total of 200 marine mammals and three sea turtles were observed (Table 1, Fig. 3). The same species of marine mammals and sea turtles identified during site selection and pre-detonation aerial monitoring were identified during shipboard monitoring. Several sightings could not be identified by species due to their distance from the vessel.

The MART vessel was present just outside the Safety Range and Buffer Zone prior to detonation on several designated test days: 10 May (misfire), 11 May (on-site escort to the operations vessel), 24 May (prior to detonation), 31 May-3 June (prior to detonation) and 11 June (prior to detonation). MART observers were on-station for approximately 28 hours, and a total of 308 marine mammals and 5 sea turtles were observed (Table 1, Fig. 3). The MART was outside the immediate area of the detonation, and therefore observers were able to spend greater time on species identification and behaviour. Most sightings were of bottlenose dolphins, with the largest group estimated at 30-35 individuals. Several groups bow rode for several minutes. It was very difficult to visually distinguish whether the animals were of the shallow, warm water ecotype, or the deep, cold-water ecotype (Duffield *et al.*, 1983; Duffield, 1987; Mead and Potter, 1995). Three groups of pilot whales and one group of seven Atlantic spotted dolphins (*Stenella frontalis*) were also seen during pre-detonation monitoring. MART observers also identified one group of two false killer whales (*Pseudorca crassidens*) that approached the vessel and one group of 13 pygmy killer whales (*Feresa attenuata*) that approached the vessel and bow rode for several minutes allowing for positive identification. There were some sightings of unidentified odontocetes from the MART vessel. Most were not identified due to distance, weather conditions, or inability

Table 1

Summary of marine mammal and sea turtle sightings and observer effort (h) during site selection, pre- and post-detonation monitoring, Spring 2001.

	Monitoring platform					
	Site selection	Pre-detonation aerial	Pre-detonation <i>Winston S. Churchill</i>	Pre-detonation MART	Post-detonation aerial	Post-detonation MART
Total observation time (h)	54	45	24	28	59	125
Species						
Odontocetes						
<i>Tursiops</i> sp.	38	109	17	180	292	75
Short-finned pilot whale	95	62	58	72	39	38
Risso's dolphin	25	46	39	0	95	23
<i>Stenella</i> sp.	24	15	5	7	72	0
False killer whale	0	0	0	2	0	0
Pygmy killer whale	0	0	0	13	0	0
Unidentified dolphin	49	462	81	34	131	2
Total odontocetes	231	694	200	308	629	138
Sea turtles						
Leatherback turtle	0	0	0	0	1	1
Loggerhead turtle	30	17	2	3	36	0
Unidentified turtle	37	7	1	2	4	0
Total sea turtles	67	24	3	5	41	1
Total animals	298	718	203	313	670	139

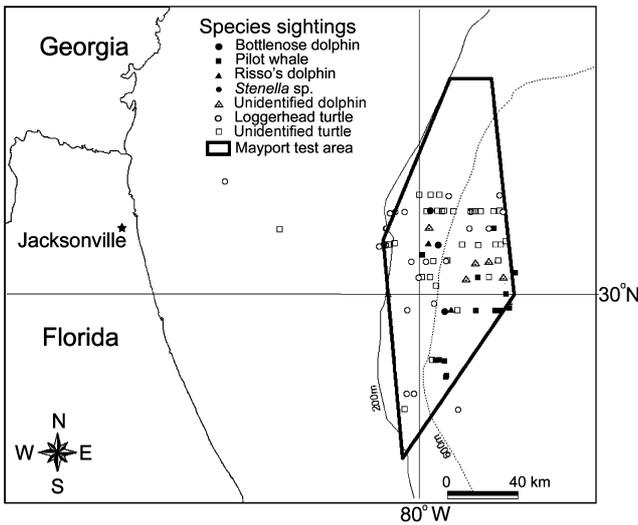


Fig. 2. Marine mammal and sea turtle sightings collected during site selection aerial surveys in support of shock trial environmental mitigation, Spring 2001.

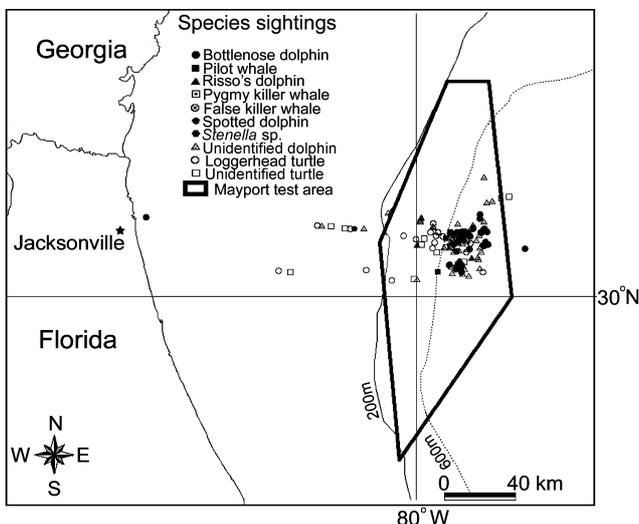


Fig. 3. Marine mammal and sea turtle sightings collected during pre-detonation aerial and vessel monitoring in support of shock trial environmental mitigation, Spring 2001.

to investigate due to monitoring protocol. Over half (159 marine mammals) of the sightings were made on 31 May.

Pre-detonation bio-acoustic monitoring on test days totalled approximately 14.5 hours. Bio-acoustic monitoring was in place for tests occurring on 24 May and 11 June; monitoring was also present on 10 May when the mis-fire occurred, and on 31 May when the test was postponed due to the high occurrence of animals within the Safety Range. Bio-acoustic monitoring was not present on 3 June when the second test occurred, due to aircraft mechanical problems. A total of 68 DIFAR buoys were deployed during acoustic monitoring. On 24 May, the initial sonobuoy field was deployed too far north and east to be useful so a second field of buoys was deployed south and west that would drift towards the planned detonation site (Fig. 4). The sonobuoy field on 11 June was initially positioned somewhat east of the planned detonation site, so an additional line of buoys was deployed farther west to improve detection and localisation capabilities. No low-frequency marine mammal calls were detected at any time (Department of the Navy, 2002). Dolphin calls were detected five times over a 1 hour, 12 minute time period on 31 May only. These calls could not be localised and were only identified based on the buoy that they were closest to.

Post-detonation aerial monitoring totalled 59 hours, and no dead or injured marine mammals or sea turtles were detected at any time. A total of 629 marine mammals and 41 sea turtles were observed during post-detonation aerial monitoring (Table 1, Fig. 5). The emphasis for post-detonation aerial monitoring was to cover as much area as possible searching for marine mammals and sea turtles that appeared dead or injured, so the data collected with each live animal sighting were minimal. The same species of marine mammals and sea turtles identified during site selection and pre-detonation monitoring were identified during post-detonation aerial monitoring.

The MART was on-site during and after the three tests continuously for a total of 14 days and approximately 125 hours: 24–26 May, 3–5 June and 11–18 June. No dead or injured marine mammals or sea turtles were seen by MART observers either at the site of each test nor down current during subsequent monitoring. A total of 138 marine

mammals and one sea turtle was recorded from the MART vessel, representing four species (Table 1, Fig. 5). The most commonly encountered species were bottlenose dolphins. One large (35-45) group of pilot whales was also seen as well as two groups of Risso's dolphins.

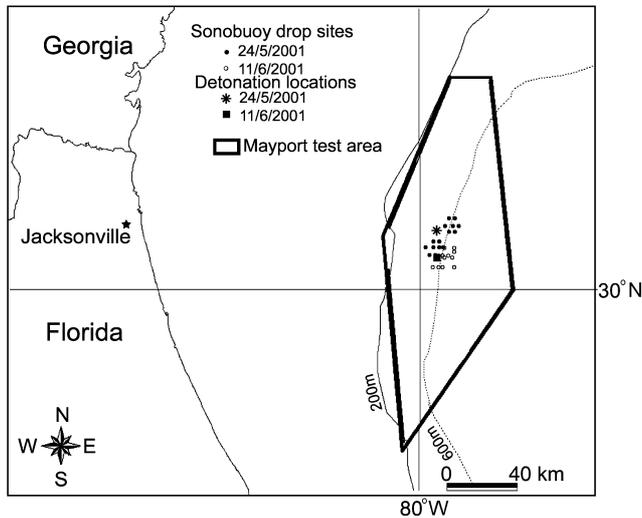


Fig. 4. Pre-detonation DIFAR sonobuoy drop locations in relation to test locations on 24 May and 11 June 2001, in support of shock trial environmental mitigation.

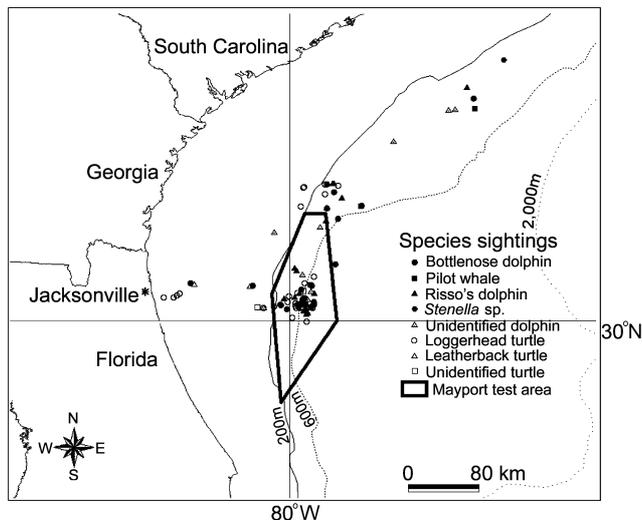


Fig. 5. Marine mammal and sea turtle sightings collected during post-detonation aerial and vessel monitoring in support of shock trial environmental mitigation, Spring 2001.

DISCUSSION

Environmental mitigation was designed to lesson the impact(s) of the shock trial on marine mammals and sea turtles (Department of the Navy, 2001; Reeves and Brown, 1994). The primary objective was to ensure, to the best of our ability, that there were no detectable marine mammals or sea turtles within the Safety Range (3.7km radius) and thereby prevent death or injury. Mitigation objectives did not include research or data collection for any purpose other than to keep the Safety Range clear of detectable marine mammals and sea turtles. Consequently, several sightings were not identified to species because the emphasis was on detection rather than identification. Group size was

estimated only for purposes of re-identifying the same group to confirm it was clear of the Safety Range. Line transect methodology was not used during most monitoring surveys, as the aircraft was often re-directed to confirm that sightings were out of the Safety Range. The resulting data collected during shock trial mitigation are not equivalent to data collected during research surveys, and cannot be used for density or abundance calculations. Despite these limitations, environmental mitigation of the *Winston S. Churchill* ship shock trial represents one of the most intensive monitoring efforts for this geographic area.

Sightings

The species sighted are in agreement with those species sighted in this area during previous survey efforts that took place during the same time of year (Department of the Navy, 1995; Department of the Navy, 1998; Department of the Navy, 1999), with the exception of sperm whales and rough-toothed dolphins (*Steno bredanensis*), which were not seen during the shock trial. Bottlenose dolphins are often found along the continental shelf break (waters >25m), extending into continental slope waters (Kenney, 1990). They were also the most commonly sighted species (number of groups) during a ship-based, line-transect survey conducted between Maryland and central Florida to the boundary of the US Exclusive Economic Zone (EEZ) (Mullin and Fulling, 2003). Sightings of pilot whales within the US Atlantic EEZ are usually associated with the Gulf Stream (Waring *et al.*, 2001), so their presence in the test area was not unexpected. Risso's dolphins are a widely distributed, cosmopolitan species inhabiting deep pelagic and continental slope waters throughout tropical and temperate regions. They occur along the Atlantic coast of North America, therefore their presence in the Gulf Stream region was also expected. They have been sighted associated with the Gulf Stream in the northeastern US along the continental shelf (Waring *et al.*, 1992). Spotted dolphins are commonly found along the southeastern US (Waring *et al.*, 2000). Pygmy killer whales are distributed in tropical and subtropical waters worldwide (Ross and Leatherwood, 1994), overlapping in range with false killer whales, which are distributed in tropical and warm-temperate oceans (Odell and McClune, 1999). Nearly all species observed prior to shock trial tests during site selection and pre-detonation monitoring were also sighted after the tests occurred (see Table 1).

Mitigation effectiveness and evaluation

Overall, the environmental mitigation effort for the shock trial was effective, since no dead or injured marine mammals or sea turtles were detected after the detonations, despite several days of dedicated searching. The success of this mitigation effort emphasises the need for future shock trials and other activities of this size and scope to employ similar procedures. It is important to note that this mitigation was designed specifically for this shock trial, and would not necessarily be appropriate for other types of activities. Generally, individual activities each have unique factors (location, time of year, type of activity, potential effects) that need to be addressed, and environmental mitigation should be specifically planned and implemented separately for each activity.

Nonetheless, some elements of this mitigation effort would be essential for nearly all marine mammal and sea turtle mitigation activities. For example, the mitigation team leader should be familiar both with marine mammal and sea turtle survey techniques, as well as with the activity to be mitigated, to be able to quickly and appropriately respond to

unforeseen situations. Experienced and trained observers are crucial for detecting and tracking marine mammals in the Safety Range; if those animals had not been detected, they likely would have been killed or mortally injured. Animals killed or injured as a result of the tests likely would have resulted in delays and postponements of the shock trial effort, at significant additional cost. Monitoring the Safety Range absolutely requires aerial and vessel observers working in tandem. Aerial coverage provides the means to monitor fairly large areas in a short amount of time, as well as the means to quickly investigate possible sightings at the outer limits of the Safety Range. Vessel observers are able to monitor all of the Safety Range from their central position near the detonation site, and track mammals and turtles as they leave the area. Incorporating only one of these platforms would not provide the coverage needed for adequate monitoring of a test of this magnitude. Cooperation, assistance and support from the shock trial team are also essential to the successful implementation of environmental mitigation, and allowed for smooth handling of the small problems that inevitably arose. Flexibility is critical in mitigation planning and implementation. All participating organisations, including the shock trial team, mitigation team, ship's force and sponsoring and regulatory agencies, must be keenly aware that adjustments to plans may be required as the trial proceeds, and be willing to work closely and effectively to expedite any changes. The mitigation of the *Winston S. Churchill* shock trial was greatly enhanced by including a NMFS representative within the on-site monitoring team. As unforeseen circumstances presented themselves (e.g. bio-acoustic monitoring system unavailable; redesigning pre-detonation aerial monitoring to account for Gulf Stream currents), they were immediately discussed and alternative courses of action quickly implemented.

Despite the success of the mitigation effort, there are some elements of mitigation planning and implementation that should potentially be reassessed as to their usefulness and effectiveness.

- (1) Bio-acoustic monitoring of the shock trial was the most expensive mitigation component to design and implement, however no large whales (e.g. mysticete or sperm whale) were heard or seen during the entire shock trial period. Tests that are conducted during time periods and in geographic areas where, based on previously collected data, large whales are not likely to occur probably do not require bio-acoustic monitoring. Bio-acoustic monitoring that focuses on detecting marine mammal species that are difficult to detect visually (e.g. cryptic species, deep divers) would likely be more useful, but is logistically and methodologically difficult to implement (Barlow *et al.*, 1997). Therefore, bio-acoustic monitoring should be reconsidered as to need, purpose, cost and benefit.
- (2) Pre-detonation aerial monitoring was possible with a single aircraft, but a second aircraft on-site would have improved overall coverage. With two aircraft available for monitoring immediately prior to the planned detonation, monitoring of both the detonation site and the outer areas of the Safety Range would have been more effective. This would likely have reduced the number of test delays as well as provided better coverage of the area, reducing potential risks even further. Two survey aircraft in a fairly confined airspace (~25km²) would require greatly improved air traffic control to ensure flight safety. Flight safety risks could

be significantly reduced with the addition of detailed briefings of all shock trial aerial support (mitigation and operational) conducted immediately prior to each test.

- (3) Operational requirements will probably dictate that future shock trials should continue to be conducted in the Gulf Stream. Post-detonation aerial monitoring should be increased (e.g. more survey days and more hours surveyed per day) because it is the main search platform for detecting dead or injured animals, which can move rapidly with the Gulf Stream current, and may not surface for a few days. If aerial post-detonation monitoring is increased, MART responsibilities could be limited to recovery of dead or injured animals only. If aerial post-detonation monitoring is not increased, the MART vessel should be better equipped for marine mammal and sea turtle observations (e.g. additional observers, *Bigeyes* binoculars, laptop computer with tracking program, etc) because without the aerial support, the MART becomes the principal post-detonation search platform. Weather and sea state conditions can hinder post-detonation aerial and vessel monitoring, which should be adjusted to ensure that monitoring is adequate enough to detect dead or injured animals.
- (4) The EIS process included selecting the test area that was least likely to negatively impact marine mammals and sea turtles. The three test areas considered for the shock trial (Norfolk, VA; Mayport, FL and Pascagoula, MS) were evaluated based on the best available data (Department of the Navy, 2001), and the Mayport test area was eventually selected. However, marine mammal and sea turtle data for the three test areas were collected during survey efforts that were not similar in timing, design or scope. Marine mammal and sea turtle data collected prior to the planning process in all potential test areas during concurrent time periods and using the same methodology should provide better and more equal data. This would enhance the test area selection process, whereby marine mammal and sea turtle abundance in all potential test areas would be more easily evaluated and the test area least likely to be negatively impacted more definitively identified. Although dedicated surveys can be expensive, the costs incurred would be offset by more accurate and reliable data on abundance estimates, distribution, and seasonality of marine mammals and sea turtles in all proposed test areas. This would ultimately decrease the potential for impacts to these animals during the shock trial, as well as potentially decrease the number of costly shock trial delays and postponements caused by animals in the area.

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