CRM D0014936.A4/1REV
March 2007

Sonar Use and Whale Strandings: Caribbean/SE U.S. Correlation Analyses

Ronald J. Filadelfo · Edward S. Michlovich ·
Jonathon D. Mintz · Crystal L. Parker ·
Jessica S. Wolfanger

(Outside contributing author: A.D. D'Amico
SPAWAR Systems Center, San Diego)

CNA

4825 Mark Center Drive • Alexandria, Virginia 22311-1850

Approved for distribution: March 2007

Alan J. Marcus, Director
Infrastructure and Readiness Team
Resource Analysis Division

Approved for Public Release; Distribution Unlimited. Specific authority: N00014-05-D-0500.
Copies of this document can be obtained through the Defense Technical Information Center at www.dtic.mil
or contact CNA Document Control and Distribution Section at 703-824-2123.

Contents

Summary

Background and tasking

Marine mammals routinely strand along U.S. shorelines and in many other parts of the world. In most cases, the cause of strandings is unknown. Some identified causes include disease; parasite infestation; harmful algal blooms; injuries from ship strikes or fishery entanglements; and exposure to pollution, trauma, and starvation. A handful of mass strandings[1] of marine mammals coincided in time and location with Navy sonar operations at sea. Although a conclusive "cause and effect" relationship has not been established, there is concern that military sonars could cause marine mammals, particularly beaked whales, to strand [2-10].

Most previous attempts to determine whether military sonar use contributes to whale strandings have looked at individual events and pointed out those instances in which military operations seemed to coincide in time and location with a whale mass stranding. However, the Marine Mammal Commission Beaked Whale Workshop [11] and [12] suggest that a more objective retrospective analysis of stranding and naval operation data is necessary.

Last year, CNA and SPAWAR Systems Center, San Diego, worked together on the first objective retrospective study of this type [13]. Using the best available information on beaked whale mass strandings in the Mediterranean Sea and in the waters around Japan, and an objective compilation of information on naval operations from both open and classified sources, we found a strong correlation between sonar activity and strandings in the Mediterranean, but no correlation in Japan. Our findings were consistent with previous

1. A mass stranding is defined as two or more animals, not a mother/calf pair [1].

hypotheses [14, 15] of a potential link between strandings and acoustic propagation conditions, specifically the presence of surface ducts. We stated, however, that more work needs to be done on the potential implications of surface ducts.

The Environmental Readiness Division in the office of the Chief of Naval Operations (CNO-N45) asked us to perform an additional study of the correlation between military sonar use and mass strandings, looking at additional regions of concern. We were asked to address the following specific questions:[2]

- Using the statistical methods developed in [13], what is the level of correlation between naval operations and mass strandings in
  - The Caribbean Sea?
  - The southeast U.S. coast?
- Are there any operational or environmental conditions under which naval activity seems to correlate with strandings?
  - How do findings in this regard compare with those from previous studies of the Mediterranean Sea and off the coast of Japan?
  - Are consistent patterns emerging?

Analytical approach

Previous anecdotal examinations have usually counted only the number of instances in which strandings and military operations seemed to coincide. They have not examined the important related questions of how many times military operations took place without any observed impact on whales, or how often mass strandings

2. Within this study we were also tasked to analyze the events associated with the appearance of 150 Melon-headed Whales in Hanalei Bay, Kauai, during the early stages of RIMPAC-2004. The results of that study are described in [16].

occurred in the absence of military operations. Among the first to address this important issue was D'Amico et al. [14].

An objective look at the correlation between naval operations and strandings requires both a valid statistical technique and representative samples of naval operations and whale strandings.

For our statistical analyses, we use a standard statistical test (chi-squared test) of proportions, to examine the significance of observed differences between stranding rates when naval activity is taking place and when it is not.

We used various sources to build our datasets of strandings and naval operations. However, we are quite certain that we have not captured every whale stranding event or naval operation that took place in the regions we studied. Fortunately, for a study such as this one, neither of the datasets need to be complete. However, the data must be unbiased. For example, if whale stranding networks focused all their data gathering effort on times and locations of naval operations, a biased sample would result. Or, if we looked only at naval exercises in areas where we knew stranding observations were not made, a bias the other way would result. We have no reason to believe that our data suffer from biases in either direction.

Procedure and supporting data

Procedure

We first defined the two regions for study, as follows:[3]

- Caribbean
  - Time period: 1980-2000
  - 10 to 27 degrees north by 086 to 060 degrees west
- Southeast U.S coast

3. The time periods for each region were based on availability of stranding and naval operations data.

— Time period: 1987-2003

— 27 to 40 degrees north by 082 to 070 degrees west

Next, we compiled information on mass strandings and on naval operations and plotted the events on timelines to look for instances of coincidence.

After determining whether the stranding data was constant over time, we performed statistical tests to quantify the level of correlation between strandings and naval activity.

Finally, we looked at potential environmental factors that might relate to stranding incidence, including the acoustic propagation path and bathymetry relative to the locations of naval operations.

Supporting data

SPAWAR Systems Center, San Diego, (SSC-SD) compiled data on beaked whale mass strandings in the Caribbean from 1980 to 2000. For the southeast U.S., we obtained NOAA's stranding database,[4] which included multiple species.

We compiled data on naval operations from various sources, including an unclassified literature and internet search and the classified sources noted below:

- We searched the Navy's Employment Schedule Database [17], resident at CNA. This includes data from 1977 to present. To identify events in which mid-frequency sonar was likely used, we extracted all records for underway Cruiser-Destroyer (CRUDES) ships in which the activity field indicated likely anti-submarine (ASW) operations and sonar use (ASWEX, COMPTUEX, FleetEx, etc.).
- We reviewed the archive of the Navy Command Center's daily OPNOTES; CNA archives these daily summaries of worldwide Navy operations for the Navy Command Center in the

4. Personal communication between R. Chase of CNA and J. Litz of NOAA Fisheries, Miami, March 2006.

Pentagon. This data covered 1998 to present, with a 3-month gap in 1998 and a 5-month gap in 2001. We obtained amplifying information on many exercises from various CNA exercise reconstruction reports.

- We visited the Operational Archive maintained by the Navy Historical Center at the Washington Navy Yard. We reviewed the annual command history documents for COMSECONDFLEET, plus various related message traffic and planning documents.
- We also visited the Ship History Branch of the Navy Historical Center at the Washington Navy Yard, and reviewed ship deck logs for some cases in which we needed amplifying information, such as the type of exercise or the general location.

We obtained sound-speed profiles from the Navy's Generalized Digital Environmental Model (GDEM) version 3.0 [18]. GDEM provides climatological profiles every 15 minutes of latitude and longitude (i.e. 16 profiles per 1-degree by 1-degree box). Actual conditions at the times of specific events could vary from the climatological profiles used here.

Caveats

Despite our assumption that the data used for this study are unbiased, a few caveats remain:

- Correlation is not the same as causation.
- We noted that our stranding data and naval operation data are not complete; we cannot even estimate what fraction of the population of events our data captures. Have we captured 90 percent of the strandings, or only 10 percent?
- Sonar use was inferred based on type of naval exercise. In general we do not know whether, or how much, active sonar was actually used. Therefore, our correlation analyses are really between strandings and *naval operations in which sonar was likely used.*

- Our discussion of the potential effects of acoustic propagation path, based on climatological conditions, is very preliminary. We include it because it has been suggested as a factor in previous studies (including our own), and because the Navy already factors the presence of surface ducts into its exercise mitigation plans. However, as the Bahamas incident clearly showed, actual propagation conditions can vary greatly from climatological conditions, and could be a major factor.

Summary of findings

We found a statistically significant correlation between beaked whale mass strandings and naval operations in the Caribbean, but no significant correlation for the southeast U.S.

We used climatological sound speed profiles to look at acoustic propagation path in these two regions. In the Caribbean we saw ducting conditions in most places throughout the entire year. Most notably, the four locations where we observed coincidence between strandings and naval operations were all ducting (according to climatology): the Bahamas in March, Jamaica in April, Puerto Rico OPAREA (PROA) in July, and the U.S. Virgin Islands (USVI) in October. For the southeast U.S., ducting conditions vary with season and are not present in all months. The instance in this region in which we observed coincidence between strandings and naval operations showed ducting conditions (according to climatology) in the Navy operating areas offshore of the stranding locations. This is consistent with the findings of our earlier study of strandings in the Mediterranean and near Japan, again suggesting that ducting conditions may to come into play. This association with ducting conditions remains tentative, however, because many of the observed surface ducts were very weak and do not meet the current Navy definition of "strong duct." We hope to obtain in situ sound speed profiles for these locations to enable further study.

We also looked at the differences in topography between the two regions. Beaked whales tend to cluster where the topography drops off steeply to deep waters, such as at the shelf break or around trenches. Along the East Coast this is occurs far from land, and naval operations tend to be shoreward of this area. In the Caribbean, and especially in the areas where stranding and naval operations coincided, the drop-off is near shore and naval operations take place seaward. Thus, we may have a situation whereby, in the Caribbean, naval operations tend to drive the whales on shore, but off the southeast U.S., the whales are seaward of the operations and can thus swim out to sea to avoid naval operations. These conclusions are still preliminary, and we hope to examine this issue further in subsequent studies.

Organization of this report

The next chapter discusses the correlation analyses for the Caribbean and the southeast U.S. For each region, we ~~first~~ present timelines of naval operations and strandings, followed by the statistical tests for correlation.

The final chapter discusses potential environmental factors that may come into play: propagation path and topography.

Correlation analyses

Caribbean

Timelines

For analysis purposes we divided the Caribbean into three areas: the Puerto Rico OPAREA (PROA), where until recently the Navy has conducted many large-scale exercises; the Bahamas, which contains the Navy's AUTEC range; and the rest of the Caribbean (labelled "Other" in figures 1, 2, and 3, below).

Figures 1 through 3 show periods of naval activity (blue bars) and times of beaked whale mass strandings (red and green lines) in each of these three areas. The green lines indicate strandings that did not coincide with naval activity; the red lines indicate strandings that did. All the stranding events shown in these figures involved the species Ziphius cavirostris (Zc), Cuvier's Beaked Whale.

Figure 1. Timeline of naval operations and strandings, Caribbean, 1980-1986

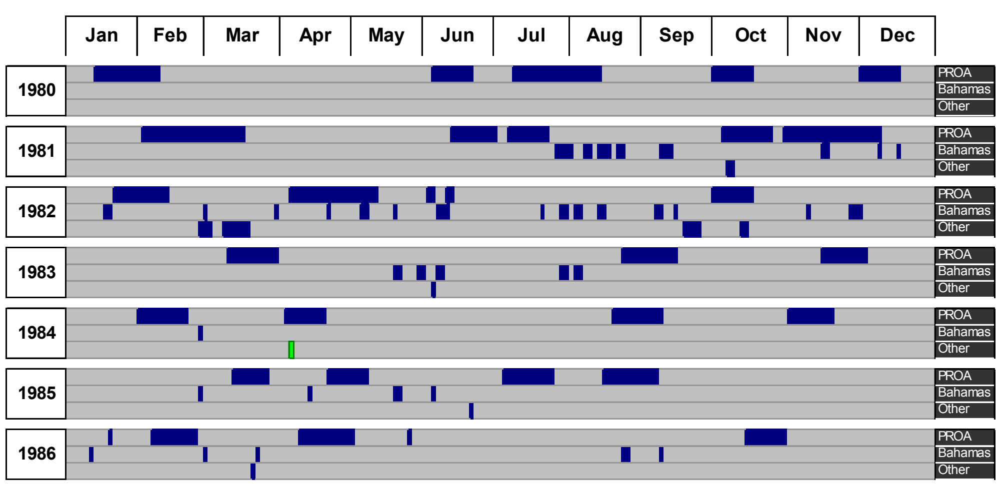


Figure 2. Timeline of naval operations and strandings, Caribbean, 1987-1993

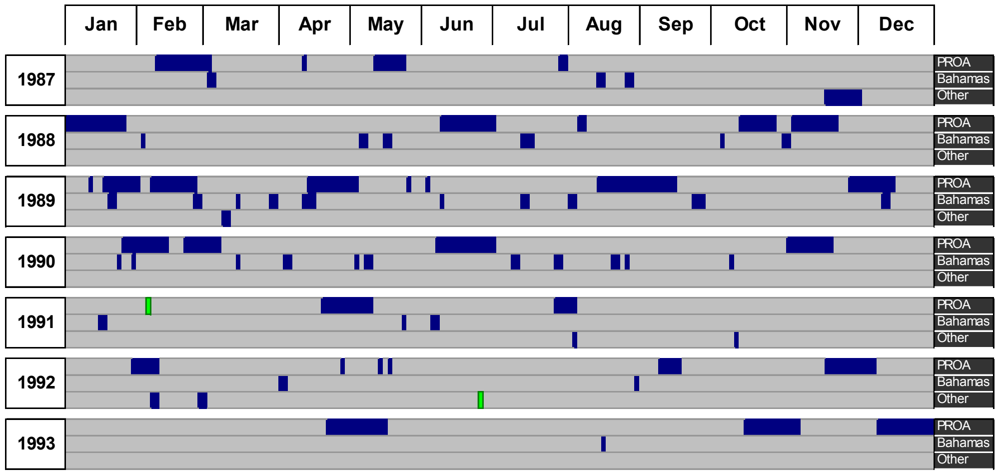
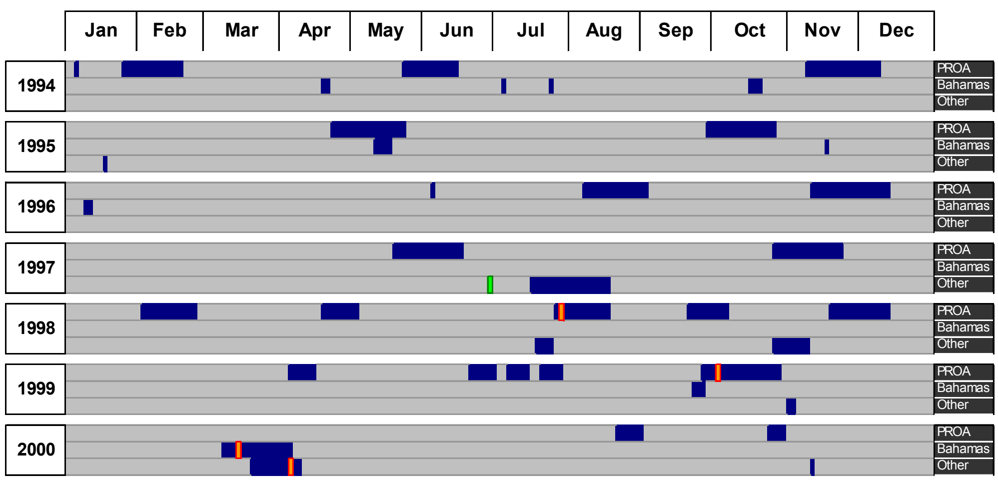


Figure 3. Timeline of naval operations and strandings, Caribbean, 1994-2000



During the 11-year period from 1980 through 1990, only one stranding was reported, but during the 10-year period from 1991 through 2000, seven strandings were reported. This raises three concerns for a statistical analysis of this data set:

- How good is the data on strandings before 1990? Were they not being reported?
- In the 1980s the U.S. Navy's emphasis was on deep water ASW. In the 1990s the USN began to emphasize shallow water ASW, with an increased emphasis on active sonar, so the way the Navy was using sonar may be quite different in the two time periods.
- The rate of strandings does not appear constant over time, although the level of naval activity appears to be relatively constant. In fact, a test for homogeneity (shown in tables 1 and 2 below) confirms this impression.

Is the stranding rate constant?

Looking at figures 1 through 3, the stranding rate from 1997 through 2000 appears to be much higher than in the earlier periods. We tested this hypothesis by putting the data into 4-year bins, shown below in table 1:

Table 1. Chi-squared test for time variation in stranding rate, Caribbean, 1980-2000

	80-84	85-88	89-92	93-96	97-00	Total
Observed Strandings (O)	1	0	2	0	5	8
Years	5	4	4	4	4	21
Expected Strandings (E)	1.9	1.5	1.5	1.5	1.5	
$(O\text{-}E)^2 / E$	.43	1.52	.14	1.52	7.93	$\chi 2 = 11.6$

The results in table 1 yield a significance level of 0.009 (for three degrees of freedom). Therefore, under the assumption of a constant stranding rate, the probability of this much variation being solely due to chance is 0.009, so we conclude that the difference in 1997-2000 is statistically significant at the 1-percent level.

Examining the 1991-2000 data for homogeneity, we get the data shown in table 2 :

Table 2. Chi-squared test for time variation in stranding rate, Caribbean, 1991-2000

	91	92	93	94	95	96	97	98	99	00	Total
Observed Strandings (O)	1	1	0	0	0	0	1	1	1	2	7
Expected Strandings (E)	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	
$(O-E)^2 / E$	.13	.13	.7	.7	.7	.7	.13	.13	.13	2.4	$\chi 2 = 5.9$

The results in table 2 yield a significance level of 0.66 (for eight degrees of freedom), so the probability of this much variation being solely due to chance is 0.66. Therefore, we accept the hypothesis of constant stranding rate over this 10-year period. As a result, our statistical analyses will focus on the 10-year period from 1991 through 2000.

Correlation analysis

Overall, four of the seven strandings from 1991 through 2000 coincided with naval operations. The four that coincided with naval operations were:

- PROA, July 1998 – Enterprise battle group COMPTUEX, stranding position 18.43N / 67.18W
- USVI (adjacent to PROA), Oct 1999 – COMPTUEX, stranding position 18.18N / 64.80W
- Bahamas, March 2000 (the well-known "Bahamas event") – stranding position 26.02N / 77.4W
- Jamaica, April 2000 – UNITAS Caribbean Phase (ships underway in Caribbean), stranding position 18.47N / 77.92W

Of the three strandings that did not coincide with naval operations, the stranding in June 1997 is particularly interesting. It occurred in the Dutch Antilles about 2 weeks before the start of the UNITAS-39 Venezuela / Colombia phase, which was in that general area. It is possible that the Venezuela and/or Colombia navies were conducting some ASW events pre-UNITAS, but we found no supporting data, so we consider it uncorrelated. The other two strandings were in February 1991 (USVI) and June 1992 (Florida Keys).

We performed a standard test of proportions on the difference in stranding rates between the times sonar activity was occurring and when it was not occurring. By dividing the Caribbean into three regions, we obtained 10,950 (10 years x 365 days/year x 3 regions) region-days from 1991 to 2000. For the sonar periods, we observed four strandings during the 733 region-days of sonar activity. For the non-sonar periods, we observed three strandings during the 10,217 region-days of non-sonar activity. The stranding rate during the sonar periods certainly seems higher, but is this difference significant?

To examine the correlation between naval activity and strandings we assume each region-day represents an independent draw from a binomial distribution. We count a success if a stranding occurs and a failure if not. Let p_n be the daily probability of stranding when sonar is not present and p_s be the probability when it is present. The null hypothesis (H_0) is that there is no difference between the sonar and non-sonar stranding rates,

H_0: $p_n = p_s$,

The alternative (H_A) is that the sonar rate is higher,

H_A: $p_s > p_n$

Recall that in the 10-year period from 1991 to 2000 we have 3 x 10 x 365 = 10,950 region-days, 733 sonar-days, 7 total strandings, and 4 sonar-coincident strandings. The estimated stranding rate under the null hypothesis is $p_{est} = 7/10950 = 0.0006$ strandings per region-day. If there is no difference in stranding rates, the expected number of strandings on sonar-days is $733 * p_{est} = 0.47$. However, the observed number of strandings on sonar days is 4. The likelihood of this difference occurring due to chance fluctuations can be calculated using the Poisson approximation to the binomial: the probability of observing 4 or more strandings in 733 region-days when p_{est} is the true stranding rate is given by:

$$P = 1 - \sum_{x=0}^{3} \frac{e^{-\mu} \cdot \mu^{x}}{x!}$$

With $\mu = 733\, p_{est}$, P = 0.0014, so we would reject the null hypothesis (and thus conclude that the stranding rate is indeed higher during sonar-days), at the 1-percent level, or with an achieved significance level of 0.0014.

Southeast U.S.

Timelines

We divided the southeast U.S. analysis region into three areas: the Virginia Capes (VACAPES), an OPAREA where the Navy conducts many large-scale exercises; off the Florida coast near Jacksonville (JAX), another heavily used Navy OPAREA; and the rest of the southeast U.S. region (labelled "Other" in figures 4 and 5, below). Unlike the stranding data we used for the Caribbean, strandings for the southeast U.S. include several species[5]. All of the mass strandings for the SE U.S. are listed in table 3.

Table 3. Mass strandings, southeast U.S., 1987-2003

Species	Date	Lat (North)	Long (West)	Analysis Area
Pygmy Sperm	23 Aug 1987	27.87	80.45	JAX
Pygmy Killer	7 May 1988	31.00	81.42	JAX
Sperm	19 Apr 1990	27.40	80.27	JAX
Pygmy Killer	12 Apr 1991	30.85	81.42	JAX
Pygmy Killer	30 Mar 1992	28.67	80.58	JAX
Short-finned Pilot	3 Nov 1993	30.20	81.37	JAX
Pygmy Sperm	21 Nov 1993	29.67	81.20	JAX
Short-finned Pilot	17 Feb 1994	30.45	81.43	JAX
Short-finned Pilot	26 Feb 1994	36.45	75.85	VACAPES
Pygmy Sperm	11 Dec 1995	29.35	81.07	JAX

5. We do not know if all the multispecies strandings in this NOAA data set have been fully validated. Restricting this analysis to beaked whales only would not change the overall findings.

Table 3. Mass strandings, southeast U.S., 1987-2003 (continued)

Species	Date	Lat (North)	Long (West)	Analysis Area
Short-finned Pilot	1 Jan 1998	28.92	80.82	JAX
Gervais' Beaked	28 Aug 1998	35.00	76.37	VACAPES
Long-finned Pilot	6 Nov 1998	29.67	81.22	JAX
Cuvier's Beaked	17 Jun 2001	27.67	80.38	JAX
Pygmy Sperm	4 Apr 2002	35.77	75.55	VACAPES

Figures 4 and 5 show periods of naval activity (blue bars) and times of mass strandings (red and green lines) in each of the three areas of the U.S.

Figure 4. Timeline of naval operations and strandings, SE U.S., 1987-1995

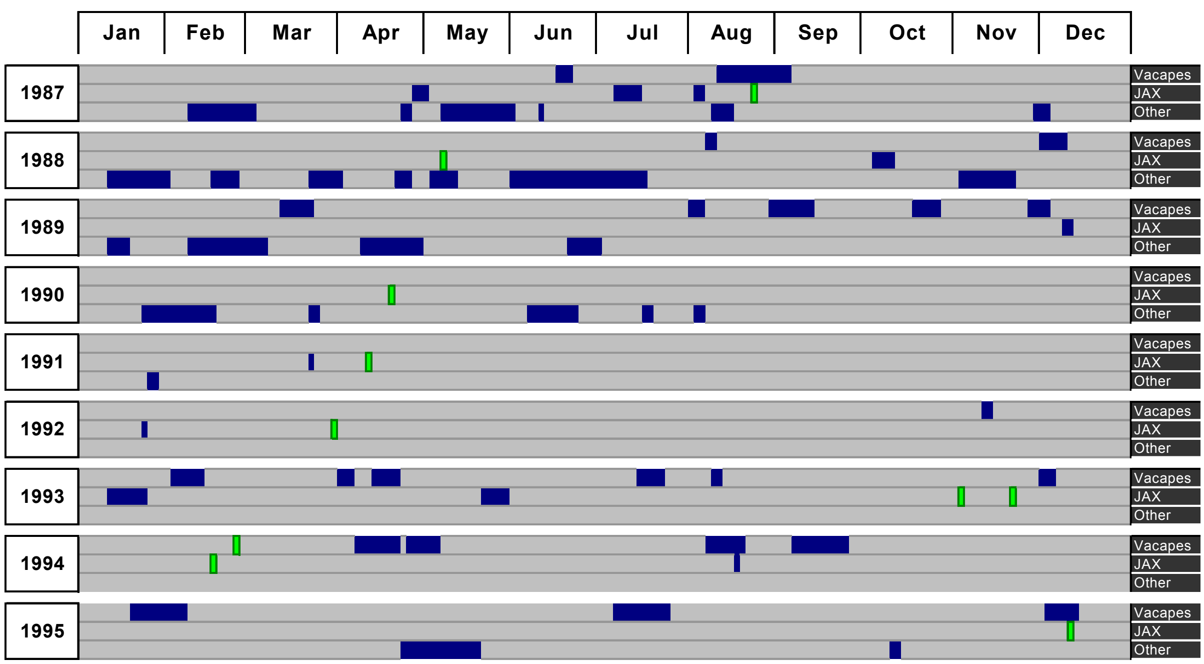
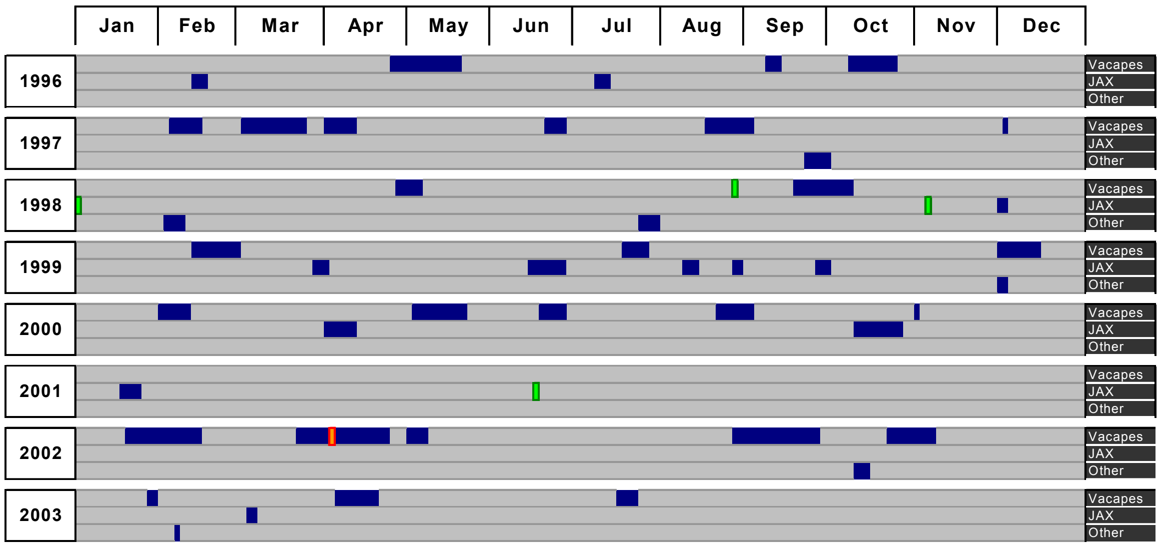


Figure 5. Timeline of naval operations and strandings, SE U.S., 1996-2003



Is the stranding rate constant?

As we did for the Caribbean data, we first determine if the stranding rate is constant over the period covered by our data. Details of this analysis are shown in table 4. A $\chi 2$ value of 13.3 for 15 degrees of freedom yields a significance level of 0.64, so we assume the stranding rate to be constant over time.

Table 4. Chi-squared test for time variation in stranding rate, southeast U.S.

	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	Total
Observed Strandings (O)	1	1	0	1	1	1	2	2	1	0	0	3	0	0	1	1	0	15
Expected Strandings (E)	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	
$(O-E)^2 / E$	.02	.02	.88	.02	.02	.02	1.42	1.42	.02	.88	.88	5.08	.88	.88	.02	.02	.88	$\chi 2=13.3$

Correlation analysis

Overall, one of the fifteen mass strandings coincided with naval operations:

- Outer banks of North Carolina, April 2002 – Pygmy Sperm Whales; coincided with a COMPTUEX in the VACAPES OPAREA

By dividing the southeast U.S into three regions, we obtained 18,615 (17 years x 365 days/year x 3 regions) region-days from 1987 to 2003. For the sonar periods, we observed 1 strandings during the 1,862 region-days of sonar activity. For the non-sonar periods, we observed 14 strandings during the 16,753 region-days of non-sonar activity. The stranding rate during the sonar periods in fact seems lower, but is the difference significant in this case? We will now apply the same statistical model that we applied to the Caribbean data.

The estimated stranding rate under the null hypothesis is p_{est} = 16/ 18615 = 0.00081 strandings per region-day. If there is no difference in stranding rates, the expected number of strandings on sonar-days is 1862 * p_{est} = 1.5. The observed number of strandings on sonar days is 2. The likelihood of observing two or more strandings if there is no difference in stranding rates is given by:

$$P = 1 - e^{-\mu} = .78$$

Thus the observed number of strandings during sonar days is not inconsistent with the (null) hypothesis of no difference in stranding rates between sonar and non-sonar days. Therefore, we do not conclude that strandings are more likely or less to occur when sonar is present.

Potential environmental factors

Once again we have conflicting results from our correlation studies: one region shows a correlation (Caribbean), and one region does not (southeast U.S.). We will now look at two important environmental factors – topography and sound propagation path – to try to explain the differences in results between these two regions.

Acoustic propagation path

We generated acoustic propagation path maps for a source at 8 meters depth, for each region, as a function of month of the year. We used climatological sound speeds from the Navy's GDEM sound speed profile database. We characterized the propagation path as one of the following: downward refracting, convergence zone, surface duct, or duct-over-CZ.

In January, both areas are dominated by surface ducts or duct-over-CZ. As spring warming progresses off the southeast U.S., we begin to see the disappearance of some of the ducting as surface waters warm. Much of the deeper areas that were duct-over-CZ have lost the surface ducts, and we see some downward refracting close to shore off of Florida. In the Caribbean, the ducting conditions tend to remain present, due to the mixing influence of the trade winds. In the summer, the southeast U.S. coast and shelf is almost all downward refracting, with CZ propagation in deep waters, but we continue to see ducting conditions in much of the Caribbean. By October, much of the ducting conditions have returned to the southeast U.S., and the Caribbean is all ducting (or duct-over-CZ).

We found that, in the Caribbean, ducting conditions exist in most places throughout the entire year. The four times and places where we observed coincidence between strandings and naval operations were ducting: Bahamas in March, Jamaica in April, PROA in July, and USVI in October. The southeast U.S. was not ducting in all months, but the stranding that coincided with naval operations was south of the Chesapeake mouth in April, when ducting conditions were present in the Navy operating area offshore of the stranding locations.

As we noted in our previous study [13], this potential association of Navy-coincident strandings with ducting conditions, first speculated in [2] and [15], is still tentative for two reasons.

- Many of the climatological surface ducts we observed here are weak. In fact, the propagation conditions meet the criteria for "strong duct" (as specified in recent Navy environmental assessments [19]) in only two of the six cases noted above: Bahamas, March 2000; and USVI, October 1999.
- We based these observations on climatological sound speed profiles. As the investigation of the Bahamas incident showed, actual conditions can vary greatly from climatological norms [2].

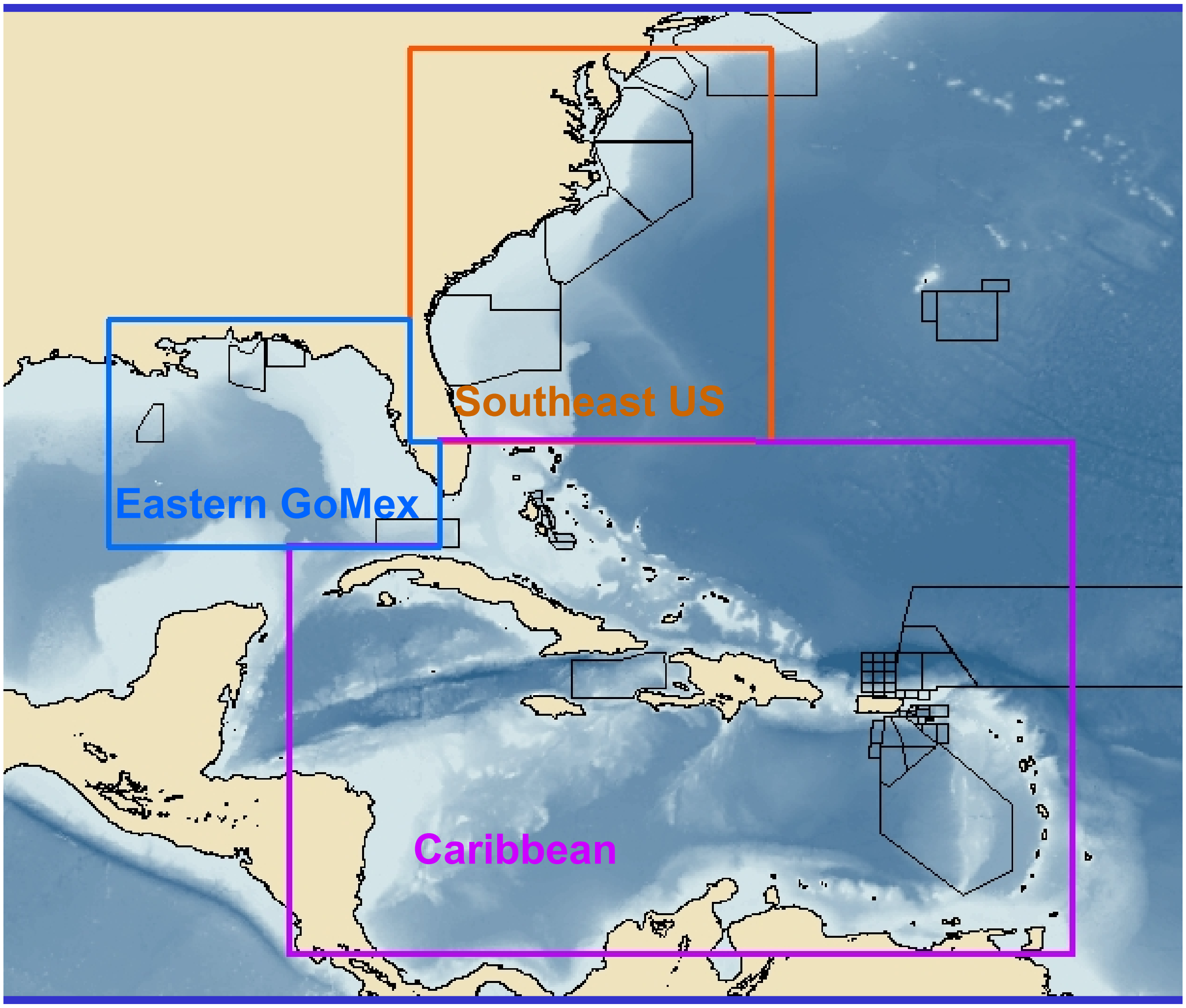
Other potential factors

Figure 6 shows a broad-area map of the bathymetry for the Caribbean and the southeast U.S., with the major Navy operating areas superimposed.

In the Caribbean the drop offs tend to occur quite close to shore, with most of the naval operations to the seaward of the drop-off. This is especially prominent near Puerto Rico and the U.S. Virgin Islands, where we saw coincidence between naval operations and beaked whale mass strandings. This is not the case, however, for most of the southeast U.S. (particularly the area south of the Virginia Capes), where the shelf break (generally coincident with the 200-meter contour) is far from shore and much of the Navy operating area is shoreward of the drop-off.

We also looked to see where the Navy tends to operate, relative to bathymetry and likely whale locations. To do this we estimated patterns for Navy surface vessel traffic throughout the SE U.S. over the last five years, using the data and methods described in [20]. We

Figure 6. General bathymetry and Navy operating areas, Caribbean and SE U.S.



interpolated between known positions to generate estimated hourly positions for each vessel movement. Each resulting datapoint represented a vessel's hourly position, estimated to a 15-minute resolution (i.e., a .25-degree-latitude x .25-degree-longitude box). We then counted these points for each 15-minute geographical box.

We then looked at a distribution of ship-hour counts for all of the 15-minute boxes, over the entire area of interest. Figure 7 shows the resulting pattern of Navy operations off the southeast U.S. If the number of ship-hours counted in a given 15-minute box was in upper quartile in terms of traffic density (i.e., the top 25 percent of all boxes), we shaded it with a "+". If it fell in the second quartile (i.e., next highest in terms of traffic density), we shaded it with a "-"; the third quartile is shaded with a ":", and the bottom quartile boxes are left blank[6].

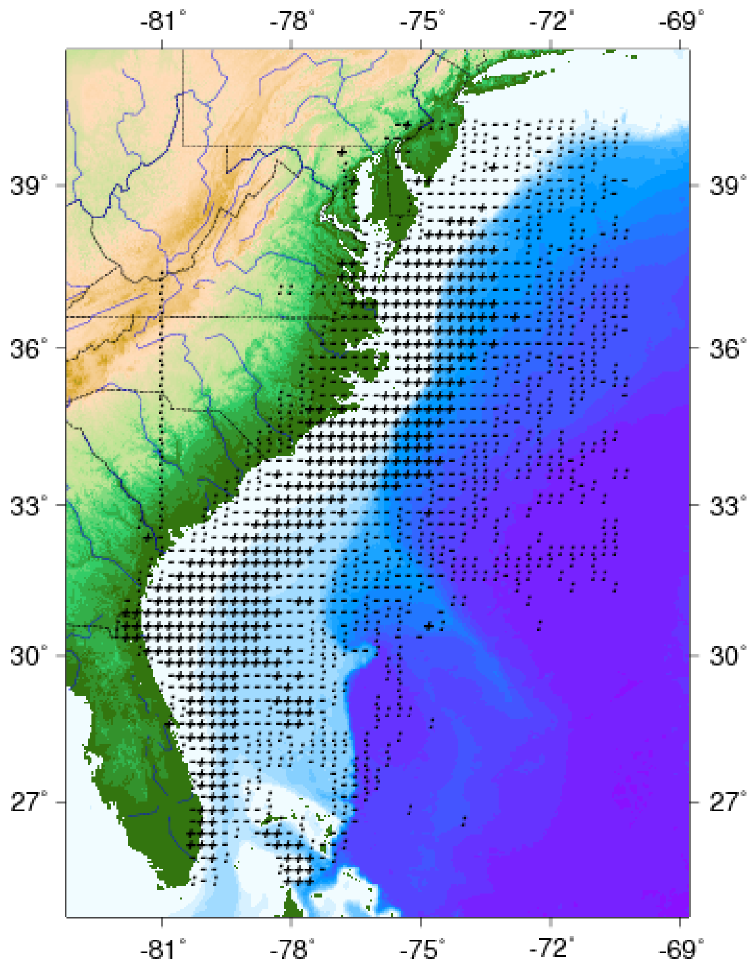
The majority of the Navy operations off Florida occur well within the drop-off where the whales tend to congregate. Similarly in the VACAPES area, much of the Navy traffic is inside the drop-off[7].

Beaked whales tend to cluster where the topography drops off to deep waters – such as at the shelf break or around trenches. Along the east coast this is far from land and naval operations tend to be shoreward of this. In the Caribbean, and especially in the areas where we had stranding/naval coincidence, the drop-off is near shore and naval operations take place to the seaward. Thus, we may have a situation whereby in the Caribbean naval operations tend to drive the whales on shore but off the southeast U.S. the whales are seaward of the operations and can thus are not driven ashore by naval operations.

6. The few data points indicated over land are the result of interpolating positions between sporadic reports.

7. An important caveat: The pattern of Navy vessel traffic shown includes transits as well as exercises and operations involving sonar. We plan to study this further by generating maps for Navy sonar exercises and operations only, similar to those we compiled in our correlation analyses.

Figure 7. Navy traffic pattern, SE U.S.



References

[1] R. Geraci and V.J. Loundsbury. *Marine Mammals Ashore: A Field Guide for Strandings.* Galveston, TX: Texas A&M University Sea Grant Program, 1993

[2] D L. Evans and G. England. *Joint Interim Report Bahamas Marine Mammal Stranding Event of 15–16 March 2000*, www.nmfs.noaa.gov/prot_res/overview/interim_bahamas_report.pdf

[3] P. Evans and L. Miller. "Introduction." In P. Evans and L. Miller (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans held at the European Cetacean Society 17th Annual Meeting 8 March 2003*, Feb 2004 (European Cetacean Society Newsletter 42 – Special Issue)

[4] V. Martin, A. Servidio, and S. Garcia. "Mass Strandings of Beaked Whales in the Canary Islands." In P. Evans and L. Miller (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans held at the European Cetacean Society 17th Annual Meeting, 8 March 2003*, Feb 2004 (European Cetacean Society Newsletter 42 – Special Issue

[5] Jepson, P.D. et al. "Gas Bubble Lesions in Stranded Cetaceans." *Nature* 425, 9 Oct 2003: 575

[6] R. Gentry. "Mitigation Measures for Use With Military Sonar." In P. Evans and L. Miller (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans held at the European Cetacean Society 17th Annual Meeting, 8 March 2003*, Feb 2004 (European Cetacean Society Newsletter 42 – Special Issue)

[7] L. Freitas. "The Stranding of Three Cuviers Beaked Whales Ziphius Cavirostris in Madeira Archipelago–May 2000." In P. Evans and L. Miller (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans held at the European Cetacean Society 17th Annual*

Meeting, 8 March 2003, Feb 2004 (European Cetacean Society Newsletter 42 – Special Issue)

[8] A. Frantzis, A. "Does acoustic testing strand whales?" *Nature vol* 92, number 29, 5 March 199

[9] A. Frantzis. "The first mass stranding that was associated with the use of active sonar (Kyparissiakos Gulf, Greece, 1996)." In P. Evans and L. Miller (eds.), *Proceedings of the Workshop on Active Sonar and Cetaceans held at the European Cetacean Society 17th Annual Meeting, 8 March 2003*, Feb 2004 (European Cetacean Society Newsletter 42 – Special Issue)

[10] D'Amico, A., ed. "Summary Record and Report, SACLANTCEN Bioacoustics Panel, La Spezia, Italy, 15-17 June 1998; Summary Record, Marine Mammal Environmental Policy and Mitigation Procedures Panel; La Spezia, Italy 17-19 June 1998; SACLANTCEN Human Diver and Marine Mammal Environmental Policy and SACLANTCEN Marine Mammal and Human Diver Risk Mitigation Rules." SACLANTCEN M-133

[11] http://mmc.gov/sound/beakedwhalewrkshp/beakedwhalewrk shp.html

[12] R. Brownell et al. *Mass Strandings of Cuviers Beaked Whales in Japan: U.S. Naval Acoustic Link?*, 2004 (European Cetacean Society Report SC/56E37)

[13] R. Filadelfo, E. Michlovich, J. Wolfanger, and A.D. D'Amico (SPAWARSYSCEN San Diego), *Sonar Use and Beaked Whale Mass Strandings,* Nov 2005 (CNA Annotated Briefing D0012756.A3)

[14] A. D'Amico et al. *Beaked Whale Strandings and Naval Activities*, in preparation, SPAWAR Systems Center, San Diego 2005

[15] G. A. D'Spain, A. D'Amico, and D. Fromm. *Properties of Underwater Sound Fields During Some Well Documented Beaked Whale Mass Strandings.* in press, Journal of Cetacean Research, 2006.

[16] R. Filadelfo. *Reconstruction of Hanalei Bay Whale Incident,* Apr 2006 (CNA CME D0013984.A1)

[17] Karen Domabyl and Patricia Reslock. *Ship Employment Histories and Their Use*, Jul 1986 (CNA Research Memorandum 86-178)

[18] U.S. Navy Oceanographic Office, GDEMV 3.0 Database, https://128.160.23.42/cgi-bin/ gdemv/gdemv_input_v30

[19] U.S. Navy, Commander Pacific Fleet, *2006 Rim of the Pacific After Action Report*, 23 Oct 2006

[20] J. D. Mintz and R. J. Filadelfo. *Estimating Navy and Non-Navy Vessel Traffic in Areas of Interest*, Jul 2004 (CNA Research Memorandum D0010124.A2)

List of tables

List of figures

CRM D0014936.A4/1REV

CNA