MED-09 Final Cruise Report

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Acknowledgments

This project would not have been possible without the support and involvement of a large number of organizations and dedicated individuals. Many of the individuals are identified within their respective teams in the sections below. Here, the co-principal investigators (P. Tyack, A. D'Amico, and B. Southall) and the scientist in charge (Walter Zimmer) and deputy scientist in charge (Kendra Ryan), would like to acknowledge the supporting and participating organizations.

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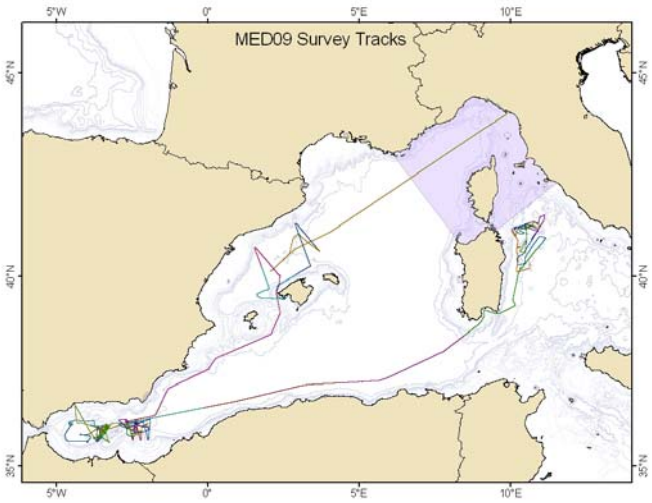
Participating organizations included the following (in alphabetical order): Alnitak Marine Environment, Bluwest, CIBRA, Delfini Metropolitani, IFREMER, SECAC, Museo Natural History Milano, NURC, NUWC, Politech Milano, AMBAR, SEA, Inc., SSC Pacific, and WHOI. This project was carried out under all relevant national and international authorizations for the study of marine mammals, including an environmental assessment by the NATO Undersea Research Centre and a U.S. National Marine Fisheries Service permit (#14241) to P. Tyack.

Finally, we would like to particularly acknowledge the excellent support and collaboration with the NATO Undersea Research Centre (NURC), particularly Jeff Haun and Kendra Ryan, the captain and crew of the R/V Alliance, and the NURC ETD and IT staff.

Executive Summary

A research expedition to study the basic biology of marine mammals in the western Mediterranean Sea and the prevalence and impacts of anthropogenic noise on marine life in these areas was conducted from late July to early September, 2009. This project, notionally referred to as "MED-09", was developed to (1) establish and/or enhance the basic understanding of physical and biological parameters in three specific operational areas (Balearic Islands, Alboran Sea, and Tyrrhenian Sea) and (2) contribute to the scientific capacity to estimate risk and minimize impact of sound-producing activities for navies and regulators internationally. Among the primary objectives were tracking and tagging of several cetacean species, controlled exposure experiments using different sound, monitoring of ambient noise in areas of variable human interaction, and environmental measurements to support habitat modeling.

Operated from the NATO research vessel *Alliance*, based at the NATO Undersea Research Center in La Spezia, Italy, MED-09 was divided into an initial leg (La Spezia to Balearic Islands to Alboran Sea) and, following a port call in Malaga, Spain, a second leg (Alboran Sea to Tyrrhenian Sea to La Spezia). The actual survey track lines are shown in the figure to the right with different colors along the track indicating each survey day; note that the tracks for each day are given individually in Appendix II. Combined, these legs included a total of 39 operational days, 54.5% of which was spent on-effort (survey and focal follow modes), 21.8% of which was off-effort due to unworkable weather conditions, and 23.7% of which was in transit/port or other reasons.



MED-09 achieved some but not all of the specified objectives. Weather and the inability to achieve sufficient range to focal individuals for suction-cup tag attachments were the primary limitations ultimately precluding the tagging of beaked whales. Other obstacles included loss of daylight (many focal follows were initiated late in the day), restrictions on the selection of focal groups arising from permitting stipulations (*e.g.*, presence of calves in focal groups), territorial borders, and other factors (*e.g.*, unscheduled port calls due to injury). While efforts to tag and conduct controlled exposure studies with beaked whales were ultimately not successful for a host of reasons, numerous other major accomplishments were realized. These included:

- Sucessful, repeated detection and extended focal follows of Cuvier's beaked whales using integrated, onboard passive acoustic and visual detection systems (without the benefit of an undersea acoustic monitoring range as had been used in previous studies in the Bahamas);

- Integration and visualization of visual and acoustic data in real time using custom geospatial (GIS-based) software developed for MED-09 (WILD);

- Environmental data collection to support habitat modeling in previously poorly-known areas;

- Production sonobuoy deployment (n=113) for ambient noise measurements in wide areas of the western Mediterranean Sea with variable densities of human activity; and

- Successful tagging and focal follow of two long-finned pilot whales.

The combined results will be of interest and value to scientists and managers working in these biologically important areas of the western Mediterranean Sea. They also demonstrate the feasibility of using integrated visual detections with mobile passive acoustics systems to track difficult-to-study, deep-diving cetacean species such as beaked whales. Studying these species and conducting controlled exposure experiments is extremely difficult for a variety of reasons, as has been seen in both MED-09 and similar work in the Bahamas. However, MED-09 demonstrated that many of the obstacles in terms of detection and tracking individual focal groups can be overcome without the aid of a dedicated, fixed passive acoustic array.

Future efforts should carefully consider all relevant biological, environmental, and other (*e.g.*, regulatory/legal) risk factors in species, site, season selection for operations. Additionally, there is a critical need for careful and systematic dedicated pre-engineering tests for assessing the capabilities and integration of hardware and software systems and platforms. These and other lessons-learned from MED-09 will continue to inform subsequent efforts to obtain direct measurements of behavioral responses of marine mammals to human sounds, including military sonar.

Overview and MED-09 Objectives

MED-09 was a research project designed to measure where, why, and how different species of whales and dolphins live in interesting and important biological areas of the western Mediterranean Sea, including measurements of how these animals may change their behavior when they hear different sounds. The project took place on the NATO research vessel (NRV) *Alliance* from late July to early September in deep canyon-like areas around the Balearic Islands and in the Alboran Sea off the Spanish Mediterranean coast and the Tyrrhenian Sea to the west of the Italian mainland. MED-09 involved a diverse collaboration of world experts in marine mammal distribution, diving, and behavior, as well as specialists for using underwater sound to find marine mammals and safely measure their responses to controlled sound exposures. MED-09 included a diverse array of marine mammal and acoustic experts working on a specialized research vessel.

MED-09 contributed to a long-term, integrated research effort involving nine research cruises on the NRV *Alliance* since 1999, and field efforts to tag beaked whales in the Mediterranean, Canary Islands, Bahamas, California and Hawaii since 2001. This coordinated international program addresses many of the priorities identified by The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) and other international bodies regarding the understanding and protection of cetaceans from adverse effects of anthropogenic noise.

This project was conducted in the western Mediterranean Sea with scientists from Italy, US, and Spain. The cruise departed from La Spezia Italy, within the Pelagos Sanctuary, and only involved passive acoustic monitoring and visual observations while transiting to outside the sanctuary waters. The first phase of the cruise took place primarily in international waters near Spain (particularly the Balearic and Alboran Seas) and the second phase of the cruise ended in the Tyrrhenian Sea outside of the Pelagos Sanctuary before the ship transited back to La Spezia.

The primary purpose of MED 09 was to tag/track beaked whales and other cetaceans in order to conduct controlled sound exposure experiments, according to specific protocols and procedures similar to those used in the Bahamas BRS experiments with no evidence of harm to experimental subjects. Successful tagging and controlled exposure experiments with beaked whales require very calm conditions and the presence of taggable animals. These conditions did not exist on all available days and MED-09 included other secondary science objectives, including the detection of marine mammals using visual observers and passive acoustic monitoring (PAM), both for possible tagging and also to increase scientific data on their presence and abundance in the Western Mediterranean. Along with measuring oceanographic parameters, the

surveys also mapped ambient noise with the objective of linking noise to the human activities producing it. These data will be used, among other things, to help develop predictive models of the distribution of beaked whales and how their distribution may be affected by anthropogenic noise.

International, Multidisciplinary Teams

A complex and challenging study such as finding very deep-diving and difficult to detect species such as beaked whales, tracking them over a large area without the sophisticated acoustic range present at AUTEC in the Bahamas, and safely monitoring animals to conduct high-quality CEEs requires a specialized set of skills. MED -09 included highly experienced scientists and engineers, as well as some of the most state-of-the-art tools and technologies currently available. These assets were organized into specialized teams either on or deployed from the **NRV *Alliance***, each serving specific, inter-related functions.

Photo courtesy of NURC

Layout of NRV *Alliance*, courtesy: NURC

Visual observers were trained and experienced in sighting marine mammals up to several miles away using high-powered binoculars. They searched for marine mammals and monitored focal and other marine mammals in survey and focal follow modes.

Visual observer during BRS-07

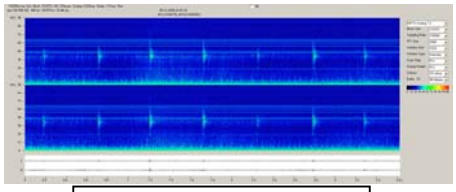


Image courtesy of G. Pavan, CIBRA

Passive acoustic observers used multiple different kinds of listening systems towed behind, draped off, or deployed around the NRV *Alliance* to detect vocalizing whales during both day and night.

Photo identification was used to catalog and keep track of individuals and groups of marine mammals sighted.

Tagging teams carefully approached focal animals and deployed Dtags using non-invasive suction cups; tag teams also provided visual monitoring of focal groups that were tagged and reported all behavioral observations.

Geographical Information Systems (GIS) engineers integrated different kinds of data, including the position of the NRV *Alliance* and small boats, visual sightings and acoustic localizations (or positioning) of animals, and environmental information, for real-time presentation on maps and synchronized MED-09 data archive.

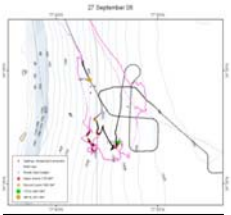


Figure from BRS -08

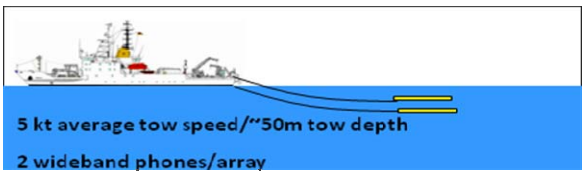
Photo courtesy of NURC

Sound source technicians calibrated the specialized underwater speaker (on left before deployment) that was to be used to play both artificial and biological sounds during CEEs.

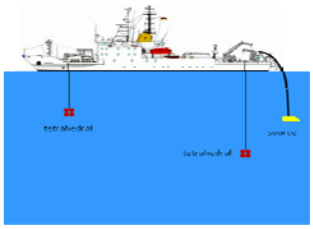
MED -09 operated in three operational "***modes***" depending on the timing in the study, weather conditions, and whether focal animal species are identified.

Transit mode involved getting from one operational area to another at cruising speed. Listening arrays of hydrophones were used day and night for detecting marine mammals and contributing to sighting records. Visual observers similarly monitored for marine mammal presence during daylight hours when conditions permitted. Simultaneous oceanographic data were collected using a variety of sensors, including satellite remote sensing. However, no efforts were made in transit mode to track or tag individual marine mammals.

During ***survey mode***, the NRV *Alliance* followed specifically-designed track lines at slower speed in areas of interest; multiple track options were developed to account for variable weather and biological conditions. Visual and acoustic surveys were conducted and various oceanographic data were collected. When animals of interest were detected and conditions were appropriate, the NRV *Alliance* broke from survey mode to focus on specific groups.



In ***focal follow mode***, specific focal groups and/or individuals were tracked and tagging teams were deployed. Using specific criteria to ensure the safety of researchers and animals, photo identification and/or tagging efforts were initiated. Visual observers on the NRV *Alliance* and small boats were used during focal follow mode and some or all listening capabilities were deployed. Because MED -09 did not have the luxury of a large listening array of hydrophones on the bottom that BRS 07-08 had, we



approximated this over a small area using hydrophones deployed from the NRV *Alliance* and real-time sonobuoys deployed by small boats. After focal follows of an individual or group, the NRV *Alliance* switched back from focal follow to survey and/or transit modes.

MED-09 Public Outreach

There was a concerted effort to publically communicate the planning and execution of MED-09 and to ensure open transparency of the project.

Before the project, this included meetings between the co-PIs and government officials in Spain; an open meeting with environmental group representatives and local researchers, including representatives of the ACCOBAMS scientific committee; several exchanges of questions and responses between the co-PIs and environmental groups; information provided through the U.S. Embassy to Italian government officials; a general public presentation as part of the "Science Made Public" lecture series at Woods Hole Oceanographic Institute; and publically available summaries of MED-09 in both simple summary format and greater scientific detail.

During MED-09, co-PIs posted daily blogs of activities and results; the website remains active as of the publication of this report http://med09-expedition.blogspot.com and all postings can be seen in Appendix 1. These blog postings were intended to provide an overview of the research activities and accomplishments, but at a level of detail appropriate for a general audience.

Visual Observer Data

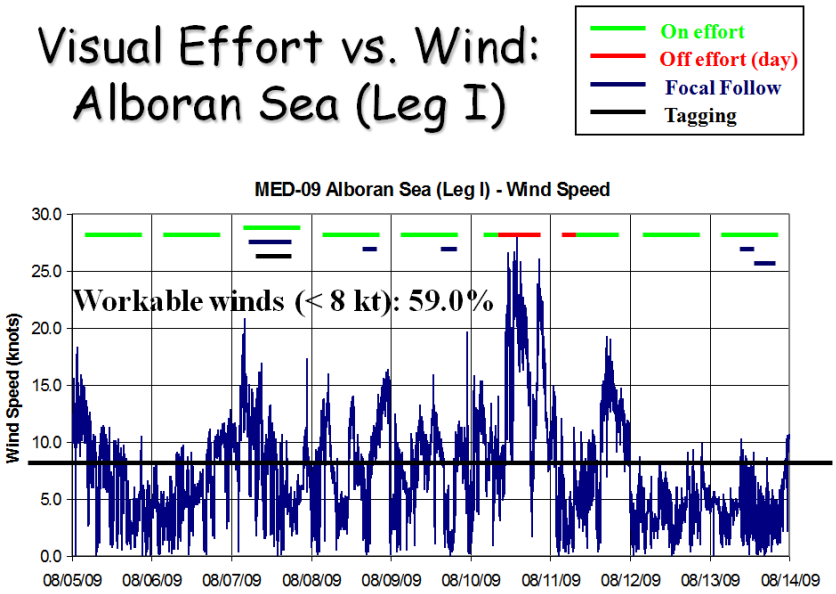
The visual observer team for Phase I of MED-09 was: Ana Cañadas, Todd Pusser, Eletta Revelli, Maria Elena Quero, María Ovando, Antonella Servidio, Marco Ballardini, Leire Armentia, and José Antonio Vásquez. The visual observer team for Phase II was: Fulvio Fossa, Eletta Revelli, Todd Pusser, Caterina Lanfredi, Michela Podestá, Nicolo Gavazzi, Maria Elena Quero, Marco Ballardini.

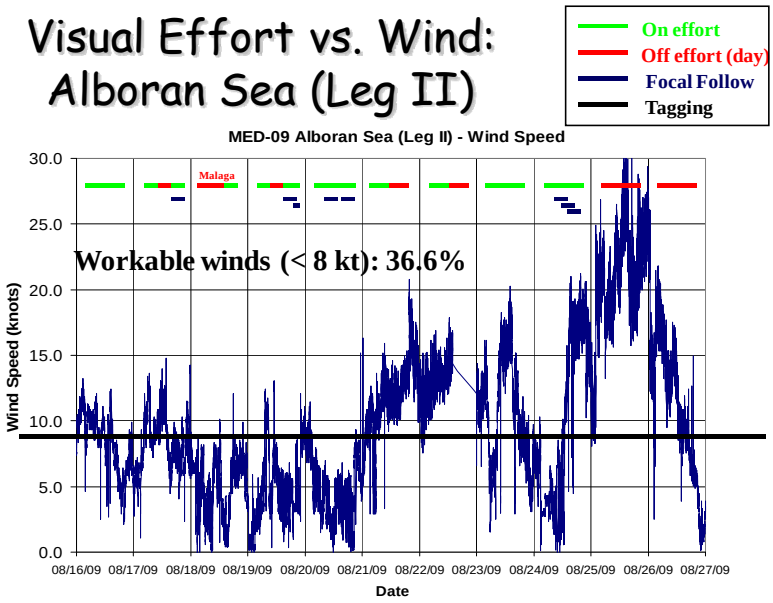
When MED-09 was in survey mode, the primary objective was to search for beaked whales and other cetaceans following track lines designed for both visual and acoustic surveys. There was thus an integration and interaction of the visual team with the passive acoustic teams, coordinated by the co-PIs, to locate and identify marine mammals. MED-09 then switched to focal follow mode when appropriate subjects were identified for tagging and playbacks in suitable tagging conditions. Oceanographic data (see below) were simultaneously collected along survey lines as possible for use in habitat modeling efforts.

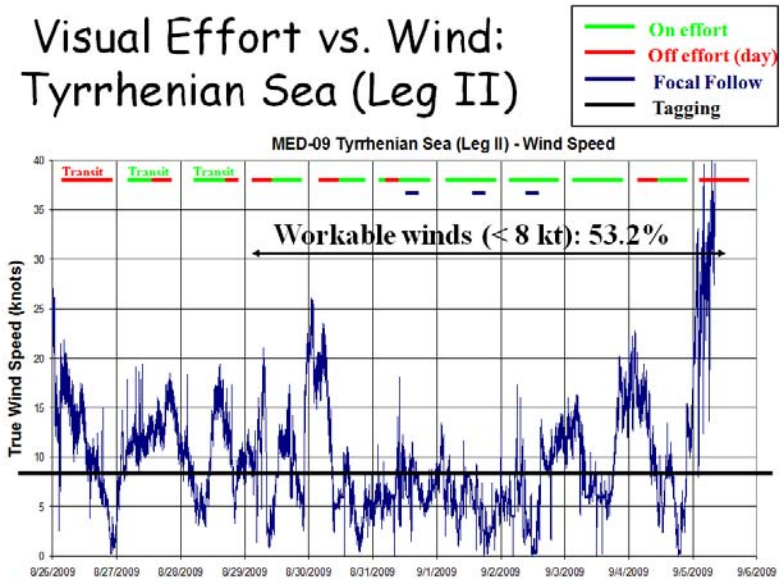
MED-09 included various track modules, depending on weather conditions and local biological factors (e.g., proximity to suitable depth contours for beaked whales). In total, visual teams spent 172.5 hours on effort (*i.e.*, actively scanning for marine mammals using high=power binoculars) in survey mode and 85.2 hours on effort in focal follow mode during the 39 operational days of MED-09. The total number of days (and percentages of total time) in MED-09 that were spent on-effort and off-effort due to weather or other circumstances is summarized here.

Leg	Days	On-Effort (Survey & Focal Follow)	Off-Effort (Weather)	Off-Effort (Transit/port, shake-down, rescue)
I	17	**10.25** (60.3%)	**2.75** (16.2%)	**4** (23.5%)
II	22	**11** (50%)	**5.75** (26.1%)	**5.25** (23.9%)
TOTAL	39	**21.25** (54.5%)	**8.5** (21.8%)	**9.25** (23.7%)

The capability for visual teams to effectively work was strongly controlled by the wind conditions experienced. Eight knots of wind was the level at which visual detection of beaked whales became difficult. While our visual teams remained on effort during stronger wind conditions, as can be seen from the figures below, most of our success in detecting animals and switching into focal follow mode was in the calmest conditions. The figures shown here indicate the local wind conditions, and the resulting operational modes during the Alboran and Tyrrhenian Sea phases of MED-09.






Visual Effort vs. Wind:
Tyrrhenian Sea (Leg II)
On effort
Off effort (day)
Focal Follow
Tagging
MED-09 Tyrrhenian Sea (Leg II) - Wind Speed
Transit
Transit
Transit
Workable winds (< 8 kt): 53.2%
True Wind Speed (knots)
0
5
10
15
20
25
30
35
40
8/26/2009
8/27/2009
8/28/2009
8/29/2009
8/30/2009
8/31/2009
9/1/2009
9/2/2009
9/3/2009
9/4/2009
9/5/2009
9/6/2009

VISUAL SURVEY DATA

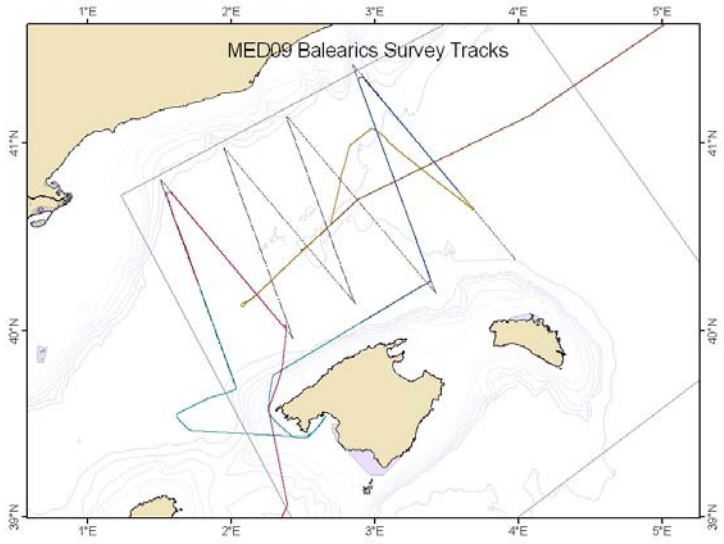
The daily visual survey effort for each day the first half of MED-09 (consisting of phase I and a small part of phase II is given below, indicating the total effort and sightings.

Phase	Data	Hours on survey (hh:mm)	Area	Total hours on survey
1 phase	29-lug-09	5.18	Ligurian Sea	5.18
1 phase	31-lug-09	12.00	Ligurian-Balearic	12.00
1 phase	01-ago-09	11.00	Balearic islands	
1 phase	02-ago-09	6.00	Balearic islands	29
1 phase	03-ago-09	12.00	Balearic islands	
1 phase	04-ago-09	10.30	Balearic-Alboran	10.30
1 phase	05-ago-09	4.00	Alboran East	
1 phase	06-ago-09	5.00	Alboran East	
1 phase	07-ago-09	6.00	Alboran East	
1 phase	08-ago-09	8.30	Alboran East	34,30
1 phase	09-ago-09	9.00	Alboran East	
1 phase	10-ago-09	2.00	Alboran East	
1 phase	11-ago-09	6.00	Alboran West	
1 phase	12-ago-09	8.00	Alboran West	17
1 phase	13-ago-09	3.00	Alboran West	
2 phase	16-ago-09	10.30	Alboran West	
2 phase	17-ago-09	9.39	Alboran West	
2 phase	18-ago-09	3.37	Alboran West	
2 phase	19-ago-09	3.37	Alboran West	
2 phase	20-ago-09	3.33	Alboran West	43
2 phase	21-ago-09	6.09	Alboran West	
2 phase	22-ago-09	6.00	Alboran West	
2 phase	23-ago-09	3.11	Alboran East	10.21
2 phase	24-ago-09	7.10	Alboran East	
Total		**161**		
	24 days			alboran east
	530 sightings			44,51
				alboran west
				60,00

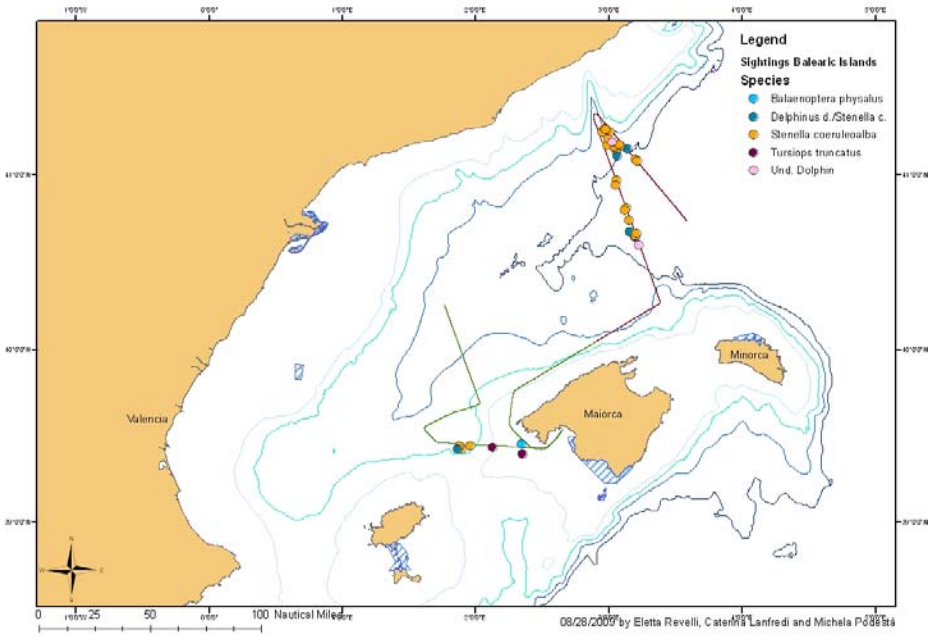
The visual survey effort for the remainder of phase II are shown below, along with the total effort and number of sightings.

Phase	Data	Hours on survey (hh:mm)	Area	Total hours on survey
2 phase	27-ago-09	5.46	Alboran_Tyrrhenian	15,00
2 phase	28-ago-09	8.56	Alboran_Tyrrhenian	
2 phase	29-ago-09	7.41	Tyrrhenian Sea	
2 phase	30-ago-09	8.21	Tyrrhenian Sea	
2 phase	31-ago-09	6.30	Tyrrhenian Sea	
2 phase	01-set-09	7.00	Tyrrhenian Sea	53,00
2 phase	02-set-09	4.00	Tyrrhenian Sea	
2 phase	03-set-09	12.30	Tyrrhenian Sea	
2 phase	04-set-09	7.00	Tyrrhenian Sea	
Total				
	9 days			
	114 sightings			

The figures below show the visual survey data broken down by operational area and species identified. The survey track figures show the notional track lines planned for MED-09 in light black lines, along with the actual track lines in different colors for each day. The survey statistics tables indicate the total number of hours on effort, species identifications, number of sightings for each species, and estimated number of animals for each of the operational areas.



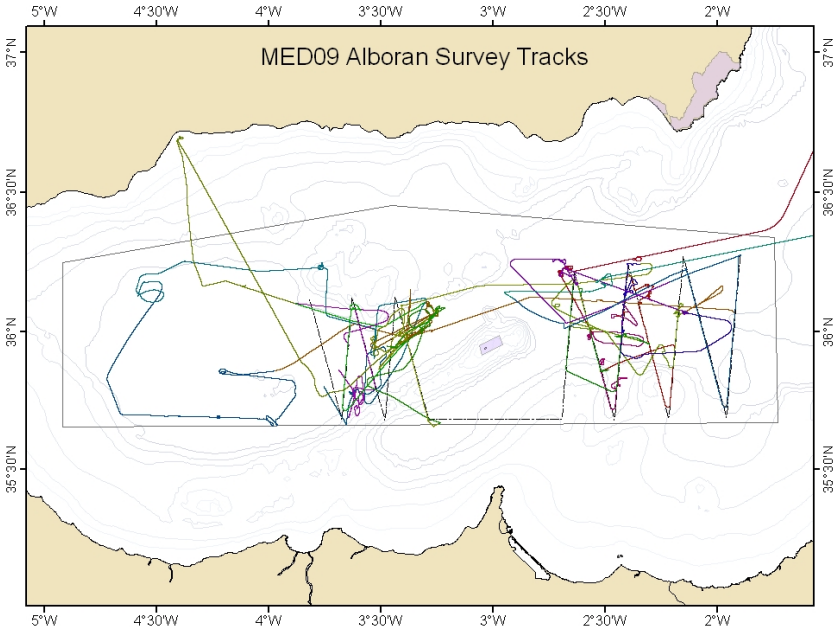
Notional versus actual survey track lines for the Balearic Islands operational area.



Individual or group sightings in survey mode for the Balearic Islands.

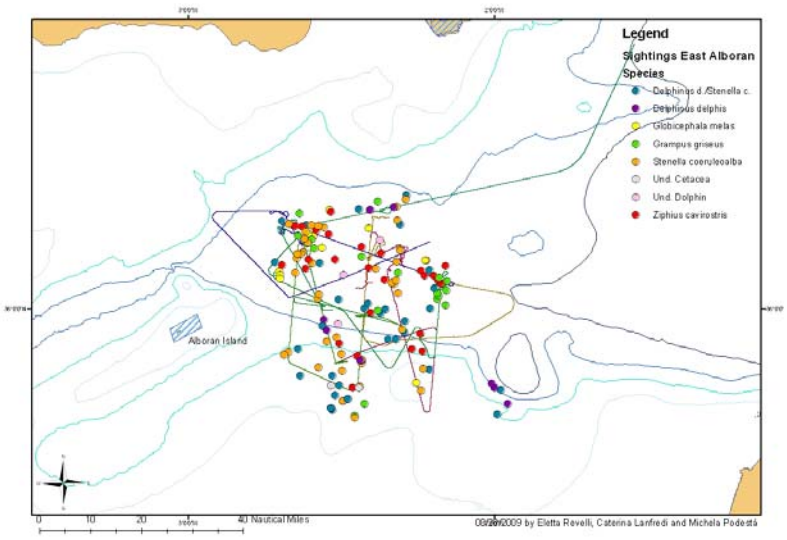
Balearic Islands (29 hours on effort)		
Species	**# sightings**	**# animals**
Balaenoptera physalus	1	1
Tursiops truncatus	2	13
Stenella coeruleoalba	22	265
Delphinus d.-Stenella c.	5	60
Undetermined Dolphin	2	5
Total	**32**	**344**

Summary data of species sighted in survey mode for the Balearic Islands.



Notional versus actual survey track lines for the Alboran Sea operational area.

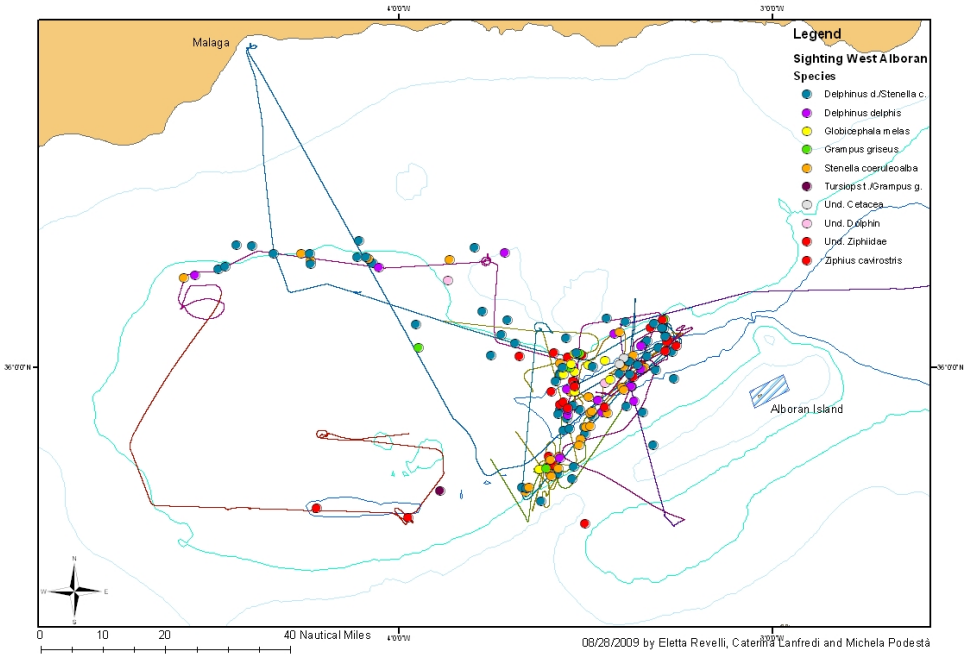
(note that for figures below, the survey data are given for East and west regions of this area)



Individual or group sightings in survey mode for the Alboran Sea (East).

Alboran East (45 hours on effort)		
Species	**# sightings**	**# animals**
Ziphius cavirostris	27	67
Globicephala melas	11	168
Grampus griseus	19	89
Delphinus delphis	11	304
Stenella coeruleoalba	42	870
Delphinus d.-Stenella c.	32	454
Undetermined Dolphin	3	16
Undetermined Cetacea	2	2
Total	**147**	**1970**

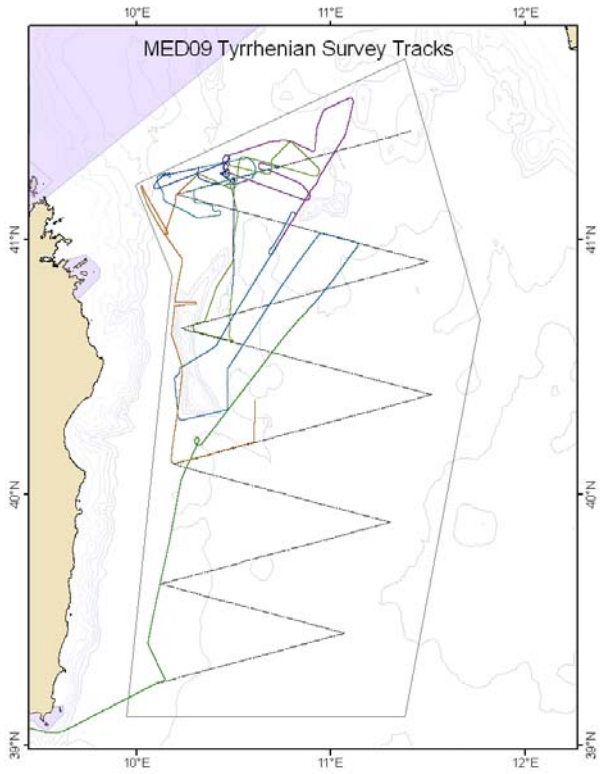
Summary data of species sighted in survey mode for the Alboran Sea (East).



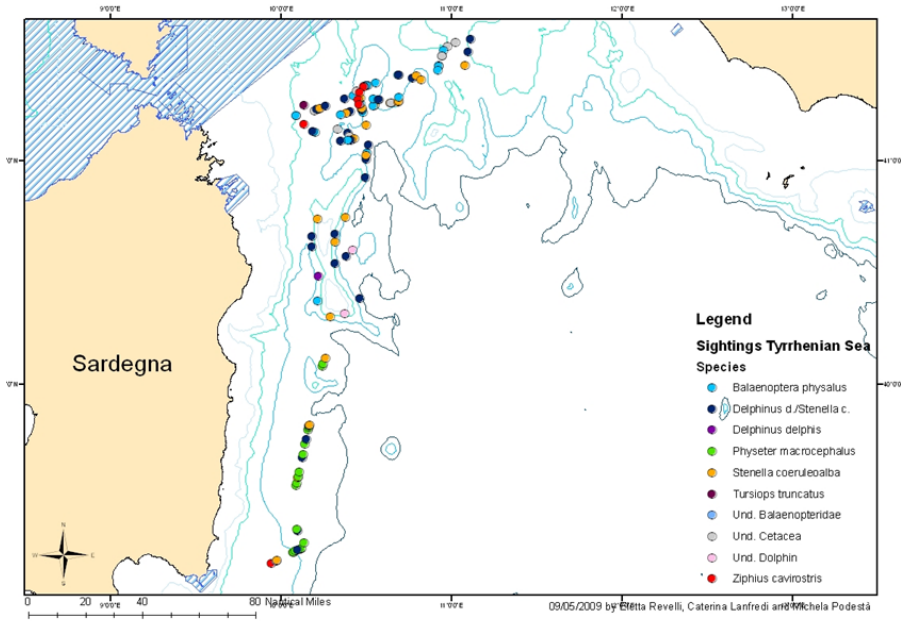
Individual or group sightings in survey mode for the Alboran Sea (West)

Alboran West (60 hours on effort)		
Species	**# sightings**	**# animals**
Ziphius cavirostris	25	56
Globicephala melas	9	71
Grampus griseus	6	38
Delphinus delphis	15	222
Stenella coeruleoalba	30	550
Delphinus d.-Stenella c.	64	1233
Tursiops t.-Grampus g.	1	5
Undetermined Dolphin	3	52
Undetermined Ziphiidae	3	4
Undetermined Cetacea	2	2
Total	**158**	**2233**

Summary data of species sighted in survey mode for the Alboran Sea (West)



Notional versus actual survey track lines for the Tyrrheninan Sea operational area.



Individual or group sightings in survey mode for the Tyrrhenian Sea

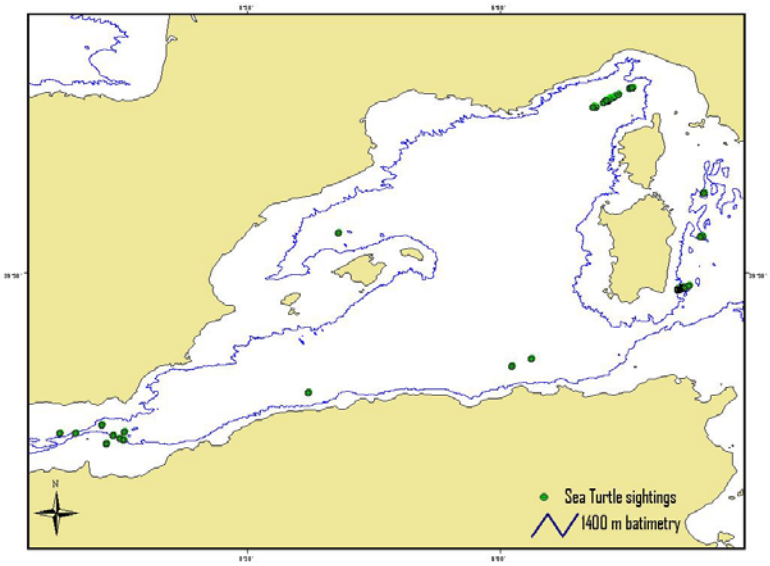
Tyrrhenian Sea (53 hours on effort)		
Species	# sightings	# animals
Balaenoptera physalus	22	27
Physeter macrocephalus	18	24
Ziphius cavirostris	6	12
Tursiops truncatus	1	4
Delphinus delphis	1	45
Stenella coeruleoalba	23	366
Delphinus d./Stenella c.	30	288
Undetermined Cetacea	10	10
Undetermined Dolphin	2	6
Und. Balaenopteridae	1	1
Total	**114**	**783**

Summary data of species sighted in survey mode for the Tyrrhenian Sea

Survey statistics during transit between operational areas

Other Areas (28 hours on effort)			
Area	Species	# sightings	# animals
Ligurian Sea			
	Balaenoptera physalus	1	1
	Physeter macrocephalus	1	1
	Ziphius cavirostris	2	2
	Grampus griseus	1	1
	Stenella coeruleoalba	24	232
	Undetermined Dolphin	35	250
	Total	**64**	**487**
Ligurian-Balearic			
	Stenella coeruleoalba	12	129
	Delphinus d./Stenella c.	10	165
	Undetermined Dolphin	1	12
	Total	**23**	**306**
Balearic-Alboran			
	Physeter macrocephalus	4	4
	Globicephala melas	1	17
	Tursiops truncatus	1	8
	Stenella coeruleoalba	2	45
	Delphinus d./Stenella c.	12	59
	Undetermined Cetacea	1	1
	Total	**21**	**134**
Alboran-Tyrrhenian			
	Balaenoptera physalus	1	1
	Physeter macrocephalus	4	6
	Delphinus d./Stenella c.	8	93
	Grampus griseus	1	3
	Stenella coeruleoalba	5	52
	Total	**19**	**155**
	Overall Total	**127**	**1082**

Other Species Detected in Survey Mode: Loggerhead Sea Turtle Sightings



Loggerhead Sea Turtle: Survey Statistics

Sea Turtles			
Area	**Date**	**Species**	**# animals**
Ligurian Sea	29-lug-09	*Caretta caretta*	24
		Total	**24**
Ligurian_Balearic	31-lug-09	*Caretta caretta*	1
		Total	**1**
Alboran East	5-ago-09	*Caretta caretta*	1
	8-ago-09	*Caretta caretta*	2
	9-ago-09	*Caretta caretta*	3
		Total	**6**
Alboran West	12-ago-09	*Caretta caretta*	1
	19-ago-09	*Caretta caretta*	1
		Total	**2**
Alboran_Tyrrhenian	27-ago-09	*Caretta caretta*	1
	28-ago-09	*Caretta caretta*	2
		Total	**3**
Tyrrhenian Sea	29-ago-09	*Caretta caretta*	28
	30-ago-09	*Caretta caretta*	3
	31-ago-09	*Caretta caretta*	1
	2-set-09	*Caretta caretta*	1
		Total	**33**
		Overall Total	**69**

MED-09 Focal Follow Data

As described in the protocols above, once a suitable candidate group or individual was identified, MED-09 visual and passive acoustic teams switched into focal follow mode. During this period, the visual teams and often the small tagging boat would conduct visual observations, photo identification, and the acoustic team would monitor the focal group as possible during foraging dives. We conducted a total of 15 high-quality focal follows on Cuvier's beaked whales during MED-09, each of which is shown individually below the summary statistics (note: the pilot whale focal follow and tagging efforts are described in the section on tagging later in this report). The tables here provides summary statistics for these focal follows, as well as a summary of the causes of why each ultimately ended without successful tag attachment.

# Good Focal Follows	**15** (4 in Leg I; 11 in Leg II)
Average Focal Follow Time	Leg I :**150** min. Leg II:**108** min.
Total Shallow Dives (both)	**67**
Avg. distance shallow dives	**423 m**
Total Deep Dive (both)	**4**
Avg. distance deep dives	**1828 m**

Cause of Ending *Zc* Focal Follows (n=15)

Sunset	5
Determined Calves in Group	4
Lost contact (deep dive, groups mix)	2
Deteriorating Weather	2
12 nm boundary	1
Dolphins	1

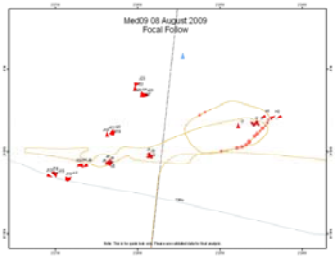
2/15 (13%) ended due to lost contact

13/15 (87%) ended for other reasons

INDIVIDUAL FOCAL FOLLOW SUMMARIES AND GIS TRACKS[1]

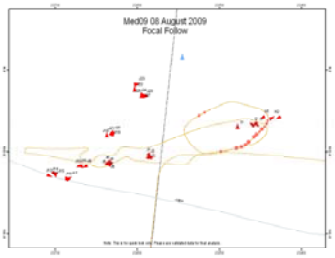
Focal Follow – 8 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: J
Location: 36° 10'N; 2° 38'W
Duration: 1:51 (1823 to 2014)
Group composition: 4 animals (3 adults, possibly female; 1 juv.)
Number shallow dives: 5
Avg. shallow dive time: 20.6 min
Avg. distance between dives: 648 m
What ended follow: SUNSET
Comments: Good follow and on animals with good tracking, just ran out of light



Focal Follow – 9 Aug 2009 (*Zc*)

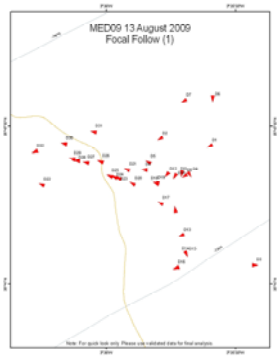
Species: *Ziphius cavirostris*
Group identifier: H
Location: 35° 59'N; 2° 25'W
Duration: 1:36 (1905 to 2141)
Group composition: 3 animals (2 adult males; 1 juv.)
Number shallow dives: 4
Avg. shallow dive time: 22.3 min.
Avg. distance between dives: 226m
What ended follow: SUNSET
Comments:



[1] **see p. 38 for a detailed description of one focal follow GIS plot**

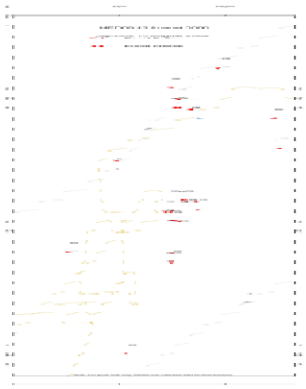
Focal Follow (1) – 13 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: D
Location: 37° 45' 30" N; 3° 36' W
Duration: 1:28 (1049 to 1216)
Group composition: 4 animals (possibly 2 male, 2 females)
Number shallow dives: 4
Avg. shallow dive time: 20.5 min.
Avg. distance between dives: 426 m
What ended follow: DOLPHINS
Comments: At 1153 the TB was within 100m when a group of striped dolphins harassed Zc and they dove before TB arrived



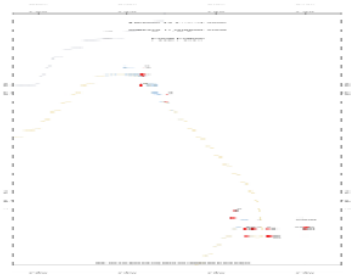
Focal Follow (2) – 13 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: K
Location: 35° 47'N; 3° 36' 45" W
Duration: 5:05 (1343 to 1848)
Group composition: 3 animals (possibly 1 male, 2 female)
Number shallow dives: 7
Avg. shallow dive duration: 26.6 min.
Avg. distance between dives: 509m
What ended follow: LOST ON DEEP DIVE
Comments: One deep dive was just performed by the male



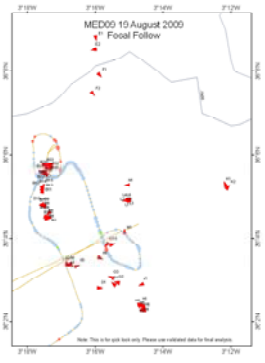
Focal Follow – 17 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: A
Location: 36° 4'N; 3° 15'W
Duration: 1:23 (1710 to 1833)
Group composition: 3 possible males; 1 possible juvenile
Number shallow dives: 3
Avg. shallow dive duration: 29 min.
Avg. distance between dives: 853 m
What ended follow: 12 nm BOUNDARY FROM ALBORAN ISLAND
Comments: Good focal and looked like workable group but swam inside 12 nm box



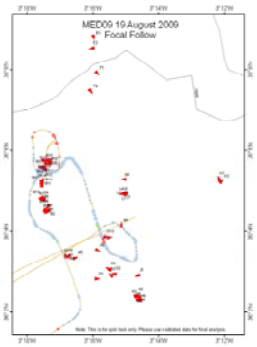
Focal Follow (1) – 19 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: A
Location: 36° 4'N; 3° 16'W
Duration: 0:49 (1518 to 1607)
Group composition: 3 animals (possibly 1 male; 1 female; 1 calf)
Number shallow dives: 2
Avg. shallow dive duration: 23.5 min.
Avg. distance between dives: 776m
What ended follow: WE SWITCHED TO ANOTHER GROUP BECAUSE CALVES
Comments: Larger group was spotted and we broke off to follow them (B)



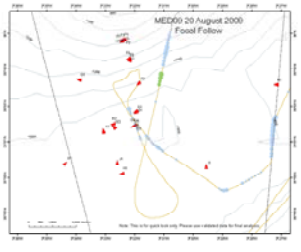
Focal Follow (2) – 19 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: B
Location: 36° 5'N; 3° 17'W
Duration: 1:51 (1528 to 1719)
Group composition: 4 animals (2 cow-calf pairs)
Number shallow dives: 4
Avg. shallow dive duration: 25 min.
Avg. distance between dives: 563 m
What ended follow: WRONG GROUP COMPOSITION
Comments: We broke off following this group when determined small calves



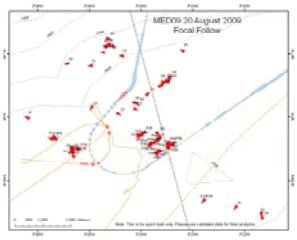
Focal Follow (1) – 20 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: F
Location: 36°' N; 3° 32'W
Duration:1:25 (1256 to 1421)
Group composition: 1 animal (pale adult)
Number shallow dives: 3
Avg. shallow dive duration: 28 min
Avg. distance between dives: 798m
What ended follow: SINGLE ANIMAL TRIED FOR FEW SHALLOW DIVES
Comments: We knew chances were low but gave it a shot briefly



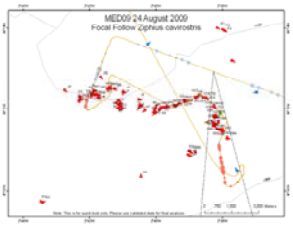
Focal Follow (2) – 20 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: P
Location: 36° N; 3° 24'W
Duration: 3:51 (1711 to 2102)
Group composition: 4 animals (possibly 2 males and 2 juveniles with many scars)
Number shallow dives: 5
Avg. shallow dive duration: 27.2 min.
Avg. distance between dives: 466m
What ended follow: SUNSET
Comments: Good group and we had a good bead on them, but just ran out of light



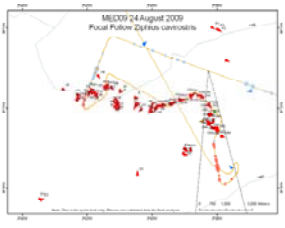
Focal Follow (1) – 24 Aug 2009 (*Zc*)

Species: *Ziphius cavirostris*
Group identifier: A
Location: 36° 12'N; 2° 43'W
Duration: 1:31 (1036 to 1209)
Group composition: 4 animals (3 adults; 1 juv./calf)
Number shallow dives: 5
Avg. shallow dive duration: 27.2 min.
Avg. distance between dives: 526m
What ended follow: GROUPS MIXING
Comments: This group and several others came together during shallow dives and we switched over to group K in the mix



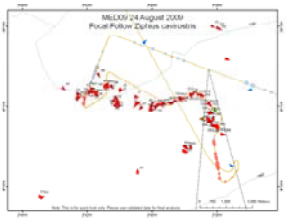
Focal Follow (2) – 24 Aug 2009 (*Zc*)

Species: *Zipihius cavirostris*
Group identifier: K
Location: 36° 12'N; 2° 40'W
Duration: 0:43 (12:27 to 1310)
Group composition: 4 or 5 animals (3-4 adults with 1 calf)
Number shallow dives: 2
Avg. shallow dive duration: 19 min.
Avg. distance between dives: 717m
What ended follow: DETERMINED CALVES IN GROUP
Comments: This was the group we switched to from A; crossed and some mixing of groups



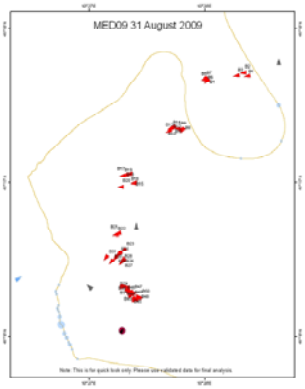
Focal Follow (3) – 24 Aug 2009 (*Zc*)

Species: *Zipihius cavirostris*
Group identifier: O
Location: 36° 12'N; 2° 36'W
Duration: 2:31 (1324 to 1555)
Group composition: 4 animals (2 adult and 2 juvenile)
Number shallow dives: 8
Avg. shallow dive duration: 16.1 min.
Avg. distance between dives: 370m
What ended follow: WIND
Comments: Another promising group interrupted by deteriorating conditions



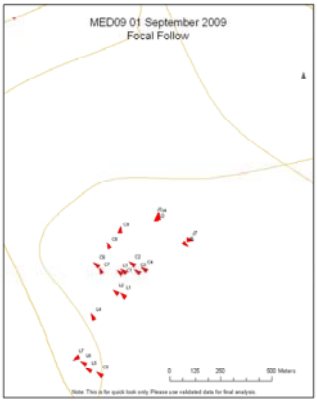
Focal Follow – 31 Aug 2009 (*Zc*)

Species: *Zipihius cavirostris*
Group identifier: B
Location: 41º 17' N; 10º 27' E
Duration: 1:53 (1541 to 1743)
Group composition: 3 animals (1 male, 1 cow-calf pair)
Number shallow dives: 6
Avg. shallow dive duration: 18.9 min.
Avg. distance between dives: 549 m
What ended follow: SUNSET
Comments: Trying to tag male in the group since all other groups had been outside box or w/calves



Focal Follow – 1 Sept 2009 (*Zc*)

Species: *Zipihius cavirostris*
Group identifier: J
Location: NEED
Duration: 0:42 (1912 to 1935)
Group composition: 2 animals (likely cow-calf pair)
Number shallow dives: 3
Avg. shallow dive duration: 14 min.
Avg. distance between dives: 236 m
What ended follow: SUNSET
Comments: Followed this group of two for three shallow dives; ran out of light and determined cow-calf pair



Focal Follow – 2 Sept 2009 (*Zc*)

Species: *Zipihius cavirostris*

Group identifier: A

Location: 41º 14' N; 10º 27' E

Duration: 3:05 (1215 to 1535)

Group composition: 2 animals (1 male, 1 (possible) female

Number shallow dives: 7

Avg. shallow dive duration: 15.3 min.

Avg. distance between dives: 336 m

What ended follow: WIND

Comments: Great follow and some good chances; followed through 1 deep dive and fair idea on second but wind blew up

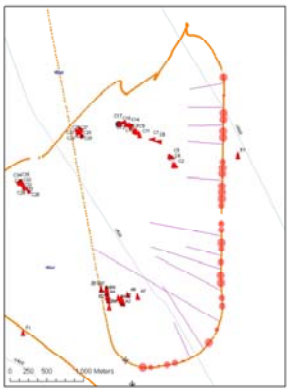


Photo Identification Contributions

The MED-09 project included photo-identification of priority species including Cuvier's beaked whale, *Ziphius cavirostris* and short-finned pilot whales, *Globicephala melas*. Sirena08 and MED-09 have started a *Ziphius* catalog for the Alboran Sea. 400 photographs of *Ziphius* were taken. Of these 47 were used in the catalog, defining 17 different individual whales. The identification photos are categorized by quality and by coloration patterns that may indicate age/sex class.

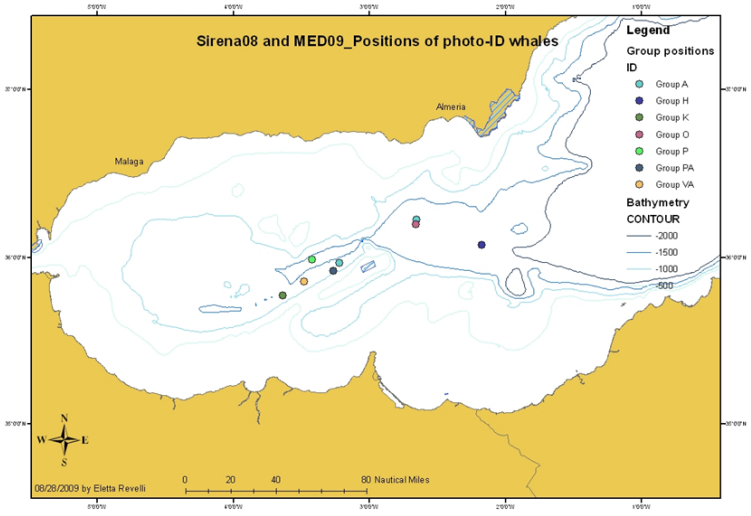
Ziphius Catalog: Categorization

Example of an identification photo from the MED-09 catalog rated as excellent.

Photos are rated as excellent, good, fair, or poor depending on the sharpness of the image, lighting, and the position of the animal relative to the photographer. The ability to identify the individual is ranked into one of 4 classes: very distinctive (heavily scarred and/or bold pigmentation), distinctive (many distinct scars and/or bold pigmentation pattern), slightly distinctive (few scars and lack of bold pigmentation), and not distinctive (solid brown animal with no scars).

The *Ziphius* in the catalog can be categorized into Sex/Age Classes based upon the following visual cues:

- *Adult males* - very white and heavily scarred, two visible teeth.
- *Adult females* - from dark brown with pale melons to very pale cream colored animals; little to no scarring on their bodies, no teeth.
- *Immature individuals (male or female)* - dark brown, no teeth and scars



Locations of *Ziphius* photo-identifications during the Sirena 08 and MED-09 cruises

Of the 17 *Ziphius* in the current catalog, there are 8 possible males, 4 possible females, 1 unknown, and 4 immatures. The above figure indicates the locations from which *Ziphius* were photo-identified during the MED-09 cruise.

MED-09 contributions to photo-identification of pilot whales from the Alboran Sea

Ana Cañadas (of Alnitak) and colleagues maintain a photo-ID database for pilot whales from the Alboran Sea. The Alboran Sea Pilot Whale Catalog includes 701 animals from 484 sightings up to 2007. Many pilot whales were encountered during MED-09 in large groups and hundreds of high quality identification photographs were made on multiple days at close range from ship/small boats. During these MED-09 pilot whale encounters, approximately 20 pilot whale groups and 240 individuals were sighted. The MED-09 photos and observations from were provided to Ana Cañadas for the first leg and coordinated by Leigh Hickmott during second leg and then sent to Cañadas. Initial comparisons to the catalog on board the ship during Med09 revealed at least 3 resighted whales, which suggests that there will be considerable amounts of resightings. Analysis of photo-ID records to determine total number of re-sighted or new animals to the database will take considerable time and effort which will be conducted by a Ph.D. student of Cañadas.

The process used for analysis of pilot whale identification photographs is as follows. Images are studied and each animal in a photograph where the dorsal fin can be seen, is catalogued (moving from left of image to right). Every animal is given an identification number (*e.g.*, Gm001) and a record of whether it is the left or right side of the animal is made. Each image is graded for

quality (from poor (0) to excellent (3)). Only quality 3 images are subsequently used for mark-recapture analysis. Quality grading depends upon distance, sharpness, lighting, and relative position of the animal, all relating to the ability to clearly see small identifiable features on the dorsal fin (nicks, scars etc).

Photograph of pilot whales taken from R/V *Alliance* during MED-09

The age/sex class of pilot whales can be categorization from photo-identification using the following features

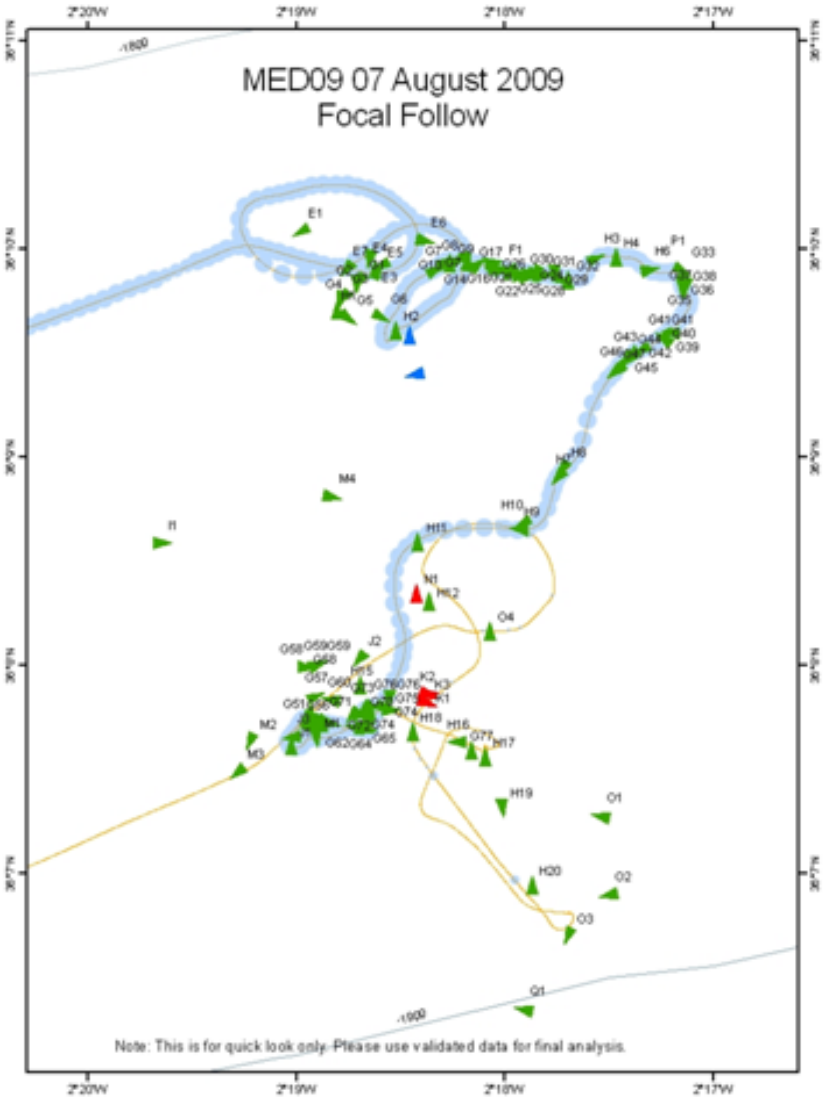
- Adult male – large size with broad based hooked dorsal fin
- Sub-adult male – large size with broad sprouting dorsal fin
- Adult/sub-adult female – adult size, dark colour pigmentation
- Juveniles and calves – small size, pale slate grey pigmentation

Tagging

The tagging team for Phase I of MED-09 included Ann Allen, Alex Bocconcelli, and Leigh Hickmott. The tag team for Phase II included Matt Weingartner, Stacy DeRuiter, and Leigh Hickmott.

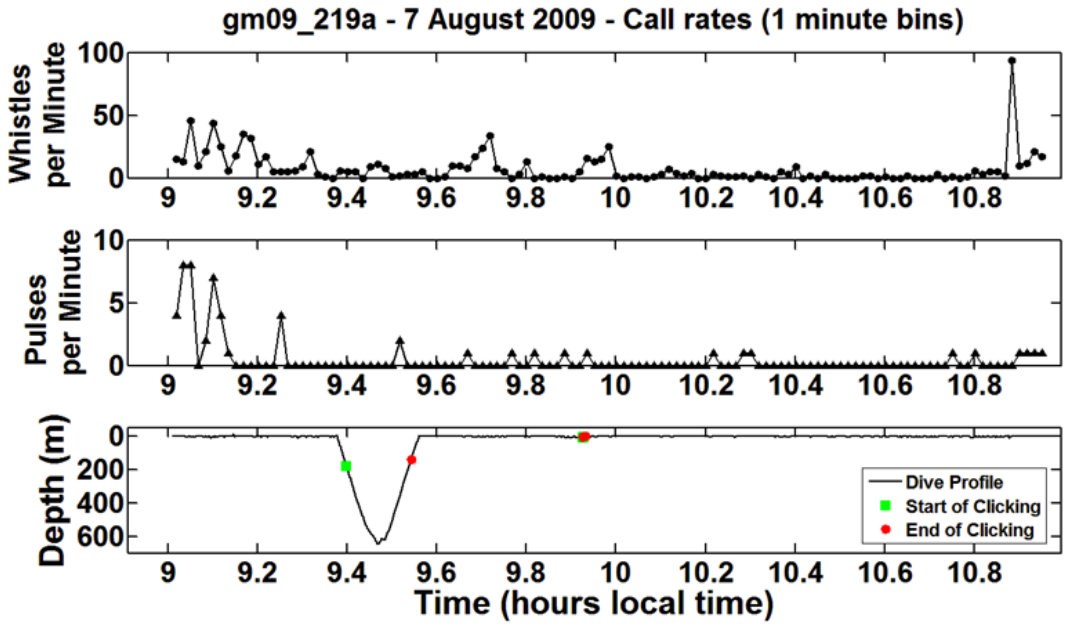
Dtags

DTags on MED-09 [Upper left: Tagging boat; Upper right: Dtag on the deployment pole; Bottom: Dtag on a pilot whale].

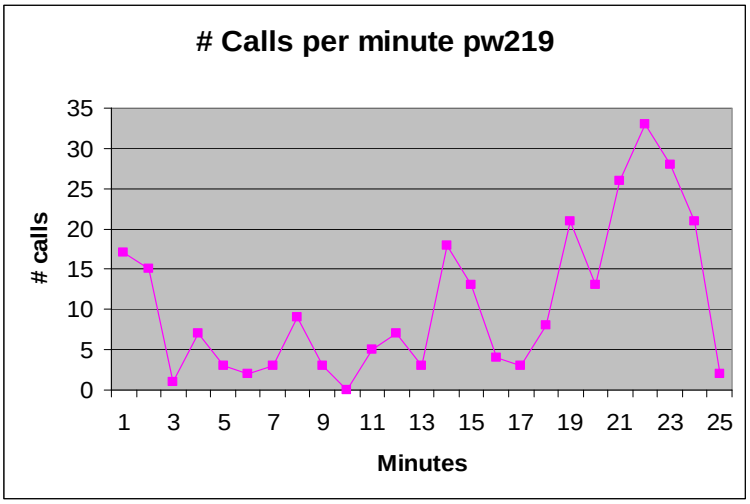


The only whales Dtagged on MED-09 were two pilot whales tagged on 7 August 2009 at 36° 9’ N and 2° 18’ W. The first whale Gm09_291a, indicated in visual records as whale “F” was tagged at 0901 and the tag was recovered at 1225. The second whale Gm09_291b, indicated in visual records as whale “G” was tagged at 0913 and the tag was recovered at 1652.

The first pilot whale tagged (gm09_219a) made one deep foraging dive to nearly 600m, but otherwise spent its time near the surface. The rate of calling (both clicks and whistles) was quite variable with high rates initially, followed by longer silent intervals.

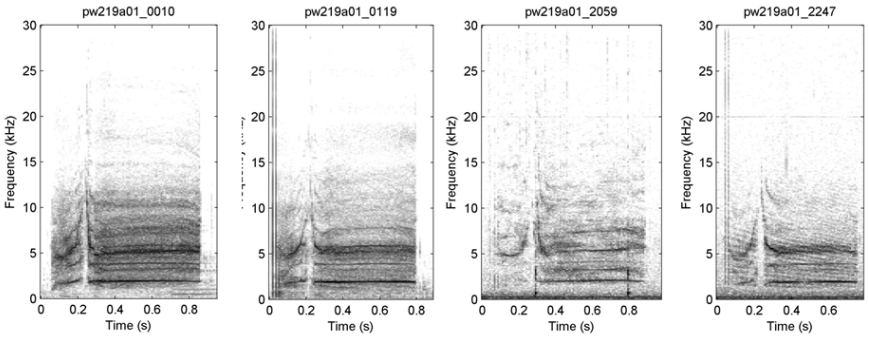


The second tag deployment of whale Gm09_219b contained 24 minutes of audio before the tag stopped because of salt water leakage. During this time 265 calls were recorded; 47% were of good or excellent signal-to-noise ratio. Almost all of these calls fell into three distinct types: type A made up 21% of calls, type B made up 10% of calls and type C: 16% of calls

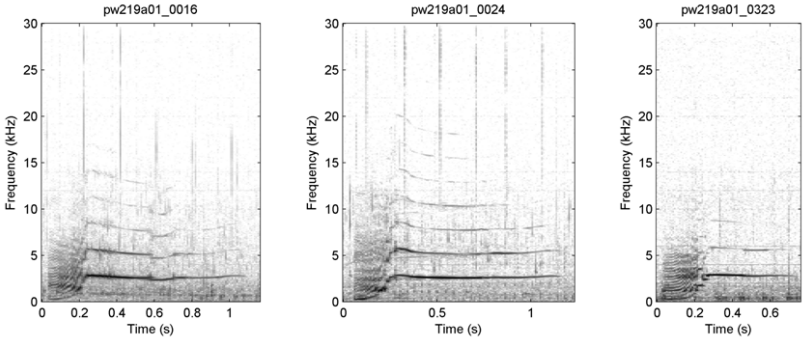


Call rates from the 24 minute audio record of pilot whale Gm09_219b.

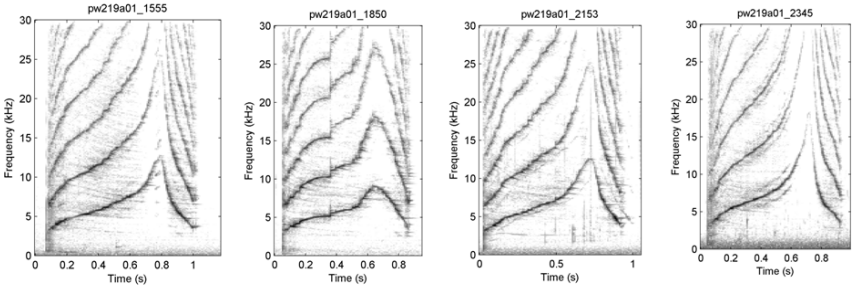
Call “A” examples



Call “B” examples



Call “C” examples



Spectrograms of examples of calls A, B, and C recorded from the second pilot whale tagged. These are stereotyped calls.

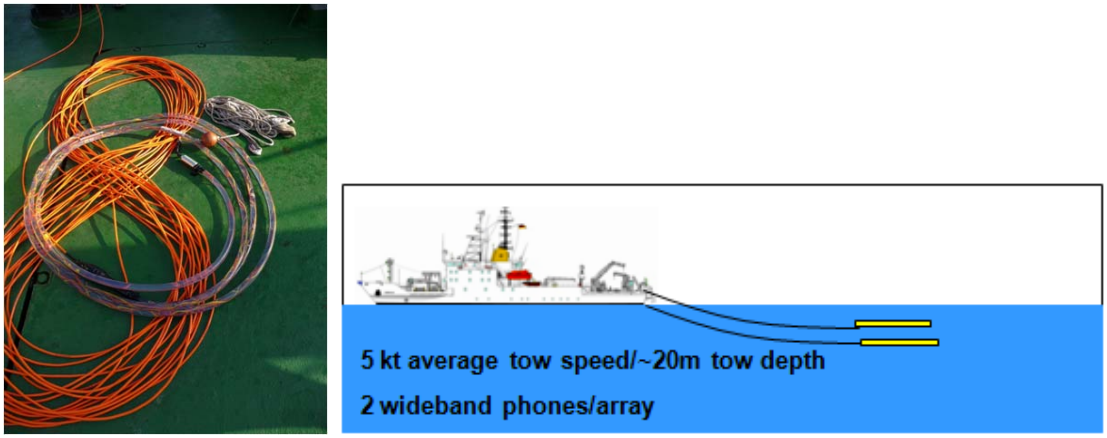
Passive Acoustic Data

The passive acoustics team for MED-09 consisted of: Gianni Pavan, Claudio Fossati, Walter Zimmer, Nancy DiMarzio, Odille Gerard, and Robin Brake. NURC Engineering and IT support and provided by: Angelo Mandaliti, Allesandro Carta, Ivan Pennisi, and Paolo Saia.

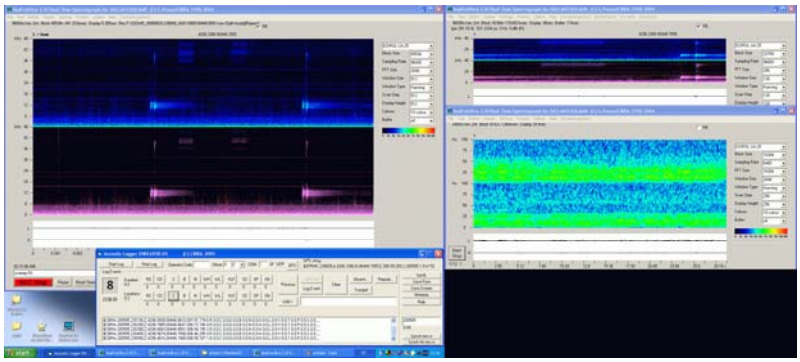
CIBRA Arrays

The CIBRA (Centro Interdisciplinare di Bioacoustica a Ricerche Ambientali, Università degli Studi di Pavia) acoustic monitoring package is based on two wide-band towed arrays with two hydrophones each, connected to a PC-based workstation for sound analysis/display/recording. The two arrays were towed from the stern of the NRV Alliance to allow solution of the left-right ambiguities in locating animals by Time Difference of Arrival (TDOA). The two hydrophones on each array are spaced 8 meters apart and have a flat response up to 40 kHz, which extends to 80 kHz. During survey mode, ship speed was ~5kts, yielding an array tow depth of 18-20 m. The maximum tow speed was 8-10 kts for a single array.

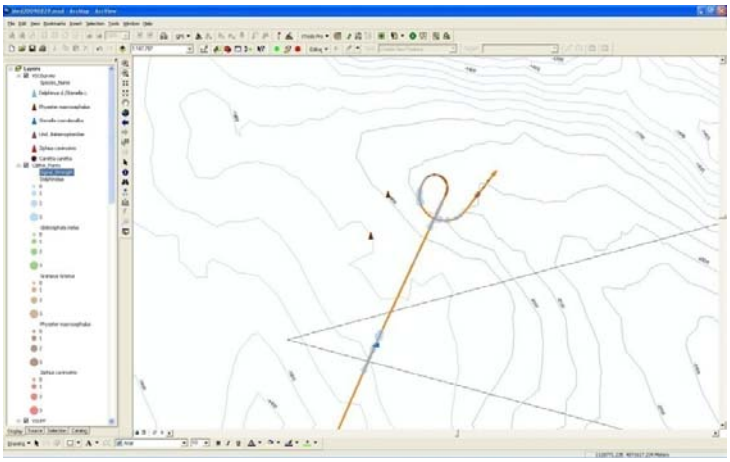
A desktop PC workstation provided real-time monitoring and continuous recording capabilities of up to 8 channels with sampling rates up to 192 kHz per channel. A companion laptop PC provided navigation data logging and display, classification logging and GIS mapping. SeaPro, the real-time high-resolution sound analysis software developed by CIBRA, was used to monitor the sounds. Acoustic detections were classified in real-time, with 1 minute resolution according to the categories and protocols used in previous SIRENA cruises. Acoustic detections were stored in text log file files for later processing and broadcast in real-time on the ship's network according to an established protocol.



Figures showing the towed array on deck (left) and the notional towing configuration (right).



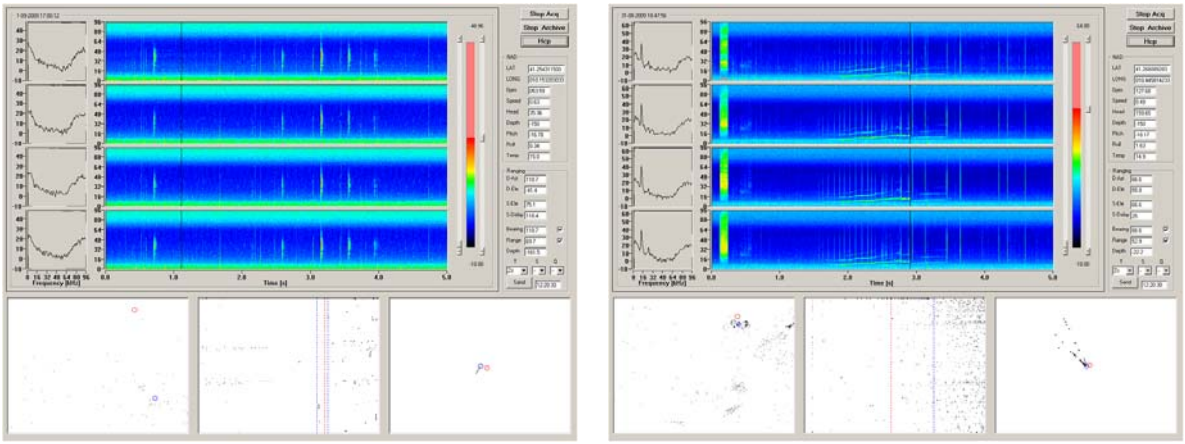
Example outputs of the SeaPro system



Example of detection information as displayed on the SSC Pacific WILD system.

NURC CPAM

The NURC CPAM (Compact Passive Acoustic Monitor) is a small array of 4 hydrophones that are in a tetrahedral configuration to allow three-dimensional direction finding. The CPAM consisted of two units, a wet-end system linked with fiber-optics to a dry-end system. The wet-end system is comprised of hydrophones, temperature compensated depth sensor, orientation sensor (pitch, roll, heading), water temperature sensor, and interface logic. The dry-end system includes interface logic, a TI-6416 processor, and a digital USB interface to a general purpose (GP) computer. Real time displays of acoustic, non-acoustic data, as well as results are presented on the GP computer. The processor implements click detection and direction finding algorithms. The CPAM was tested during the trial and was deployed off the stern of the NRV Alliance. Cetacean detections were made in real time during the final days of the cruise.



Examples of CPAM detection of beaked whale clicks (left) and dolphin whitles (right).

NUWC Tetrahedral array

An Applied Physical Science 4-element bearing array was provided by NUWC for hand deployment. The hardware consisted of a small array, 200ft cable, and electronics package. This array was used in testing mode only.

Sonobuoy Systems

Two types of passive sonobuoys produced by Undersea Sensor Systems Inc (USSI) were used. These include the AN/SSQ-53F and AN/SSQ-53F GPS modified sonobuoys. The hydrophones on the buoys can be deployed to a maximum depth of 1,000 ft, are battery powered and will last up to 8 hours. The units are expendable and scuttle at the end of their usable life.

The GPS modified 53F sonobuoys have a bandwidth of ~100Hz to 40 kHz. They have been modified to process audio frequencies up to 40 kHz versus the normal cutoff of 20 kHz. This modification was developed to enable scientists to monitor and analyze marine mammal vocalizations in support of Marine Mammal Mitigation (MMM) research. The position of the modified sonobuoys is tracked via GPS. Acoustic and GPS positional data were transmitted to a remote receiver via VHF radio. The standard AN/SSQ-53F is manufactured for the U.S. Navy which combines a passive directional and calibrated wide band omni capability into a single multi-functional sonobuoy.

Passive acoustic laboratory configuration and sonobuoy deployment.

All acoustic data was logged on the CIBRA SeaPro system. Preliminary analysis for the duration of the MED-09 project (29 July – 4 September 2009) indicates over 550 hours of broadband towed array data and over 100 hours of sonobuoy recordings were made. The species recorded include: sperm whales, Cuvier's beaked whales, pilot whales, Risso's dolphins, striped dolphins, and common dolphins

Real time acoustic tracking was accomplished for pilot whales using the two towed arrays and for Cuvier's beaked whales using the towed arrays and GPS sonoubuoys. The table to the right, provided by CIBRA, tabulates the ***preliminary*** passive acoustic monitoring results for each basin and the total cruise of the length of time each species was acoustically detected in real time.

MED-09 *Preliminary* passive acoustic monitoring results

Balearic sea (31 July to 04 August)

Species	Duration
Dolphins	19h 18min
Sperm whale	2h 55min
Pilot whale	0
Rissoõ dolphin	34min
Cuvieõ beaked whale	6 min

Alboran sea East (5 August to 10 August and 22 August to 26 August)

Species	Duration
Dolphins	55h 40min
Sperm whale	42min
Pilot whale	1h 10min
Rissoõ dolphin	2h 32min
Cuvieõ beaked whale	4h 36min

Alboran sea West (10 August to 22 August)

Species	Duration
Dolphins	66h 10min
Sperm whale	0
Pilot whale	32min
Rissoõ dolphin	1h 02min
Cuvieõ beaked whale	3h 40min

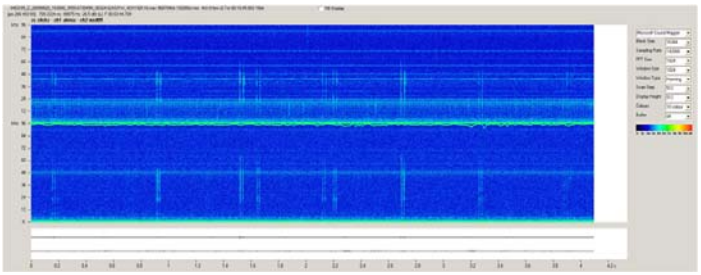
Transit and Tyrrhenian (27 August to 4 September)

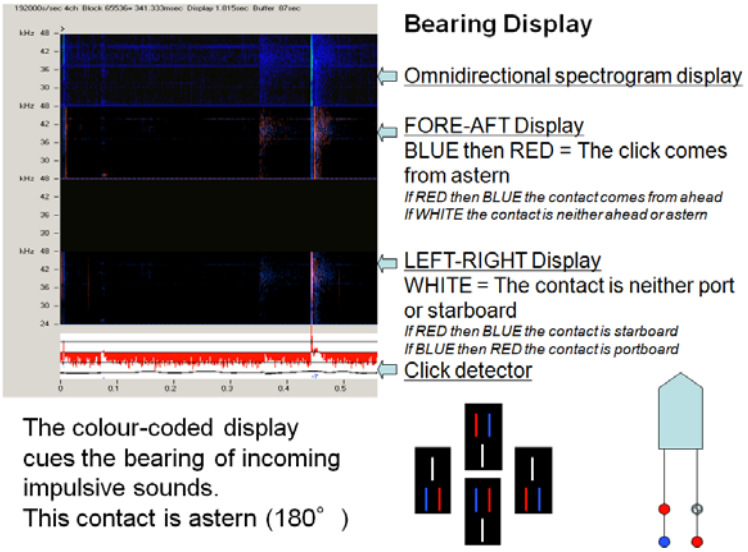
Species	Duration
Dolphins	30h 42min
Sperm whale	4h 40min
Pilot whale	1min
Rissoõ dolphin	0
Cuvieõ beaked whale	2h 17min

Grand total

Species	Duration
Dolphins	171h 52min
Sperm whale	8h 17min
Pilot whale	1h 43min
Rissoõ dolphin	4h 8min
Cuvieõ beaked whale	10h 39min

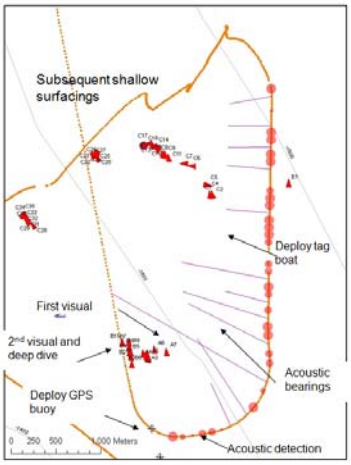
The figure shown here shows an example of an acoustic detection of Cuvier's beaked whale on a single hydrophone from each of the CIBRA arrays (top: port; bottom: starboard). Both the direct path and the surface reflection of the beaked whale click is seen. This information is valuable in estimating the relative location of the animal with respect to the hydrophone. As described by Zimmer and Pavan (2008)[2], the presence of delayed surface reflections is an important classification cue indicating that the received sound originated from a beaked whale foraging at depth.





Example showing a spectrographic-bearing display of a dolphin click coming from astern; the display is composed by four strips showing frequencies from 24 to 48kHz.

The output of the Whale Identification and Logging Display (WILD) system, that provided the geospatial tools to integrate both visual and acoustic data in real time, is shown in the figure to the right. This sequence began with the ship in the northwest (upper left) corner of the figure and moving along at 6 knots (shown by orange dots). As the ship moved to the

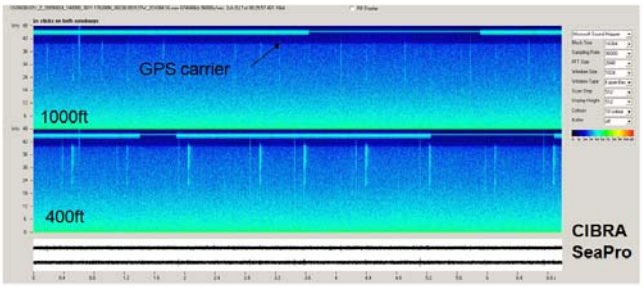


Zc focal follow – Tyrhennian Sea
2 September

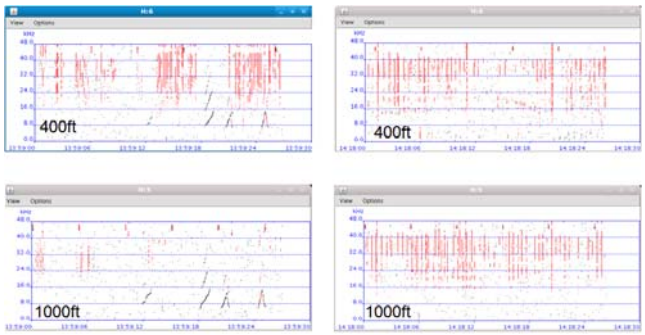
[2] Zimmer and Pavan (2008) IEEE Proceedings, Passive 08

southeast, a group of two adult beaked whales was spotted visually during their brief surface intervals. The red trianges marked "A" and "B" labels are multiple positions and direction of travel of the same two whales during two surfacings. A sonobuoy was dropped to monitor their vocalizations (small circle with crosshairs) after the animals went down on a deep feeding dive. The PAM devices on the ship began tracking the beaked whales acoustically. The red circles on the trackline indicate acoustic presence, relative strength (larger circles indicate stronger signals) and relative bearing (purple lines) when available provided by the CIBRA system. Using the WILD display, the ship was able to keep the group on the port side with very consistent detections. The tag boat was deployed prior to the group surfacing from the deep dive. When the animals re-surfaced (positions C1-C5), the tag boat was about 500m away, despite the fact that the animals were down for 79min and had moved 1500m. This group was followed by the visual observers during the multiple "shallow" dives (positions C6 – C35).

Acoustic data from the broadband GPS sonobuoys were monitored in real time using the CIBRA SeaPro system. The figure here shows Cuvier's beaked whale detections from 2 different hydrophone depths (400 and 1000 feet) for 2 sonobuoys deployed concurrently while the beaked whale was on a deep foraging dive. The double click structure is due to the surface reflection which are louder and more visible on the shallower phone. This information can be used for classification of beaked whales, as described in Zimmer and Pavan (2008).



- Surface reflection louder and more visible on shallow buoy
- Surface reflections are spaced more than on the towed arrays' sensors
- TDOA among the two buoys is 300ms

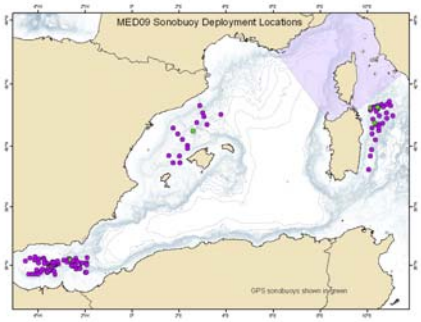


Delphinids *Ziphius cavirostris*

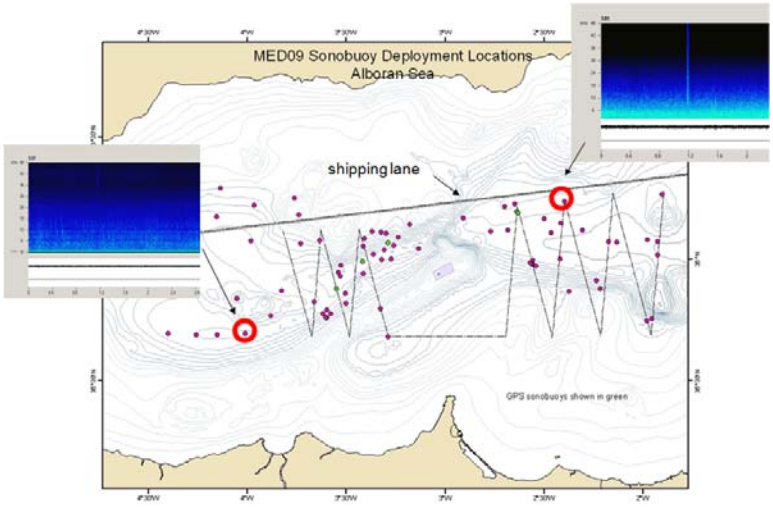
An example of the output from the NUWC M3R system adapted for use with remote sonsobuoys in MED-09 is shown in the figure to the left. This figure shows the simultaneous outputs of sonobuoys at two different depths (400 and 1000 feet) for a group of dolphins (left side of figure) and for a beaked whale on a deep foraging dive (right side of figure).

A total of 113 production sonobuoys were successfully deployed throughout the three basins. Concurrent data on the positional of all other nearby vessels was collected during all sonobuoy deployments (and at other times). Species recorded using real-time sonobuoys include sperm and

pilot whales and Risso's, striped and common dolphins. The figure here shows the locations of all buoy deployments, including 15 GPS sonobuoys, deployed during MED-09; information on specific deployment locations is available on request.

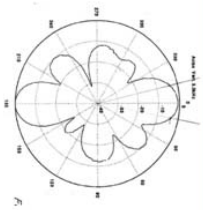


The figure here shows an example of relative noise levels in the Alboran Sea as displayed on the CIBRA system. 2 seconds of data are shown. The spectrogram on the left is from the southern portion of the basin and shows relatively low noise levels as compared to the spectrogram on the right which is near a shipping lane and shows higher levels, as indicated by the increased intensity of turquoise color in the lower frequencies of the spectrogram.

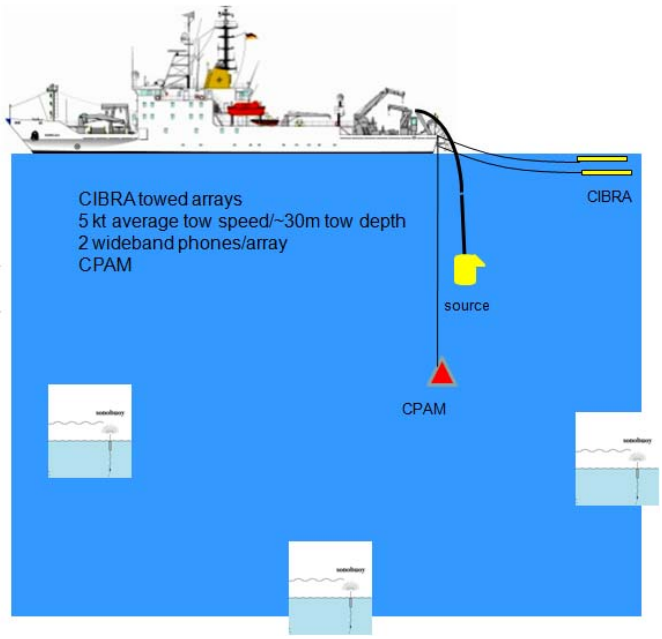


Acoustic Source

The NURC mid-frequency (MF) sound source consists of 3 ceramic free flooded ring transducers co-axially mounted on a central stainless steel air-filled cylinder. Spacing of the rings is 38cm (λ/2 at 2kHz). The beam pattern at 3 kHz is shown below with the notional configuration for the source and the passive monitoring assets for use in CEEs**.**



Bandwidth 2 – 4 kHz
Max MED 09 transmit level = 211dB
Vertically directional
Source deployment depth = 75m



Geospatial Analysis

The geospatial (WILD) team for MED-09 included: Chris Kyburg, Rowena Carlson, and Howard Coven. MED-09 was a successful demonstration of the ability to closely integrate visual and acoustic monitoring of beaked whales, off of specialized acoustic monitoring ranges, like the AUTEC array where BRS-07/08 were conducted. Significant advances were made in passive acoustic monitoring using multi-element towed arrays, a deep towed tetrahedral array, and wideband sonobuoys. Acoustic information from these different systems was integrated with visual observation data and displayed using the WILD system developed by SSC Pacific. WILD provided real time integration of navigation data, visual observations and several shipboard acoustic systems to provide sucessful off-range detection and focal follow of beaked whales.

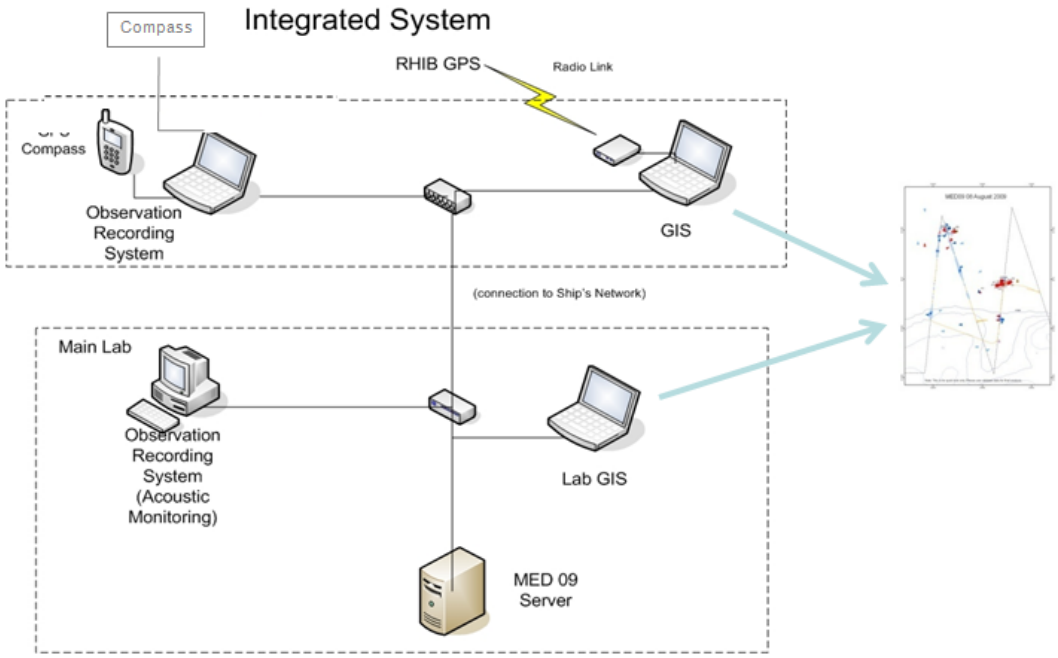
The WILD system successfully demonstrated a novel new capability for marine mammal data collection and archiving that successfully integrated both acoustic and visual survey data in real time and displays and archives the data in a geo-spatial format. The type of real time data that was logged and displayed included:

- animal lat/long and direction of travel
- vocalization lat/long and relative signal strength
- acoustic bearing information
- continuous ship track
- tag boat and GPS buoy locations
- measure tool for field distance measurements
- each station has own GIS tools

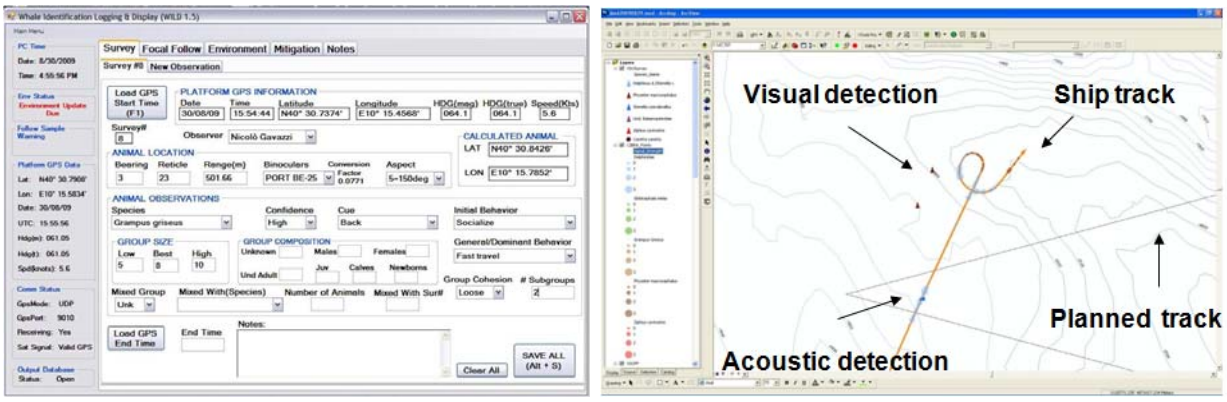
Archival base maps were available that contained the following information:

- bathymetry
- planned track lines
- marine sanctuaries
- 0PAREA boundaries
- Territorial sea boundaries
- Ports
- Land
- Ferry and cargo ship routes

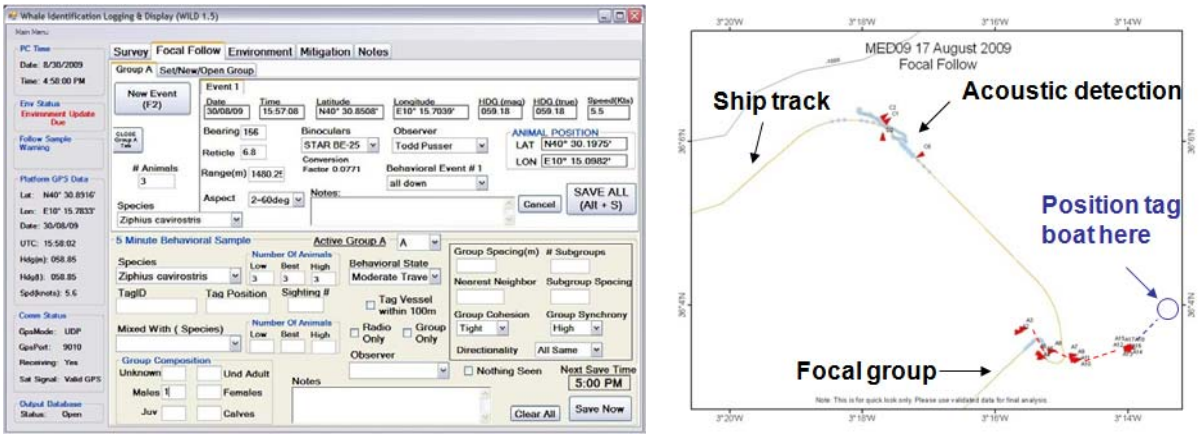
All of the dynamic and static parameters were displayed concurrently at 3 locations on the ship. The system configuration is shown below. Data management was achieved using automatic archiving in geodatabase format. Data transfer was accomplished via UDP protocol using standard NMEA strings.



WILD System Configuration

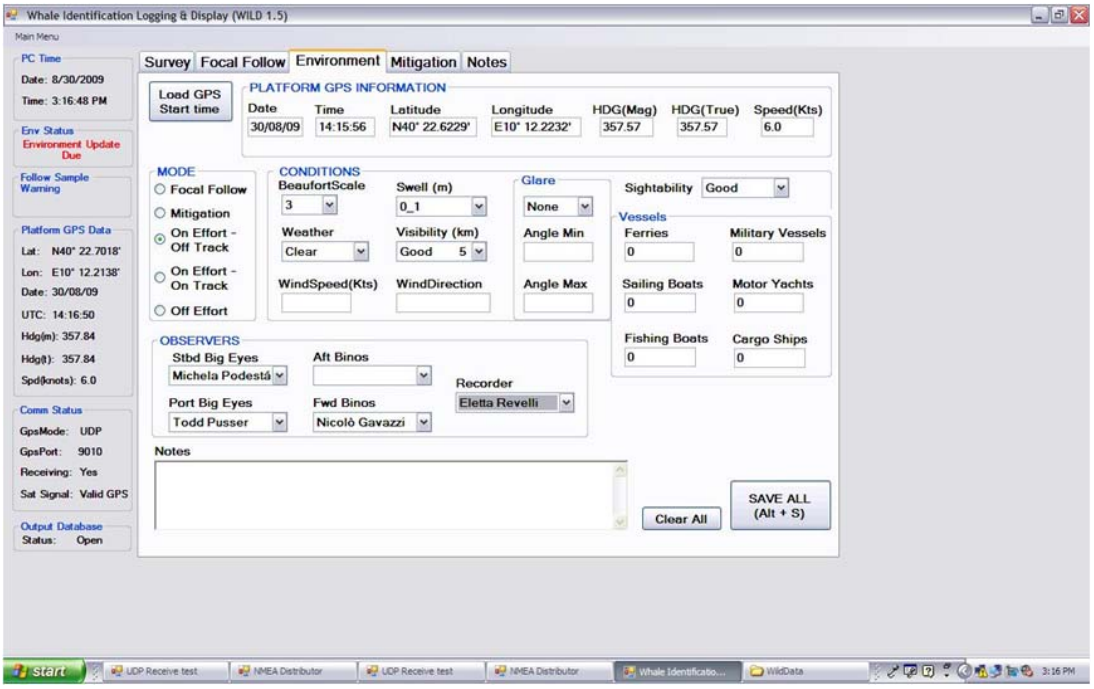


WILD data entry screen for survey mode (left) and resulting GIS display (right)



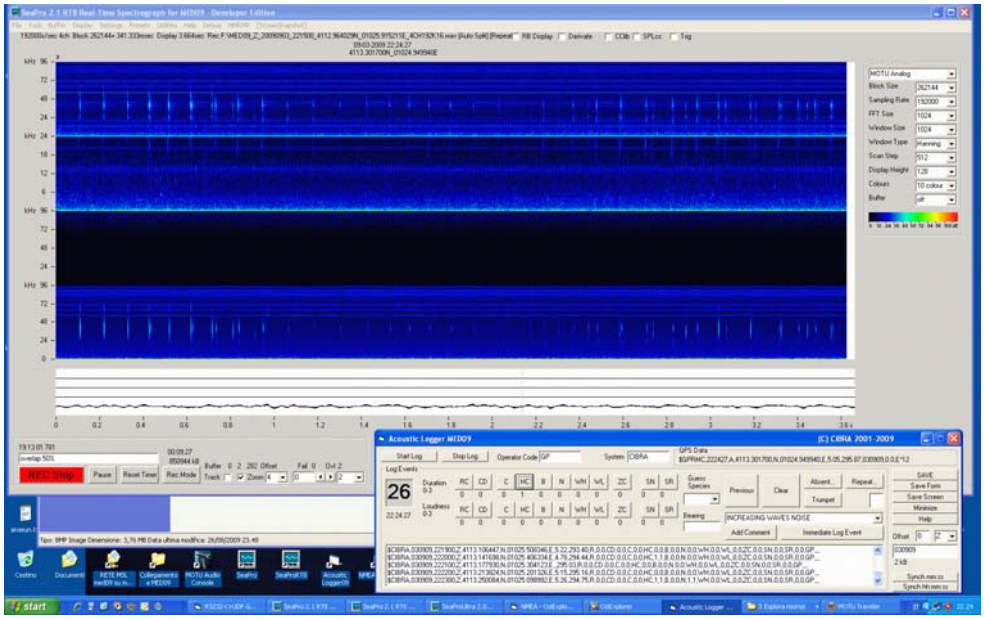
WILD data entry screen for focal follow mode (left) and resulting GIS display (right).

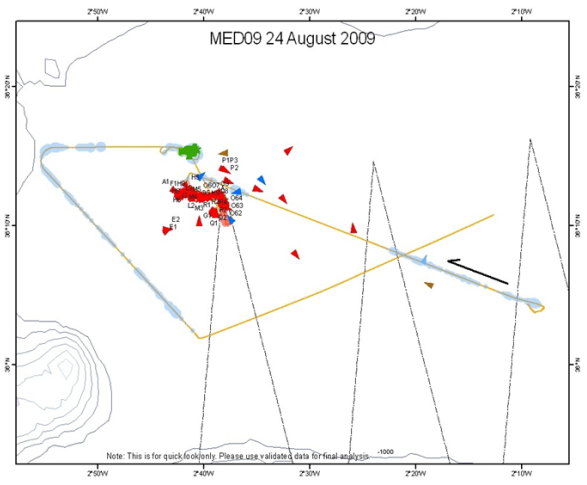
[Note here that the WILD system was used to estimate the location of the focal group surfacing position, so as to vector the tag boat.]



WILD data entry screen for screen for environmental data collection, logged every half hour.

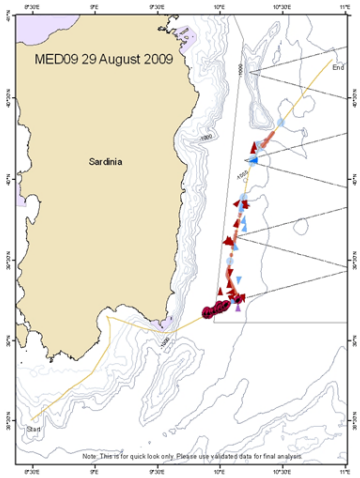
WILD also concurrently plotted acoustic detections made by the CIBRA system as shown here. The NMEA strings that transferred detection data to the WILD GIS display are shown in the lower right.

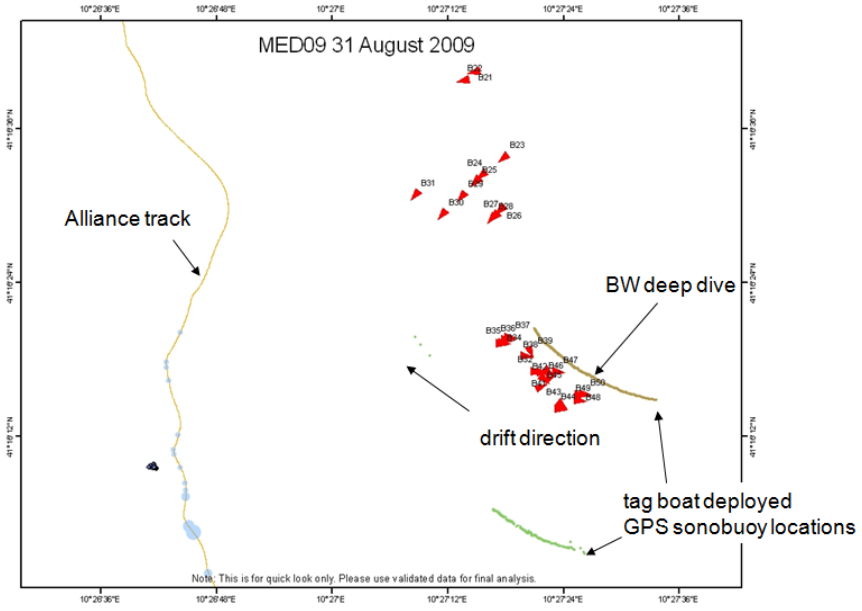




Geo-spatial summaries of all MED-09 operations were generated for each day of the cruise and contained in Appendix II. The example given here shows the summary data for 24 August 2009 in the Alboran Sea. The Alliance track is again shown in yellow (black lines are the planned tracklines) and the red triangles show surface locations and direction of travel for Cuvier's beaked whales. The blue circles along the track line show acoustic detections of dolphins and the blue triangles show visual detections and direction of travel of dolphins. The green triangles show visual detections and location of travel of pilot whales.

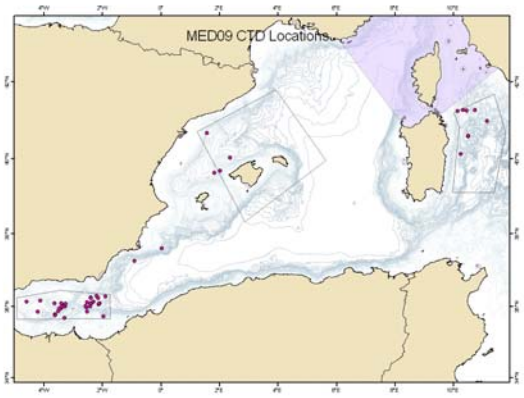
A second example to the right provides summary data for 29 August 2009 in the Tyrrhenian Sea. The Alliance track is shown in yellow (black lines are the planned tracklines) and the red triangles show surface locations and direction of travel for sperm whales. The blue circles along the track line show acoustic detections of dolphins and the blue triangles show visual detections and direction of travel of dolphins. The red circles with a black turtle in the centre show the visual detections of loggerhead turtles.





Example of the track of 2 drifting GPS sonobuoy locations shown with WILD geospatial software

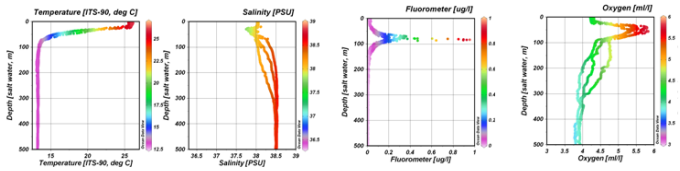
Oceanographic Data



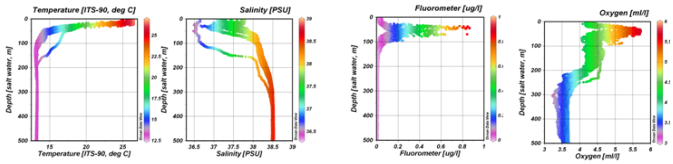
Various oceanographic data were obtained in MED-09 and were coordinated by Marina Ampolo. These included a total of 56 CTD (Conductivity, Temperature, Depth) casts taken in the three operation areas (see figure to right; specific deployment locations are available on request). The CTD stations collected the following oceanographic data: Conductivity (to determine salinity), temperature, pressure (to determine depth at which measurements are taken), fluorescence (as a proxy for chlorophyll_A), dissolved oxygen and sound velocity (derived from salinity and temperature measurements).

The images shown below give temperature, salinity , fluorescence and dissolved oxygen (plotted from left to right) as a function of depth (to 500m) for each of the operating areas. As the Alboran basin is quite large, the data are plotted for the regions east and west of Alboran Island.

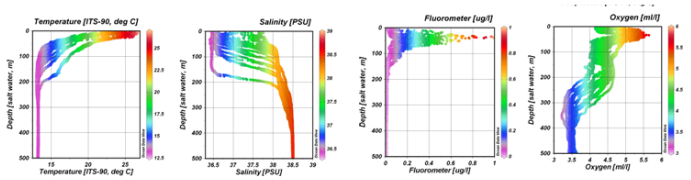
Balearics



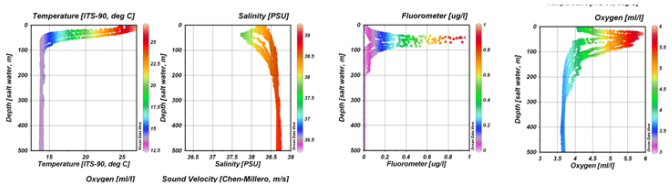
Alboran East



Alboran West

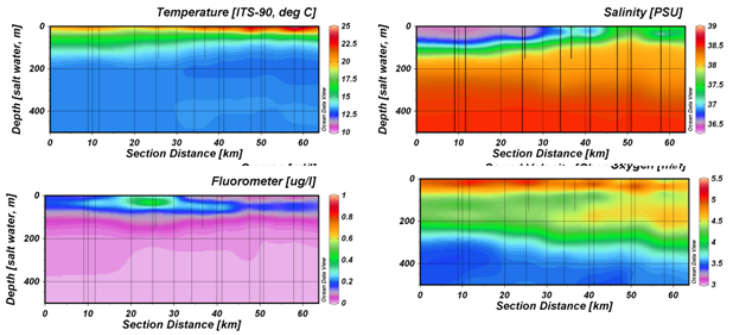


Tyrrhennian

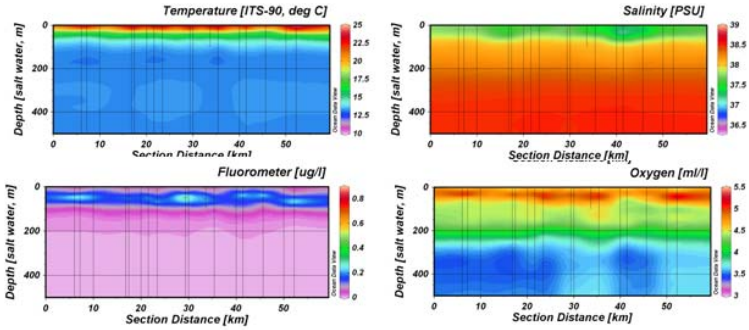


Two linear transects of several of the measured oceanographic parameters in the Alboran Sea are given below. An influx of cooler, fresher water is seen in the western Alboran as compared to the eastern Alboran Sea.

West Alboran



East Alboran



Conclusions

MED-09 achieved some but not all of the specified objectives. Weather and the inability to achieve sufficient range to focal individuals for suction-cup tag attachments were the primary limitations ultimately precluding the tagging of beaked whales. Other obstacles included loss of daylight (many focal follows were initiated late at night), restrictions on the selection of focal groups arising from permitting stipulations (*e.g.*, presence of calves in focal groups), territorial borders, and other factors (*e.g.*, unscheduled port calls due to injury). While efforts to tag and conduct controlled exposure studies with beaked whales were ultimately not successful for a host of reasons, numerous other major accomplishments were realized. These included:

- Sucessful, repeated detection and extended focal follows of Cuvier's beaked whales using integrated, onboard passive acoustic and visual detection systems (without the benefit of an undersea acoustic monitoring range as had been used in previous studies in the Bahamas);
- Integration and visualization of visual and acoustic data in real time using custom geospatial (GIS-based) software developed for MED-09 (WILD);
- Environmental data collection to support habitat modeling in previously poorly-known areas;
- Production sonobuoy deployment (n=113) for ambient noise measurements in wide areas of the western Mediterranean Sea with variable densities of human activity; and
- Successful tagging and focal follow of two long-finned pilot whales.

The combined results will be of interest and value to scientists and managers working in these biologically important areas of the western Mediterranean Sea. They also demonstrate the feasibility of using integrated visual detections with mobile passive acoustics systems to track difficult-to-study, deep-diving cetacean species such as beaked whales. Studying these species and conducting controlled exposure experiments is extremely difficult for a variety of reasons, as has been seen in both MED-09 and similar work in the Bahamas. However, MED-09 demonstrated that many of the obstacles in terms of detection and tracking individual focal groups can be overcome without the aid of a dedicated, fixed passive acoustic array.

Future efforts should carefully consider all relevant biological, environmental, and other (*e.g.*, regulatory/legal) risk factors in site and season selection for operations.

Additionally, there is a critical need for careful and systematic dedicated pre-engineering tests for assessing the capabilities and integration of hardware and software systems and platforms. These and other lessons-learned from MED-09 will continue to inform subsequent efforts to obtain direct measurements of behavioral responses of marine mammals to human sounds, including military sonar.

Appendix 1: MED-09 Blog Archive

Note: A complete .pdf of the blog posts (including some photos and images not included here) is available on request. As of January 2010 when this report was issued, the MED-09 Blog was still available on-line at: http://med09-expedition.blogspot.com/

Expedition Overview

Wednesday, July 22, 2009

Cruise Dates: July 27 - September 7, 2009
Research Cruise MED 09 (short for Mediterranean 2009) is part of an ongoing, international, and interdisciplinary effort to better understand whale behavior, particularly the effects of sound in the sea on beaked whales and other marine mammals. Researchers want to understand how whales change their behavior when they hear different sounds, both natural and man-made. The blog will be starting soon. For more information view: Cruise Overview
Posted by WHOIExpeditions at 12:33PM (-07:00)

28 July Arriviamo

Wednesday, July 29, 2009

The research team arrived in La Spezia on the 27th and 28th of July along with loads of equipment – hydrophones, cable, big eye binoculars, tagging equipment, and more computers than people. The task for these days is to unpack, organize and install equipment. No escaping the last trip to the hardware and electronics stores to buy wire, connectors, batteries … The Permit Division of the Office of Protected
Resources issued the scientific research permit for this research well ahead of schedule, relieving the anxiety of worrying whether it will be issued in time. Tagging equipment is ready to go. So is the entire crew.

29 July Departure

Wednesday, July 29, 2009

The ship left port at about 0900 in perfect weather, warm, no clouds, and calm seas. After a safety drill and initial all hands meeting to go over the science plan, the visual observers got their equipment ready to work, and they started observations after lunch. We are transiting through the Pelagos Sanctuary today, so our only marine mammal related activity is sighting for marine mammals. The visual observers sighted large
numbers of sea turtles and dolphins in the good visibility conditions, along with two Cuvier's beaked whales, and a fin and two sperm whales in the distance. The more complicated installation and testing of acoustic gear is underway.

30 July Transit

Thursday, July 30, 2009

We are underway from Italy. Unlike yesterday, today we have winds up to 40 knots. Too rough for sighting whales and putting out the tag boat. The team is testing acoustic and computer equipment, practicing operating the observer data logging programs, etc. While the cruise is in the Mediterranean, readers who are concerned about the bombing in Mallorca should rest assured that we are far away.

Shakedown

Friday, July 31, 2009

Today we tested acoustic equipment such as the sonobuoy pictured here, which records sound from an underwater microphone or hydrophone and broadcasts the signal back to the ship using radio. As usual, there are little glitches to work out, but most of the equipment is working very well. We were ready to look for whales in the afternoon.

Weather was very calm -- excellent for visibility and tagging. The visual observers saw dolphins, but we did not find either of our prime candidates for tagging -- Cuvier's beaked whales or pilot whales.

Start survey

Saturday, August 01, 2009

Today the teams and equipment were ready to start surveying for whales. The ship is towing hydrophones that allow the acoustic team to monitor for whale sounds while visual observers watch from the flying bridge. As you can see from the picture, the acoustic monitors spend all day inside the main scientific lab monitoring computer screens and listening, while tomorrow you will see that the observers spend all day outside watching for whales with special binoculars. The visual observers saw (and acoustic monitors heard) lots of dolphins today. The acoustic monitors heard one group of a few Cuvier's beaked whales, but the wind was up for a brief period during that time and the observers did not see any. The tagging team is champing at the bit!

Survey 2

Sunday, August 02, 2009

Even though wind was forecast, the weather remained good for visual survey through the morning and into the early afternoon. The visual team got a good workout on the data logging program and GIS displays, but did not see any beaked whales nor many dolphins. Nor did the acoustic team hear them. We will continue
to survey in this area for one more day as weather in the Alboran Sea looks like it will be windy by the time we get there, but we anticipate transiting before too long.

3 August 09 Survey

Tuesday, August 04, 2009

This morning dawned unusually cloudy for this time of year. It was calm enough for the visual observers to work, but they needed to bundle up to stay warm. The wind came up by the afternoon, making it difficult to
sight whales, but the acoustic monitors kept listening. At the same time, the engineers on the ship were working on troubleshooting one of the systems designed to measure the bearing to echolocating beaked whales. At this point we have done 4 legs of the survey designed for the Balearic Sea with very few detections of marine mammals other than dolphins. There appears to be a much lower rate of detecting deep divers than in the Alboran Sea, so we have decided to transit to the Alboran Sea. On the transit we passed near Mallorca as the moon rose.

4 August Transit

Wednesday, August 05, 2009

Today we transit towards the Alboran Sea. This provides a time to talk about one of the most important parts of any ship -- the galley. The Italian cooks on the Alliance make sure that the crew eats at a level that is sure to keep up morale. Breakfast always has fresh focaccia and plenty of espresso. Lunch and dinner have antipasti, primi, secondi, dolci and caffe. I do not know how they keep bringing out such fresh vegetables and fruits so long from port, but the produce is fresh and wonderful. The photo on the top right shows the ship's crew making wooden cylinders for making cannoli. We'll report on the results when we taste them! It is hard to overemphasize how much the dedication and skill of the galley crew contribute to the morale of a ship.
Complimenti!

Entangled whale

Wednesday, August 05, 2009

This morning the sea conditions were not perfect but were OK for sighting. We listened and looked for whales, picking up lots of animals as we near our primary study site. This afternoon the visual observers sighted a Cuvier's beaked whale, Ziphius cavirostris, and noticed that she was logging at the surface in an unusual way. This whale was entangled in a fishing net, with two cuts on her side. Her skin was abraded by the net and looked white on the top of her back. We sent out our small inflatable boat to approach the whale,

which came over and actually rubbed on the side of the boat for a short time before sinking down very slowly in an unusual dive behavior. The crew on the tag boat tried to slowly approach the whale to attempt to cut free some of the net line loose, but they were unable to approach closely enough to help the whale. We have alerted Spanish marine mammal experts about her location and condition. Globally, hundreds of thousands of marine mammals entangle in fishing gear each year, and many of them die slow painful deaths. We were unable to free this whale, which was very disappointing for the team. We hope that humans can change their behavior to reduce the risk of entanglement for marine mammals.

Listening to beaked whales

Thursday, August 06, 2009

Beaked whales are very difficult to sight at sea. Their blows are seldom visible, they can hold their breath on a dive for 1 - 1.5 hours, and when they do surface it is for a short time. When beaked whales were first tagged with acoustic recording tags in early part of this decade, we learned that they make deep dives to almost 2 km deep, over one mile below the sea surface to feed on deep prey. Once they reach a depth of a few hundred meters, they start to produce echolocation clicks that are so high in frequency that they are barely audible to our ears. These clicks are short upsweeps that are different from the sounds of any other marine animals, so when we hear their clicks, we can know their is a beaked whale around. The whale directs most of the sound energy forward, like a flashlight beam, but some of the energy goes in all directions. When you are several kilometers from a clicking beaked whale, when the whale sweeps its beam past the hydrophone, the phone detects several clicks getting louder as the beam points towards the phone and then fainter as the beam points away. The photos show the hydrophones, or underwater microphones, that CIBRA from the University of Pavia provided for this project. They are designed to be towed from the ship.

In the past few years, scientists have learned to tow hydrophones and use these short scans to detect beaked whales on surveys. But Med09 needs to be able to listen to most of the clicks from when a whale starts clicking to when it stops. The Pavia towed hydrophone system uses 4 hydrophones that can tell us whether the whales are forward or behind us, left or right, so we can steer towards them. Today was the day that we used this ability to follow beaked whales during a dive and to link sightings with acoustic detections. Once we heard faint scans from a group of beaked whales, we approached it and started circling the group. Once the clicks stopped, we notified the visual observers to get ready for the whales to surface. The observers then sighted a group of whales where we expected them to come up, and we picked up clicks on the next dive. By circling the whales with a radius of about 500 m, we were able to hear clicks more or less continuously until the whales stopped to surface again. This capability was an important part of our study design, so we were very happy to show how well it could be achieved with the towed hydrophones.

The weather conditions were ok but not excellent for tagging. We put the tag boat out twice to follow and attempt to tag beaked whales, but the taggers were not able to approach whales close enough to do so. Tagging beaked whales requires a small boat being able to approach to within about 12 feet to attach the tag using a pole. We are hoping for better luck tomorrow.

Tagging Pilot Whales

Friday, August 07, 2009

Today was predicted to have moderate winds. At first light, it was clear that it would be too windy to try to find and tag beaked whales, so we decided to work with pilot whales. As luck would have it, we heard distinctive sounds of pilot whales by 0700 and sighted them by 0800. One of the unusual things about pilot whales in this part of the Mediterranean is that they seem fascinated by ships. These whales came right over to the Alliance and inspected it, then swam along surfing in the wind-driven waves, following the ship for some time. We deployed the tag boat, which took photographs to identify individual animals, and attached tags to two adult female pilot whales. Unlike beaked whales, which are extremely difficult to find and approach for tagging, pilot whales are quite easy to follow and approach. In fact these whales approached the tag boat and the first whale was tagged within five minutes of the tag being readied for attachment. The tags attach to the smooth skin of the whales with four suction cups, and are attached using a long carbon fiber pole that you can see lashed to the port side of the orange tag boat. The whales showed little reaction, continuing to swim near the ship. The pilot whales form sub-groups that are usually well defined, although the subgroups will merge and separate at times. Adult males can be distinguished from adult

females, and many females in these groups had calves, including neonates so young that fetal creases were visible. Under the conditions of our research permit, we did not conduct a sound playback with these groups, but we collected fascinating baseline data with bouts of complex vocalizations alternating with periods of silence. We tracked the tagged whale for more than six hours. After the tag released from the whale, it floated to the surface and broadcast a radio signal that we can use to recover the tag. Once the tag is recovered, we connect it to a computer and download the data before we can explore it.

A day in the work of tagging a beaked whale

Saturday, August 08, 2009

The equipment and training that the teams on the Alliance have been doing are all dedicated to the difficult task of tagging beaked whales. The species we are working on in the Mediterranean Sea is Cuvier's beaked whale, Ziphius cavirostris. Today pretty much everyone on the ship was focused on this job all day. The ideal weather for tagging a beaked whale is flat calm. Calm weather makes it easier to sight these hard-to-see animals when they surface for a series of blows lasting about 8 minutes. After a deep foraging dive that will typically last about an hour, they do a series of shallow dives each of which lasts for about 15 minutes or so. This means that the observers have to wait about an hour for their opportunity to sight whales when there is a deep foraging dive, but the duration of shallow dives is short enough that this provides the best opportunity to tag. This means that it is critical for the research vessel to get near enough to the whales during the deep foraging dive that it can direct the tag boat near the whales during the first surfacings after shallow dives. This morning there were light swells and light whitecaps from wind, which makes sighting beaked whales more difficult, but still possible with the excellent height of eye on this ship and with the powerful bigeye binoculars used by trained observers who know the cues that indicate a beaked whale sighting. The acoustic monitors have no problem hearing beaked whale clicks in these conditions. During the morning we detected several groups of beaked whales but they had small calves, which made them not good candidates for tagging efforts.

We continued the search throughout the day, with the teams rotating through a watch schedule to maintain high levels of attention for a difficult task. Looking for beaked whales, you need to scan the water systematically, looking for a cryptic surfacing. Unlike baleen or sperm whales, the blow is not very visible, and the beaked whale usually surfaces quickly and goes down again, meaning you have to be very attentive to see the surfacing and be able to recognize the species. Similarly for acoustics, when you are far from a beaked whale, all you will hear is a scan of several clicks as the whale's sonar beam passes the hydrophone. This means that if the monitors take their gaze away from the computer screen for more than 10 seconds, they may miss the cue.

We continued to survey, focusing all of our efforts on detecting the beaked whales. At 5 in the afternoon, the visual team detected a group of 3-4 Ziphius at the surface with no young calf. These initial sightings are marked with a yellow triangle to the right of the figure, and are marked H and I. We left the survey line and headed towards this group. Within about 10 minutes after the whales dove, the acoustic monitors started to pick up beaked whale clicks in the direction of the group. A few minutes later as we approached closer, the acoustic monitors started hearing relatively constant series of clicks with the 0.4 sec interval between clicks that is typical of beaked whales. This meant that we were close enough to hear the clicks even when the whale was not pointing at the hydrophone. The two straight yellow lines on the plot here give acoustic bearings to the sounds of these whales at two different times. Where they intersect indicates an estimate for the location of the whales. The ship was maneuvered to stay close enough to continue to pick up these clicks until they petered out about 20 minutes later. At this point, the ship was maneuvered to the west so that the visual observers could look away from the glare of the sun, and then was repositioned so the observers, who must orient towards the bow of the ship, had a clear view of where they expected the whales to come up. There was a strong current to the east, which

caused the ship to move east. It typically takes about 20 minutes for whales to ascend to the surface after they stop clicking. The visual observers did not sight the whales for about 45 minutes after the stop of clicking, so they probably missed the first surfacing. Over this interval, the ship moved farther east than was ideal for observing the area where we expected the whales to come up. The next sighting is the one marked J1-J3 in the center of the plot, just to the left of the orange line indicating our survey track. As soon as that sighting was made, the ship could move closer and reposition. This is the critical point to get the information required to place the tag boat near where the whales will next come up on one of their shorter dives. While one surfacing tells us where the whales are, we need a second surfacing to get an idea of their direction of travel. We prepared the tag boat for deployment, waited until the group was next sighted 19 minutes later, and deployed the tag boat 6 minutes later. For the next two hours, the visual team radioed the tag boat to position it near their estimates of where the whales would surface, then to direct it towards the whales as soon as they surfaced. Even though the tag boat was closer to the whales, the elevated platform and excellent optics of the visual team usually allowed them to sight the whales first. The whales usually only spend around 8 minutes at the surface, so the tag boat does not have long to approach the whales. We use a small quiet vessel for the tag boat and move slowly so as not to disturb the whales, so the tag boat needs to be within a few hundred meters of the whales when they surface in order to have a chance to tag. One complication with our tagging attempt today, was that the whales, which had been moving consistently WSW the entire time until the sightings marked J13-J14, suddenly switched direction, surfacing to the E in surfacings J16 and J17, then off to the NE for the final two surfacings. While the tag boat could see the whales, they did not get close enough for any opportunities to tag before sunset and we recovered the tag boat a little after 9 PM. The equipment and teams are intensely focused on tagging and are operating at a high level. Even so, beaked whales are so difficult, that our previous experience suggests that it will take days of these efforts to succeed in tagging a whale. We just need to keep doing what I have described here.

Working to tag beaked whales

Sunday, August 09, 2009

Last night we set a track line for today designed to get a combination of the best weather suggested by our forecasts and the best beaked whale habitat. This morning there were low waves and whitecaps -- marginal for sighting and tracking beaked whales, but possible. We were hearing pilot and beaked whales near sunrise. We were not able to sight the beaked whales we heard, but we did sight pilot whales by 9:30. We decided to continue to try for beaked whales as they are our top priority for tagging. The weather did not cooperate with us through most of the day, and the wind came up in the middle of the day. However, at 6 PM, the wind had changed direction and the seas lay down quickly.

The visual observers sighted beaked whales and we directed the ship to head towards the whales. Within half an hour the acoustics team picked up beaked whale clicks, probably from a different group, as the sighted whales were still making shallow dives. Right in this area, we sighted several different groups of beaked whales in a relatively short time, and hauled in the hydrophone arrays to get better mobility of the ship. We selected a group of 3 beaked whales with no calves and with a male with a well marked dorsal fin to be the focal group we would try to tag. We prepared the tagging boat to be ready to deploy and maneuvered the ship towards the whales, which surfaced just a few hundred meters from the ship. We then slowed down the ship and were able to deploy the tag boat close to the whales, which were doing shallow dives. For the next two hours until sunset, the weather and visibility conditions remained excellent, and the visual team used a plot of the times and locations of this group's surfacings to direct the tag boat to get as near as possible to where they thought the whales would surface. The plot comes from the GIS system that integrates all of the different kinds of data logged during the project, a real advance over earlier ways to store and display data from this kind of cruise. The key is to direct the tag boat to get within a few hundred meters of where the whales surface after a dive, so that the tag boat has time to maneuver to the whales with enough time to get close enough on a slow, quiet approach, to tag them. The tag boat did get within 20 m, but unfortunately, we ran out of daylight before we were able to tag them. The entire sequence from sighting, to acoustic detections, to maneuvering the ship and then the tag boat were as good as it gets! It was great for the morale of the team to see how well our training has paid off. We just need more time with animals and good weather!

Wind and waves

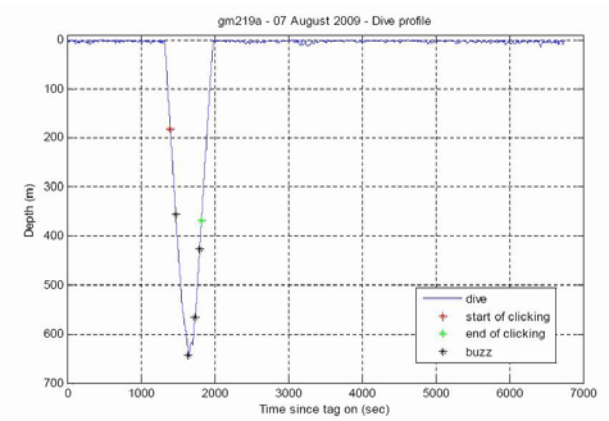
Monday, August 10, 2009

Today dawned with OK weather but a forecast for increasing winds. We had positioned the ship to an area where beaked whales had been detected and weather was forecast to be best, but we did not encounter workable weather nor beaked whales. The wind increased so much that the visual team had to come down from the flying bridge in the midmorning, and reached above 30 knots during the afternoon. The acoustic monitors could continue listening, although wave noise made it a little harder to detect signals. The rest of the teams went over data from the earlier parts of the cruise. The seas will be up, and the forecast is for continued winds, but we are hoping for enough of a window to try to tag in the next 2 days. It must be the start of the southward migration season for european birds. We have regularly been seeing hawks from the ship. Today a hoopoe landed on the railing of a crane for awhile to rest before resuming its flight. I am afraid that the Roman augurs thought that hoopoes could detect changes in the atmosphere and that they heralded storms.... We are relying on the best meteorological data our computers deliver us, and we hope for better auguries.

Not so much wind, but waves remain

Tuesday, August 11, 2009

After the winds of yesterday, it was a relief today to have winds mostly around 10 knots or less. But swells and waves remained from yesterday, creating difficulties for the visual observers. The acoustic monitoring worked well, and we set a course outside of our normal survey tracks in order to get the best weather conditions we could find for beaked whales. Twice during the day, acoustics got good enough detections to direct the ship nearby the whales, get a bearing, and orient the ship for optimal location for the visual observers to monitor the location where the whales were heard. Both times the visual observers were able to sight whales even though the visibility conditions were marginal.



Unfortunately, the conditions were too rough to attempt tagging. We considered using a large workboat from the ship for tagging, but even then the conditions were not good enough. The tag team kept itself busy analyzing data from one of the tagged pilot whales from earlier in the cruise. The dive profile shows that this whale spent most of its time near the surface in the top 15 m, but it did make one deep dive to nearly 650 m that lasted 11 min. Even though we had great observation conditions of the pilot whales, none of the visual observers had any idea that the whale had made this dive. The whale made echolocation clicks starting at the red asterisk and ending at the green asterisk. The black asterisks in between mark times that the whale accelerated the clicks, which we think means that she had identified a prey item she wanted, and she attempted to capture it. The recordings from the surface also include lots of social calling. All in all, a fascinating glimpse into a few hours in the life of these whales.

the mystery clicks

Wednesday, August 12, 2009

Today dawned calmer than predicted. In our efforts to find workable seas over the past few days, we have moved out of the area surveyed for whales last year. This morning we started heading back to the hot spots in the areas surveyed last year and during the earlier parts of this cruise, listening and watching for whales, with a course that we hoped would cover favorable habitat for beaked whales. Many who study the distribution of beaked whales have noticed that not only do beaked whales favor areas where the bottom is 1000m deep, they also seem to congregate in submarine canyons or seamounts. Our course took us in deep water past several sea mounts. In the early afternoon, the acoustic monitors started picking up faint clicks like those of beaked whales in the direction of the seamount where beaked whales had been detected on a survey track last year. When they noticed that there appeared to be several whales clicking at the same time, we diverted the ship to the area, pulled up the hydrophones for maneuverability, and maneuvered the ship for optimal sighting of where the clicks were detected. The sighting conditions were excellent, yet the observers did not sight any beaked whales at all. Beaked whales can dive for more

than an hour, but in a concentration, some whales should certainly have surfaced at that time. In deciding whether to continue to wait or to move on, we noticed that our depth was shallower than optimal for beaked whales. We therefore decided to move directly into deeper water where concentrations of whales were sighted last year. As we reached this area, around 6:30 PM, the visual observers sighted several groups of beaked whales and the acoustic team heard clicks from at least one foraging dive. We approached toward the groups, recovered the hydrophone arrays for maneuverability, and once we got close, we deployed the tagging boat. For some reason on this cruise, the tag boat keeps getting deployed late in the day even though we start at sunrise! The visual team noticed calves in several of the groups and was able to position the tag boat near surfacings of a group that did not have a calf in it. However, we were not able to get the tag boat close enough to attempt to tag before the whales appear to have made a deep foraging dive. The daylight did not hold out for us to be able to follow the whales and attempt tagging later. Today's efforts reinforce again how difficult it is to tag a beaked whale. You have to find animals, select a promising group, get an idea of their behavior and movement patterns and get a small boat within a few hundred meters of a group of whales coming up from a 15+ minute dive, when the whales could move more than a few hundred meters.

Tantalizing

Thursday, August 13, 2009

The forecast last night was for winds around 12 knots this morning, but it dawned very calm. The whales we stopped working with at 9 last night were near a main concentration of beaked whales seen last year. To get the best odds of being with whales this morning, we conducted an acoustic survey of much of last year's concentration from midnight to 0700 when there starts being enough light for the visual team to work. Unfortunately, there were so many dolphins that it was difficult to search for the subtle clicks of beaked whales among the cacaphony of sound that dolphins make in the Med when they are feeding at night. In fact, one of the sounds is called nacchere in Italian. This is the word for castanets. When striped dolphins are around at night, there is often a constant background of these sounds. Because it was so hard to detect beaked whales acoustically last night, we positioned the ship where we last were with whales at 9 the night before. The dolphins were still active acoustically, but the observation conditions were excellent for the visual observers.

As the morning went on, the sounds of the dolphins became quieter, making it possible to search for beaked whale clicks acoustically as well. Just before 11 AM the visual observers sighted beaked whales, and as before, several groups were sighted relatively quickly in the same general area. As before on this cruise, there seem to be clusters of groups of animals. The observers first settled on a group of 4 adult whales, 2 males (which can easily be identified by the white coloration of the front of their bodies), and 2 females. The tag boat was deployed just before 1140. The best opportunity to tag this group came when the tag boat was within about 100 m of a surfacing, the perfect distance, but as the tag boat moved over, a group of dolphins swam over to the beaked whales and swam around them. Apparently, they were bothering the whales, as one of the beaked whale breached right among them. After the dolphin incident, the behavior of the whales changed. They changed their direction of travel and this prevented the tag boat from completing its approach. At 1343, the visual observers switched to follow a group with two females and one male that was with a dorsal fin that was curled over to the side. This marking made it easier to make sure we were on the same group. In addition, this group seemed to keep surfacing in pretty much the same area, making it easier to position the tag boat. After the observers switched to the group of three, the white male surfaced and blew normally, and then swam for about ten minutes just several meters below the sea surface. It was quite easy from the ship to observe the white shape of the male continuously, and the visual observers directed the tag boat close enough that they were able to follow him underwater even from their lower vantage point. They tailed long behind him until he and the females surfaced. Even though they were quite close, the beaked whales were travelling, and at this speed it was hard for the small tag boat to close on them for tagging.

In the end we were able to follow the same group of 3 beaked whales from surfacing to surfacing over a period of 5 hours. This leads to what probably are the craziest tracks that the Alliance has ever made. It is a tribute to the bridge officers that they are able to position such a large ship so well for following whales. The ability to make these kinds of observations is remarkable for a species that is so cryptic that new species of these large mammals are regularly discovered each decade. The coordination with the tag boat was excellent, and they had several good opportunities for tagging, but in the end we just were not able to close to a few meters distance for tagging. This is the reality with tagging beaked whales. There are a series of steps, each of which takes time, skill, and the appropriate equipment. It

just takes a reasonable number of attempts even in the best of conditions to succeed in getting all steps done in time. This was the last day of tagging effort before a partial change of crew tomorrow. We had to stop an hour before sunset and recover the tag boat. The entire team had a barbecue out in the middle of the study area as the sun went down before we head into port. Everyone who is leaving wishes the second phase of the cruise fair seas and best of luck with tagging.

Port Call

Saturday, August 15, 2009

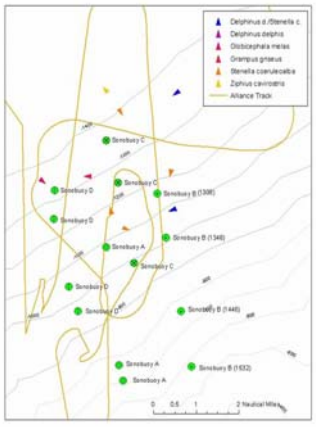
The past two days we made our scheduled port call in Málaga, Spain for supplies and to transfer several of the scientific crew. Those on the first leg of the project were glad to stretch their legs ashore for a short time in between the bustle of debriefing those arriving to ensure consistency in protocols and data collection. It was a festive time in the city; our brief time there happened to coincide with the beginning of Feria de Málaga which is celebrated for nine days beginning on the Friday of the second half of August in honor of the merging of Málaga to the Castilian Crown due to the conquest by the Catholic Monarchs in 1487. This made for some minor challenges in getting people and gear to the port with the crowds, but all went according to schedule and we are now steaming back out to sea. The picture here shows our departure from this Spanish port city under a pleasant sunset.

Tonight we had an all-hands meeting to discuss plans for the second leg and review the protocols with everyone as a group. We have a good deal of consistency between the two legs, but do have some changes in personnel in key roles. Thus we wanted to make sure we were all on the same page with the many specific protocols for safety and data collection for our different operational modes. Additionally, we will conduct several practice drills tomorrow deploying gear and personnel in a mock run of a tagging and controlled exposure exercise. The sound source will be deployed for practice and timing, but not turned on during this drill. After this drill, we will switch to survey mode and begin searching for animals. The weather forecast is for marginal conditions, but improving over the next several days.

Drills, Waves, and By-catch

Sunday, August 16, 2009

Today was the first operational day of the second leg of MED -09. Some gear had been adjusted or repaired and new personnel were in certain key roles, so we began the day deploying and testing the hardware and software needed for the very challenging task of finding, following, tagging, and safely exposing beaked whales to sound. We remained vigilant throughout these drills for animals either seen or heard (and we did have some – see below), but the weather was marginal with winds around 10-15 knots for most of the day and a light swell. So we did not feel we were missing perfect conditions in working through the drills deliberately, and with so many things that must go right here to succeed we require considerable precision in the sequence and timing of deployments.



After a successful test of one of the repaired passive listening systems that had been having some problems, we conducted a drill of deploying an array of real-time listening buoys (called "sonobuoys") we will use to monitor vocalizing whales once a focal group is tagged. One of our small boats delivered the sonobuoys in a grid while we deployed the sound source for controlled exposure experiments to a depth of 75 m (but did not turn it on). Meanwhile, our visual team practiced tracking a "whale" (which was actually our own tagging boat) and we tested our ability to safely maneuver for visual monitoring with both the listening gear and the source in the water. As you can see from the plot here, we dropped a total of four sonobuoys (labelled A-D) in a counterclockwise fashion at a spacing of about 2.5 km. These listening devices have a relatively deep listening sensor and relay sound information using a radio signal back to the ship; with them we can monitor the area around focal whale groups during a controlled sound exposure. This figure shows one of the challenges we face here in the dynamic Alboran Sea, which is the affect of currents on free-floating buoys. Notice that various green symbols (starting from the north) moved consistently to the SSE over time (on average about 4.5 km in 2.5 hours). For instance, note the four green bulls-eye symbols furthest

to the east labeled "Sonobuoy B" and the consistent drift (time noted for just this example). We know from the ship's sensors that there was a fairly strong current (almost 2 knots) in this direction, so this was not surprising to us. However, it demonstrates another challenge facing us in being able to not only read the position and behavior of the animals, but also the position and behavior of our monitoring gear in relation to the movement of the water (and other factors such as the wind and sun). Practice and drills are required to understand and manage such challenges, which was part of why we worked so carefully through it today. Ultimately we were very pleased with the timing of the operation and in our ability to monitor an area in which we and all our gear was being strongly moved in the active sea.

We continued to monitor acoustically and visually for marine mammals and did manage a number of detections in both modalities of several species. Some Cuvier's beaked whales were heard early in the day but not seen and then a total of five animals were sighted near sunset. Additional detections were made of other cetaceans, including Risso's dolphins, striped dolphins, and common dolphins, although no attempt was made to tag these animals. Unfortunately, one of the common dolphins we located had been caught in a fishing net and was floating dead in the water. As you can see from the picture here, it had been killed relatively recently and the flukes (tail) and dorsal fin were severed, presumably by fishermen trying to remove the entangled animal without cutting their nets. We approached the carcass in one of the small boats to document the species (Delphinus delphis) and sex (female) and to obtain photo documentation and samples for genetic analysis. We also sighted an ocean sunfish floating dead and seemingly entangled and what may have also been a dead sea turtle as well. By-catch (the incidental killing of animals in fishing gear) is a serious problem for marine mammals around the world, including here in the western Mediterranean.

We hope for better weather and less morbid observations tomorrow and are primed and ready to accomplish our objectives if weather and animals will allow. Knock on wood, the forecast looks more promising.

Beaked Whales Near Sunset

Monday, August 17, 2009

Our first full day on effort for the second leg dawned windier than hoped. Seas were light, but the 10-15 knot winds made things difficult for the visual teams who came on at first light. Acoustics had a large amount of dolphin activity again before dawn but did not pick up any beaked whales while scanning. We ran a slightly westerly track across promising areas for deep-diving whales in order to keep the glare from the rising sun from making things harder for the visual team. Despite our efforts, there was little action through the morning and mid-day other than some scattered groups of dolphins and our regular oceanographic and ambient noise measurements. As has been the case for much of the project, however, the weather began to cooperate in the late afternoon and early evening. We came back through some canyon-like areas where beaked whales had been detected previously and found five different groups as the seas began to settle, in addition to several groups of common and Risso's dolphins. Here you can see a Cuvier's beaked whale "spyhopping" to have a look above the surface. Unfortunately we had several groups that were not good candidates for tagging attempts because of their group composition or how they were traveling. The two groups we attempted to tag stayed too far from the tag boats for us to attach acoustic tags before the setting sun ended our efforts for today. The outlook for tomorrow is for even stronger winds (up to 20 knots) and moderate swell, which will prove very challenging if the forecast is correct. We continue our passive acoustic surveys at all possible times and will conduct these throughout the night tonight.

Unscheduled Stop -- Bumpy Seas

Tuesday, August 18, 2009

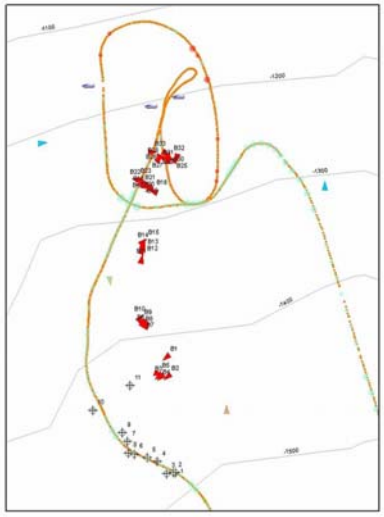
Last night we ran an all-night passive acoustic survey on our way back toward the Spanish coast through the dark. We needed to make a brief, unplanned return to enable some medical assessments and crew-changes. Safety comes first and everyone is well and on the ship ready for action. Nevertheless, it took much of the day away from our efforts to tag beaked whales, though we did return into deep water in search of them by late afternoon.
However, our return to what we believe (based on previous observations) to be good beaked whale habitat largely confirmed the earlier weather forecasts of conditions that would be unsuitable for sighting and tagging beaked whales; none were sighted or heard on the acoustic systems today. Multiple dolphin groups were sighted, and at one point several large groups of dozens of common dolphins were swimming and socializing on all sides of our vessel. We

weren't traveling fast enough for them to want to ride on the bow wave, but they streaked gracefully around and by us for 20 minutes. A group of Risso's dolphins was sighted just after dinner, but by about 2000 the wind and swell were at unworkable levels. Tomorrow we plan to work through a deep canyon where many previous sightings of beaked whales have been made. The forecast is for marginal conditions much of the day but calming in the area where we will be operating in the afternoon.

Calmer Seas -- Many Animals

Wednesday, August 19, 2009

Today dawned calmer with light seas and winds between just 5-10 knots for most of the day dropping to almost zero by late afternoon and evening. These are the conditions we need to reliably sight and tag beaked whales. Throughout the day we sighted many cetaceans, including hundreds of common, striped, and Risso's dolphins, pilot whales, and about 8-10 different groups of Cuvier's beaked whales. Both teams monitored the vast horizon and the cacophonous underwater acoustic scene these animals covered, trying to find the right situation. Several times our acoustic teams were hampered in extracting the beaked whale clicks from similar vocalizations from other nearby species. Also, almost all of the groups of beaked whales we found today either had small calves or were single individuals, which meant we could not work with them for different reasons. We did follow two different (we think!) groups of adult animals near the end of the day as good candidates, but despite the flat seas, visuals, acoustics, and tag boat in the water, they gave us the slip.



The figure you see here shows a bit of our track from today and gives you a sense of the relative movement of the animals and some of our tactics in using different sensing gear in monitoring their movement and behavior. The orange line shows the movement of the vessel starting at the southern edge of the plot (note the depth contours in meters along the track). The crosses with numbers 1-10 show different positions of a real-time, high-frequency GPS sonobuoy we dropped early in this encounter. These locations are over about four hours and if you noted the sonobuoy tracks from the blog several days ago you can appreciate the quite different current conditions we encountered today. The red triangles are sequential positions and headings of the focal group of beaked whales we were tracking. The triangles of other colors are sightings of other cetacean species and the little boat symbol is the position of our inflatable tag boat. As you can see, the animals increasingly tracked to the north and then the northeast (away from our first sonobuoy) and we monitored them from some distance, relying entirely on the visual team to track them since they are silent during the surface diving interval. When the group went for a deep (~1000m or more) dive after the last red triangles, we dropped our towed arrays back in the water and initiated a large circle around their position to monitor for their clicks. You can see some orange symbols along the Alliance track during this circle, showing that we successfully detected the animals with expected bearings during this period. This plot shows the complexity and integration of the visual and acoustic capabilities we have here, how they complement one another to enable us to monitor deep-diving animals in real-time, and the importance of real-time GIS visualization to guide our decision making in this challenging task.

The forecast for tomorrow and Friday is for excellent conditions such as we had today followed by possibly high winds over the weekend so we are all very much focused on the window the next few days looks to hopefully afford us.

Many Beaked Whales (most with calves)

Thursday, August 20, 2009

We had another very good day today in terms of wind and sea conditions. We consequently found many cetaceans, including our primary species of interest. We worked mostly in the deep axis of the same canyon area and detected many groups of Cuvier's beaked whales throughout a very long and full day of activity. Acoustic surveys begin at

0500, visuals come on at dawn, and both teams operated continuously throughout the day with these many animals. As you can see from the picture here, it was another pleasant sunset but we just missed getting a tag on at the very end of the day. Around 20 different groups of beaked whales were sighted, in addition to a large number of the four other species we've been seeing regularly out here (pilot whales, and common, striped, and Risso's dolphins). While it is likely some of these were the same groups at different points in the day, or different combinations of groups (they do come together and break off from one another), with the distance we traveled it is likely we detected a dozen or so distinct individuals or groups. This confirms earlier evidence that this is an excellent place to find these elusive animals when the conditions are right and we have the capabilities that exist on this ship.

However, despite the large number of sightings, it took many hours to find a good candidate group, as almost all those we found today (as yesterday) had one or more calves or were single individuals. In the late afternoon we found a good group of adult and sub-adult animals that we tracked for about four hours, both visually and acoustically through relatively shallow surface intervals and one deep foraging dive (after which we found them at the surface again). We vectored the tag boat during the subsequent surface intervals and we again came tantalizingly close (within a few feet) of tagging the animals before they slipped into the depths again.

We expect good conditions again tomorrow and will give it our all again. We will be trying some similar areas where we hope to be less likely to find so many groups with calves that we cannot work around. Despite it impacting our ability to work many of the groups here, the large number of calves is encouraging and we are learning some interesting things about the ecology and behavior of these poorly known animals in when and where we find groups with different social structure. It is remarkable how challenging these animals are to work with, even with the amazing amount of expertise and technology available to us, but we know this can be done and we should have another good chance tomorrow if the forecast holds true.

Blown Out

Friday, August 21, 2009

Despite the favorable predictions, the weather front we expected tomorrow seemed to arrive a day early. We experienced winds around 15 knots for most of the day with regular whitecaps - conditions that are inconsistent with spotting beaked whales visually. We continued in survey mode focusing on areas where we might expect pilot whales; the weather would have allowed us to work with them for most of the day. While we were waiting for conditions to improve, we made measurements comparing how our different acoustic systems performed in detecting the same underwater sounds in order to further refine capabilities and procedures. We also made additional oceanographic measurements and conducted acoustic surveys in support of the habitat modeling efforts that will benefit from MED -09 data.

Ditto

Saturday, August 22, 2009

Today was a repeat of yesterday – if anything a little worse. We had steady 15 knot winds for most of the day picking up to near 20 later on. We surveyed for pilot whales until afternoon when it became too strong to search for anything visually. As yesterday, we continue to search acoustically and some beaked whale clicks were detected during the day in areas where we had sighted them before. So they are still where we expect them to be and we can detect them using our acoustic assets, but even being right on top of them it is impossible to spot them visually in the Beaufort 5 wind conditions.

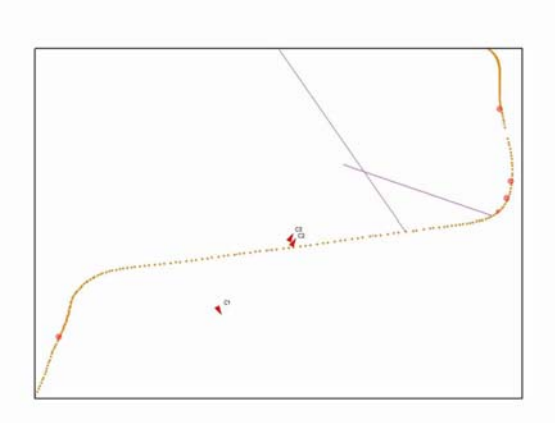
The Beaufort scale is an empirical measurement of wind speed that is related to sea conditions. To give you a sense of how remarkably calm we need the conditions to be, consider that the scale goes from 0-12 and 5 (our wind for much of today) is categorized as a "fresh breeze" of 15-20 knots (29-38 km/hr or 16-24 mph) and the resulting seas have moderate waves of some length, many white caps, and small amounts of spray. For sighting and tagging beaked whales, we need Beaufort 0 ("clam" with winds <1 knots), Beaufort 1 ("light air" with winds 1-2 knots), or Beaufort 2 ("light breeze" of 3-6 knots) conditions. Anything Beaufort 3, a "gentle breeze" of 7-10 knots (12-19 km/hr, 8-12 mph), or above makes it difficult or impossible to visually detect and tag beaked whales. Beaufort 3 and 4 ("moderate breeze" of 11-15 knots) can be workable with pilot whales and other cetaceans, but at Beaufort 5 we tend to put the covers on the big-eye binoculars, not because we can't take it but because it isn't worth looking.

We continue to refine and cross-calibrate all our detection systems and await the opportunity. Tomorrow looks as bad in terms of wind and the seas may be building with the steady wind from the east, though we have learned not to put too much faith in weather forecasts. We are moving to what we hope may be a better area in terms of weather where beaked whales have been spotted previously.

Chances early...then more of the same

Sunday, August 23, 2009

Today dawned much calmer than expected and we were on animals both visually and acoustically quickly. We searched around our first beaked whale acoustic detection and soon thereafter had a visual sighting. We also crossed paths with a large group of common dolphins (50 animals or more), saw some large Risso's dolphins riding on the bow of a nearby large ship, heard pilot whales, and saw a large tuna leap several times in the air with a large fish in it's mouth. We followed one promising group of three adult/sub-adult Cuvier's beaked whales, tracking them both visually and acoustically (see below), and had our tag boat over the side and ready to go. But we hadn't managed to tag them by about 1100 and the wind picked up from the east again rather quickly and by noon we had the Beaufort 5 conditions described yesterday that were predicted for today. We continued searching for pilot whales, but by mid-afternoon the winds again ended our day early.



During the mid-morning focal follow on the beaked whale group, we demonstrated again an effective capability to integrate information received from our visual and acoustic teams to position the ship relative to animals while adjusting for other environmental factors as well. In the figure here, you can see the track of the ship as the orange symbols in a line beginning in the southwest (lower left) section of this GIS plot; the closer together the symbols the slower the ship and the further apart the faster the ship. As we moved to the northeast, we had a visual sighting (red C1) of a beaked whale, identified as a single animal. We continued forward and had a subsequent acoustic detection of beaked whales (seen as the pink circle on top of the ship's track) and an approximate bearing to the animals ahead of and to the starboard (right) side. About 25 minutes later we had two good visual sightings of a group of three beaked whales (red C2 and C3) at the surface and had clear direction bearing (heading) for them to the northeast (direction of arrows). The animals then did a shallow dive that we expected would take another 15-30 minutes. Now we had a choice - and a problem. It was still morning at this point. The sun was coming up in the southeast and there was a serious glare on the sea that would prove difficult for our visual observers if we did not adjust the position of the ship relative to the whales. So we turned toward the sightings, sped up significantly (note the orange symbols spacing out), and cut behind them while maintaining acoustic detection. This maneuver worked perfectly as we passed them and then slowed down, turning to the north while continuing to hear them now off our port (left) side (additional small pink circles along ship track). The two purple lines show two of the acoustic bearings which predict direction to the animals underwater; they are close enough in time that where they cross is an estimated location. Using the sighting location, visual bearing, and these acoustic bearings, we had a good prediction of where they were and where they might come up. Now we had the sun on our stern (back) and also a better orientation to the significant current from the east as well. Ultimately we were precluded from seeing them come up despite, being in an ideal position, because throughout this maneuver the wind jumped from 5 to 15+ knots. Nevertheless, this kind of fairly complex tracking with integrated visual and acoustic information - reading the animals using these tools and orienting ourselves correctly relative to the sun and the current - demonstrates that everything is working together quite well.

The wind is dropping this evening and we hope to catch a nice calm window tomorrow as the wind switches from the east to the west. If we get flat seas we know the animals are here and that we are ready.

Hot Spot

Monday, August 24, 2009

Our read of the weather was right on today. We had excellent conditions in the morning, workable weather in the middle of the day, and strong winds by mid-afternoon. As has been the case every day we have been in beaked whale areas with suitable sea conditions, we saw many animals today. If you look closely at the picture here you can see the three different sizes of binoculars we use to monitor visually at different distances. Initially we were spotting just single animals, who are very difficult to tag relative to groups, and we kept moving. Soon, however we came into an area with many different groups. It was difficult to track who was who and how many groups there were because it seemed very likely that some of the groups were splitting apart and re-forming in different configurations while traveling in the same general direction. Some of these groups had calves, but generally speaking we were seeing more large and workable animals.

With the excellent conditions, we soon got a good read on a group of four animals without calves. We followed them through several surface intervals and "shallow" dives and had a good bearing on their direction. The tag team had two close approaches to within about 10m of the animals (the picture here is of the focal group during one of these approaches), but was not able to attach one of the DTags to the animals. We continued to track them as they went into a long, deep foraging dive and began producing echolocation clicks, using our listening assets. As yesterday, with the integrated information on bearing from the visual teams and acoustic bearings from the listening arrays, we felt quite confident that we maintained them on our port side and had a probable zone where they would resurface. Also like yesterday, however, as we positioned ourselves like this and were ready, the winds came up quite rapidly to 20 knots and we were forced to break off the search. We continued to search for pilot whales in the marginal conditions and ultimately found a moderate size group - using acoustic cues since the wind caused poor visibility. However, there were small calves in their groups and both that and the sea state would have prevented a CEE with them as well, so we did not attach pilot whale tags.

The weather forecast for tomorrow looks poor with strong winds from the west; Wednesday may offer us another window of calm as the winds shift back to the east. We will, of course, be ready to go tomorrow if the forecast is incorrect, but if we cannot look for beaked whales visually, we intend to conduct acoustic surveys over what looks to be an interesting seamount and submarine canyon area that has not been extensively explored. Once we have good conditions again, we will likely return to the area where we worked today. Even accounting for likely re-sighted animals, a conservative estimate of the number of individual Cuvier's beaked whales we saw is about 20 within about a 60-square-mile patch of ocean -- quite a high density for our newest "hot spot".

Rough

Tuesday, August 25, 2009

The wind blew steady all day today from the west at 20-25 knots with gusts to 30, building heavy swell. The combination of Beaufort 6-7 winds and resulting seas was way beyond what our visual or tag team could work in for any species and they were not placed on effort at any point today. We did continue to monitor acoustically, while holding on, and covered some interesting-looking areas. But even our acoustics team was affected by the conditions to some extent with the rough seas and had limited detections. We are hoping for better wind conditions at some point tomorrow as it changes from the west back to the east, but we know we will still be dealing with residual swell from it the strong and steady winds today. We are having strategic discussions about our next course of action.

Still Rolling

Wednesday, August 26, 2009

The winds gradually came down from the gales of last night throughout the day, but the swell from the sustained strong (Beaufort 7) winds remained prohibitively high for us. Our visual observers went on watch several times as we looked for pilot whales. We did find some, but with the seas and the fact that most of the subgroups had small calves, we did not attempt to attach acoustic tags. As usual, we had our passive listening arrays deployed and had intermittent detections of marine mammals at different points during the day. Overall it was another day where the weather prevented us from achieving our primary objective. Based on our experiences the last few weeks and the wind and wave forecasts for the next five days, we will be leaving our current location and transiting to one of our

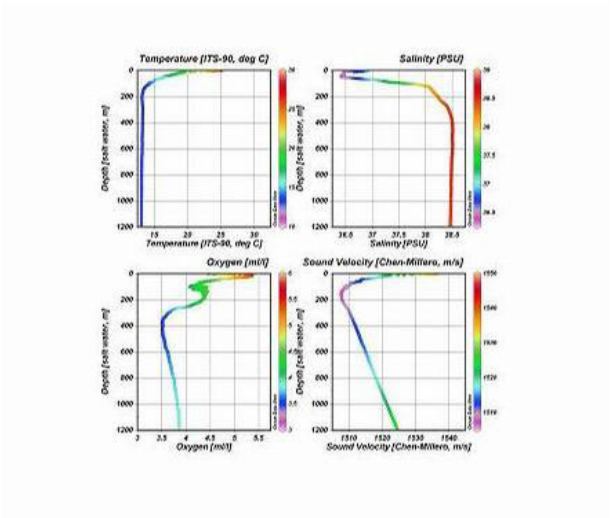
other large operating areas closer to Italy. Thus, the next few days we will be in fast transit survey mode as we cover a large amount of ocean. We will listen with one array in the water and conduct visual surveys as the conditions allow. The area we will be passing through has not been surveyed systematically and thus even as we transit through this area we hope to provide some useful contributions to the scientific understanding of part of the western Mediterranean Sea.

MED-09 Oceanographic Measurements

Thursday, August 27, 2009

Today was the first of two days transit to our new operating area in the Tyrrhenian Sea. We continued both visual and acoustic observations while traveling and were quite interested in what we might see or hear because the areas we are passing through have not been well-studied. Some dolphin groups were detected, but not much else. We had reasonable seas and the wind was just 10-12 knots, but it was straight from the east and on our bow so effectively closer to 20 knots which made things tough for the visual team. As we transit, we continue to process all of the biological and oceanographic data that have been collected thus far.

An important and interesting kind of oceanographic sampling that is being done is to measure different properties of sea water at various depths in areas where we have been operating. We use a device to measure the conductivity (a proxy for salinity), temperature, and depth (measured with pressure) of the water (called a "CTD"). Measurements are made by lowering the CTD slowly in the water column to provide real-time data about biologically-important ocean parameters. The CTD has two salinity probes, two temperature sensors, and one pressure sensor; it passes through and samples the water for these parameters at approx one meter/sec. It also operates a pumped system from the different sampling tubes seen in the picture here to guarantee that the same sample of water is measured at specified times. Additionally the Alliance CTD includes two sensors, which directly measures the oxygen content in the water column. In this way we can fully characterize the oceanographic parameters of the water column and can also calculate how sound travels at different depths in real-time using the salinity, temperature, and depth information. In the images here you can see four different plots from a recent deployment of the CTD to 1000m, each of them showing a different measurement with increasing depth (downward on the plots). The temperature plot shows the much warmer surface water and colder deep water; note that below about 200m there is almost no change in the ocean temperature here. The salinity trace shows another common pattern in this area which is fresher water near the surface and saltier water with depth. The oxygen plot shows higher levels near the surface (where waves mix the water) and lower levels deeper. Finally, the sound velocity profile resulting from the other measurements shows more rapid sound speed at the surface and deeper, with a minimum sound speed around 150m. Like light, sound bends to areas where it travels more slowly and the minimum seen here is called a "sound channel" that would tend to carry sound greater distances than where the sound velocity is higher.



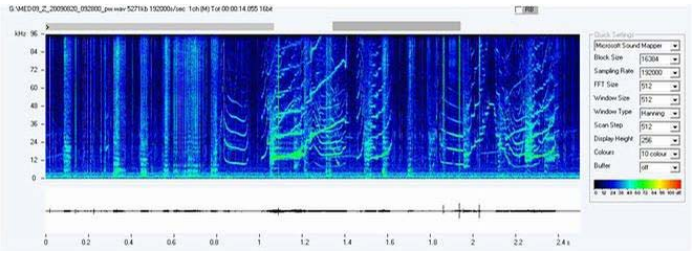
By making these measurements in different areas of interest, and at depths down to 1000m (over 3,000 feet), and comparing them to where we see and hear different marine mammals, we can get a better sense of which kinds of environmental conditions are most important for different species. Additionally, the sound velocity profiles are useful in predicting broadly the underwater sound fields during controlled exposure experiments using real-time oceanographic measurements; these are also directly measured at different places with other sensors (e.g, acoustic tags, sonobuoys).

Eavesdropping

Friday, August 28, 2009

We have been steaming for 48 hours now and are nearing our final operational area. The winds were a bit lighter for part of the day today as we moved further away from the north African coastline, but as got into quite deep water we did not see a great deal of marine life. Several sperm whales, dolphin groups, and a sea turtle were spotted throughout the day, however, as we came through these poorly-studied waters. As we did during our transit yesterday, we have used this time to process the large amount of biological, oceanographic, and acoustic data that have been obtained thusfar.

One of our primary tools in eavesdropping on the underwater acoustic scene to locate, identify, and track marine mammals are arrays of hydrophones. With these listening sensors towed behind the vessel you can see one being deployed here), and with the expert acoustic observers we have to fine-tune measurements and interpret what we are hearing (and also seeing on special displays), different species can be discriminated and estimates of signal strength (to give a sense of near or far) and bearing to calling animals can (sometimes) be made. There are two arrays of hydrophones towed in parallel behind the ship, one on the right side, one on the left side. Each array is composed by a 150m long towing cable (which can be extended to 300m) ending with a 12m long oil filled tube that holds two wideband acoustic sensors each and their preamplifiers. The electronics onboard amplify the signal to be digitized with a 4 channels AD converter at 192kHz sampling rate connected to a powerful computer with dedicated, custom software designed for both research and mitigation purposes. This software allows us to acquire, record to disk, analyze and display up to 8 channels in real time. A high resolution spectrographic display (a picture of the sound showing frequency, or "pitch", over time) shows all the features of the incoming sounds, even those we can't hear, because they are too high in frequency or too brief for our ears to detect. Several examples of the kinds of recordings made with these specialized listening sensors and processing software are given here; these are of long-finned pilot whales and striped dolphins recorded recently in our research.



A special directional display shows the signals coming from the two arrays (4 hydrophones) to provide intuitive cues as to the direction of incoming sound. By using these two displays, researchers can recognize sounds coming from different species and estimate the direction from which they came. This information is especially important in the current research project to position the tag boat as close as possible to the position where the diving animals are supposed to emerge at the surface. Tomorrow morning we will be back on effort in our new operating area. The weather forecast is quite favorable for the next several days, while it remains quite poor for the Alboran Sea area we recently left. So, we embark on the last week of our collective efforts here with renewed hope and optimism for favorable seas and accommodating whales.

Sperm Whale Central

Saturday, August 29, 2009

We were all very happy today to be back on effort and for much of the day in very calm seas. After a short pit stop at dawn to restock with some supplies we began searching for marine mammals in our new operating area. Shortly thereafter we spotted a mother-calf pair of Cuvier's beaked whales. This was encouraging since the area where we are now has not been systematically surveyed and, despite some anecdotal observations and promising bathymetry (bottom features), we weren't sure what we would find. We subsequently ran across quite a bit of marine life, though not our primary focal species. We came through a cluster of loggerhead sea turtles, found patches of striped dolphins, and heard Risso's dolphins chattering away. But the mammals that would dominate our day were deep-divers like beaked whales.

Our first sperm whale sighting, which was in water about a mile (1.6 km) deep, was followed over the next eight hours by 19 other sightings of other (mainly) individuals or groups. We recorded a total of 26 individual sperm whales sighted. As with our other observations, we could have re-sighted some of the same animals more than once, but since we were moving at 10 knots in one general direction for much of the day to cover a good amount of water in this new area, most of these were probably different animals. We saw several sperm whales breaching and heard them on our acoustic arrays much of the day, but never saw any close enough to the boat for good pictures. It is a promising sign that we are seeing other deep-diving, primarily squid-eating marine mammals (like beaked whales are) and it is also interesting to observe such relatively high densities of sperm whales in this area.

The weather outlook for tomorrow is relatively promising and we are refreshed to be back in water that is more amenable to our objectives than what we left in the Alboran Sea; we hope to locate more beaked whales (and fewer sperm whales). Throughout this project that we have been treated to some fantastic sunrises and sunsets on the Mediterranean Sea, such as this one from yesterday.

Searching...

Sunday, August 30, 2009

Today was spent searching widely across our new operating area -- in search of suitable wind and sea conditions and, once we found those, in search of beaked whales. The day dawned rougher and windier than we expected from the forecasts, but we had a clear picture of where to find better seas. By mid-morning we worked into relatively calm winds and workable swell conditions and began running across some of the steep drops and seamounts on the bottom of this once-volcanic area. For the rest of the day we had relatively good viewing conditions and we worked at speeds where we could monitor as much area as possible using both our visual and acoustic teams. However, somewhat surprisingly to us, we didn't see a single beaked whale today and heard just one sperm whale on a sonobuoy. There were the occasional striped dolphins and a few sea turtles, but relative to where we were yesterday, this area was relatively devoid of marine mammals.

We have quite a lot of other promising looking areas to cover and the wind and wave forecasts for tomorrow are promising. We will try and work in an area where there have been some incidental sightings of beaked whales from ferries.

Fins, Brief Winds, and then Ziphius

Monday, August 31, 2009

The weather was good for the most part today as we worked through an area where Cuvier's beaked whales had been seen from ferries and a few sightings from other researchers. We covered a lot of water during the day and found a lot more marine mammals than the area covered yesterday. Our first sighting was a group of three fin whales and throughout the day we would have more than 20 sightings of other groups or individuals. We saw several fin whales breaching, which is an impressive sight, and had several within a mile or less from the boat. There were also several large groups of dolphins leaping and skimming the water around us several times. The speed and maneuverability of these sleek animals never ceases to be amazing. After seeing the fins in the morning, the middle of our day was briefly interrupted by a small storm cell that we watched form over the sea and then move past us. The wind kicked up for about an hour and we had to stand down our visual team briefly. It actually rained for a few minutes, which we haven't seen for a long time, but it passed quickly and we could again work.

By mid-day the conditions were workable again and we continued searching for beaked whales. We found a group of three and our visual team guided the tag boat toward them. It was good for all to be back on our focal species again after the transit over and two days of searching here. We followed them through a number of surface intervals and the tag boat had two close approaches with reasonably good chances at tagging, but the animals then went down for a deep dive and again we ran out of daylight. The weather predictions for Tuesday look outstanding and we will begin in the same area where we had our first successful focal follow here.

Flat Seas -- Many Beaked Whales

Tuesday, September 01, 2009

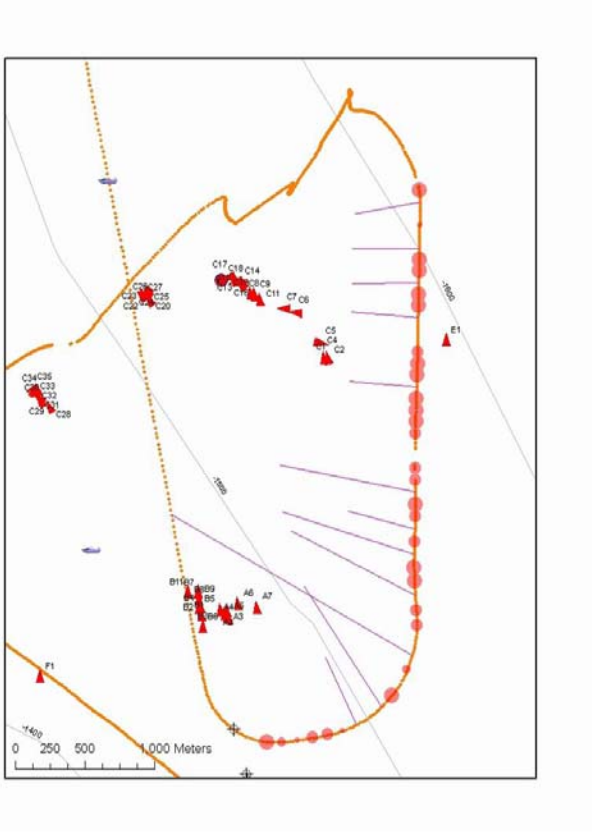
The sea was glassy calm for several hours this morning - perfect conditions for our visual team. The wind picked up a little bit throughout the day and shifted more to the south where the islands provide us less shelter but it remained workable throughout the day. We again spotted quite a few fin whales and had the intermittent groups of dolphins, including some that were harassing a group of beaked whales we were following. With the favorable weather, we found multiple beaked whales groups clustered in a relatively small area. One challenge was that this area was close to the edge of our allowed operational box, which limited our ability to follow several good candidate groups. Another was that many of the groups had small calves, preventing us from close approaches for tag attempts. Overall we had more than 10 different group sightings but are still searching for the right combination of conditions for tagging. Tomorrow looks to be workable but a little less calm than today.

Close again -- then sudden winds

Wednesday, September 02, 2009

Today we were tantalizingly close again and had an excellent, four-hour focal follow of an adult male and adult female Cuvier's beaked whale (seen here from the tag boat during one of several close approaches). Note the prominent scars marking the male (top), which are thought to result mainly from fights with other males, and the absence of these scars on the female (bottom). The higher winds we had feared from the forecast held off quite a few hours beyond what was predicted and we had outstanding conditions for much of the day. We have quickly figured out where to locate Cuvier's beaked whales in this area (along the 1500m depth contour on the edges of canyons has been the best) and we soon found multiple groups of animals again. We passed up the first group because it was a mother with a small calf, but then found a good candidate group and began to track them.

The image to the left shows a sequence during today's focal follow. It is a bit of a complicated figure (you may need to blow it up a bit) with a lot going on (there was!). But it is a great example of how we can use all our tools to follow animals that dive for over an hour to great depth and then re-spot them at the surface and track them for hours. The sequence began with the ship in the northwest (upper left) corner of the figure and moving along at 6 knots (note the orange dots showing our position being spaced further apart than the rest of track where we were going slower). As we moved to the southeast, the group of two adults was spotted visually during their brief surface intervals. The red symbols with "A" and "B" labels are multiple positions of the same two whales during two surfacings in the same general area. After the animals went down on a deep feeding dive, we passed their spot and dropped a sonobuoy to monitor near that location (small circle with crosshairs along our track). We then moved around the spot monitoring with multiple arrays of listening sensors towed slowly (note our orange position markers being closer together) and began tracking them acoustically. The red circles on our track indicate when the acoustics team heard beaked whale clicks (the bigger the circle the stronger the sounds) and the purple lines show the direction from which they think the sounds are coming. We moved slowly along and kept the group on our port (left) side with very consistent detections - and the acoustics team could even tell that it was two animals. As we approached 30 min of clicking we felt confident enough of where they were and where they would come up that we deployed our tag boat and positioned them accordingly. When the animals re-emerged (positions C1-C5), we had our



tag boat about 500m away, despite the fact that the animals were down for 79min and had moved 1500m in directly the opposite direction we had been traveling! As you can see from the increasing number of the "C" sightings in clusters ("E" was another single animal) we moved with the group over multiple other surface intervals between the multiple "shallow" dives (shallow is relative for beaked whales since they can be over 500m) that the animals do before deep feeding dives. The tag boat had several excellent chances, but the animals banked away several times in the last few moments before the tag could be attached. Eventually the group went on another feeding dive and we tracked them again by listening and had a bead on where they would surface. Just at that time, though, the winds tripled very suddenly (we saw the wind line coming) and the tag boat had to be recovered.

We have just a few more days at sea on MED-09 and remain hopeful we can get a few more chances like this and can have the sustained conditions needed to get that last few meters to attach one of the tags and conduct the sound exposure experiment. The weather for tomorrow does not look great, but possibly workable, and we are now fairly confident of where to find beaked whales in the Tyrrhenian Sea when we have the right weather.

Where Did They Go?

Thursday, September 03, 2009

Today was a bit of a puzzle. Due to heavier winds and swell around our favored locations, we started our day well south of where we have had the most luck in this area. The conditions were better than expected and the heavier seas were further to the north. Consequently, we adapted our search plan to proceed to the area where we found multiple groups yesterday. Conditions ranged from acceptable to excellent throughout the day, though we did get some rolling swell by late afternoon. We covered quite a lot of ocean, moving down the canyon edges around the 1500m contours that haven proven to be good here but, despite having workable conditions from dawn to dusk, we did not have a single beaked whale sighting all day. A few fin whales were seen, along with the occasional group of dolphins, but it was puzzlingly quiet. The forecast is for marginal conditions over much of our area tomorrow, but we are hoping for better than expected weather again and for the beaked whales to 'pop up like mushrooms' as was described on one of our better days by one of our Italian colleagues.

Found the calm, not the whales

Friday, September 04, 2009

We started the day in the northern part of our area where we have had almost all of our beaked whale sightings, but there was enough swell and wind that we headed south in search of better seas. We found enough lee from the island as we headed down to have workable weather by mid-morning. We covered over 80 miles along and across canyons and seamounts we had previously not searched that looked promising. However, like yesterday we saw almost no marine mammals (and zero beaked whales) despite the favorable conditions. At least in our week's worth of intense visual and acoustic surveys in the Tyrrhenian, marine mammals in the areas we have surveyed seem to be concentrated in particular spots. Tomorrow will be the last operational day for MED-09. We intend to conduct visual and acoustic surveys, as conditions allow, heading back north and then continue on during the evening back to LaSpezia.

End MED-09

Saturday, September 05, 2009

Today marks the end of operations for MED-09 after over 5,000 nautical miles covered across the western Mediterranean Sea. We could not try to tag animals today since we needed to leave the operational area by evening, but we attempted to run some additional visual and acoustic surveys to add to the biological data already obtained. The seas were not friendly, however, and as we got further north they became rougher and we had to break off the surveys and begin the trek back to LaSpezia. We had sustained winds of 35 knots, with gusts of over 40 with large waves rolling the ship most of the day as we left. While all of us are looking forward to being back on land for different reasons, we are also sad to see this project come to an end. We have had assembled, on an outstanding and quiet research vessel, an all-star team of specialized experts from around the world.

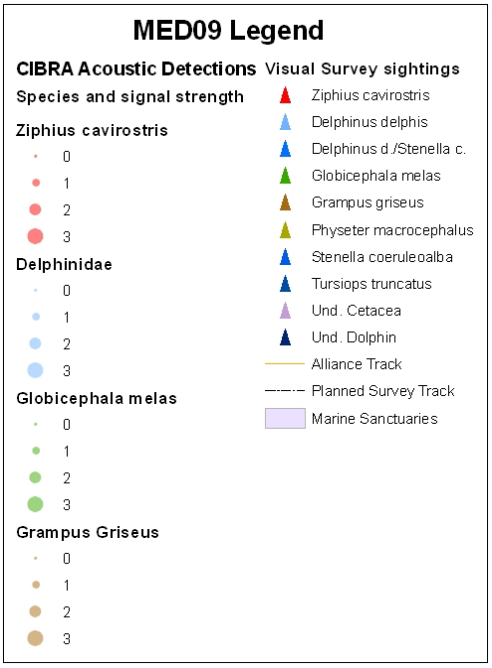
What we have been trying to do is incredibly difficult -- measuring behavior in some of the most challenging animals on Earth to study. Certainly there is some disappointment that we were not able to tag and conduct controlled exposure experiments on beaked whales. But that is counterbalanced by some of the significant accomplishments that were made in this project, many of them related to improvements in methodology and technology in working with such difficult species.

Perhaps our most significant accomplishment was refining and demonstrating the ability to use an integration of visual and multiple acoustic methodologies to follow focal groups of beaked whales over multiple dives for hours. This was the first BRS project for beaked whales off of an acoustic listening range where there are many hydrophones mounted on the bottom. All our assets were based on the main vessel, and we demonstrated that we could use them in an integrated way to track animals that dive for long periods and cover large areas. A key part of this integration was the development of custom geospatial software for displaying the visual and acoustic animal detection data along with the position of the ship, tag boat, and important ocean features. This capability proved to be essential for real-time decision making in tracking focal animal groups. Lessons learned in developing and refining these capabilities will be imperative in subsequent efforts to track and study beaked whales and other cetaceans. Additionally, we made several major contributions to understanding the biology and oceanography of three different areas of the western Mediterranean that have not been extensively studied. We made nearly 500 sightings of over 5,000 individual cetaceans from eight species. When and where these animals were seen relative to the physical, biological, and acoustic environments will be very useful in developing and refining predictive habitat models for where marine mammals will occur in the Mediterranean Sea and other areas. Our oceanographic data (see post of 27 August) will be critical in that regard. So too will the large number of passive acoustic measurements made from sonobuoys to measure ambient noise be useful in assessing the extent to which human sounds (e.g., from the dense shipping traffic we saw in many areas) affect the acoustic environment for marine mammals who depend heavily on the use of sound. Summary information regarding our efforts and accomplishments will be publicly available at a later date. Each of the participating organizations will be provided a link to this information and a subsequent message will be posted to this blog when it is available. We expect that many of our measurements will be used by participating researchers and graduate students in different areas and results will ultimately be presented in scientific meetings and journals.
Thank you to those who have been following the blog for this project. We appreciate the interest in this project. We would like to acknowledge the outstanding crew of the NATO research vessel Alliance that has been our home for the last six weeks. From the captain on down, it is an outstanding platform from which to work with an extremely precise and professional crew. Efforts to better understand the behavior of marine mammals and how sound we make in the oceans can affect and harm them will continue in different ways and places around the world, and it will be served by the efforts of the many dedicated people involved in this project (the team from the second leg appears below).

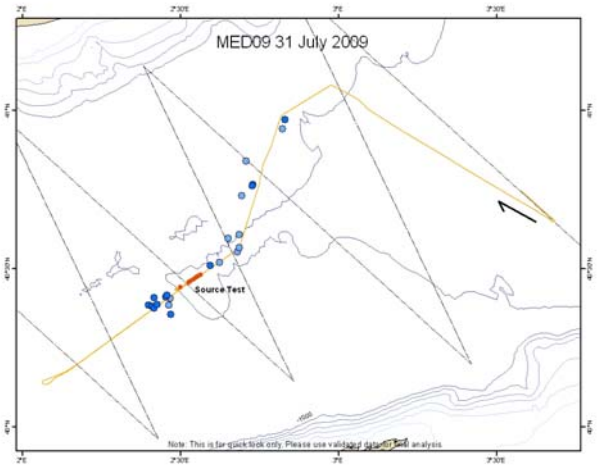
Appendix II – Day-by-Day GIS Tracks and Survey Sighting Data

Data contained in this appendix summarize the daily tracks, CIBRA acoustic detections, and visual sightings depicted in GIS format for each operational day of MED-09. Tables depicting total survey sightings for all species on each operational day do not include focal follow data (summarized above). Several additional things to note include the following:

- Many of the GIS images are depicted on different spatial scales;
- Black arrows on the GIS plots indicate the initial direction of travel for the day;
- Visual detections shown on the GIS plots with alphanumeric indicators depict sightings from focal follow mode (and are thus not reflected in the survey sighting summaries;
- Different GIS legends are used for the Balearic Islands/Alboran Sea versus the Tyrrhenian Sea, because of different species composition in these areas;
- There are different labels for small odontocetes depending on whether common versus striped dolphins could be identified or not.

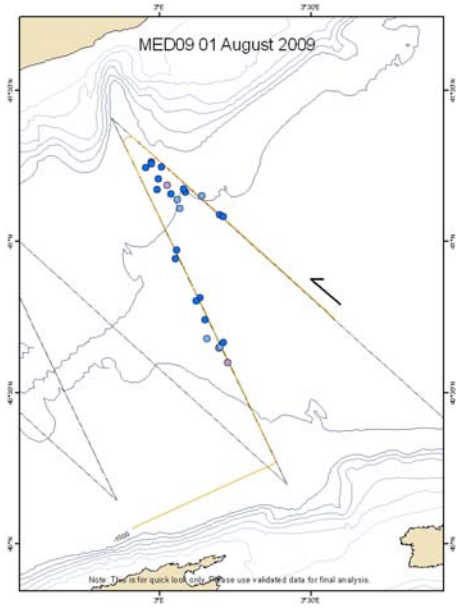


GIS Display Legend for Balearics and Alboran Sea



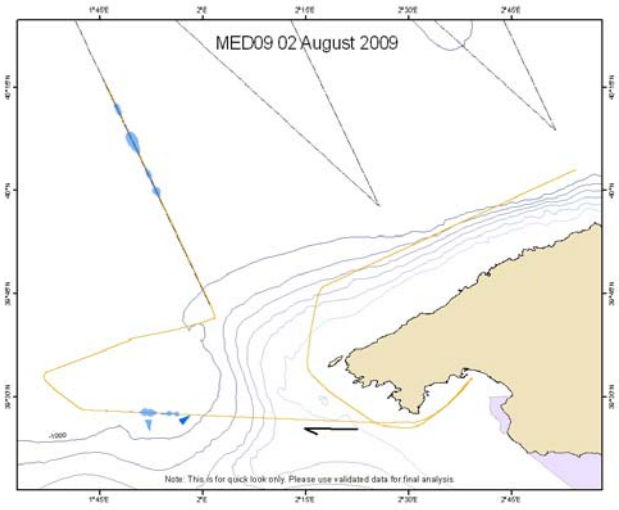
31-Jul-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	10	165
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	12	129
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	1	12
Ziphius cavirostris	0	0

Balearic Shakedown - 31 July 09



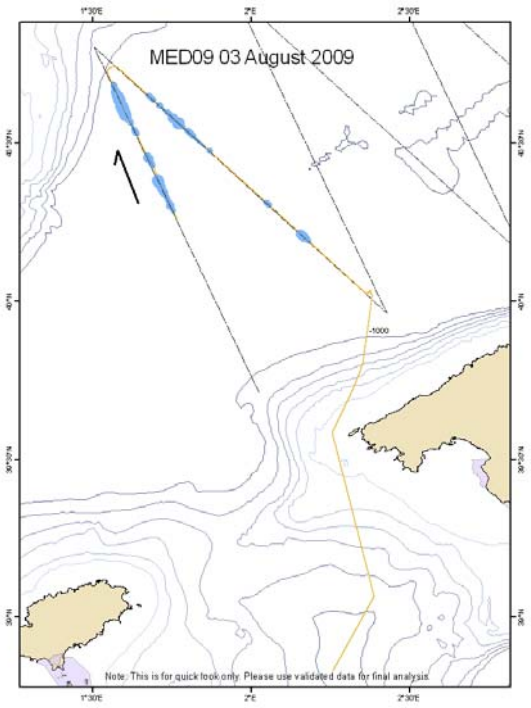
01-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	4	50
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	19	232
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	2	5
Ziphius cavirostris	0	0

Balearic Islands - 1 August 09

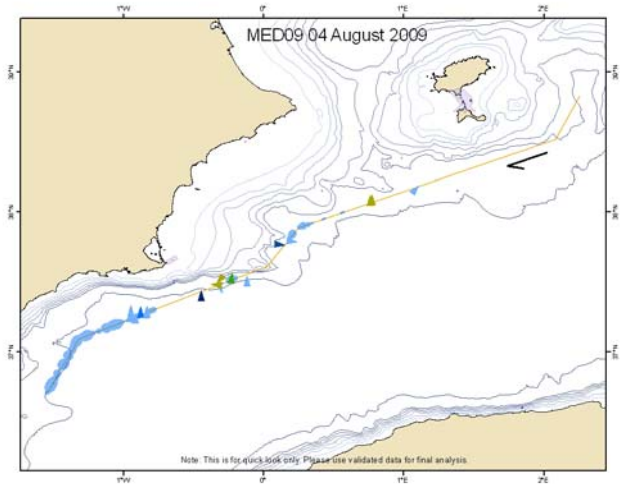


02-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	1	1
Delphinus d./Stenella c.	1	10
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	3	33
Tursiops t./Grampus g.	0	0
Tursiops truncatus	2	13
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Balearic Islands - 2 August 09

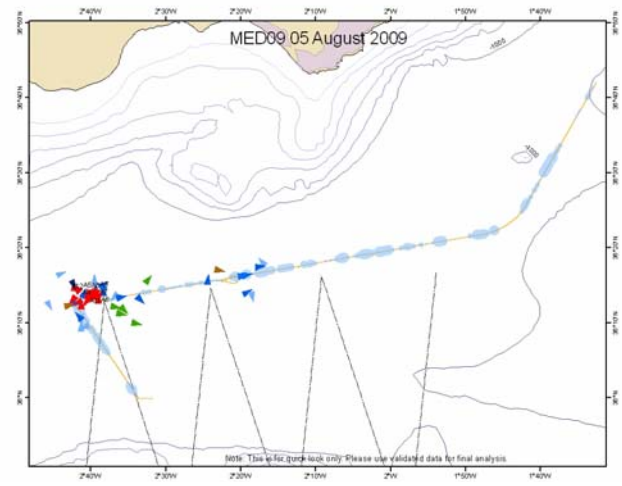


Balearic Islands - 3 August 09 (note no visual survey detections)



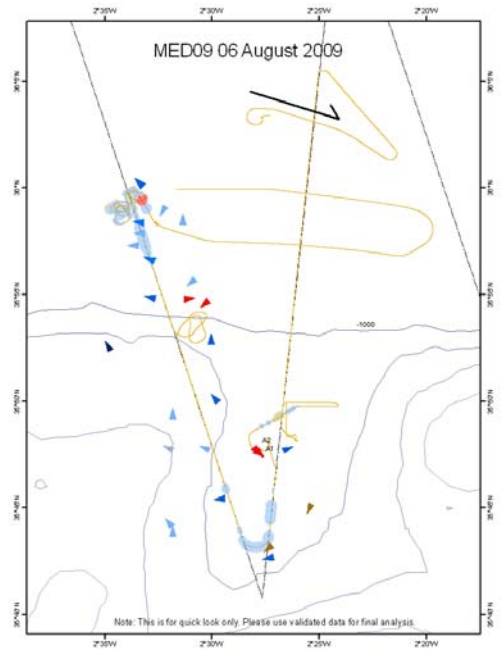
04-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	12	64
Delphinus delphis	0	0
Globicephala melas	1	17
Grampus griseus	0	0
Physeter macrocephalus	4	4
Stenella coeruleoalba	2	45
Tursiops t./Grampus g.	0	0
Tursiops truncatus	1	8
Und. Cetacea	1	1
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Fast Transit to Alboran Sea - 4 August 09



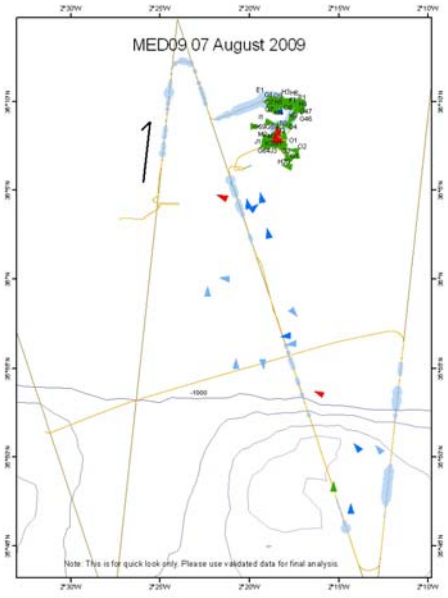
05-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	3	12
Delphinus delphis	2	7
Globicephala melas	5	46
Grampus griseus	2	13
Physeter macrocephalus	0	0
Stenella coeruleoalba	6	140
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	1	3
Ziphius cavirostris	1	1

Alboran Sea – 5 August 09



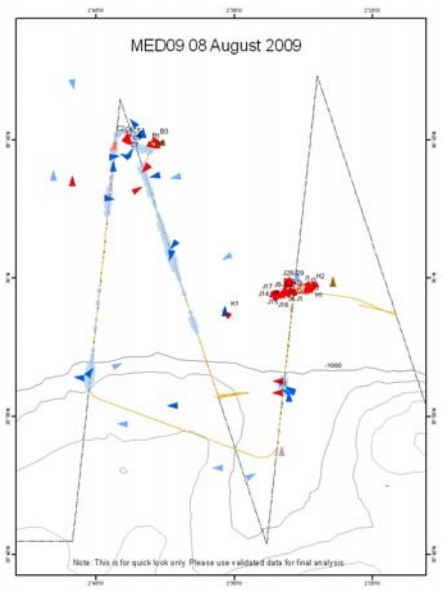
06-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	5	69
Delphinus delphis	4	207
Globicephala melas	0	0
Grampus griseus	2	18
Physeter macrocephalus	0	0
Stenella coeruleoalba	7	131
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	1	1
Und. Dolphin	0	0
Ziphius cavirostris	2	6

Alboran Sea – 6 August 09



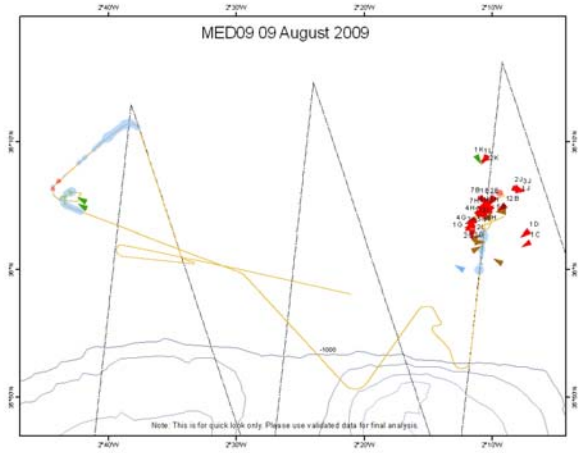
07-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	8	111
Delphinus delphis	0	0
Globicephala melas	2	85
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	9	294
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	2	3

Alboran Sea – 7 August 09



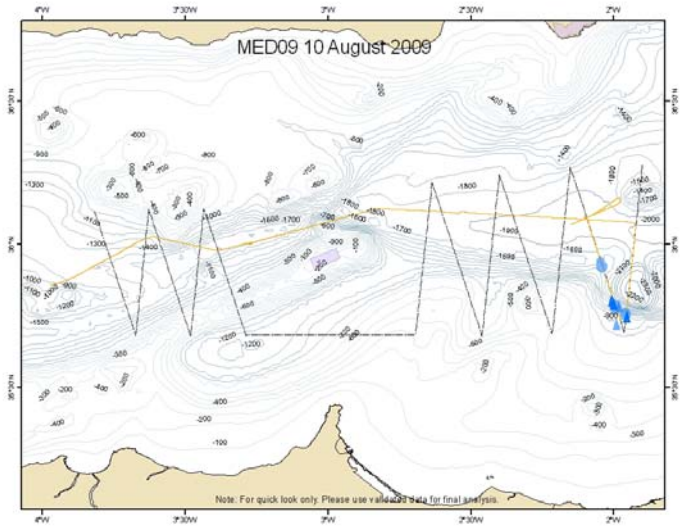
08-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	11	122
Delphinus delphis	2	30
Globicephala melas	0	0
Grampus griseus	3	9
Physeter macrocephalus	0	0
Stenella coeruleoalba	15	250
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	1	1
Und. Dolphin	1	5
Ziphius cavirostris	5	11

Alboran Sea – 8 August 09



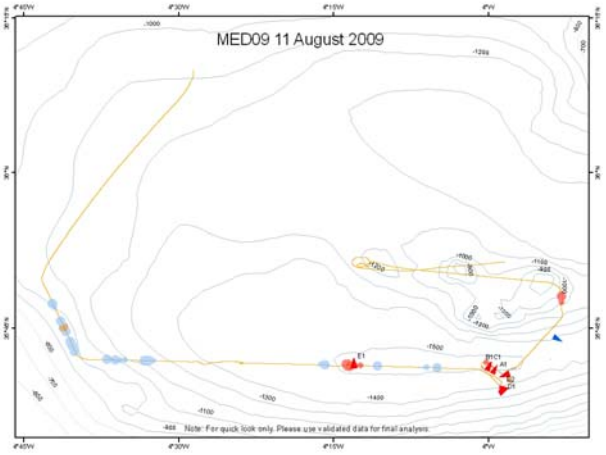
09-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	3	116
Delphinus delphis	0	0
Globicephala melas	4	32
Grampus griseus	8	27
Physeter macrocephalus	0	0
Stenella coeruleoalba	0	0
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	9	17

Alboran Sea – 9 August 09



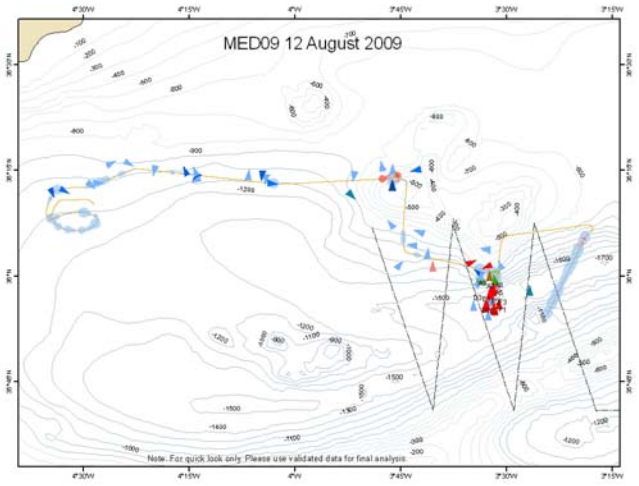
10-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	2	24
Delphinus delphis	3	60
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	0	0
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Alboran Sea – 10 August 09



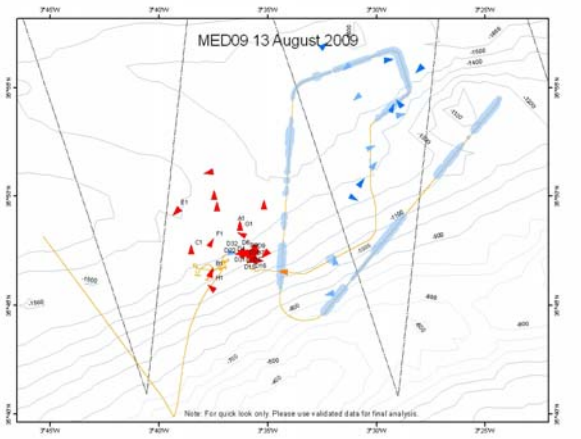
11-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	0	0
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	0	0
Tursiops t./Grampus g.	1	5
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	2	2

Alboran Sea – 11 August 09



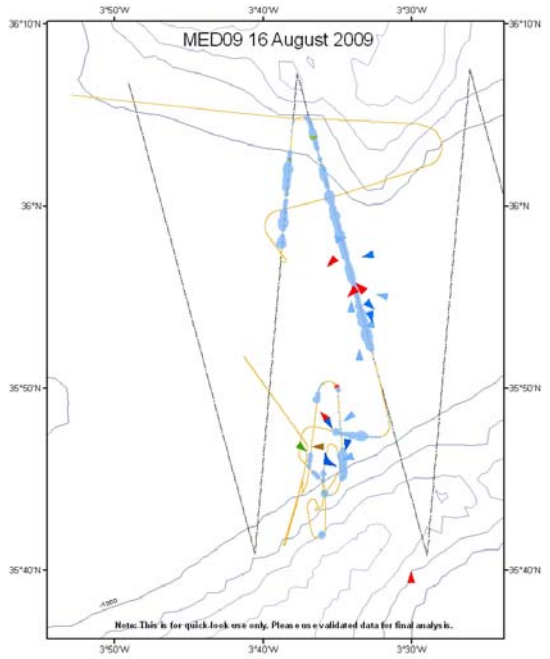
12-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	20	343
Delphinus delphis	3	18
Globicephala melas	2	18
Grampus griseus	1	1
Physeter macrocephalus	0	0
Stenella coeruleoalba	6	115
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	2	22
Und. Ziphiidae	3	4
Ziphius cavirostris	3	8

Alboran Sea – 12 August 09



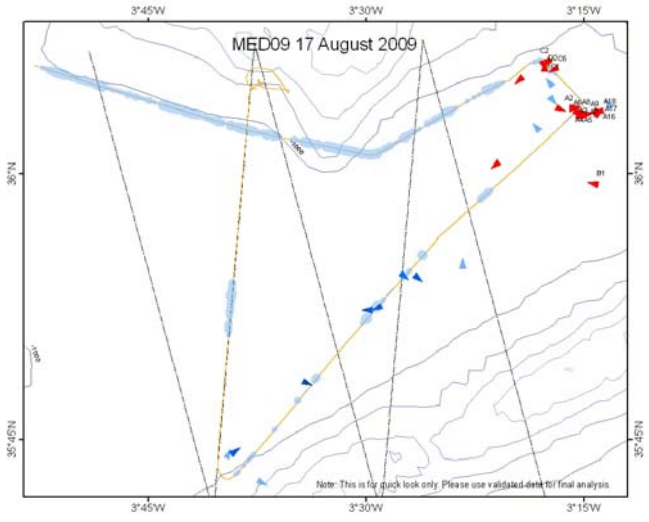
13-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	6	41
Delphinus delphis	1	5
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	7	156
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Dolphin	0	0
Und. Ziphiidae	0	0
Ziphius cavirostris	2	7

Alboran Sea – 13 August 09



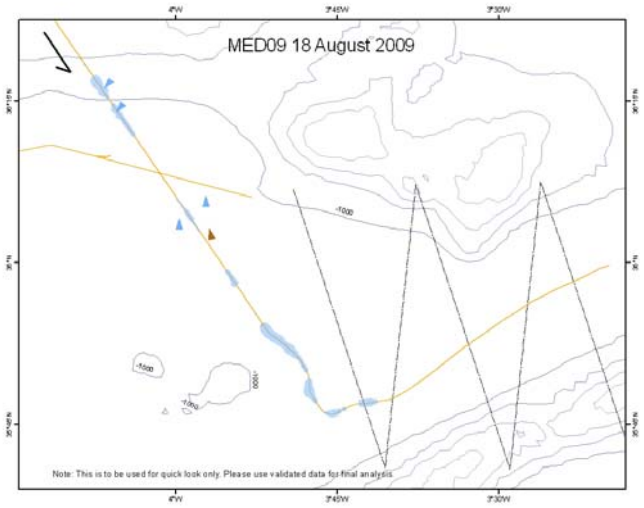
16-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	6	69
Delphinus delphis	3	36
Globicephala melas	1	8
Grampus griseus	1	10
Physeter macrocephalus	0	0
Stenella coeruleoalba	5	123
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	5	8

Alboran Sea – 16 August 09



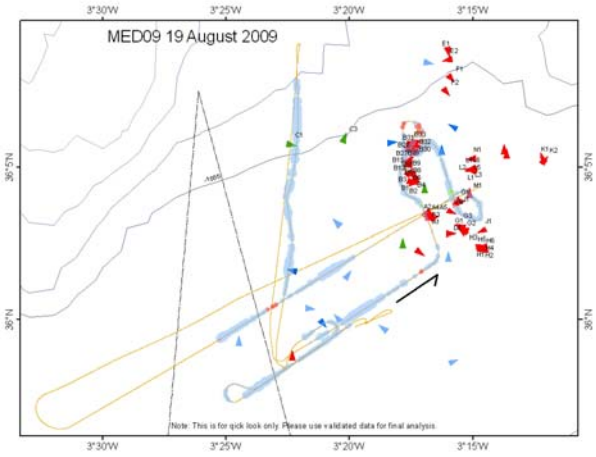
17-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	7	55
Delphinus delphis	2	33
Globicephala melas	0	0
Grampus griseus	1	4
Physeter macrocephalus	0	0
Stenella coeruleoalba	5	65
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	4	12

Alboran Sea – 17 August 09



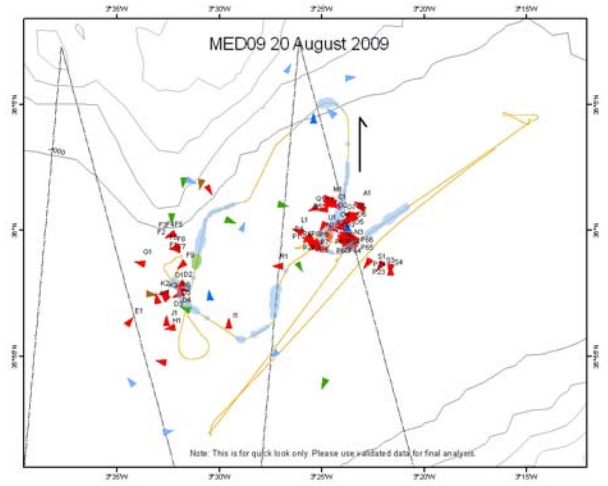
18-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	3	427
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	2	13
Physeter macrocephalus	0	0
Stenella coeruleoalba	0	0
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Malaga Port Call and Alboran Sea – 18 August 09



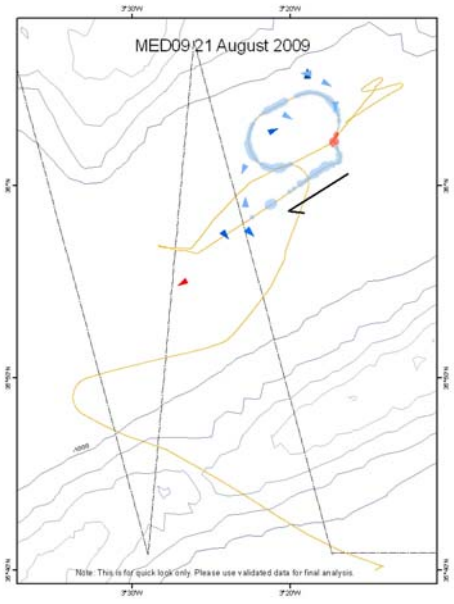
19-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	7	93
Delphinus delphis	1	30
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	2	32
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	4	7

Alboran Sea – 19 August 09



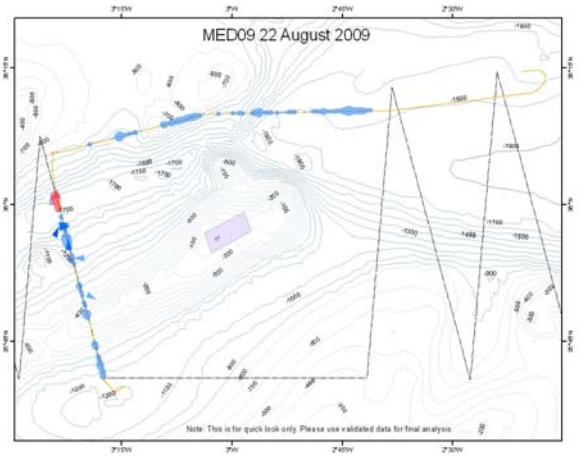
20-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	7	61
Delphinus delphis	1	10
Globicephala melas	6	45
Grampus griseus	1	10
Physeter macrocephalus	0	0
Stenella coeruleoalba	2	15
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	4	10

Alboran Sea – 20 August 09



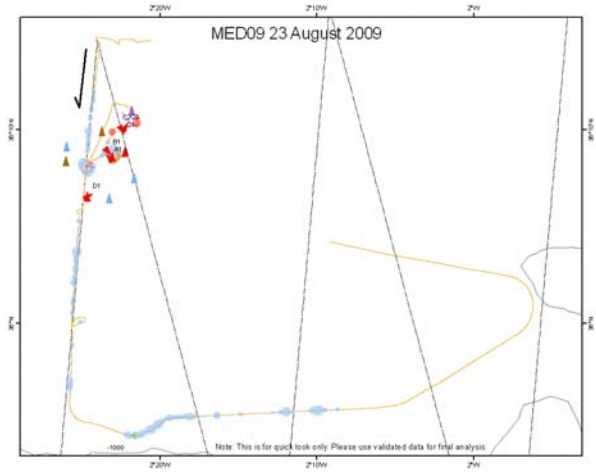
21-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	6	43
Delphinus delphis	2	52
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	12
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	1	30
Ziphius cavirostris	1	4

Alboran Sea – 21 August 09



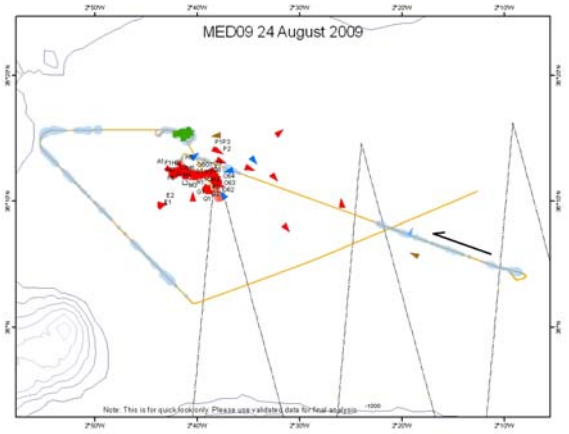
22-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	2	101
Delphinus delphis	2	38
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	2	32
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	2	2
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Alboran Sea – 22 August 09



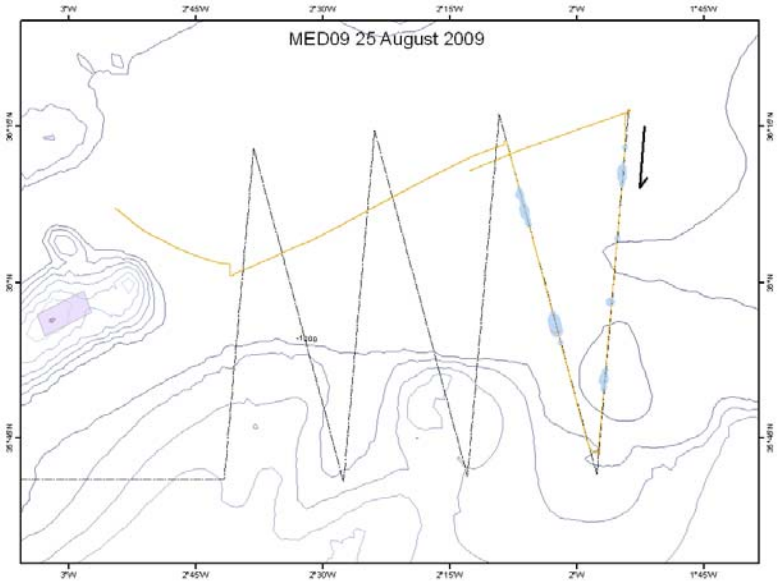
23-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	0	0
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	1	5
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	15
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	1	8
Ziphius cavirostris	2	3

Alboran Sea – 23 August 09

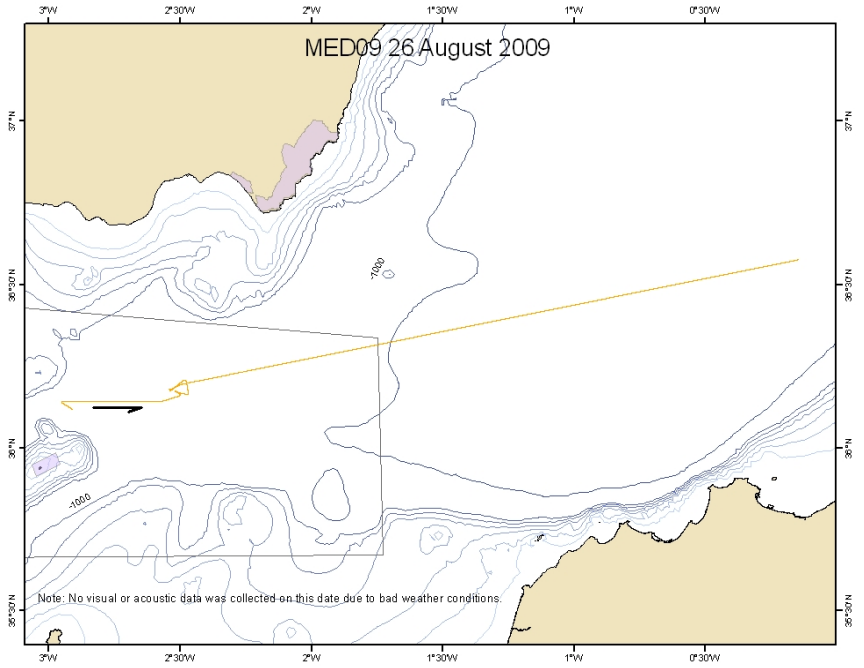


24-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	0	0
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	3	17
Physeter macrocephalus	0	0
Stenella coeruleoalba	4	40
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	6	7

Alboran Sea – 24 August 09

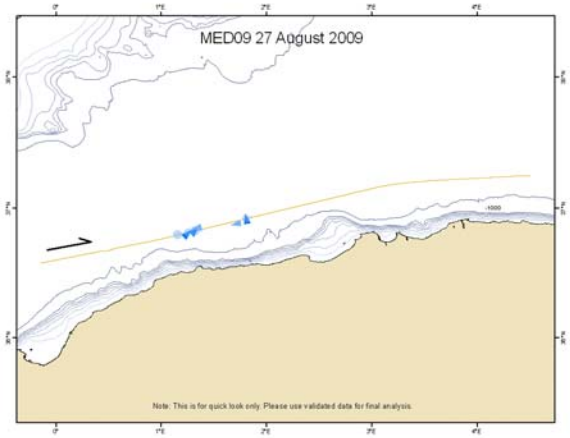


Alboran Sea – 25 August 09 (note no visual detections)



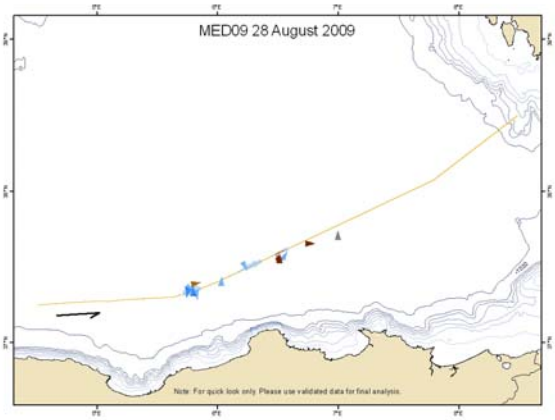
Fast Transit: Alboran Sea to Tyrrhenian Sea – 26 August 09

(note no visual detections)



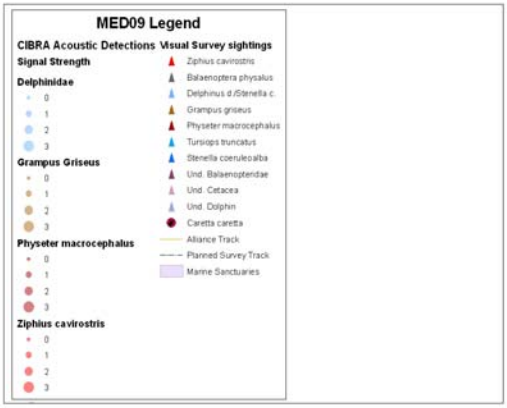
27-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	2	10
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	3	25
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Fast Transit: Alboran Sea to Tyrrhenian Sea – 27 August 09

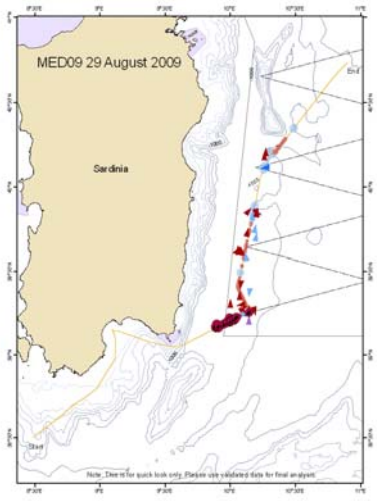


28-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	1	1
Delphinus d./Stenella c.	6	83
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	1	3
Physeter macrocephalus	4	6
Stenella coeruleoalba	2	27
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Fast Transit: Alboran Sea to Tyrrhenian Sea – 28 August 09

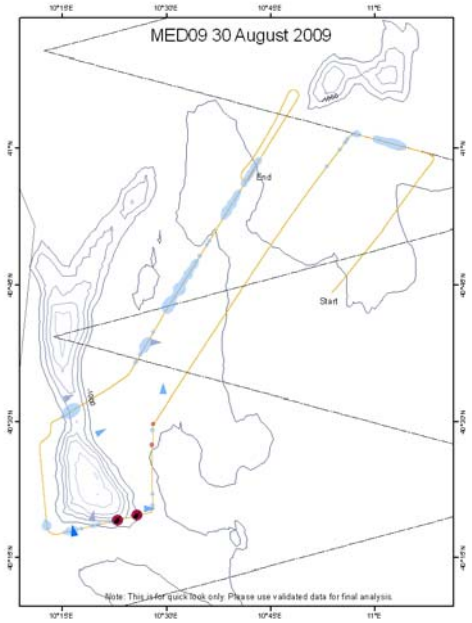


GIS Display Legend for Tyrrhenian Sea



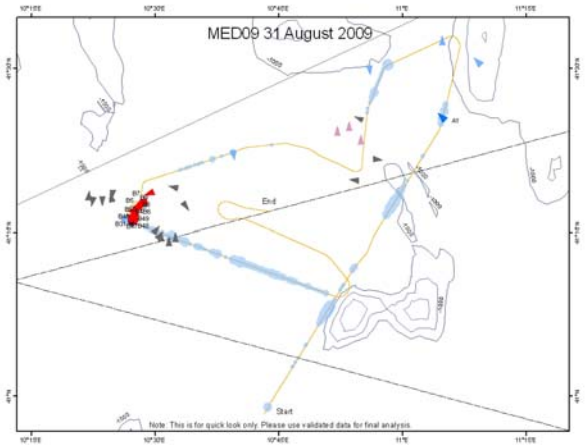
29-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	5	56
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	18	24
Stenella coeruleoalba	4	39
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Balaenopteridae	1	1
Und. Dolphin	0	0
Ziphius cavirostris	1	2

Tyrrhenian Sea – 29 August 09



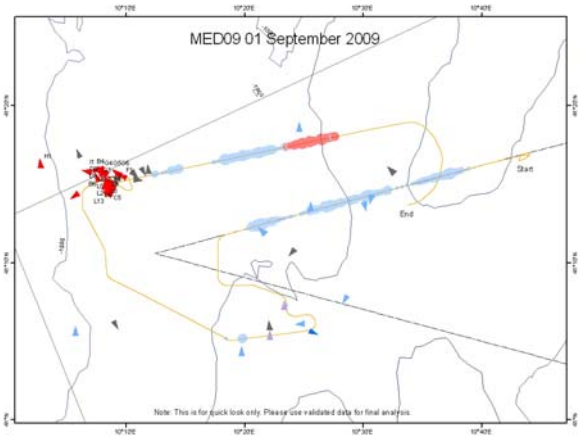
30-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	0	0
Delphinus d./Stenella c.	3	27
Delphinus delphis	1	45
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	20
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	2	6
Ziphius cavirostris	0	0

Tyrrhenian Sea – 30 August 09



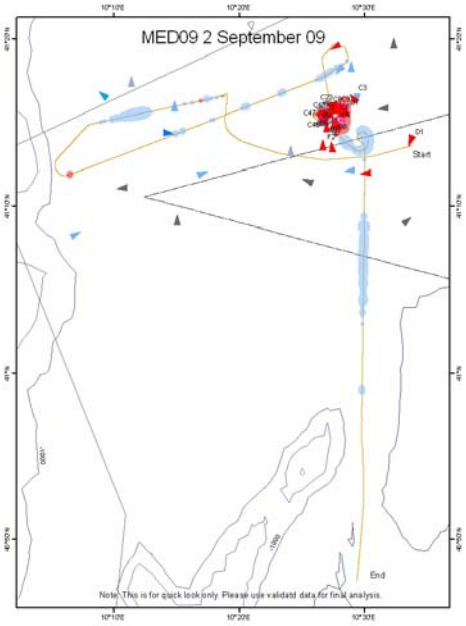
31-Aug-09		
Species	Number of events	Number of animals
Balaenoptera physalus	8	11
Delphinus d./Stenella c.	4	63
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	10
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	4	4
Und. Dolphin	0	0
Ziphius cavirostris	1	3

Tyrrhenian Sea – 31 August 09



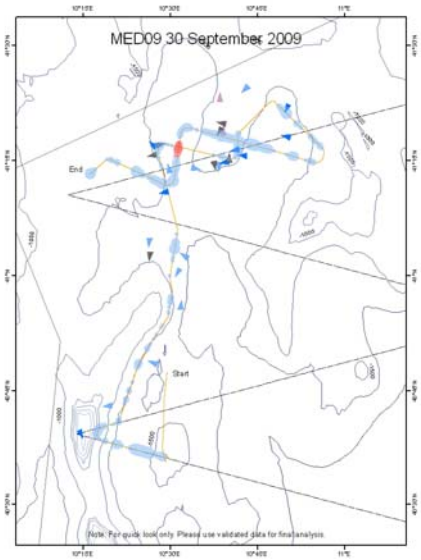
01-Sep-09		
Species	Number of events	Number of animals
Balaenoptera physalus	4	5
Delphinus d./Stenella c.	5	40
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	4	135
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	2	2
Und. Dolphin	0	0
Ziphius cavirostris	1	1

Tyrrhenian Sea – 1 September 09



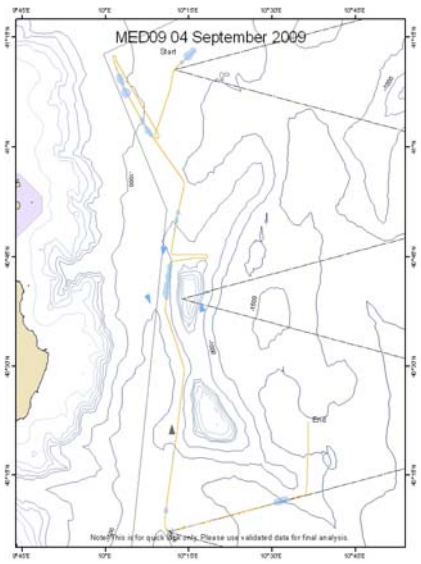
02-Sep-09		
Species	Number of events	Number of animals
Balaenoptera physalus	3	4
Delphinus d./Stenella c.	4	31
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	10
Tursiops t./Grampus g.	0	0
Tursiops truncatus	1	4
Und. Cetacea	2	2
Und. Dolphin	0	0
Ziphius cavirostris	3	6

Tyrrhenian Sea – 2 September 09



03-Sep-09		
Species	Number of events	Number of animals
Balaenoptera physalus	6	6
Delphinus d./Stenella c.	7	65
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	11	132
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	2	2
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Tyrrhenian Sea – 3 September 09



04-Sep-09		
Species	Number of events	Number of animals
Balaenoptera physalus	1	1
Delphinus d./Stenella c.	2	6
Delphinus delphis	0	0
Globicephala melas	0	0
Grampus griseus	0	0
Physeter macrocephalus	0	0
Stenella coeruleoalba	1	20
Tursiops t./Grampus g.	0	0
Tursiops truncatus	0	0
Und. Cetacea	0	0
Und. Dolphin	0	0
Ziphius cavirostris	0	0

Tyrrhenian Sea – 4 September 09