ACCOBAMS GUIDELINES

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MONITORING GUIDELINES TO ASSESS CETACEANS' DISTRIBUTIONAL RANGE, POPULATION ABUNDANCE AND POPULATION DEMOGRAPHIC CHARACTERISTICS

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Introduction

The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) has been working for several years on defining an exhaustive program for estimating abundance of cetaceans and assessing their distribution and habitat preferences in the Black Sea, Mediterranean Sea and the adjacent waters of the Atlantic (the "ACCOBAMS Survey Initiative"). This initiative consists in a synoptic survey to be carried out in a short period of time across the whole Agreement area and it will combine visual survey methods (boat- and ship-based surveys) and passive acoustic monitoring.

This document was elaborated based on the documents prepared by the ACCOBAMS Scientific Committee that has worked for several years on the definition of the most appropriate methodologies for collecting data on cetaceans at the Mediterranean and Black Seas scale, taking into account the protocols used in other regional contexts[1]. It presents specific information on monitoring by visual line transect surveys (conducted from boat and airplane) and by acoustic survey. It should be noted that it does not address all the tools and methods that could be used for cetacean survey, neither new technologies that are currently experimented (i.e. drones and satellite imagery). Significant information also comes from stranding networks. Lastly, this document is considering surveys using large ships, but the shipboard cetacean surveys conducted from small vessels would also make use of this document.

Monitoring cetacean species may be addressed at two spatial scales:

1) **Regional monitoring** - if the requirement is to monitor the use of a specific area by a particular species, e.g. monitoring the status of relative abundance between and within years in national waters or marine protected areas.

2) **Population level monitoring** - if the requirement is to monitor the status of a whole population, e.g. estimate density and abundance of cetaceans in the whole ACCOBAMS area.

Before conducting any type of monitoring of animal populations, it is important to define the objectives. The main aim in both aerial and vessel-based surveys is to assess density and abundance and, if systematic monitoring programs are in place, assess potential trends over time. Monitoring at the regional level may require data collection throughout the year, to better understand seasonal patterns in distribution, whereas monitoring at the population level would mainly address inter-annual changes.

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[1] *e.g.* in the Atlantic waters within the framework of (i) the SCANS surveys undertaken to assess the populations of Small Cetaceans in the European Atlantic and North Sea, and (ii) the CODA surveys (Cetacean Offshore Distribution and Abundance in the European Atlantic) aiming to estimate cetacean abundance in European Atlantic waters.

Cetaceans generally occur in low densities and are highly mobile. They are difficult to spot and to follow at sea, even during good survey conditions, because they typically only show part of their head, back and dorsal fin while surfacing and spend the majority of their time underwater.

There are a number of actions that need to be taken when initiating any type of monitoring, either for species distributional range or to estimate population abundance of selected species.

1. Select the target species (surveys can be multi-species or single-species).
2. Determine whether to monitor an entire population or a portion of it (in a given region).
3. Define the population or area to monitor and the time-window.
4. Define monitoring objectives.
5. Consider logistics for the monitoring (e.g. size of area, weather, depth of area, available survey platforms).
6. Conduct statistical power analysis to find the best method to meet the monitoring objectives.
7. Conduct a cost-benefit analysis.

Currently, there are at least five potential approaches to be used in monitoring cetaceans:

1. Visual surveys from ship, aircraft or land observation platforms (LOP).
2. Passive acoustic monitoring carried out during ship surveys with towed hydrophones.
3. Passive acoustic monitoring performed by means of static acoustic monitoring, e.g. using T-PODs.
4. Photo-identification and mark-recapture analysis.
5. Satellite telemetry to track individual animals.
6. A combination of all or some of the above methodologies.

When deciding which monitoring method to implement, it is important to consider the limitations of each approach and compare the different methodologies. In general, surveys from ship or aircraft have a low temporal resolution, ship surveys may have bias due to responsive movements of animals, stationary acoustic systems have low spatial resolution and logistical problems with deployment, photographic identification relies on visual differences between individuals to allow identification, and telemetry typically only allows small samples resulting in much inter-individual variation.

There are different types of platforms and methods of detection that can be used for each approach, e.g. fixed observation points such as headlands or moving survey platforms such as ships and aircraft, or direct visual or acoustic detections of vocalizing animals, respectively. The methods can therefore range from very basic, yielding simple indices of abundance in limited areas, to very advanced providing accurate (how close the estimate is to the true value) and precise (the statistical variation in estimates generated from repeated samples) estimates of absolute abundance across wide areas.

Target species

Cetaceans

Eleven species of cetaceans are considered to regularly occur in the Mediterranean area: short-beaked common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), long-finned pilot whale (*Globicephala melas*), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*) and killer whale (*Orcinus orca*). In the Black Sea, three small cetaceans' species are represented by resident populations: common dolphin (*Delphinus delphis ponticus*), bottlenose dolphin (*Tursiops truncatus ponticus*) and harbour porpoise (*Phocoena phocoena relicta*).

Knowledge about the ecology, abundance and habitat preferences of some of these species, including the most abundant ones, is in part scant and limited to specific sectors of the ACCOBAMS area, due to the uneven distribution of research effort during the last decades. In particular, the south-eastern portion of the basin, the coasts of North Africa and the central offshore waters are amongst the areas with the most limited knowledge on cetacean presence, occurrence and distribution (2010 ACCOBAMS Status report - Conserving whales, dolphins and porpoises in the Mediterranean and Black Seas, by Giuseppe Notarbartolo di Sciara & Alexei Birkun, Jr.).

Other marine endangered species

Even if cetacean species are the first targets of this monitoring effort, the observations of other marine endangered species, such as marine turtles, giant devil rays, monk seals and sea birds, and other elements such as marine debris, could be reported during the surveys. Specific protocols have to be designed for these opportunistic observations, bearing in mind that the primary objective is to collect data on cetaceans.

Dedicated vessel or aircraft visual surveys

For monitoring programmes involving dedicated visual surveys both ship-based and aerial methods are well established. Although in some situations the choice of platform will be determined by logistical constraints, and despite the fact that a full and comprehensive comparison of aerial and vessel-based surveys has not yet been carried out, generally the method which provides an estimate with the required precision for the lowest cost should be chosen.

For visual surveys, it is important to consider observer skill and experience. Observers may vary in sighting efficiency and observer training is important to obtain consistent results. Furthermore, consistency in data collection protocols, observers, survey design and planning is essential to guarantee reliable and robust results in the long term, especially when systematic monitoring programmes are scheduled.

Line transect sampling is typically used to estimate abundance and assess density. In line transect sampling, a survey area is defined and surveyed along pre-determined transects. The distance to each detected animal is measured and consequently used to obtain a detection function, from which an estimate of the effective width of the strip that has been searched can be calculated. This is necessary because the probability of detecting an animal decreases the further away it is from the transect line. Abundance is then calculated by extrapolating estimated density in the sampled strips to the entire survey area. The calculated number is therefore an estimate of abundance in a defined area at a particular time.

On ships, distances are either estimated by naked eye (observers should be trained in distance estimation and use individually calibrated tools) or using binoculars with distance calibrated reticules. Video range measuring methods allow distance to be accurately measured. To calculate the perpendicular distance to a sighting the radial angle should be recorded using an angle board. If an aircraft is used, an inclinometer reading, taken when the sighting is abeam of the aircraft, and the altitude of the aircraft allow precise calculation of the perpendicular sighting distance to the transect. Animals occur in groups in many cetacean species so the target for detection in a line transect survey is often a group rather than individuals. Hence, data on the group size and composition must also be accurately collected.

When estimating absolute abundance using the line transect distance sampling method, it is assumed that all animals on the track line are detected, i.e. probability to detect an animal or a group of animals is maximum (g(0)=1).

There are two potential categories of bias that may invalidate the assumption that g(0)=1:

- availability bias (when the animal is underwater or, in general, not available to be seen during the period it is within visual range) and
- perception bias (when for whatever reason an observer misses an animal that is available at the surface).

To address the availability bias, data on diving behaviour of the target species could be taken into consideration and used as a correction factor. With trained observers and large cetaceans, perception bias can be considered equal to or approximately equal to 1. However, if g(0) is significantly lower than one (as is often the case for small cetaceans) then this will result in a considerably negatively biased estimate and the true value of g(0) must be estimated. For shipboard surveys, the double-platform approach has been successfully used to address this problem. Availability bias is a particular problem for animals with very long dives; in the case of the sperm whale, acoustic techniques can overcome this problem.

The logistics of aerial surveys often prevent the use of two independent platforms to allow estimation of the proportion of animals missed on the transect line, however, recently Partenavia P-68 planes have been equipped with two sets of bubble windows, to allow double-platform data collection by means of independent observers on board of the same aircraft. Data collection protocols implementing aircraft circling back after a sighting to simulate the second research platform can be also used.

Relative abundance using only one platform may be sufficient for detecting population trends, reducing surveys cost considerably and may be used to monitoring the status of the target population between large-scale absolute abundance surveys based on larger budgets.

Another assumption for line transects methodology is that animals do not move prior to detection. This is not a problem for aerial surveys, but may bias shipboard surveys that typically survey at speeds around 10 knots. Evasive movements lead to negative bias in estimates of abundance, while attractive movements lead to positively biased estimates. Double-platform methodology can be applied to assess responsive movements. According to this method, observations are carried out from two platforms. Observers from the secondary or 'tracking' platform search an area ahead of the 'primary' survey area and sufficiently wide to ensure that animals are detected prior to any responsive movement to the ship, and to allow the tracking of animals until they are detected by the primary platform. The observers from the primary platform search independently of the tracking platform.

To assist in planning a line transect survey and to analyse the data there is a comprehensive analysis program available called DISTANCE.

DISTANCE provides software for estimating detection functions, density and abundance, and can be used to design the surveys. The latest version also includes mark-recapture distance sampling which allows analysis of dual observer distance sampling surveys, where the probability of detection on the trackline can be estimated. All versions of DISTANCE can be downloaded free from http://www.ruwpa.st-and.ac.uk/distance/.

It is clear from the above examples that proper design of the survey is critical to address monitoring issues of cetacean populations, and in particular that a large enough area is covered so that shifts in distributions can be accounted for when analysing the data.

The areas to be surveyed are usually divided into survey blocks and the transects are designed to ensure equal coverage probability, using the dedicated software.

Survey design

The basic requirement for a line transect survey is that it provides representative coverage of the area for which an abundance estimate is desired *(i.e.* each point in the area has an equal or quantifiable probability of being sampled). A common design for vessel-based surveys at sea is a set of zig-zag lines following a regular pattern, starting from a random point along one edge of the survey area. In aerial surveys, ‘parallel transects’ are to be preferred and the coverage should be allocated according to target species’ density: more coverage where their density is higher.

Survey blocks

The development of appropriate survey blocks is a combination of biological factors (species, distribution/stock structure and abundance, habitat types etc.) and pragmatism associated with the logistics (numbers of vessels/planes; port/airport facilities; transit times; national boarders etc.).

Effort required per block

The effort required per block is determined as a function of ship/airplane time available in each block, available information on density of species and logistical constraints. The higher the level of coverage the better, as it allows for a larger sample size and therefore for more precise and robust abundance estimates.
There are some practical points needing attention when designing a survey. Transects should, as far as possible, run perpendicular to any density gradient; for example, coastal surveys typically have transects that run more or less perpendicular to the shore line.

Closing mode versus passing mode

In order to confirm certain information (species identification, group size and, historically, distance to sighting), cetacean surveys could be operated in ‘closing mode’. In this mode, once a sighting has been made and the initial distance and angle been recorded, the vessel then approaches the animal(s) to identify the species and group size. It is also used if, for example, it is desired to obtain biopsy samples or photographs.

Nevertheless, operating in ‘closing’ mode can result in biased abundance and estimates. The preferred approach is thus to operate in ‘passing mode’ whenever possible (*i.e.* once a sighting is made the vessel remains on the designated course). However, this too has its problems, if, for example, many sightings are unidentified to species (the use of cameras with large stabilized zoom lenses may facilitate species identification).

Deciding between vessel and aerial surveys

Visual line transects surveys can be operated from a ship and from an aircraft. When deciding which platform to use, the relative merits of each approach for the species and areas to be covered must be considered. These include:

- aerial surveys are usually more cost-efficient per area than large vessel surveys, provided that the area to be covered is within the range of the aircraft from an airport and taking safety considerations into account (this often means not travelling more than 200 nautical miles or so offshore);

- aerial surveys can take better advantage of good weather conditions, in that they can cover much larger areas in the same period;
- aerial surveys are more efficient (and trackline design is easier) if the area to be covered has complex coastlines, many islands or large areas of shallow waters;
- aerial surveys can be more tolerant of swell but less tolerant of sea state and low cloud – they can also be affected by poor weather at the airport even if survey conditions are acceptable at sea;
- animals are less disturbed (if at all) by aircraft at normal flying altitudes and thus the problem of responsive movement is minimal;
- for multispecies aerial surveys, compromises must be made in terms of the optimum altitude for flying e.g. flying at the optimum altitude for a harbour porpoise survey means that the searching area for larger species such as fin whales is considerably reduced;
- vessels are generally better platforms for photo-identification and aircraft are unsuitable for biopsy sampling and acoustic recording;
- availability bias is much greater for aerial surveys;
- it is generally easier to obtain a suitable vessel than a suitable aircraft.

Platforms of opportunity

Platforms of opportunity are a potentially valuable resource for monitoring but it is usually not possible to choose the time or area of operation. Survey coverage is therefore typically extremely uneven and some areas, crucial for the presence of a target species, may not be covered; such unrepresentative coverage may introduce bias into assessment of distribution and abundance.

Platforms of opportunity using visual and/or acoustic methods are the cheapest way to monitor cetaceans. However, the success of using such vessels depends on finding the right platform that can cheaply and effectively accommodate observers and equipment and that cover appropriate areas at suitable speeds. These criteria are seldom fulfilled, especially since long term monitoring ideally requires the conditions to be consistent. Ferries may be suitable in some areas but spatial coverage is likely to be poor because of the fixed routes covered. Research vessels conducting annual monitoring of e.g. oceanography or fish resources have the potential to be valuable platforms of opportunity for monitoring if they take place at the right time(s) in the right place(s).

Acoustic surveys

The collection of acoustic data for cetaceans has some significant advantages over visual methods. Acoustic methods can be automated, data can be collected 24-hrs a day and data collection is not dependent on observer's skills, is less sensitive to weather conditions and can detect the presence of diving animals not available for visual observations. Disadvantages are that these methods rely on animals making sounds within a useful detection range and are identifiable to the species level.

Furthermore, with exception of some species such as the sperm whale, methods to estimate abundance are not well established yet.

All odontocetes (toothed whales) have the ability to echolocate by producing and listening to particular “click” sounds. This allows them to navigate during night time or in murky waters, and to find and catch preys. Most toothed whales such as most dolphins (e.g. bottlenose and common dolphins) also produce other frequency modulated sounds (whistles) used for intraspecific communication. The monitoring of these sounds allows for the collection of information on spatial and temporal habitat use, as well as estimation of relative density.

Ship-board line transect acoustic survey is the most effective way of surveying sperm whales in the open sea and to collect the data required for accurate and robust estimation of absolute abundance in these waters. Visual-only survey techniques could introduce biases due to the long dive duration abilities demonstrated by the species and the little time generally spent at the surface, which makes them mostly unavailable for visual detection.

Acoustic data from sperm whales can be used to assess both relative and absolute abundance provided that the appropriate equipment and survey design is followed. Sperm whales produce loud regular clicks, which can be detected at ranges of tens of kilometres. Sperm whale click characteristics are generally easily recognisable. Thus, software automatization has been developed and used on a number of surveys resulting into real-time tracking and location to single animals or groups. By tracking a whale for a period of time, crossed bearings to successive clicks give a position for each whale, which can be used in a distance-based analysis.

A major task in this type of analysis is the assignment of clicks to individual whales when many animals are vocalizing simultaneously. Often, clicks from different whales are easily resolved using bearing information with dedicated software implementing beamforming. The regularity of the click train on each bearing indicates that they represent a single whale. On occasions where more than one whale is on the same bearing, clicks can be assigned to individuals using spectral and amplitude information, inter-click intervals and inter-pulse intervals. By identifying the most obvious whale in a group and removing those clicks from the analysis, identification of successive whales becomes progressively easier until all clicks are assigned.
Since acoustic detection ranges are generally ~10 km, a survey vessel travelling at 18 km per hour (10 knots) will be in acoustic range of a sperm whale close to the track line for over an hour. Typically, sperm whales dive for approximately 30-50 minutes followed by 10-15 minutes at the surface. Clicking is generally continuous when the whales are submerged and they are silent while resting at the surface.

On occasion, whales cease clicking regularly for periods of 2-3 hours, but evidence from tagging and observational studies suggests this is infrequent. The probability of a whale to remain silent for the entire time that the vessel is in range is therefore considered to be small, indicating that g(0) for acoustic surveys is close to 1. However, calves (which may represent up to 20% of the population) do not make long foraging dives and are not clicking regularly. Consequently, their detection may have low efficiency and a correction factor calculated from existing data should be applied.

Acoustic survey data for sperm whales can generally be collected simultaneously with visual data for other species particularly if the survey is operating primarily in passing mode. Survey vessels can also continue acoustic sampling in conditions unsuitable for visual survey (bad weather and night time).

Abundance estimates, based on acoustic methods, are only possible for sperm whales. Potentially, information on distribution can be obtained from acoustic data for all species, although with much more uncertainties for common and striped dolphins, given the difficulties in distinguishing their vocalizations.

A hydrophone array is towed behind each vessel. The equipment consists of a desktop computer running automatic detection software, the towed hydrophone, and various interface cards for getting sounds into the computer. The computer is running all the time, and one scientist is in charge of the acoustic system on each vessel.

Photo-identification

Photo-identification is a widely used technique in cetacean research that can provide estimates of abundance and population parameters e.g. survival and calving rate. It has been used for monitoring purposes for common bottlenose dolphins and killer whales since the 1970s. The technique relies on being able to obtain good quality photos of animals' body parts that constitute unique recognizable markings.

This method can be used for population level monitoring of species with appropriate markings, if data can be collected across the distribution of the population. This approach cannot be applied to species that lack suitable individual identification marks.

Using photo-identification, it is sometimes possible to census the whole population when all individuals can be encountered at any given time in an area, all are well marked and no individuals seem to be moving in or out of the population. This is however unusual and has only been accomplished for a few populations of bottlenose dolphin, e.g. Sado Estuary, Portugal and Doubtful Sound, New Zealand, and for killer whales off Vancouver Island. More commonly, mark-recapture models must be applied to photo-identification data to estimate abundance (rather than a census the whole population) for specific areas that populations or part of populations occupy during one or more seasons of the year.

Information on the proportion of the population possessing recognisable markings is also required to allow estimation of population size.

The standard software program for mark-recapture analysis is program MARK (http://www.cnr.colostate.edu/~gwhite/mark/mark.htm), which includes a wide range of models to estimate population size and survival rates. There are models that can take account of heterogeneity of capture probabilities, a common problem in mark-recapture studies. These include program CAPTURE, a widely used multi-sample closed population model. If animals are believed to emigrate temporarily from the study area, there are also methods available for taking this into account in analysis.

Satellite tracking

Information on the movements and distribution of individual animals can help to identify important habitats, migration routes and to define boundaries between populations. Effective conservation of animal populations is enhanced by this information, which can also be valuable when designing monitoring programmes. In recent years satellite tagging of cetaceans has been increasingly used to obtain information on seasonal movements, distribution and diving behaviour.

To make inferences about large populations ranging over a wide area, many animals must be tagged, especially in species with high individual variation in behaviour. For some areas and species this would be a significant logistical challenge.

Many kinds of tags have been used in studies of cetaceans, including VHF transmitters, satellite tags and GPS data loggers. Satellite telemetry has the advantage that because data are transmitted to an earth based station via a satellite, it is possible to follow animals all over the world without retrieval of the tag.

Each tagged animal can provide a wealth of information but the limitation is that typically only a few animals can be tagged in a study due to limited funding or access to live animals. General conclusions are therefore often difficult especially if all members of the population are not equally available for tagging.

Power analysis

For any type of monitoring it is necessary to ensure that the chosen method and the study design will be able to provide an answer to the question posed with a useful level of precision. A power analysis can indicate the ability of the statistical procedure and the available or planned data to reveal a certain level of change i.e. the ability to detect a trend of a given magnitude. Power analysis can be used in two situations: firstly for interpretation of results of analysis of existing data; and secondly to plan studies to calculate the necessary sample size e.g. the length of time series of abundance estimates, or the coefficient of variation (CV) of those estimates, needed to detect specified rates of population change in a trend analysis.

TRENDS is a freely available program designed to carry out a power analysis of linear regression, particularly in the context of monitoring populations in wildlife studies:
(https://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=228&id=4740).

TRENDS summarises the power analysis in five parameters: duration of study, rate of change, precision of estimates, Type 1 error rate, and power (1 - Type 2 error rate). The value of any one of these can be estimated if the other four are specified. TRENDS is therefore designed to help answer such questions as:

- How many years are required to detect a trend?
- How much effort would be required to detect a certain level of change in a certain time period? What is the probability of detecting a trend?