

## MARINE MAMMAL SURVEY TECHNIQUES APPLICABLE IN DEVELOPING COUNTRIES

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### Abstract

Several survey techniques for marine mammals are applicable in developing countries. We present methods, requirements and potential outputs for the following: interview surveys, land/shore based monitoring, ship/boat and aerial surveys, and carcass analysis. The most appropriate survey techniques depend on the survey objectives, spatial scale, location, budget and timing, and the availability of logistical support. Interviews are the least expensive method and can be used for obtaining the basic qualitative information required to design more technologically sophisticated surveys. Land-based monitoring can be an inexpensive method of obtaining quantitative information on trends in the abundance of populations of some coastal marine mammals in certain limited situations. Ship/boat and aircraft surveys can be used to obtain information on the distribution and the absolute and relative abundance of marine mammals, although such surveys can be expensive and require extensive logistical support. Carcass analysis can be an important technique for obtaining information on marine mammal diversity. Interview surveys and land-based monitoring may be the most inexpensive and practical techniques in developing countries, although their limits must be clearly recognized. We recommend starting with a simple inexpensive technique before using sophisticated and expensive surveys.

### Introduction

The increase in human population in coastal developing countries has resulted in overexploitation of marine resources. Marine mammals are threatened by incidental takes in fishing operations, directed fisheries, habitat loss and pollution (Leatherwood and Reeves 1989; Perrin 1989; Leatherwood and Donovan 1990; Van Waerebeek and Reyes 1990; Aragonés 1990, 1994; Leatherwood *et al.* 1992; Perrin and Brownell 1994; Perrin *et al.* 1994; Dolar 1994; Dolar *et al.* 1994; Reeves and Leatherwood 1994).

The magnitude of the impact of these activities on marine mammals is unknown. In the waters of Southeast Asia; as in the rest of the world, little

reliable information documents these impacts (Leatherwood and Donovan 1990; Leatherwood *et al.* 1992; Baird *et al.* 1994; Dolar *et al.* 1994). Thus, there is an apparent need to focus more effort on surveying and assessing marine mammal populations.

Sophisticated survey techniques have been developed for marine mammals. These include conducting line transect surveys from ships or boats (Hammond 1986a; Holt 1987; Holt and Cologne 1987; Holt and Sexton 1989, 1990; Gerrodette and Wade 1991; Buckland *et al.* 1992, 1993; Wade and Gerrodette 1992, 1993; Borchers 1994; Barlow 1995; Jefferson and Leatherwood 1997) and airplanes (Ross *et al.* 1989; Marsh and Saalfeld 1989; Marsh and Sinclair 1989; Buckland

*et al.* 1993; Forney and Barlow 1993; Forney *et al.* 1995). Techniques for shore-based surveys of large cetaceans have also been developed using theodolites or reticles in binoculars to measure sighting distances (Krogman *et al.* 1989; Rugh *et al.* 1990). These methods often have limited application in developing countries, because they require expensive and sophisticated equipment, trained support personnel, or cost too much.

Selection of techniques or methods appropriate for surveying marine mammals in developing countries is therefore a challenge. In this paper, we will focus on and discuss modifications of techniques that may be applicable in developing countries: interview, land-based, and carcass analysis. Surveys conducted from ships and aircraft will also be reviewed with the notion that these techniques can be simplified for use in developing countries, and/or may be used in their advanced forms, if resources and expertise are available.

### **Choice of population assessment technique**

There is no single best technique. It is important to identify research techniques most suitable for each survey. These will depend on objectives that need to be defined before surveys begin. In deciding on the most appropriate technique, the following factors need to be considered.

#### *Objectives of the survey*

Objectives can be divided into three main categories:

1. To obtain broad-scale (regional) information on distribution and species diversity of marine mammals
2. To estimate absolute or relative abundance
3. To acquire local information on habitat utilisation.

Broad-scale surveys usually cover hundreds of kilometres of coastline. Detailed or local-scale surveys usually focus on specific sites or localities. Survey effort varies according to the scale of the survey and the size of the study area.

Abundance can be measured with absolute or relative methods. Absolute abundance is difficult to determine exactly because of biases related to constraints imposed by marine mammal behaviour and the aquatic environment. However, absolute abundance can be estimated with varying degrees of confidence. If the objective of a survey is to estimate absolute abundance, potential biases and violations of the assumptions of the survey method used must be considered. For example, absolute abundance estimates may generally be used for relative abundance purposes, i.e., regressed over time to detect population trends, however, if the objective of a survey is to estimate relative abundance, survey techniques and variables should be held constant over the study period. Monitoring trends in abundance requires multiple surveys over a long period of time (preferably during similar seasons to avoid confounding affect of season), and in such case, statistical power to detect trends, i.e., power analysis, must be considered (Gerrodette and Wade 1991; Taylor and Gerrodette 1993; Marsh 1995). Precaution should be taken as there is usually a low power to detect population trends in marine mammals, particularly those that occur in low abundance and/or are rare (Taylor and Gerrodette 1993). This does not imply that relative abundance surveys are of little or no value for assessing populations, but that researchers need to carefully consider the issue of survey design and evaluate the relative importance they attach to committing a Type 1 (null hypothesis of no significant trend is rejected, but is true) *versus* a Type 2 (null hypothesis of no significant trend is accepted, but is false) error.

#### *Spatial scale and location of survey*

Optimum methods will vary with the size of the area to be surveyed. The expected occurrence and abundance of marine mammals may be higher in regions with broad continental shelves and/or long coastlines. Estimating the distribution and absolute or relative abundance and monitoring trends in abundance of marine mammals may be more expensive and problematical in these regions. For example, Indonesia has 54,716 km of coastline; Cambodia only 443 km (World Resources Institute 1992). Therefore, the capacity to use more

expensive methods, e.g., ship or aerial surveys, may be more limited in countries with long coastlines than in smaller countries. In areas where coastlines, or rivers and estuaries, are shared between countries, cooperative surveys, such as the joint survey conducted in Malaysian and Philippine waters of the Sulu Sea (Dolar *et al.* 1997) are desirable.

The location of a survey depends on the target species (and on the objectives). Some species of marine mammals are restricted to riverine, e.g., *Lipotes vexillifer*, *Platanista* spp. or coastal waters, e.g., *Orcaella brevirostris*, *Neophocaena phocaenoides*, *Sousa chinensis*, *Dugong dugon*; others occur mainly in offshore/oceanic environments, e.g., *Delphinus delphis*, *Stenella coeruleoalba*, (Leatherwood and Reeves 1983; Jefferson *et al.* 1993). Some whales migrate along coasts, e.g., some *Balaenoptera musculus*, *Megaptera novaeangeliae*, while others are primarily pelagic, e.g., *Physeter catodon*, *Mesoplodon* spp. (Leatherwood and Reeves 1983; Perrin 1989; Jefferson *et al.* 1993). Bathymetric/hydrographic maps are essential for planning marine mammal surveys and can help identify the most important areas to focus subsequent survey efforts.

#### *Budget and timing of survey*

The budget will limit the design and extent of most surveys. A project with a budget of tens of thousands of US dollars may be able to afford complex, 'high technology' survey techniques. A project with a limited budget will be restricted to techniques that require less costly methods.

The relative costs of labour and vessel, i.e., aircraft or ship/boat, rental should be carefully considered. Labour is usually cheaper in developing countries than in developed countries. Labour-intensive techniques, including shore-based surveys (Aragones 1994), may be more practical in developing countries than in developed countries, although the limits of these types of surveys must be clearly recognized.

Here is a short checklist of some costs that

should be considered:

1. Hire of survey vessel.
2. Labour costs for surveys and analyses of data.
3. *Per diem* for observers.
4. Purchase (whenever possible) of some basic equipment, e.g., Global Positioning System, binoculars, computer, cassette recorder/player, camera/lens.

The timing of the surveys is also important. Factors such as weather, wind speed and direction, tidal strength and range, and glare may vary seasonally at regional and/or local scales.

#### *Logistical support*

Logistical support may be divided into two categories: equipment, e.g., survey vessels and computers, and personnel. Ship and aircraft surveys often require extensive logistical support. However, surveys for coastal cetaceans can be accomplished by using local fishing, transport or tourist vessels which require minimal logistical support. One of us (Aragones) is currently using tourist (dolphin watching) boats for monitoring cetaceans around Tañon Strait, in the central Philippines. Aircraft surveys will usually require several refuelling stations, each with an all-weather runway. It is often difficult to obtain the logistical support required for aerial surveys in remote areas and on some islands.

Trained personnel are required both for surveying and data analyses. Different survey techniques may require different personnel. To minimise inter-observer variability between surveys it is advisable to retain the same personnel for a sequence (or the duration) of surveys. The costs of training and employing observers can also be substantial. Students and volunteers may provide cheaper alternatives; however, they must still be trained. A computer, appropriate software and a person competent with statistics are important for data analyses. However, they are not necessarily essential if the objectives of the survey are to investigate distribution and relative abundance.

## Survey techniques

We provide a brief description of each survey technique in the context of its application in developing countries. Details on any particular technique can be found in the cited literature.

### *Interview survey*

Interview survey is a process of obtaining and examining information by meeting with or consulting people. Interviewing is one of the least expensive survey methods. Interviews can be used to obtain basic information on the occurrence and distribution of species, although the reliability of such information has to be carefully verified. This survey method has been used in countries such as Papua New Guinea (Hudson 1977, 1981), Philippines (Leatherwood *et al.* 1992), Sri Lanka (Leatherwood and Reeves 1989) and Vanuatu (Chambers *et al.* 1989). Verified data from interviews can be used for designing more technologically sophisticated surveys. Aragones (1990) used information from interview surveys to design an appropriate land-based sighting/monitoring program for dugongs at Calauit Island, Busuanga, Palawan, Philippines. Also, interview surveys can be valuable for generating research hypotheses for future surveys.

## Methods

Well designed interviews are important if reliable results are to be obtained. Knowledge of the people being questioned is essential. For example, some idea of the proportions of experienced and novice fishermen at various locations in the survey region can be useful. Information on the people to be interviewed may be obtained from local or regional social services departments. Experienced fishermen are usually the best source of information.

Successful interview surveys require a thorough knowledge of the different interview techniques. Appropriate ethnographic interview procedures (Spradley 1979) and participant observation techniques are available (Spradley 1980; Smith 1987). Interviews can be conducted

either informally or formally. A semi-structured interview procedure is usually used if there are only a few knowledgeable informants (Johannes 1981; Smith 1987).

Interview surveys require as much training as ship/boat, aerial or land-based surveys. In some situations, e.g., interviews regarding traditional hunting), informants may be intimidated by formal interviews and become suspicious. In such cases, a less formal approach may be more appropriate. There is an apparent bias towards male-oriented information, e.g., how a certain species of fish is harvested, in interview surveys at some coastal communities (Hudson 1981; Johannes 1981, Smith 1987). In most coastal villages in developing countries fisheries activities (except gleaning for intertidal resources) are male dominated.

There are several forms of questions which may be employed in acquiring information during interview surveys. Spradley and Smith recommended that informants be asked a series of descriptive, structured and contrast (validation) questions. Descriptive questions require informants to describe what they have seen or know. Structured questions focus a discussion to obtain detailed information. Contrast questions require the informants to differentiate certain things, e.g., ask the informant to differentiate a fish from a marine mammal. Correct or erroneous answers to contrasting questions can help the interviewer assess the reliability of any acquired information from any informants. Similarly, the reliability of answers can be assessed by asking questions to which the interviewer already knows the answer and questions to which the informant could not possibly know the answer (Johannes 1981).

Examples of the (structured) questions that might be asked (in actual interviews or through questionnaires) are:

1. What type of fishing do you do?
2. Where do you fish?
3. How far do you travel to your primary fishing grounds (approximate distance and travelling time)?
4. How long have you been fishing?
5. What are marine mammals, i.e., dolphins, whales and/or dugongs?
6. Can you describe the marine mammals in the

areas where you fish?

7. When did you last see one? Where?
8. How often and in what seasons do you see marine mammals?
9. How often have you seen a marine mammal in the last month?
10. What size groups do you see them in? Do you usually see them in big groups or in a few individuals at a time?
12. Have you noticed changes in the number and location of these mammals since you were young?

It is important to establish a good rapport with the informant before beginning the interview. Questions on bycatch of dolphins and dugongs in fisheries, fisheries regulations and marine conservation awareness should be asked in a non-threatening manner.

Sighting sheets may also be used to collect anecdotal information from informants, such as boat skippers and school children. In Torres Strait, between Australia and Papua New Guinea, poster-size wall calendars and dugong stickers (of various categories, male, female, young and pregnant) were supplied to schools, and students reported the catches on a daily basis by placing a particular sticker for each date (Harris *et al.* 1994). During school holidays, records were kept and continued by the resident school teachers at their homes, notified by students or fishermen when animals were caught. Although the scientific value of the information resulting from these types of studies may be questionable, these programmes have great value for increasing public awareness of marine mammal conservation concerns.

'Sighting sheets' given to ship captains, local fishers, and school children can provide useful information on the occurrence, directed catch, and incidental catch of marine mammals. Survey sheets and interviews have been used in the Torres Strait area (Harris *et al.* 1994; Marsh *et al.* in press), Papua New Guinea (Hudson 1977, 1981) and Vanuatu (Chambers *et al.* 1989) to monitor dugong catches. Potentially misleading information gathered from interviews should be verified.

## Requirements

A trained interviewer is required with a good knowledge of marine mammals and excellent interpersonal skills. Knowledge of the local language or access to an interpreter is essential.

Requirements suggested for the interview survey technique include:

1. Transport (personal vehicle, local bus, boat).
2. Tape recorder and tapes.
3. Camera and film.
4. Writing materials and data sheets and
5. Maps.
6. Photographs of animals or field guides.
7. Interpreters (if necessary).

## Survey outputs

### *Broad scale distribution/abundance*

It is possible to use interview surveys to cover large areas, several hundreds of kilometres of coastline for example. Interview surveys can provide data on the diversity of the marine mammal fauna at a broad scale and can be used to collect anecdotal information on fisher/marine mammal interactions, e.g., sources and levels of mortality and hunting methods. This can be done by showing pictures of the various marine mammal species (even of species which could not be found there) and asking the informant whether or not it occurs in the region. For species which are difficult to identify, such information will not be reliable at the species level. Some animals are easier to see than others, especially for an untrained observer. Thus there can be bias in the species list of marine mammals produced by this method. This problem is not unique to this method, but a general problem for any marine mammal survey technique. These surveys can also identify areas where conservation efforts should be concentrated, e.g., areas of high levels of fishing activities where marine mammals are locally abundant. Additionally, data from these surveys can provide information in assessing attitudes towards conserving marine mammals. e.g.,

awareness of legislation and other conservation initiatives.

### *Monitoring trends*

Interview surveys can provide general information on spatial, i.e., regional and local, and temporal (seasonal, annual) variations in the qualitative perception of size of marine mammal populations which can be used to generate hypotheses. Testing of these hypotheses involves ecological studies which seek to answer questions about the processes which may contribute to changes and/or the magnitude of change that is occurring, and over what time scales.

### *Habitat use*

Data from interview surveys can provide useful information for generating hypotheses on the biology and ecology of marine mammals, especially at the local scale. For example, data on food preferences, timing of births, and seasonal and temporal movements of marine mammals, may be obtained from long-term observations of experienced fishers and confirmed by more direct investigations.

### *Land-based Surveys*

This technique employs observers on a fixed, usually shore-based, platform to identify species, estimate the group size, and study the behaviour and ecology of coastal marine mammals with the naked eye and/or with the aid of binoculars. Land-based survey techniques have been extensively applied in studies of some migratory whales, as their movements are seasonally predictable (Krogman *et al.* 1989; Rugh *et al.* 1990).

The land-based survey method can be applied at various levels of technological sophistication, starting with binoculars and a field notebook. Hence land-based surveys can be suitable for application in some developing countries with coastal populations of marine mammals. The wages of observers are likely to be the major cost, unless volunteers are available. Researchers should be cautioned that, even under the most ideal situations, sighting animals, making species

identification and estimating school sizes from fixed platforms are difficult tasks and will be practicable only under limited circumstances, e.g. good weather conditions, such as Beaufort 0–2 (Table 1), marine mammal species with nearshore distribution, and the availability of elevated platforms.

## **Methods**

Land- or shore-based sighting techniques use stationary, elevated platforms, e.g., hilltops, cliffs, buildings, which provide a good view. Marine mammals are observed, identified and counted from these platforms. In some areas, elevated tower-like watch houses have been constructed at appropriate vantage points to improve the field of view (Aragonés 1990). This technique can also make use of man-made platforms in the water, e.g., reef pontoons and oil drilling platforms. For each group of marine mammals, the time and bearing of the initial sighting, sighting distance, identification and estimate of size must be recorded. This technique can be improved by increasing the density of stations and by using multiple observers. Reasons for using more than one observer are:

1. To reduce observer fatigue. It is unrealistic to expect an observer to scan the sea all day without losing concentration. Observers should be rotated every two hours or so.
2. To estimate the number of animals that are available to observers, but missed. No observer, no matter how experienced, sees all the marine mammals that surface in his/her viewing field.

This 'perception bias' can be estimated using paired observers working independently (i.e. without communication) and mark-recapture methodology (Hammond 1986b; Zeh *et al.* 1988). Discrepancies between paired counts should be examined and the factors responsible for the discrepancies identified, e.g., differences in angle of view, and distance and times of sightings (Eberhardt and Simmons 1987), as has been done for shore-based counts of whales (Krogman *et al.* 1989; Rugh *et al.* 1990). This can provide a

measure of consistency. In addition, the weather conditions, e.g., Beaufort sea state/wind scale and cloud cover), and levels of boat traffic should be assessed at regular intervals (we suggest hourly) to help explain differences in counts between days (Aragones 1994).

## Requirements

Land-based surveys require trained observers and information on the surfacing characteristics of locally occurring marine mammals, i.e., field guides, (Leatherwood *et al.* 1982; Jefferson *et al.* 1993), binoculars and a standardised methodology for recording the information, e.g., sighting sheets, tape recorder, laptop computer. A sample sighting sheet is shown in Figure 1. Some scientists use a theodolite (or vertical reticule in binoculars, clinometer, or laser rangefinder) to estimate the distance of each marine mammal group sighted. With practice, distances can be estimated with handheld binoculars, by using various landmarks or buoys, with known distances, as targets. Sighting distances (usually measured or estimated distances from a line) are important for estimating the density of marine mammals in a study area, as detectability will decrease with increasing distance from a point (Buckland *et al.* 1993).

## Survey outputs

### *Broad scale distribution/abundance*

Local areas (tens of kilometres of coasts extending several kilometres offshore, depending upon the visibility of the target species, height of elevated platform, observer skills, and magnification and optical quality of binoculars) can be surveyed using this method. At this scale, the method will require numerous observers and systematic positioning of platforms. This method has been used to estimate the abundance of Bowhead whales, *Balaena mysticetus* Linnaeus (Krogman *et al.* 1989), and Gray whales, *Eschrichtius robustus* Lilljeborg (Rugh *et al.* 1990) and may be

applicable to studying the abundance and local distribution of other nearshore coastal marine mammals.

### *Habitat use*

Information on habitat use and seasonal patterns of use can be obtained using this technique. For example, Aragones (1994) was able to identify important coves for dugongs at Calauit Island, where he eventually focussed his study.

### *Ship/boat surveys*

Ship/boat survey employs observer(s) on each side of the vessel, i.e., large commercial or research ship to a small fishing boat, to identify the species and estimate the group size of marine mammals with the naked eye and/or with the aid of binoculars. Ship or boat surveys can also be used to: (1), investigate the spatial and temporal distribution of identified species; (2), estimate an index of relative abundance to monitor trends over time; (3), estimate absolute abundance using line transect techniques; (4), collect information on habitat use and (5), identify conservation threats. Ship or boat surveys are also often used to collect data for photo-identification studies. Generally, close-up, sharp photographs of individual dolphins or whales are taken using long lenses and the photos are then examined and individual animals are recognized using natural marks, such as fin shapes, nicks and scars on fins and flukes, body scars, and colour patterns (see Würsig and Jefferson 1990 and other papers in Hammond *et al.* 1990). Information on movement patterns, social organization, habitat use, and reproductive parameters can be obtained from photo-identification studies.

Photo-identification data can also be used to estimate population abundance using mark/recapture techniques originally developed for tagging studies. There are many different models that can be used to analyse such data, and Hammond (1986b) provided a good summary. Assumptions involved in this type of work vary with the model being used (Hammond 1986b).



## Methods

Ship or boat surveys generally use line transect methods to estimate density and abundance. The transect line is the path of the ship/research vessel. Observers record the group size and species composition of marine mammals as the ship moves along this path. The perpendicular distance from the transect line of each group of marine mammals sighted is estimated from the sighting (= radial) distance and sighting angle (Burnham *et al.* 1980; Buckland *et al.* 1993).

Strip transects are a special case of line transect surveys, in which it is assumed that all target objects are sighted out to a defined distance on either side of the centre line, i.e., there is a complete census of the strip. They are rarely used for marine mammal ship/boat surveys (but often used in aerial surveys, see below).

Two teams comprised of three trained observers, which alternate every two hours, are typically employed for line transect surveys in oceanic areas (Holt and Sexton 1989; Wade and Gerrodette 1993; Barlow 1995; Jefferson 1996). Two observers, one on each side of the boat, simultaneously search from directly ahead to abeam of their respective sides through 20X or 25X binoculars. A 10° overlap at the bow (between observers) is allowed to ensure double coverage of the trackline. A third observer records the data and also “guards the trackline” near the ship. The observers rotate positions every 30 to 45 minutes or so. By using trained observers, species identification can be reliably obtained. However, some species like the Pygmy killer (*Feresa attenuata* Gray, 1875) and beaked whales are difficult to identify, even if the animals approach the vessel, or if the vessel deviates from the track line and approaches the groups to obtain close observations. Some species like sperm, humpback and killer whales can be reliably identified even at a distance (~ 5–10 km). Coastal surveys using line transect methodology often use teams of only two observers (Jefferson and Leatherwood 1997).

Unbiased estimates of the density of each species can be obtained from distance data if the following assumptions are met (Burnham *et al.* 1980; Buckland *et al.* 1993):

1. All groups on or very close to the trackline are

detected and identified or corrected for in the analysis.

2. Animals do not make responsive movements prior to the recording of distance and angle data.
3. Sighting distances and angles are measured without significant error.
4. Sightings are independent events.
5. Mean group size is estimated without bias (if the group contains more than one species, the presence of each species is recorded without error) or such bias is corrected for.

These assumptions should be interpreted with caution. Assumption 1 is usually violated in the case of diving mammals. Detection of all animals cannot always be assured, as this survey technique is constrained by the animals' behaviour and their aquatic environment. However, correction factors have been developed (Buckland *et al.* 1993) for some species (Hammond 1986a). If these are factored into the transect line equation, violations of Assumption 1 are no longer a problem. Assumption 2 can be a problem if dolphins are attracted to vessels to ride the bow or avoid vessels because of prior harassment. Methods are, however, available to compensate for this in some cases (Hammond 1986a; Turnock and Quinn 1991).

Well designed ship surveys conform to standard procedures such as searching only during Beaufort sea states of 5 or less (Table 1) (Holt and Cologne 1987; Holt and Sexton 1989, 1990; Buckland and Turnock 1992; Palka 1993; Wade and Gerrodette 1993; Jefferson 1996). The method is sometimes improved by comparing results obtained from different vessels, e.g., commercial vessels and research vessels (Polacheck and Smith 1989). Effects of nonrandomness on line transect estimates of dolphin abundance collected from boat surveys have been tested and corrected by stratification (Edwards and Kleiber 1989). Ship survey techniques for marine mammals were improved by comparing results obtained from different vessels as a result of the research effort to monitor trends in abundance of dolphins caught incidentally by purse seiners in the eastern tropical Pacific (Holt 1987; Holt and Cologne 1987; Holt and Sexton 1990; Gerrodette and Wade 1991;

Wade and Gerrodette 1992; Buckland and Anganuzzi 1988; Anganuzzi and Buckland 1989, 1994; Buckland *et al.* 1993; Borchers 1994; Barlow 1995).

Local boats or ships can be used for surveying coastal and offshore waters for presence or absence, and identification of species of and threats to marine mammals. These local surveys can be conducted periodically, e.g., specific season, within more or less the same area, so that data from these surveys can be compared across seasons or even years. These surveys should, however, be performed, if possible, under similar survey conditions.

### Requirements

The major expenditure is usually the operational cost of the survey vessel. Local vessels can be modified and used at a fairly low cost. For example, Dolar *et al.* (1995) rented a 20-m open 'pump-boat'. Her team fitted a sighting platform 2 m above the water. Sighting and navigation equipment included a compass, a global positioning system (GPS), one set of 20X binoculars mounted on a stanchion, and four handheld binoculars (three 7X — one with built in reticle and compass and one 10x). The total value of the equipment was approximately US\$8000 and the cost of the operation \$100 per day. A disadvantage of smaller vessels is their low tolerance to sea conditions greater than Beaufort 3 or 4 (Table 1), but sighting conditions are generally unacceptable in seas much rougher than these anyway.

Reticles etched into the eyepiece of binoculars and graduated scales at the base of the mount allow for accurate measurement of distance and angle data, respectively. Examples of formulae for reliable estimation of sighting distance from reticle readings are provided by Barlow and Lee (1994). Angle boards and binoculars with a built-in compass may be used to record sighting angles. Data sheets are required (Appendices A and B). Sighting distances (using ordinary handheld binoculars) can be estimated with practice. It is, however, important that distance calibration be

undertaken (see Jefferson and Leatherwood 1997).

When dedicated vessel surveys are not possible, options for opportunistic platform surveys can be explored. These include: (1), "hitching a ride" from another project which has access to research vessels or (2), using regular commercial vessels like ferry boats, luxury liners or even private boats. Ship surveys have been conducted from commercial tuna vessels, e.g., purse seiners, by trained observers (Buckland and Anganuzzi 1988; Anganuzzi and Buckland 1989, 1994; Buckland *et al.* 1992). Placing trained observers on commercial fishing vessels, e.g., tuna vessels, can be much cheaper than maintaining or hiring a dedicated research vessel.

The design and analysis of the data from ship surveys requires knowledge of line transect analysis, statistical skills and access to appropriate software, e.g., DISTANCE Program (Laake *et al.* 1994). Access to a computer is essential. Examination of histograms of perpendicular distance data can alert the analyst to problems of heaping (resulting from rounding errors), vessel attraction/avoidance, and other violations of the assumptions. These must be dealt with in the analysis (Hammond 1986a). Cartographic skills are also desirable.

Shortage of funds is not a justification for compromising the design of a survey, but is a justification for evaluating the priorities of the survey objectives. For the line transect method to become immune to violations of the assumptions requires money to pay for training observers, additional ship time, additional "independent" observers, and ancillary studies to validate assumptions.

For photo-identification studies, the major additional expenses will be the costs of a camera and lens, and film and development costs. High-speed autofocus cameras and fast zoom or telephoto lenses, such as a 300 mm f2.8 telephoto are commonly used and will enhance the effectiveness of photo-identification work (but they are expensive). Statistical analysis of photo-identification data can be quite simple, but for some of the more complex models, good statistical background and access to a program such as CAPTURE (Rexstad and Burnham 1991) is useful.

**Table 1. Sea state conditions measured by the Beaufort scale (after Bowditch 1966).**

Wind Force (Beaufort)	Knots	Breeze description	Sea conditions	Probable wave height (in feet)
0	0–1	Calm	Sea smooth and mirror-like	0
1	1–3	Light air	Scale-like ripple without foam crests	1/4
2	4–6	Light breeze	Small short waves; crests have a glassy appearance and do not break	1/2
3	7–10	Gentle breeze	Large wavelets; some crests begin to break; foam of glassy appearance. Occasional white foam crests	2
4	11–16	Moderate breeze	Small waves, becoming longer; fairly frequent white foam crests	4
5	17–21	Fresh breeze	Moderate waves, taking a more pronounced long form; many white foam crests; there may be some spray	6
6	22–27	Strong breeze	Large waves begin to form; white foam crests are more extensive everywhere; there may be some spray	10

## Survey outputs

### *Distribution and abundance*

Ship surveys can provide quantitative data on the relative and absolute abundance and distribution of marine mammals at the species level. Photo-identification studies may provide population information such as discreteness and abundance.

### *Monitoring trends*

Although line transect methodology can be designed to provide a quantitative assessment of temporal trends in abundance, this is usually difficult to achieve without an extensive survey effort extending over many years and sophisticated methods to stratify the data for variations in school size and/or sighting conditions such as Beaufort sea state and/or cloud cover (Buckland *et al.*

1993). Most estimates of abundance obtained from ship surveys have a relatively low precision, making it difficult to detect trends except at large spatial scales (thousands of km<sup>2</sup>) and relatively long time periods (decades) (Holt 1987). However, the line transect method is still probably the best option for detecting trends, particularly to determine whether a specific marine mammal population is declining in a specific region or site. This is achieved by performing regular surveys in such regions/sites and comparing results through time. The important considerations on the power of detecting trends in marine mammals and abundance surveys have already been discussed above.

### *Habitat use*

Information on the ecology, e.g., habitat use, and biology, e.g., breeding season, movements, of

various species of marine mammals can be obtained from ship surveys. The nature of the information obtained will depend on the timing of the surveys, the sampling intensity (percentage of survey area sampled) and the relevant information available about the survey area, e.g., bathymetry and positions of upwellings. Photo-identification data can be useful to examine habitat use and movement patterns.

### *Aircraft Surveys*

Aircraft or aerial survey is one of the most reliable methods for estimating the numbers of large animals inhabiting a large area (Caughley 1977). Like ship/boat surveys, aircraft surveys employ observers to identify and count marine mammals from a moving platform.

Using an aircraft as the survey platform enables large areas to be surveyed relatively quickly. Aerial surveys are most useful for surveying species of marine mammals that are:

1. Easy to identify from the air.
2. Limited to coastal waters.
3. Difficult to see from a boat.
4. Relatively dispersed, i.e., group size is generally small.

Additionally, Obura *et al.* (1996) suggested a phased approach for the proper application of (aerial) survey methodologies (applicable also to boat surveys):

1. Review all available data in advance, for survey planning.
2. Conduct preliminary aerial surveys to obtain distributional patterns and relative abundance.
3. Plan and execute more detailed surveys in 'hot spots' areas and/or 'ground-truthing'.
4. Plan follow-up surveys for monitoring trends.

### **Methods**

During an aerial survey to estimate marine mammal abundance, the survey aircraft flies over predetermined transects (the position of at least the initial transect is often randomly chosen) at a constant speed and altitude (Caughley 1977; Eberhardt *et al.* 1979). Many aerial surveys use

strip transects with a relatively narrow strip width because of the difficulty of estimating sighting distances when the survey platform is moving fast. However, line-transect methodology has been adapted for aerial surveys (Buckland *et al.* 1993). Various methods are used to define transect width in strip surveys. Marsh and Saalfeld (1989) mounted fishing rod blanks from the wing-struts; other workers rely on marks on the windows. Here, we discuss an example of a relatively sophisticated aerial survey methodology using strip transects.

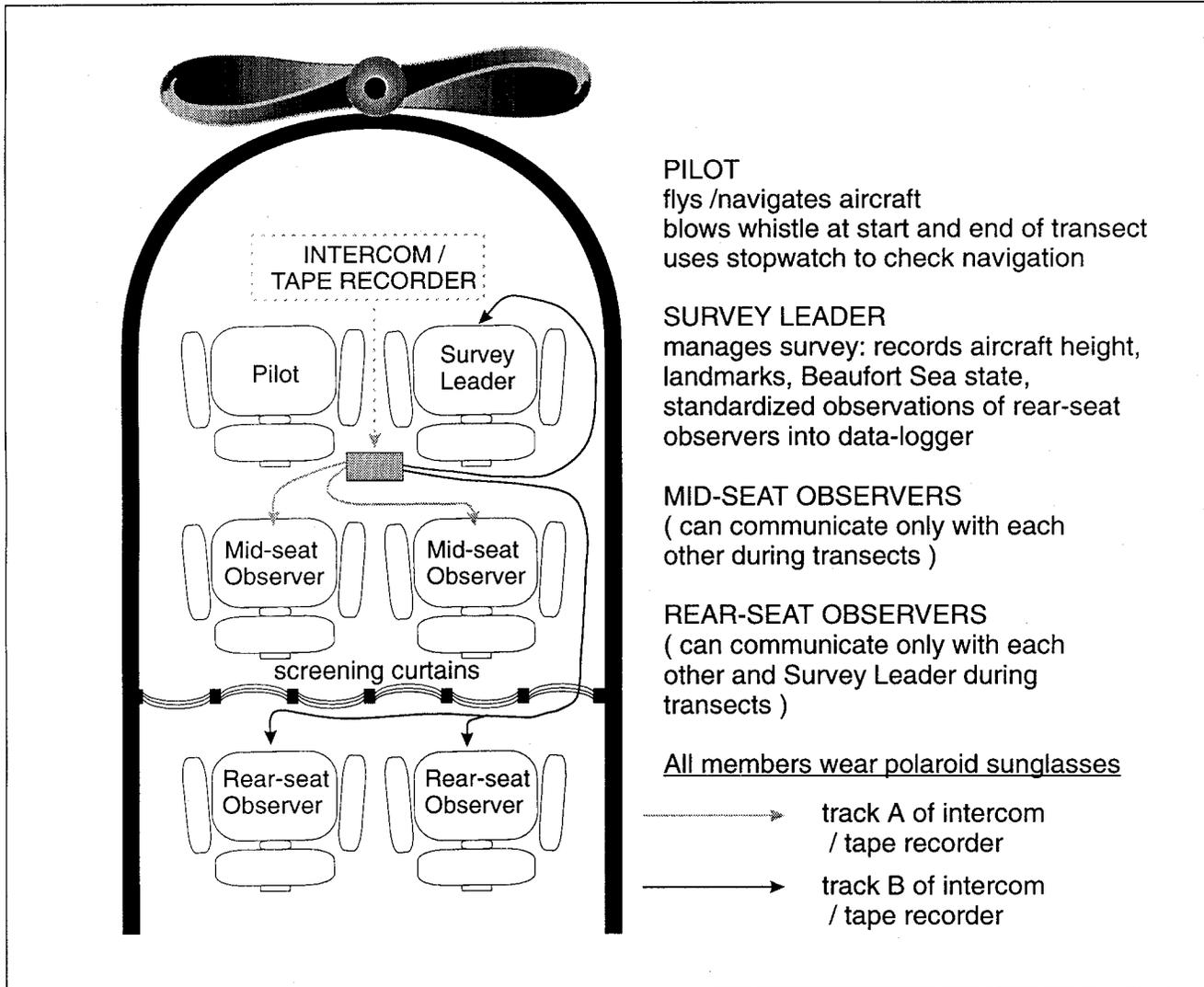
The survey team consists of the pilot, a front-seated survey leader, two mid-seat observers, and two rear-seat observers. Observers on each side identify and count the animals. Diagrammatic representation of the arrangement and duties of the crew used for aerial surveys of dugongs in Australia (after Marsh and Sinclair 1989) is shown in Figure 2. A similar arrangement can be used for aerial surveys for any marine mammals.

If aerial surveys are to be used to estimate absolute abundance, corrections must be made for animals that are not seen by the observers. Marsh and Sinclair (1989) distinguish two types of bias (also applicable to ship surveys):

1. Perception bias (the proportion of animals visible within the strip which are missed by observers).
2. Availability bias (the proportion of animals that are invisible due to water turbidity or inability to detect them below the surface).

Perception bias can be corrected by using two independent observers, one behind the other on either side of the aircraft, and mark-recapture methodology (Marsh and Sinclair 1989). Availability bias is usually estimated by recording the proportion of animals sighted at the surface and then estimating those which are not seen because they are below the surface, on the basis of data obtained by monitoring individual animals over prolonged periods. Such monitoring is usually done separately from the survey and it is generally not known how applicable the resultant correction factors are to surveys conducted at different times and places (Marsh and Sinclair 1989).

As for ship surveys, the sampling design is



**Fig. 2.** Schematic diagram of the arrangement and duties of the crew for aerial surveys (modified from Marsh and Sinclair 1989).

very important and usually should be based on the results of a pilot study. For species that are distributed along coasts, it is important to consider the sampling errors that may result from surveying parallel rather than perpendicular to the coast. The most appropriate sampling design will depend on the objectives of the survey and the distribution of the target animals relative to the coast.

Stratification of survey effort according to habitat or pre-determined estimates of abundance will usually improve the precision of the population estimate (Caughley 1977; Eberhardt *et al.* 1979; Holt and Cologne 1987; Buckland *et al.* 1993).

The ability to sight marine mammals from the

air is strongly dependent on sea surface conditions, and a survey should be cancelled when the sea state is rough (above Beaufort 3). This means that the budget for the survey should include the cost of a high proportion of down time. Marsh estimates that she is able to fly on about one day in three in Torres Strait (between mainland Australia and Papua New Guinea) during the least windy time of year.

Simplified aerial surveys can also be used for obtaining essentially qualitative information on the distribution and relative abundance of marine mammals. Periodic aerial surveys along specific sites can be performed by simply recording sightings, number (or school size) and, if possible,

species composition of marine mammals and other large marine vertebrates. This will require only aircraft flying time and experienced observers. As for ship or boat surveys, surveys for monitoring trends in abundance should be performed, whenever possible, preferably under similar survey conditions.

## Requirements

The most expensive item in the budget of an aerial survey is the aircraft charter. A high-wing aircraft with a slow cruising speed (100 knots) aided with a GPS and a radar altimeter is desirable for aerial surveys. The survey leader may use a laptop computer or tape recorder for recording the data. Intercom systems for communications are also necessary. Helicopters can be used successfully but they are very expensive and tend to have low endurance. Ground support, including airstrips with refuelling capabilities, must be available unless special arrangement can be made to ship fuel to remote airstrips.

Observers should be trained and must be immune to airsickness. The load that the aircraft can carry on takeoff and the duration of flight are limited. So, observers light in body weight are sometimes advantageous. The survey leader needs an understanding of the principles of strip or line transect methodology. Statistical and cartographic skills are also important; and a knowledge of the principles and practice of Geographic Information Systems (GIS) is advantageous (applicable also to ship surveys). These techniques are important in analysing the data and overlaying the results (estimates of animal abundance) on maps. Access to a computer is essential for the data analysis.

## Survey outputs

### *Broad-scale distribution and abundance*

Aerial surveys provide quantitative indices of absolute and relative abundance (density), and distribution of marine mammals at various spatial scales, depending on the sampling intensity. These surveys can also identify threats to conservation,

e.g., illegal fishing. Similar information for other large marine vertebrates, e.g., sea turtles and sea birds, can also be collected simultaneously.

### *Monitoring trends*

This survey technique can provide information on population trends. However, as Marsh (1995) has pointed out, power analysis of survey data for dugongs indicate that chronic low-level declines in marine mammal populations are very difficult to detect at a local-scale in a useful time period. For example, she calculated that it would take at least 10 years of annual aerial surveys before it could be determined, within the usual limits of statistical error, that a regional dugong population, apparently declining at 5% per year, was in fact declining. By that stage, numbers would have declined to about two-thirds of their level at the time of the first survey. The difficulties of detecting such a trend at a more localised level are much greater than this. For most marine mammals, it will be impossible to detect trends at spatial and temporal scales that are useful to management, using present aerial survey techniques, especially in areas where densities are expected to be low. This problem is not unique to aerial surveys. It applies to all the survey techniques discussed here (see above).

### *Habitat use*

Aerial surveys can reliably indicate habitat use and the extent of potential habitat. Most of the seagrass beds in remote areas of northern Australia have been identified from dugong sightings. Ground-truthing has shown that the animals were always right! Concentrations of marine mammals may also be an excellent indicator of upwellings. Additionally, long-term studies of the abundance and distributional ecology of marine mammals may give researchers insight into the impacts of human-caused environmental disturbances.

### **Carcass analysis**

Carcass analysis involves the dissection of a dead animal. It is not a survey method *per se* but it is

an important research method. In the past, it was usually performed to investigate the possible cause of death. Nowadays, however, carcass analysis is often more than just a necropsy procedure. Samples which provide information on some important aspects of the biology of the animals, e.g., genetics, histopathology, reproductive biology and feeding ecology, can be obtained through this method. This method also involves morphometric measurements. Carcass analysis is an important technique for surveying the diversity of marine mammals.

Marine mammal carcasses are usually obtained from directed fisheries, bycatch and/or strandings. As values change, the last two sources of marine mammal carcasses have become much more important than the first. The method is most applicable in accessible areas where there is periodic anthropogenic mortality or stranding events.

Strandings of live marine mammals must be handled carefully. The major objective is to return the stranded animals to the sea. Many developed countries have stranding networks of interested volunteers to do this work (Geraci and Lounsbury 1993). Standard procedures should be agreed and followed. If rescues are unsuccessful, deaths from stranding should provide carcasses for analysis. Remember that in many countries, marine mammals are protected by law and it is often illegal to keep them (dead or alive) without permits.

## Methods

If decomposition of a carcass is at an advanced stage, it may not be possible to do much more than identify the species from the skull and age it from the teeth if they are still present. Sometimes other information like gender (from gonads or external reproductive features), reproductive status, genetics or stock identity (from skin) and gross anatomy can also be obtained. Fresh carcasses can provide information on age, gender, cause of death, diet, reproductive state and history, genetics, anatomy, contaminants, parasites, pathology, virology, bacteriology and

haematological status (Perrin *et al.* 1984). Longitudinal sections of the teeth of dolphins can provide an estimation of their age by counting the number of growth layers. Gender of cetaceans can usually be determined by the presence of mammary slits in females and location of the genital openings in two well-separated depressions in males. Lactating females can be determined by pinching the mammary slits or using a knife to make shallow slice across the slits. In all marine mammals, scars in the ovaries usually reflect the number of ovulations. However, this does not mean that all of these scars resulted in successful births (calves). Geraci and Lounsbury (1993), and Jefferson *et al.* (1994) provide detailed procedures for sampling marine mammal carcasses.

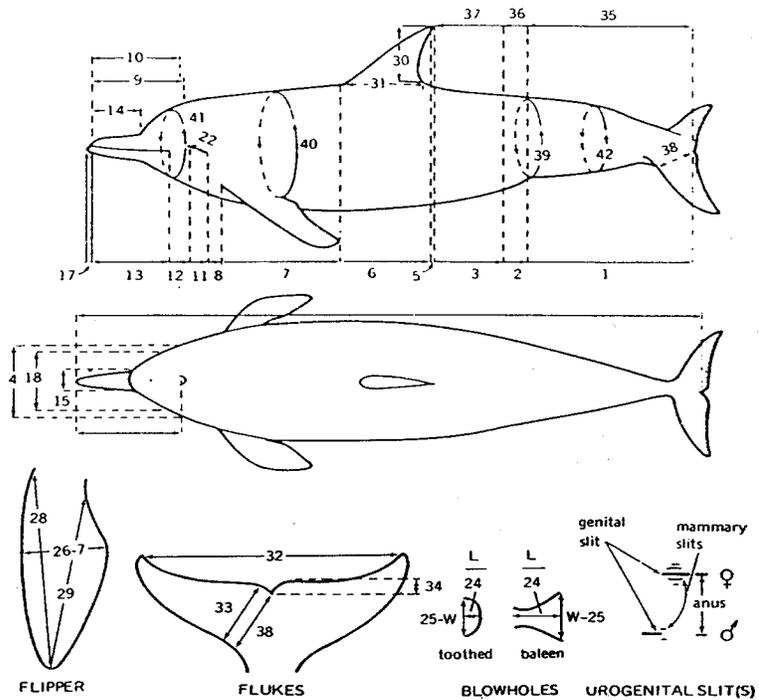
## Requirements

Carcass analysis requires a basic knowledge of marine mammal taxonomy and anatomy and an appreciation of the procedures and priorities for carcass salvage. A necropsy kit includes collecting containers, preservatives, knives and scalpel, measurement tapes, and specimen labels. Suitable data sheets have been developed for large and small cetaceans (Leatherwood *et al.* 1982; Geraci and Lounsbury 1993; Jefferson *et al.* 1994) and dugongs (Marsh 1981). A sample (carcass or live stranding) data sheet for cetaceans (after Leatherwood *et al.* 1982) is shown in Figure 3. A fresh marine mammal carcass is a valuable resource, and it is worth ensuring that all marine laboratories have the personnel and relatively modest equipment required for such work.

## Outputs

Much of the information on the diversity, biology and life history of marine mammals has been obtained from systematic studies of their carcasses or from records of their remains in museums and other collections (Leatherwood and Reeves 1983; Perrin *et al.* 1984; Evans 1987; Jefferson *et al.* 1994).

### CETACEAN (CARCASS) DATA SHEET



Some important external measurements. The numbers correspond to the numbers on the blank cetacean data record form below. Readers are encouraged to photocopy, use, and return to appropriate offices these forms with data on stranded cetaceans.

#### CETACEAN DATA RECORD

SPECIES \_\_\_\_\_ SEX \_\_\_\_\_ LENGTH \_\_\_\_\_ WEIGHT \_\_\_\_\_

DATE/TIME STRANDED \_\_\_\_\_ DATE/TIME DATA COLLECTED \_\_\_\_\_

LOCATION OF COLLECTION \_\_\_\_\_

OBSERVER NAME/ADDRESS \_\_\_\_\_

SPECIMEN SENT TO \_\_\_\_\_

#### MEASUREMENTS:

	Straight line parallel to the body axis	Point to point
1. Tip of upper jaw to deepest part of fluke notch	_____	_____
2. Tip of upper jaw to center of anus	_____	_____
3. Tip of upper jaw to center of genital slit	_____	_____
4. Tip of lower jaw to end of ventral grooves	_____	_____
5. Tip of upper jaw to center of umbilicus	_____	_____
6. Tip of upper jaw to top of dorsal fin	_____	_____
7. Tip of upper jaw to leading edge of dorsal fin	_____	_____
8a. Tip of upper jaw to anterior insertion of flipper (right)	_____	_____
b. Tip of upper jaw to anterior insertion of flipper (left)	_____	_____
9. Tip of upper jaw to center of blowhole(s)	_____	_____

Fig. 3. An example of a (carcass or live stranding) data sheet for cetaceans (after Leatherwood *et al.* 1982).

Marine mammal survey techniques

	Straight line parallel to the body axis	Point to point
10. Tip of upper jaw to anterior edge of blowhole(s)	_____	_____
11a. Tip of upper jaw to auditory meatus (right)	_____	_____
b. Tip of upper jaw to auditory meatus (left)	_____	_____
12a. Tip of upper jaw to center of eye (right)	_____	_____
b. Tip of upper jaw to center of eye (left)	_____	_____
13. Tip of upper jaw to angle of gape	_____	_____
14. Tip of upper jaw to apex of melon	_____	_____
15. Rostrum - maximum width	_____	_____
16. Throat grooves - length	_____	_____
17. Projection of lower jaw beyond upper (if reverse, so state)	_____	_____
18. Center of eye to center of eye	_____	_____
19a. Height of eye (right)	_____	_____
b. Height of eye (left)	_____	_____
20a. Length of eye (right)	_____	_____
b. Length of eye (left)	_____	_____
21a. Center of eye to angle of gape (right)	_____	_____
b. Center of eye to angle of gape (left)	_____	_____
22a. Center of eye to external auditory meatus (right)	_____	_____
b. Center of eye to external auditory meatus (left)	_____	_____
23a. Center of eye to center of blowhole (right)	_____	_____
b. Center of eye to center of blowhole (left)	_____	_____
24. Blowhole length	_____	_____
25. Blowhole width	_____	_____
26. Flipper width (right)	_____	_____
27. Flipper width (left)	_____	_____
28a. Flipper length - tip to anterior insertion (right)	_____	_____
b. Flipper length - tip to anterior insertion (left)	_____	_____
29a. Flipper length - tip to axilla (right)	_____	_____
b. Flipper length - tip to axilla (left)	_____	_____

	Straight line parallel to the body axis	Point to point
30. Dorsal fin height	_____	
31. Dorsal fin base	_____	
32. Fluke span	_____	
33. Fluke width	_____	
34. Fluke depth of notch	_____	
35. Notch of flukes to center of anus	_____	
36. Notch of flukes to center of genital aperture	_____	_____
37. Notch of flukes to umbilicus	_____	
38. Notch of flukes to nearest point on leading edge of flukes	_____	
39. Girth at anus		_____
40. Girth at axilla		_____
41. Girth at eye		_____
42. Girth _____ cm in front of notch of flukes		_____
43a. Blubber thickness (middorsal)		_____
b. Blubber thickness (lateral)		_____
c. Blubber thickness (midventral)		_____
44. Width of head at post-orbital process of frontals	_____	
45. Tooth counts: right upper _____		
right lower _____		
left upper _____		
left lower _____		
46. Baleen counts: right upper _____		
left upper _____		
47. Baleen plates, length longest		_____
48. Baleen plates, no. bristles/cm over 5 cm	_____	
49a. Mammary slit length (right)		_____
b. Mammary slit length (left)	_____	
50. Genital slit length	_____	
51. Anal slit length	_____	

## Conclusions

There are several research techniques for marine mammals that are applicable in developing countries. The most appropriate techniques should be identified to meet the research objectives within the constraints of funds and infrastructure available. Techniques such as interview surveys and shore-based sightings may be the most practical, particularly when funds are short and infrastructure undeveloped. It is better to start with simple techniques, with a view to using it as a basis for more sophisticated techniques, if funds and expertise become available.

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## References

- Anganuzzi, A.A. and Buckland, S.T. 1989. Reducing bias in trends in dolphin relative abundance, estimated from tuna vessel data. *Reports of the International Whaling Commission* **39**: 323–34.
- Anganuzzi, A.A. and Buckland, S.T. 1994. Relative abundance of dolphins associated with tuna in the eastern Pacific ocean: analysis of 1992 data. *Reports of the International Whaling Commission* **44**: 361–6.
- Aragones, L.V. 1990. The status, distribution and basic feeding ecology of the dugong, *Dugong dugon* at Calauit Island, Busuanga, Palawan, Philippines. M.Sc. thesis, University of the Philippines, Diliman, Quezon City. pp. 82.
- Aragones, L.V. 1994. Observations on the dugongs at Calauit Island, Busuanga, Palawan, Philippines. *Wildlife Research* **21**: 709–17.
- Baird, I.G., Mounsouphom, B. and Stacey, P. 1994. Preliminary surveys of Irrawaddy dolphins (*Orcaella brevirostris*) in Lao PDR and Northern Cambodia. *Reports of the International Whaling Commission* **44**: 367–9.
- Barlow, J. 1995. The abundance of cetaceans in California waters: part I. Ship surveys in summer and fall 1991. *Fisheries Bulletin* **93**: 1–14.
- Barlow, J. and Lee, T. 1994. The estimation of perpendicular sighting distance on SWFSC research vessel surveys for cetaceans 1974 to 1991. NOAA Technical Memorandum NMFS-SWFSC 207, 46 pp.
- Borchers, D.L. 1994. Methods of estimating mean school size from IWC sightings survey data. *Reports of the International Whaling Commission* **44**: 429–37.
- Bowditch, N. 1966. *American Practical Navigator*. Washington, D.C.: U.S. Government Printing Office. 1524 pp.
- Buckland, S.T. and Anganuzzi, A.A. 1988. Estimated trends in abundance of dolphins associated with tuna in eastern tropical Pacific. *Report of the International Whaling Commission* **38**: 411–37.
- Buckland, S.T. and Turnock, B.J. 1992. A robust line transect method. *Biometrics* **48**: 901–9.
- Buckland, S.T., Cattanach, K.L. and Anganuzzi, A.A. 1992. Estimating trends in abundance of dolphins associated with tuna in the eastern tropical Pacific Ocean, using sightings data collected on commercial tuna vessels. *Fisheries Bulletin* **90**: 1–12.
- Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance sampling: estimating abundance of biological populations*. London: Chapman and Hall. 446 pp.
- Burnham, K.P., Anderson, D.R. and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monograph* **72**: 1–202.

- Caughley, G. 1977. *Analysis of Vertebrate Populations*. New York: John Wiley and Sons. 234 pp.
- Chambers, M.R., Bani, E. and Hudson, B.E.T. 1989. The status of the dugong (*Dugong dugon*) in Vanuatu. *SPREP Topic Review* 37. 63 pp.
- Dolar, L. 1994. Incidental takes of small cetaceans in fisheries in Palawan, central Visayas and Northern Mindanao, Philippines. *Reports of the International Whaling Commission* (Special Issue) **15**: 355–63.
- Dolar, L., Leatherwood, S., Wood, C., Alava, M., Hill, C. and Aragones, L. 1994. Directed fisheries for cetaceans in the Philippines. *Reports of the International Whaling Commission* **44**: 439–49.
- Dolar, L., Perrin, W.E. and Taylor, B. 1995. Line-transect surveys of cetacean abundance in the Philippines; cost-effective methods for developing countries. Abstracts, Symposium on the Biology and Conservation of Small Cetaceans and Dugongs of Southeast Asia, 26 June 1995, Dumaguete City, Philippines.
- Dolar, M.L.L., Perrin, W.F., Yaptinchay, A.A.S.P., Jaaman, S.A.B.HJ., Santos, M.D., Alava, M.N. and Sulianasa, M.S.B. 1997. Preliminary investigation of marine mammal distribution, abundance, and interactions with humans in the Southern Sulu Sea. *Asian Marine Biology* **14**: 61–81.
- Eberhardt, L.L., Chapman D.G. and Gilbert, J.R. 1979. A review of marine mammal census methods. *Wildlife Monograph* **63**: 1–46.
- Eberhardt, L.L. and Simmons, M.A. 1987. Calibrating population indices by double sampling. *Journal of Wildlife Management* **51**: 665–75.
- Edwards, E.F. and Kleiber, P.M. 1989. Effects of nonrandomness on line transect estimates of dolphin school abundance. *Fisheries Bulletin* **87**: 859–76.
- Evans, P.G.H. 1987. *The Natural History of Whales and Dolphins*. London: Christopher Helm Ltd. 343 pp.
- Forney, K.A. and Barlow, J. 1993. Preliminary winter abundance estimates for cetaceans along the California coast based on a 1991 aerial survey. *Report of the International Whaling Commission* **43**: 407–15.
- Forney, K.A., J. Barlow, and Carretta, J.V. 1995. The abundance of cetaceans in California waters: part II. Aerial surveys in winter and spring of 1991 and 1992. *Fisheries Bulletin* **93**(1): 15–26.
- Geraci, J.R. and Lounsbury, V.J. 1993. *Marine Mammals Ashore: A Field Guide for Strandings*. Texas A & M Publications. 305 pp.
- Gerrodette, T. and Wade, P.R. 1991. Monitoring trends in dolphin abundance in the eastern tropical Pacific: analysis of 1989 data. *Reports of the International Whaling Commission* **41**: 511–5.
- Hammond, P.S. 1986a. Line transect sampling of dolphin populations. In *Research on Dolphins* (ed. M.M. Bryden and R. Harrison), 251–79. Oxford: Oxford University Press.
- Hammond, P.S. 1986b. Estimating the size of naturally marked whale populations using capture-recapture techniques. *Reports of the International Whaling Commission*. (Special Issue) **8**: 253–82.
- Hammond, P.S., Mizroch, S.A. and Donovan G.P. eds. 1990. Individual recognition of cetaceans: use of photo-identification and other techniques to estimate population parameters. *Reports of the International Whaling Commission* (Special Issue) **12**, 440 pp.
- Harris, A.N.M., Dews, G., Poiner, I.R. and Kerr, J. 1994. *The traditional and island based catch of the Torres Strait Protected Zone*. Unpublished Report to the Scientific Advisory Committee of the Torres Strait Protected Zone.
- Hill, P.S., Jackson, A. and Gerrodette, T. 1991. Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel McArthur, July 28–Dec 6, 1990. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFC-159. 142 pp.
- Holt, R.S. 1987. Estimating density of dolphin schools in the eastern tropical Pacific ocean by line transect methods. *Fisheries Bulletin* **85**: 419–34.
- Holt, R.S. and Cologne, J.B. 1987. Factors

- affecting line transect estimates of dolphin school density. *Journal of Wildlife Management* **51**: 836–73.
- Holt, R.S. and Sexton, S.N. 1989. Monitoring trends in dolphin abundance in the eastern tropical Pacific using research vessels over a long sampling period: analysis of 1987 data. *Reports of the International Whaling Commission* **39**: 347–51.
- Holt, R.S. and Sexton, S.N. 1990. Monitoring trends in dolphin abundance in the eastern tropical Pacific using research vessels over a long sampling period: analysis of 1988 data. *Reports of the International Whaling Commission* **40**: 471–6.
- Hudson, B.E.T. 1977. Dugong: distribution, hunting, protective legislation and cultural significance in Papua New Guinea. *Wildlife in Papua New Guinea* **77 (16)**: 1–22.
- Hudson, B.E.T. 1981. Interview and aerial survey data in relation to resource management of the dugong in Manus Province, Papua New Guinea. *Bulletin of Marine Science* **31**: 662–72.
- Jefferson, T.A. 1996. Estimates of abundance of cetaceans in offshore waters of the northwestern Gulf of Mexico, 1992–1993. *Southwestern Naturalist* **41**: 279–87.
- Jefferson, T.A. and Leatherwood, S. 1997. Distribution and abundance of Indo-Pacific hump-backed dolphins (*Sousa chinensis* Osbeck, 1765) in Hong Kong waters. *Asian Marine Biology* **14**: 93–110.
- Jefferson, T.A., Leatherwood, S. and Webber, M.A. 1993. *Marine mammals of the world. FAO species identification guide*. Rome: FAO and UNEP. 320 pp.
- Jefferson, T.A., Myrick, A.C. and Chivers, S.J. 1994. Small cetacean dissection and sampling: a field guide. NOAA Technical Memorandum NMFS SWFSC **198**: 54 pp.
- Johannes, R.E. 1981. Working with fishermen to improve coastal tropical fisheries and resource management. *Bulletin of Marine Science* **31**: 673–80.
- Krogman, B., Rugh, D., Sonntag, R., Jeh, J. and Ko, D. 1989. Iced-based census of bowhead whales migrating past Point Barrow, Alaska, 1978–1983. *Marine Mammal Science* **5**: 116–38.
- Laake, J.L., Buckland, S.T., Anderson, D.R. and Burnham, K.P. 1994. *DISTANCE User's Guide V2.1*. Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, Colorado, 84 pp.
- Leatherwood, S. and Donovan G.P. eds. 1990. *Cetaceans and Cetacean Research in Indian Ocean Sanctuary*. Nairobi, Kenya. UNEP, Marine Mammal Technical Report Number 3. viii + 287 pp.
- Leatherwood, S. and Reeves, R.R. 1983. *The Sierra Club Handbook of Whales and Dolphins*. San Francisco: Sierra Club Books. 302 pp.
- Leatherwood, S. and Reeves R.R. eds. 1989. *Marine Mammal Research and Conservation in Sri Lanka, 1985–1986*. Nairobi, Kenya. UNEP, Marine Mammal Technical Report Number 1. vi + 138 pp.
- Leatherwood, S., Reeves, R.R., Perrin, W.F. and Evans, W.E. 1982. *Whales, dolphins, and porpoises of the eastern north Pacific and adjacent Arctic waters: A guide to their identification*. NOAA Technical Report NMFS Circular 444, 245 pp.
- Leatherwood, S., Dolar, L., Wood, C., Aragonés L. and Hill, C. 1992. Marine mammal species confirmed from Philippine waters. *Silliman Journal* **36**: 65–86.
- Marsh, H. 1995. Limits of acceptable change. In *Sustainable Use of Wildlife* (ed. G. Grigg, P. Hale and D. Lunney). Centre for Conservation Biology, University of Queensland.
- Marsh, H. ed. 1981. *The Dugong: Proceeding of the Dugong Symposium/Workshop*. James Cook University, Townsville. 240 pp.
- Marsh, H. and Saalfeld, W.K. 1989. Distribution and abundance of dugongs in the northern Great Barrier Reef marine park. *Australian Wildlife Research* **16**: 429–40.
- Marsh, H. and Sinclair, D.F. 1989. Correcting for visibility bias in strip transect aerial surveys of marine fauna. *Journal of Wildlife Management* **53**: 1017–24.
- Marsh, H., Harris, A.N. and Lawler, I. (In press). Is the indigenous dugong fishery in Torres Strait sustainable at current harvest levels? *Conservation Biology*.
- Obura, D., Ilangakoon, A., Jayewardene, H. and Stone, G. 1996. Integrating marine

- conservation in the Indian Ocean: 1996 and beyond. Summary and Working Group Reports, November 28-December 1, 1995. pp 31-35.
- Palka, D.L. 1993. Estimating density of animals when assumptions of line transect surveys are violated. Ph.D. thesis, University of California, San Diego.
- Perrin, W.F. 1989. *Dolphins, Porpoises and Whales. An Action Plan for the Conservation of Biological Diversity: 1988-1992*. Gland, Switzerland: IUCN. 30 pp.
- Perrin, W.F. and Brownell Jr, R.L. 1994. A brief review of stock identity in small marine cetaceans in relation to assessment of driftnet mortality in the North Pacific. *Reports of the International Whaling Commission (Special Issue) 15*: 393-401.
- Perrin, W.F., Brownell Jr., R.L. and DeMaster D.P. eds. 1984. Reproduction in whales, dolphins and porpoises. *Reports of the International Whaling Commission (Special Issue) 6*, 495 pp.
- Perrin, W.F., Donovan, G.P. and Barlow J. eds. 1994. Gillnets and cetaceans. *Reports of the International Whaling Commission (Special Issue) 15*, 617 pp.
- Polacheck, T. and Smith, T. 1989. A proposed methodology for field testing line transect theory for shipboard surveys of cetaceans. *Reports of the International Whaling Commission 39*: 341-5.
- Reeves, R.R. and Leatherwood, S. 1994. *Dolphins, porpoises, and whales: 1994-1998 action plan for the conservation of cetaceans*. IUCN.
- Rexstad, E. and Burnham, K.P. 1991. *User's guide for interactive program CAPTURE*. Colorado Cooperative Fish and Wildlife Research Unit. 29 pp.
- Ross, G., Cockcroft, V., Melton, D. and Butterworth, D. 1989. Population estimates for bottlenose dolphins, *Tursiops truncatus* in Natal and Transkei waters (South Africa). *South African Journal of Marine Science 8*: 119-29.
- Rugh, D.J., Ferrero, R.C. and Dahlheim, M.E. 1990. Inter-observer count discrepancies in a shore-based census of Gray whales (*Eschrichtius robustus*). *Marine Mammal Science 6*: 109-20.
- Smith, A. 1987. An ethnobiological study of the usage of marine resources by two Aboriginal Communities on the east coast of Cape York Peninsula, Australia. Ph.D. thesis. James Cook University, Townsville, Queensland 280 pp.
- Spradley, J.P. 1979. *The Ethnographic Interview*. New York: Holt, Rinehart and Winston. vii + 247 pp.
- Spradley, J.P. 1980. *Participant Observation*. New York: Holt, Rinehart and Winston. xi + 195 pp.
- Taylor, B. and Gerrodette, T. 1993. The uses of statistical power in conservation biology: the Vaquita and Northern spotted owl. *Conservation Biology 7*: 489-99.
- Turnock, B.J. and Quinn, T.J. 1991. The effect of responsive movement on abundance estimation using line transect sampling. *Biometrics 47*: 701-15.
- Van Waerebeek, K. and Reyes, J. 1990. Catch of small cetaceans at Pucusana Port, Central Peru, during 1987. *Biological Conservation 51*: 15-22.
- Wade, P.R. and Gerrodette, T. 1992. Estimates of dolphin abundance in the eastern tropical Pacific: preliminary analysis of five years of data. *Reports of the International Whaling Commission 42*: 533-9.
- Wade, P.R. and Gerrodette, T. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. *Reports of the International Whaling Commission 43*: 477-93.
- World Resources Institute. 1992. *World Resources 1992 - 1993*. New York: Oxford University Press. xiv + 385 pp.
- Würsig, B. and Jefferson, T.A. 1990. Methods of photo-identification for small cetaceans. *Reports of the International Whaling Commission (Special Issue) 12*: 43-52.
- Zeh, J., Raftery, A. and Styer, P. 1988. Mark-recapture estimation of bowhead whale, *Balaena mysticetus*, population size and offshore distribution from 1986 visual and acoustic data collected off Point Barrow, Alaska. Paper SC/40/PS5 presented to the IWC Scientific Committee, May 1988.

Appendix A. Research ship marine mammal sighting record (after Hill *et al.*1991).

CRUISE #		DATE			SIGHT #	SERIES #	LEG #	CARD #
YEAR	MONTH	DAY						
							01	

RESEARCH SHIP  
MARINE MAMMAL  
SIGHTING RECORD

SIGHTING CUE				ENVIR. COND. AT CUE				POSITION AT TIME OF CUE				OBSERVER POSITIONS				
TIME	BEARING FROM SHIP	DISTANCE nm & 10ths		SURF TEMP °F & 10ths	HORZ SUN	VERT SUN		LATITUDE	N S	LONGITUDE	E W	TIME M.M. SIGHTED	LEFT BIN.	RIGHT BIN.	REC	M.M. DETECTED BY

OBSERVER 1

OBS. CODE	SCHOOL SIZE ESTIMATE			CARD #	SPECIES PROPORTIONS											
	BEST	HIGH	LOW		SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	SPECIES 3 %	SP 3 CODE	SPECIES 4 %	SP 4 CODE				
				02												
	S	P	1		S	P	2		S	P	3		S	P	4	

OBSERVER 2

OBS. CODE	SCHOOL SIZE ESTIMATE			SPECIES PROPORTIONS												
	BEST	HIGH	LOW	SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	SPECIES 3 %	SP 3 CODE	SPECIES 4 %	SP 4 CODE					
	S	P	1		S	P	2		S	P	3		S	P	4	

OBSERVER 3

OBS. CODE	BEST	CARD #	HIGH	LOW	SPECIES PROPORTIONS											
					SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	SPECIES 3 %	SP 3 CODE	SPECIES 4 %	SP 4 CODE				
		03														
	S	P	1		S	P	2		S	P	3		S	P	4	

OBSERVER 4

OBS. CODE	SCHOOL SIZE ESTIMATE			SPECIES PROPORTIONS								CARD #	SP 4 CODE		
	BEST	HIGH	LOW	SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	SPECIES 3 %	SP 3 CODE	SPECIES 4 %					
												04			
	S	P	1		S	P	2		S	P	3		S	P	4

OBSERVER 5

OBS. CODE	SCHOOL SIZE ESTIMATE			SPECIES PROPORTIONS											
	BEST	HIGH	LOW	SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	SPECIES 3 %	SP 3 CODE	SPECIES 4 %	SP 4 CODE				
	S	P	1		S	P	2		S	P	3		S	P	4

OBSERVER 6

OBS. CODE	SCHOOL SIZE ESTIMATE			SPECIES PROPORTIONS								RC 1	RC 2	RC 3	RC 4	RC 5	RC 6
	BEST	HIGH	LOW	SPECIES 1 %	SP 1 CODE	SPECIES 2 %	SP 2 CODE	CARD #	SPECIES 3 %	SP 3 CODE	SPECIES 4 %						
								05									
	S	P	1		S	P	2		S	P	3		S	P	4		

Research ship sighting continuation record.

CRUISE #	DATE			SIGHT #	SERIES #	LEG #	OBS CODE
	YEAR	MONTH	DAY				
1	5	7	9	11	13	15	17

SIGHTING SUMMARY

LIST ALL DIAGNOSTIC FEATURES OBSERVED (INCLUDING ESTIMATED BODY LENGTH)

SKETCH FEATURES OF ANIMALS SIGHTED

BEHAVIOR - (DESCRIBE AGGREGATION, MOVEMENT, BOW AND STERN RIDING, BLOWS, ETC.)

MOVEMENT OF SCHOOL : SPEED (KTS)

DIRECTION (RELATIVE TO BOW)

ASSOCIATED ANIMALS - (INCLUDE NUMBER AND SPECIES OF BIRDS)

PHOTOS: ROLL #

FRAME(S): #

TOTAL TIME OF OBSERVATION

ENVIR. COND. (RAIN, OVERCAST, FOG, CHOPPY)

CLOSEST DISTANCE OF OBSERVATION

AMT. OF TIME AT CLOSEST DISTANCE

TAGS ASSOCIATED WITH SIGHTING

METHOD OF OBSERVATION (EYE, 7x, 10x, 25x)

