Standardizing At-sea Monitoring Programs for Marine Birds, Mammals, Other Organisms, Debris, and Vessels, including Recommendations for West-Coast National Marine Sanctuaries

Peter Pyle
The Institute for Bird Populations
P.O. Box 1346
Point Reyes Station, CA 94956
ppyle@birdpop.org

Prepared as part of :

Integration of a Multi-sanctuary Ecosystem Observation Effort:
Gulf of the Farallones, Cordell Bank, and Monterey Bay National Marine Sanctuaries

1 June 2007

Summary
The National Oceanic and Atmospheric Administration (NOAA) has sponsored several at-sea monitoring programs for mammals and birds, and has recently supported the establishment of long-term, observer-based programs within National Marine Sanctuaries (NMS's). Although these surveys all contain similar goals, to obtain density estimates of marine vertebrates and correlate these estimates to oceanic and marine events, methods for programs operating in NMS's have not been standardized and, in some cases, are not adequately documented. With the goal of providing data for on-line syntheses, there is also interest in affecting Pacific-wide standardization of methodology and for developing protocols for monitoring marine debris and vessels.

The purpose of this report is to provide a detailed synthesis of ship-based, at-sea-sampling methods used throughout the Pacific Basin, with the aim of standardizing observation programs, including those specific to four WCNMS's: Olympic Coast (OCNMS), Cordell Bank (CBNMS), Gulf of the Farallones (GFNMS), and Monterey Bay (MBNMS). Methods from six past and on-going shipboard monitoring programs were compared, differences in protocols were analyzed, and final recommendations are provided. A workshop on at-sea methods, held in Santa Cruz, California, in December 2002 was attended by representatives from all six programs, and minutes from this workshop were incorporated into this evaluation. Initial recommendations were presented at a two-day standardization meeting hosted by GFNMS in April 2007 and attended by representatives of most at-sea programs operating in the North Pacific. Final recommendations were based on consensuses achieved at this meeting.

It is fully recognized that differences in protocols between sanctuaries are unavoidable due to differences in observation platforms, specific interests of conducting researchers, purposes of sampling, specifics and capabilities of research vessels, and number and experience level of available observers. The protocols recommended here attempt to account for known and potential differences that may arise, but provide minimum criteria that must be standardized to enable effective data combining for broad-scale synthesis. The goal of standardized monitoring will be to obtain, as close as feasible, accurate density estimates of all organisms, which will form the measure by which data from different programs can be combined.

The best use of "ship of opportunity" surveys (cruises in which there is no dedicated ship time for mammal/bird surveys but in which observers can be accommodated may provide opportunities for additional censusing within WCNMS waters. In this respect all programs should establish a sampling regime that is as vigorous as possible with respect to geographic coverage relative to questions being asked. Survey design must have goal and purpose of the data based on management question and a science program for direction. Provided this foundation is established then data from ships of opportunity can be of value, as long as observers are well trained. These ship-of-opportunity cruises represent excellent opportunities to perform critical tests that will allow more effective data combination on observer variability, sampling techniques, and other methodological considerations.

For birds (and often at least some mammals, pelagic fish, turtles, and debris), all six protocols reviewed follow basic, strip-transect methodology. Organisms are recorded within a quartile-circular area (90^{o} quadrant) in front of and to one side of the survey vessel, with the width of the survey area depending on height of observation, taxa being sampled, observer experience, and other factors. The side (port or starboard) of the sampling quadrant is chosen as that with the best observation conditions, as affected by glare, lighting, and sea state.

For marine mammals, the line-transect method has now been agreed upon as the preferred method for obtaining density estimates that can be compared across programs; however, strip-transect methods for marine mammals may still be an appropriate method in certain circumstances (e.g., when only one observer is present). Line-transect surveys record all visible marine mammals to the horizon, along with distance and angle from the observer. Protocols for line-transect methods are contained in the computer program DISTANCE, and WindCruz, developed by SWFSC. Rigorous line-transect methods are optimally performed with three on-effort observers at all times solely observing marine mammals, one on each side of the vessel and one focusing on the track line in front of the vessel and recording data. Observers rotate frequently (e.g., every 40 minutes) such that six highly trained observers carry out continuous sampling, and clear horizons are best for obtaining distance estimations at precisions required for this methodology.

It is anticipated that most WCNMS programs will lack the capability to perform line-transect methodology at this level. However, line-transect methodology can still be employed effectively with a single observer on effort and an additional person to record data; the recorder can likely keep up with both mammal and bird observations. In such circumstances it is also best if bird observer, mammal observer, and recorder rotate through the three duties, as long as all three are trained for each duty.

Although line-transect methods have greater statistical power to detect densities and may have advantages over strip-transect methods for sampling seabirds in certain circumstances or where they are very sparse, these conditions are rarely met within WCNMS and other Pacific at-sea studies. Precise distance estimations to each individual bird are far too difficult to obtain at seabird density levels typically encountered in the Pacific. This is especially true when the horizon is obscured by fog or haze, as is often the case in WCNMS and other Pacific waters. However, line-transect methodology can be performed on a random subset of birds to obtain density estimations that can be compared with concurrent strip-transect data and can be used to investigate the effects of ship-attraction and ship-avoidance. At-sea programs should experiment with this method by employing an extra observer aboard to record birds with line-transect methodology on a subset of individuals.

Strip-transect methods require a predetermined, fixed survey width which depends on observation height above the water surface, visibility, sea state, observer abilities, and other factors. The most important factor in determining strip width is that observers are comfortable with their ability to detect close to 100% of all targets within the survey area. During surveys in WCNMS waters from 8-15 m height, the standard strip radius used for seabirds is 300 m for observations from 3.8 m height it is recommended that observations be performed to 200 m.

When using the strip-transect methods it is recommended that estimated observation distance be binned into 100-m intervals or “zones." Binning may also allow greater analytical flexibility to 1) calculate different maximum detection distances for use in determining densities for different species and observers; 2) assess levels of species-specific ship-avoidance and ship-attraction by analyzing densities by strip width; 3) estimate observer ability and biases; and 4) more effectively compare surveys using different strip widths. Currently, two different methods for binning seabirds are employed, recording the zone of minimum distance from the observer and recording the zone for which an organism was first observed. The former method allows more robust analyses of effective detection distance, assessing ship avoidance and attraction, and comparing surveys with different strip widths whereas the latter method is used when combining zones with observation conditions. Since binning is considered non-critical data at this time, it is left up to each program how to treat the binning of data to zone or distance.

It is imperative that distance estimations for both areas and zones be as accurate as possible. For line-transect methodology, distances will often have to be calculated directly, when the horizon is not clear, as is often the case in WCNMSs, preventing the use of reticular binoculars. It is thus recommended that all area and zonal distances used during a program be calibrated at a given observation height, using a dowel or pencil held at arms length and the calculations presented by Heinemann (1981). High-quality, range-finding binoculars are currently available that can be used for both observations and to obtain accurate distance estimations up to 700 m; these should be further tested for use during at-sea monitoring programs.

Inter-observer variation in detection, identification, and distance-estimation skills represents the greatest potential for bias during ship-based surveys, and particular attention should be given to selecting and training highly skilled observers and to standardizing observer effort. It was concluded at the April 2007 meeting that the minimum number of observers present in most cases (including WCNMS's) should be two to record birds and two to record mammals, or three to record both groups of organisms. Too many mammals or birds will be missed in high-density situations if the observer also has to record data (unless a tape-recorder is employed). However, in low-density situations such as often occur in tropical waters, a single bird observer is sufficient to both observe and record birds.

For strip-transect methodology it is recommended that all observers assist one another with observations. Collective effort best achieves the assumption that all vertebrates within the survey areas are recorded, and reduces biases associated with species identification, numbers observed, and distance estimation. However, Line-transect methods require mammal observers to be independent because detection distances are often calculated on an observer-specific basis and observations need to be of constant effort. Therefore, it is recommended that the line-transect surveyor not be assisted. If a marine mammal is detected by the seabird observer or recorder they should not alert the mammal observer until the mammal has passed from the observation area. Thus, the most effective approach to mammal and bird surveying within WCNMS's with three observers will be to have one observer conduct line-transect methodology on mammals from the center of the vessel, one observer record seabirds within a strip on the side of the vessel with the best observation conditions, and one recording data for both mammal and bird observers. All three observers can assist with bird observations but the mammal observer should remain independent.

Computer entry programs are recommended for use as part of WCNMS protocols provided that 1) screens are easily viewed; 2) enterers are able to immediately review and make correction to data *in situ*; and 3) the program has a frequent, automatic saving function to prevent loss of data. The *SeeBird* (strip-transect) and *WinCruz* (line-transect) programs used by CSCAPE, OCPS, and Wind-to-Whales currently satisfying all three requirements. In April-May 2007 a modified version of *SeeBird/WinCruz* was developed by SWFSC programmers specifically for WCNMS surveys and it is recommended that this program be used during NMS surveys. It is imperative that a notebook be immediately available to record errors for future correction and record data if (and usually when) the computer or computer program ceases to function.

There is currently little standardization to the taxonomic categories or alpha codes employed by at-sea programs, especially concerning unidentified species, “species pairs” (e.g., Clark's/Western Grebe), and hybrids. It is recommended that a relational database ("taxa driver") and accompanying document be created to address this issue within WCNMS's. The database should list codes for all ocean-monitoring programs (including three beach-monitoring programs operated by OCNMS, GFNMS, and MBNMS) and allow direct data inter-phasing for future broad-scale analyses and on-line syntheses.

Seabird and marine mammal attraction to, or avoidance from, survey vessels can introduce a significant bias to strip-transect methods. It is recommended that individuals that are determined to be attracted to the boat be recorded as such. Certain groups (gulls, albatrosses, fulmars, tropicbirds, sulids, frigatebirds) are more likely to be recorded as ship attracted individuals. Since it may not be possible to affect standardization of this variable it is recommended that all individuals entering the survey zone be recorded (rather than some individuals that are considered attracted be ignored entirely). Observers must be extensively trained to become as standardized as possible in their determination of what is coded as an attracted individual and what is not. Travel direction of ship attractants should also be recorded to allow the greatest flexibility in the future to combine data sets using various treatments of ship-attracted individuals.

Sitting and transiting birds and mammals should be separated and coded as part of the data set, along with travel direction of all individuals in transit, to the closest 10° relative to the orientation of the survey vessel. These data help eliminate biases associate with inter-specific differences in travel speed and non-random travel-direction patterns. Non-directional travel ("milling"), and "feeding" should also be recorded separately.

Other behavioral codes for seabirds and marine mammals should be considered, given adequate time and observer training as to the definition of each behavioral category, but there may be advantages to recording fewer overall categories and having observers explain some of the less-commonly observed behaviors as comments attached to the observation.

Recording age, sex, and morph classifications, if possible, is important in describing population phenology and it is recommended that each individual be discriminated to age, sex, and morph to as specific a class as is feasible. It is recommended that age categorization by year-class be utilized as part of WCNMS protocols provided that observers are skilled enough to attempt discriminating age groups of birds and mammals. Sex and morph, although applicable to only a few birds and/or mammals in the field, should also be recorded. It is also recommended that the undertail-covert color in Black-footed Albatross be scored. Both intra-specific and inter-specific association codes should also be considered, although there is currently quite a bit of inter-program and inter-observer inconsistency in the use of association codes. Marking associated birds and mammals with the same time and position stamp may be the simplest method of indicating association.

It is recommended that data on other visible fauna and flora such as pelagic fish, marine turtles, *Velella velella*, various jellyfish species, kelp, and other drift algae be collected during WCNMS surveys. Abundance estimates for such organisms can be scored on a per-segment basis because densities are often too great and would result in too much distraction to attempt recording these organisms *in situ*. Most programs in the WCNMS's also collect data on acoustic backscatter, from zooplankton and icthyoplankton, with the use of echosounders. After an observation program is established and funding is in place for analysis of observation data, NMS programs may want to look into acquiring a split-beam, 120-kHz echosounder (the currently recommended type and frequency for a single device). The use of net-tows to ground-truth backscatter data and to correlate invertebrate distribution with surface observations is also recommended, if feasible and funding (potentially substantial) is available to process samples.

There is recent interest in monitoring vessels and debris as part of at-sea-observation programs. Protocols have been developed and currently are being tested. These protocols divide both vessels and debris into major categories as well as subtypes or activities (vessels). Four-letter codes have been developed for these vessel and debris categories. Vessels are sampled to the horizon and in front of the survey vessel and debris are divided into five size classes and recorded either in the small or large survey area depending on size. It is anticipated that vessel and debris protocols will be finalized in 2007. Following discussion at the April 2007 meeting it is recommended that a separate observer be funded to collect these data, especially in areas of high debris content.

Weather affects both vertebrate distribution and the detection ability of observers, and should be recorded as part of all sampling efforts. However, the ability to detect organisms, vessels, and debris can also be affected by environmental factors not adequately quantified with environmental data. It is thus recommended that WCNMS protocols provide a means to qualify observation conditions through an "observation" or "quality of visibility" score. Thus far these codes have not been used in density estimations except to the degree in which they define species-specific strip-widths, and it is left up to the program whether of not to use these codes and how they should be employed.

Physical oceanographic data can be collected both *in-situ* and from remote-sensing devices such as buoys and satellites. It is recommended that WCNMS protocols include the use of thermosalinographs and incorporate a standardized program for taking CTD casts. Other important data that can be incorporated include ocean depth, distance to subsurface features, and the position and activity level of oceanic fronts in the vicinity of the survey area during the sampling period. Many NOAA and other websites now exist from which data can be downloaded and incorporated with those collected by at-sea programs. However, it was noted at the April 2007 meeting that buoy weather data are not yet reliable enough to use consistently with at-sea observation programs.

Based on the results of the April 2007 meeting it is recommended that the goal of all programs be to provide as accurate density estimates as possible for both birds and mammals. It is vital that all programs carefully document their selection choices for each entry field. Standardization of these choices is much more important than standardization of the codes themselves. Only five fields of *in-situ* observations are absolutely critical to standardized combining of strip-methodology data. These are: taxon, number of individuals, strip-width for each observation, behavior (including categories for at least directional flight, non-directional activity, and ship attraction), and travel direction (for directional flight and ship attraction). It is also recommended that as much ancillary data as possible be collected, including those pertaining to weather, observation conditions, zone of observation, additional behaviors, age, sex, morph, and other organisms.

An ultimate goal of the NMS program is to accumulate data from at-sea observation programs into a single database, from which maps based on temporal and seasonal parameters, within each NMS, can be developed and made available to sanctuary managers and the public on-line. Funding is currently being sought to achieve this goal. In the mean time, it is hoped that this evaluation, along with the development of standard at-sea monitoring protocols will provide a valuable step toward achieving these goals.

Introduction

Long-term, at-sea monitoring programs provide information on the distribution, seasonality, and ecology of marine mammals, birds, and other organisms. This information is critical for understanding marine biological processes, assessing natural and anthropogenic effects on these processes, developing immediate response actions to catastrophic events, and formulating long-term management strategies for marine resources. For these reasons the National Oceanic and Atmospheric Administration (NOAA) and other agencies have sponsored several at-sea monitoring programs for mammals and birds, and have recently supported the establishment of long-term, observer-based programs within National Marine Sanctuaries (NMS's). Although ship-based surveys all contain similar goals, to obtain density estimates of marine vertebrates and correlate them to other oceanic and marine events (see Ainley et al. 2005 for a recent summary), methods for programs operating in NMS’s have not been standardized and, in some cases, are not adequately documented. In addition, there has been recent interest in developing protocols for the contemporaneous monitoring of marine debris and vessels in Marine Sanctuary waters, but protocols for such monitoring have not been established.

In December 2002 The National Marine Sanctuaries Program (NMSP) hosted a workshop in Santa Cruz, California, on at-sea methods in West Coast National Marine Sanctuaries (WCNMS’s), and concluded that standardization of at-sea methods (for both ship-based and aerial surveys) should be instituted as much as feasible (NMS 2003; *cf.* Tasker et al. 1984, 1985; but see Haney 1985). Following further calls for standardization and in light of the increased interest and potential to combine at-sea data sets on line, the NMSP hosted another meeting in April 2007 in San Francisco, California, to fully consider ways in which Pacific at-sea programs could be standardized. Representatives from all major programs operating in the eastern Pacific Ocean reviewed differences in on-going at-sea methodologies and came to consensus about important issues that should be standardized.

The purpose of this report is to provide a detailed synthesis of ship-based, at-sea-sampling methods used throughout the Pacific Basin, with the aim of standardizing observation programs, including those specific to four WCNMS's: Olympic Coast (OCNMS), Cordell Bank (CBNMS), Gulf of the Farallones (GFNMS), and Monterey Bay (MBNMS). Methods from six past and on-going shipboard monitoring programs within these sanctuaries are compared, differences in protocols are analyzed, and final recommendations based on the results of the April 2007 meeting are provided. It is fully recognized that differences in protocols between sanctuaries are unavoidable due to differences in observation platforms, specific interests of conducting researchers, purposes, and capabilities of research vessels and cruises, and number and experience level of available observers. The protocols recommended here attempt to account for known and potential differences that may arise, but provide minimum criteria that must be standardized to enable effective data combining for broad-scale synthesis. The goal of standardized monitoring will be to obtain, as close as feasible, accurate density estimates of all organisms, which will form the measure by which data from different programs can be combined.

Methods and Sources of Information

Six ship-based programs for censusing birds and mammals have operated within the east-central Pacific including WCNMS's. The methods of each were evaluated to develop recommendations for standardized WCNMS protocols. The six programs are summarized in Table 1. The National Centers for Coastal Ocean Science (2003) and Ford et al. (2004) provide similar data for programs operated in MBNMS, GFNMS, and CBNMS during 1980-2001. Table 1 updates the information provided by Ford et al., including the establishment of four additional programs in WCNMS's, through 2005. Programs in Table 1 are divided by Principal Investigator and methods used; some programs encompass several data sets (*cf.* Ford et al. 2004).

Table 1. Six ship-based at-sea observation programs considered in this report, that have collected data in the Olympic Coast (OCNMS), Cordell Bank (CBNMS), Gulf of the Farallones (GFNMS), and Monterey Bay (MBNMS) National Marine Sanctuaries.

Program	Principal Investigator	Sanct-uaries	Platform and Height	Years	Strip Width for Seabirds	Method/ Width for Mammals	No. Observers
EPOCS, NMFS Rockfish, SF-DODS	David Ainley, HTH & Assoc.	CBNMS GFNMS MBNMS	NOAA Vessels, 10-15 m	1984-present	300 m	Strip, 300-800 m	2-3
ORCAWALE, CSCAPE	Lisa Ballance, Karin Forney SWFCS	OCNMS CBNMS GFNMS MBNMS	NOAA Vessels, 10-15 m	2001, 2005	300 m	Line	7
OCPS	OCNMS	OCNMS	NOAA Vessels 11-15 m	1995-present	300 m	Line	2-7
Wind-to-Whales	Don Croll CIMT, UCSC	MBNMS	*John Martin* 4.3 m	1996-present	100 m	Line	6
PRBO Surveys	Jaime Jahncke, PRBO	CBNMS GFNMS	*John Martin* 4.3 m	2003-present	100 m	Line	3
CBOMP	CBNMS	CBNMS	*C. Magister* 3.8 m	2004-present	200-600 m	Strip, 600 m	3

EPOCS = Eastern Pacific Ocean Climate Study; NMFS = National Marine Fisheries Service; SF-DODS = San Francisco Deep Ocean Disposal Site; ORCAWALE = Oregon, California, and Washington Marine Mammal Survey; CSCAPE = Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem; OCPS – Olympic Coast Pelagic Surveys; CBOMP = Cordell Bank Ocean Monitoring Program; HTH & Assoc. = H.T. Harvey and Associates; SWFCS = Southwest Fisheries Science Center; CIMT = Center for Integrated Marine Technology, UCSC = University of California at Santa Cruz; PRBO = PRBO Conservation Science.

Methods have been specifically documented by four of the six programs: HTH (Spear and Ainley 1997a, Spear et al. 2002), SWFSC (Ballance 2005, Forney 2005), OCPS (Troutman 1995, Calambokidis et al. 2004), and CBOMP (Pyle et al. 2005). Published papers and technical reports in the scientific literature provide further information on the methods used by HTH (e.g., Oedekoven et al. 2001, Ainley et al. 2005, Keiper et al. 2005), SWFSC (e.g., Pitman 1986, Philbrick et al. 2003), and Wind-to-Whales (e.g., Benson et al. 2002). PI's and/or representatives from all of these programs were present at the April 2007 meeting. In addition there is interest in affecting Pacific-wide standardization of methodology. While outside of the geographic area of initial interest, representatives of at-sea monitoring programs in Alaska attended the April 2007 meeting with the objective of affecting standardization between WCNMS and Alaska programs.

Comparison of Field Methods and Recommendations

Each at-sea monitoring program may have specific goals, temporal periods of field work, and geospatial areas that it intends to survey. This report will not cover design of survey areas. Discussion of this and related topics, as they pertain to sampling within the Pacific, is summarized within the methods of each program. Each program varies in terms of survey height, available equipment, and the number of observers that can be accommodated. The following synthesis and recommendations incorporate consideration of these differences.

During the April 2007 meeting the best use of "ship of opportunity" surveys (cruises in which there is no dedicated ship time for mammal/bird surveys but in which observers can be accommodated, and/or that are not temporally or geographically consistent with the survey design) was discussed. These include both "biased" (e.g. whale-watching trips) and unbiased or more random (with respect to bird and mammal distribution) survey routes. It was concluded that all programs establish a sampling regime that is as vigorous as possible with respect to geographic coverage relative to questions being asked. Survey design must have goal and purpose of the data based on management question and a science program for direction. Provided this foundation is established then data from ships of opportunity can be of value, as long as observers are well trained. These ship-of-opportunity cruises represent excellent opportunities to perform critical tests that will allow more effective data combination, on observer variability, sampling techniques, and other methodological considerations. Getting a better handle on ship attraction and avoidance by birds was stressed as a priority subject for further study. Some examples of these sorts of experiments include:

1) Collecting a random subset of data on seabirds (one species at a time, or all species at random intervals) with line-transect methodology to determine species-specific detection functions which can be used to help interpret strip-transect methodology, and determine ship avoidance and attraction factors.
2) Comparing aerial and ship-based data for selected (especially diving) species to assess the degree of ship avoidance.
3) Effects of observer variability on results.

4) Effects of number of observers; e.g., can one observer really do an adequate line transect for cetaceans? Can a correction factor be applied to seabirds based on differences between numbers of observers (e.g., 1 vs. 2).
5) Effects of distance estimation using recticles (with clear horizon) based on direct ship-to-object estimates with no horizon.
6) Effect of ship size on results
7) How does "assisting" between line and strip observers affect results. Which is better? Can the recorder help guard the midline?
8) Should observations be binned according to zone of closest approach or zone of first detection?

Survey Method: Strip-Transect and Line-Transect Protocols
For birds (and often at least some mammals, pelagic fish, turtles, and debris), all six protocols reviewed follow basic, strip-transect methodology described and recommended by Powers (1982), Tasker et al. (1984), and Gould & Forsell (1989). Organisms are recorded within a quartile-circular area (90^o quadrant; see Figure 1) in front of and to one side of the survey vessel, with the width of the survey area depending on height of observation, taxa being sampled, observer experience, and other factors. The side (port or starboard) of the sampling quadrant is chosen as that with the best observation conditions, as affected by glare, lighting, and sea state.

For marine mammals, the line-transect method (Burnham et al. 1980, Buckland et al. 1993, Lerczak & Hobbs 1998, Garner et al. 1999) has now been agreed upon as the preferred method for obtaining density estimates that can be compared across programs. Strip-transect methods for marine mammals, as described above and occurring in either a 90^o quadrant or a semi-circular (180°) area in front of the vessel have also been employed (Tasker et al. 1984, Keiper et al. 2005; see Figure 1), and may still be an appropriate method in certain circumstances (e.g., when only one observer is present in low-density situations or when an observer lacks the training or equipment for line-transect surveys). Statistical procedures exist whereby strip transects may be able to produce similarly rigorous estimates of marine mammal densities to those of line transects (Clarke et al. 2003), but most statisticians favor a line-transect approach, and line-transect methods are the convention recognized by the SWFSC and the International Whaling Commission (IWC) to allow calculation of actual population size of mammal stocks. Thus, the line-transect method, even if performed by a single observer, is recommended, with strip-transect surveying for mammals only occurring when line-transect methodology cannot be employed.

Line-transect surveys record all visible marine mammals to the horizon, along with distance and angle from the observer. Effective detection distances can be calculated and used to estimate densities. These methods assume that all organisms on the projected line forward of the ship are recorded. Many correction factors were researched to allow for situations where detection distance may show substantial variation, as with marine mammals that occur in various sizes and that spend variable (usually small) proportions of time at the surface. Protocols for line-transect methods are contained in the computer program DISTANCE (Thomas et al. 2001) or WindCruz, developed by Robert Holland at

SWFSC. Rigorous line-transect methods, performed to SWFSC and IWC standards, are optimally performed with three on-effort observers at all times focused on marine mammals, one on each side of the vessel and one guarding the track line and recording data. Particular attention must be paid to the track line in front of the vessel, as line-transect analysis assumes that all animals along this line are detected. Two pairs of mounted binoculars on a stable platform are often used. Observers rotate frequently (e.g., every 40 minutes) such that six highly trained observers carry out continuous sampling. Continuous transiting often is interrupted to confirm species identification and number (although surveys can also be performed uninterrupted or in “passing mode”), and clear horizons are best for obtaining distance estimations at precisions required for this methodology. See Burnham et al. (1980), Buckland et al. (1993), Lerczak & Hobbs (1998), Garner et al. (1999), and Thomas et al. (2001) for more information on line-transect methodology.

It is anticipated that most WCNMS programs will lack the capability to perform line-transect methodology at this level. However, line-transect methodology in passing mode can still be employed effectively with a single observer, as performed by Calambokidis et al. (2004). In this case a single observer is stationed at the front of the vessel, scans 180°, and records distance and angle at first observation to all marine mammals observed. Having an additional person to record data is necessary in such a situation, although the recorder can likely keep up with both mammal and bird observations. In such circumstances it is also best if bird observer, mammal observer, and recorder rotate through the three duties, as long as all three are trained for each duty (see below concerning number of observers and assistance).

Although line-transect methods have greater statistical power to detect densities and may have advantages over strip-transect methods for sampling seabirds in certain circumstances (Hyrenbach et al. 2001), e.g., for a single species (Black-footed Albatross or Marbled Murrelet) or where seabirds are very sparse, these conditions are rarely met within WCNMS and other Pacific at-sea studies. Precise distance estimations to each individual bird are far too difficult to obtain at seabird density levels typically encountered in the Pacific. This is especially true when the horizon is obscured by fog or haze, as is often the case in WCNMS and other Pacific waters. Thus, little or no adjustment to standard strip-transect methods are recommended for WCNMS protocols.

However, line-transect methodology can be performed on a random subset of birds to obtain density estimations that can be compared with concurrent strip-transect data. Not all organisms have to be recorded to obtain such densities. On clear days (when more accurate distance estimations can be obtained; see below), at-sea programs should experiment with this method by employing an extra observer aboard to record birds with line-transect methodology on a subset of individuals. Densities and detection functions based on these data can be compared to those of strip-transect data to assess the accuracy of density estimates and to investigate the effects of ship-attraction and ship-avoidance. These and other experimental tests to better understand observation biases may best be performed during surveys that are not part of program design, "ships of opportunity."

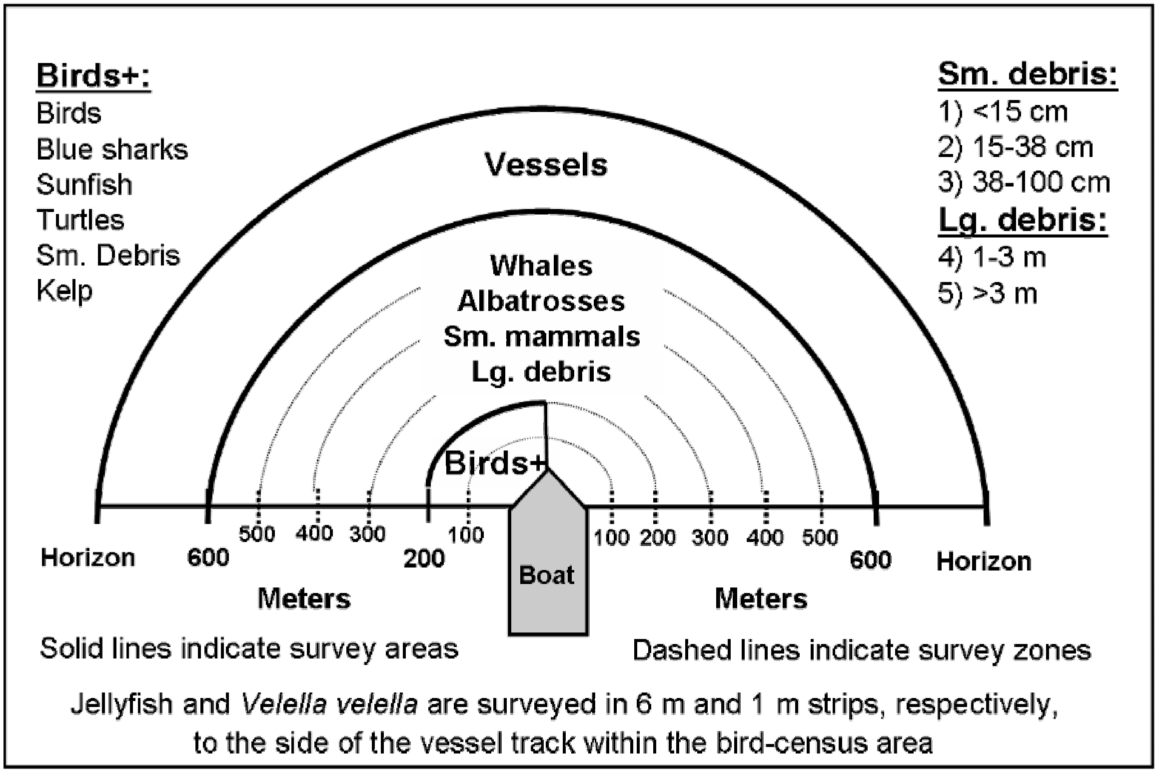

Figure 1. An example of survey areas and zones for recording birds, mammals, other organisms, debris, and boats, during the Cordell Bank Ocean Monitoring Program (CBOMP) in 2004-2006, using strip-transect methodology. Most birds, pelagic fish, turtles, and debris items were sampled in a quartile-circular area (90° quadrant) to one side of the vessel; albatross and marine mammals were sampled within 600 m in a semi-circular (180°) area in front of the vessel (resulting in a 1200-m strip); and boats are sampled to the horizon (hull visible at the water line) in front of the vessel. The bird and mammal areas are binned into 100-m zones. These distances were determined based on the height of the observers above the water, 3.8 m in this case. From survey heights ≥ 8 m, bird area-strips of 300 m and the mammal area-strips of 800 m have been used. Based on the results of the April 2007 meeting, however, it is now recommended that all birds, pinnipeds, and other organisms be surveyed in the smaller area and that most mammals (including cetaceans and sometimes pinnipeds) be surveyed with line-transect methodology.

For groups of flying seabirds a “continuous” recording approach during strip-transect sampling is recommended (see Tasker et al. 1984, Gaston et al. 1987, Gould and Forsell 1989, van Franeker 1994, Spear et al. 2004). Birds are continuously recorded as they enter the survey zone and corrections to densities are subsequently made to address bird flux, using direction of movement and speed calculations of both the survey vessel and the birds (Spear et al. 1992a). In some programs (e.g., HTH, SWFSC, CBOMP), when bird numbers are high, all observations of birds of the same species are summarized at intervals (often of 1-5 minutes) irrespective of whether or not they are showing the same behavior or are directly associated. This is convenient during periods of high density and should be part of protocols in WCNMS's, where high densities of birds are frequently encountered. Many programs also record pinnipeds using strip-transect methodology, as too many individuals may be missed using line-transect methodology.

Strip Widths for Seabird (and Mammal) Surveys
Strip-transect methods require a predetermined, fixed survey width which depends on observation height above the water surface, visibility, sea state, observer abilities, and other factors. The most important factor in determining strip width is that observers are comfortable with their ability to detect close to 100% of all targets within the survey area. During surveys in WCNMS waters from 8-15 m height, the standard radius used for seabirds is 300 m (and that for mammals, if used, is 800 m, for an 800 m strip width on one side of the boat or a 1600 m strip-width if both sides are sampled). Larger distances have been considered from higher platforms in areas of lower density (Spear et al. 2002) but it is generally felt that 300 m is the maximum distance in which the assumption of 100% detectability of seabirds can be approached.

During the CBOMP (and certain surveys conducted by HTH from tugboats) at 3.8 m height, it was concluded after substantial experimentation that a survey radius of 200 m could be adequately surveyed for seabirds, and a 600-m radius on both sides of the vessel [1200-m strip width] could be used for mammals and albatross if strip-transect methodology is employed (Figure 1). However, Wind-to-Whales and PRBO Conservation Science generally use a strip width of 100 m for all seabirds, from an observation height of 4.3 m, assuming that too many birds will be missed at distances out to 200 m. Ship avoidance may bias observations within 100 m of larger vessels so it is recommended that observations be performed to 200 m (as binned into 100-m zones; see below), if feasible, from observation heights of 5-8 m asl. But, again, it is most important that observers choose the strip width in which they are most comfortable, and this may depend on observation conditions (see below).

Binning Areas into Zones
Binning data is not a critical component to density estimation at this time but may become so in the future. Therefore, when using the strip-transect methods it is recommended that estimated observation distance be binned into 100-m intervals or “zones” (see Figure 1). Certain programs (e.g., SWFSC) combine zonal or "distance" data with observation conditions to exclude certain species from certain areas. Binning may also allow greater analytical flexibility to 1) calculate different maximum detection distances for use in determining densities for different species and observers; 2) assess levels of species-specific ship-avoidance and ship-attraction by analyzing densities by strip width; 3) estimate observer ability and biases; and 4) more effectively compare surveys using different strip widths. It was concluded at the April 2007 meeting that 200 or 300 m are probably insufficient distances to effectively analyze ship attraction and avoidance, but this still needs to be tested.

Currently, two different methods for binning seabirds are employed. HTH and CBOMP protocols require that the minimum distance from the observer be recorded; thus, e.g., a seabird that is observed passing through Zones 3 and 2 to Zone 1 (cf. Figure 1) gets recorded for Zone 1. CSCAPE and OCPS methods record the Zone for which an organism was first observed; Zone 3 in the above example. The former method allows more robust analyses of effective detection distance, assessing ship avoidance and attraction, and comparing surveys with different strip widths whereas the latter method is used when combining zones with observation conditions. Recording both zone of first observation and zone of closest approach might allow further refinement of data, and perhaps should be considered in situations where time allows. Since binning is considered non-critical data at this time, it is left up to each program how to treat the binning of data to zone or distance.

Accuracy of Distance Estimations

It is absolutely imperative during at-sea surveys that distance estimations for both areas and zones be as accurate as possible (Spear et al. 1992, Ballance 2005, Forney 2005, Pyle et al. 2005). For line-transect methodology, distances will often have to be calculated directly, when the horizon is not clear, as is often the case in WVNMS, preventing the use of reticular binoculars. It is thus recommended that all (or most) distances used during a program (e.g., each or every other 100-m strip up to at least 800 m) be calibrated at a given observation height, using a dowel or pencil held at arms length and the calculations presented by Heinemann (1981). These calibrations are complex and easily botched when calculations are performed by hand. It is thus recommended that they be performed with a computer program where strip distance, observation height, and arm-length distance are entered for each calculation. It is also recommended that sets of pencils be created for given arm lengths (e.g., 600, 650, 700, and 750 mm) rather than creating individual pencils for each observer (which can get lost or are a hassle to make for each new observer). If need be, observers can calibrate the flex in their arms to one of these four arm-length distances. Analyses of the equations given by Heinemann (1981) indicate that variation in height of eye above water results in very little variation in detection distance, given other factors, and experiments conducted during the CBOMP program has shown the above method to be easy and reliable.

All surveys should also be equipped with one or more pairs of reticular binoculars for help in calibrating and determining distance estimations. High-quality, range-finding binoculars are currently available that can be used for both observations and to obtain accurate distance estimations up to 700 m. It is recommended that a pair of these binoculars be purchased and further tested for use during at-sea monitoring programs. Use of the ship’s radar or a laser range-finder can also be used to determine distances to immobile objects (e.g., Spear et al. 2002) but certain radars are inexact and care must be taken when using this approach. An effective approach, if time allows, is to extend a float out via marked fishing line to the different survey distances (Pyle et al. 2005) to confirm the accuracy of marked dowels or pencils and obtain an accurate visual cue of each survey distance. See also Gordon (2001) for approaches to distance estimation using photographic equipment.

Number and Responsibilities of Observers

Inter-observer variation in detection, identification, and distance-estimation skills represents the greatest potential for bias during ship-based surveys (*cf.* van der Meer and Camphuysen 1996), and particular attention should be given to selecting and training highly skilled observers, and to standardizing observer effort, as is performed by SWFCS (Ballance 2005, Forney 2005). The maximum number of observers available for at-sea surveys is dependent on observation platform capacities, and funding, and will thus vary with program. It was concluded at the April 2007 meeting that the minimum number of observers present in most cases (including WCNMS's) should be two to record birds and two to record mammals, or three to record both groups of organisms. Too many mammals or birds will be missed in high-density situations if the observer also has to record data (unless a tape-recorder is employed). However, in low-density situations such as often occur in tropical waters, a single bird observer is sufficient to both observe and record birds.

At-sea sampling in WCNMS's for both birds and mammals appears to be most efficiently accomplished by three observers on-effort, one responsible for sampling mammals with line-transect methodology (or, sub-optimally, a larger strip), one responsible for sampling seabirds with strip-transect methodology, and the third responsible for recording both mammal and seabird data. Continuous sampling can be made feasible by the addition of a fourth observer, with a rotation in which one observer is off-effort for 30-60 minute periods of time. In areas of high bird density, many individuals will be missed by a single observer who also needs to accurately record data (Spear et al. 2004). If mammals are also being recorded in a single 90° quadrant, two observers may be sufficient in many situations, although this should be considered a minimal approach.

There are differing viewpoints on whether or not observers can or should assist each other with observations. Line-transect methods require mammal observers to be independent because detection distances are often calculated on an observer-specific basis. Another problem with assistance by seabird observers and recorders in line-transect methodology is that the assistance needs to be constant in effort, which does not occur (degree of assistance effort decreasing with increased density of birds). Therefore, it is recommended that the line-transect surveyor not be assisted. If a marine mammal is detected by the seabird observer or recorder they should not alert the mammal observer until the mammal has passed from the observation area. For strip-transect methodology, collective effort best achieves the assumption that all vertebrates within the survey areas are recorded; e.g., smaller birds are missed frequently by single observers, even at lower-density levels (Spear et al. 2004, Pyle et al. 2005). Collective effort also reduces biases associated with species identification, numbers observed, whether or not an individual was a ship attractant (see below), and distance estimation (i.e., whether an individual was in or out of the survey area or zone). Thus, it is recommended that the recorder and line-transect surveyor be able to assist the bird observer with observations within the strip width.

Thus, in summary, the most effective approach to mammal and bird surveying within WCNMS's and elsewhere when only three observers can be present will be to have one observer conduct line-transect methodology on mammals from the center of the vessel, one observer record seabirds within a strip on the side of the vessel with the best observation conditions (due to glare, lighting, or sea state), and one recording data for both mammal and bird observers. All three observers can assist with bird observations but the mammal observer should remain independent.

Methods of Recording Observations

Computer data-entry programs are currently used for most at-sea observation programs. The primary advantage to immediate computer entry is that data do not need to be entered later by hand, which can be a time-consuming process, especially for multi-day surveys. Data can also be linked directly to positional data and other continuous data sets recorded by the survey vessel. Entry programs for line-transect methods also allow the immediate plotting of position data for stationary or traveling mammals with respect to the survey vessel. Disadvantages to immediate computer entry include the potential to lose data or enter erroneous data, especially in times of stress due to high densities of organisms. In addition, quality assessment and control generally is not as rigorous as when written data is later screened and entered by hand, although verification programs can account for some QAQC.

Computer entry programs have developed sufficiently to avoid the above problems and should be used as part of WCNMS and other protocols, provided that 1) computer screens are easily viewed, even in direct sunlight and without the need for (seasickness-inducing) hoods; 2) enterers are able to immediately review and make correction to data *in situ*; and 3) the program has a frequent, automatic saving function to prevent loss of data. The several computer data-entry programs that exist for strip-transect surveys satisfy these requirements to various degrees, with the *SeeBird* (strip-transect) and *WINCRUZ* (line-transect) programs used by CSCAPE, OCPS, and Wind-to-Whales currently satisfying all three requirements. In April-May 2007 a modified version of *SeeBird/WinCruz* was developed by SWFSC programmers specifically for WCNMS surveys and it is recommended that this program be used. Contact Lisa Ballance at SWFSC (see this page) for more information.

Whatever program is used, it is imperative that a notebook be immediately available to record errors for future correction and record data if (and usually when) the computer or computer program ceases to function, or when entry of a mammal observation is occurring when seabirds are involved.

Taxonomic Entries and Codes

Each program has its own set of taxonomic categories for recorded individuals and its own set of species-specific alpha-codes to facilitate rapid data recording. There is currently little standardization to the taxonomic categories employed, especially concerning unidentified species, “species pairs” (e.g., Clark's/Western Grebe, Sooty/Short-tailed Shearwater) and hybrids. Alpha codes used in most NMS at-sea programs consist of four letters based on the Common or English name of the species, but different rules have been used to derive these codes (for example, the code for Sooty Shearwater is “SOSH” for CBOMP and Wind-to-Whales but “SHSO” for HTH, CSCAPE, and OCPS). Numeric codes are also used for mammals sampled with line-transect methods (Forney 2005). It is generally recommended that these codes be standardized to such lists as that presented by Pyle and DeSante (2003) for birds or a similar standardized list for mammals and other organisms. It is further recommended that a relational database ("taxa driver") and accompanying document be created to address this issue within WCNMS's. The database should list codes for all ocean-monitoring programs (including three beach-monitoring programs operated by OCNMS, GFNMS, and MBNMS) and allow direct data inter-phasing for future broad-scale analyses and on-line syntheses. It is not critical that each program use the same codes, however, it is critical that all codes and categories be strictly defined, that there are few cases with overlapping definitions (e.g., "grebe sp." vs. "Western/Clark's Grebe") where different observers may record different codes for the same thing, and that observers are very well trained on the use of each code and category.

Recording of Organisms using Strip-Transect Methods

All six strip-survey methods are consistent in not recording seabirds that are flushed by the survey vessel off the water from the opposite quadrant to that being sampled and this approach is recommended for WCNMS protocols. Birds flushed or induced to dive before entering the survey area, or flying individuals deflected away from the survey area, that would have passed through the survey area had they not reacted to the vessel, also should be recorded (Spear et al. 2004, Ballance 2005), in the zone that corresponds to that in which they would have been present had the vessel not altered their behavior. Thus, observers need to look ahead of the survey strip for diving birds, and record these to appropriate zone if within the strip distance (and zone) of the track line of the vessel.

Seabird and marine mammal attraction to and avoidance of ships can introduce a significant bias to strip-transect methods (Spear et al. 1992a, Hyrenbach 2001), and represent the largest unquantified problems for seabird surveys (to a lesser degree, mammal surveys). Currently, birds that are attracted to ships are variously recorded but marked as such (e.g., CSCAPE, OCPS, Wind-to-Whales, CBOMP) or are partially or entirely ignored (e.g., HTH). Using the former method, all birds entering the zone are counted once, with birds circling the ship not being counted more than once. Rationale behind the former method is that animals recorded as ship-attractants can always be excluded from analyses and that there is too much observer bias in determining whether or not an individual bird or mammal is attracted. Using this reasoning, it is possible that calculated “densities” that include ship attractants may prove to be more comparable between observers and survey programs than those that include potentially un-standardized decisions on what constitutes an attracted individual, although it should be recognized that densities including ship-attractants will be larger than true densities. Using the latter method, decisions are made whether or not birds entering the zone are attracted or not, and, based on the species and their behavior, they are either excluded altogether or recorded as non-attracted individuals. Rationale behind the latter method is that data on ship attractants are of limited use, and recording them presents a distraction to the observers (Spear et al. 2004). Unfortunately, these separate methods will result in substantially varying density estimates, which will preclude our ability to combine data.

At the April 2007 meeting it was decided that, because 200 and 300 m surveys are probably not adequate to assess ship attraction or avoidance (see above), and because analyses on gulls and albatross have shown that accounting for ship attraction produces more accurate density estimates (as compared with known colony sizes; Spear et al. 2004), it is recommended that individuals that are determined to be attracted to the boat be recorded as such. Certain groups (gulls, albatrosses, fulmars, tropicbirds, sulids, frigatebirds) are more likely to be recorded as ship attracted individuals. Since it may not be possible to affect standardization of this variable (see below) it is recommended that all individuals entering the survey zone be recorded (rather than some individuals that are considered attracted be ignored entirely). Some models that account for ship attraction (e.g., HTH) discriminate between those attracted to the ship from the quadrant of observation and all others. Therefore, travel direction for ship attracted birds should be recorded in the same manner as it is recorded for directionally traveling birds. Recording all birds that enter the survey area along with direction of travel will allow the greatest flexibility in the future to combine data sets using various treatments of ship-attracted individuals.

Observers must be extensively trained to become as standardized as possible in their determination of what is coded as an attracted individual and what isn't, and this needs to be standardized across programs as much as possible. Observers must follow the flight path of each bird to see if they wind up following the ship or not. If they circle or follow the ship they should be recorded as ship-attracted (see below) and the direction in which they are traveling also be recorded. If they do not seem to be effected by the vessel, they would be recorded as directionally flying.

Hyrenbach (2001) proposed statistical methods for calculating the degree to which individual albatrosses were attracted to a survey vessel off Southern California. Spear et al. (2004) point out some discrepancies in this technique but indicate that it has promise, although it is unclear how general correction factors might be applied to different species, survey areas, seasons, and availabilities of natural food resources, among which degree of ship-attraction may vary substantially. Analyses based on survey zones and directions of flight can be useful in discriminating degrees of ship attraction and ship avoidance, and it is recommended that in such tests all organisms be recorded to the closest zone of approach, whether or not they are deemed to have been attracted to the vessel (Hyrenbach 2001, Spear et al. 2004). Another good experiment to assess ship attraction and avoidance could be to employ line-transect methodology on a subset of birds to obtain density estimates from a larger area, to compare with those found in the smaller strip.

Behavioral Categories and Codes

Spear et al. (1992a, 1992b, 2002, 2004), Spear and Ainley (1997b, 1997c), Broni et al. (1985), and Clarke et al. (2003) provide substantial documentation for the advantages of separating sitting from flying birds when sampling seabirds, and for recording flight direction of all individuals, to eliminate biases associate with inter-specific differences in flight speed and non-random flight-direction patterns. Accounting for such flux is the only way to obtain accurate density estimates and compare data sets. All observation programs currently discriminate these behavioral traits for birds and it is recommended here that these data continue to be recorded as part of WCNMS and Pacific-wide protocols. Care should be taken to estimate the long-term direction of travel for Procellariiformes and other birds that can tack while traveling, or that divert to fly forward of the ship to go around the survey vessel's bow. Non-directional flight or "milling," including circling over a prey school, can also be recorded, and active "feeding" should be recorded for ecosystem-based analyses. Milling and feeding are treated essentially as stationary individuals in analyses to determine flux. The categorization of stationary, traveling, and milling mammals should also be recorded in the same manner. Thus, at a minimum, at-sea programs need to discriminate between directionally flying birds and those that are not directionally flying, as separated into sitting, milling, and feeding. Ship attraction represents a fifth category that should be recorded, along with direction of travel of attracted individuals (see above).

Flight direction of birds is currently being recorded in various ways: using HTH and PRBO methods, true direction of travel to the nearest 10° is estimated requiring *in-situ* adjustment for vessel direction of travel; using CSCAPE, OCPS, and Wind-to-Whales methods, direction of travel to the nearest 10° is estimated relative to the direction of the ship's travel; and using CBOMP methods direction of travel to the nearest 30° was originally estimated (in units equivalent to those on a clock face) relative to the direction of the ship's travel. Spear et al. (2005) performed an analysis showing that use of the "clock-face" methods of CBOMP results in the overestimation of densities by 7-27% (among 4 species tested) once analyses for flight speed and adjustment were performed. It is thus recommended that a 36-point scale be used to record transit direction. Either method of recording flight direction is fine, although many believe that it is easier to record these directions relative to boat direction. The method of recording must be part of the data documentation. Other behavioral codes such as "piracy" and those describing flight behavior can be recorded as long as each category is clearly indicated as directional flying or not, such that calculations for flux can be applied. There is currently some inconsistency in the use of behavioral codes by different programs and observers and there thus may be advantages to recording fewer overall categories and explaining some of the less-commonly observed behaviors in comments attached to the observation.

Age, Sex, and Morph Categorization

Recording age, sex, and morph classifications, if possible, is important in describing population phenology and it is recommended that each individual be discriminated to age, sex, and morph as specifically as feasible. However, this is not considered to be critical data in determining density estimates and it is thus left up to each program to decide on their classification schemes and codes.

There is currently little precision or standardization of age-coding within WCNMS at-sea programs. Categories typically include such terms as "juvenile", "pup", "calf", "immature", "subadult", and "adult". CBOMP and HTH methods include the categorization of age groups by year class, which, in addition to helping describe age-specific distributional patterns, may eventually be useful in assessing annual productivity values. Individuals are coded by calendar year; e.g., '1Y' for a bird hatched or mammal born that year, '2Y' for a bird hatched or mammal born the year before the current year, '3Y' for a bird hatched or mammal born two years before current year, etc., 'AD' for an Adult in definitive plumage or growth stage, and 'UN' for unknown age. Most seabirds are of unknown age but for frigatebirds, boobies, gulls, and jaegers, age can be designated for birds of up to 3 or 4 years. It is understood that codes may be difficult to assign to certain individuals (e.g., 3-4 year old gulls and subadult pinnipeds), such that certain species-age combinations are understood to be plus-or-minus one year of age. Never-the-less, this approach is recommended as part of WCNMS protocols provided that observers are skilled enough to attempt discriminating age groups of birds and mammals.

Sex determination is possible in only a few seabirds that are not recorded often in WCNMS data sets (e.g., scoters) and it is thus not very useful for bird data sets. For mammals it can be of use for pinnipeds and killer whales, although in most species only adults can be accurately sexed, and adult females can be difficult to separate from immature and subadult animals. Sex coding for mammals is important, however, in analyses that are based on organism biomass. Likewise, morph is useful for only a few species of birds (fulmars, a few shearwaters, and jaegers) and is not recorded during all WCNMS programs; however, recording both morph and sex is recommended for WCNMS surveys. Scoring the undertail-covert color in Black-footed Albatross is also recommended, for potential age-specific analyses (Hyrenbach 2000). Under CBOMP methods, the undertail color is scored as 1 (completely dark), 2 (mostly dark), 3 (mixed dark and pale), 4 (mostly pale), and 5 (white).

Bird and Marine Mammal Associations

It may be of interest to know how birds associate with each other and with marine mammals, especially during feeding events, and most programs have codes or directives to record such associations. Both intra-specific and inter-specific associations have been recorded as part of CSCAPE and HTH surveys whereas inter-specific associations only has been recorded as part of CBOMP methods. Either method is recommended here; although it is important that the definitions of "associations," both within and among species, be clearly defined. As with some behavioral codes, there is quite a bit of inter-observer inconsistency in the use of association codes, even within programs. The *SeeBird* program (including the version modified for WCNMS surveys) has an option to mark the same time and position stamp for associated organisms and this may be the simplest method of indicating association. Recording of intra-specific associations or flocks (as opposed to individuals within the same time period of recording) may potentially assist with analyses incorporating detection biases, as flocks are easier to detect than single individuals (Tasker et al. 1984). Association codes are not currently critical to obtain abundance estimates so it is left up to the program how to record associations.

Data on Other Organisms

A primary purpose of at-sea surveys is to describe and understand correlations between vertebrate distribution and that of invertebrate communities, each as affected by physical oceanographic processes. For this reason it is recommended that as much ancillary data as feasible be collected while in the field. Most programs record surface-inhabiting fish such as *Mola mola* and blue sharks, along with sea turtles, if they are detected within the bird-survey area, and this is recommended, along with the recording of survey zone, for WCNMS protocols. Some programs within WCNMS's collect data on visible fauna and flora such as *Velella velella*, various jellyfish species, and kelp and other drift algae. Increasing populations of jellyfish worldwide (due indirectly to over-fishing) is becoming a concern. For the CBOMP program, *Velella* are recorded within a 1-m strip, jellyfish are recorded within a 6-m strip, and kelp is recorded within the bird-survey area. In all cases abundance estimates are scored on a per-segment basis because densities are often too great and would result in too much distraction to attempt recording these organisms *in situ*. This approach is recommended for WCNMS protocols. It is also recommended that comment sections be used frequently to record other organisms that are not part of the data set (e.g., krill swarms, bait fish, etc.) and any other observations of relevance.

Most programs in the WCNM's also collect data on acoustic backscatter from zooplankton and icthyoplankton with the use of echosounders. These data appear to provide some correspondence with surface-level activity at a very broad scale, although it is currently being debated whether or not the data collected is worth the high cost of the equipment. After an observation program is established and funding is in place for analysis of observation data, NMS programs may want to look into acquiring a split-beam, 120-kHz echosounder (the recommended type and frequency for a single device). Should an echosounder be employed, the use of net-tows to ground-truth backscatter data and to correlate invertebrate distribution with surface observations is also recommended, if feasible and funding (potentially substantial) is available to process samples. NOAA Fisheries Science Centers (2003) provides a good overview of tow-sampling methods and data processing.

Vessels and Debris

There is recent interest in monitoring vessels and debris as part of at-sea observations programs. Protocols have been developed and currently are being tested. These protocols divide vessels into four categories (Recreational, Government, Commercial Fishing, and Transport) and 33 types/activities (e.g., sailing, under power, fishing), and divide debris into 10 material types (organic, plastic, wood, etc.) and 38 categories (bottles, cans, ropes, etc.) for entry. Debris Categories are modified from those used by the UNESCO/Sandwatch program. Four-letter codes have been developed for these vessel and debris categories. Vessels are sampled to the horizon and in front of the survey vessel (bow line in water visible, not over the horizon), and the strip width for vessel surveys thus becomes the visible horizon from a given height (the calculation *v* of Heinemann 1981). Debris are divided into five size classes and recorded either in the bird-survey area (debris < 1 m in length) or in the mammal-survey area (debris > 1 m). See Figure 1. It is anticipated that vessel and debris protocols will be finalized in 2007.

At the April 2007 meeting some problems were raised with the collection of debris data, especially when there was so much that it distracted observers from seabirds and mammals. It was generally recommended that a separate observer be funded to collect these data, especially in areas of high debris content. Recommended methodologies for recording vessels and debris will be finalized based on efforts and results so far. Fishing trawlers may be especially important to record (re albatross distribution). Generally, the recording of these variables may have to be funding dependent, as it is of only peripheral interest regarding bird and mammal data. It will be left up to the program whether or not it wants to pursue monitoring debris and vessels. Coast Guard (AIS) and CODAR data sets may be a better way to get vessel use data.

Quality of Visibility Scores

The ability to detect organisms, vessels, and debris can be affected by several environmental factors (visibility, sea state, lighting condition, etc.), not all of which can be adequately quantified with environmental data. Most WCNMS protocols provide a means to qualify observation conditions through an "observation" or "quality of visibility" score. Because these scores are somewhat subjective it is recommended that they not be too detailed; e.g., for the CBOMP and CSCAPE programs, these scores are limited to "poor", "fair" "good" and "excellent". Using CSCAPE and OCPS methods, certain scores, indicating lower quality of visibility, preclude recording smaller species (storm-petrels, phalaropes, and small alcids) in outer zones. This is necessitated by the binning methods, which differs from that of other protocols (see above). Alternatively, birds can be recorded in all zones under all conditions (and using the alternate binning methods of HTH and CBOMP), enabling later statistical treatment of the proportion of birds missed, by species and zone, under poor conditions. Data from outer zones can always be excised or calibrated on a species-specific basis prior to calculation of densities. Thus far these codes have not been used in density estimations except to the degree in which they define species-specific strip-widths, and it is left up to the program whether of not to use these codes and how they should be employed.

Weather and Oceanographic Data

Weather affects both vertebrate distribution and the detection ability of observers and should be recorded as part of all survey efforts. Primary weather variables that need to be recorded as part of WCNMS protocol include visibility, glare, wind speed/sea state (usually using the Beaufort Scale), swell height, cloud cover (which affects glare and thus detection capabilities), and in high latitudes the amount of pack ice. These variables, along with a quality of visibility score, will allow adjustments of data for variation in detectability according to species and detection distance. It was noted at the April 2007 meeting that buoy weather data are not yet reliable enough to use consistently with at-sea observation programs.

Physical oceanographic data can also be collected both *in-situ* and from remote-sensing devices such as buoys and satellites. All programs currently collect surface temperature, salinity, and other parameters with continuous-recording instruments, and all programs obtain thermocline depth and measure oceanographic parameters by depth with CTD casts. It is recommended that WCNMS protocols include the use of thermosalinographs and incorporate a standardized program for taking CTD casts. Other important data that can be incorporated include ocean depth, distance to subsurface features, and the position and activity level of oceanic fronts in the vicinity of the survey area during the sampling period. Ainley et al. (2005) provide a good example of the collecting and analyzing of such data. Many NOAA and other websites now exist from which data can be downloaded and incorporated with those collected by at-sea programs.

Inter-Program Comparison of Data Sets

Because of differences in methods, comparison of data sets between WCNMS programs will involve some data massaging and processing (Ford et al. 2004). For this reason it is recommended that, at least initially, only simple density values of organism per unit area be compared. Because all programs record flight behavior and direction, it is recommended that the correction factors of Spear et al. (1992a, 1992b) be applied to bird data, to account for biases introduced by flight speed relative to ship speed and non-random flight directions. Otherwise, calculating simple densities by temporal and spatial area is likely the best that can be achieved when comparing data collected by different methods, including aerial survey data (Ford et al. 2004). Briggs et al. (1985) and Henkel et al. (in prep) provide comparisons of methods and discuss data integration; further comparisons would be extremely valuable. It is imperative that all programs develop detailed metadata to document their data fields and scoring options within each field. Without such metadata, inter-program comparison will not be possible.

Based on the results of the April 2007 meeting it is recommended that the goal of all programs be to provide as accurate density estimates as possible for both birds and mammals. This is the only way that data from different programs can be combined. Generally it was concluded that data sets and codes could be combined fairly readily even if different sets of codes are used. However, it is vital that all programs carefully document their selection choices for each entry field. Standardization of these choices is much more important than standardization of the codes themselves. Only five fields of *in-situ* observations are absolutely critical to standardized combining of strip-methodology data. These are: taxon, number of individuals, strip-width for each observation, behavior (including categories for at least directional flight, non-directional activity, and ship attraction), and travel direction (for directional flight and ship attraction). It is also recommended that as much ancillary data as possible be collected, including those pertaining to weather, observation conditions, zone of observation, additional behaviors, age, sex, morph, and other organisms.

An ultimate goal of the NMS program is to accumulate data from at-sea observation programs into a single database, from which maps based on temporal and seasonal parameters, within each NMS, can be developed and made available to sanctuary managers and the public on-line. Funding is currently being sought to achieve this goal. In the mean time, it is hoped that this evaluation, along with the development of standard at-sea monitoring protocols will provide a valuable step toward achieving these goals.

Acknowledgments

This evaluation was made possible through NMS Science Mini Grant in FY05: *Integration of a Multi-sanctuary Ecosystem Observation Effort: Gulf of the Farallones, Cordell Bank, and Monterey Bay National Marine Sanctuaries*; I thank Dan Basta, Steve Gittings, and Charles Alexander for evaluating and supporting this project. Lisa Ballance and Karen Forney (SWFSC), Don Croll and Kelly Newton (*Wind-to-Whales*), and Bill Sydeman and Jaime Jahncke (PRBO Conservation Science) shared their protocols and collaborated with NMS personnel on at-sea surveys. Input from NMS personnel Jan Roletto, Shannon Lyday, Jamie Hall, and Dru Devlon (GFNMS/FMSA), Lisa

Etherington, Michael Carver, and Dan Howard (CBNMS), Ed Bowlby and Barbara Blackie (OCNMS), and Andrew.DeVogelaere (MBNMS) helped to enhance the content and improve the manuscript; Lisa Etherington prepared Figure 1. I especially thank David Ainley and the late Larry Spear (H.T. Harvey and Associates) for assistance, evaluation, and review of the manuscript.

Literature Cited

Ainley, D.G., L.B. Spear, C.T. Tynan, J.A. Barth, S.D. Pierce, R.G. Ford, and T.J. Cowles. 2005. Physical and biological variables affecting seabird distributions during upwelling season of the northern California Current. Deep-sea Research 52:123-143.

Ballance,L.T. 2005. Seabird survey instruction manual, CSCAPE 2005. Unpublished Document. Ecosystem Studies (Ecology) Program, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037.

Benson, S.R., D.A. Croll, B.B. Marinovic, F.P. Chavez, and J.T. Harvey. 2002. Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Niño 1997-98 and La Niña 1999. Progress in Oceanography 54:279-291.

Briggs, K.T., Tyler, W.B., Lewis, D.B. 1985. Comparison of ship and aerial surveys of birds at sea. J. Wildl. Manage. 49: 405-411.

Broni, S.C., Kaicener, M., Duffy, D.C. 1985. The effect of wind direction on numbers of seabirds seen during shipboard transects. J.Field Ornithol. 56(4): 411-412.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. Chapman and Hill, London.

Burnham, K.P., Anderson, D.R., Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72: 1-202.

Calambokidis, J., G. H. Steiger, D. K. Ellifrit, B. L. Troutman, and C. E. Bowlby. 2004. Distribution and abundance of humpback whales and other marine mammals off the northern Washington coast Fisheries Bulletin 102:563-580.

Clarke, E.D., L.B. Spear, M.L. McCracken, F.F.C. Marques, D.L. Borchers, S.T, Buckland, and D.G. Ainley. 2003. Validating the use of generalized additive models and at-sea surveys to estimate size and temporal trends of seabird populations. Journal of Applied Ecology 40:278-292.

Ford, R.G., D.G. Ainley, J.L. Casey, C.A. Keiper, L.B. Spear, and L.T. Ballance. 2004. The biogeographic patterns of seabirds in the central portion of the California Current. Marine Ornithology 32:77-96.

Forney, K. 2005. Marine mammal survey instruction manual, CSCAPE 2005. Unpublished Document. Southwest Fisheries Science Center, Santa Cruz, CA.

Garner, G.W., S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald and D.G. Robertson, eds. (1999), *Marine Mammal Survey and Assessment Methods*, Proceedings of the Symposium on Surveys, Status & Trends of Marine Mammal Populations, Seattle WA, USA, 25-27 February 1998. A.A. Balkema, Rotterdam.

Gaston, A.J., Collins, B.L., Diamond, A.W. 1987. The 'Snapshot' count for estimating densities of flying seabirds during boat transects: a cautionary comment. Auk 104: 336-338.

Gordon, J. 2001. Measuring the range to animals at sea from boats using photographic and video images. Journal of Applied Ecology 38:879-887.

Gould, P.J., Forsell, D.J. 1989. Techniques for shipboard surveys of marine birds. Fish and Wildlife Technical Report 25: 20 pp. Washington D.C.

Haney, J.C. 1985. Counting seabirds at sea from ships: Comments on interstudy comparisons and methodological standardization. Auk 102: 897-898.

Heinemann, D. 1981. A Range finder for pelagic bird censusing. J. Wildlife Manage. 45(2): 489-493.

Henkel, L.A., R.G. Ford, B.W. Tyler, and J.N. Davis. In prep. Comparison of aerial and at-sea survey methods for Marbled Murrelets and other birds. Institute for Marine Sciences, Long Marine Laboratory, University of Santa Cruz, Santa Cruz, CA 95060.

Hyrenbach, K.D. 2000. Plumage-based ageing criteria for the Black-footed Albatross. Marine Ornithology, 30: 85-93.

Hyrenbach, K.D. 2001. Albatross response to survey vessels: implications for studies of the distribution, abundance, and prey consumption of seabird populations. Marine Ecology Progress Series 212:283-295.

Hyrenbach, K.D., C.L. Baduini, and G.L. Hunt, Jr. (2001). Line transect estimates of Short-tailed Shearwaters (Puffinus tenuirostris) in the Southeastern Bering Sea: 1997-1999. Marine Ornithology 29:11-18.

Keiper, C.A., D.G. Ainley, S.G. Allen, and J.T. Harvey. 2005. Marine mammal occurrence and ocean climate off central California, 1986 to 1994 and 1997 to 1999. Marine Ecology Progress Series 289:285-306.

Lerczak, J.A., & Hobbs, R.C. 1998. Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. Marine Mammal Science 14: 590-599.

National Centers for Coastal Ocean Science (NCCOS). 2003. A biogeographic assessment of North/Central California. Phase 1. NCCOS in cooperation with the National Marine Sanctuary Program, 1305 East-West Highway, Silver Spring, Maryland, 20910.

National Marine Sanctuaries (NMS). 2003. Minutes from the Marine Mammal and Seabird Workshop, Santa Cruz, California, December 2002. Olympic Coast National Marine Sanctuary, 115 East Railroad Ave., Suite 301, Port Angeles, WA 98362-2925

NOAA Fisheries Science Centers. 2003. NOAA Fisheries protocols for icthyoplankton surveys. National Marine Fisheries Sevrice, Washington, D.C.

Oedekoven, C.S., D.G. Ainley, and L.B. Spear. 2001. Variable responses of seabirds to change in marine climate: California Current, 1985-1994. Marine Ecology Progress Series 212:265-281.

Philbrick, V.A., P.C. Fiedler, L.T. Balance, and D.A. Demer. 2003. Report of ecosystem studies conducted during the 2001 Oregon, California, and Washington (ORCAWALE) marine mammal survey on the research vessels David Starr Jordan and McArthur. U.S. Dep. Commerce, NOAA Tech. Memorandum NOAA-TM-NMFS-SWFSC-349. 50 pp.

Pitman, R.L. 1986. Atlas of seabird distribution and relative abundance in the Eastern Tropical Pacific. Admin. Rept. LJ-86-02C. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Powers, K.D. 1982. A comparison of two methods of counting birds at sea. J. Field Ornithol. 53(3): 209-222.

Pyle, P. In prep. Standardized protocols for at-sea surveys of marine birds, mammals, fish, invertebrates, debris and vessels, in West Coast National Marine Sanctuaries. Unpublished Report, Gulf of the Farallones National Sanctuary, Fort Mason, San Francisco, CA 94123.

Pyle, P., and DeSante, D.F. 2003. Four-letter and six-letter alpha codes for birds recorded from the American Ornithologists' Union Check-list area. *North American Bird-Bander* 28:64-79

Pyle, P., B. Becker, C. Keiper, M. Carver, and D. Howard. 2005 Cordell Bank Ocean Monitoring Project (CBOMP): Goals, methodology and 2004 results. Unpublished Report. Cordell Bank National Marine Sanctuary, P.O. Box 159, Olema, CA 94950.

Spear, L.B., and Ainley, D.G. 1997a. Sampling marine birds and mammals at sea. Unpublished Document, H.T. Harvey and Associates, San Jose, CA; and Gulf of the Farallones National Sanctuary, Fort Mason, San Francisco, CA 94123.

Spear, L.B., and Ainley, D.G. 1997b. Flight behaviour of seabirds in relation to wind direction and wing morphology. Ibis 139: 221-233.

Spear, L.B., and Ainley, D.G. 1997c. Flight speed of seabirds in relation to wind speed and direction. Ibis 139: 234-251.

Spear, L., Nur, N., Ainley, D.G. 1992a. Estimating absolute densities of flying seabirds using analysis of relative movement. Auk 109: 385-389.

Spear, L., Nur, N., Ainley, D.G. 1992b. A comment: estimating absolute densities of flying seabirds using analysis of relative movement. Auk 109(4): 937-938.

Spear, L., D. Ainley, and J. Roletto. 2002. Theory and background to census marine birds and mammals at sea. Unpublished Document. Gulf of the Farallones National Marine Sanctuary, Fort Mason, San Francisco, CA, 94123.

Spear, L.B., D.G. Ainley, D. Hardesty, S. N.G. Howell, S. Webb. 2004. Reducing biases affecting at-sea surveys of seabirds: use of multiple observer teams. Marine Ornithology 32:147-157.

Spear, L.B., D.G. Ainley, and P. Pyle. 2005. Estimating population trends in seabirds using at-sea surveys: results affected by method of recording flight direction. Unpublished Report, Gulf of the Farallones National Marine Sanctuary, Fort Mason, CA 94123.

Tasker, M.L., Hope Jones, P., Dixon, T., Blake, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101(3): 567-577.

Tasker, M.L., Hope Jones, P., Blake, B.F., Dixon, T.J. 1985. Response to J.C. Haney. Auk 102: 899-900.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F., Borchers, D.L., Buckland, S.T., Anderson, D.R., Burnham, K.P., Hedley, S.L., and Pollard, J.H. 2001. Distance 4.0. Beta 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. (http://www.ruwpa.st-and.ac.uk/distance/).

Troutman, B. 1995. Unpublished cruise report for OCNMS marine mammal survey off NOAA Ship McArthur. Olympic Coast National Marine Sanctuary, Port Angeles, WA.

Van der Meer J., & Camphuysen, C.J. 1996. Effect of observer differences on abundance estimates of seabirds from ship-based strip transect surveys. Ibis 138: 433-437.

Van Franeker, J.A. 1994. A comparison of methods for counting seabirds at sea in the Southern Ocean. J. Field Ornithol. 65(1): 96-108.