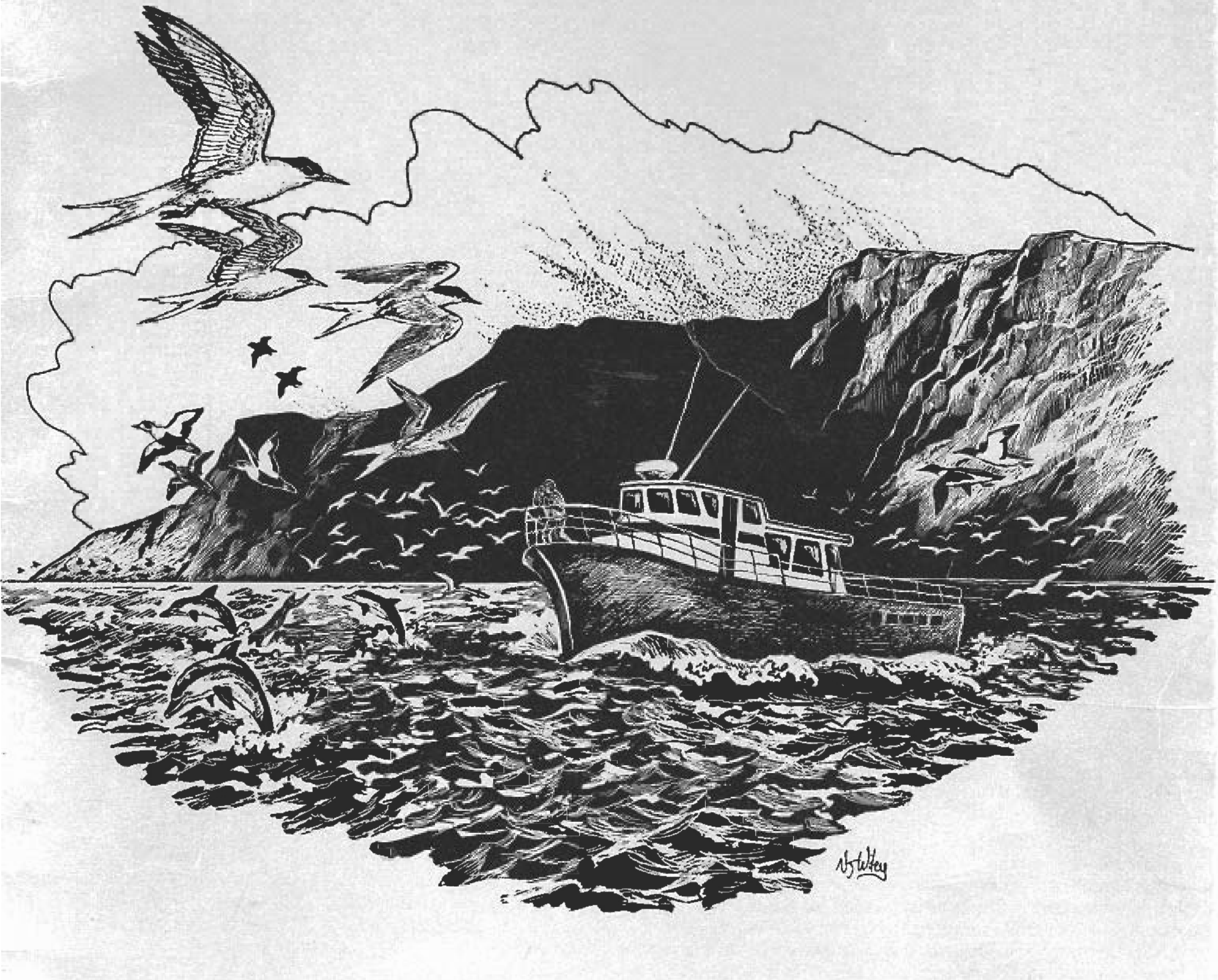
Techniques for Shipboard Surveys of Marine Birds



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Contents

Techniques for Shipboard Surveys of Marine Birds

by

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ABSTRACT.—We describe shipboard and small boat techniques used by the U.S. Fish and Wildlife Service in Alaska to survey marine birds at sea. The basis is a 10-min, 300-m-wide, strip transect taken from a platform moving at a constant speed in a constant direction. Special routines, such as instantaneous counts of traveling birds, are explained to help reduce biases caused by factors such as varying flight patterns, ship-following and avoidance, and patchy distributions. Data recording and coding techniques and formats, based on those developed for the National Oceanic Data Center, are described.

The collection and management of data on marine birds is of vital concern to agencies and individuals interested in coastal and marine ecosystems in Alaska. Surveys of marine birds that, by nature, spend most of their lives in pelagic habitats, are important for assessing and monitoring migratory bird populations that are affected by man's use of natural resources. The U.S. Fish and Wildlife Service, long active in population surveys, has established a survey data bank along the lines suggested by King et al. (1967) and King et al. (1974). This data bank now contains more than 8,000 h of observations from areas throughout the North Pacific Ocean and from the Beaufort, Bering, and Chukchi Seas. The impetus for the development of survey techniques, data formats, and codes, and the collection of the original data, came from the research efforts of the Outer Continental Shelf Environmental Assessment Program, funded by the Bureau of Land Management in the 1970's. The data bank has already proved useful (Hunt et al. 1981; Gould et al. 1982; Thorsteinson 1984), and will become increasingly so as it grows with future contributions. This system will enable resource managers to delineate critical habitats, monitor populations, and assess potential effects of coastal developments on marine birds.

A data bank of this magnitude is dependent on contributions from many sources, and all of the data residing in it must be comparable. We present a standardized set of techniques for surveying birds in oceanic habitats, with instructions for their use by anyone planning to contribute to this bank. With modifications, we have relied on the codes and data formats established and standardized by the National Oceanic Data Center (NODC) of the National Oceanic and Atmospheric Administration. Researchers interested in developing similar survey programs can contact NODC at their Services Division in Washington, DC, or their Alaska regional office in Anchorage, for complete and current listings. Similarly, researchers can contact the U.S. Fish and Wildlife Service, Office of Migratory Bird Management Bird Banding Laboratory, for alpha codes relating to all North American bird species.

Working conditions aboard different vessels vary considerably and can greatly affect the quantity, quality, and type of data collected. Frequently, marine bird or mammal observations are secondary to the major purpose of a cruise and the observers on board have limited ability to set itineraries such as cruise track, speed, and duration. A cruise protocol may or may not be established before leaving port and changes in ship routine may be necessary on short notice during the cruise. Not all ships are equipped to provide accurate or timely information on weather and water conditions; in some cases even accurate positions and ship speed are difficult to obtain for individual transects. The obvious consequences include small sample sizes and incomplete data sets. While this manual deals with shipboard techniques developed for Alaska, we offer it as a model for planning or conducting seabird surveys anywhere in the world. The codes and formats that we describe can also be used for aerial surveys. The reader is refered to Savard (1979) and Forsell and Gould (1981) for techniques of aerial shoreline surveys, and to Harrison (1982) and Briggs et al. (1985) for pelagic aerial survey techniques.

Shipboard Surveys

Most shipboard investigators of marine bird populations have relied on modifications of line- or strip-transect methods and have reported their results as indexes of occurrence or abundance, supplemented with anecdotal information (e.g., Jespersen 1930; Wynne-Edwards 1935; King and Pyle 1957; Kuroda 1960; Bailey 1968; King 1970; Shuntov 1972; Gould 1974; Brown et al. 1975a, 1975b; Ainley and Jacobs 1981; Powers 1982; Blake et al. 1984). These methods, however, have differed greatly, especially in handling such problems as locating and counting a variety of species differing in behavior and conspicuousness. Among the early pioneers, Wynne-Edwards (1935) demonstrated the importance of structured observations related to unit of effort and repeated in the same area in different seasons and years. He also recognized the need for special handling of ship-following species. Wiens et al. (1978) analyzed differences in detectability as they affect measurement of densities of birds at sea, and suggested techniques that allow for greater control of specific bias-producing factors (e.g., flying birds and determining the distances at which birds are first detected). However, the effort needed to reduce the entire suite of biases inherent in transect surveys of seabirds seriously reduces the cost-effectiveness of the surveys and thus limits their usefulness. This is especially true if information in addition to abundance and distribution (e.g., behavior or age structure) is being sought. Griffiths (1981) discussed biases produced by the effect of the ship on the behavior of birds at sea. Bailey and Bourne (1972) and Tasker et. al. (1984) discussed problems involved in counting birds at sea and called for standard techniques. Bailey and Bourne (1972) stressed the need to use 10- or 15-min transects that could be analyzed separately or could be combined, depending on local density and distribution patterns. Tasker et al. (1984) reviewed the major types of at-sea survey techniques and recommended three major components of the system we describe—a 300-m-wide strip census, 10-min duration counts, and an instantaneous count of flying birds. Haney (1985) and Tasker et al. (1985) also discuss methods of counting birds at sea, with an emphasis on standardized methods.

Our survey method evolved from attempts to accumulate the maximum amount of information on the distribution and abundance of marine birds within realistic time, money, logistic, and environmental constraints (Gould et al. 1982). Of primary importance was the establishment of a standardized system that would be easy to use and teach, and that would provide consistent results in a system useful for both management (monitoring and inventory) and research programs.

We use strip census techniques to develop indexes of density (birds per square kilometer per transect). These indexes, while not being actual counts, are consistent within the data base and provide a baseline from which one may define changes in the size and distribution of seabird populations in time and space (Forsell and Gould 1981; Gould et al. 1982; Gould 1983). When conditions do not permit the use of strip transects, we suggest five supplemental techniques: skiff counts, station counts, ship-follower counts, coastline counts, and general observations. These additional methods are a part of the standardized system but are adaptable to a variety of geographic conditions.

Sampling Design for Strip Transects

Serious consideration and planning should be given to sampling design before leaving port. Once the cruise has begun, the sampling design should rarely be changed. Special sightings, such as large flocks, which cannot be predicted but are important to record, are handled by supplemental techniques (see General Observations). Situations do arise, however, that make it worth modifying the sampling design. A change in the cruise plan would require a reevaluation of sampling design to accomodate new areas. Encountering unexpected habitat features would make it worth extending a set of 3 transects into a set of 12 or more. In such a case, however, it would still be correct to code the additional transects as general observations, especially if the habitat change is small, very localized, of short duration, or not likely to reoccur. Experience in both observation and data analysis makes these decisions easier.

Pelagic Areas

There are three strategies that work well in pelagic areas, depending on the mission and schedule of the cruise. Single transects, or sets of transects, may be conducted at preset times throughout the cruise, but the observer should be consistent in the number of transects used during each observation (e.g., one per hour). Three consecutive 10-min transects every hour works well in most situations. This type of sampling is useful to observers who have other duties during the cruise and only limited observation time.

Transects taken continuously for an extended period of time are used while a ship is moving between two points, or when conducting radials either perpendicular to a given location (such as a breeding colony) or parallel to it (along or across a habitat such as the ice edge, fronts, or continental shelfbreak). If only a single observer is available, short breaks should be inserted in the series at predetermined intervals. If two or more observers are available, they should alternate recording transect data (hourly), or one should scan the transect while the other transcribes data and occasionally relieves the first observer.

With dedicated ship time, the observer can take sets of transects within each identifiable habitat in the study area. Unfortunately, our knowledge of the oceanography of most areas is limited and it usually takes a considerable amount of sampling to identify and define oceanic habitats. Kessel (1979) has classified major habitat types for Alaska and Favorite et al. (1976) describe the marine environment of the subarctic Pacific in terms of domains and current systems. There are a few fairly reliable clues that can be used to identify habitats, such as major or rapid changes in surface water temperature, depth, or salinity. The problem of adequate sample sizes for habitats has still not been resolved for our techniques. Seabirds are frequently clumped, even within apparently homogeneous habitats, and their distribution pattern may change dramatically in a relatively short time: a density index of 1 bird per square kilometer at 0800 h in a given location may change to 1,000 birds per square kilometer in the same location at 0900 h. This is particularly true for species, that may occur in very high densities and tend to form enormous, short-term aggregations from many small, wandering flocks (e.g., the short-tailed shearwater, *Puffinus tenuirostris*). The number of transects needed to adequately form a mean density index for a given area will vary depending on the distribution of birds, the homogeneity of the habitat, and the extent of the habitat. Sample sizes should be as large as possible.

Seabirds are not uniformly or predictably active throughout the day, and different species almost certainly have different activity cycles. This variation should be recognized and allowed for by conducting surveys during as many parts of the day as possible.

Bays

Most bays and passes have varied bottom topographies, substrates, and tidal conditions. These factors affect the distribution of marine birds and their foods, and dramatic changes in abundance often occur over short distances and times. Transect paths within these habitats should sample the varied bottom topography; for example, zigzagging from shore to shore across the area. Sample as many of the habitats available to marine birds as possible, hopefully sampling each habitat in proportion to its availability to the birds. Shoreline habitats are usually undersampled when following the zig-zag pattern suggested above. When possible, adjustments should be made to the cruise tracks in order to bring the percentage of coastline sampled closer to the percentage of other habitats sampled. Timing of transect coverage is more important in bays than it is in pelagic areas; tides, for example, have a great effect on seabird activity within bays and passes.

Observation Techniques for Strip Transects

Each survey unit (e.g., 10-min counting period) is called a transect. The width and length of the transect define a rectangle; the area within the rectangle is the count zone of the transect (Fig. 1). Determining whether a bird is or is not counted depends on how a transect is defined and on the location and movement patterns of the birds. We recognize three basic types of flight patterns for this purpose: (1) feeding flight is when the bird actively

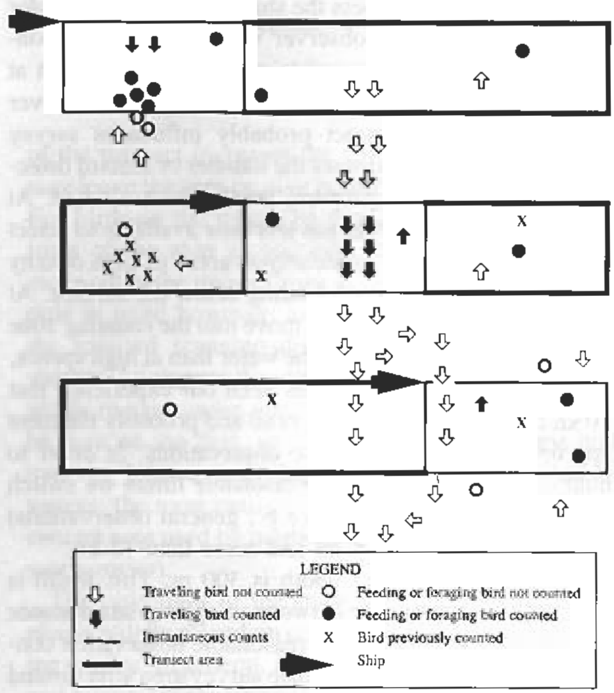

Fig. 1. Bird sightings to be included or excluded from transect, with three instantaneous counts of flying birds.

feeds, usually remaining within a relatively small area; (2) foraging flight is when the bird is moving slowly in a search pattern back and forth over the water or milling above a food source; and (3) traveling flight is when the bird is headed in a straight line, generally at a fast pace, and is not concerned with the waters immediately below it. A sighting is the observation of a single bird or group of two or more birds acting as a unit (e.g., a feeding flock).

The basic survey technique requires the ship to move along a straight path at a constant speed. For a specified length of time, an observer counts birds observed on one side of the ship out to a specified distance and forward of mid-ship until the end of the transect (Fig. 1). All feeding and foraging birds are counted whenever they are observed within the count zone. Birds in each sighting are counted only once, thus birds in a feeding flock that are outside the count zone when the flock is first sighted cannot be counted later as being within the transect. Traveling birds are counted only during periodic "instantaneous" counts (see Counting Birds).

Area Surveyed

The area surveyed during each transect varies with the ship's speed, the width of the count zone, and the duration of the observations. Different ships have different cruising speeds and unless the ship is dedicating time for bird observations, the observer will not be able to control this speed; thus, transects will have to be taken at many different speeds. The speed at which the observer moves along the transect probably influences survey results, but how it influences the number of seabird detections has never been properly studied or evaluated. At high speeds, the observer has less time available to detect and identify all birds, especially in areas of high density and areas where birds are feeding below the surface. At slow speeds, more birds may move into the counting zone and become associated with the water than at high speeds, thus inflating the count. It has been our experience that 10 kn is an average cruising speed and probably the most appropriate speed for pelagic observations. In order to hold data variability within reasonable limits we switch to supplemental techniques (e.g., general observations) at speeds of less than 6 kn and more than 15 kn.

Our standard transect width is 300 m. This width is essentially a compromise between an appropriate distance for detecting all birds under reasonable observation conditions and covering an adequate survey area with limited time and money. Detection of all birds—especially the smaller species—out to 300 m becomes difficult or even impossible when the seas are rough, or when rain, fog, or reflected sunlight reduce visibility. The height of the observer above the water also affects detection distance and a 300 m width may not be practical from a small boat except under ideal conditions.

Thus, surveys using 300-m widths are not always possible. The problem with narrower transects is that as the ship approaches some birds tend to move away from the ship, leaving the count zone and creating higher densities farther out. When most of the birds cannot be detected out to 300 m, the observer may wish to reduce the transect width to 200 m. If 200 m is too far, then only general observations should be conducted.

The ability to estimate distances is of major importance in conducting shipboard transects. Distance estimation is principally affected by the height of the observer above the water. An observer 15 m above the water often overestimates the transect width because his line of sight to the distal boundary of the survey zone is longer than that of an observer only 4 or 5 m above the water; the latter tends to underestimate because he or she perceives a foreshortened distance. Choose an observation spot as high as possible, especially on small ships. The flying bridge is usually a good choice if it is available, because it affords an ample view of the count zone. On large ships, the bridge wing may be high enough and more convenient than the flying bridge. It is rarely advisable to conduct observations from inside the pilot house.

Many techniques and kinds of equipment are available to aid in determining distances, and a primary objective of the observer when first boarding a ship should be to develop an accurate method of estimating the transect width. Most harbors are very accurately charted. Locate several objects that are known distances from the ship (e.g., 300, 500, and 1,000 m) and spend some time looking through your binoculars and getting oriented to these distances. Often you will be able to relate the distance to the sizes of birds. The relative sizes of bird species on the water is quite helpful. Practice in the harbor before leaving on the cruise will help you to use bird sizes in judging distances during a survey.

Heinemann (1981) developed a range-finder for pelagic bird censusing that can help maintain consistency in determining the border of the count zone during transects. A set of dial or slide calipers can be used as the range finder. The major limitation of this device is that the horizon must be in clear view; thus, it is not usable in bays, fog, or in rough seas. The up and down motion of the ship adds to the difficulty of using the instrument. The rangefinder's accuracy is considerably reduced at heights of less than about 8 m because the angle is so slight that minor differences in the setting will greatly affect the estimate. Other considerations in using the device are described by Heinemann (1981). Always check the range-finder during the cruise with objects whose distances can be verified by radar or other means (e.g., other ships or buoys). See Siniff et al. (1970) for another useful type of range-finder.

On small ships and where the horizon is not visible, a good technique is to trail a cylindrical buoy or other marker behind the ship so that it is 300 m behind the observer. Use floating line that will not stretch too much and has several hundred pounds breaking strength. Ship followers may congregate around this buoy enabling the observer to keep track of them as well as judge the size of birds at a known distance. If the ship's speed is known, estimates of distance can be checked by timing how long it takes to approach a floating object. When the ship is approaching floating objects such as logs, buoys, trash, or even birds, observers should estimate when the ship is an arbitrary distance (e.g., 300 m) and time how long it takes the ship to reach the object. By matching the resulting figures with those in Table 1, observers can check their estimation of distances. Be aware that currents affect the estimate depending on the relative directions of the ship and current.

Table 1. *Number of seconds*[a] *required for a ship to cover specific distances at selected speeds.*

Speed	Distance traveled (m)			
(kn)	200	300	500	1,000
6.0	64	96	160	320
6.5	59	89	148	295
7.0	55	82	137	274
7.5	51	77	128	256
8.0	48	72	120	240
8.5	45	68	113	226
9.0	43	64	107	213
9.5	40	61	101	202
10.0	38	58	96	192
10.5	37	55	91	183
11.0	35	52	87	175
11.5	33	50	83	167
12.0	32	48	80	160
12.5	31	46	77	154
13.0	30	44	74	148
13.5	28	43	71	142
14.0	27	41	69	137
14.5	26	40	66	132
15.0	26	38	64	128
15.5	25	37	62	124
16.0	24	36	60	120
16.5	23	35	58	116

[a] $\frac{1.92 \times \text{distance (m)}}{\text{speed (kn)}} = \text{seconds.}$

Duration of Observations and Length of Transects

The duration of observations not only affects the amount of area surveyed, but several other important variables, especially frequency of occurrence. Short transects cover small areas, but provide a large sample size. Long transects are less likely than short transects to miss uncommon species, thus they reduce the sometimes severe problem of accumulating many transects with no birds; many transects without sightings compound the difficulty of analyzing the data. Short transects allow observers to count bird numbers in rapidly varying habitats and have the advantage of being easier to fit into a tight schedule or into small bays and fjords, while long transects have the advantage of requiring less paper work per set of observations—not an inconsiderable problem. In the past, we have used both 10- and 15-min transects. We now use only 10-min transects. Remember that the greater the variability within or between data sets, the more difficult the data are to analyze and compare.

Counting Birds

Detecting and identifying birds at sea is a skill that has to be developed. Do not depend on your naked eyes to spot birds. Make frequent sweeps of the entire count area with your binoculars. Scanning forward to the end of the transect increases the chance to detect birds that may leave the area or dive before the ship reaches them. For birds on the water, be sure to count them as far in front of the ship as possible, since they may dive or move out of the transect zone as the ship approaches. Keep time in mind however; as the transect end approaches, the forward scanning distance becomes progressively shorter. Look over the same area more than once. Many alcids remain under water for a long time and may not be seen on the first, or even second, scan. Some birds may be located and identified by sound. In Alaskan waters, the most easily heard and recognized call is the contact note used by marbled murrelets (*Brachyramphus marmoratus*).

The objectives of the study will dictate whether emphasis will be placed on counting individuals or identifying species. In general, it is more important to detect birds and accurately enumerate them than it is to identify them. For example, it is more important to count all murres (*Uria* spp.) than to spend excessive amounts of time trying to identify each bird to species. Usually enough birds are identified to species to provide a guide to interpreting unidentified birds. If birds are being missed because the observer is concentrating on identification, the observations should be coded as "general observations" and not used to develop indexes of abundance. Studies devoted to single species can make use of our techniques, but the surveys cannot be pooled with data relating to total seabirds.

Concentrate on the actual count zone and do not spend much time scanning outside of that area. Uncommon sightings and flocks observed outside of the count zone should be recorded, but they should not be actively sought, as this can result in birds being missed within the count zone itself. Perception of the transect's width narrows with distance, and it does not appear to be as wide at 1,000 m as it does at 100 m; take this into account when deciding which birds should or should not be recorded as within the transect zone. One often has to wait until a bird is directly abeam of the ship to decide if it is within the transect zone—but be cautious, for by that time the bird may have moved out of the zone in trying to avoid the ship. Record all sightings of marine mammals and of bird flocks greater than 1,000, whether they are in or out of the count zone. In the case of large flocks over large areas try to make one estimate of total flock size even if it may extend for several miles.

Theoretically, one is attempting to obtain an instantaneous count of birds within the count zone rectangle (Fig. 1). Birds that enter the count zone from behind the ship (area already surveyed) are not counted, while those that enter or leave in front of the ship are counted. There is one exception to the rule about not counting birds entering the count zone from behind the ship. If traveling birds are moving in the same direction as the ship, then those in the count zone during instantaneous counts should be recorded.

Large numbers of traveling birds present a special problem. If the observer counted all the individuals flying through the count zone, density indexes would not only be greatly exaggerated, but would reflect birds using the air corridor over the water rather than being associated with the water itself. To reduce this particular bias, we have a special method of counting traveling birds.

When there are traveling birds passing through the area each individual is not recorded. Instead, we make instantaneous counts of these birds within successive sections of the count zone (Fig. 1). The number and size of instantaneous count zones depends on the maximum distance at which all of the traveling birds can be detected and the speed of the ship. The area covered by all of the instantaneous counts added together always equals the total transect count zone. For example, during a 10-min transect at a speed of 10 kn, the ship would cover a total distance of 3,087 m (Table 2). For large flying birds, we would take three instantaneous counts each covering an area extending about 1,000 m ahead of the ship and 300 m to one side. One count would be taken at the start of the transect, one at 200 s (ca. 3.3 min) into the transect, and one at 400 s (ca. 6.7 min) into the transect. The three counts added together would be our estimate of the number of traveling birds in the entire transect at any one time. Value judgements as to distance and whether to include this or that bird become easier and more trustworthy with experience. For smaller flying birds, such as storm-petrels (Hydrobatidae), an instantaneous count zone of 300–500 m is usually more appropriate. Instantaneous counts to 300 m ahead of a ship moving at 10 kn would be taken at approximately 58-s intervals. If birds are sitting on the water or there are other indicators of position, instantaneous counts can be judged by these objects rather than by the time and speed of the ship. In summary, instantaneous counts are an attempt to obtain a single picture of traveling birds within the total count zone at any one time by putting together a series of smaller pictures.

Occasionally a judgement will be required as to whether to use instantaneous counts for a large flock of foraging birds. Normally such flocks are counted only once when first observed, but if the flock is larger than the total transect then it may be more appropriate to treat them as traveling birds and use the instantaneous count method. The distance from the observer to the end of the transect at various ship speeds can be obtained from Table 2.

A situation requiring special treatment is that of a large flock of birds being deflected in front of the ship; for example, 10,000 short-tailed shearwaters, all in one flock, streaming along the side of the ship and then across the bow. The flock is continuously passing in front of the ship because it is being deflected forward (Fig. 1). Such a flock should only be counted once (i.e., in the first instant count) and then ignored in all future counts.

Land birds and flocks of shorebirds that are obviously just passing over the area on migration or moving between two distant points are handled differently than marine birds. By using proper coding techniques (see Appendix B), these sightings can be included in the data base without influencing density indexes.

Estimating numbers is a major source of bias in surveys. Before going into the field, practice estimating large numbers of objects such as beans on a table or birds in pictures (Arbib 1972). Most field observers estimate the number of birds in large flocks by counting in 10's or 100's. This requires the observer to maintain a firm mental

Table 2. *Meters to the end of the transect per minute into transect.*

Speed made good (nmi/h)	Minutes into transect														
	00[a]	01	02	03	04	05[b]	06	07	08	09	10	11	12	13	14[c]
6.0	2,778	2,593	2,408	2,222	2,037	1,852	1,667	1,482	1,296	1,111	926	741	556	370	185
7.0	3,241	3,025	2,809	2,593	2,377	2,161	1,945	1,729	1,512	1,296	1,080	864	648	432	216
8.0	3,704	3,457	3,210	2,962	2,716	2,469	2,222	1,975	1,729	1,482	1,285	988	741	494	247
9.0	4,167	3,889	3,611	3,334	3,056	2,778	2,500	2,222	1,945	1,667	1,389	1,111	833	566	278
10.0	4,630	4,321	4,013	3,704	3,395	3,087	2,778	2,469	2,161	1,852	1,543	1,235	926	617	309
11.0	5,093	4,753	4,414	4,074	3,735	3,395	3,056	2,716	2,377	2,037	1,698	1,358	1,019	679	340
12.0	5,556	5,186	4,815	4,445	4,074	3,704	3,334	2,963	2,593	2,222	1,652	1,482	1,111	741	370
13.0	6,019	5,618	5,216	4,815	4,414	4,013	3,611	3,210	2,609	2,408	2,006	1,605	1,204	803	401
14.0	6,482	6,050	5,618	5,186	4,753	4,321	3,889	3,457	3,025	2,593	2,161	1,729	1,296	864	432
15.0	6,945	6,482	6,019	5,556	5,093	4,630	4,167	3,704	3,241	2,776	2,315	1,852	1,389	906	463
16.0	7,408	6,914	6,420	5,926	5,432	4,939	4,445	3,951	3,457	2,963	2,469	1,975	1,482	988	494

[a] Meters traveled in 15 min (= start of 15-min transect).
[b] Meters traveled in 10 min (= start of 10-min transect).
[c] Meters traveled in 1 min.

1 nautical mile = 1,852 meters = 6076.12 feet.

picture of 10 or 100 birds. Distant flocks usually appear to have fewer birds than is actually the case because many will be hidden by other birds or by waves and swells; some birds in feeding flocks may even be sitting on the water or diving beneath it. Distant vision at sea may also be impaired by atmospheric conditions such as rising heat and mist, which tend to obscure birds. Do not become overwhelmed with large numbers of birds; continue to count numbers of birds rather than to make guesses.

Support Data

Before departure, observers should learn as much as possible about the activities and protocol of the ship. They should meet with the appropriate officers and crew to explain what research will be conducted and what help will be needed. Techniques should be explained, stressing the importance of the ship maintaining a constant speed and course during observation periods. Plan your observation periods ahead of time and try to stick to the plan. Let the officers and crew know when you will be making observations and have them inform you about projected maneuvers and course changes. You can leave a standing call to be notified when large concentrations of birds are encountered, but use these times for general observations rather than transects. It is important that you conduct transects throughout the survey in accordance with your regular schedule. Do not add or delete transects just because you encounter exceptionally high or low bird densities. In planning your schedule do not try to cram as many observations into a day as possible. Remember that you have lots of paper work to do for each transect you take, and that you see fewer birds when you are tired. It is preferable to collect a few data of high quality than many data of only moderate quality. The NODC defined many support fields that we have elected not to use because the time and effort needed to record, transpose, and analyze them would prevent accomplishment of our primary goals. The two most important pieces of supporting data that must be obtained for each transect are the correct position and the speed made good.

Position

Do not simply accept positions given by bridge personnel, especially if they are being read from a LORAN C or satellite navigation system—these systems can be inaccurate and may vary from minute to minute. If land can be detected on radar, it is best to get a position by measuring the distance from at least two, and preferably three, distinct landforms; the correct position is where the arcs of the distances cross each other. Try to plot the position on a nautical chart immediately to be sure there are no errors, and record the depth from the chart. If the position matches an electronic system such as a LORAN C interpolator, it can be assumed that the electronic system is correct and positions can be taken from it for the next hour or two. The position should be checked at least every 2 h. If the ship is too far from land to obtain good distance readings from a radar, or only one distance is available, the position from the LORAN C can be checked by a combination of depths, LORAN C lines, and bearings to a land mass.

To interpolate between two good positions, divide the speed in knots by 60 and multiply by the minutes duration of the transect. This gives you the distance traveled on each transect. This distance can then be stepped off with dividers between the beginning and ending positions, and each new position can then be read from the chart. The positions should always be calculated as soon as possible after the observations. When obtaining positions from a chart, the depth should also be taken and compared with the depth obtained from the ship's equipment. If the ship's crew are not plotting positions on a nautical chart at least every 2 h, do so yourself, and be sure a position is taken at every course change. Check all of your positions for a logical and consistent progression. Write all the particulars of the fix in the field notes on the data form.

Speed

The speed made good can be calculated by obtaining two accurate positions (preferably at least a couple hours apart) and measuring the distance between the two points with a pair of dividers. Move to the left or right edge of the chart at the same latitude (the scale varies with latitude on a mercator projection) and measure the nautical miles on the latitude scale. One nautical mile is equal to 1 min of latitude, and 1° of latitude is equal to 60 nmi. The speed made good is obtained by dividing the nautical miles traveled by the elapsed time (expressed in tenths of hours). The speed made good is the distance traveled over the ocean floor. Due to tides, or the action of currents, the speed made good may be different from the speed through the water. In most cases, the difference between the two speeds is negligible, but in some passes, water may flow at a rate of several knots. Birds are usually associated with the water column, thus moving with it, and speed through the water may give a more accurate representation of bird density than speed over the bottom. Many research ships are now equipped with water speed indicators, and in areas of fast moving currents the speed through the water should be used. Speed is always taken in nautical miles per hour (knots). One knot is equal to 1.15 statute mi/h or 1.852 km/h.

Depth

Depths can be read directly from a fathometer by yourself or by a crew member. If positions are accurate and navigation charts of sufficient scale are available, depths can be determined directly. However, it is always best to use the fathometer. We often record the depths in fathoms below the field on the transect form and convert it to meters at a later time (1.83 m = 1 fathom).

Temperature and Salinity

Sea-surface temperature and salinity are obtained in various ways. The ideal method is a continuously recording thermo-salinograph, which records both temperature and salinity on graph paper. Most ships measure sea temperature at the water intake for cooling their engines. This is often a couple of meters below the surface, but mixing is generally sufficient to get reasonable readings. Large ships usually record this temperature each hour. Unfortunately, the reading may be done by different persons during each day and often little care is taken when reading the thermometer. Ask to see where the temperature gauge is located and impress on the engine room personnel the importance of consistent and accurate readings. The best method is to check the temperatures yourself at the beginning and end of each series of transects. Both water temperature and salinity can be measured with inexpensive hand-held devices using water samples freshly collected in a bucket over the side of the ship. Take the sample on the side of the ship opposite the outlet for hot water from the engines. Occasional bucket temperatures should be taken to check on the more frequently obtained intake temperatures. Depth, temperature, salinity, and other environmental data are best taken at the mid-point of each transect, but it is often more convenient to obtain them at the beginning. In either case, be consistent throughout the survey.

Ice

The presence of ice is an environmental variable that affects the density and distribution of birds at sea. Coverage and pattern are the most important features of ice both inside and outside of the count zone. The distance to the ice edge is also important, especially out to 20 mi, and should be recorded whenever possible.

Miscellaneous

Seabirds may react to meteorological events (Manikowski 1971) and we record barometric pressure, weather, and wind speed for each transect. Sea state, swell height, and tide are low priority items and are not recorded when time is scarce.

Survey Procedures

Make sure all necessary environmental data (e.g., depth and temperature) and locational data (e.g., positions and speed) will be available and that the bridge personnel know that you are beginning observations. Select the best point on the ship from which you can obtain an unobstructed view of the potential count zone. Set your watch to match your time with that of the ship. Obtain from the bridge the ship's approximate speed and direction. Determine how many instantaneous counts you will need to fill up the transect. Recording begins with all environmental data, such as barometric pressure and sea state, and a determination of the observation conditions. Spend several minutes studying the birds in the immediate vicinity of the ship, noting the general behavior of all birds within the area, and then record the maximum number of each ship-following species on the transect form. Bow-riding porpoises are handled the same as ship followers. Begin the transect by making the first instantaneous count.

Supplemental Techniques

Skiff Counts

Transects can be conducted from skiffs. All birds are counted within a specified distance on both sides of the skiff; 50–75 m on each side is a fairly standard distance if the observer is sitting, and 75–100 m if standing. The area covered by the survey is determined by the distance between a starting and ending position, rather than by speed and time. To obtain accurate positions it is best to conduct transects between known points of land or buoys. Linear distance (in hundreds of meters) should be placed in columns 76–78 of the coding form (Fig. 2).

Coastline Counts

Coastline surveys are best conducted from platforms such as skiffs or small ships. The observer should stay as far offshore as possible, while still being able to detect and identify all birds on the water and roosting on shore. All birds between the shore and the platform and from the platform to the limit of visibility on the other side of the platform are counted. On this type of survey, birds on shore can be included by recording them with a "4" in the Zone column. Usually the width of the count area is about 75 m on each side, but it varies with visibility and water conditions. Density estimates are impossible to construct, and the unit of analysis is birds per kilometer of coastline. We recommend using distinct headlands as the divisions between counts so counts can be readily repeated.

Ship-follower Counts

The only time a ship-following bird is coded as being in a transect is when it joins the ship for the first time (i.e., before it becomes a ship-follower). Otherwise, ship-following birds are not included in density indexes. It is worthwhile, however, to keep a continuous record of their numbers, especially when individual birds cannot be separated. On every transect the observer records the largest number of each ship-following species seen at any one time. Ship-follower counts add to the observer's awareness of what birds are in the area and how the birds are reacting to the ship. In addition, they help an observer determine whether to count birds approaching the ship and whether a sighting represents a new bird or one counted previously.

Station Counts

These counts are taken from a fixed point, usually from a ship stopped for oceanographic sampling or fishing. These counts are valuable for determining the numbers of birds that may be dependent on fishing vessels or are vulnerable to pollution from ships. They also provide an excellent opportunity to obtain ratios (e.g., color phases, age, sex, species). The survey area is generally a circle with a 300–600 m radius and the observer at the center. All birds are counted within the count zone by making a circular sweep of the entire area as rapidly as is consistent with accurate detection and counting of birds within the area. Only one sweep is made per survey. The length of time the ship has been stationary should be recorded for each survey, because numbers of birds usually continue to increase for a long period after the ship has stopped. The best place to record this information, along with pertinent information on the ship's activity, is in the Field Notes section of the data sheet. Whenever possible, these counts should be repeated every 30 or 60 min.

General Observations

Important incidental observations should be recorded and are maintained within the data base. Of particular importance are the location of feeding flocks, large assemblages, and rare species that would not otherwise be recorded. General observations are used: when transects terminate before the designated time; when the ship makes large-scale changes in course or speed during the

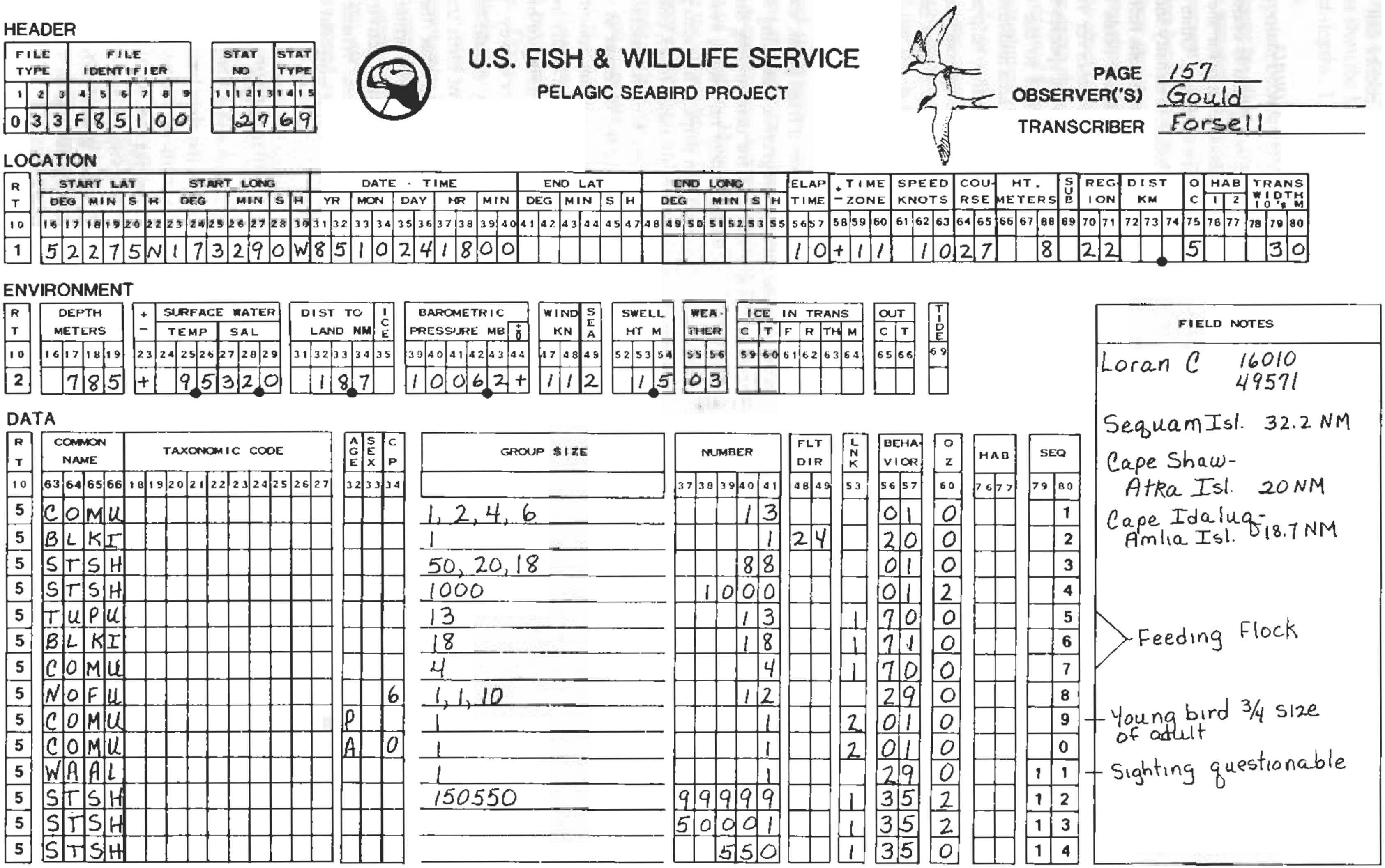

Fig. 2. Annotated coding form for marine bird surveys.

transect; when other reasons invalidate the use of the observations to develop density indexes; between standard transects; or in areas and times where transects were not planned.

Record Keeping

Data collected during pelagic surveys are transcribed onto coding forms (Fig. 2) using information fields (Appendix A), and special codes (Appendix B). Data are then entered into the computer from the coding forms. These forms are usually filled in at the time of the observation, directly from binoculars to coding form (always if a second observer or helper is available). If it is impossible to record directly onto the form (e.g., because of high bird numbers), then tape recorders or waterproof notebooks can be used, but data should be transferred to the coding forms as soon as possible. The disadvantages of a tape recorder or notebook are in the time needed to transcribe information from one place to another, and in adding another step where transcription errors can occur. Transcription errors are a major problem in automating data. The tape recorder must also be checked frequently to be sure that it is not malfunctioning. As with the direct entry method, use of a notebook also distracts the observer's attention from the count zone. All marine mammal sightings inside and outside the transect zone are recorded using the same format as bird sightings, except that the codes for Behavior are different. Coding forms constitute our major field record, and as such should be filled out meticulously in pencil, double checked for accuracy, and kept clean and in a safe place. Any pertinent observations that cannot be coded should be printed clearly in the space provided under Field Notes. This should include documentation of all rare or unusual sightings. Figure 2 gives examples of proper entry of raw data onto the coding form.

Do not enter numbers into any field when the information is unknown or in doubt unless there is a specific code for unknown or doubtful. Zeros represent actual data. When a field (e.g., Station, Transect Width, Number of Birds) is used, zeros should not be placed in the columns to the left of the first significant number or letter entered (i.e., fill in zeros to the right but not to the left). For example, in the Station Number field, transect number 1 should be entered as "--1", transect 10 as "-10", and transect 100 as "100". If there are no birds observed within the count zone then the form is filled out with NONE or BIRD for the alpha identification code, a "0" in the Number column, and a "0" in the Zone column. Our data-entry program will automatically generate the taxonomic code when the proper species alpha code (Appendix C) is entered. It is thus necessary to enter the taxonomic code on the data sheet only if an alpha code is not listed.

We have developed analyses programs that require certain coding fields to be entered. These fields are listed and explained in Appendix A. It is of vital importance that observers read Appendix A carefully in order to understand coding techniques. The codes, coding forms, and placement of many of the fields were originally developed by researchers in the Outer Contentinal Shelf Environmental Assessment Program. We have tried to keep our format as similar as possible to the NODC file type "033" format and codes.

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