Methods for Shorebird Surveys in the Arctic[1]

Jonathan Bart[2] and Susan L. Earnst[2]

Introduction

A substantial effort is being made to develop a long-term monitoring program for shorebirds in North American (Brown et al. 2000, Donaldson et al. 2001, Bart et al. this volume). The current program, PRISM (Program for Regional and International Shorebird Monitoring), has four segments: arctic and boreal breeding surveys, temperate breeding surveys, temperate non-breeding surveys, and neotropical surveys. The arctic breeding surveys are intended to provide estimates of population size for each of the species and subspecies breeding in the arctic, to improve our understanding of distribution and abundance of breeding shorebirds, and to provide baseline data for future surveys that will be used to estimate trends in population size. More information about PRISM and how the arctic surveys will help accomplish the PRISM goals may be found in Bart et al. (this volume). This report describes the approach being used to survey shorebirds in the arctic.

The arctic surveys use double sampling to estimate numbers present on a sample of plots and habitat-based regression models to extrapolate from the plots to large study areas. The methods were developed during 1994-1997. Operational work was carried out during 1998-2001 and is continuing.

Plot Selection

Several methods have been used for plot selection, the best approach depending to some extent on habitat configuration. On the Colville River Delta and the eastern portion of the National Petroleum Reserve, where the field methods were developed, most shorebirds occur in wetlands which cover only a small fraction of the landscape and are sharply delineated from the surrounding upland (tussock tundra). In this situation, it proved effective to use computer methods to eliminate from the habitat map wetlands less than 5 ha in size (due to the logistic costs of reaching such small areas), and to delineate the remaining wetlands, principally

---

through repeated use of the Majority Filter command in ArcView, throughout the study area. We then selected one set of plots in the wetlands and one in the uplands. When a selected wetland exceeded 25 ha, it was subdivided into areas of 10-15 ha and one of these was randomly selected as the plot. Plots thus varied in size from 5-25 ha, and plot borders followed the very distinct borders between wetland and uplands. This approach was helpful because most birds were in the wetlands, but it was often hard to know where they were nesting. If a plot covered only a portion of the wetland, the surveyors would have had difficulty deciding whether birds they encountered should be recorded as within the plot or not. A small sample of plots in the uplands was selected by randomly choosing locations and regarding each one as the southwest corner of a 9-ha, square plot. Any portions of the plot that were in wetlands or unsuitable habitat (water, unvegetated areas) were excluded. This procedure sometimes resulted in very small plots being selected (e.g., because the selected point was just south of a large water body), and such plots were ignored. A better procedure would have been to work out computer procedures for combining such plots with an adjacent plot so that a true random selection of plots could have been made.

In other portions of the National Petroleum Reserve of Alaska, good areas are more extensive and less distinct. Many areas classified as uplands on the habitat map are flooded in June and may have as many shorebirds as the lower areas. The distinction between wetlands and uplands still seemed useful, because many upland areas had few birds. Delineating wetlands and selecting them as the plots, however, was not feasible because the wetland areas were much too extensive. Furthermore, it seemed wise to select equal-sized samples in the wetland and upland areas due to the higher density of shorebirds in areas classified as uplands. Another difference from the early work on the Colville River Delta was that we were using helicopters to access plots, and this limited our ability to have plot size – and therefore survey time – vary. The procedure we adopted involved an initial classification of the entire study area into wetlands, uplands, and unsuitable areas. A systematic sample of plots was then selected from throughout the study area, and a cluster of plots was selected at each point. The exact procedure for selecting the plots varied but in principle involved determining which habitat the initial point fell in and then, if the point was in

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

907

wetland or upland, expanding away from this plot following a pre-determined rule (e.g., move outward equally in all directions, but not crossing a habitat border, until the desired plot size was obtained). If the plot fell in unsuitable area, we selected another point. In the first year using this approach we needed a second plot, within walking distance. We did not want the plots closer than 1 km together to keep from sampling the same area, and they could not be more than 3 km apart to keep walking time reasonable. We accommodated these constraints by creating an annulus around the initial plot with a 1-km inner radius and 3-km outer radius and then randomly selecting points within this area until we obtained one in the desired habitat. The plot was then delineated by growing outwards from the point until we achieved the desired plot size. Variations of this approach were used in western Alaska, northeastern Alaska, and in Canada.

Rapid Surveys

In double sampling, a large sample of plots is surveyed with a rapid method and then a subset of these plots is surveyed intensively to determine actual numbers present. The detection rates on the rapid surveys of these plots are then used to adjust the results from rapid surveys. See Bart and Earnst (2002) for details of the general approach in bird surveys.

A first step in developing the method was defining the parameter at both the population and plot scale. For the population, our parameter was number of birds that occurred in the study area excluding young hatched that year. Various definitions of the number "present" on a given plot were considered. Assume that the study area is subdivided into plots in such a way that every point within suitable habitat falls in exactly one plot (i.e., suitable habitat is partitioned into plots). If the definition of "present" in a plot assigns every bird in the population to one plot, then the sum of the numbers present in all plots equals population size, and by selecting a random sample of plots we can estimate the mean number present per plot and thereby estimate population size, which was our primary goal. Other approaches to estimating population size might be imagined but we felt that assigning every bird to exactly one plot had substantial conceptual advantages so we considered definitions of "present on a plot" that met this requirement. An obvious approach would be to define present as meaning present at the time the survey started. This definition, however, was unsuitable because we could not conduct the intensive surveys to determine the "true" number present. Instead, we defined the number of birds on a plot as "the number of territorial males, and their mates, whose first nest of the season, or territory centroid for non-nesters, was within

the plot". We used "territorial" broadly to include all males that had a well-bounded utilized area. The term, however, did not include floaters because we could not imagine any way to assign floaters to a particular plot that would also allow field workers on the intensive plots to determine the number of floaters present on their plots. When we developed this definition, we believed that floaters are rare in most if not all arctic shorebird species and were therefore not too concerned with excluding these birds. Robert Gill (pers. comm.) has recently commented, however, that Rock Sandpiper (*Calidris ptilocnemis*) populations may include a substantial floater population, so this whole issue may require more work.

The general goals in developing guidelines for the rapid surveys were (a) that results would be as consistent as possible between surveyors if they could somehow all survey the same plot at the same time; (b) that the ratio of number recorded to number present would be as consistent as possible among plots, weather conditions, times of season, times of day, and so on; and (c) that the ratio of number recorded to number present would be as close to 1.0 as possible. The reasons for these rules are fairly clear, but it may be worth noting that double sampling does require that detection rates are constant. We only need to estimate the overall ratio, number recorded/number present, on all plots surveyed, and we must believe that this is an essentially unbiased estimate of the ratio that would be obtained if all plots in the study area were surveyed. Achieving the three goals above, however, makes the overall detection rate easier to estimate, and facilitates comparisons among sub-populations which does require an assumption that the detection ratio is similar or that separate estimates of it are made for each sub-population.

We considered distance methods as a rapid method but found that the birds responded too strongly to the observer with the result that assigning distances would be highly arbitrary and would therefore vary substantially between observers. Weather conditions and time of season also seemed to have a strong effect on movement behavior. We therefore did not study this method in detail, though we tentatively plan to do so in the future, as some other observers have found it useful.

The rapid survey method we adopted was an area search in which surveyors covered about 10 ha per hour and recorded all evidence that might help them estimate the number of birds present on each plot. This information was recorded on plot maps using predetermined codes for nests, probable nests, pairs, males, females, unknown sex birds, and groups. Surveyors were encouraged to add arrows for flights and other notes that might help them decide how many birds were present on the plot according to the definition above. Immediately after each survey, a summary

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

908

Table 1– *Example of field form used in the rapid survey portion of the double-sampling approach. Total is the row total; the estimate is often less than the total because the surveyor believes that >1 observation was made of the same pair.*

Species	Nests	Probable nests	Pairs	Males	Females	Unk. sex	Total	Estimate
BBPL	1			1			2	1
AMGP		1	1				2	1
SESA	2		3			2	7	5
PESA		2			1		3	3
etc.								

was prepared (*table 1*), and an estimate of the number of birds present was made. We always assumed that single territorial birds had mates (at some time during the season even if not when the survey was conducted).

The final estimate prepared after completing the rapid survey was clearly subjective. Accordingly, we developed detailed guidelines, summarized below, in an effort to insure that different surveyors, detecting the same cues, would record the same final estimate for number present. A general guideline was that we were seeking unbiased estimates of the number present, not the number known by the surveyor to be present. Only recording numbers known to be present would sharply reduce the detection ratio and some species would almost never be recorded as present. We suggested several guidelines for surveyors to help them adopt the approach of making unbiased estimates:

(1) When uncertain whether to record a bird as within the plot, try to define the generalization being followed and then ask whether following that generalization would tend to over- or under-estimate the number present. For example, some species do not flush unless the observer almost steps on them, they do not display conspicuously near the nest, and they cover large areas. This might cause a surveyor to be uncomfortable in recording an individual of such a species as present on a plot unless its nest was found. But the species would then almost never be recorded. Another approach is to record the bird if it appeared to be present on the plot at the start of the survey. Assuming that one member of each pair is incubating and thus essentially undetectable (or that it occurs with its mate when off the nest), this procedure would lead to a detection rate of close to 1.0. Conversely, birds that cover large areas flying, or that approach observers from a great distance, should obviously not be recorded because doing so would lead to detection ratios greatly exceeding 1.0. In general, however, most birds found in the plot, on the ground, should be included in the estimated total.

(2) When birds appear to be on the edge of the plot, the best procedure is probably to make a quick estimate of how much of the probable territory is within the plot. On a rapid survey, these estimates are crude, but habitat configuration and behavior of the bird – especially territorial interactions with others – do often provide useful information. The final estimate for number present may then be computed as the sum of the proportions of territories within the plot. Thus, if three territories were felt to be largely, but not completely, outside the plot, then counting one as within the plot would be reasonable. Another approach is to make a judgment for each bird at the time it is recorded.

(3) Deciding which sightings represent distinct pairs is often difficult, especially when density is high. The best remedy for this problem seems to be keeping track of different birds, observing each one multiple times during the rapid survey. The rapid survey thus differs fundamentally from point counts in which a small area is surveyed for a short time and the observer then moves on. In the area search, when densities are high, the surveyor spends much time scanning ahead and looking backwards to work out territory boundaries and sort out how many individuals and pairs are present.

(4) In large patches of suitable habitat, substantial problems may be caused by birds that approach the observer from far away. These birds may follow the surveyor for long distances, and it may be impossible to tell during the survey whether they are nesting on the plot. The best way to avoid the problems these birds cause is by watching for them when approaching the plot and by watching them again when leaving the plot. Moving well away from the plot to a good vantage point and then waiting a few minutes for these birds to return to their territory is also often effective.

A particularly difficult problem arises when nesting and foraging habitat occurs in patches large enough that they tend to be in different plots. We have studied

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

909

this problem in western Alaska especially with respect to Western Sandpipers (*Calidris mauri*) which nest in the uplands but forage in the lowlands. The two habitats are sharply separated from one another (by 1 m in elevation) and in many areas the patch sizes are large so that a given plot occurs in only one area. The problem is that the sandpipers are often recorded in lowlands where they do not nest. If plots were always in one habitat or the other, the guideline could be "don't ever record Western Sandpipers as present in lowland plots because they don't nest there". This would minimize variation in detection ratios from plot to plot but would also depress the overall detection rate since many – perhaps most – of the individuals detected would not be included in the estimates. Furthermore, and perhaps of greater concern, we suspect that patch sizes will be smaller in some areas so that plots will include both habitats. Thus, the guidelines, "don't record western sandpipers as present in lowland plots" would not be practical. The best solution is probably to insure that surveyors are knowledgeable about nesting habits of the species and to rely on them to judge the likelihood that a bird seen foraging in wetlands is nesting within the plot. Information from following marked birds on how far from their nest they routinely travel to forage would also be most helpful. This issue, however, merits more thought and study.

Intensive Surveys

The purpose of the intensive surveys is to determine the number of nests, or number of territory centroids for those individuals whose nests were not found, present on the plot. Any other information gathered, e.g., habitat associations or nest success, is secondary to this goal.

Locating and Marking Plots

There are typically a total of four intensive plots (approx. 12-14 ha each) per camp with each intensive observer assigned two plots. It is important for the observer to become intimately familiar with a plot, thus better not to share plots among observers. It is convenient, with respect to travel logistics and safety, to locate intensive plots in sets of two, one for each observer in each location. The importance of choosing intensive plots randomly among all plots is discussed below. Once chosen, the borders of the intensive plot should be well marked. Wooden stakes, either plain or tipped with orange paint, or pin flags work well; the former may be less attractive to curious jaegers and ravens, and do not rip apart in high wind, but are more difficult to carry and install. If landmarks are lacking and the habitat is homogeneous, it may be necessary to create a center line of markers to facilitate mapping and

re-locating territories and nests, but the number of markers should be minimized.

If an endangered species is discovered nesting, or is highly suspected of nesting on a plot, re-draw the plot borders to remain the approved distance (usually 200 m) from the likely nesting area or use an alternate plot.

Schedule

The short season places a premium on beginning as early as possible and working efficiently each day. For example, on the Colville River Delta, peak nest-searching was conducted from approximately 13-22 June, although during 8-12 June observers can become familiar with plots, and some nests can be found until hatch (roughly 1-4 July). Timing is optimal if one-fourth to one-half of nests found on the first day are 3-egg clutches. Given 10 days of peak nest-finding, each plot can be searched for a total of 5 full-day equivalents, with each plot covered every second day. Typically a full-day equivalent is approximately 8+ hrs on plot (travel time to and between plots is not counted). If travel time between plots is minimal, observers may wish to spend one-half day on each plot each day. Nest searching is efficient at all times of day, and can be conducted in all types of weather, except perhaps in extreme cold and rain which might cause egg cooling when incubating birds are disturbed. Nest finding is least efficient on windy days but worthwhile. On cold days, birds appear to flush closer to the observer, which increases the detectability of nests of species that typically flush at great distances, and makes the optimal nest-finding strategy one of intensive, systematic pacing rather than one of watching behavior.

Marking Nests

Nests should be marked with plain wooden pot markers (Forestry Suppliers sells a type that resembles a tongue depressor, pointed at one end), not a pin flag, at 1-2 m from the nest. A medium-point Sharpie can be used to write the species, nest number, distance, and an arrow indicating direction on the nest marker. We strongly suggest that each nest be plotted on a map and described on a nest card at the time it is found. Avoid leaving scent at the nest. Common mistakes include the following: touching vegetation around the nest with hands (use a stick or nest marker if necessary), standing at the nest while making the nest card or marker (move away a few meters where you can still see the nest), or placing a backpack or notebook on the ground near the nest. On the day preceding the first rapid survey of the intensive plot, all nest markers must be removed to avoid providing cues to rapid surveyors. Small, unobtrusive sticks placed flat on the ground, perhaps pointing in the direction of the nest, can be substituted for nest markers. It may be necessary to add

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

910

additional sticks as landmarks and further notes to nest cards.

Nest Cards

Nest cards are recommended for recording and re-locating nests even if nest monitoring is not an objective. We use a 4 x 6 inch custom-printed card with a large box on the front for a drawing of nest location; cells at the top of the card for observer's initials, species, nest number, and pair identity; and smaller cells near the bottom for optional nest and vegetation measurements of interest to the particular study. The back of the card contains one row for each visit to the nest, and columns for date, number of eggs, number of chicks, number of parents present on the plot, comments, and observer's initials. The essential part of the card is the drawing and description of nest location. The description should be written to allow a naive observer to find an empty scrape (i.e., in the case of predation). A common error is to write a less detailed description because a nest seemed easy to find due to the behavior of the flushing bird or the visibility of the eggs, neither of which may be present on subsequent visits. Use landmarks, number of paces, and cardinal directions to guide the observer from one landmark to another, then to the nest marker, and then to the nest. Keep the distance between landmarks short, especially if landmarks are small – it is much easier to consistently find a tongue depressor after 3 paces than after 50 paces. A crude drawing indicating the landmarks, paces and direction between landmarks, the nest marker, and the nest is very useful. In a landscape with many landmarks, such as on the Colville River Delta, we found that compass bearings were unnecessary and too time-consuming both while writing the card and re-locating the nest, but they may be useful in other habitats.

Numbering Nests

Each observer numbers his/her nests consecutively regardless of species or plot. The most common error is to use a number more than once; if separate runs were kept for plots or species, the potential for this error would multiply. At the beginning of the season, one observer is assigned the numbers 1-99 for his/her exclusive use, the second observer is assigned 101-199, etc. It is advisable for each observer to keep a list in a field notebook of nest number, species, plot, and day on which it was found. On maps and in notes, refer to nests by species and number (e.g., SESA 14).

Probable Nests

The definition of a probable nest (PN) is a location from which an individual flushes using a broken-wing, rodent-run or other distraction display. The location must be precise enough for the observer to be certain that the actual nest is on the plot. No other definitions of probable nests are acceptable. Probable nests should be numbered, mapped, recorded on nest cards, and mentioned on daily summary sheets. Refer to a probable nest as species-PN-#, for example, SESA-PN-15.

Scheduled Visits to Nests

It is important that intensive plots not have higher rates of nest loss than other plots, and thus important to visit nests as infrequently as possible. Curiosity leads observers to visit nests more often than necessary. We recommend the following scheduled visits: a) the day on which the nest marker is removed preceding the first rapid survey; and b) the day following the final rapid survey. If estimating nest success is a study objective, and if the final rapid survey is >3 days from estimated hatch, then each nest may be visited a final time approximately 3 days prior to hatch. There are several reasons not to visit near hatch: a) knowing nest outcome at hatch is not necessary for use of the Mayfield method; b) adults and newly hatched chicks easily become separated when disturbed; and c) it is usually not possible to tell whether an empty scrape was successful or not (except by a very detailed examination for shell fragments which can be done well after hatch). Note the results of each nest visit on the nest card; indicate that the visit was scheduled. Only scheduled visits should be used in estimating Mayfield daily survival rates.

Unscheduled Visits to Nests

During the course of nest-finding, a bird incubating a known nest may be visible from a distance or may be accidentally flushed. Record this information on the nest card as an unscheduled visit. Despite the risks of increased nest loss, it is important to continue intensive nest-searching in the vicinity of a known nest, even if the bird flushes as a result. On the Colville River Delta, it was not uncommon to find nests of other species within 1-2 m of a known nest, and Semipalmated Sandpipers (*Calidris pusilla*) sometimes nested within 1 m of a conspecific. Similarly, it may sometimes be necessary to flush a bird from a known nest to determine whether a nearby bird is associated with the known nest or is a member of a separate pair. It is also important to search for shorebird nests near the nests of charismatic species such as swans and geese; the increased risk of predation to these species is an unfortunate necessity of obtaining an accurate estimate of shorebird density on an intensive plot.

Plotting Nests and Territories

For use as a base map, scan the largest-scale aerial photo available, print black-and-white or color copies, and take several of each plot to the field. In the windy and

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

911

misty arctic environment, we find it best to place the map in a standard sheet protector, anchor it to a clip board with rubber bands, and write on the sheet protector with an ultra-fine tipped Sharpie (alcohol will remove ink for re-use of sheet protector). After each day in the field, transfer new nests and territory borders to permanent maps kept at camp. Also make a field copy of the permanent map and use it within a sheet protector for the next visit to the plot. Update both the field and camp copies after each visit. For plots with many nests and species, we find it useful to use fine-tipped permanent markers in 3-4 colors so that the three most common species can be mapped in one color and all other species in the fourth color on the paper copies of the maps. We use only black Sharpie on the sheet protector because other colors tend to rub or wash off easily.

The term "territory" is used in a broad sense to mean the area of primary use. For example, the area of use of a Semipalmated Sandpiper pair that is staying close to a nest may be drawn as a very small circle. The area of use of an American Golden-Plover (*Pluvialis dominica*) pair whose nest has not been found and who travels widely on and off the plot, may be indicated by a series of arrows denoting movements rather than by a well-bounded circle.

To provide correspondence between the map, field notes, and daily summaries, use consecutive letters within species to label pairs (or individuals) whose nests have not been found, e.g., SESA-A, SESA-B, PESA-A. Labeling is a matter of record-keeping and convenience. Label pairs (or individuals) that appear to be distinct from others; it is expected that several individuals will be labeled that are later determined to be outside the plot or determined to be the mate of another bird that has already been labeled or whose nest has been found. These extraneously labeled pairs do not affect data analysis or interpretation.

Estimating Number Present and Recording Effort

We use two forms to record daily records on number present and effort. The purpose of keeping daily records is two-fold: 1) final cumulative nests can be plotted against cumulative hours to illustrate the cumulative effort at which the number of nests asymptotes, i.e., after which few nests are found – if this effort is noticeably less than the total hours spent per plot, we can be more confident that all nests were found; 2) to keep track of the daily events that lead to changes in the estimated 'number present' and to the final end-of-season decision about whether a territory centroid is in or out of the plot. In the field, use a form similar to the "Birds Without Nests – Daily Summary" (*table 2*) to record whether each bird was observed on or off the

plot and whether, based on all previous and current information, the territory centroid is estimated to be in or out of the plot at the end of each full-day equivalent of effort. Comments at the end of each line indicate the observations that led to your daily decision and eventually the final end-of-season decision. Once a bird's nest is found, it is no longer necessary to summarize its behavior on this form. After each visit, copy the list of birds without nests (first column) onto the next day's daily summary form (the identity of birds without nests should also be obvious from the field map). In addition, use the "Summary of Effort" form (*table 3*), which is kept in camp, to record hrs on plot, and number of new nests for each species. Comments at the bottom of the form explain cases in which number of cumulative territories for a species changed between visits, for example, "16 June, BBPL-A now clearly off plot" or "18 June, SESA-B is mate of bird at SESA 14 nest".

Nest Finding

During the first half-day or so on a plot, it is useful to walk through the plot finding as many nests as possible and noting the location of birds that likely have nests. Since nests found in this way are typically the easiest to find, this is referred to as 'high-grading'. By the end of the first full-day equivalent, all territories will have been plotted and the first estimate of number present made. On subsequent visits, the goal is to fill each territory with a nest, sort out the identity of territory owners, find nests of pairs on the edges of plots, and then search intensively for territories and nests that were not part of the first estimate. It is particularly important to find the nests of birds holding territories near the edges of plots so they can be conclusively ruled in or out of the plot. It is not a waste of time to spend hours looking for a nest that is eventually found off the plot.

A combination of several nest-finding strategies is necessary to find all nests on a plot. Within each strategy, nests may be found by following incubating birds back to the nest or by pinpointing the location from which a bird flushes. One strategy is to pick a territory or pair whose nest has not been found, walk the known area of use until you find a nest or a bird which can be followed back to a nest. Second, any suspicious bird, or bird that does not appear to be associated with a known nest, is worthy of an extended observation. In dimorphic species in which only one sex incubates, like Pectoral Sandpipers (*Calidris melanotos*), it is easier to decide which birds are worth watching. In monomorphic species (like Semipalmated Sandpipers) or those with dual incubation (like Dunlin [*Calidris alpine*]), it is more difficult. Incubating birds sometimes appear disheveled, and breast-preening is a classic tell-tale sign of a recently incubating bird. Third, walk preferred nesting habitats of key species (e.g., pond edges or marshes for phalaropes; dryas benches for American

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

912

Table 2– Example of a Birds Without Nests form for use in recording daily observations and decisions regarding whether the territory centroid is in or out of the plot. Note that BBPL-A and BTGO-A are included here because they were included in the previous day's daily summary as birds without nests and their nests were found on the day in question (16 June).

BIRDS WITHOUT NESTS – DAILY SUMMARY

Site: Colville Riv. Delta	Plot: S. Tam 2	Date: 16 June 02	Obs: SLE	Start Time: 8:15	End Time: 18:00

Pair/Bird I.D.	OBSERVATIONS[A]		DECISIONS[B]		Comments[C]
	M or Bird-1 ON/OFF /ND/NV	F or Bird-2 ON/OFF /ND/NV	Centroid ON/OFF	Nest #	
SESA – A	BOTH	ND	ON		primarily on; observed off once
BBPL – A	ON	ON	ON	PN-ON	PN near Dune 2
DUNL-A	ON	ON	ON		DUNL-A & B terr. encounter on ground 3m inside border
DUNL-B	BOTH	ND	OFF		DUNL-A & B parallel aerial displays inside plot
BTGO-A	BOTH	BOTH	ON	14	

[A] Record ON, OFF, BOTH, or ND if the area used by the bird was visited but the bird was not detected, or NV if the area used by the bird was not visited. Note that every section of the plot must be visited during every two days so that the Decisions column can be filled in.

[B] Record after each full-day equivalent. Record ON or OFF for territory centroid. Record Nest # once nest is found, otherwise leave blank. If a probable nest (PN) is located, write PN-ON or PN-OFF in the Nest # column.

[C] Record comments explaining Decisions or describing territorial encounters, etc.

Golden-Plovers). Fourth, for some habitats or sections of the plot with few landmarks, it may be necessary to search using a systematic grid to ensure complete coverage. The endpoints of parallel lines, approximately 3-5 m apart, can be temporarily indicated with pin flags. When the observer leaves the line to follow a bird, an additional pin flag can be placed at the point of departure until the observer returns. Fifth, nests of some species are more easily found by observing individuals at a distance before they are disturbed; this works well for Bar-tailed Godwits (*Limosa lapponica*), American Golden-Plovers and Black-bellied Plovers (*Pluvialis squatarola*). Species-specific hints for nest finding are beyond the scope of this document. However, here we give suggestions for two taxa because their behavior is particularly useful early in the season and might be missed if not given priority. Early in the season, attention should be given to phalaropes and other species in which one sex deserts early. Note the number of males and females, the location of pairs and their movements if possible. Pairs can often be followed to a prospective scrape, and it is not unusual to see the male or female sit in a newly formed cup. It is best to map the location and return in a few days rather than disturb her, but do not assume that this is the actual nest. Apparently cups are formed that are not used for egg-laying; this has also been observed in Dunlin and Semipalmated Sandpipers. Also, when a male phalarope suddenly appears in a pond near the observer, it is likely that he has come toward the observer from some distance away. He may make long flights to other ponds before returning to the pond nearest his nest, often leading the observer in a long circle back to the pond on which he was originally observed. Males sometimes land in the pond nearest their nest and walk discretely to the nest, or they fly to within a few meters of the nest and walk to it. Similarly, the behavior of male Pectoral Sandpipers early in the season is a useful indication of female and sometimes nest presence. During a male's aerial display, he often swoops low and "booms" directly over a female. Prior to incubation, he may perform this display over a foraging female or a group of females, but during incubation, he often displays over an incubating female.

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

913

Table 3– *Example of a Summary of Effort form for use in recording number of new nests, cumulative nests, cumulative territories, and new effort after each visit.*

SUMMARY OF EFFORT

Site: Colv Riv Delta	Year: 2002	Obs: SLE	Plot: S. Tam 2

	Vis 1 (date): 14 June			Vis 2 (date): 16 June			Vis 3 (date): 18 June		
Species	New Nests	Cum. Nests	Cum. Terr's	New Nests	Cum. Nests	Cum. Terr's	New Nests	Cum. Nests	Cum. Terr's
SESA	6	6	12	2	8	11	2	10	11
PESA	3	3	5	1	4	4	0	4	4
BBPL	1	1	2	1	2	3	0	2	3
etc									
Tot New Nests									
New Effort (hrs)	8.25			7.5			8.0		

Comments (Explain any changes between visits in number of cumulative territories):

Date	ID	Comments	Date	ID	Comments
16 Jun	SESA-A	same as SESA-B			
16 Jun	PESA-A	nest found; outside			
16 Jun	BBPL-C	not same as BBPL-B			

Habitat Data

Habitat data are useful in several ways in this study. They provide the regionwide GIS layers that are used to build the regression models and extrapolate findings from the surveyed plots to the entire study area. Observations made on the ground help us understand both the accuracy of the regionwide GIS layers and the relevance to shorebirds of the variables these layers contain. Observations made on the ground also help improve our knowledge of the shorebirds' habitat relationships which is one of the PRISM goals. Finally, in areas that have not been surveyed previously, observations made in this project may contribute useful information about other birds or other species.

On each plot, surveyors make brief notes of the general habitat (13 categories), ground cover including vegetation (13 categories), and moisture level (4 categories). Separate notes are made when more than one major habitat type is present within the plot. In addition, at the end of the field season, surveyors are asked to summarize their impressions of the major habitat relationships for each species. Where aerial photography is not available, photographs are often made as the helicopter is descending onto the plot.

Analytic Methods

The estimate, $\hat{X}$, of population size in a given study area is

$$\hat{X} = \frac{\hat{Y}}{\hat{P}}$$

where $\hat{Y}$ is an estimate of the number of birds that would have been recorded if surveyors had surveyed all plots in the study area and $\hat{P}$ is an estimate of the proportion of the population that would have been recorded on the surveys.

The numerator is obtained by developing regression models, from the rapid plots, and applying these models to every plot in the study area. Numbers of birds are converted to densities per km. Areas are converted to proportions. The dependent variable, for a given species, is the density of birds recorded. The independent variables are the proportions of the plot covered by each of the habitat variables in the GIS layers used for the study area. Other independent variables, such as distance to the coast or distance to the nearest wetland, may also be constructed. A conservative modeling approach has been adopted in which (1) only habitat variables with a positive relationship to density are allowed to enter the model, (2) only a few variables are used, and (3) every variable retained has a significant coefficient. The ideal model has an intercept of 0.0, meaning that if none of the explanatory variables is present the species is not present, and the variables believed to be of most

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

914

importance, based on impressions from the field, have the highest coefficients. For example, consider the following hypothetical model:

Pectoral Sandpipers/km^2 = 5 + 65(habitat 1)
          + 15(habitat 2)

This model would be interpreted in the following way. Habitats 1 and 2 appeared to be most important to Pectoral Sandpipers and the species was very rare (5/km^2) when neither of these habitats was present. Their density was substantially lower in habitat 2 (15 vs. 65). Different models are constructed for each species and with a large study area consideration is given to developing different models for different portions of the area if evidence of substantially different habitat relationships is present.

Different approaches have been used to compute $\hat{Y}$. In early work, the study area was actually partitioned into (ca. 12,000) plots. It was therefore straightforward to apply the models for each species to every plot, convert the estimated density to number present (using plot size) and sum the results. More recently (see above) only the plots actually surveyed have been delineated. If no spatial variables were included, the entire study area could be viewed as a single plot and the model could be applied to it. Distance to the coast, however, has been included for some species and it is anticipated that other spatial variables such as east-west and a north-south variables will be important. Furthermore, it has been interesting to compute densities for subdivisions of the study area. For both reasons, the study area has been partitioned into a few dozen sub-areas and estimates have been computed for each (*fig. 1*).
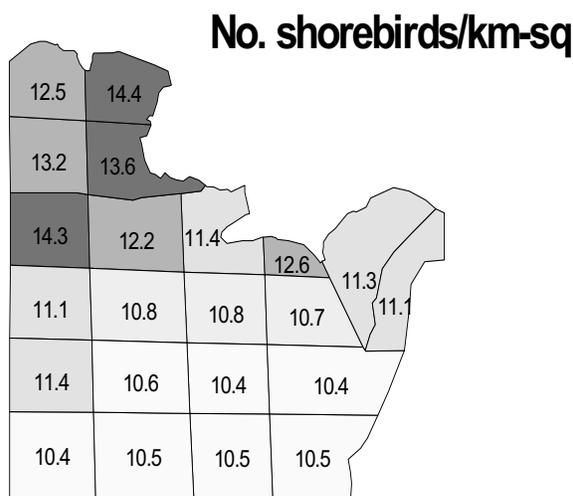
No. shorebirds/km-sq

Figure 1— Density of breeding shorebirds in the eastern third of the National Petroleum Reserve of Alaska as determined during 1998-2000 using the double-sampling method.

In estimating $V(\hat{Y})$, we have treated the plots as a simple random sample and used standard regression methods. This approach, however, ignores the complex sampling plan used to select the plots which usually involves both stratification (based on habitat) and cluster sampling (for logistic reasons). It has recently been pointed out (Eric Reed, pers. comm.) that mixed effects regression models are available for grouped data. It appears likely that such models could be used to acknowledge clustering, and perhaps also the stratification. This approach warrants attention in the future. Another issue that should be studied is whether to use weighted or unweighted regression, with plot size being the weight. Theoretically, it seems more appropriate to use weighted regression since plots actually do vary in size. On the other hand, plot size is always evaluated as an independent variable, has never entered a model, and if it does not, then the accepted model assumes that plot size does not affect density. It might be thought that using a weighted regression approach would produce smaller standard errors but this was not the case in an early analysis we performed. Nonetheless, this issue also probably warrants further study.

Estimation of $\hat{P}$ is fairly straightforward although attention is needed to define the sampling plan correctly so that pseudoreplication is avoided. We are interested in making inferences about the overall detection rate that would be achieved by the surveyors we actually used in the study – not to some hypothetical population of surveyors. But any surveyor might survey any plot so we wish to estimate the overall detection rate if each surveyor could somehow survey each plot at every possible time of the season. The statistical population may thus be thought of as a two-dimensional array with plots as rows and "surveyor-times" as columns. The entries would be the number of birds recorded. The parameter we are trying to estimate could be represented as

$$P = \frac{\sum_i^N \overline{y}_i}{\sum_i^N X_i} = \frac{\overline{\overline{y}}}{\overline{X}}$$

where $\overline{y}_i$ is the mean number that would be recorded on plot i by all surveyors recording at all times, and X_i is the number actually present on plot i. We estimate P with the following steps: (1) randomly select the intensive plot; (2) for every surveyor and plot (since all surveyors conduct at least 1 rapid survey on every intensive plot), randomly select one or more times to conduct rapid surveys; (3) compute the mean result for each surveyor and the mean of these means. The sampling plan for the numerator is thus three-stage: selection of plots, selection of surveyors (all surveyors

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

915

are selected), selection of 1 or more times. This being the case, the variance of the numerator is $V(\bar{y}_i)/n$ where n is the number of intensive plots selected (Cochran 1977, p. 298 with $f_1, f_2 = 0$). The variance of the denominator is just $V(X_i)/n$.

We use the standard formula for the variance of a ratio to estimate $V(\hat{X})$ (Cochran 1977, Section 6.4), assuming that $\hat{Y}$ and $\hat{P}$ are independent.

The description above, however, is incomplete in one important respect. It does not specify what random plan is used to select the intensive plots. This is an important issue because it is tempting to place the intensive plots in "good" or "typical" areas and doing so may result in variation between detection rates on them being less – in a worst case scenario much less – than in the suite of all plots in the study area. For example, there is no point in putting an intensive plot in an area with no birds so we have tried in the past to place them in locations with many birds. But it is possible that detection rates vary with density so this may not be appropriate. A more serious problem arises when species nest and forage in different habitats. It seems natural to put the plots in nesting habitat because the number nesting in foraging habitat may be low or even zero if there is no nesting habitat on the plot. But surveyors may record the species as being present in the foraging habitat if they do not fully understand the way habitat is used by the species. Under this scenario, detection rates would be over-estimated because we would exclude plots that would contribute positive numbers to the numerator and zeros for the denominator. More generally, if detection rates are similar, then failure to have a well-defined sampling plan to select intensive plots is not too serious and logistic considerations such as accessibility and number of birds on the plots are reasonable to include in deciding where to place the intensive plots. But if detection rates vary substantially, then – as with any estimation – following a well-defined sampling plan becomes much more important. In early years of this study we believed that detection rates did not vary much between plots (or species) and so we did not worry too much about how the intensive plots were selected. In the past few years, however, this issue has become more of a concern and we are now following a fully random plan in selecting the intensive plots around each camp.

One other issue is important to consider in selecting the intensive plots. We have had at least one case in which we felt a fox was attracted to a spike camp and, due to spending time near camp, may have seriously depressed nesting success on our intensive plots. It is possible that the fox also spent more time on the intensive plots than it would have otherwise due to the scent trails left by the observers, though we do not believe it was actually following these trails to nests (we avoid visiting nests after finding them for this reason). Nest loss probably reduces detection rates in at least some species due to the pair leaving the area. Thus, this form of visitor impact could cause a significant bias in our detection rates. Part of the solution is probably to locate intensive plots as far from camp as possible. Extreme care not to leave food scraps – even tiny ones – in the eating area may also reduce the extent to which predators are attracted to the camp area.

A final issue in defining the sampling plan for selecting the intensive plots is whether the plot, or the camp, should be considered the primary sampling unit. Concerns such as the one immediately above suggest that the detection rates might vary substantially from one camp to another. We will therefore probably consider the camp as the first stage in intensive plot selection. It is thus important to have as many camps – or sets of intensive plots – as possible.

An Example

The eastern portion of the National Petroleum Reserve of Alaska was surveyed during 1998-2000. Each year four plots were searched intensively to determine the number of birds present. About 20 percent of the survey effort was devoted to the intensive surveys. In 2000, a record was kept of new nests found per unit of effort (*table 4*). The results, and estimates of the total

Table 4– *Search effort and results obtained during each of three complete nest searches on intensive plots during 2000.*

	1st Search (15-20 June)	2nd Search (21-25 June)	3rd Search (26 June-1 July)
Search hr	62	65	72
Search hr/ha	1.2	1.2	1.4
New nests	44	31	4
New nests/hr	0.71	0.48	0.06
Estimated total	89	81	79

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

916

number present made periodically during the searching effort, both indicated that all or nearly all territorial males were located during the intensive surveys.

Surveyors not familiar with the intensive plots carried out 1-2 rapid surveys on each plot. The results showed that the average ratio (number estimated)/(number actually present) was 0.79 (*table 5*). All but one of the ratios was between 0.71 and 1.05, and the variation was not statistically significant. The outlier (Red Phalarope [*Phalaropus fulicaria*]) was probably caused by departure of the females well before the end of the season and, in most years, before the detection rates were measured (they were usually made late in the season for logistic reasons). Most operational surveys, however, were carried out before female Red Phalaropes left, and the investigators knew of no reason to believe that Red Phalaropes would have lower detection rates than other species. Thus a single correction factor of 0.79 was used for all species. As more data are accumulated, species-specific detection rates will probably be identified and they will then be used in place of the single rate.

More than 300 plots covering >100 km^2 were surveyed using the rapid method. The proportion of each plot covered by each of 17 habitat types (based on a map prepared by the Bureau of Land Management and Ducks Unlimited) was determined, and a few derived variables (e.g., distance to the coast) were also calculated from each plot. These data, and the numbers of birds recorded on each plot were used to construct regression models that predicted the density of birds on each plot (*table 6*).

The models were used to predict the number of birds that would be recorded if every plot (>12,000 plots) in the study area was surveyed. This total, or the total for any sub-region of interest, was divided by the estimated detection rate, 0.79, to obtain the estimated population total. The total population of all shorebirds in the eastern third of the National Petroleum Reserve of Alaska was estimated to be 356,000-455,000 (95 percent confidence interval). Application of the estimation procedure in each of 22 sub-regions showed that numbers were slightly higher closer to the coast (*fig. 1*).

Literature Cited

Bart, J., B. Andres, S. Brown, G. Donaldson, B. Harrington, V. Johnston, S. Jones, G. Morrison, S. Skagen. This volume. **The Program for Regional and International Shorebird Monitoring (PRISM).**

Bart, J. and S. L. Earnst. 2002. **Double sampling to estimate bird density and population trends.** Auk 119: 36-45.

Brown, S., C. Hickey, and B. Harrington. 2000. **The United States National Shorebird Conservation Plan.** Manomet, MA: Manomet Center for Conservation Science.

Cochran, W. G. 1977. **Sampling techniques, 3rd edition.** New York, NY: J. Wiley and Sons.

Donaldson, G. M., C. Hyslop, R. I. G. Morrison, H. L. Dickson, and I. Davidson, editors. 2001. **Canadian Shorebird Conservation Plan.** Ottawa: Canadian Wildlife Service.

Table 5– *Index ratios on the rapid surveys for breeding shorebirds.*

Species	Number present	Average number recorded	Ratio
Semipalmated Sandpiper	101	72	0.71
Pectoral Sandpiper	45	46	1.02
Red Phalarope	27	13	0.49
Red-necked Phalarope[1]	36	29	0.80
Dunlin	14	15	1.05
Ruddy Turnstone[1]	7	7	0.93
Black-bellied Plover	6	6	1.00
Others	10	7	0.74

[1] Scientific names not reported in text: Red-necked Phalarope (*Phalropus lobatus*) and Ruddy Turnstone (*Arenaria interpres*).

Table 6– *Examples of models used to predict the density of shorebirds on plots on the North Slope of Alaska.*

Species	Model[1]
Black-bellied Plovers/km^2	0.5 + 2 (deep *Carex aquatilus*)
American Golden-Plovers/km^2	1.0 + 3.2 (upland sedge)
Bar-tailed Godwits/km^2	0.0 + 2.6 (shallow *Carex aquatilus*)
Red Phalaropes/km^2	3.3 + 13 (*Carex aquatilus*) – 0.2 (distance to coast)

[1] Habitat variables were defined as the proportion of the plot covered by the habitat; habitat types were from the land cover map prepared by the Bureau of Land Management and Ducks Unlimited.

USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005

917