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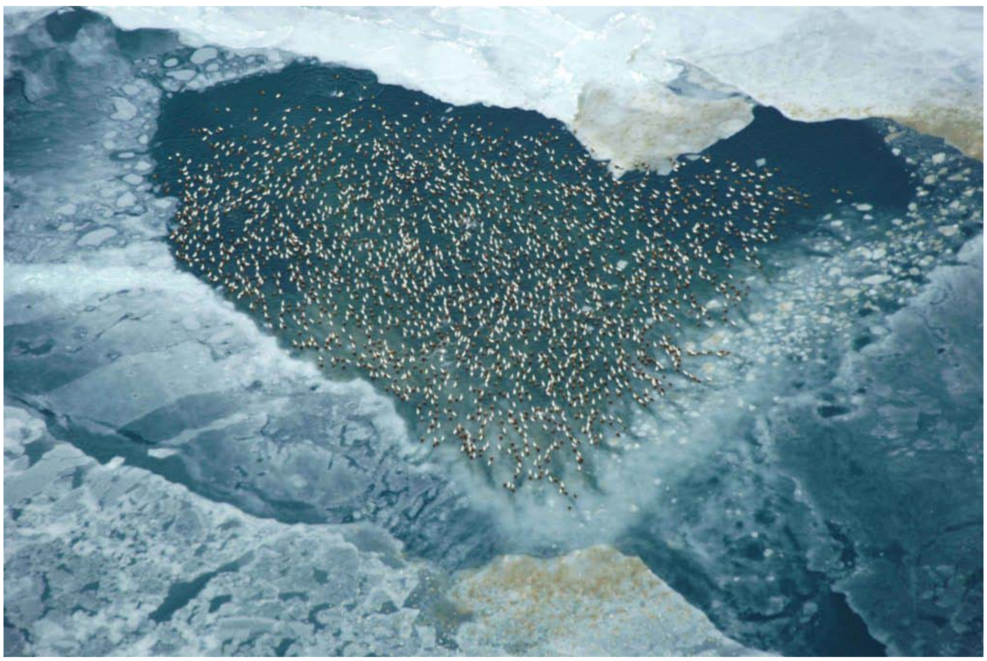

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Measuring and Modeling Habitat Use by Spectacled Eiders Wintering in the Bering Sea

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Abstract.
Results of satellite telemetry and aerial surveys from 1993-1998 suggested that nearly the entire global population of spectacled eiders (*Somateria fischeri*) wintered together as an assemblage of dense flocks in the northern Bering Sea south of St. Lawrence Island, Alaska. We conducted aerial surveys in that area on 1–2 April 2009 and 14–17 March 2010 to describe the current distribution and abundance of the wintering population of spectacled eiders. We surveyed systematic parallel transects centered around recent locations of spectacled eiders instrumented with satellite transmitters, visually searching for all eider flocks among open leads in the sea ice that covered the search area. During surveys we estimated flock size, recorded GPS waypoints for each flock, and photographed most of the flocks obliquely using a high-resolution, 35-mm digital camera. We obtained digital images of 79 flocks in 2009 and 45 in 2010, which we later analyzed for flock size using image processing software with a counting and marking extension. We estimated 305,261 spectacled eiders from photographs and visual counts in 2009 and 369,122 in 2010, and mapped the location of each flock using ESRI ARCVIEW software. Satellite telemetry and survey data indicated eider movements northward from the surveyed wintering area just before the 2009 survey; these movements cast doubt on the accuracy of both abundance and winter distribution results due to late timing of the survey. However, results from the more appropriately timed 2010 survey suggest a stable wintering population when compared to results of similar photo censuses in 1997 (363,030 eiders) and 1998 (374,792 eiders). Using subsets of images selected for resolution quality, we estimated sex ratio (after-hatch-year females [AHYF] per after-hatch-year male [AHYM]) as 0.84 in 2009 and 0.74 in 2010. Productivity indices were hatch-year males [HYM] per AHYM of 0.052 in 2009 and 0.08 in 2010, and (HYM+HYF) per AHYF of 0.13 in 2009 and 0.24 in 2010. We include maps illustrating daily survey flight paths and locations of all recorded flock observations.

Key Words: waterfowl, spectacled eider, *Somateria fischeri*, aerial survey, Bering Sea, Alaska

INTRODUCTION

Before 1993, the location and characteristics of habitats used by spectacled eiders (*Somateria fischeri*) outside the breeding season were largely unknown. From 1993 through 1998, satellite telemetry and aerial surveys identified the main wintering area in the Bering Sea pack ice south of Saint Lawrence Island, and four major molting areas: Norton Sound and Ledyard Bay in Alaska, and Mechigmenskiya Bay and marine waters offshore between the Indigirka and Kolyma River deltas in Arctic Russia (Petersen et al. 1999). The Alaskan areas were subsequently designated as critical habitats, requiring federal agencies to undergo formal consultation for any actions that might pose a threat to survival of the eiders within those areas. Though the spectacled eider wintering area in the Bering Sea was delineated during the late 1990s based on satellite telemetry, aerial photographic surveys and shipboard benthic sampling suggested that the distributions of benthic invertebrate prey were changing through time with potential negative implications for wintering eiders (Lovvorn et al. 2009). Recent interest by the commercial fishing industry to explore the fishing potential of the northern Bering Sea, including portions of the spectacled eider critical wintering habitat, prompted the North Pacific Research Board to fund studies on the current and projected spatial distribution of wintering eiders and their benthic prey. Here we report the results of aerial photographic surveys conducted 1–2 April 2009 and 14–17 March 2010 relative to the following objectives.

<u>Primary Objectives</u>

1. Describe the spatial distribution of the spectacled eider wintering population during the late winter period of relative spatial stability (as shown by recent satellite telemetry studies). Data will consist of precise locations and population counts or estimates of individual flocks, to be used in a model of the spatial distribution of viable foraging habitat.

2. Estimate the current late winter population, and compare with estimates from 1997 and 1998 surveys.

The high quality of photographic imagery collected during the study also allowed us to address the following secondary objectives, which are of management interest to the Eider Recovery Team.

<u>Secondary Objectives</u>

3. Estimate adult sex ratio for each survey year.

4. Estimate average duckling production for the 2008 and 2009 nesting seasons, defined as the ratio of hatch-year males (HYM) to after-hatch-year males (AHYM) on the survey date in 2009 and 2010, respectively. Also estimate total hatch-year eiders (HYM+HYF) per after-hatch-year female (AHYF) for each survey.

5. Based on ratios from objectives 3 and 4 above, estimate population structure for each survey, defined as the total number of eiders in each cohort: hatch-year males, hatch-year females, after-hatch-year males, and after-hatch-year females.

METHODS

We created an initial systematic search grid based on recent locations of spectacled eiders (27 in 2009 and 23 in 2010) instrumented with satellite transmitters (Matthew Sexson, US Geological Survey, unpubl. data; Figs. 4 and 7). We assumed that the gross distribution of the study birds would be similar to that of the general population, as was determined during previous surveys (Larned and Tiplady 1997, 1999). That assumption, plus reports of relatively little movement of the instrumented birds from January to March 2009 and 2010, suggested spatial stability of the current population through winter (M. Sexson USGS unpubl. data). The initial search area was centered 120–130 km southwest of the village of Gambell, St. Lawrence Island, Alaska (Fig. 7). We used a high-wing, twin piston-engine, Aero Commander Model 680 aircraft to fly a series of parallel transects (Figs. 4, 7) at approximately 167–185 km/h (90–100 knots), at altitudes of 150–360 m. The crew used a moving map and data-recording program on a laptop computer (GPS VOX, dev. by J. Hodges, USFWS) to maintain orientation relative to the transect layout and to record geo-referenced observations continuously. The crew, consisting of pilot, right front observer-photographer, and rear seat observer all searched for flocks of eiders as we proceeded along transects. In general, eider flocks were easily visible at a distance of 3.9 miles (one-half the transect spacing), but we occasionally used image-stabilized 12×36 binoculars to aid in detecting small flocks at marginal distances (Larned and Tiplady 1997, 1999).

We obtained oblique photographs of nearly all flocks through the copilot’s (front starboard) window using a hand-held, digital, 35-mm camera. As each flock was detected, the pilot maneuvered the plane to position the observer-photographer over the flock as close to vertically as possible, while enabling him to keep the flock in view continuously to photograph the entire flock with one or more sequential images in a single pass. The camera, which had a 12.4 megapixel sensor, was set at shutter-priority auto-exposure with center-weighted metering. We used a Nikon 28–105 mm f3.5–5.6 VR lens in 2009, and a Canon EF 70–200 F4 IS lens in 2010, with image-stabilization engaged. We set ISO at 200 and shutter speed at 1/500 or 1/640, depending on light intensity. The rear-seat observer recorded a visual estimate of the number of birds in each flock, and other notes, into the computer using the GPS-linked data recording program. Each day, after completing the initial survey grid, we reviewed the distribution of our observations (Figs. 5, 8), plotted additional transects where more flocks were likely, and flew them on the subsequent day (Figs. 6, 9, 10). In 2009 we used a Nikon camera which we connected to a portable Global Positioning System (GPS) unit to record geographic coordinates into the camera metadata for each frame. In 2010 we used a Canon camera lacking this capability, so to obtain precise photo location we time-matched the metadata for each frame with the position coordinates recorded by the GPS-linked laptop, making sure to synchronize the camera clock to match that of the survey computer before each survey flight.

We analyzed images using photographic editing software (Adobe Photoshop CS-4 extended) and the following procedure to count or estimate numbers of birds in each flock. First, to avoid undercounting or double-counting in overlapping serial images, we simultaneously displayed each two adjacent images and drew “match lines” on each image using a *Photoshop* “draw” tool. Using the Photoshop count extension, we positioned the curser over each bird to be counted and clicked the mouse, which left a marker and incremental number over the bird. Examination of the images revealed that for each flock we had an image or series of images adequate for enumeration, but resolution and resulting classification potential varied considerably among images.

Attainment of definitive plumage, or at least the appearance of males as adults from a distance (or in flock photographs), normally occurs during the second winter (Portenko 1952, Palmer 1976). Therefore in high resolution images we could expect to be able to visually discriminate between hatch-year (HY) and after-hatch-year (AHY) males. Indeed, we found that a maximum of 3 sex-age cohorts were possible to discriminate in the best images: after-hatch-year males (AHYM), hatch-year males (HYM), and all females (age classes of females appeared similar in all images) (Fig. 1). However, for many images, sex-age cohorts had to be combined or omitted. For instance, in some images adult males stood out prominently; but all females and HYMs looked similar, and some were indistinguishable from each other or the dark water background. Our primary objective was to obtain the best possible total estimate for each flock, but we also hoped to obtain reasonably precise sex and age indices for the population. We devised seven count rules based on image resolution and our ability to classify eiders confidently into sex and age cohorts (Table 1). Each image from the 2009 survey fell into one of the 7 count rules, while we were able to describe each 2010 image using only count rules 1, 5, or 7 due to improvements in photographic resolution.

Table 1. Count rules used to classify eiders in aerial photographs from spectacled eider aerial surveys, Bering Sea Alaska, April 2009 and March 2010.

1. One count group: all birds counted, no sex-age classification
2. One count group: AHYM counted, females and HYM not counted
3. One count group: combined males (AHYM + HYM) counted, females not counted
4. Two count groups: AHYM and HYM counted separately, females not counted
5. Two count groups: AHYM and combined “brown” birds (all females + HYM) counted separately
6. Two count groups: combined males (AHYM + HYM) and all females counted separately
7. Three count groups: AHYM, HYM and all females, each counted separately

Photo data from each year were entered into a spreadsheet with formulas to calculate sex and age ratios, as well as standard errors from appropriate count group subsets based on ratio estimation procedures (Cochran 1963). These ratios were then applied, by individual image, to estimate those sex-age cohorts not counted directly from the photos, after which totals were calculated for the four sex-age cohorts and the total population. All calculations were automated with an Excel spreadsheet. We defined sex ratio as AHYF/AHYM, calculated using only count rule 7 data (where AHYM, HYM and all female cohorts are counted). For each flock, AHYF were estimated by subtracting HYM from total F (we assumed HYM = HYF). The results were totaled for all count rule 7 flocks or partial flocks, and this sum was divided by the corresponding AHYM total.

To produce an annual index to production and first-year survival of young, we calculated the ratio of HYM/AHYM by using only those flocks suitable for count rules 4 and 7, where both AHYM and HYM were counted directly. A more traditional and useful productivity index is total young per adult female. We calculated this index by dividing estimated total HYF+HYM by estimated total AHYF.

We used a sampling and extrapolation procedure to facilitate the counting procedure for flocks with large numbers of eiders in a relatively even spatial distribution (3 flocks in 2009 and 3 in 2010). We projected a grid over the image using the Photoshop "grid" tool, then stratified the grid by classifying each cell as either "edge" (containing portions of the edge of the flock) or "field" (those entirely inside the flock edges). The "edge" cells were all counted and the results treated as a separate image. We numbered all "field" cells sequentially, arbitrarily selected a sampling interval (e.g. every fifth cell) and random starting point, and counted eiders within each cell corresponding to the interval selected (e.g. cells 5, 10, 15, …), according to the selected count rule. The resulting cell bird counts were averaged, 95% confidence intervals (CIs) were calculated, and the results multiplied by the total number of field cells to compute the point estimate and CI for the entire field. If necessary, additional cells were added to the sample in the same systematic manner to obtain a 95% CI within 10% of the mean field population estimate. Visual estimates of flocks not photographed were simply added to the total population estimate after all other calculations were completed.

To estimate the total population we added all direct counts to estimates of uncounted flock cohorts (those cohorts not counted in count rules 2, 3, and 4). Direct counts were assumed error free, but standard errors were calculated for all uncounted cohorts that were estimated using the ratios derived from our samples of directly counted cohorts (count rules 4 and 7). Population confidence intervals were derived from the sum of these standard errors. For 2010 data there were no uncounted cohorts, and thus the only error for total population was contributed by the 3 flocks estimated by extrapolation. We presented the estimate of each flock in both tabular form and projected in a Geographic Information System (ESRI ARCVIEW) to map the spatial distribution of the recorded population.

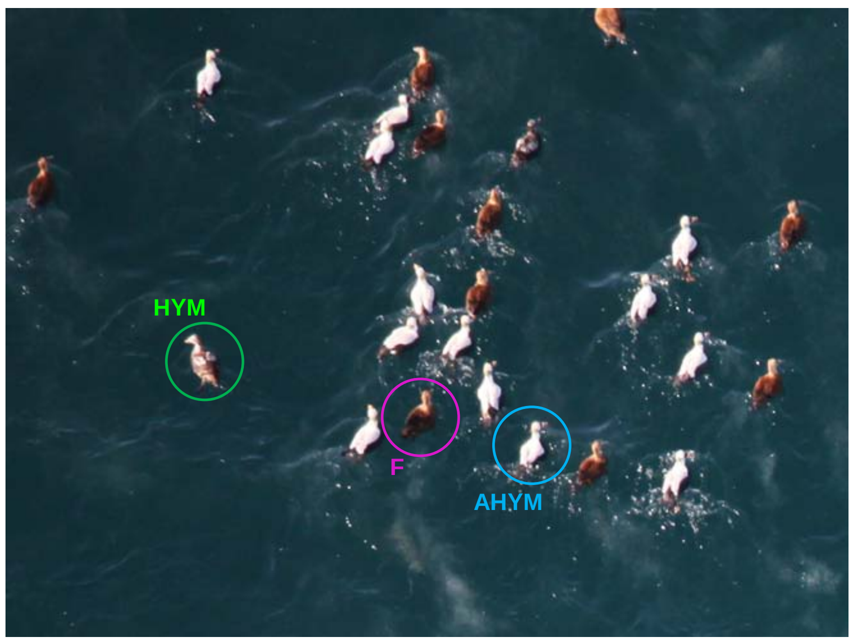

Figure 1. Aerial photograph showing appearance of three spectacled eider sex-age classifications: Blue = **after hatch-year males**, green = **hatch-year males**, purple = all females.

RESULTS

2009 narrative

The survey crew for the 2009 survey included Bill Larned as project Principal Investigator and photographer, Karen Bollinger as assistant and rear seat observer, and Andy Harcombe as pilot. The 2009 survey was originally scheduled for the first favorable weather period in March. However, delays due to persistent inclement weather in early to mid-March, followed by frequent violent eruptions of nearby Mt. Redoubt Volcano through late March, prevented our departure from Anchorage until 30 March. After one additional weather delay on 31 March in Nome, we surveyed the initial grid on 1 April and a second adjacent grid the following day. Weather was excellent both days during the survey: on 1 April, scattered clouds changing to clear with light haze in the afternoon, wind from the northwest at 10 knots, temperature −12°C; on 2 April, clear skies, wind from the south at 5 knots, temperature −11°C. Sea ice covered >99% of the entire initial search area, with scattered open leads, from tiny holes to linear openings several km long and up to about 1 km wide. To the north and east of the initial search area leads were larger, and interspersed with large pans of ice which appeared thicker than the ice in the search area (Fig. 2). Inspection of satellite imagery revealed neither perceptible directional drift nor dispersal differences in pack ice among the two survey days.

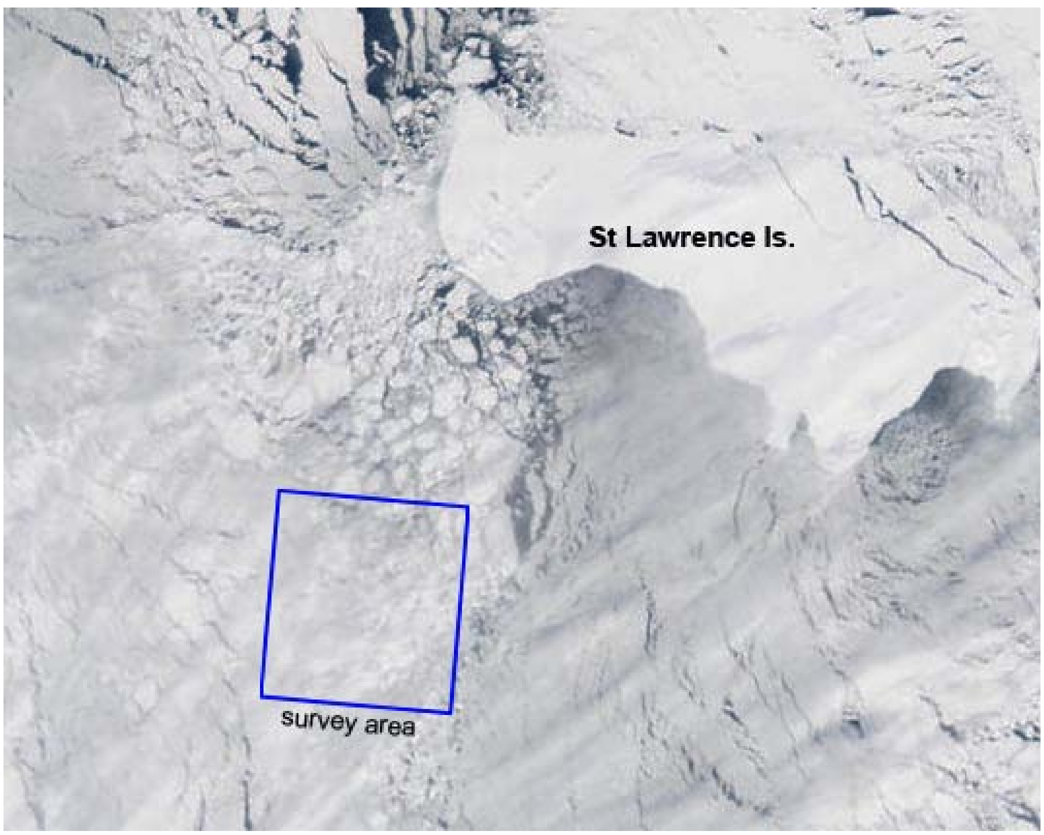

Figure 2. Satellite image of the Bering Sea, St. Lawrence Island region, showing the approximate location of the survey area, spectacled eider aerial survey, Bering Sea, Alaska, 1 April 2009. Image from http://rapidfire.sci.gsfc.nasa.gov/realtime/.

On 1 April we recorded visual estimates and photographic images of 60 flocks of spectacled eiders, plus visual estimates only of 4 small flocks ranging in size from 60–100 birds (Fig. 5). Our observations near the north and east borders of the initial search grid suggested there were more flocks beyond the grid in those directions. Therefore we returned to the area the following day (2 April) and surveyed 5 transects eastward, and 2 transects northward of the initial grid, recording 20 additional flocks (Fig. 6). Of the 79 photographed flocks, we obtained "countable" images of 72 entire flocks, while 7 had minor gaps in sequences due to limitations of the camera's memory buffer – i.e. we exceeded the continuous image storage speed for multi-image sequences. We estimated that about 5,000 total birds were not photographed due to this limitation, based on frame spacing and interpolation from adjacent photographs from the same flock. This omission is not accounted for in the point estimate of 305,261 (SE = 3,375; Tables 1, 2).

2010 narrative

The survey crew for the 2010 survey included Karen Bollinger as substitute Principal Investigator and rear seat observer (PI Bill Larned was unavailable due to a family illness), Tim Bowman as photographer, and Andy Harcombe as pilot. After arrival in Nome on 12 March and a brief weather delay, we flew the survey on 14, 15, and 16 March, under excellent weather conditions (conditions at nearby Gambell airport were clear, unlimited visibility, temperatures ranging from −23 to −12°C, winds from the south to east at 15 to 30 km/h). Sea ice covered >99% of the surveyed area, with scattered open leads, from tiny holes to linear openings several km long and up to about 1 km wide – similar to 2009 (Fig. 3).

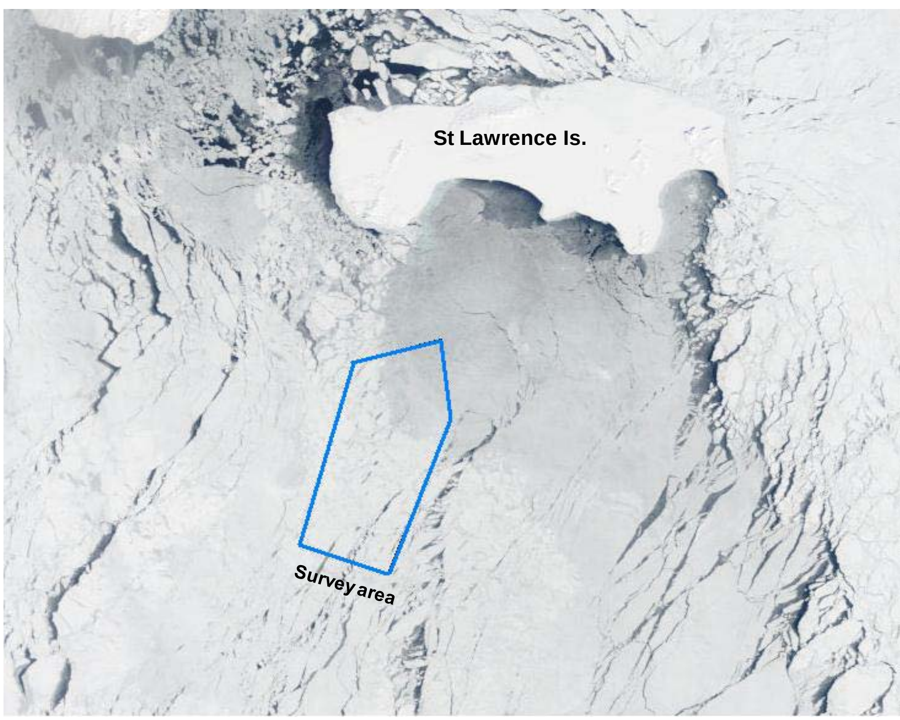

Figure 3. Satellite image of the Bering Sea, St. Lawrence Island region, showing the approximate location of the survey area, spectacled eider aerial survey, Bering Sea, Alaska, 16 March 2010. Image from http://rapidfire.sci.gsfc.nasa.gov/realtime/.

We surveyed the northern 4 transects in the initial search grid (Fig. 7) on 14 March, recording visual estimates and photographic images of 18 flocks of spectacled eiders, plus visual estimates only of 2 small flocks (Fig. 8). We flew the remaining 4 east-west search grid transects on 15 March, recorded and photographed 21 flocks, and recorded visual estimates only of 3 small flocks. We later deleted 12 flocks observed on 15 March due to their proximity to flocks counted on the previous day and our suspicion that these flocks, perhaps along with the leads they occupied, had drifted southward into the new transect due to southward ocean currents (Fig. 9). We considered the remaining 9 flocks as new, and kept them in the data set. On 16 March we returned to an area where we had observed an assemblage of large flocks south of our 15 March transects, and recorded and photographed 16 mostly very large flocks (Fig. 10). We flew two more transects to the west and 5 to the south of the large aggregation, but observed no additional eiders. On 17 March we returned to the area and re-photographed many of the birds recorded previously, but results were ambiguous and poorer quality, so we did not include them in the quantitative analysis. In all, we included 45 photographed flocks, all of which we could use for population estimation, and 5 flocks not photographed, for which visual population estimates were made during the survey and included in the final data set.

Quantitative Results

Data from this study include counts or estimates and precise geographic coordinates for all spectacled eider flocks observed during aerial surveys in early April 2009 and mid-March 2010. Based on multi-year and contemporary satellite telemetry studies (Petersen et al. 1999, M. Sexson, unpubl. data) and earlier similar aerial surveys (Petersen et al. 1999; W. Larned, unpubl. data), we believe we have recorded the vast majority of the global population of spectacled eiders. The numbers and geographic distribution of eiders recorded during the 2009 and 2010 surveys are briefly described in this report (Tables 2, 3; Figs. 4–11), and are available in greater detail from the US Fish and Wildlife Service (Migratory Bird Management, Region 7, Anchorage, Alaska).

The relative distribution of flocks and weighted geographic means recorded during aerial surveys from 1996 to 2010 suggest that the primary wintering location of spectacled eiders has shifted approximately 45 km eastward from the late 1990s to the 2009–2010 period (Fig. 11). Comparison of point estimates (1997: 363,030, 90% CI= ±24,761, Larned and Tiplady 1997; 1998: 374,792, 90% CI= ±2,948, Larned and Tiplady 1999; 2009: 305,261, 90% CI= ±2,977, Table 4; and 2010: 369,122, 90% CI= ±4,932, Table 4) suggests global population stability within that 14-year period.

Estimates of adult sex ratio varied between years. Our result for 2009 was 0.84 AHYF per AHYM (90% CI=0.784–0.890, n=19 flocks, Table 4), and that for 2010 was 0.74 AHYF per AHYM (90% CI=0.703–0.779, n=31 flocks, Table 4). The difference between the two years seems large for adult sex ratio in a long-lived species, but is barely significant at α=0.10.

Similar to age ratios, our index to production also varied among survey years. The 2009 index, obtained by dividing total HYM by AHYM for all count rule 7 flocks or partial flocks, was 0.05 HYM per AHYM (90% CI=0.029–0.076, n=19 flocks, Table 4), while that for 2010 was 0.08 HYM per AHYM (90% CI=0.027–0.136, n=31 flocks, Table 4). These values are not significantly different, but the CI is much larger for 2010 despite the much larger sample size (same as for sex ratio in the paragraph above), suggesting frequent concentration of HY birds into “brood flocks,” a distribution that was confirmed by visual inspection of the survey photographs.

Our traditional productivity index (total young per adult female) estimate in 2009 was 0.13 (un-weighted range 0.03–0.23, n=79 flocks, Table 4) and 0.24 in 2010 (un-weighted range 0.03–3.88, n=45 flocks, Table 4). As a measure of annual productivity (young surviving through the first winter) or recruitment (females being added to the breeding population), both of these values are negatively biased because age at first breeding for female spectacled eiders is believed to be between 2 and 5 years, with <50% of females nesting prior to their third year (US Fish and Wildlife Service 1996). Thus, we would expect the AHYF cohort to include a potentially large number of pre-breeding females, and the result would be negatively biased as a measure of production per *breeding* female. This shortcoming notwithstanding, in the absence of better information the indices provide at least crude means of modeling population structure.

DISCUSSION

The surveys were completed without difficulty, with excellent weather and extensive sea ice cover that tended to concentrate the eiders into dense flocks, thereby facilitating flock detection and photography. However, there were four areas of uncertainty we considered as possible sources of error:

1. *Double-counting or undercounting within a survey day or among survey days due to flock movements or the search area not encompassing the entire population*

During the 2009 survey the crew felt that there was little chance of double-counting within either survey day, as most flocks remained in the small open leads they occupied as we flew by. The few that flushed either quickly resettled where they had been or headed in a direction which made us reasonably certain we would not encounter them again. However, there was opportunity among survey days for significant flock movements, and thus for positive or negative count bias. Satellite telemetry during the period from one week before to one week after our survey revealed movements of 31 instrumented eiders within the survey area, averaging 24 km northeastward (M. Sexson, unpubl. data). Passive movement of sedentary flocks via sea ice drift could cause bird movement among days, but the small amount of local ice movement at that time revealed by satellite imagery was southward. Assuming these experimental birds are representative of the general wintering population, this general distributional shift made over counting possible due to flocks moving out of the day 1 survey area and into the survey area for day 2. Also, six (19%) of these instrumented birds departed the wintering area from 1 to 5 April and moved 276 to 357 km north prior to 9 April (ibid.), suggesting that a small portion of the population moved out of the count area prior to completion of the survey. Other ambiguities between survey days may have contributed small errors in our counts. The total number estimated on survey day 1 was about 252,000, and 50,000 on day 2. Of the latter, the largest flock, estimated at 30,827 birds, was close to where several large flocks were recorded the day before on the east-central edge of the grid (Fig. 6). However, immediately after recording that flock, a brief search revealed that the nearby flocks from day 1 were still where they had been the previous day, and their size and arrangement appeared unchanged, making a double count of large numbers of birds in this flock unlikely. However, an overnight shift of day 1 birds northward into the area of the day 2 transects running east and west, north of the day 1 grid (Fig. 6), seemed to us more likely, and may account for some of the 14,555 birds estimated there on day 2.

The 2010 survey was spread out over 3 days, and the cut-off points between days were in areas containing large numbers of flocks, making shifts of birds among daily surveys more likely than if we had ended daily flights in extensive areas devoid of birds. We attempted to mitigate this perceived problem by deleting day 2 (14 March) data from day 3 (15 March) results adjacent to the southernmost transect from day 2 (Fig. 9). The crew also noticed a tendency for flocks to flush and fly among leads during the survey much more often in 2010 than in 2009. Some eiders appeared to be flying in the distance, their departure unlikely to have been triggered by the survey aircraft. We were able to photograph the airborne flocks adequately, but there was greater potential for inadvertent double-counting or undercounting due to these movements of eiders during the survey.

2. Undercounting due to flocks not detected within the search area

It is reasonable to assume that with 7.8-km transect spacing an occasional small or sparse flock may have escaped detection. However, excellent visibility during the survey and occurrence of most flocks in large, dense aggregations that contrasted with the background of pack ice and dark open water made it appear to the crew that most flocks, certainly all large flocks, within the search area were detected and recorded. We did not evaluate flock detection bias, but believe it to be numerically insignificant.

3. Undercounting due to birds diving and thus avoiding detection

Diving behavior, from both feeding and escape response, is often observed during Steller's eider (*Polysticta stelleri*) surveys. Indeed, counting and photographing entire flocks of Steller's eiders is often challenging and frustrating due to intensive synchronous or sequential diving, involving most or all of a flock. However, during winter surveys of spectacled eiders we have never witnessed the eiders engaged in synchronous diving, a behavior which would be difficult to miss if it occurred often. Nor, for that matter, did we note any other diving behavior during this survey in either year. However, while processing the photographs, particularly those with eiders sparsely distributed, we observed occasional light-colored shapes visible in the water among the ducks, which we initially interpreted as submerged ducks, or bubble trails from diving ducks. Closer examination in the clearest images revealed that most were in fact "clouds" of fecal material, while relatively few were definitely eiders either beginning a dive or about to surface. We conclude (a) if there had been a significant amount of diving it would have drawn our attention, and (b) extensive diving would have made a notable difference in appearance among replicate photos of individual flocks, indicating portions of the flock under water, and we did not detect such a change. We therefore conclude that diving probably created a relatively insignificant negative bias to flock counts of spectacled eiders.

4. Undercounting due to northward migration prior to or during the survey

Mean departure dates of eiders with active satellite transmitters from the surveyed wintering area was 20 April 2009 (range 28 March to 12 May) and 9 April 2010 (range 21 March to 3 May) (Matthew Sexson, pers. comm.). In 2009, data provided by Sexson revealed that as of 2 April, of the 27 eiders carrying active satellite transmitters, 24 were still transmitting from within the survey area, while 1 was offshore near the village of Gambell. The two remaining transmitters did not provide locations for several days, but one was in the Gambell area on 3 April, while the other was located along the Chukotka coast by 5 April, and was joined within the next 4 days by four others. Again assuming the experimental birds are representative of the general wintering population, these observations suggest that some of the eiders began their northward migration as we completed our survey, and an unknown but probably small portion of them likely had already left the survey area on or by 2 April, leaving some uncertainty about the comprehensiveness of our 2009 survey. A wind change we observed from 10 knots from the northwest on 1 April to a more favorable 5 knots from the south on 2 April may have stimulated a portion of the population to begin their northward migration at this time.

In 2010, we did not anticipate significant numbers of birds departing northward prior to or during the mid-March survey because of the relatively early survey date (compared to 2009) and heavy sea ice. A single instrumented eider was located north of the survey area in the polynya near Gambell prior to the survey (Fig 7, multiple locations of a single transmitter), but opportunistic reconnaissance flights over that area during the survey revealed no eider flocks there.

CONCLUSIONS

In 2009, it appeared that some of the spectacled eider population may have departed the wintering area before or during our survey. We therefore recommend that the 2009 estimate of population size be considered low. Would departure of some of the eiders before the survey also have biased estimates of sex and age structure? In congeneric king eiders (*Somateria spectabilis*), males arrive earlier than females at offshore areas near breeding grounds, where much pair-bonding appears to occur after females arrive and before they move to inland nesting sites as pairs (MacPherson and McLaren 1959; Woodby and Divoky 1982 and refs. therein). In spectacled eiders, it is unknown whether males depart the wintering area earlier than females before pair-bonding occurs. In high-resolution aerial films taken in 2008, most eiders on the wintering area appeared to be unpaired as late as 23 March (Lovvorn et al. 2012). Regardless, our total population estimate suggests that most of the population was still present during our 2009 survey, so that adult sex ratio should be representative. Regarding age ratio, we could find no information on differential migration of age cohorts of spectacled eiders; however, immature-plumaged Steller's eiders (*Polysticta stelleri*) stay longer on wintering areas than do adults (McKinney 1965), and few immature king eiders accompany adults during spring migration (Myres 1958). If spectacled eiders are similar, completion of the 2009 survey after departure of some adults might have inflated productivity estimates.

In contrast to 2009, satellite telemetry (M. Sexson unpubl. data) indicated that the survey in 2010 was well timed. Survey conditions were excellent, and our photographic data provided reliable total counts of all but five observed flocks for which visual estimates totaled only 920 birds. Uncertainties included a 3-day survey period, with an ambiguous interface between days 1 and 2; both these aspects provided opportunity for double-counting or undercounting. However, we attempted to mitigate this issue by deleting 11 flocks totaling 25,841 birds which were very likely to have been counted the previous day. We feel that the resulting total of 369,122 birds is a reasonable estimate of the wintering spectacled eider population in 2010, and this estimate is similar to photographic survey results from 1997 and 1998. We were able to use a relatively large sample (about 37% of total birds) to calculate adult sex ratio and productivity indices in 2010, and we have no reason to suspect that our survey was biased due to improper timing. Thus, we recommend accepting the 2010 survey as more reliable among the two years of the project.

RECOMMENDATIONS

1. Future surveys should be designed based on recent telemetry data whenever possible, to greatly reduce search time and increase likelihood of success.

2. In certain situations, photographic techniques can greatly enhance precision and replicability, and minimize observer bias, in aerial surveys. However, quantifying large populations such as the global population of spectacled eiders involves many hours of tedious work. We strongly recommend development of techniques for higher resolution vertical photography that are compatible with automated image processing.

3. In this and previous similar surveys we have used a single-contract, multi-engine aircraft, primarily due to concerns for overwater crew safety. It is becoming difficult to procure these services due to the very small pool of capable and available aircraft and appropriately qualified pilots within Alaska. The US Fish and Wildlife Service Alaska Region recently obtained a fleet of four single-engine, turbine-powered, amphibious Quest Kodiak aircraft which can perform such missions safely. We recommend conducting future surveys with two Kodiak aircraft, each with photographer and pilot-observer aboard. Two planes operating simultaneously would be safer, would reduce time needed for the survey during short windows of good weather, and would thereby reduce the likelihood of double-counting or undercounting.

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LITERATURE CITED

Cochran, W. G. 1963. Sampling techniques. Second edn. John Wiley and Sons, New York. 413 pp.

Larned, W., and T. Tiplady. 1997. Late winter distribution of spectacled eiders (*Somateria fischeri*) in the Bering Sea, 1996–97. Unpublished report, U.S. Fish and Wildlife Service. Anchorage, Alaska. 13 pp.

Larned, W., and T. Tiplady. 1999. Late winter population and distribution of spectacled eiders (*Somateria fischeri*) in the Bering Sea, 1998. Unpublished report, U.S. Fish and Wildlife Service. Anchorage, Alaska. 9 pp.

Lovvorn, J. R., J. M. Grebmeier, L. W. Cooper, J. K. Bump, and S. E. Richman. 2009. Modeling marine protected areas for threatened eiders in a climatically changing Bering Sea. Ecological Applications 19:1596–1613.

Lovvorn, J. R., R. H. Mossotti, J. J. Wilson, and D. McKay. 2012. Eiders in offshore pack ice show previously unknown courtship behavior: acceleration of readiness for a constrained breeding period? Polar Biology 35, DOI 10.1007/s00300-012-1156-9.

Macpherson, A. H., and McLaren, I. A. 1959. Notes on the birds of southern Foxe Peninsula, Baffin Island, Northwest Territories. Canadian Field-Naturalist 73:63–81.

McKinney, F. 1965. The spring behavior of wild Steller's eiders. Condor 67:273–290.

Myres, M. T. 1958. Preliminary studies of the behavior, migration, and distributional ecology of eider ducks in northern Alaska, 1958. Interim Prog. Rep. to the Arctic Inst. of North America, McGill Univ., Montreal.

Palmer, R. S. 1976. Handbook of North American Birds, Vol. 3. Yale Univ. Press, New Haven, Connecticut.

Petersen, M. R., W. W. Larned, and D. C. Douglas. 1999. At-sea distribution of spectacled eiders: a 120-year-old mystery resolved. Auk 116:1009–1020.

Portenko, L. A. 1952 . Age and seasonal changes in eider plumages. Trudy Zool. Inst. AN., USSR, Vol. IX, No. 4, 1100–1132. (Can. Wildl. Serv. Translation).

U.S. Fish and Wildlife Service. 1996. Spectacled eider recovery plan. Anchorage, Alaska. 157 pp.

Woodby, D. A., and G. J. Divoky. 1982. Spring migration of eiders and other waterbirds at Point Barrow, Alaska. Arctic 35:403–410.

Table 2. Summary of counts and estimates of spectacled eider in 84 flocks, from oblique aerial photographs and visual estimates, northern Bering Sea, Alaska, 1-2 April 2009.

Survey Date	flock #	# photos	count Rule	estimate or count	Survey Date	flock #	# photos	count Rule	estimate or count
4/1/2009	1	1	5	73	4/1/2009	43	3	6	5,394
4/1/2009	2	1	5	672	4/1/2009	44	1	6	554
4/1/2009	3	1	1	469	4/1/2009	45	8	2	37,431
4/1/2009	4	3	1,6	1,826	4/1/2009	46	8	2,5	20,089
4/1/2009	5	1	5	62	4/1/2009	47	2	7	2,312
4/1/2009	6	1	6	4,295	4/1/2009	48	1	7	57
4/1/2009	7	1	3	366	4/1/2009	49	1	5	356
4/1/2009	8	1	6	574	4/1/2009	50	1	1	415
4/1/2009	9	2	3,6	2,749	4/1/2009	51	8	5	8,529[1]
4/1/2009	10	8	6,7	10,642	4/1/2009	52	7	5	5,148[1]
4/1/2009	11	1	6	2,216	4/1/2009	53	1	1	8,864[2]
4/1/2009	12	1	7	1,520	4/1/2009	54	6	7	3,397
4/1/2009	13	2	6	334	4/1/2009	55	3	2	8,522
4/1/2009	14	3	6	5,233[1]	4/1/2009	56	1	3	34,374[2]
4/1/2009	15	2	6	792	4/1/2009	57	1	7	2,884
4/1/2009	16	3	6	544	4/1/2009	58	4	2,4,7	7,611
4/1/2009	17	1	6	208	4/1/2009	59	4	2	7,303
4/1/2009	18	3	6	3,783	4/1/2009	60	8	2,5	12,280[1]
4/1/2009	19	7	6	3,990	4/2/2009	61	1	7	815
4/1/2009	20	5	5,7	3,082	4/2/2009	62	1	7	254
4/1/2009	21	1	5	544	4/2/2009	63	1	5	251
4/1/2009	22	3	2	7,307	4/2/2009	64	1	7	401
4/1/2009	23	3	5	2,520	4/2/2009	65	4	1,5	994
4/1/2009	24	2	7	1,331	4/2/2009	66	1	7	235
4/1/2009	25	9	1,5	4,017	4/2/2009	67	1	1	315
4/1/2009	26	10	2,5	4,354	4/2/2009	68	1	7	553
4/1/2009	27	14	2	11,646	4/2/2009	69	1	7	1,619
4/1/2009	28	1	5	1,766[1]	4/2/2009	70	2	5	1,428
4/1/2009	29	1	5	129	4/2/2009	71	1	5	230
4/1/2009	30	2	5	1,575	4/2/2009	72	7	2	5,104
4/1/2009	31	4	5	1,141	4/2/2009	73	1	5	254
4/1/2009	32	2	6	1,470	4/2/2009	74	1	5	74
4/1/2009	33	1	5	689	4/2/2009	75	3	1,5	1,795
4/1/2009	34	2	5	242	4/2/2009	76	5	1,2	30,984[2]
4/1/2009	35	2	6	1,388	4/2/2009	77	4	5	3,952
4/1/2009	36	2	6	212	4/2/2009	78	1	1	172
4/1/2009	37	4	6	2,638	4/2/2009	79	1	5	139
4/1/2009	38	8	6	1,482[1]	4/1/2009	80	0		60[3]
4/1/2009	39	2	7	333	4/1/2009	81	0		60[3]
4/1/2009	40	1	7	664	4/1/2009	82	0		90[3]
4/1/2009	41	1	7	149	4/1/2009	83	0		100[3]
4/1/2009	42	1	7	813	4/2/2009	84	0		25[3]
							TOTAL		305,261

1. Flocks with incomplete photographic coverage, thus counts are unknown amount low. 2. Flocks sampled and extrapolated for estimation.
3. Flocks not photographed - numbers presented are visual estimates.

Table 3. Summary of counts and estimates of spectacled eider in 50 flocks, from oblique aerial photographs and visual estimates, northern Bering Sea, Alaska, 14-16 March 2010.

Survey Date	flock #	# photos	count Rule	estimate or count	Survey Date	flock #	# photos	count Rule	estimate or count
3/14/2010	1	1	7	513	3/15/2010	38	1	7	583
3/14/2010	2	1	7	24	3/15/2010	39	1	7	40
3/14/2010	3	4	5	10,780	3/16/2010	40	8	5,7	8,064
3/14/2010	4	1	7	671	3/16/2010	41	13	1,7	94,633[1]
3/14/2010	5	3	5,7	2,386	3/16/2010	42	5	7	7,686
3/14/2010	6	1	7	71	3/16/2010	43	9	7	9,277
3/14/2010	7	5	7	1,704	3/16/2010	44	4	5,7	10,203
3/14/2010	8	5	7	3,349	3/16/2010	45	13	1	43,928[1]
3/14/2010	9	5	7	4,741	3/16/2010	46	2	5	1,530
3/14/2010	10	2	7	1,622	3/16/2010	47	7	1,5	9,280
3/14/2010	11	1	5	1,654	3/16/2010	48	2	7	959
3/14/2010	12	1	5	1,182	3/16/2010	49	17	5,7	49,058[1]
3/14/2010	13	1	7	3,268	3/16/2010	50	11	5	25,670
3/14/2010	14	1	7	158	3/16/2010	51	4	5	2,995
3/14/2010	15	1	7	1,738	3/16/2010	52	8	5	8,749
3/14/2010	16	6	1,5	4,883	3/16/2010	53	7	5	15,149
3/14/2010	17	2	5	7,227	3/16/2010	54	3	5	2,422
3/14/2010	18	1	7	4,703	3/16/2010	55	2	7	2,126
3/15/2010	31	5	5,7	4,989	3/14/2010	56	2	7	1,445
3/15/2010	32	1	7	808	3/14/2010	57	1	7	206
3/15/2010	33	10	7	9,327	3/14/2010	58	0		40[2]
3/15/2010	34	1	7	551	3/14/2010	59	0		60[2]
3/15/2010	35	3	1	694	3/15/2010	60	0		100[2]
3/15/2010	36	2	7	522	3/15/2010	61	0		600[2]
3/15/2010	37	8	5,7	6,705	3/15/2010	62	0		120[2]
					Totals	**50**	**192**		**369,122**

1. Flocks sampled and extrapolated for estimation. 2. Flocks not photographed - numbers presented are visual estimates.

Table 4. Summary of demographic estimates, spectacled eider aerial surveys, Bering Sea, Alaska, April 2009 and March 2010. Confidence intervals are derived from variance associated with sampling error only.

		Estimated Population Structure			
	Total eiders **est** (90%CI)	AHY males **est** (90%CI)	AHY females **est** (90%CI)	HY males **est** (90%CI)	HY females **est** (90%CI)
2009					
From flock photographs	**304,926**	**162,781** (±117)	**128,667** (±312)	**8,367** (±127)	**8,367** (±127)
Unphotographed flocks	**335**				
Total 2009 estimate	**305261 (**±2,977**)**				
2010					
From flock photographs	**368,202**	**198,717** (±164)	**137,159** (±282)	**16,163** (±197)	**16,163** (±197)
Unphotographed flocks	**920**				
Total 2010 estimate	**369122** (±4,932)				

	Productivity		Adult sex ratio
	HYM&F/AHYF (unwtd range by flock)	HYM/AHYM (90%CI)	AHYF/AHYM (90%CI)
2009	**0.13** (0.03-0.23) n=79 flocks	**0.05** (0.029 - 0.076) n=19 flocks	**0.84** (0.784-0.890) n=19 flocks
2010	**0.24** (0.03 - 3.88) n=45 flocks	**0.08** (0.027-0.136) n=31 flocks	**0.74** (0.703-0.779) n=31 flocks

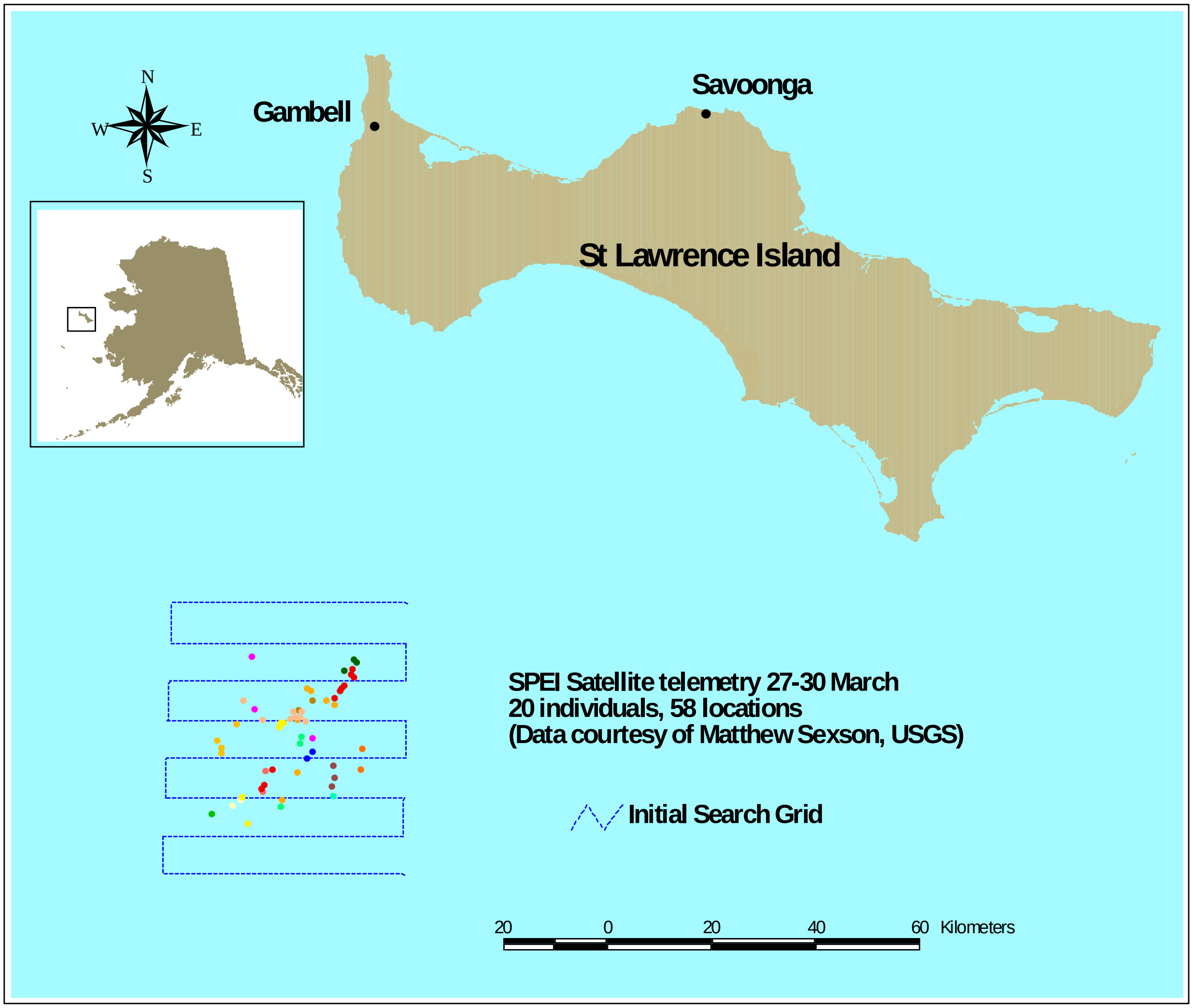

Figure 4. Spectacled eider satellite telemetry locations and initial aerial survey transects, Spectacled eider aerial survey, Bering Sea, Alaska, April 2009. Telemetry data courtesy of Matthew Sexson, USGS.

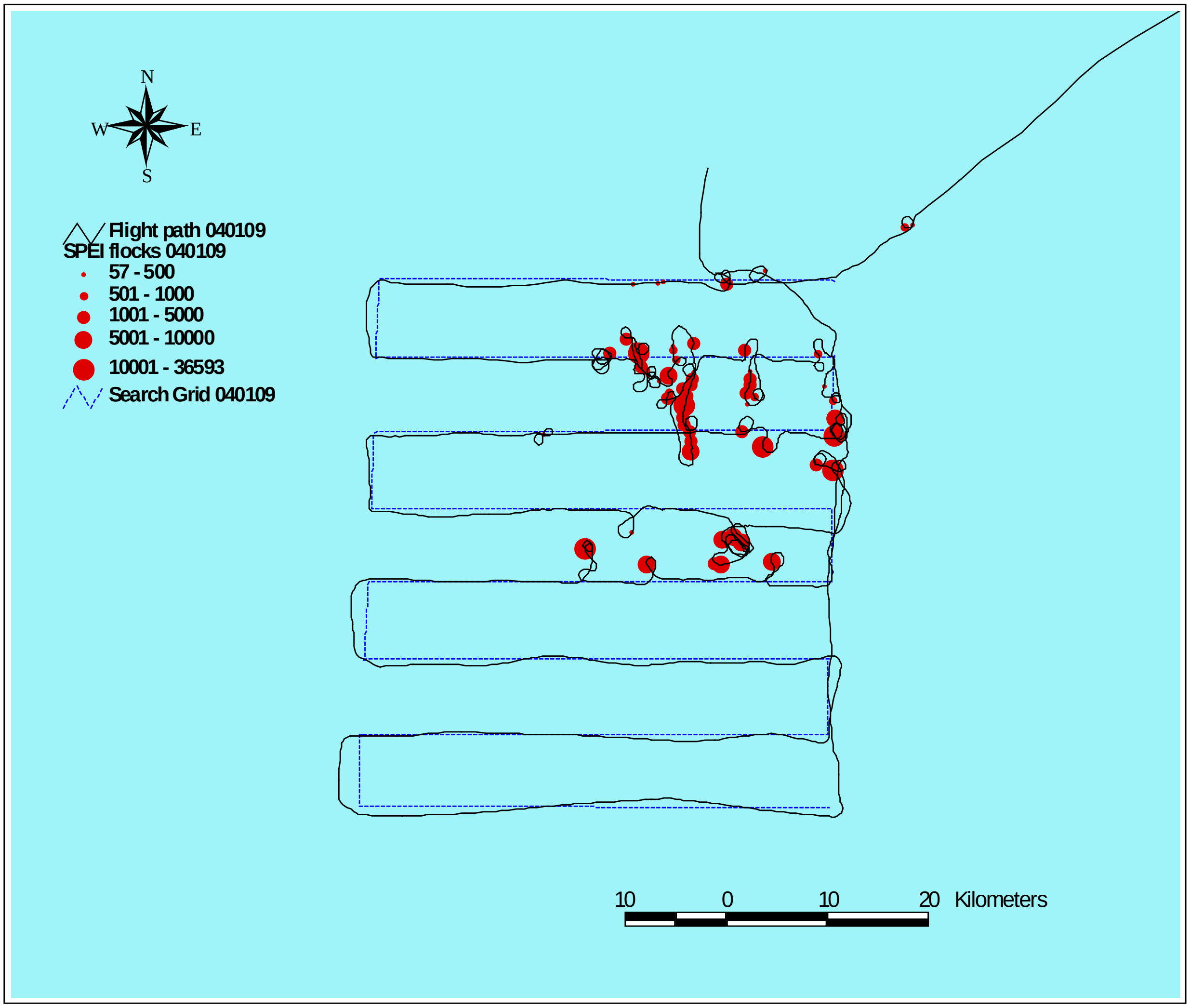

Figure 5. Flight path, location and relative size of spectacled eider flocks recorded during spectacled eider aerial survey, Bering Sea, Alaska, 1 April 2009.

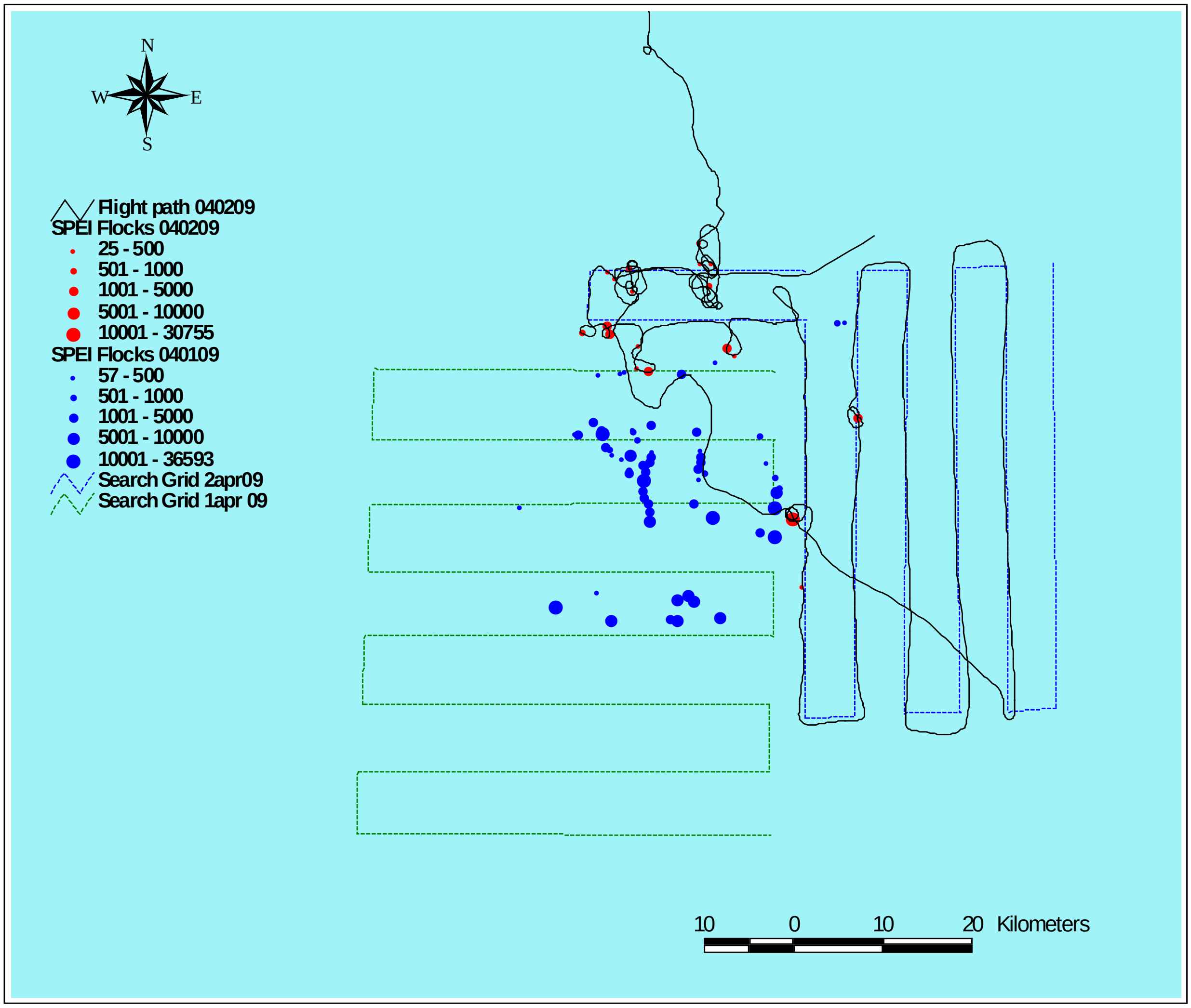

Figure 6. Flight path, locations and relative size of spectacled eider flocks recorded during spectacled eider aerial survey, Bering Sea, Alaska, 2 April 2009.

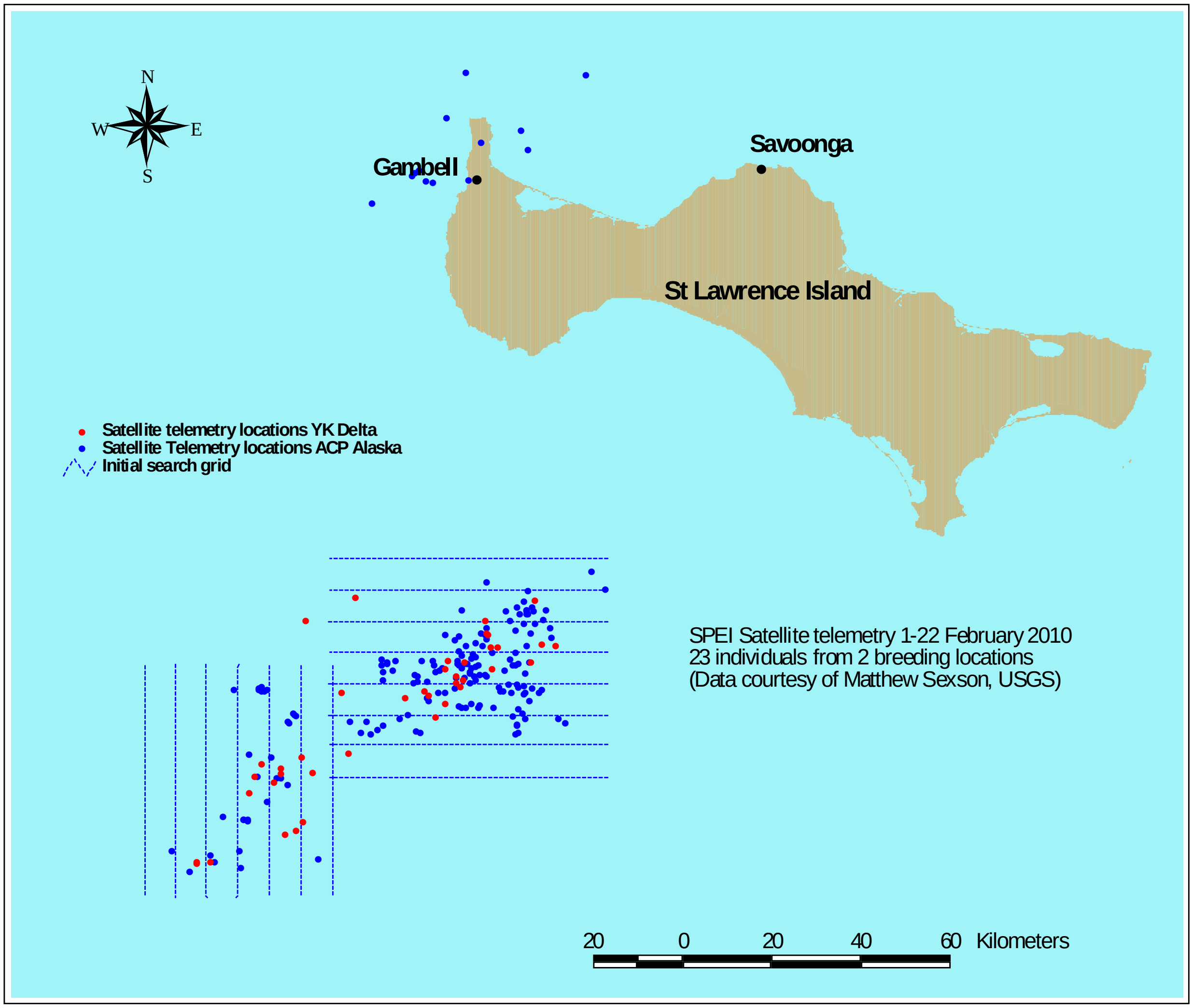

Figure 7. Spectacled eider satellite telemetry locations and initial aerial survey transects, Spectacled eider aerial survey, Bering Sea, Alaska, March 2010. The dots in the vicinity of Gambell represent multiple locations from a single eider. A recon flight during the survey revealed no eider flocks in that location. Telemetry data courtesy of Matthew Sexson, USGS.

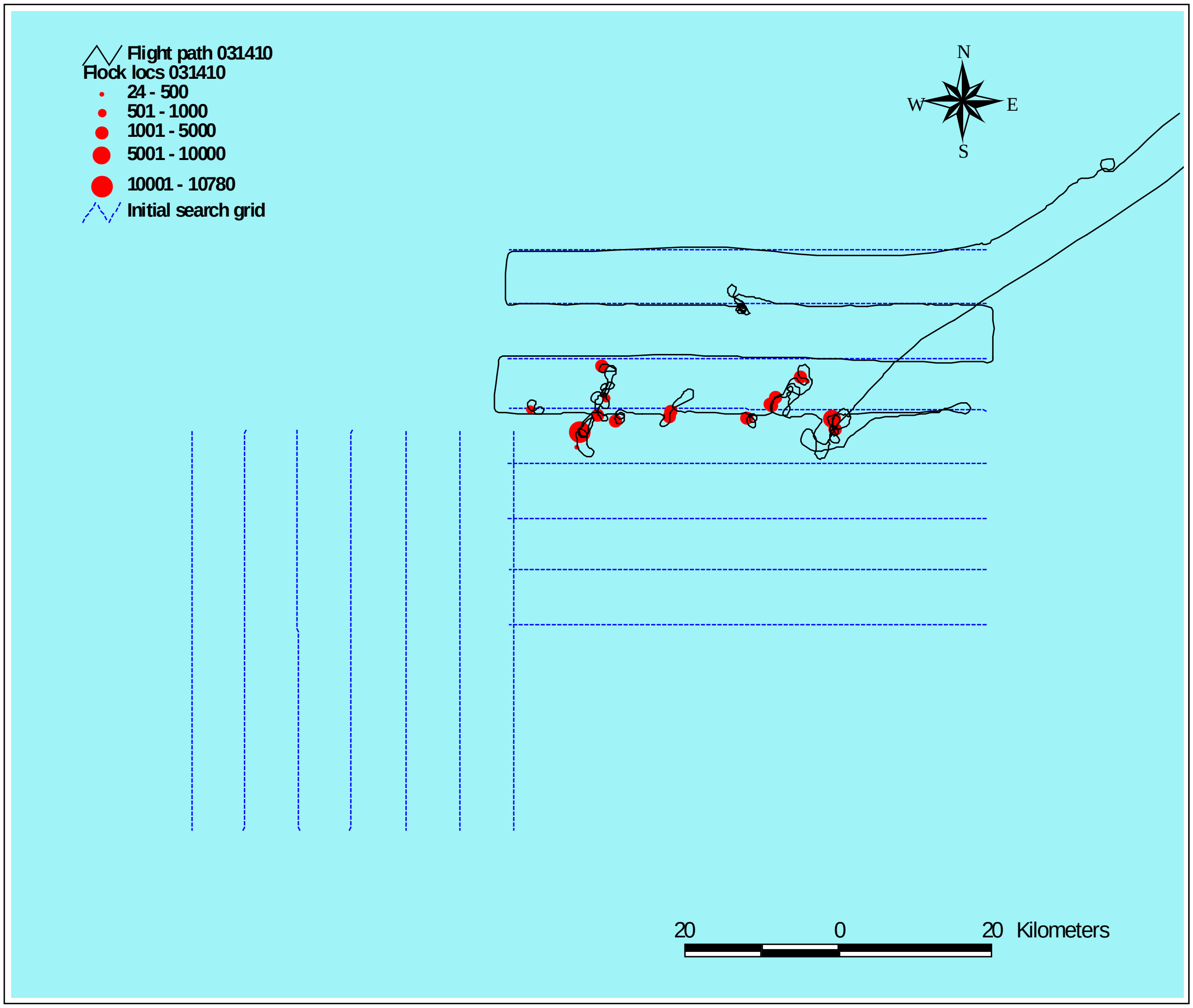

Figure 8. Flight path, locations and relative size of eider flocks recorded during a spectacled eider aerial survey, Bering Sea, Alaska, 14 March 2010.

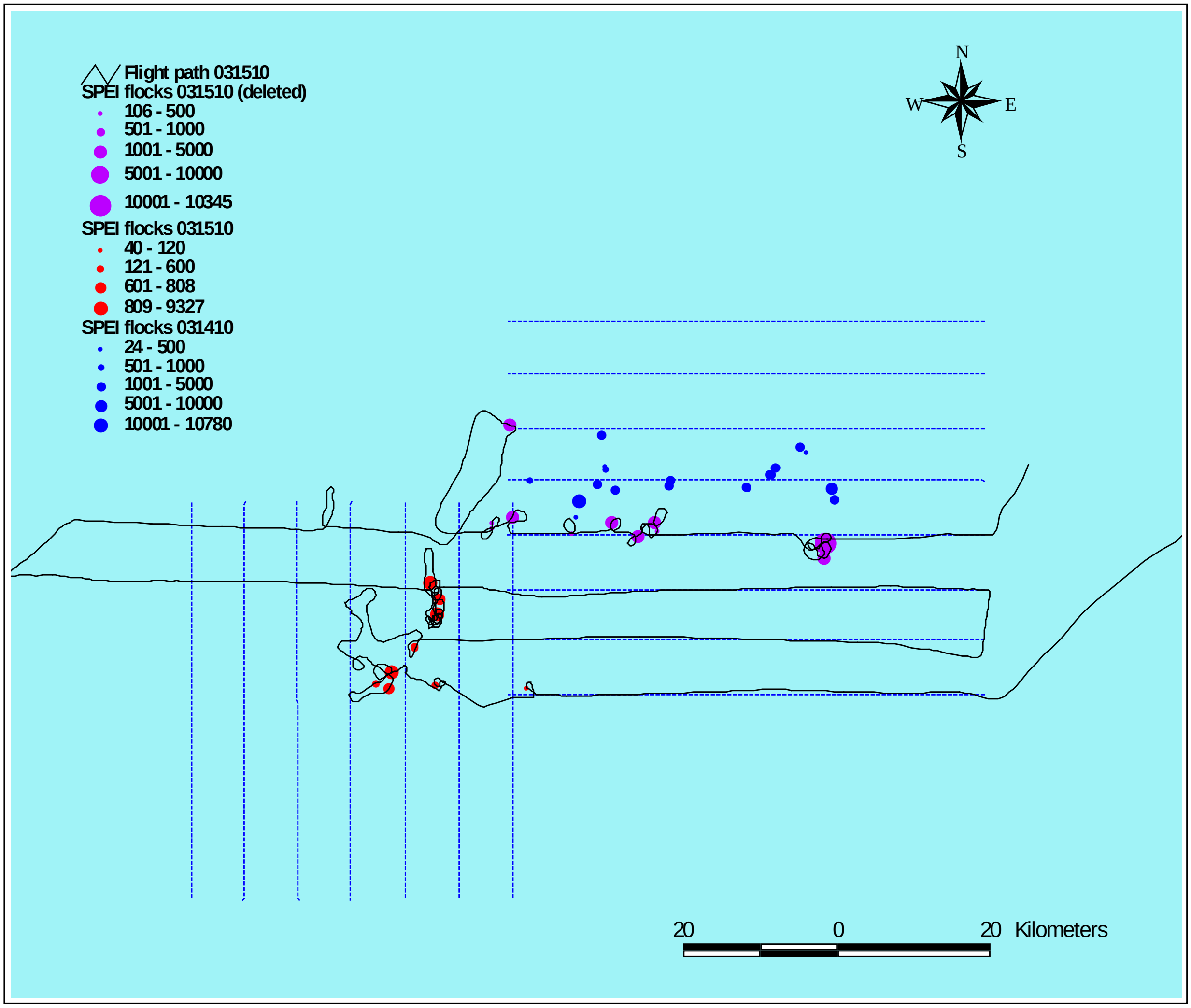

Figure 9. Flight path, locations and relative size of spectacled eiders recorded during a spectacled eider aerial survey, Bering Sea, Alaska, 15 March 2010. Lavender colored symbols are locations of eider flocks suspected of being double-counted due to their proximity to flocks recorded during the previous day. They were subsequently deleted from the data set thus not included in calculation of population statistics.

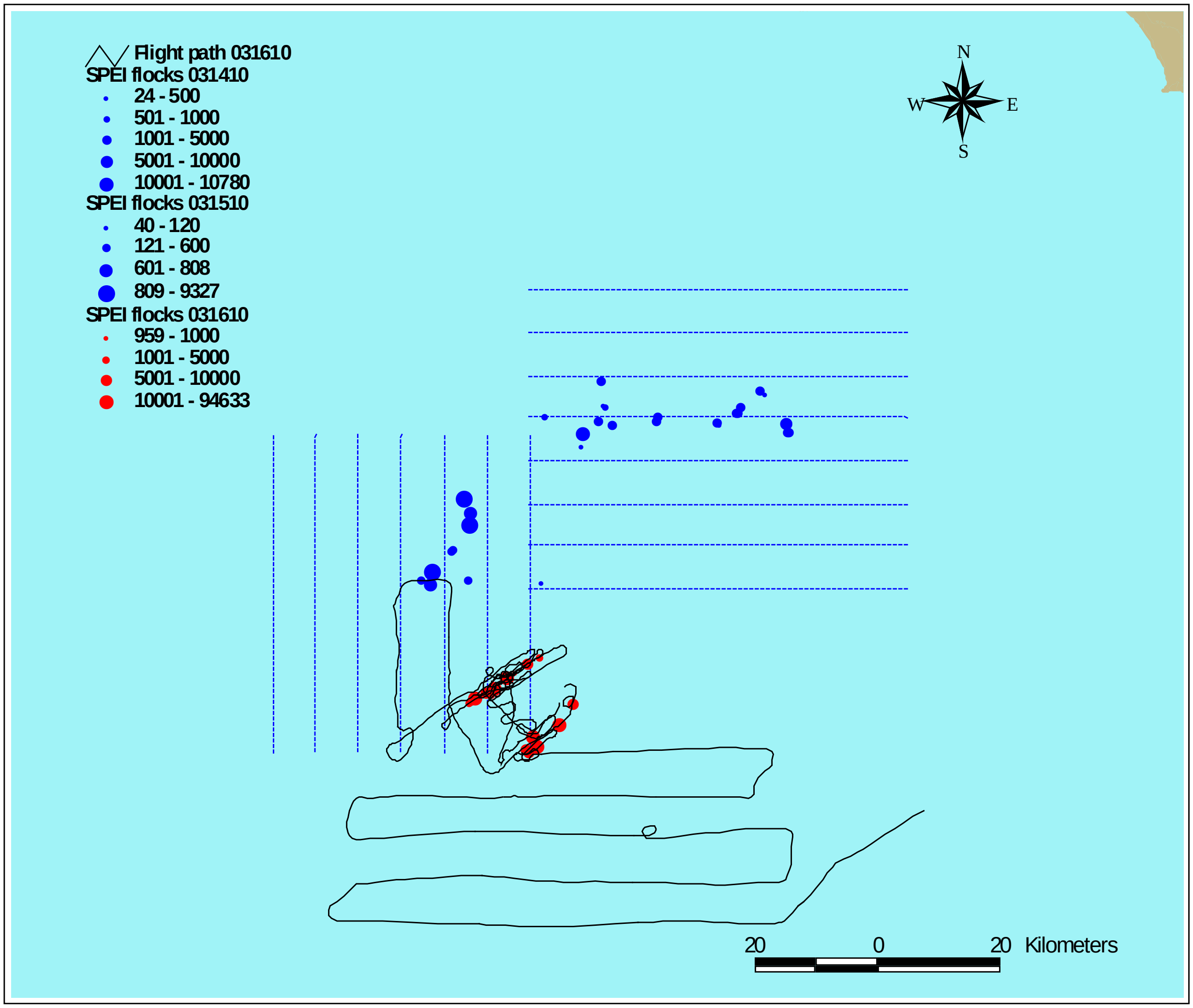

Figure 10. Flight path, locations and relative size of spectacled eiders recorded during a spectacled eider aerial survey, Bering Sea, Alaska, 16 March 2010.

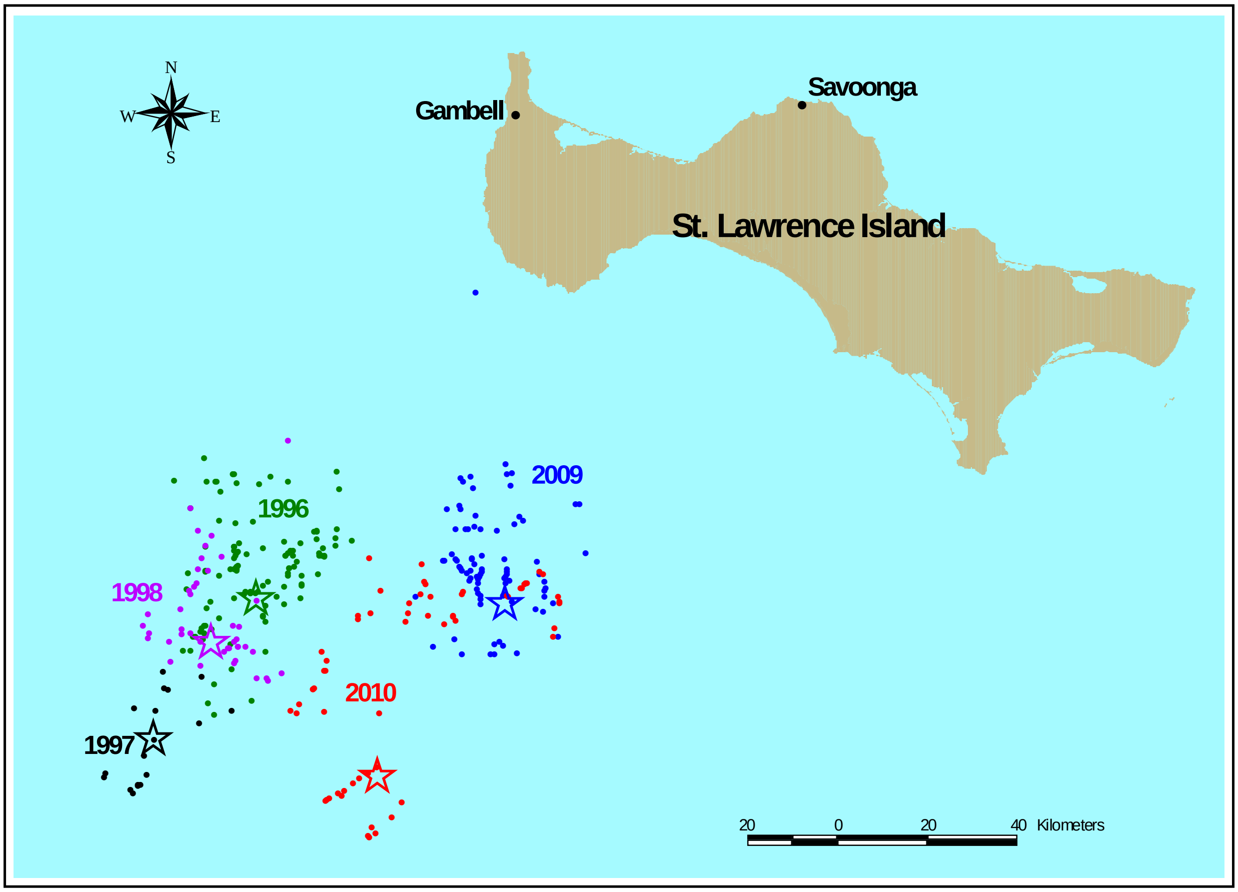

Figure 11. Distribution of spectacled eider flocks recorded during aerial surveys conducted in March 1996, 1997, 1998, 2010, and April 2009, Bering Sea, Alaska. The star symbols illustrate the relative geographic centers of distribution of each annual data set, weighted by flock size.