Tapes were replayed and observations entered into computers using custom software with keys programmed to species codes. The transect start point, each observation and the transect end point were entered into the computer in synchrony with the actual observations played back on the tape. The computer calculated the distance to each observation using the internal clock.

We calculated population estimates and variances using ratio estimate procedures described by Cochran (1977). Population estimates were based on area expansion and visibility correction factors (Conant et al. 1988). Variance estimates presented were based on the fixed wing survey. The variance associated with the correction factors was not calculated for this report.

Population estimates were calculated within the DPS for 1989, 1990 and 1991. Population estimates from the 1989 and 1990 expanded breeding pair transects were analyzed using a 3 strata design (Fig. 7) to examine the importance of the DPS compared to refuge land outside the DPS. We determined the relative importance of federal versus non-federal lands in the DPS in 1991 by calculating population estimates using a 5 strata design (Fig. 8).

Distribution Maps and Coverages

We produced point location and density maps of waterfowl distribution from 1991 transect data. We converted linear distances to each observation to map coordinates using a True Basic program and input this data into PC ARC/INFO software. Maps displaying specific point locations for major species and species groups were generated. We used a True Basic program to calculate bird density at regular intervals along each transect. The resulting density data were input into PCTin, a 3-dimensional terrain modelling software package, and contour maps of waterfowl density distribution for major species and species groups were generated. PC ARC/INFO computer coverages of waterfowl density distribution were also produced.

Duck Production Surveys

We generated 90 2.59 km^2 (1-mi^2) plots using a True Basic program and PC ARC/INFO. The plots were systematically spaced within the DPS and centered along the 1991 intensified breeding pair survey flightlines. A subset of 30 plots was surveyed by helicopter from 6 July to 9 July 1991 (Fig. 9). Survey procedures followed those for the Alaska Statewide Duck Production Survey (U.S. Fish and Wildlife Service 1991) for helicopter surveys except that a Hughes 500 helicopter was used. Data were analyzed using the custom Lotus 1-2-3 software for the Alaska Statewide Duck Production Survey (Hodges and Witmer 1990).

RESULTS

Population estimates and relative abundance

Tables 1, 2, and 3 show indicated total numbers (corrected for visibility bias) for all duck species within the DPS for 1991, 1990, and 1989, respectively. Scaup were consistently the most abundant species. The coefficients of variation were lower for populations estimates in 1991 than in 1989 or 1990.

Non-federal lands were relatively more important for ducks. Non-federal lands supported 56% of the total duck population and federal land supported 44% (Table 4). Populations of dabblers were generally higher on the non-federal land as were populations of some divers, especially canvasbacks. In terms of total ducks, the non-federal land was estimated to have approximately 50,000 more birds than the federal land.

Based on estimates of total ducks in 1989 and 1990, approximately 80% of the refuge waterfowl population occurred within the DPS and 20% outside (Table 5). Habitats within the DPS supported a higher proportion of the populations of all species. However, the relative importance of habitats outside the DPS was higher for goldeneye, bufflehead, merganser, white-fronted goose and loons compared to other species.

Distribution maps and coverages

Ducks were widely distributed throughout the DPS (Fig. 10). They occurred in at least low densities in most areas within the DPS and were concentrated in several areas (Fig. 11). The point location map presents the survey data in its rawest form and helps to interpret the relative density contour map. Total duck density polygons were overlain with land ownership to show distribution on non-federal versus federal land (Fig. 12). Additional point location and contour maps are presented in the appendices.

Two relative density maps for each major species and group of ducks were produced. One map shows the distribution of all birds (i.e. includes indicated singles and pairs plus flocks) and the other shows the distribution of indicated singles and pairs only (no flocks). The latter can be considered the relative distribution of breeding birds.

ARC/INFO computer coverages of density distributions were created for each species.

Duck production surveys

The largest number of estimated broods was green-winged teal, followed by northern pintail, northern shoveler, and American

wigeon and scaup (equal numbers of broods) (Table 6). Few diver broods were seen due to the early timing of the survey. The highest density of broods was on the plot near the Black River west of Chalkyitsik in the eastern part of the DPS (Fig. 13). The highest number of broods seen was 10. One-third of the plots had no broods and another third had 3 or less broods. The remaining third had greater than 4 broods.

DISCUSSION

Population estimates and relative abundance

The acquisition of point location data by intensive aerial survey allowed calculation of population estimates for any designated geographic area sampled by survey transects. This kind of data provides for the evaluation of administrative units important to the refuge and Division of Realty for management and to MBM for survey design.

Approximately 51% of the DPS is privately owned. Population estimates based on land ownership (Table 4) indicate 56% of the total duck population in the DPS occurred on private lands. This suggests that the relative importance of habitats on private lands is slightly higher than would be expected by area alone. A significant proportion of the population of some species, such as canvasback, occurred on private lands. An understanding of waterfowl population demographics based on administrative units is an important advantage of point location data, realizing that oil development will primarily occur on private lands.

The 1989 and 1990 population estimates (Table 5) were based on transects that systematically sampled the entire refuge (Figure 5). The population estimates from the DPS and the stratum outside the DPS inside the refuge provided an indication of the relative importance of each area to the total refuge waterfowl population. These population estimates were also the best estimates to date of the waterfowl population within the refuge boundaries.

Hodges (1990) made the point that the traditional breeding pair survey transects are in high density habitat (Figure 4) and expanding to lower density unsampled areas results in total population estimates that are biased high. Our analysis of 1989 and 1990 expanded surveys confirmed and quantified his conclusion by showing the DPS contained 80% of the waterfowl. Any expansion into outlying areas having 20% of the population would overestimate the total population.

The 1991 intensified survey estimated 198,222 (uncorrected for visibility bias) ducks within the DPS. The 1991 traditional breeding pair survey estimated 262,178 (uncorrected for visibility bias) ducks within the DPS for a difference of 63,956

ducks. Some of the difference in estimates could be the result of survey timing because earlier surveys may include birds staging before moving to breeding grounds elsewhere (Hodges 1990). Also, the intensive survey systematically sampled the total survey area and the traditional survey did not (Figures 4 and 6). Thus, the traditional breeding pair transects may sample high density areas within the DPS disproportionally.

The population and variance estimates calculated for the DPS from 1989-91 (Tables 1-3) also provide information about current and future survey design. The sample size increased four fold in the DPS in 1991 (Figures 5 and 6). The increased effort improved the precision of the 1991 population estimate by 30 and 46 percent, compared to 1990 and 1989, respectively, as measured by the coefficients of variation (Tables 1-3). It is unlikely that the level of effort expended in 1991 is economically feasible to sustain over the long term. If improved precision of population estimates is desired stratification of the survey area will be needed.

Distribution Maps

Intensive equally spaced transects were established in the DPS in 1991 primarily for development of detailed distribution maps. The point locations form the primary data which is converted to x,y,z data files by a True Basic program and to contours of waterfowl density by PCTin and ARC/INFO. The accuracy of these maps is based on the distance between transects and the accuracy of point location data. Our data from the Yukon Delta goose surveys indicates that point location data is very accurate. The mean difference between map measured and computer calculated distances to known locations along transects from the Yukon Delta was 360 m.

We know there is a high correlation on the Yukon Delta surveys between aerial goose observations and goose nests on the ground ($r = .81$ for cackling Canada geese). Although we haven't obtained similar data for ducks we believe the contour maps accurately depict the distribution of ducks at the time of the survey. Examination of the total duck contour map (Fig. 11) clearly shows the Ohtig Lake and Canvasback Lake areas to be high in duck numbers. These areas are known for their high numbers of ducks and suggest the other regions of high density identified on the contour map are real.

We visually compared the distribution map from Lensink (1965) (based on intensive transects and observations recorded at four mile intervals) with the total duck contour map from 1991 (Fig. 11). There is a marked similarity in density areas even after 36 years. This suggests that there are underlying habitat factors that have remained stable. Waterfowl habitat