9.0 SUMMARY OF RESULTS

This chapter presents the results of the avian surveys and studies conducted for NJDEP Wind Ocean Ecological Baseline Surveys project. For specific information on design, methodology, and results of avian surveys and studies please refer to the section number noted.

9.1 AVIAN SHIPBOARD AND SMALL BOAT COASTAL SURVEYS

The primary goal of the avian shipboard surveys was to collect avian occurrence, distribution, and abundance data within the project area for the development of a Study Area avian predictive model. A secondary goal was to collect diurnal avian flight altitudinal distribution data to determine bird altitude distribution relative to the RSZ. For information on the survey design and methodology see **Section 2.1.**

9.1.1 Survey Results

Avian shipboard offshore surveys were conducted January 2008 through December 2009, with associated small-boat coastal surveys being conducted each month after completion of the shipboard offshore survey. A total of 15,483 km (8,360 NM) and 2,700 km (1,457 NM) of trackline were surveyed on the offshore and coastal surveys, respectively, with >1,100 hrs of combined survey effort. The resultant dataset fills a large gap in our understanding of at-sea bird distribution in the western North Atlantic Ocean.

9.1.1.1 Avian Occurrence

A total of 176,217 birds representing 153 species were recorded, with 84,428 birds of 145 species being recorded during the shipboard offshore surveys and 91,789 birds of 82 species recorded during the small-boat coastal surveys. Federally endangered, threatened, and candidate species were not detected during avian surveys. Fourteen of the 21 federally listed species of concern and 16 of the 20 state-classified endangered, threatened, and special concern species potentially occurring in coastal and offshore waters were observed during the survey.

9.1.1.2 Distribution and Abundance

Cumulative: Total Birds

Avian densities were highest near shore at all seasons, although this finding was much more pronounced in winter than in summer (ratio of abundance on offshore surveys vs. small-boat coastal surveys ranged from 2:5 to 1:5). This was due primarily to the and the large numbers of coastal-breeding gulls and terns and wintering waterfowl along the New Jersey coast and the relative lack of true pelagic seabirds in the Study Area (although there were large numbers of Wilson's Storm-Petrels, an austral migrant from the Southern Ocean, present offshore in the summer). Overall, the areas of highest abundance were restricted to inshore waters, with the highest avian abundances recorded south and east of Hereford Inlet, south and east of Ocean City, and east of Atlantic City. Offshore, the most consistent area of high avian abundance was near a shoal area east of Barnegat Inlet (**Section 2.3.3.1**; **Figure 2-7**).

Seasonal: Total Birds

Comparisons of avian distribution and abundance between the two winter seasons (**Figures 2-9** and **2-13**) were difficult because of the limited data obtained in winter 2008. The majority of the high abundance areas in winter were nearshore. Only two high abundance areas were found offshore (both in winter 2009). Highest avian densities in the two springs were shifted offshore relative to the winter seasons. Spring 2009 had higher avian densities than spring 2008. Areas with the highest offshore avian abundances during both spring seasons were similar offshore; however, in spring 2008 the higher abundances were in the middle and northern portions of the Study Area and more widespread throughout the Study Area in spring 2009 (**Section 2.3.3.2**).

High avian densities shifted more offshore during the summer seasons, compared to winter and spring seasons. For example, 47% of the highest abundance areas in 2008 and 68% in 2009 were in offshore waters.

Patterns of abundance in the two fall seasons were similar though with a distinct northward shift of abundance in fall 2009 relative to that of fall 2008. This difference was primarily attributable to lower avian observations in the northeast corner of the Study Area in fall 2008. Offshore densities were lower in the fall than the summer seasons,

An interesting difference among these four seasons was that highest relative abundance was shifted quite noticeably from offshore in summer to nearshore in winter. Spring and fall were transitional seasons and both nearshore and offshore areas were intermediate in abundance. This variation is a result in differing habitat preferences between the seasonal avifauna, with the winter avifauna dominated by inshore-foraging species (e.g., scoters; **Appendix F**) and the summer avifauna dominated by offshore-foraging species (e.g., Common Tern; **Appendix F**).

The summer seasons exhibited the lowest absolute abundance, with the majority of individuals detected being of locally-breeding species, primarily Common Tern and the three breeding gull species (Laughing, Herring, and Great Black-backed). Further details on seasonal distribution/abundance patterns may be found in the species accounts (**Appendix F**).

Species

The ten most abundant species recorded during each season are presented in **Table 9-1** through **Table 9-4.** Although survey effort was higher in winter 2008-2009 than winter 2008 (**Section 2.3.1, Table 2-1**), four species (Black Scoter, Herring Gull, Northern Gannet, and scaup species) that ranked in the top 10 species during both winter seasons were in lower abundance and two species (Long-tailed Duck, Common Loon) were in higher abundance during winter 2008-2009 than winter 2008 (**Table 9-1**) Between spring 2008 and spring 2009 survey effort was similar. Three species (Common Loon, Long-tailed Duck, Laughing Gull) that occurred in both spring seasons were in higher abundance and four species (Northern Gannet, Surf Scoter, Herring Gull, and Red-throated Loon) that occurred in both spring seasons were in lower abundance in spring 2009 than spring 2008. No comparisons were made between summer 2008 and summer 2009 because one of the months (July 2009) was not surveyed since the project modification start date was 01 August 2009. Between fall 2008 and fall 2009 the survey effort was similar. Seven species (Northern Gannet, Laughing Gull, Herring Gull, Wilson's Storm-Petrel, Great Black-backed Gull, and Red-throated Loon) were in lower abundance in fall 2009 than fall 2008. The reason for these differences is unknown, however many variables (e.g., prey availability, weather, differences in yearly sampling dates) affect the abundance of a species recorded in a given season. Further discussion of the most abundant avian groups and species is found in **Appendix F**. For additional information on abundance similarities and differences between seasons see **Appendix C: Figures C-26** through **C-70**.

9.1.1.3 Altitude Distribution

In addition to examining abundance and distribution, data were also analyzed to determine frequency of occurrence within the potential RSZ of power-generating wind turbines, defined as 100 to 700 ft (30.5 to 213.4 m).Of a total 71,834 individuals recorded, 3,433 (4.8%) occurred in the potential RSZ. Birds recorded on the small-boat coastal surveys occurred in the RSZ 83% more often than birds recorded on the shipboard offshore surveys.

The species/groups with the highest overall percentage of occurrences in the RSZ were: geese (46.5); herons (33.3). scaup (29); dabbling ducks (26.9); Osprey (20.0); Common Loon (9.0); large gulls (8.2), cormorants (7.0), and Northern Gannet (3.9). For histograms of cumulative and seasonal altitudinal distribution of total birds and selected species, see **Section 2.3.4** and **Appendix D: Figures D-1** through **D-40.**

Table 9-1. Seasonal Top-10 species tables for the ship and boat surveys (Winter).

Winter 2008				Winter 2008-2009		
Species	**Total n**	**#/km**		**Species**	**Total n**	**#/km**
Black Scoter	1,307	2.03		Black Scoter	2,811	1.13
Herring Gull	798	1.24		Long-tailed Duck	2,747	1.11
Northern Gannet	779	1.21		Surf Scoter	2,290	0.92
Scaup (unknown), *Aythya* (unknown)	750	1.17		Greater Scaup	1,572	0.63
Long-tailed Duck	464	0.72		Common Loon	1,149	0.46
Ring-billed Gull	397	0.62		Scoter dark-winged (unknown)	1,133	0.46
Red-throated Loon	206	0.32		Herring Gull	928	0.37
Sanderling	206	0.32		Northern Gannet	926	0.37
Common Loon	130	0.20		Scaup (unknown), Aythya (unknown)	900	0.36
Great Black-backed Gull	107	0.17		Scoter (unknown)	634	0.26
Total	**5,435**	**8.44**		**Total**	**17,310**	**6.99**

Table 9-2. Seasonal Top-10 species tables for the ship and boat surveys (Spring).

Spring 2008				Spring 2009		
Species	**Total n**	**#/km**		**Species**	**Total n**	**#/km**
Northern Gannet	3,281	1.27		Northern Gannet	1,455	0.57
Surf Scoter	2,738	1.06		Surf Scoter	944	0.37
Herring Gull	1,882	0.73		Common Loon	897	0.35
Black Scoter	709	0.27		Herring Gull	831	0.32
Common Loon	450	0.17		Black Scoter	691	0.27
Red-throated Loon	436	0.17		Long-tailed Duck	669	0.26
Long-tailed Duck	420	0.16		Razorbill	498	0.19
Great Black-backed Gull	401	0.16		Laughing Gull	354	0.14
Scoter dark-winged (unknown)	320	0.12		Red-throated Loon	334	0.13
Laughing Gull	241	0.09		Double-crested Cormorant	326	0.13
Total	**12,024**	**4.66**		**Total**	**8,144**	**3.18**

Table 9-3. Seasonal Top-10 species tables for the ship and boat surveys (Summer).

Summer 2008				Summer 2009		
Species	**Total n**	**#/km**		**Species**	**Total n**	**#/km**
Laughing Gull	823	0.45		Laughing Gull	345	0.38
Wilson's Storm-Petrel	700	0.38		Northern Gannet	280	0.31
Common Tern	495	0.27		Common Tern	253	0.28
Northern Gannet	171	0.09		Wilson's Storm-Petrel	120	0.13
Great Black-backed Gull	107	0.06		Herring Gull	85	0.09
Cory's Shearwater	99	0.05		Great Black-backed Gull	74	0.08
Forster's Tern	52	0.03		Forster's Tern	34	0.04
Herring Gull	49	0.03		Tern (small)	24	0.03
Whimbrel	49	0.03		Common Loon	17	0.02
Royal Tern	21	0.01		Osprey	6	0.01
Total	**2,657**	**1.44**		**Total**	**1,261**	**1.39**

Table 9-4. Seasonal Top-10 species tables for the ship and boat surveys (Fall).

Fall 2008				Fall 2009		
Species	**Total n**	**#/km**		**Species**	**Total n**	**#/km**
Laughing Gull	3,661	1.01		Northern Gannet	2,403	0.68
Northern Gannet	3,284	0.90		Laughing Gull	1,532	0.43
Surf Scoter	2,245	0.62		Herring Gull	644	0.18
Wilson's Storm-Petrel	1,248	0.34		Wilson's Storm-Petrel	557	0.16
Black Scoter	1,175	0.32		Great Black-backed Gull	535	0.15
Double-crested Cormorant	1,136	0.31		Red-throated Loon	449	0.13
Common Tern	1,040	0.29		Surf Scoter	435	0.12
Herring Gull	882	0.24		Bonaparte's Gull	241	0.07
Great Black-backed Gull	865	0.24		Common Loon	196	0.06
Red-throated Loon	765	0.21		Common Tern	177	0.05
Total	**20,446**	**5.62**		**Total**	**8,538**	**2.42**

Scaup (*Aythya* spp.) represented 54.5% of all birds in the RSZ for the small-boat coastal surveys alone, and 31.8% of all birds in the RSZ overall. Of the 1,091 scaup recorded in the RSZ, 1,088 individuals (99.7%) were recorded on the 17 January 2009 small-boat coastal survey. On this date, a severe cold snap froze many inland bodies of water, forcing many “bay ducks” to the coast. This illustrates the potential effects of a major weather event on both the dataset and avian mortality, as removing the scaup recorded on that date causes the overall percentage of birds in the RSZ to drop from 4.8% to 3.3%. Offshore, Northern Gannet was the species occurring most often in the RSZ (594 individuals) and was also one of only three species recorded in the RSZ in every season. The fact that Northern Gannet forages on the wing, takes 4-7 years to reach maturity, and lays only one egg per breeding season make it, perhaps, the most likely species to be impacted negatively by turbine-related mortalities within the Study Area.

Winter had both the most individuals (1,551) and highest percentage of individuals (8.01%) in the RSZ, despite the fact that there were far more survey effort hours in both spring and fall. As mentioned above, this was due in large part to the 1,088 scaup recorded in the RSZ on the 17 January 2009 small-boat coastal survey. Northern Gannets and large gulls (*Larus* spp.) also accounted for a large portion of the winter RSZ totals with 138 and 160 individuals, respectively.

In spring, Northern Gannet was the most abundant species in the RSZ (385 individuals), followed by scoters (*Melanitta* spp.) with 193 individuals and large gulls with152 individuals. Loons (*Gavia* spp.) and small terns (*Sterna* spp.) accounted for 69 and 30 individuals, respectively.

Summer had both the lowest overall percentage of birds recorded in the RSZ (0.82%) and the least diversity in the RSZ (five species). The reduced survey effort in summer was a factor but in addition, most individuals of the highest-flying species/groups (Northern Gannets, Common Loon, and most ducks and geese) had departed the area for their breeding grounds. Of the 29 individuals recorded in the RSZ during summer, 20 were large gulls.

Although 21 species were recorded in the RSZ for the fall season, RSZ occurrence numbers were largely driven by Canada Geese (399 individuals) and Double-crested Cormorants (158 individuals). None of the other 19 species exceeded 65 individuals in the RSZ for the season.

9.1.2 Flight Direction Analysis

9.1.2.1 Mean and Median Flight Direction

Mean angles and median flight angles are reported for all species that were included in the top five list in at least one-time period (month, season, year, or overall) in **Appendix E; Table 2-11**. In addition to abundances, observations, and cluster sizes, results are also shown for sample size n (the number of birds observed for which flight direction data are available), length vector r, angular deviation, circular SD, deviation, and the 95% CI for the mean angle.

Mean flight direction (mean angle) for total birds was NE in both spring seasons (2008: 33-39° with a mean angle of 36°; and 2009: 36-45°, mean 40°), SW in fall 2008 (228-230°, mean 229°), and W in fall 2009 (246-260°, mean 253°). Flight directions (mean angles) were more variable (in terms of both directional differences and width of the 95% CI) in the summer and winter seasons across the two years. For total birds, mean angles were S (165-190°, mean 177°) and NE (35-86°, mean 60°) in summer 2008 and summer 2009, respectively. A southerly component was present in the mean angle for all three winter seasons: SE (109-134°, mean 121°) in winter 2008, S (179-186°, mean 182°) in winter 2009, and SW (229-239°, mean 234°) in winter 2010. In terms of annual averages, mean flight directions were SW (219-220°, mean 219°) and NW (274-325°, mean 299°) in 2008 and 2009, respectively, with an overall two-year mean angle of 223° (SW). For additional details relating to mean and median flight direction see **Section 2.3.5.1**.

9.1.2.2 Tests for Circular Uniformity of Flight Direction

Results of these hypothesis tests to test for circular uniformity of flight direction show that, in the majority (though not all) of cases and combinations of species and time periods, the H_o of circular uniformity is rejected, suggesting that a significant mean flight direction (mean angle) exists. These results support the visual results discussed earlier for mean angle. Frequency distribution of flight directions across the eight octants generally exhibits a distinct mean flight direction (mean angle) especially in the migration seasons, with an expected general northward tendency in spring and southward tendency in fall/winter. The frequency distributions of flight directions across the eight octants is, in many cases, far from uniform, with percentage distributions in any one octant often exceeding 20% especially in migration seasons, compared to an expected frequency distribution of 12.5% in each octant if a completely uniform distribution is assumed. In summary, the results that were visually detected in the earlier analyses of mean angle and frequency distributions across the eight octants have been statistically confirmed and validated with these various hypothesis tests. For additional details circular uniformity testing see **Section 2.3.5.2**.

9.2 OFFSHORE AVIAN AERIAL SURVEYS

Avian aerial surveys were initially scheduled for three separate occasions: once each in spring 2008, fall 2008, and spring 2009. After the April survey the efficacy of such limited surveying was discussed by the NJDEP committee members, and the pros and cons of conducting aerial surveys were compared. Benefits consisted of better detection of peak activity (if conducted during peak activity) and a “snapshot” collection of avian data over the whole day. The negatives consisted of limited detection of small and darker-colored birds, the temporal variation of migration, the small number of planned surveys (considering the limited data already gathered), the safety of flying at low altitudes, and the cost involved. A vote was taken and it was decided to discontinue aerial surveys and instead increase radar validation surveys.

9.3 SUPPLEMENTAL AVIAN OFFSHORE AND ONSHORE SURVEYS

Supplemental shipboard avian surveys were conducted during December 2008, and from August through December 2009. Three types of supplemental surveys were conducted: shoal/station surveys, ship sawtooth transects, and land-based migration counts associated with shipboard transects. The primary goal of the shoal/station surveys was to help determine whether high densities of waterbirds occur in association with shoals. The primary goal of the ship sawtooth transect surveys was to determine whether increased survey effort would cause changes in abundance estimates of avian species. The primary goal of the land-based counts and seawatch transect surveys was to determine the passage rates of migrating waterbirds relative to distance from shore. For information on the survey design and methodology see **Section 4.1**.

9.3.1 Survey Results

The results of the supplemental avian offshore and onshore surveys during the study are summarized below. For additional details regarding results please refer to **Section 4.3**.

9.3.1.1 Shoal Surveys

Although a very low survey effort did limit the amount of data collected, this supplemental survey effort did help validate the importance of shoals as feeding areas for birds in general, for Northern Gannets in particular.

9.3.1.2 Ship Sawtooth Transect Surveys

For the most part, the additional survey effort conducted during this supplemental effort did not differ from the results of the regular shipboard transects during the same period; however, some differences were noted. For example, 237 Double-crested Cormorants were observed during the supplemental surveys and only 17 during regular transect surveys (**Section 4.3.2**). This difference is due primarily to ship scheduling, as most regular transect effort in fall 2009 took place outside the period during which the majority of the Double-crested Cormorants migrate through the project area (Sibley 1997; see also **Section 4.3.2** concerning this species). Additionally, Laughing Gull comprised 19% all birds detected on the supplemental transects and only 9% on the regular transects during the same period (**Section 4.3.2**). These data suggest that, indeed, additional effort at offshore transects would have added materially to the understanding of the dynamic bird distribution and abundance within the Study Area, although the additional survey data would probably result in an understanding at a finer temporal scale than intended by the scope of work of this study.

9.3.1.3 Seawatch: Land-based Counts/Shipboard Transect Surveys

Fall seawatch transect-survey data from Avalon and Barnegat Light were analyzed relative to distance from shore, in bands of 1.866 km (1.007 NM). More than 77% of all migrating individuals were within 9.26 km (5 NM) of shore; almost 61% were within 5.56 km (3 NM) of shore.

Though nearly all species seen from the ship were detected throughout the width of the entire Study Area (shore to 20 NM offshore), distribution and abundance is generally greater closer to shore and diminishes as distance from shore increased. Because the land-based counts and the shipboard transects were conducted concurrently, the much lower numbers of migrating waterbirds beyond 9.26 km (5 NM) relative to that inside 9.26 km can be shown to document actual occurrence. Overall, the land-based surveys yielded higher observations than offshore surveys. For more detailed information see **Section 4.3.3**.

9.4 AVIAN RADAR SURVEYS

The primary goals of the avian radar surveys were to determine seasonal bird altitudinal distribution over offshore and nearshore sites within the Study Area and determine the density of flight activity moving through the radar survey area over a specific time period. A secondary goal was to identify dominant bird flight directions. For information on the survey design and methodology see **Section 5.4**.

Vertically scanning radar (VerCat) and horizontally scanning radar (TracScan) data were analyzed and data filters were developed to remove detections from rain (especially virga) and sea clutter, because these detections generate false tracks. Track counts were adjusted for dropped tracks that received a new track ID when the target was the same as the original track. The TI-VPR system sampled targets passing through a 20° cone directed vertically to determine the proportion of each type of biological target (e.g., birds, bats, insects) detected by VerCat. The TI-VPR data were used to develop a correction factor for insects in the radar count data from the VerCat. Data from barge-based, boat-based, and onshore-based observer validation surveys were analyzed and used to evaluate the results of radar analyses.

The results of the studies with VerCat are expressed in terms of three metrics: **median altitude quartile** (the 50% quartile containing the altitude at which half the total number of birds observed were flying below the median, and half were flying above the median), **flux** (adjusted bird tracks/km^3/hour), and **AMTR** (number of bird tracks crossing over a kilometer per hour). Data related to cumulative diurnal and nocturnal flux were sorted into three altitude bands with reference to the potential RSZ: (1) below the RSZ (low altitude band, 1 to 99 ft AMSL), (2) within the RSZ (middle altitude band, 100 to 700 ft AMSL), and (3) above the RSZ (high altitude band, 701+ ft AMSL). The AMTR provides a quantitative passage rate. Although many variables affect the possibility of bird-turbine collision risk, in general the greater the AMTR value the greater the potential for bird-turbine collision.

Median altitude quartiles provide information on the frequency of occurrence of birds in the RSZ. The AMTR provides a quantitative passage rate. Although many variables affect the possibility of bird-turbine collision risk, in general the greater the AMTR value the greater the potential for bird-turbine collision. Flux is a measure of bird density in the RSZ and is the most important metric for determining bird collision risk impacts.

Based on the direct visual validation studies, only 10-20% of the birds flying at very low altitudes were detected with the radar. This is because of constraints of the marine radar detecting wave clutter that obscures return from low flying birds. Consequently, in the lowest altitude quartile the reported bird counts are underestimated (i.e., lower than the number actually present) and the radar measured median altitudes are likely lower than those given in this report. Bird counts in the RSZ are affected less by return from wave clutter, because the effect is reduced as the height of the radar beam increases.

The TracScan radar was used primarily to determine direction of target movement. Because different offshore study sites were sampled at different times during a season, it is difficult to attribute changes to time of season, or location, or both. Monitoring all offshore sites throughout each season would have been prohibitively expensive even if equipment and personnel had been available (and they were not).

9.4.1 Offshore

9.4.1.1 Spring 2008

During spring of 2008 the VerCat radar operated for 940.5 hours and the TracScan radar operated for 1,044.3 hours. Daytime flux values gradually decreased within the low altitude band and gradually increased within the RSZ for nearshore and offshore sites. During the night greater flux values occurred within the RSZ than below the RSZ as the spring season advanced for both nearshore and offshore grids. The dominant diurnal and nocturnal nearshore and offshore flux directions during most of the survey weeks was from the south and southwest to the north and northeast. AMTR increased as season progressed near shore and offshore. The peak diurnal AMTR occurred offshore on Grid 26 (137.0 abt/k/h) from 24-30 April and on Grid 17 (113.0 abt/k/h) from 07-11 May 2008. Peak nocturnal AMTR occurred 30 April - 07 May (320.3 abt/k/h) on Grid 26 and from 07-11 May 2008 (333.5 abt/k/h) on Grid 17. Because the offshore grids were sampled later in the season, one cannot conclude that more birds were offshore than nearshore, because the high counts may have been the result of more migration occurring later in the season than earlier in the season.

9.4.1.2 Fall 2008

During fall 2008 radar surveys were limited to two offshore sampling grids in the southern section of the Study Area. The VerCat operated for 442.5 hours and the TracScan operated for 415.1 hours. The data are limited and insufficient to make any conclusions. All the median altitudes were within the RSZ for daytime and nighttime samples. The flux was greater in the RSZ than the low altitude band during daytime and nighttime and there was no difference in flux between daytime and nighttime. Cumulative diurnal and nocturnal AMTR decreased from Grid 22 to Grid 26, but Grid 26 was sampled later in the fall. Peak diurnal AMTR was 104.3 abt/k/h and peak nocturnal AMTR was 134.3 abt/k/h from 30 September through 12 October 2008. The direction of movement was from the north to the south.

9.4.1.3 Spring 2009

The VerCat radar operated for 39.8 hours and the TracScan radar operated for 41.3 hours. The data collected were limited and insufficient to analyze and make any conclusions. Three onshore sites were sampled: IBSP, Brigantine, and Corson's Inlet-Sea Isle City (CI-SIC).

9.4.2 Onshore

9.4.2.1 Spring/Early Summer 2008

VerCat operated for 657.9 hours and TracScan operated for 657.3 hours. The majority of the median altitude quartiles were within the RSZ at all of the onshore sites. The cumulative diurnal flux values varied within and between the onshore sites and were in general greater during the daytime than at night in the RSZ. The cumulative nocturnal flux values were greater within the low altitude band than within RSZ at all onshore sites. At IBSP and CI-SIC flux values were generally similar for low altitude and RSZ. At Brigantine, cumulative diurnal flux values were greater within the low altitude band than within the RSZ. This difference may be the result of the different migratory species passing the site or the behavior of resident species at the site. AMTR values were similar between the onshore sites during the daytime. AMTR values were greater at night than during daylight indicating that some nocturnal migration was probably still in progress from mid-May into mid-June. The cumulative peak diurnal AMTR (17.6 abt/k/h) occurred at Brigantine from 29 May through 01 June 2008. The cumulative peak nocturnal AMTR (66.2 abt/k/h) was at IBSP from 15-18 May 2008. Overall, as expected during spring migration, the dominant movement of birds was from the south and southwest to the north and northeast.

9.4.2.2 Fall/Early Winter 2008

VerCat operated for 2,090.2 hours and TracScan operated for 2,039.4 hours. Most of the cumulative median diurnal altitude quartiles were within the RSZ at IBSP in early fall 2008, and the majority of the cumulative median altitude quartiles were within the low altitude band at Brigantine, CI-SIC, and at IBSP from mid-fall into early winter 2008. Most of the cumulative nocturnal altitude quartiles were within the RSZ. The majority of the cumulative diurnal flux values were greater within the low altitude band than within the RSZ. For most of the survey dates, the cumulative nocturnal flux values were generally similar between the low altitude band and the RSZ. Cumulative diurnal AMTR values were 10 abt/k/h or less and cumulative nocturnal AMTRs were 30 abt/k/h or less at all of the onshore sites. At each onshore site peak cumulative AMTR occurred at night. The dominant direction of movement during most weeks was from the north and northeast to the south and southwest.

9.4.2.3 Spring/Early Summer 2009

VerCat operated for 1,902.1 hours and TracScan operated for 1,872.2 hours. All of the cumulative weekly median altitude quartiles during the daytime were within the low altitude band at IBSP while at Brigantine cumulative weekly altitude quartiles during the day were split almost equally between the low altitude band and the RSZ. At CI-SIC, the cumulative weekly median altitudes during the daytime were all within the low altitude band. Most of the cumulative weekly median altitude quartiles at night at IBSP were within the RSZ. At Brigantine most of the cumulative weekly median altitude quartiles during the night were in the high altitude band (above the RSZ), and at CI-SIC all of the cumulative median altitude quartiles at night were within the RSZ. Cumulative weekly flux values during daylight were greater within the low altitude band than within the RSZ. Cumulative weekly flux values at night varied among sample periods and were likely dependent on when conditions were favorable for migration. The trend was for greater flux values in the low altitude band during migration events. Cumulative diurnal AMTR values were 10 abt/k/h or less and cumulative nocturnal values were less than 80 abt/k/h at all of the onshore sites. At each onshore site, peak cumulative AMTR occurred at night. The dominant direction of migration was from the south and southwest to the north and northeast. Some of these movements occurred even though winds were unfavorable, and one small scale reverse migration (towards the SW) was recorded.

9.4.2.4 Onshore Fall 2009

VerCat operated for 1,299.5 hours and TracScan operated for 1,372.9 hours. Most of the median quartiles were below the RSZ during daylight, but most were in the RSZ at night. Flux values in the RSZ were greater at night than during the day and this was particularly so during migration events. The exceptionally high flux rate during the period 08-16 November 2009 was associated with a 22 minute period of high winds and many birds aloft. Cumulative AMTR values during daylight hours were <20 abt/k/h during the majority of the study. The only exception was during the week of 08-16 November at CI-SIC when the AMTR increased dramatically but only in the 16+ mph wind category. Except for the peak cumulative nocturnal migration period 05-11 October 2009, when the AMTRs were approximately 90 abt/k/h, the cumulative weekly AMTRs at night were below 50 abt/k/h. The direction of migration during most sample weeks was from the north and northeast to the south and southwest, and many movements occurred with opposing winds from the south to the north.

9.4.3 Offshore-Onshore Comparisons

It is important to realize that statistical comparisons between onshore and offshore samples are possible only when the samples are collected at the same time. Concurrent offshore radar (Grid 22 and Grid 26; 30 September – 12 October 2008) and onshore radar (CI-SIC; 05-19 October 2008) sampling only occurred during 05-19 October 2008. Radar data from these locations were compared statistically to provide quantitative information on any onshore-offshore differences in cumulative median flight altitudes, cumulative flux values, and cumulative AMTR. The cumulative median altitude quartiles over the offshore girds were all within the RSZ during the daytime, while over the onshore site half of the cumulative altitudes during daylight were within the RSZ and half below. The cumulative median altitude quartiles over the offshore grids and over the nearshore site at night were all within the RSZ. Cumulative flux values were higher over the offshore grids than the onshore site during daylight and dark. The cumulative AMTRs were noticeably greater over the offshore grids than over the onshore site. For the limited time period of 05-19 October 2008, avian activity was concentrated at the offshore sites.

9.5 THERMAL IMAGING VERTICALLY POINTED RADAR

Use of thermal imagery and vertically pointing radar proved to be very valuable in identifying the sources of echoes detected in VerCat. The TI-VPR system could easily detect targets flying through the rotor swept zone. The vertically pointing radar provided accurate altitudes of flight and the thermal imaging video provided enough information on targets to identify them as birds, foraging bats, or insects. We recommend that all future studies use this technique to validate the identity of the sources of radar echoes.

9.5.1 Offshore

9.5.1.1 Spring 2008

TI-VPR offshore barge-based surveys were conducted at six sites for a total of 180 hrs. Grid 23, approximately 10 mi offshore, in the southern section of the Study Area, showed the highest total target count for the season (783 targets), of which 570 targets (73%) were identified as birds, 204 as insects and 9 as foraging bats. Other grids had fewer birds (69-21) birds, and overall 75% of birds were within the RSZ. The mean directions of the movements were towards the NNW-NE and one movement was a reverse migration toward the SSW.

9.5.1.2 Fall 2008

TI-VPR offshore barge-based surveys were conducted at two sites for a total of 161 hrs. Grid 23 once again showed the highest total target count (1,252 targets) for the seasonal, of which 985 targets were identified as birds (79%), 243 as insects, and 24 as foraging bats. The second grid sampled (Grid 26, also approximately 10 NM offshore in the southern section of the Study Area, had a total target count of 249, and 192 were identified as birds (77%), 57 as insects, and no foraging bats. The mean directions of the movements for both grids were towards the SW.

9.5.1.3 Spring 2009

TI-VPR offshore barge-based surveys were conducted at two sites for a total of 15 hrs. Grid 16 (nearshore in the central section of the Study Area) showed the highest total target count (97 targets), of which 39 were identified as birds (41%), 57 as insects, and no bats. Grid 22 (nearshore in the southern section of the project area) had a total target count of 57 targets, with 39 targets being identified as birds (68%), 18 as insects, and no bats. The majority (96% and 94%) of the bird movements aloft occurred within the RSZ. The mean directions of the movements for Grids 16 and 22 were towards the NNE.

9.5.2 Onshore

9.5.2.1 Fall 2008

TI-VPR surveys were conducted at the SIC site from 08 to15 December for a total of 48 hrs. The site had a total target count of 285. 270 targets were identified as birds (95%), 9 as insects, and 6 as foraging bats. Although the date is late the mean direction of the movement toward the SSW suggested a migratory movement; 90% of the birds flew at altitudes within the RSZ.

9.5.2.2 Spring 2009

TI-VPR surveys were conducted at the IBSP site during the period 21-22 and 27 March 2009 for a total of 17 hrs. The site had a total target count of 54, of which 21 targets were identified as birds (95%), and 33 as insects. Foraging bats identified were not identified. The mean direction for movement was towards the NE, and100% of the birds were at altitudes above the RSZ.

9.5.2.3 Fall 2009

TI-VPR surveys were conducted at SIC, IBSP, and BB for a total of 10 hrs. SIC had the highest total target count for the season (1,133 targets), of which 738 targets were identified as birds (65%), and 395 as insects (both season highs). IBSP had the second highest total target count with 219 targets, of which 144 targets were identified as birds (66%), 69 as insects and 6 as foraging bats. BB had 138 targets detected, with 39 targets being identified as birds (28%) and 99 as insects. 66.2% of the birds were flying in the RSZ and 33.8 % were flying above the rotor swept zone. The mean directions of the movements over the three sites were toward the SW-south-southeast (SSE), but the movements over IBSP and BB showed some variability in direction.

9.6 NEXRAD

9.6.1 Year-to-Year Pattern of Migration

During the spring the sum of nightly peak density (birds/km^3) differed from year-to-year. As expected, the maximum density of migration measured over the coastal sample areas differed from the maximum density over the offshore sample areas. This can be attributed to the bird's tendency to follow the coast line during their migration. Over the five years of spring data the sum of the nightly peak densities measured over the coastal sample areas ranged from 347 in the spring of 2006 (area 1A) to 2,836 in the spring of 2009 (area 1A), and the maximum density recorded was 569 in the spring of 2004 (area 1A). The sum of nightly peak densities recorded over the offshore sample areas ranged from 58 (area 2B) in the spring of 2008 to 264 in the spring of 2007 (area 1B), with a maximum density of 103 recorded in the spring of 2007 in area 1B. Thus during the five-year study the amount of migration in spring passing over the onshore sample areas was much higher than the amount of migration measured over the offshore sample areas.

During the fall the sum of nightly peak density (birds/km^3) also differed from year-to-year. Over the five years of fall data the sum of the nightly peak densities measured over the onshore sample areas ranged from 1,445 (area 3A) in the fall of 2004 to 4,078 (area 1A) in the fall of 2005, with a maximum density of 705 recorded in the fall of 2005 (area 1A). The range of the sum of nightly peak densities over the offshore sample areas ranged from 273 (area 1B) in the fall of 2004 to 658 (area 2B) in the fall of 2005, with a maximum density of 144 recorded in the fall of 2005 (area 2B). Just as in the spring the amount of migration passing over the onshore sample areas was much higher than the amount of migration measured over the offshore sample areas. Once again, these results suggest that birds have a tendency to follow the coast line during migration. Overall, the density of migration during the fall was on average two to three times as much as the density of migration observed during the spring.

9.6.2 Night-to-Night Pattern of Migration

Nocturnal migration during the spring and fall shows considerable night-to-night variability. In the spring, migration begins to build in late April, peaks near the middle of May, and then declines towards the end of May. This pattern can be seen in both the onshore and offshore sample areas. Within the three onshore sample areas there were 5 nights with a mean density of 100 birds/km^3 or greater over the sample areas during the five years of spring migration (21 April, and 01, 04, 07, 11 May), while within the offshore sample areas the maximum was 21 on 21 April [area 1B]). Within the offshore sample areas the mean migration density was considerably less than that measured over the onshore areas (mean peak density of 21 birds/km^3). Though sizable flights can occur anytime from the middle of April through the middle of May, the peak of migration through the area is in early to mid-May. Fall migration builds in early September and peaks in mid-October to early November. After the peak in late October/early November the density of migration declines, and by mid-November very little migratory movement takes place. This pattern can be seen both within the onshore sample areas and within the offshore sample areas. There were 17 nights with a mean density of 100 birds/km^3 or more within the onshore sample areas during the five years of fall migration (31 August, 01, 10, 13, 15, 23, 26, 29 September and 05, 12, 14, 15, 17, 20, 25 October, and 02, 09 November), while within the offshore sample areas there were zero nights with a mean density of 100 birds/km^3 or more. Area 1A measured the highest density for the fall season on 15

October with a mean density of 258 birds/km^3. Similar to the spring, the offshore sample area mean migration densities were considerably less than those measured within the onshore sample area. The maximum mean density only measured 34 birds/km^3 on 12 September within Area 1B.

9.6.3 Hour-To-Hour Pattern of Migration

The hour-to-hour pattern of migration over the sample areas during the spring (2005-2009) typically started 30-45 min after sunset, peaked on most evenings between 02:00 – 06:00 UTC (11:00 PM – 2:00 AM EST), and declined until sunrise. In the fall (2004-2008) the quantity of migration was greater than in the spring (see year-to-year pattern), and the hour-to-hour pattern of percentage of peak hourly density during the evenings was shifted slightly earlier in the evening compared to that observed in spring. Like the spring, migration typically started 30-45 minutes after sunset and the peak of a nightly movement generally occurred from 01:00 – 05:00 UTC (10:00 PM – 12:00 AM EST). The peak density for the night in the spring appears to be slightly later in the evening and more defined when compared to the peak density for the night in the fall.

9.6.4 Direction of Migratory Movements

In the spring the mean directions (μ) from which the movements originated were 203.58° in 2005, 205.14° in 2006, 205.44° in 2007, 207.37° in 2008, and 211.35° in 2009. The flights were oriented toward the north-northeast (between 23° and 32°). There was some variability in mean direction from year to year but within each year there was relatively strong directionality as indicated by the length of the mean vector [r] (a statistical measure of concentration). All yearly mean directions show low circular variance and are highly significant ($p<0.000$). In the fall the mean directions were from 33.57° in 2004, 28.18° in 2005, 17.68° in 2006, 17.72° in 2007, and 28.55° in 2008. The flights were oriented toward the southeast to south-southwest between 197° and 214°. The lengths of the mean vectors from the fall data were comparable to those in spring data. Topographic features such as the shoreline likely influence the directions of seasonal migrations, particularly those occurring at lower altitudes.

9.6.5 Migration, Weather Conditions, and Collisions

During the five years of spring data, 79 of 365 nights had conditions that would cause birds to fly lower -- sometimes with reduced visibility. Twenty-nine of these nights had migration densities of 25 birds/km^3 or greater. During the five years of fall data, 102 of 465 nights had weather conditions that might cause birds to migrate at low altitudes and 24 of these nights had bird movements of 25 birds/km^3 or greater. There were 23 more total nights over the five fall seasons than in five spring seasons with weather conditions that could cause birds to fly at low altitudes and sometimes in poor visibility, but generally on these nights there was little or no migration.

9.7 AVIAN PREDICTIVE MODELING

The primary goal of the study was to develop spatial models for predicting changes in density and spatial distribution of birds and to identify important regions used by birds within the Study Area. The objective was to quantify where birds are most likely to concentrate in relation to geophysical habitat features (e.g. depth, shoals) and predict where birds were likely to occur seasonally. The following questions were addressed: (1) Where and when are birds (species) most likely to concentrate within the Study Area? (2) Are birds more or less concentrated evenly along the coast, or do some species exhibit specific spatial gradients (i.e. latitude/longitude variation)? (3) What is the relationship between bird density/distribution and depth, distance to shoreline, distance to shoals, and slope?

Interpolation (e.g. kernel density), spatial regression, and GAMs were used to quantify the relationship between spatial covariates (e.g. bathymetric and distance based metrics) and birds. The spatial models were developed to quantify the effect of each spatial covariate for predicting changes in bird density and distribution. In summary, along with the kernel density maps (**Appendix M**) that identified where and when birds were likely to concentrate, spatial covariates were calculated to develop insight into the geographic distribution and describe the basic attributes of habitat utilized by birds. By incorporating these data in a geographic information system, changes in bird density were determined as a function of depth, slope, distance to shoreline, distance to shoals, and whether there was a spatial gradient in bird density (north/south or east/west) for a variety of species. Collection of kernel density maps was a valuable tool for identifying important locations where and when (by month and season) birds were most likely to concentrate.

9.7.1 Kernel Density Interpolation

Kernel density maps were estimated for all-behavior and sitting densities (number of birds/km^2) 2008 and 2009, and the combined two-year period 2008-2009. Numerous localized density maxima for all-behavior and sitting birds were located nearshore, midshore, and far-offshore, with the vast majority of these maxima occurring nearshore. A small portion of these density maxima for all-behavior birds are mirrored by the sitting birds, reflecting differences in the numbers of flying and sitting birds. For example, eight and 15 localized sitting density maxima occurred in 2008 and 2009, respectively; and 24 such maxima occurred in the overall cumulative two-year period, most of which occurred nearshore. In 2008, the eight sitting density maxima ranged from 110 to 830 (the latter occurring in the vicinity of Barnegat Light); and in 2009, the 15 sitting density maxima ranged from 115 to 735 (the latter occurring in the vicinity of Little Egg Inlet). In the overall cumulative two-year period, the 24 sitting density maxima ranged from 115 to 1,480 (the latter occurring in the vicinity of Little Egg Inlet). For the all-behavior birds, the highest density maxima were 1,425 in 2008 (midshore southeast of Little Egg Inlet), 1,730 in 2009 (nearshore in the vicinity of Little Egg Inlet), and 1,805 (on the offshore edge of the nearshore region, between Little Egg Inlet and Brigantine).

Observing these annual and overall cumulative spatial kernel density maps, the following general conclusions can be made:

1. Nearshore densities are higher than offshore densities, supporting an offshore gradient of decreasing densities with increasing offshore distance.

2. Within the offshore region, midshore densities were generally higher than far-offshore densities.

3. All-behavior densities were higher than sitting densities, reflecting the presence of both all-behavior and sitting birds.

4. The highest nearshore densities occurred up against the coastline rather than on the offshore edge of the nearshore region.

5. All-behavior density maxima that are mirrored by sitting birds reflect a balance between flying and sitting birds. If the sitting density is less than the all-behavior density, then both flying and sitting birds are present. If the sitting density is equal to or near the all-behavior density, then most/all of the birds in the given region are sitting rather than flying.

6. All-behavior density maxima that are not mirrored by sitting birds indicate that the majority of birds in the given region were flying rather than sitting.

9.7.2 Total Birds Seasonal Analysis

For most seasons, nearshore densities were higher than offshore densities (for both all-behavior and sitting birds). Within the offshore region, densities were generally higher midshore than far-offshore.

In fall 2008, numerous localized density maxima were located nearshore, midshore, and offshore as a result of contributions of individual species. A total of 24 detectable density maxima occurred for all-behavior birds within the Study Area, ranging in magnitude from 105 to 1,740 (the latter of which is located midshore southeast of Little Egg Inlet. The majority of these maxima were not mirrored by the sitting birds, indicating that most of the total birds in the regions of these density maxima were flying rather than sitting. Compared to 24 density maxima for all-behavior birds, only four density maxima occurred for the sitting birds: 1) 945 nearshore in the vicinity of Barnegat Light (compared to 1,420 for all-behavior birds); 2) 120 nearshore in the region midway between Little Egg Inlet and Barnegat Light (compared to 135 for all-behavior birds); 3) 145 midshore southeast of Hereford Inlet (compared to 170 for all-behavior birds); 4) 140 far-offshore southeast of Hereford Inlet (compared to 565 for all-behavior birds). Except for this far-offshore density maximum, far-offshore densities were generally lower than midshore densities. Total bird density (all-behavior and sitting) were generally lower in fall 2009 than in fall 2008 (a year earlier). In fall 2009, five localized density maxima occurred for all-behavior birds: 1) 180 nearshore at Barnegat Light (compared to 125 for sitting birds); 2) 260 nearshore between Barnegat Light and Little Egg Inlet (compared to 145 for sitting birds); 3) 300 midshore southeast of Little Egg Inlet (compared to 215 for sitting birds); 4) 300 nearshore just south of Atlantic City (compared to 235 for sitting birds); 5) 100 nearshore just south of Ocean City (mirrored by a sub-maximum density on the order of 50). In addition, numerous density maxima (on the order of 50) for all-behavior birds also occurred, both nearshore and midshore, some of which were mirrored by the sitting birds.

Comparing spring and fall for the 2008 and 2009, densities were relatively lower in spring than in fall. In spring 2008, three distinct localized density maxima occurred for all-behavior birds: 1) 745 nearshore just off Ocean City (compared to 730 for sitting birds, indicating that the majority of the birds in this region were sitting rather than flying); 2) 335 nearshore off Hereford Inlet (mirrored by a sub-maximum density on the order of 50 for sitting birds); 3) 135/km^2 midshore southeast of Ocean City (which is not mirrored by the sitting birds). In spring 2009, four distinct localized density maxima occurred for all-behavior birds: 1) 585 nearshore just south of Barnegat Light (compared to 370 for sitting birds); 2) 130 offshore east of Barnegat Light (which is not mirrored by the sitting birds); 3) 150 nearshore between Great Egg Harbor Bay and Atlantic City (compared to 140 for sitting birds); 4) 120 nearshore just off Hereford Inlet (compared to 110 for sitting birds).

Overall densities were generally lower in summer than in fall and spring for 2008 and 2009. In summer 2008, only 1 distinct localized density maximum occurred: 110 nearshore off Ocean City. Several sub-maximum densities (on the order of 25) occurred for all-behavior birds around Atlantic City and Brigantine. Densities were generally higher nearshore than offshore, and offshore densities were more patchily distributed for sitting birds than for all-behavior birds.

Overall densities were slightly lower in summer 2009 than in summer 2008. In summer 2009, the spatial distribution of all-behavior density was more uniform nearshore than offshore Nearshore sitting bird densities were lowest around Ocean City and Great Egg Harbor Bay, the region between Brigantine and Little Egg Inlet, and a small region just north of Little Egg Inlet.

Among winter and summer, overall densities were generally higher in winter than in summer (for both all-behavior and sitting birds). Among the three winter seasons, densities were generally lowest in 2008, highest 2009, and intermediate in 2010, partly reflecting the lower survey effort in the latter season. In all three winter seasons, densities were higher nearshore than offshore, and all-behavior densities were higher than sitting densities, reflecting the presence of both flying and sitting birds. In winter 2008, two localized density maxima occurred for all-behavior birds: 1) 475 nearshore between Atlantic City and Brigantine; 2) 120 nearshore between Great Egg Harbor Bay and Atlantic City. In winter 2009, densities were higher than in winter 2008 (1 year ago), with 13 localized nearshore density maxima occurring for all-behavior birds (ranging from 125 to 1,740) along the entire coastline, from south of Seaside Heights to Hereford Inlet. Eight of these 13 density maxima were mirrored by the sitting birds (ranging from 170 to 1,715). In winter 2010, five localized nearshore density maxima occurred: 1) 135 nearshore in the vicinity of Barnegat Light (compared to 110 for sitting birds); 2) 105 nearshore between Little Egg Inlet and Barnegat Light; 3) 235 nearshore between Brigantine and Little Egg Inlet (compared to 105 for sitting birds); 4) 120 nearshore at Brigantine (compared to 50 for sitting birds); 5) 105 nearshore midway between Ocean City and Hereford Inlet (compared to 50 for sitting birds).

9.7.3 Modeling Results

Modeling results are outlined in **Tables 9-5** and **9-6**. In general, depth and distance to shoreline were found to be important predictors of bird density and distribution. For example, using the combined two year dataset, it was determined that bird density and distribution declined in waters greater than 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline; however, there was a strong seasonal effect in these values that is important to consider. Although bird density was generally greater in the fall (i.e., migration and seasonal visitors take up residence along the New Jersey coastline) and birds were principally concentrated in waters up to 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline; the same result was observed for the entire dataset. When the spring season was modeled, birds were found concentrated in deeper waters (>20 m [65.6 ft]) than in the fall (<20 m [65.6 ft]). Moreover, in summer, bird density ranged further offshore (18.3 km [11.4 mi]) and increased significantly in waters greater than 30 m (98.4 ft) in depth. In winter, bird density was concentrated in waters less than 15 m (49.2 ft) in depth and within 12.2 km (7.6 mi) from the coastline.

Table 9-5. General summary of effect of spatial covariates on bird density based on GAM results: (a) description of effect.

Covariate	Effect on bird density		
	+	-	+/-
Depth	Density increases in shallower water	Density increases in deeper water	Effect on density is mixed
Slope	Density increases with slope	Density decreases with slope	Effect on density is mixed
DistShore[1]	Density increases with distance from shoreline	Density decreases with distance from shoreline	Effect on density is mixed
DistShoal	Density increases with distance to nearest shoal	Density decreases with distance from nearest shoal	Effect on density is mixed
Longitude[2]	Density increase indicates more bird in the eastern portion of the Study Area	Density decrease indicates more birds in the western portion of the Study Area	Effect on density is mixed
Latitude	Density increase indicates more birds in the northern portion of the Study Area	Density increase indicates more birds in the southern portion of the Study Area	Effect on density is mixed

[1] Distance from shore
[2] Distance from shoal

Table 9-6. Covariate effect on bird density.

Bird Variable	Depth	Slope	DistShore[1]	DistShoal[2]	Longitude	Latitude
Total birds	+		-		+	-
Total birds 'Fall'	+		-		+	-
Total birds 'Spring'	-		-		-	
Total birds 'Summer'	+/-		-	+/-	+	-
Total birds 'Winter'	+	-	-		+	-
Total sitting birds	+	-				
Total sitting birds 'Fall'	+	+	-			+/-
Total sitting birds 'Spring'	-	+/-			-	+
Total sitting birds 'Summer'	+/-		+/-	+/-	+/-	
Total sitting birds 'Winter'	+		-			
Northern Gannet			-	+	+	-
Scoter Species			+/-	+	-	+
Long-tailed Duck		+/-	-		+	-

Table 9-6 (*continued*). Covariate effect on bird density.

Bird Variable	Depth	Slope	DistShore[1]	DistShoal[2]	Longitude	Latitude
Common Loon	-				-	
Red-throated Loon			+/-	+	-	
Herring Gull	+		+	+	-	+
Laughing Gull	+		-		+	-
Common Tern			-	+/-	+	-
Wilson's Storm Petrel			+		-	+
Cory Shearwater	-		+/-	+/-	+/-	

[1] Distance from shore
[2] Distance from shoal

Total sitting bird density was modeled to identify where birds are most likely to reside, concentrate, and for some species, feed (i.e. loons, ducks, and gulls sitting on the water may indicate foraging locations). In general, sitting birds were most likely to occur in waters less than 15 m in depth and within 3.8 mi from the coastline. In fact, in fall, spring, and winter, sitting bird density was concentrated in waters within 6.1 km (3.8 mi) from the coastline, whereas in summer the distance increased to 18.3 km (11.4 mi).

The seasonal changes in density and distribution of total birds were dynamic and related to changes in bird community composition. For example, in the fall and winter there were dense concentrations of diving ducks that were absent in the summer when the bird community was primarily composed of terns, gulls and petrels. This difference in community composition was likely responsible for the varying degree of bird density clustered inshore and offshore. The models detected this and quantified habitat use by total birds as a function of depth and distance to shoreline. These dynamics were investigated further to quantify the effect of covariates for predicting changes in species distribution. Scoter density and distribution exhibited a peak in waters 10 m (32.8 ft) in depth and were concentrated within 6.1 km (3.8 mi) from the coast and decreased offshore to approximately 30.6 km (19 mi) from the coast. Northern Gannets, which were present in each season, were generally concentrated in waters greater than 10 m (32.8 ft) in depth that was within 25.3 km (9.5 mi) from the coastline. Laughing Gulls and Common Terns, which were seasonal summertime breeders in New Jersey, displayed interesting distribution patterns. Laughing Gulls were generally concentrated within 7.6 km (4.7 mi) from the coast and decreased in waters greater than 15 m in depth. On the other hand, Common Terns ranged further offshore and their density declined around 18.3 km (11.4 mi) from the coast, and thereby occupied a wider range of coastal habitat than Laughing Gulls. The density and distribution of Cory Shearwaters, which were also summertime visitors, showed an increase in density offshore in waters greater than 30 m (98.4 ft) in depth to approximately 27.3 km (17 mi) from the coastline.

Overall, bird density and spatial distribution exhibited a striking onshore to offshore gradient that was highly variable among seasons and lined to changes in community composition. The results pinpoints where repeated maximum densities are likely to occur in relation to a variety of species. This information was integral to the understanding of the spatial ecology of marine birds along the New Jersey coastline and should be used to examine potential changes in habitat due to environmental changes from human activity (e.g., offshore wind development, water quality degradation, etc.).

Along with the kernel density maps that show where and when birds are likely to concentrate, it was determined that distance to shoreline and depth were useful and important predictors of changes in bird density and distribution. Kernel density maps were a valuable tool for identifying important locations where and when (by month and season) birds are most likely to concentrate. Depth and distance to shoreline were important predictors of bird density and distribution. Overall, bird density declined significantly in waters greater than 20 m (65.6 ft) and 12.2 km (7.6 mi) from the coastline. Total bird density was greater within the southeast portion of the Study Area during fall, summer, and winter but was more concentrated in the northern section of the Study Area during spring.