2010 Atlantic Coast Wintering Sea Duck Survey

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Project Description: The 2010 Atlantic Coast Wintering Sea Duck Survey represented the third year of prerequisite work aimed at developing an operational survey to monitor sea ducks wintering along the Atlantic coast of the U.S. and Canada.

Five fixed-wing aircraft were flown along the Atlantic coast between the U.S.-Canadian border (44°46' N) and Cape Canaveral, FL (28°26' N, Fig 1) at 110 knots and 70 m (200 ft) altitude, while an observer and pilot-observer counted sea ducks and other aquatic birds within 400m-width strip transects. The survey was conducted between January 23rd and March 2nd. The survey period was more protracted than in the previous two years because (i) one crew initiated observations in late January in an effort to obtain four replicates of some transect lines, and (ii) extreme weather conditions and aircraft mechanical problems delayed survey completion.

The crews flew the same transect lines as in 2009 (Silverman *et al*. 2009). Four crews flew a total of 4,369 nm of east-west transects spaced every 5 nm. These transects extended east from the coastline to the longer of two distances: 8 nm (the average distance to 6m depth) or the distance to 16m depth (Fig 1). After each crew completed their entire set of transect lines, they flew a transect parallel to the coastline, ¼ mile offshore, northward to their first east-west transect line; the crew then replicated every other transect from north to south (2,136 nm of the original 4,369 re-flown).

The fifth crew flew 33 transects, covering the Chesapeake Bay and providing additional replication along the Maryland-Delaware coast; this crew replicated 22 transects four times so as to collect data necessary for detection and movement estimation. Both pilot and observer also indicated whether birds were detected within 100m of the transect center to provide data to assess the effect of distance on detection and species identification, as well as the interaction of these with observation condition. Analysis of these data will be included in a forthcoming appendix to this report.

Changes from 2009 survey: The ½ mile coastal transect was not flown in 2010, and the resulting survey mileage was assigned to the intensive mid-coast replicates (crew 5). This crew flew three new lines located between the 10 nm-spaced lines in the southern part of the Chesapeake Bay (at 37°11', 37°21', and 37°31' N). The Chesapeake Bay line located at 38°26' was shifted north to 38°31' N, to avoid the Calvert Cliffs Nuclear Power Plant. Each of the four primary survey crews flew a section of the ¼ mile coastal line.

Objectives: The primary objectives of the survey are to estimate population sizes of wintering sea ducks, assess yearly variation and trends in distribution and abundance, and determine habitat associations and areas of special significance. The survey will also provide information on the distributions of seabirds and near shore aquatic birds.

Analytical methods: We chose a model-based procedure because there is a high degree of process variation present (i.e., birds move over the course of the survey). Abundance estimates were calculated using a hurdle model with a truncated negative binomial count distribution (Ridout *et al*. 1998). The zero component of the model included three covariates: transect area, latitude, and latitude-squared (latitude was standardized and centered on the midpoint of each species' distribution, to optimize the parameter estimation procedure). This model is similar to the model fit in 2009 and in a related analysis (Zipkin *et al*. 2010); the hurdle model was chosen over the zero-inflated negative binomial model (ZINB) used in the 2009 analysis, because the ZINB model-fitting produced unlikely parameter values in several cases and because, overall, the hurdle models demonstrated slightly better fit to the data. Transect area was used both as an offset for the count model and as a covariate for the probability of a zero. As a component of the count model, transect area predicts larger non-zero counts on longer transects; as a component of the zero-probability model, transect area predicts the possibility of a zero count attributable to transect length. Latitude and latitude^2 should also predict presence, as sea ducks are not uniformly distributed along the coast and the presence-latitude relationship is useful in describing winter range boundaries. In these models, each transect was represented once, with counts and transect areas for replicates summed; we estimated standard errors using 500 realizations of a parametric bootstrap of the fitted models.

In order to compare changes in distribution, abundance, and range between 2009 and 2010, we fit the hurdle model to the 2009 data. The 2009 abundance estimates are substantially different than those reported in the 2009 Annual Report. This change was not due to using the hurdle model in place of the ZINB model, but resulted because the previous estimates failed to adjust for replication in the predicted counts (i.e., replicated transect predictions were mistakenly double counted). As noted in 2009, all estimates in this report are preliminary and the final modeling approach has not been determined. Despite the fact that the negative binomial hurdle model accounts for overdispersion due to both large counts and many zeros, it nonetheless appears to fail to predict the largest counts, as evidenced by the fact that estimated abundance is larger than the majority of the corresponding bootstrap estimates (hence standard errors are likely to be underestimated). We plan to next explore the fit of hurdle models that describe counts as a marked count process (i.e., using a compound count distribution to separately describe flock counts and flock size). Including a covariate in the zero-component to differentiate major bays/sounds from the offshore transects may also better describe winter habitat use and will also be explored.

Transects were classified into 12 survey regions, representing distinct sections of the Atlantic coastline and separating major bays from the coast. From north to south, these regions are: coastline north of Cape Cod, Cape Cod & Nantucket, Nantucket Shoals, Long Island Sound, Long Island south coast, New Jersey coast, Delaware Bay, Maryland/Delaware coast, Chesapeake Bay, Pamlico Sound coast (including Virginia and North Carolina coastlines north & south of the sound), Pamlico Sound, and coastline south of Pamlico Sound (Fig. 2). As a

change from 2009, we modified the southern boundary of the southern coastal region to include only transects north of, and including, 30°21' N, as we have observed no sea ducks south of 30°26' N (approximately at Jacksonville, FL) in three years of survey work. Abundance was estimated separately for each region by including region as a factor in the count component of the hurdle model. Estimated mean count for each transect was scaled up to predict the number of birds in the 5 nm latitude band centered on the transect and summed for all transects within the region.

We calculated distance from land for all flocks (including singles) recorded along the east-west transects using ArcGIS tools and a detailed coastline shapefile obtained from the Atlantic Coast Joint Venture. From these distances, we estimated average distance from land along the "coastal" east-west transects for each species (i.e., excluding flocks observed on east-west transects in Pamlico Sound, Chesapeake Bay, Delaware Bay, Long Island Sound, Cape Cod/Nantucket west of the eastern edge of the Cape, and Nantucket Shoals). Finally, we calculated the median flock size for each species over the entire survey area for 2009-10. We did not include 2008 in these comparisons, because the survey design differed from the subsequent two years (the northern coast was not surveyed, transect lengths differed, and replicates were only completed over Nantucket Shoals). The distance estimates, as well as differences between years in the relative sample size of all flocks (used to estimate median flock size) compared to sample size of flocks on the coastal transects (used to estimate distance from land), illustrate distributional shifts on/offshore and into or out of the bays.

We report a combined estimate for Bufflehead (*Bucephala albeola*), Common goldeneye (*Bucephala clangula*), and Merganser (*Mergus spp.*, primarily Red-breasted *M. serrator*). These three species are all at relatively low abundance, and are seen in similar habitats and locations along the coast (see Results); moreover, we have concerns about misidentification among them, especially the Goldeneye and Mergansers. In 2010, Bufflehead constituted 49% of the counts for these species, Goldeneye 34%, and Mergansers 17%; flock size, distance from shore, and density with latitude are summarized separately for Bufflehead and Goldeneye/Mergansers.

Preliminary Results:

Abundance. Table 1 lists preliminary estimates of total ducks by species and region, and the percent change in abundance from 2009 to 2010. The east-west transects summarized in this report (which do not include the mid-coast crew replicates, see Fig 1 inset) covered approximately 1,350 nm^2 and sample over 20,000 nm^2 of ocean. Crews counted 59,194 birds, an increase of 29% from 2009, which represent an estimate of approximately 800,000 sea ducks.

In 2010, the most abundant species in the survey region was the Black scoter (*Melanitta americana*), followed by the Common eider (*Somateria mollissima*) and Long-tailed duck (*Clangula hyemalis*) (Table 1). In addition to Black scoters, White-winged scoters (*M. fusca deglandi*) increased substantially from 2009; Common eiders declined, while Surf scoter (*M. perspicillata*) and Long-tailed duck estimates remained essentially unchanged. Forty-nine percent of the sea ducks counted were scoters, and 84% of these were identified to species: 75% Black scoters, 20% Surf scoters, and 6% White-winged scoters.

Most of the difference in raw totals between years (+25%) is due to a large number of Black scoters observed on a single transect off the coast of South Carolina (11,500 counted on the second replicate at 32°41' N). The estimated number of Black scoters for the southern coast region, when the count from only the first replicate of this transect is used, is 71,400, giving an estimate of 112,800 Black scoters for the entire survey area (a 2% increase from 2009). In this case, all scoters are estimated to total 293,800, a 20% increase over 2009 (so that 43% of all sea ducks were scoters – 51%, 38%, and 11%, Black, Surf, and White-winged, respectively).

Distribution. Tables 1 and 2, and Figures 3-5 summarize the distribution of sea ducks along the Atlantic coast of the U.S., by species, for the three survey years.

Table 2 summarizes typical flock sizes and distance offshore by year and species. All species of sea ducks were observed closer to the shore in 2010. The median distance from shore in 2009 was 1.0 nm (1.8 for the scoters, eider, and Long-tailed duck) and only 0.4 nm in 2010 (0.6 for the five more "marine" species). In 2009, 95% of scoters, eiders, and Long-tailed ducks were within 8 nm of the coast; in 2010, 95% were within 5 nm.

Figure 3 plots the regional abundance estimates from Table 1 as a proportion of the estimated total by year, as well as the relative size of the 12 regions. The north-south distribution of each species over the three survey years is illustrated in Figures 4a-c. The upper panels in Figures 4ab plot the model estimated probability of a non-zero count by latitude, for transect area equal to the mean value within the species' range. Note that the height of these curves reflects overall abundance, so that probability of presence is lower for less abundant species. The lower panels of Figures 4ab characterize how average densities varied by latitude within and between survey years. Figure 5 maps the density by species and transect, averaged over the three years, and highlights areas of consistently high use (note that the northern part of Chesapeake Bay and the coast north of Cape Cod were not surveyed in 2008, so are less well characterized by these figures than the rest of the coast).

Black Scoter. Black scoters winter the farthest south of the three scoter species and are primarily found south of the Delaware Bay (Fig 3, NB: the 2010 bars for Black scoters in Fig 3 are based on the estimates *excluding* the single replicate with an extremely large count). Their estimated range in 2010 was similar to 2009, although contracted slightly at the northern and southern edges (Fig 4a, Top). Over the course of the three years of surveys, however, they were increasingly concentrated in the south, as illustrated by the shift in their peak density (Fig 4a, Bottom). Black scoters are found further offshore than Surf and White-winged scoters (excluding White-winged scoters found on Nantucket shoals, Table 2), and are relatively less likely to be found within the major bays than Surf scoters (Tables 1-2, Fig 3, 5). Nonetheless, in a pattern similar for all the species, they were found closer to shore in 2010 than 2009, with many more flocks seen in Pamlico Sound and fewer along the offshore coastal transects.

Surf scoter. Surf scoters concentrate along the mid-coast; their north/south probability of occurrence peaks at the mouth of the Delaware Bay, and they are found at highest abundance along the Maryland, Delaware, and Virginia coasts, as well as in Chesapeake and Delaware Bays (Fig 2). Their estimate ranges for 2009 and 2010 were similar (Fig 4a Top) but they exhibit a high degree of variability in density across years within this range (Fig 4a Bottom). They appear

to rely on the major bays and inshore areas more than the other scoter species (only 16% of Surf scoter flocks were seen on the coastal transects and Nantucket shoals, compared to 45% for Black scoters and 53% for White-winged scoters). They were also found closer to shore, in more frequent, smaller flocks, in 2010 (Table 2).

White-winged scoter. The least abundant scoter species, White-winged scoters are found furthest to the north (Figs 3-5). They are regularly seen on the Nantucket Shoals (37% of flocks in 2009-10). In 2009 they were also frequent in the Cape Cod/Nantucket region, but shifted south to the southern coast of Long Island in 2010 (Fig 3, Fig 4a Top). Note that the 2010 survey was delayed in the Cape/Long Island crew area, due to weather, so the distributional shift observed for White-winged scoters in this area (and to a lesser extent, Long-tailed ducks) may reflect survey timing.

Common eider. Common eider is the most northerly distributed species counted regularly on this survey, and the survey should be extended north of the U.S.-Canadian border to fully encompass their Atlantic wintering range. Eiders are especially concentrated around Cape Cod and Long Island Sound, found near to shore (typically within 1 nm of land), and are the surveyed species with the most consistent inter-annual distribution for the survey period. The large maximum distance from shore (19 nm, Table 2) represents a flock of 30 eiders east of the northern tip of the Nantucket (transect 41^{o} 21' N). As with Surf scoters, there were more, smaller flocks of eiders seen in 2010 than in 2009.

Long-tailed duck. Long-tailed ducks are found primarily around southern Cape Cod and the Nantucket Shoals; they also winter in large numbers within the Chesapeake Bay (but not along the surrounding coast) (Table 1, Figs 3, 5). Long-tailed ducks were more abundant on the Nantucket Shoals in 2009, and shifted north (increasing around Cape Cod and the northern coast) and south (higher proportions in Chesapeake Bay and some observed as far south as Pamlico Sound) in 2010. As with the Common eider, however, changes in their distribution among regions and along the coast between 2009 and 2010 appear to be less than those of the scoter species. Their average distance from land along the coastal transects is similar to Surf and White-winged scoters (about 2-3 miles), but more variable: crews have counted significant numbers of Long-tailed ducks east of Nantucket Sound (transects 41^{o} 21' N and 41^{o} 26' N, an area that might reasonably be classified with Nantucket Shoals in this analysis). Long-tails were seen in fewer, but somewhat larger flocks in 2010 as compared to 2009.

Bufflehead/Common goldeneye/Merganser spp. Bufflehead, Common goldeneye, and the Mergansers (Red-breasted *Mergus serrator* and Common *M. merganser*) are found close to shore and in large numbers in Chesapeake Bay, Pamlico Sound, and, to a lesser extent, Delaware Bay (Tables 1-2). (NB: most Mergansers counted on the survey are not recorded to species; Red-breasted mergansers represent the vast majority of those that are.) The densities of these species north of Delaware Bay show little variation with latitude and over the three survey years (about 1-4 birds/nm^2, Fig 4c). They are found at somewhat higher densities in Chesapeake Bay and Pamlico Sound, and rare along the surrounding coastline. Their numbers drop substantially south of 34^{o} N. These species are found close to land (most within 1 nm) and in the major bays and sounds (> 50% of flocks).

Project Status: The third season of prerequisite surveys was completed successfully and we are summarizing and analyzing the data from all three years to provide recommendations for an operational survey. Analyses include finalizing the estimation methods and comparisons between years, investigating the consistency of counts on replicated transects, exploring the relationship between observation condition, distance band, and detection, as well as estimating detection probabilities. Resolving the impact of very large counts and determining the survey effort needed to ensure stable and precise abundance estimates is a high priority of further analyses and data collection.

Further survey work will also focus on determining the distribution and movement of Black scoters off the South Carolina and Georgia coasts. The December 2010 locations of 41 Black scoters outfitted with satellite transmitters in spring of 2010 suggest that approximately 40% of early wintering birds (15 tagged birds) are found along the coast between North Carolina and Georgia, with most along the South Carolina coast (S. Gilliland, unpublished data). This is a smaller percentage than estimated from the February aerial survey (47% south of Chesapeake Bay in 2009 and 77% in 2010, based on the 112,800 estimate, which excludes the largest count). In collaboration with PIs involved with the Atlantic Flyway Telemetry project, we anticipate completing a comprehensive, combined analysis of 2010-11 winter movement data and survey counts, which should provide valuable information of relative abundance and habitat use along the Atlantic coast.

Plans for an additional fourth year of prerequisite surveying include increasing replication in areas of high and variable density and reduced coverage in areas with consistently few birds and double observer replicates along the mid-Atlantic to gather data for detection estimation. Survey execution will depends on obtaining funds from the SDJV and, through the ACJV, the AMAPPs program, and will be supplemented with support from PHAB and MBSB.

References:

Ridout, M., C.G.B. Demétrio, & J. Hinde. 1998. Models for count data with many zeros. International Biometrics Conference, Cape Town, South Africa.

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Zipkin, E.F., B. Gardener, A.T. Gilbert, A.F. O'Connell Jr., J.A. Royle, and E.D. Silverman. 2010. Distribution patterns of wintering sea ducks in relation to the North Atlantic Oscillation and local environmental characteristics. *Oecologia* 163: 893.

Table 1: Total sea ducks (standard error) for the twelve survey regions estimated from a hurdle model with a negative binomial count distribution for region specific densities and using transect length and latitude as a predictor of zero counts (standard errors estimated using a parametric bootstrap). Estimates were re-calculated for the 2009 data for comparison between years. Scoter species included all birds classified as Black, Surf, White-winged, or unidentified scoter. Totals sea ducks by region are calculated using the total scoter estimate, and not the individual species estimates. Percents below the 2010 estimate represent change from 2009, with (XX%) indicating a decrease.

Species Region (nm^2)	Scoter spp.	Black scoter	Surf scoter	White-winged scoter	Long-tailed duck	Common eider	Bufflehead Common Goldeneye Merganser spp.	Total sea ducks
Northern coastline (2,400)	3,000	50 (90%)	750 130%	2,800 1330%	9,700 75%	33,000 11%	11,200 (19%)	56,800 5%
Cape Cod/Nantucket (2,050)	54,500	6,800 300%	24,400 480%	2,100 (77%)	31,300 39%	92,200 (21%)	10,700 130%	188,700 7%
Nantucket Shoals (1,300)	36,300	4,400 800%	0 (100%)	4,200 110%	70,800 (15%)	5,700 560%		112,800 26%
Long Island Sound (1,500)	22,200	2,000 (30%)	3,200 610%	710 (33%)	6,500 220%	21,200 (53%)	6,700 66%	56,500 2%
Off Long Island south coast (700)	19,300	2,500 53%	260 (93%)	14,800 1250%	1,400 (93%)	3,500	820 (86%)	25,100 (22%)
Off New Jersey coast (1,150)	1,100	90 (82%)	400 (80%)	80 (67%)	1,100 (67%)	730	8,700 114%	11,700 34%
Delaware Bay (500)	14,100	4,100 580%	6,300 72%	90 110%	120 (79%)		770 (66%)	14,900 57%
Off Maryland/Delaware coast (1,300)	17,900	3,000 (92%)	15,600 14%	1,400 210%	1,900 1990%		2,600	22,400 (70%)
Chesapeake Bay (2,200)	33,900	3,100 (77%)	18,700 (12%)	340 140%	16,500 57%		14,400 8%	64,800 13%
Off Pamlico Sound (1,200)	3,900	3,500 (69%)	720 (97%)		830		11,800 710%	16,500 (45%)
Pamlico Sound (950)	13,200	11,900 (61%)	1,600 (50%)	77	760		14,600 61%	28,500 (37%)
Southern coastline (5,450)	204,600	194,400 1890%	90 (35%)				2,200 (50%)	207,400 1350%
Total (21,700)	424,000 (111,200)	235,900 (95,300)	72,000 (18,600)	26,600 (10,600)	141,600 (45,200)	156,300 (41,800)	84,300 (18,100)	
2009 total	244,246 (46,200) 74%	110,100 (31,500) 114%	75,600 (21,100) (5%)	14,600 (4,600) 82%	149,800 (38,800) (5%)	192,600 (56,400) (19%)	62,800 (10,000) 34%	

Table 2: Median flock size, number of flocks, and mean (SD) distance of flocks to nearest land in nautical miles, by species and year. Flocks are defined as individual geo-located records, and include observations of singles and pairs. Maximum distance was calculated for observations from the two years combined. Distance calculations are based on sightings on the east-west transects, excluding transects within the major bays and shoals, i.e., without including Pamlico Sound, Delaware Bay, Chesapeake Bay, Long Island sound, Nantucket Shoals, and Cape Cod/Nantucket (but *not* excluding the lines along the eastern edge of the Cape from 41^{o} 16' N to 42^{o} 06' N); sample sizes are smaller for the distance calculations for this reason. Estimates for 2008 are not included because the survey design was substantially different, making comparison of these statistics among years difficult (in 2008 the coast north of Cape Cod was not surveyed, replicates were only completed over Nantucket shoals, and transects extended varying distances from shore).

	2009		2010		
Species	Median flock size	Mean distance	Median flock size	Mean distance	Max distance
Black scoter	5 n = 570	4.1 (2.3) n = 369	4 n = 528	2.3 (1.8) n = 107	13
Surf scoter	5 479	3.3 (2.2) 142	3 682	1.8 (1.7) 44	8
White-winged scoter	2 136	2.5 (2.3) 23	2 143	1.6 (1.4) 22	8
Common eider	4 532	1.0 (2.1) 267	3 830	0.7 (1.4) 388	19
Long-tailed duck	2 1144	3.3 (5.7) 249	3 904	1.6 (2.6) 224	25
Bufflehead	3 354	0.4 (0.4) 149	4 325	0.3 (1.0) 79	7
Merganser spp. Common goldeneye	2 356	0.5 (1.2) 203	2 353	0.4 (0.9) 160	14

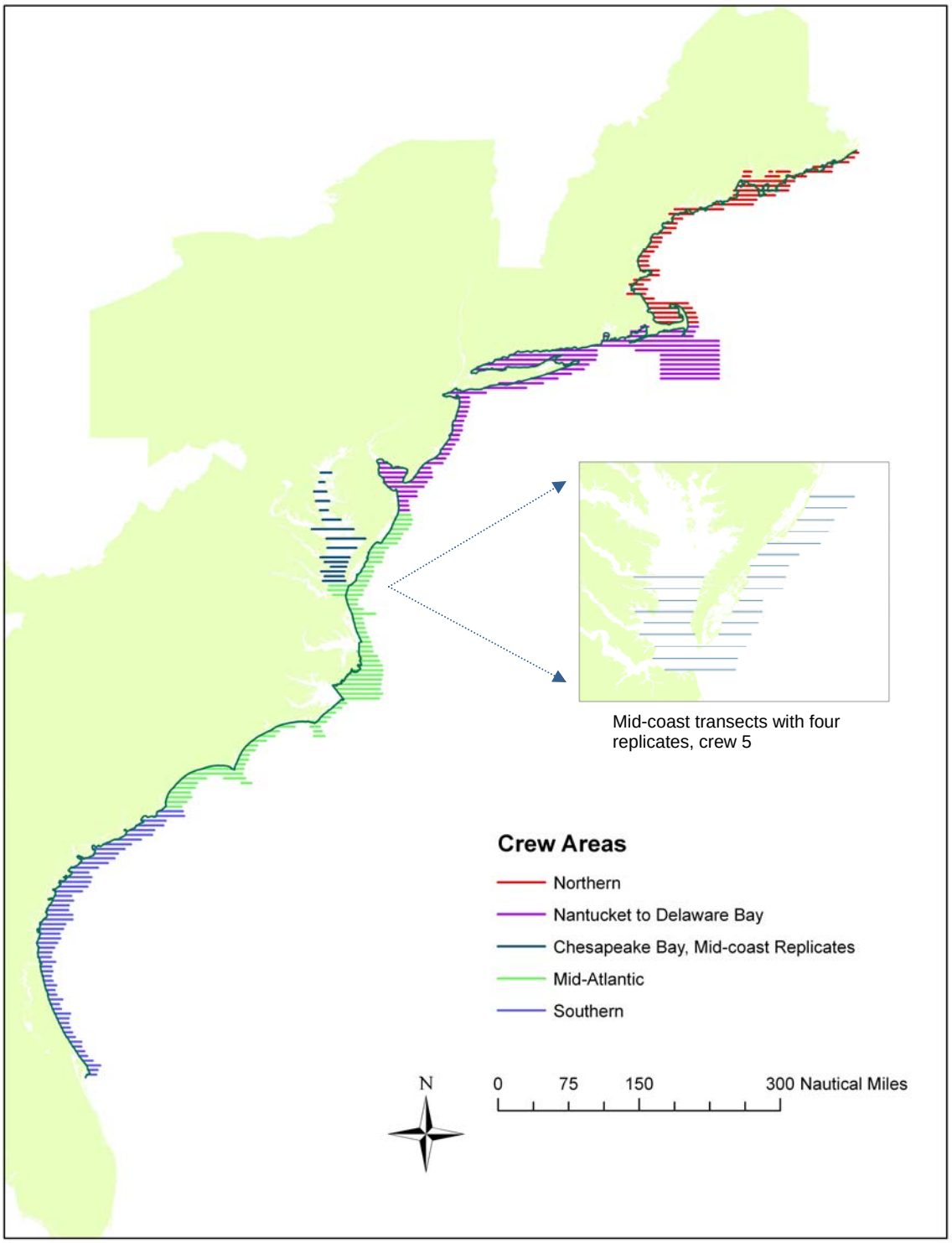

Figure 1: Map of survey design indicating the five crew areas. Every other east-west transect was flown twice by the four primary crews. The fifth crew flew the northern Chesapeake Bay lines and four additional replicates of a set of lines around the mouth of the bay (inset).

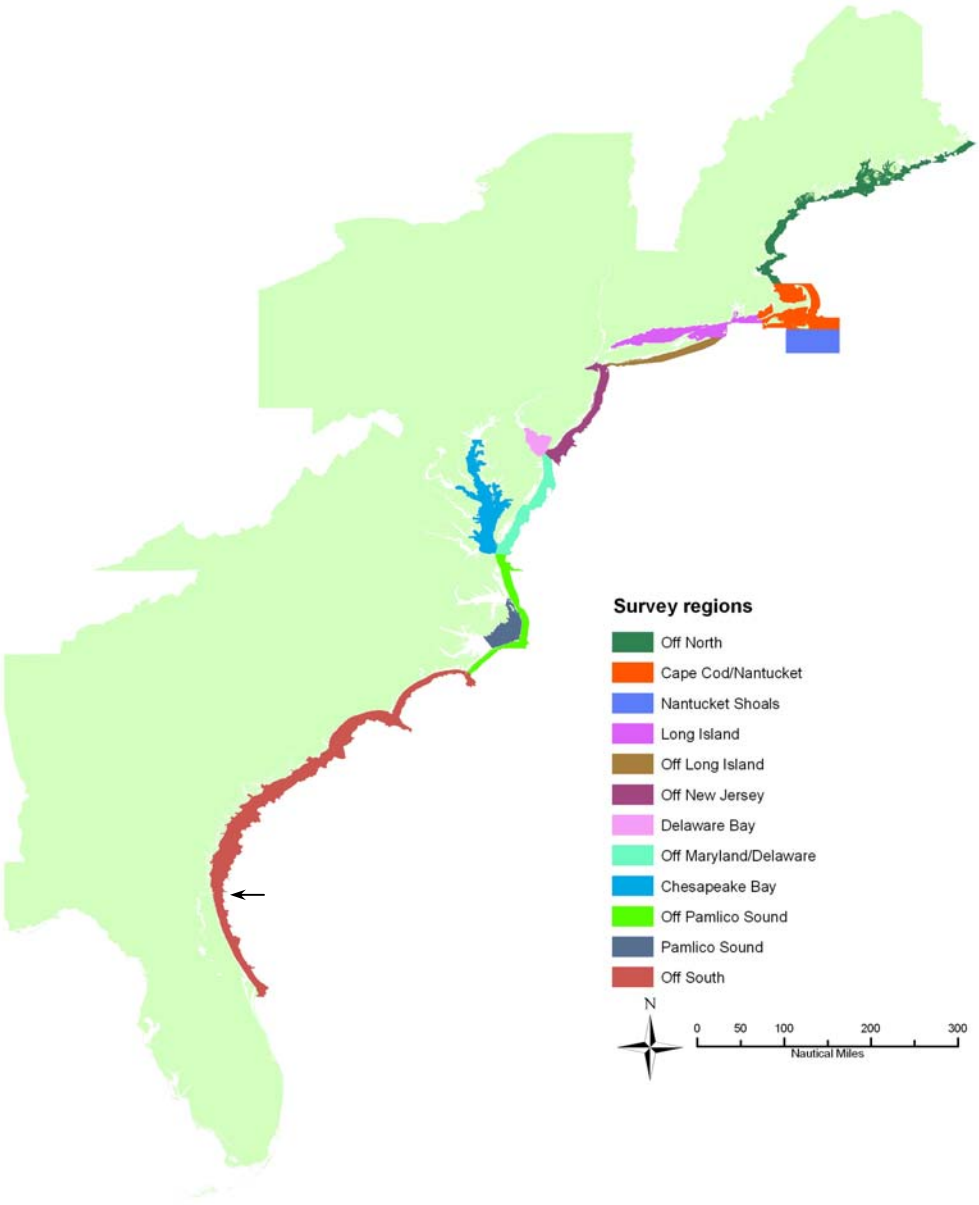

Figure 2: Survey regions used in abundance estimation. The arrow indicates the location along the southern coast (30^{o} 23.5' N) at which estimation was truncated, because no sea ducks have been seen in south of this area during the three years of surveying.

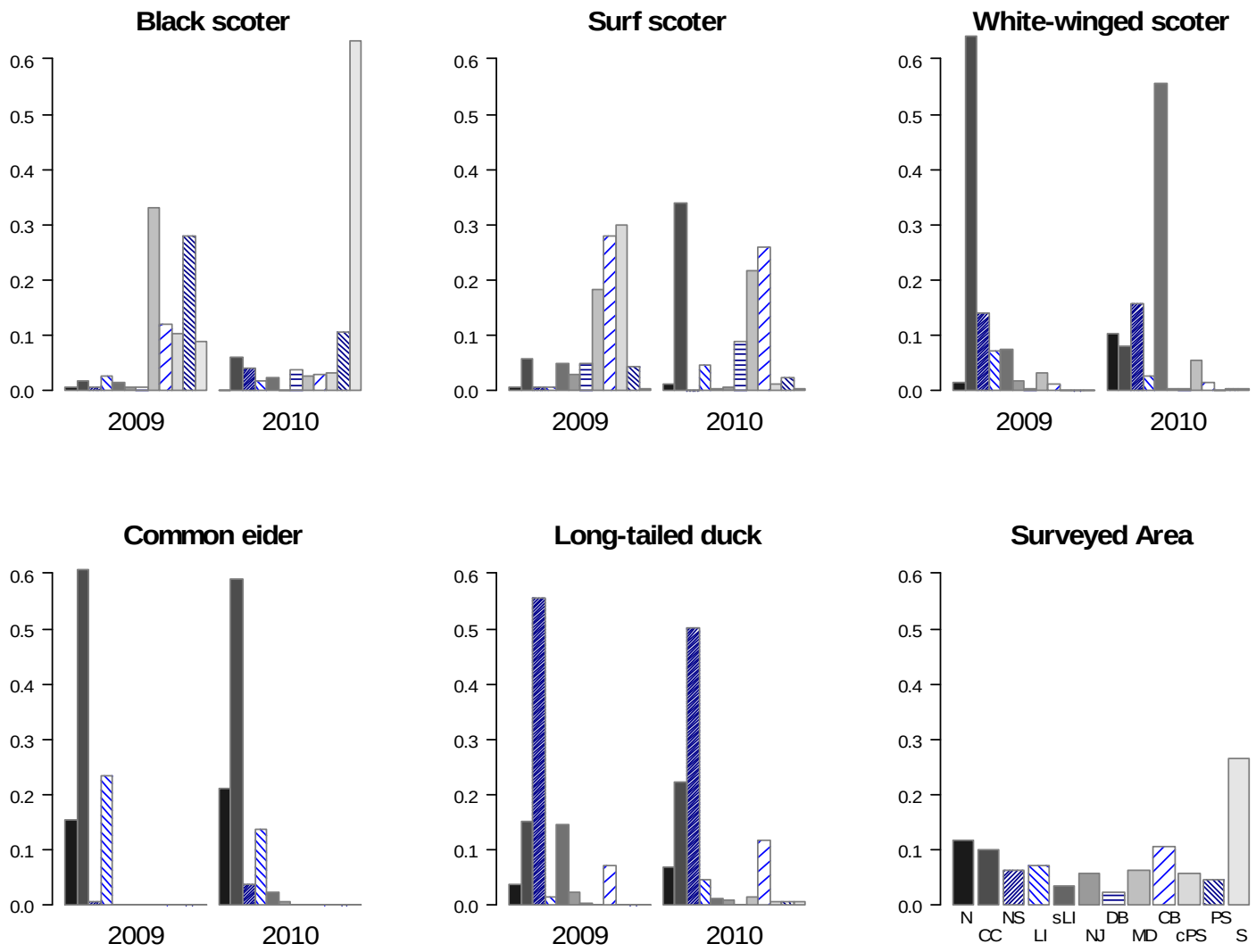

Figure 3: Relative abundance by species, year, and survey region. The relative sizes of the survey regions are also plotted (bottom right graph) for comparison. Survey region codes are N = coast north of Cape Cod, CC = Cape Cod/Nantucket, NS = Nantucket Shoals, LI = Long Island Sound, sLI = southern coast of Long Island, NJ = New Jersey coast, DB = Delaware Bay, MD = Maryland/Delaware coast, CB = Chesapeake Bay, cPS = Virgina/North Carolina coast, PS = Pamlico Sound, S = South Carolina/Georgia coast.

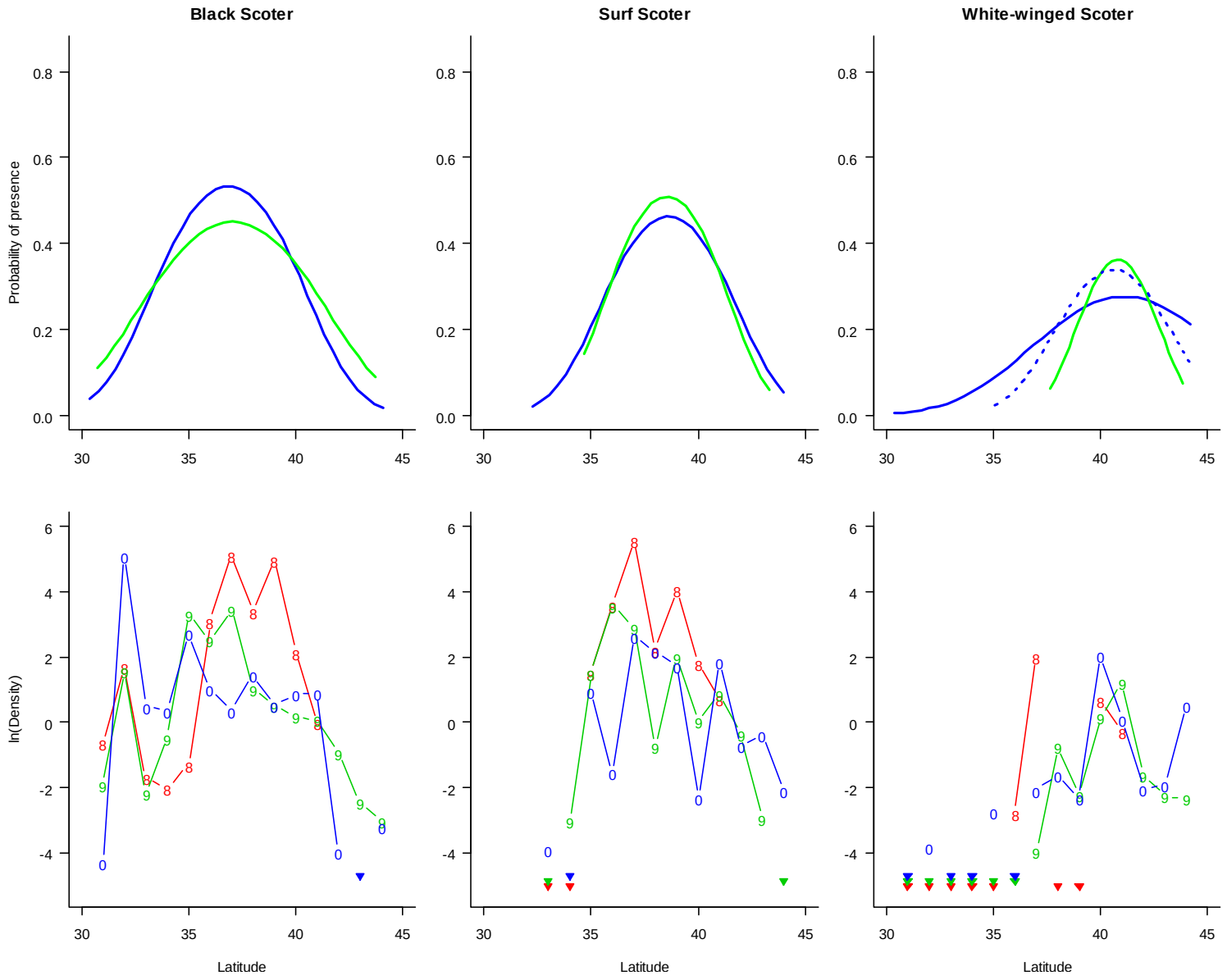

Figure 4a: Probability of presence (top) and log-density (birds/nm^2, bottom) by latitude and species. Dashed curve for the top White-winged scoter graph represents the fitted relationship not including a small number of White-wings seen in large Black scoter flocks in the south. Top: Green = 2009; Blue = 2010. Bottom row: Red 8 = 2008; Green 9 = 2009, and Blue 0 = 2010. The survey did not extend north of 42^{o}06' N in 2008 and no sea ducks have been recorded south of 30^{o}N. Inverted triangles indicate latitude-year combinations where no birds were counted.

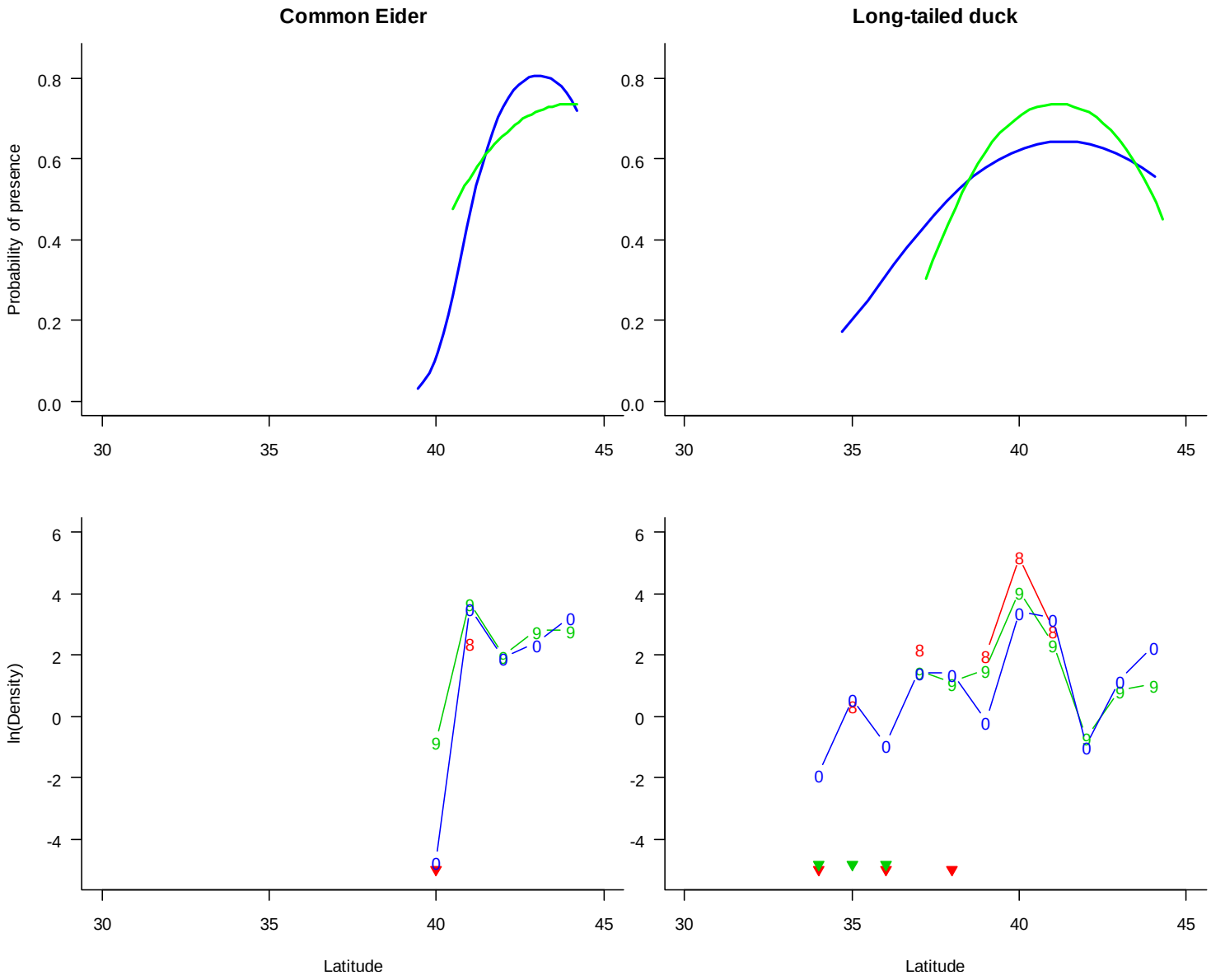

Figure 4b: Probability of presence (top row) and Density (birds/nm^2) by latitude and species. Color and symbol codes as in Fig 4a.

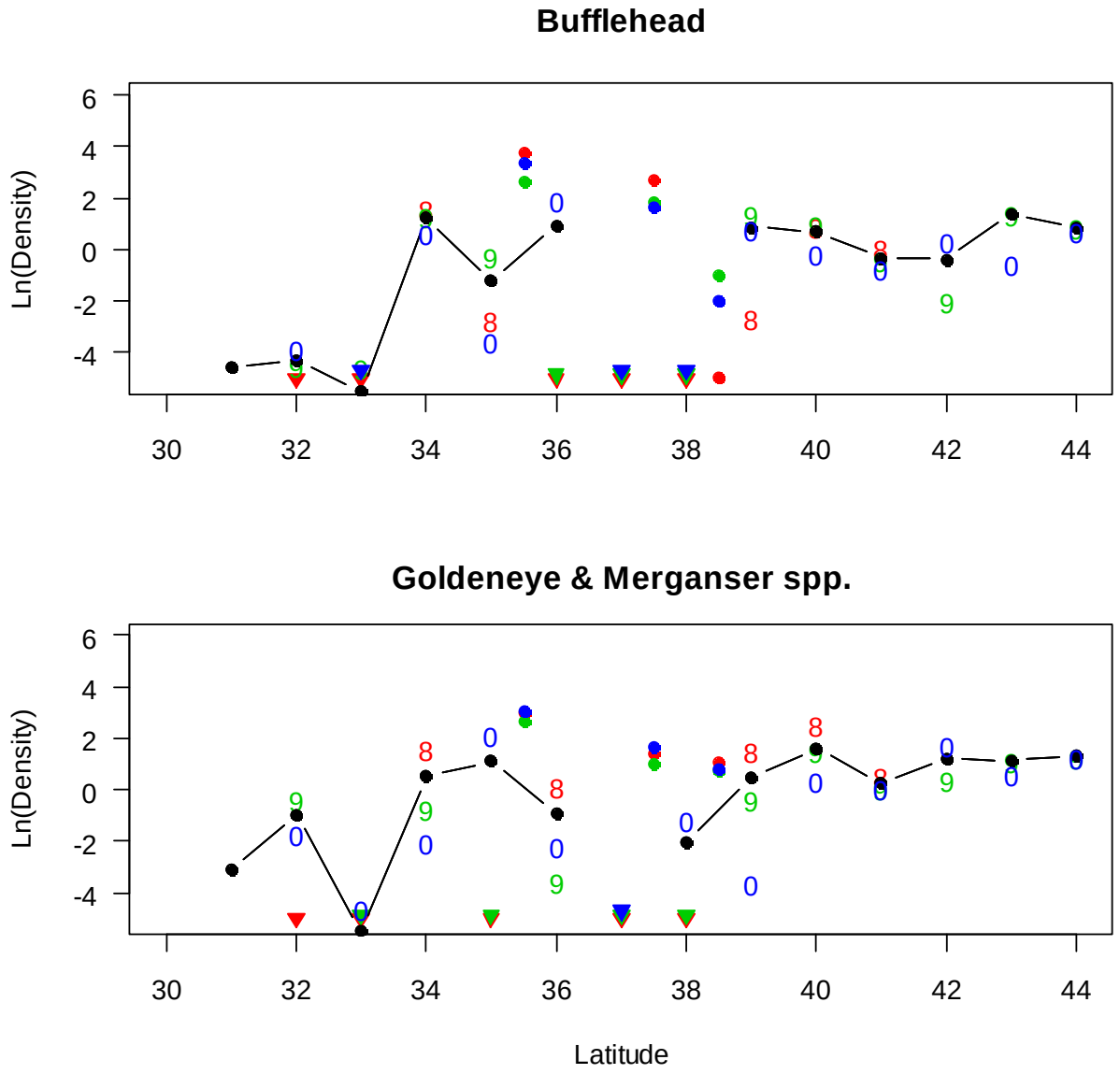

Figure 4c: Density (birds/nm^2) by latitude and species. Color and symbol codes as in Fig 4a; Colored dot symbols are for Delaware Bay, Chesapeake Bay, and Pamlico Sound, regions for which the densities are calculated separately from the coastal transects and plotted at the mid-point latitude of the region's transects.

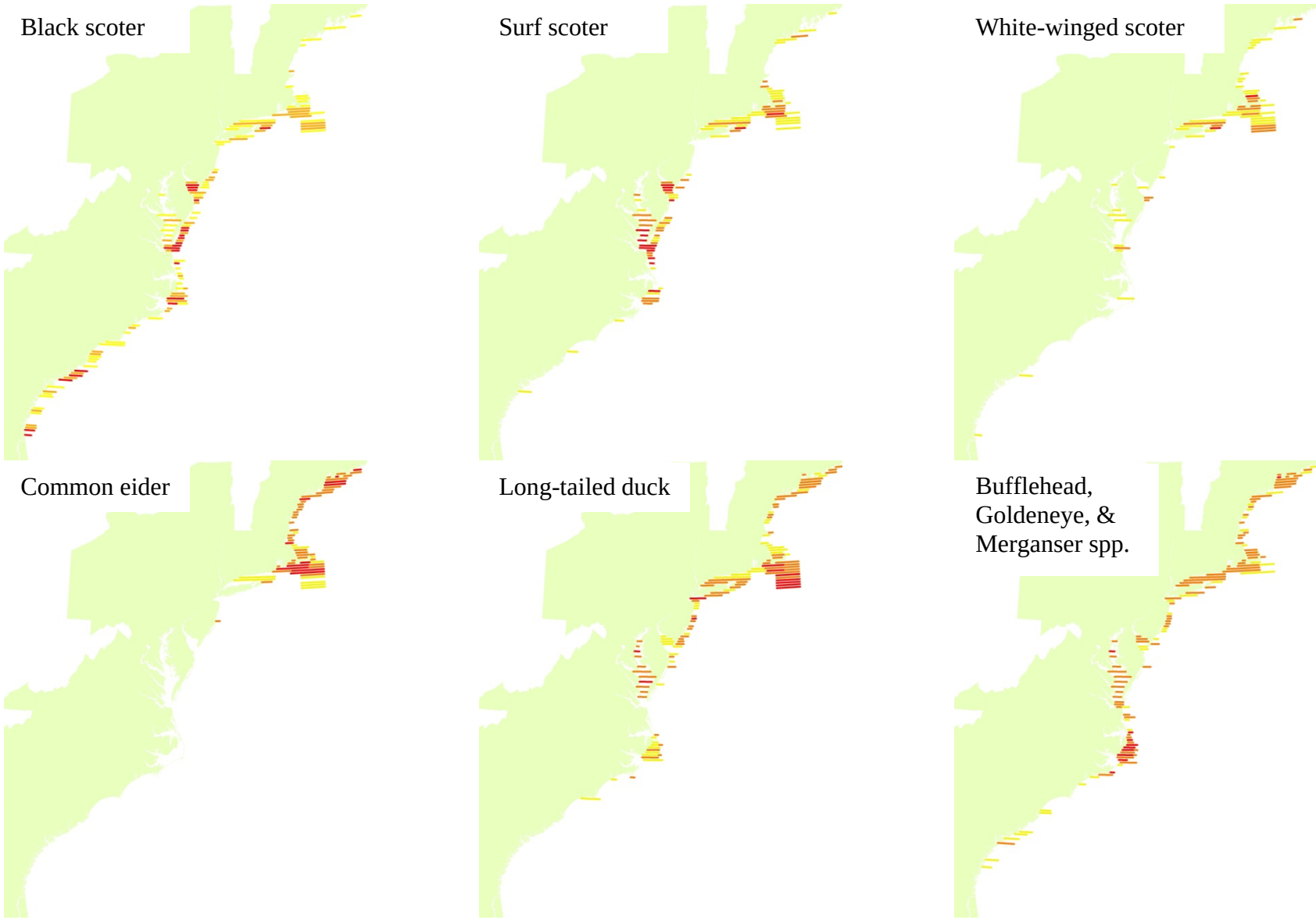

Figure 5: Average birds/nm^2 for 2008-10 by transect and species (yellow: <1/nm^2, orange: 1-4/nm^2, red: >4/nm^2)

Project Funding Sources (US$).

SDJV (USFWS) Contribution	Other U.S. federal contributions	U.S. non-federal contributions	Canadian federal contributions	Canadian non-federal contributions	Source of funding (agency or organization)
$47,864.28					
	$6,750.98				U.S.FWS, Division of Migratory Bird Management, Branch of Population & Habitat Assessment
	$25,000				U.S. FWS employees and observers (FWS, USGS, academic) time – In Kind
	$13,469.25				Minerals Management Service & Region 5, USFWS

In kind is estimated using $75/hour for pilot time, $40/hour for GIS and analysis, $20/hour for observers and accounting only for airtime for the pilots and observers.

Total Expenditures by Category (SDJV plus all partner contributions; US$).

ACTIVITY	BREEDING	MOLTING	MIGRATION	WINTERING	TOTAL
Surveys					**$86,239**
Research (Design & GIS work, Data processing & analysis)					**$6,845**