

## Origins and characteristics of Nearctic landbirds in Britain and Ireland in autumn: a statistical analysis

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We used data from eastern North America in regressions to explain autumn frequencies of Nearctic landbird species in Britain and Ireland (UK-IR). The data were: day-counts of 16 August–15 November from Nova Scotia (NS) on Sable Island 1963–2000 and Seal Island (1963–2002), combined in half-monthly intervals to account for seasonality; published seasonal totals (10- to 11-day intervals, 20 August–10 November 1955–80) of birds killed at a Florida (FL) TV tower; and published counts following a 'Fallout', 11 October 1998, of unseasonal species and southern vagrants in NS, believed to have originated as migrants in the southeast USA that followed a cold front offshore into strong southwest flow beyond. We also used the following species variables: body mass and wing length for size; sd of mass as a proxy for lipid capacity; a five-level index of migratory span (1 for within North America to 5 for almost totally to South America); latitude of easternmost breeding, and distance to nearest normal range to indicate status in NS; a two-level index for day vs. night migrants; an index, where pertinent, of significant population change (0 and 2 for a decrease and increase, respectively, 1 for no change). We also used classification and regression trees to cluster the potential transatlantic vagrants into homogeneous groups based on the explanatory variables. Standard generalized linear model regressions using counts from NS islands and FL produced highly positively skewed residuals (many species too common in UK-IR), but robust regressions eliminated statistical problems, and strengthened effects of non-count variables. Results using Fallout records, representing a subset of longer-distance night migrants, were statistically acceptable. The Fallout list, when supplied with counts from the same species from the NS islands and FL, produced highly significant ( $R^2 = 0.79\text{--}0.93$ ) and statistically acceptable regressions that were not improved by robust versions. Overall, the results indicate that October counts, especially of generally larger, longer-distance migrants, best represented those reaching UK-IR. The effect of geographical remoteness was negative – vagrants in NS were less likely to appear in UK-IR. Population changes were important in predicting the 1956–2003 UK-IR counts from 1955–80 FL counts. The seasonal characteristics, high explanatory power of the Fallout list and over-representation of probable over-ocean migrants in the standard regressions all support suggestions by others that many Nearctic vagrants in UK-IR originate in flights off southeast USA and are displaced downwind across the North Atlantic.

Avian vagrants from North America have been recorded avidly by British and Irish observers. Elkins (1979, 1988, 1999), following leads in Nisbet (1963) and Richardson (1972), detailed meteorological patterns

over the North Atlantic associated with the species composition and timing of appearances of these vagrants during autumn. He concluded that many were entrained in warm southwesterlies ahead of the offshore movement of cold fronts along the eastern seaboard of North America, and then carried in depressions or frontal waves moving rapidly across

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the North Atlantic. He found that major arrivals had followed such meteorological conditions during late September through October in several years. Elkins (1999) also examined Moss's (1998) hypothesis that the increased incidence of vagrants in northwestern Europe could be associated with a northward shift of tracks of North Atlantic depressions associated with global warming. He found no evidence for this pattern, noting that Elkins and Yésou (1998) concluded that southerly depressions might actually have increased in the previous 20 autumns. Elkins (1999) also singled out several North American species that had increased or decreased as vagrants to Europe, but found inconsistent association with population trends from the North American Breeding Bird Surveys (NABBS). Bryant (1997) further summarized the NABBS trends of all North American vagrants to Europe, but found no clear relationship between these and the recent incidence of these vagrants.

Robbins (1980) applied a statistical approach to the subject. He argued that the autumn incidence in Europe of North American passerines and near-passerines (cuckoos, nightjars, kingfishers and woodpeckers) should be related to their abundance as migrants in North America. He combined capture data for August–November from coastal bird-ringing stations in Massachusetts, New Jersey and Virginia, excluding some species (or sibling species) that breed on both sides of the Atlantic, or that were captured at these stations on average less than twice annually. He included 31 species that had occurred in Britain and Ireland during 1947–76, and 73 'candidate species' that had not. Robbins (1980) also recognized other variables that could influence the extent of vagrancy by different species, and used values or indices of the following: body mass; sd of mass as a proxy for fat storage; migration span; the west-to-east component of migration; nocturnal vs. diurnal migration; and timing of migration in relation to overseas arrivals. Robbins (1980) then used these variables, along with the capture frequencies (no transformation mentioned), in stepwise (forward) multiple regressions, as predictors of the combined autumn and winter frequencies of transatlantic vagrants in Britain and Ireland. He noted that predicted frequencies will depend on the number of species (most with frequencies of zero), so he used only ranks of predicted frequencies of species to explain the likelihood of their occurrence overseas. As the unexplained regression variance must incorporate many unrecognized biological properties, such prediction is risky. Elkins (1999), indeed, observed that

only eight of the top 20 species ranked by Robbins (1980) were among the most common during 1967–96, three had not yet occurred and five that had appeared since Robbins's analysis were not predicted to do so. It is perhaps more fruitful to think about possible reasons that some species have been much more or much less frequent than 'predicted'. Most interesting are Robbins's (1980) insights into other causes of such vagrancy. He found that three variables were selected as significant: sd of body mass ( $P = 0.0003$ ), migratory distance ( $P = 0.0010$ ), North American abundance ( $P = 0.0025$ ); he also found a weaker west-to-east migratory component (at  $P = 0.0701$ ). There has apparently been no attempt to repeat Robbins's pioneer analysis despite accumulation of data from larger samples of Nearctic vagrants overseas, more sources on relative abundance of the species in eastern North America and more robust statistical methods.

## METHODS

### Bird counts

Species names are from AOU (2004: [www.aou.org/checklist/index.php3](http://www.aou.org/checklist/index.php3)) and most scientific names are listed in Appendix 1. Full names of those not listed are given in the text. Records of Nearctic landbird vagrants to Britain and Ireland were obtained from annual reports on rare birds in Britain and Ireland in the journals *British Birds* and *Irish Birds*, now online ([www.birdguides.com](http://www.birdguides.com)). Mitchell and Young (1997), among others, believe 1958 to be the beginning of reliable field recording. Accumulated counts of Nearctic landbirds first detected in Great Britain and Ireland during August through December, from 1958 to 2002, consist of 574 individuals of 54 species.

With inevitable correlation among lists of autumn migrants in eastern North America, as noted by McLaren *et al.* (2000), many such lists would correlate with frequencies of those that have reached Europe. Nevertheless, some lists are better than others for that purpose. Robbins (1980) noted the biases in comparing frequencies of species caught (in nets) for ringing with those identified in the field. Here we use extensive field counts or estimates (accumulated by McLaren) by knowledgeable observers during many autumn visits to Sable and Seal islands, Nova Scotia, an arguably representative source region for some transoceanic vagrancy. McLaren (1981a) used earlier counts to analyse the unusual incidence of vagrant

birds on these islands. To span a broader region of possible origin of transatlantic vagrancy, we also use a large sample of autumn migrants killed at a television tower in northern Florida (Crawford 1981). Finally, we use a smaller count of unexpected 'reverse' migrants that arrived in southern Nova Scotia in early October 1998 (McLaren *et al.* 2000).

Seal Island (43°25'N, 66°01'W) is a small (~4.5 × 1.5 km) island about 24 km from the nearest mainland of southern Nova Scotia. The data consist of 397 day-counts (or estimates) of individuals of all species seen there on irregular visits by birders between 16 August and 15 November during the years 1963–2002. We include all passerines and near-passerines, except for those that also breed in Europe, or that are largely nocturnal (owls, Whip-poor-will), or that breed in numbers and stay on the island through the autumn migration period (American Crow *Corvus brachyrhynchos*, Boreal Chickadee *Parus hudsonicus*, Golden-crowned Kinglet *Regulus satrapa* and Savannah Sparrow). The selected sample included 194 399 individuals of 146 species. As many counts were made on successive days, they include both new arrivals and repeated counts of the same individuals.

Sable Island (43°57'N, 59°95'W) is a long (~30 km vegetated), narrow sandbar, about 150 km southeast of the nearest Nova Scotia mainland. Various observers have counted birds there in the course of other activities between 1963 and 2000. Counts of all passerines and near-passerine species are used here, except for the endemically nesting 'Ipswich Sparrow' (subspecies *princeps* of the Savannah Sparrow), and those that also breed in Europe. Migrants are naturally much scarcer on Sable Island than on the mainland or Seal Island (McLaren 1981a), and most individuals could be judged as new arrivals. Following McLaren (1981b), other less easily tracked birds were rated as new if they had not been recorded for more than 4 days. This accords with the average stopover time of autumn migrants on an island in nearby Maine (Morris *et al.* 1996). The sample consists of 18 214 individuals of 128 species counted between 16 August and 15 November during the years of observation.

Crawford (1981) enumerated birds killed at a Florida TV tower for each 10- to 11-day period during 1955–80, but effort varied with the timing of morning surveys and numbers of kills. We use here the counts of passerine and near-passerine species made between 21 August and 10 November as representing a plausible source for transatlantic vagrants. We again excluded species that also breed in Europe. We also excluded those that appeared less

than twice in the entire autumn record if these had never been recorded in Britain, Ireland or on the Nova Scotia islands (these were mostly nominally non-migratory, 'southern' species). The sample consists of 26 465 individuals of 104 species over the period.

A substantial arrival of unseasonable landbirds, including southern vagrants, occurred during an unusual weather event on the southernmost coast of Nova Scotia on 11 October 1998 (hereafter referred to as the 'Fallout'; a 'fall' in UK usage). These were censused during three following days along standard routes on Seal and Bon Portage islands and less formally on the nearby mainland, from which McLaren *et al.* (2000) tabulated total counts of the passerines and near-passerines involved. They excluded species that were unlikely to have been part of this arrival or that were under-sampled in the forested and scrub habitats surveyed (Common Nighthawk, swallows, sparrows, and icterids other than orioles). In all, a combined sample of 2220 individuals of 52 species was available from the Fallout. We also included four species (Veery, Gray-cheeked Thrush, Varied Thrush, Brown Thrasher) that had occurred in Britain or Ireland, but not in the Nova Scotian event.

### Other predictive variables

We consider all the potentially important variables used in the earlier analysis of transatlantic vagrancy by Robbins (1980), with some additions and modifications.

(1) Two correlated expressions of size are mass from Dunning (1993) and wing lengths (combined average of extreme values for males and females) from Pyle (1997). We used, when available, data from subspecies of the northeast USA and Atlantic Canada. Masses and wing lengths 'compete' for the effect of body size in stepwise analyses.

(2) Although means and standard deviations (sds) of fat contents are available for some potential or actual Nearctic vagrants, sd of body mass (used by Robbins 1980) is the only widely available proxy for variability of fat content. The sds of some species not listed by Dunning (1993) were obtained from accounts in Poole and Gill (1992–2002). A few unavailable values were estimated from the coefficients of variation (CVs, sd/mean) of mass of close congeners. Robbins (1980) apparently entered sds of mass directly into stepwise regressions and found them to be the most significant predictor of transatlantic vagrancy. We use CVs to avoid incorporating the independent effect of body size *per se*.

(3) To estimate geographical span of migration, Robbins (1980) used 'straight-line distance' (projection?) between a subjectively estimated 'centre of the breeding range of the eastern population and the approximate centre of the winter range'. We chose a more repeatable measure: the difference to nearest degree latitude between the median latitudes of the northernmost and southernmost limits of breeding and wintering ranges, respectively. These ranges are mapped and described by Ridgley (1981), Ridgley and Tudor (1989, 1994) Howell and Webb (1995), Raffaele *et al.* (1998) and Sibley (2003a, 2003b). However, as an alternative, we also used categorical indices of migration span based on the same sources: 1 for species that are nominally non-migratory or winter almost entirely north of Mexico; 2 for species that winter mostly in Central America (including Mexico, Caribbean), although some may remain in southern North America; 3 for species that winter largely in Central America, but also in northern South America; 4 for species that winter mostly in South America, but also in Central America; 5 for species that winter entirely (except for occasional anomalies) in South America. We also tested a two-category index that stresses extreme long-distance migration: 1 for birds that winter in South America and 0 for all others.

(4) Robbins (1980) used non-elucidated 'subjective' categories (0, 1 and 2) to represent the 'east-to-west component of migration' of species. We used two repeatable indices to reflect influences of geographical origins on tendencies to cross the Atlantic. These are based on the 'consistently and uniformly occupied' breeding ranges and 'main' migration routes mapped by Sibley (2003a, 2003b). The first index is the longitude of the easternmost limit of the breeding range (i.e. southeast Newfoundland as the potential extreme limit). This index may indicate the tendency for eastward migration among species in Nova Scotia. The second index is the distance in kilometres from the Nova Scotia sites to the nearest mapped 'regular occurrence' (as per Sibley 2003a, 2003b) of either breeding or migration range (i.e. 0 for those nesting in or normally migrating through Nova Scotia). This index may test the more general hypotheses that any bird wandering to Nova Scotia is more, or less, likely to cross the Atlantic. Because almost all the species include Florida within their breeding or migratory ranges, similar indices were not applied to data from that source.

(5) Robbins (1980) used four categories to assess whether nocturnal migrants are more likely to appear

as transatlantic vagrants. He coded species assumed to be day migrants as 1, those assumed to be night migrants as 4, and others as either 2 or 3, depending on their relative tendencies. This may be dubiously refined, given that large numbers of putative day migrants (e.g. American Robins, sparrows and icterids) on the Nova Scotian islands often appeared in early morning with large flights of known night migrants. Ralph (1981) calculated an index of diurnal vs. nocturnal migration based on numbers ringed at Long Point, Ontario, relative to numbers killed at a nearby lighthouse, but this does not include many of the species on our lists. Ralph's work was nevertheless helpful in assigning species to two categories: 1 for those widely recognized as night migrants and 0 for the rest. As the former are also much more likely to be long-distance migrants, this variable competes with migration span for independent significance.

(6) Robbins (1980) used seasonal totals, and corrected for seasonality by 'coding migration dates on a scale of 1–15 and comparing these dates with the Sharrock's [Sharrock & Sharrock 1976] histogram' of the arrival times of transatlantic vagrants. It is unclear how this index was parameterized, but presumably the peak or mean migration time of each species was expressed as a deviation from the peak of arrivals evident in that histogram. We use another approach, valid for all our samples, by summing counts for each half-monthly period for the Nova Scotian islands, and for each 10- to 11-day interval for Florida, as tabulated by Crawford (1981). These seasonal groupings then serve as independent predictors of the transatlantic counts.

(7) A variable not considered by Robbins (1980), who had been instrumental in establishing the widely used North American Breeding Bird Surveys (e.g. Robbins *et al.* 1986), is the population change of many species during the years under consideration. This was taken as unnecessary in using 1963–2002 counts from the two Nova Scotian islands to predict the 1956–2003 counts of transatlantic vagrants. It is, however, a potential effect in comparing the transatlantic records with the 1955–80 Florida totals, and also with the 1998 Fallout data from southern Nova Scotia. We used Sauer *et al.* (2005; [www.mbr-pwrc.usgs.gov/bbs/trend/tf03.html](http://www.mbr-pwrc.usgs.gov/bbs/trend/tf03.html)) with the 'estimating equation method' and trends for the 'Atlantic Flyway' to estimate mean annual change between the median years of 1968 for the Florida counts and 1982 in the transatlantic series, and between 1982 and 1998 for the birds appearing in the Nova Scotia Fallout (for some species not represented in the 'Atlantic Flyway', we

used 'survey-wide' estimates). Because the estimated magnitudes of changes are largely quite unreliable (Sauer *et al.* 2003, website above), we entered them only as a categorical variable, with 0 for significant (at  $P < 0.05$ ) decline, 1 for no significant change and 2 for significant increase.

## Statistical methods

In the following analyses we fit the data using a generalized linear model (GLM) in which the response,  $\log(\text{BICount}_i + 1)$ , is modelled as a linear combination of the other variables, e.g.  $\log(\text{BICount}_i + 1) = \log(\text{NACount}_i + 1) + \text{variable1}_i + \text{variable2}_i + \dots$  for species  $i = 1 \dots N$ . Here BICount is the combined lists from Britain and Ireland, and NACount is either the Fallout count or a seasonally divided count from the other three locations (Sable Island, Seal Island and Florida), and the other variables are the predictive variables described in the previous section. A separate analysis was done for each of the four North American counts. Although it would be possible to combine all the data into one overall model, we felt the four separate analyses allowed us to see whether patterns observed with one of the North American counts were repeated for the other counts.

We first used standard GLM with backward, stepwise variable selection (GLM regressions, SYSTAT 10). The alpha level for retaining an effect in these regressions was taken as  $P < 0.15$ . This level is often used to avoid the deletion of potentially important variables too early in the process. Where this level of significance was found in an interaction term, both main effects were retained, even if not significant. Although the regressions detected few species with excess leverage or with residuals that were statistical outliers, most exhibited severe non-normality of residuals, and accordingly many species had undue influence on the outputs. Therefore, the analyses were repeated using robust GLM regressions (Hampel *et al.* 1986) using the robust package in S-plus 6.2, Academic Site Edition. In these models, points that lie further from the bulk of the observations receive smaller weights and have smaller impacts on the results of the GLM regressions. The general procedure involves fitting models with the desired parameters using the robust technique to find the appropriate weights for the species, and then using those weights to calculate the model using, as above, the standard GLM methods. The Akaike Information Criterion (AIC; Akaike 1974) was used as a basis for deleting variables. AIC is computed as  $-2 \times \log(\text{likelihood} +$

$2 \times (\text{number of variables})$  where the second term is a penalty for adding more variables. Variables were only deleted if the resulting AIC decreased. Candidate variables for deletion were those with a  $P$  value  $> 0.15$ .

Finally, the data were analysed using Classification and Regression Tree Analysis (using S-plus 6.2, Academic Site Edition), as an alternative to GLMs for addressing regression problems (Breiman *et al.* 1983). For consistency, we used the same variables as in the GLMs, including  $\log + 1$  transformation of the bird counts, but without interactions between the counts and migration category. The models are fitted by binary, recursive partitioning of the data into increasingly homogeneous subsets (Clark & Pregibon 1992). The general procedure is to 'grow' the tree, then 'prune' back the nodes to obtain a more simplified tree with only a small increase in residual deviance. The optimal tree model was then selected by random, ten-fold cross validation, a procedure in which the data are randomly divided into ten subsets and the tree is fitted and pruned by removing each of the subsets sequentially. The removed subset is then used to estimate the predictive power of the tree as measured by the deviance, which is then summed over all replications at each number of terminal nodes. The optimal number of terminal nodes is chosen as having the smallest deviance and the original tree is pruned accordingly.

## RESULTS

### Standard GLM regressions

Using  $\log(n + 1)$  transformations (as usual for bird-count analyses) of both the transatlantic and the North American counts always gave better-fitting results than did the original counts. In addition, fits were always better, with fewer statistical problems, when migration spans were entered as categories (and five-level better than two-level), rather than as continuous variables, and when interactions with the seasonal counts were included. The final models explain substantial variance of the combined British and Irish counts (Table 1). It is well known that stepwise procedures produce coefficients and  $P$  values that are doubtfully accurate, and that slight changes in explanatory variables can have large effects. There were few actual statistical outliers. (Standardized residuals for those that occurred were: for Sable Island, Eastern Kingbird =  $-4.73$ ; for Seal Island, Chimney Swift =  $3.91$  and Northern Parula =  $3.65$ ;

**Table 1.** Final results of stepwise GLM regressions relating counts [ $\log(n + 1)$ ] of transatlantic landbird vagrants in Britain and Ireland with counts [ $\log(n + 1)$ ] and other characteristics of landbirds in North American samples. The  $P$  values of the K–S test (Kolmogorov–Smirnov one-sample test, with Lilliefors correction) are for departure of the residuals from normality. The signs and  $P$  values of regression effects are for those retained at  $P < 0.15$  (signs unspecified for categorical effects); a blank entry indicates that the variable was not selected in the model, and ‘– na –’ that the variable was not included in the model. In addition, where effects of seasonal counts or migration category were detected only as interactions, their main effects were also included, and designated ns (i.e.  $P > 0.15$ ). Variables not applicable in some regressions are shown as na.

Independent variable	Sable Island $n = 128$		Seal Island $n = 146$		Florida $n = 104$		Fallout $n = 55$	
Explained variance, $R^2$	0.5929		0.6473		0.6659		0.6272	
K–S test, $P$	0.0142		0.0000		0.0023		0.1702	
Variable	Effect	$P$	Effect	$P$	Effect	$P$	Effect	$P$
Wing length			+	0.1361	+	0.0007	+	0.0000
Body mass								
CV of mass							+	0.0727
Distance from NS							+	0.1125
Longitude							–	0.0013
Night/day flight								
Population change	– na –		– na –				+	0.0096
Migration category	ns		0.0026		ns		*	
Late Aug. counts	– ns		– ns				– na –	
Early Sep. counts	+	0.0591					– na –	
Mid-Sep. counts	– na –		– na –		– na –			
Late Sep. counts			+	0.1351	+	ns	– na –	
Early Oct. counts	+	0.0435	+	ns	+	ns	– na –	
Mid Oct. counts	– na –		– na –		+	ns	– na –	
Late Oct. counts	– ns		+	ns			– na –	
Early Nov. counts	– ns						– na –	
Late Aug.:Migr.Cat.		0.0127		0.0340			– na –	
Early Sep.:Migr.Cat.		0.0112		ns			– na –	
Mid-Sep.:Migr.Cat.	– na –		– na –		– na –			
Late Sep.:Migr.Cat.				0.0026		0.0081	– na –	
Early Oct.:Migr.Cat.		ns		0.0104		0.0006	– na –	
Mid-Oct.:Migr.Cat.	– na –		– na –			0.0010	– na –	
Late Oct.:Migr.Cat.		0.0015		0.0000			– na –	
Early Nov.:Migr.Cat.		0.0140					– na –	
Fallout counts	– na –		– na –		– na –		+	0.0026
Fallout:Migr.Cat.	– na –		– na –		– na –			0.1477

\*The non-significant effect of migration was excluded from the Fallout regression for reasons explained in the text.

for Florida, Baltimore Oriole = 3.40; and for Fallout, no outliers.) Also, no excessive leverages were detected. However, the residuals in three of the four regressions were highly non-normal (Kolmogorov–Smirnov tests, Table 1): all except the Fallout residuals were positively kurtotic, and those for Seal Island and Florida were strongly positively skewed (at  $t > 2$ ). Accordingly, we consider these regressions only for further comparisons among the various methods and samples. As will be seen, suggestive patterns emerge.

The counts from Nova Scotian islands and Florida produced similar results overall. Wing length was the only morphological character selected: strongly

positive using the Florida counts and weakly using the Seal Island counts. Population changes (not tested for the largely contemporaneous island and transatlantic counts) were significant in using the 1955–80 Florida counts to predict the 1958–2002 counts from Britain and Ireland. Only the Seal Island sample produced a significant direct effect of migration category. That effect was, however, irregular: all except migrants to South America were variously under-represented among the overseas vagrants. The strongly correlated seasonal counts had generally weak or non-significant main effects, with the exception of late August counts from Seal Island, but were

widely and strongly expressed in their interactions with migration category.

The Fallout produced strikingly different results from those using the much larger, seasonally partitioned data. The Fallout lacked many species present in the other lists. Some of the absent species had reached Europe in small numbers, but were excluded because of their resident status in the Fallout sample areas, or because they occurred in under-sampled habitats (see Methods). Despite substantially reduced numbers of species, and greatly restricted timing of the Fallout counts, the fit was statistically adequate (Table 1), with no outlier or excessive leverages, and with normal distribution of residuals. Compared with the others, the Fallout regression revealed a stronger direct effect of species counts and weaker interaction with migration category. It also revealed important effects of morphology (wing and CV of mass) and of closest longitude of normal range. Note that migration category was not re-entered (as done for the Sable Island and Florida regressions) after its stepwise removal as this rendered both it and its interaction effect non-significant. Removing the (weak) interaction term, by contrast, produced a poorer overall fit ( $R^2 = 0.5660$ ), with excessive leverage from the far-western Varied Thrush.

### Robust GLM regressions

Unless otherwise stated, the same explanatory variables used in the standard regressions were entered in the initial models. The final, reduced models (Table 2) are presented here, again as tabulations of the sign and significance of the coefficients of the retained variables. The alpha level for significance of these effects was again taken as 0.15, and thus a  $t$  value of  $\pm 1.44$ . The robust regressions, as expected, fit considerably better than the standard ones (cf. Tables 1 & 2). However, this involved significant down-weighting (weighting coefficients  $< 0.3$ ) of the abundances of many species in the North American counts (Appendix 1), including: 40/128 (31%) of the Sable Island species; 38/146 (26%) of those from Seal Island; 31/104 (30%) from Florida; and 18/55 (33%) of the Fallout species.

Species are down-weighted typically if there is a large discrepancy between the observed value and the value predicted by the model. For instance, in the Sable Island data, American Robin and Black-and-White Warbler have very low weights because far more have been observed than predicted, whereas no Cedar Waxwings or Eastern Kingbirds have been

observed, although the model predicts a moderately large count. Of interest is the exposure of other explanatory variables (cf. Tables 1 & 2) attending the down-weighted seasonal abundances of many species. Size (wing length or body mass) of the Nova Scotian and Florida species becomes much more influential. There is a strong negative influence of either longitude or distance from Nova Scotia. Migration category becomes a more important determinant for the Nova Scotia birds, although not for those from Florida. The direct effects of the seasonal counts are generally stronger in the robust regressions, and their interactions with migration category differ somewhat from those in the standard versions.

### Fallout species combined with counts from other samples

The statistically untroublesome fit of the standard regression for the Fallout sample (Table 1) and the marginal improvement in the robust version (Table 2) suggest that the Fallout species were a plausible selection of potential transatlantic vagrants, marred by small sample sizes. To test this we fitted GLM regressions using the Fallout species supplied with the, much larger, seasonally partitioned, numbers of the same species on the other lists. This substantially increased  $R^2$  values over those of the original regressions, strengthened effects of morphological variables and of seasonal counts and their interactions, eliminated outlier species, and normalized distributions of residuals (cf. Tables 1 & 3), although all were still positively (although not significantly) skewed. The robust GLMs of the same data (Table 4) still had significant down-weighting for up to half the species. The majority of these were species that had been down-weighted in the original fits. In a sense, the robust fits are already filtering out the species for which the model does not fit well, so we should not expect a better fit when we limit the number of species.

### Patterns of residuals

Residuals from the standard regressions using the original data, along with those from combining Fallout species with counts from the other locations, were all positively skewed, although the Fallout regression and the combined regression using the Fallout species with the other counts were formally acceptable statistically. The seven species with strongly

**Table 2.** Final models using robust, stepwise GLM regressions relating counts [ $\log(n + 1)$ ] of transatlantic landbird vagrants in Britain and Ireland with counts [ $\log(n + 1)$ ] and other characteristics of landbirds in North American samples. The values of explained variance ( $R^2$ ), Mallows's Cp, and the Akaike Information Criterion (AIC) are measures of the fit of the final models (see text). The signs and  $P$  values of regression effects are for those retained at  $P < 0.15$  (signs unspecified for categorical effects); a blank entry indicates that the variable was not selected in the model, and '– na –' that the variable was not included in the model. In addition, where effects of seasonal counts or migration category were detected only as interactions, their main effects were also included, and designated ns (i.e.  $P > 0.15$ ). Variables not applicable in some regressions are shown as na.

Independent variable	Sable Island $n = 128$		Seal Island $n = 146$		Florida $n = 104$		Fallout $n = 55$	
Explained variance, * $R^2$	0.7860		0.8788		0.9270		0.6638	
Mallow's Cp	355.59		350.48		122.25		581.87	
AIC	406.80		445.38		312.59		168.88	
Independent variable	Effect	$P$	Effect	$P$	Effect	$P$	Effect	$P$
Wing length			+	0.0003	+	0.0000	+	0.0000
Body mass	+	0.0470						
CV of mass							+	0.1495
Distance from NS	–	0.0365			– na –			
Longitude			–	0.0039	– na –		–	0.0000
Night/day flight	–	0.0199			– na –			– na –
Population change		– na –		– na –	+	0.0000		
Migration category	+	0.0000	+	0.0007	–	ns	+	0.0332
Late Aug. counts	–	0.0032	+	0.0000	–	ns		– na –
Early Sep. counts	+	0.0017	–	0.0001	+	0.0753		– na –
Mid-Sep. counts		– na –		– na –	+	ns		– na –
Late Sep. counts	+	0.0553			+	0.0077		– na –
Early Oct. counts			+	0.0037	–	0.0000		– na –
Mid Oct. counts		– na –		– na –	+	0.0002		– na –
Late Oct. counts	+	ns†	–	0.0002				– na –
Early Nov. counts	–	0.0131	+	0.0003	–	0.1317		– na –
Late Aug.:Migr.Cat.			–	0.0001				– na –
Early Sep.:Migr.Cat.			+	0.0006				– na –
Mid-Sep.:Migr.Cat.		– na –		– na –	–	0.1480		– na –
Late Sep.:Migr.Cat.	–	0.0569						– na –
Early Oct.:Migr.Cat.			+	0.1003	+	0.0073		
Mid-Oct.:Migr.Cat.		– na –		– na –				– na –
Late Oct.:Migr.Cat.	–	ns†	+	0.0007	+	0.0007		– na –
Early Nov.:Migr.Cat.	+	0.0257	–	0.0003				– na –
Fallout counts		– na –		– na –		– na –	+	0.0002
Fallout:Migr.Cat.		– na –		– na –		– na –		

\*Estimated as (null deviance – residual deviance/null deviance).

†Although removing the late October count for Sable Island improved the fit slightly, there were problems fitting a model without its interaction with migration category, so both were included.

negative deviations (all with no autumn records overseas) each occurred in different regressions, but six of the 12 with strongly positive deviations were detected in more than one regression (Table 5). As might be expected, all the species with absolute values of standardized residuals greater than 2 (Table 5) were also strongly down-weighted in the robust regressions (Appendices 1 & 2). These results should perhaps be tempered by the fact that a number of the species on Table 5 were not used in the Fallout-based regressions.

### Classification and regression trees

These analyses use the same variables listed for the GLMs (Tables 1 & 2) without the interactions as the tree mechanism incorporates the useful interactions. The final pruned trees (Fig. 1) give the most informative clustering of the overseas vagrants into homogeneous groups based on the explanatory variables. The residual variance represents the deviation or variation within each cluster, so the smaller, the better. The responses at the terminal nodes are similar

**Table 3.** The results of stepwise GLM regressions using the species that occurred in the 'Fallout' counts (analysed in Table 1) along with the numbers [as  $\log(n + 1)$ ] of these same species detected in the longer term records from Nova Scotia and Florida. The  $P$  values of the K-S test (Kolmogorov–Smirnov one-sample test, with Lilliefors correction) are of the departure of the residuals from normality. The signs and  $P$ -values of regression effects are for those retained at  $P < 0.15$  (signs unspecified for categorical effects); a blank entry indicates that the variable was not selected in the model, and '– na –' that the variable was not included in the model. In addition, where effects of seasonal counts or migration category were detected only as interactions, their main effects were also included, and designated ns (i.e.  $P > 0.15$ ). Variables not applicable in some regressions are shown as na.

	Sable Island <i>n</i> = 55		Seal Island <i>n</i> = 55		Florida <i>n</i> = 55		Fallout <i>n</i> = 55	
Explained variance, $R^2$	0.8932		0.7944		0.7406		0.6272	
K-S test, $P$	0.6133		0.1354		0.6241		0.1702	
Independent variable	Effect	$P$	Effect	$P$	Effect	$P$	Effect	$P$
Wing length	–	0.0008					+	0.0000
Body mass	+	0.0004			+	0.0302		
CV of mass	+	0.0115	+	0.0796			+	0.0727
Distance from NS			–	0.0008			+	0.1125
Longitude			–	0.0013				
Night/day flight								
Population change								
Migration category		0.0007		0.0043		ns		ns
Late Aug. counts	–	0.0059		ns			– na –	
Early Sep. counts	+	0.0371					– na –	
Mid-Sep. counts	– na –		– na –		+	0.0277	– na –	
Late Sep. counts		ns	–	0.1089		ns	– na –	
Early Oct. counts	+	0.0016	+	0.0688		ns	– na –	
Mid Oct. counts	– na –		– na –			ns	– na –	
Late Oct. counts				ns			– na –	
Early Nov. counts	+	0.0035					– na –	
Late Aug. *Migr.Cat.		0.0022		0.0054			– na –	
Early Sep. *Migr.Cat.		0.0000					– na –	
Mid-Sep. *Migr.Cat.	– na –		– na –			0.0491	– na –	
Late Sep. *Migr.Cat.		0.0189		0.0011		0.0065	– na –	
Early Oct. *Migr.Cat.		0.0013		0.0345		0.0036	– na –	
Mid-Oct. *Migr.Cat.	– na –		– na –			0.0105	– na –	
Late Oct. *Migr.Cat.				0.0002			– na –	
Early Nov. *Migr.Cat.		0.0028					– na –	
Fallout count	– na –		– na –		– na –		+	0.0026
Fallout count:Migr.Cat.	– na –		– na –		– na –			0.1477

to the regression predictions except that they are for the group or cluster of species at the node, rather than for individual species. For example, classifying the Sable Island birds by migration category has a slightly larger effect than classifying each group subsequently by seasonal abundances (early September and early October). However, the subsequent division of the early September birds by counts of the same species in early October (although indicating that the more abundant species are more likely to be found overseas) has a smaller effect in improving the overall fit.

Combining the Fallout species with the seasonal numbers of the same species in the other datasets gave quite different results from those using the

original datasets. The trees using numbers from Seal Island and Florida (Fig. 2) show convergence with the original Fallout tree, with weight as the primary basis for classification, followed by migration category and numbers.

## DISCUSSION

There are three levels of interpretation of the results: (1) each analysis type (standard and robust GLM regressions, and Classification and Regression Trees) has shortcomings, but produces different insights; (2) within each type of analysis, results from the four datasets may reflect their differing geographical and other sample properties; (3) finally,

**Table 4.** Comparisons of robust, stepwise GLM regressions using the species observed in the Fallout along with numbers [ $\log(n + 1)$ ] of the same species in the seasonal counts from Nova Scotia and Florida to predict, with other variables, counts [ $\log(n + 1)$ ] of transatlantic landbird vagrants in Britain and Ireland. Fallout counts are included from Table 2 for comparison. The  $R^2$  values, Mallow's Cp and the Akaike Information Criterion (AIC) are measures of the fit of the final models (see text). The signs and  $P$  values of regression effects are for those retained at  $P < 0.15$  (signs unspecified for categorical effects); a blank entry indicates that the variable was not selected in the model, and '– na –' that the variable was not included in the model. In addition, where effects of seasonal counts or migration category were detected only as interactions, their main effects were also included, and designated ns (i.e.  $P > 0.15$ ). Variables not applicable in some regressions are shown as na.

	Sable Island <i>n</i> = 55		Seal Island <i>n</i> = 55		Florida <i>n</i> = 55		Fallout <i>n</i> = 55	
Explained variance, $R^2$	0.6960		0.6686		0.7738		0.6638	
Mallow's Cp	513.33		314.96		247.11		581.87	
AIC	447.67		481.80		168.16		168.88	
Independent variable	Effect	<i>P</i>	Effect	<i>P</i>	Effect	<i>P</i>	Effect	<i>P</i>
Wing length					+	ns	+	0.0000
Body mass								
CV of mass							+	0.1495
Distance from NS					– na –			
Longitude					– na –		–	0.0000
Night/day flight					– na –		– na –	
Population change	– na –		– na –		+	0.0004		
Migration category	ns		0.1204		ns			0.0332
Late Aug. counts	+	0.0413	–	ns			– na –	
Early Sep. counts	+	0.0008	+	0.1280	+	0.0202	– na –	
Mid-Sep. counts	– na –		– na –				– na –	
Late Sep. counts	–	0.0008	+	0.0550	+	0.1618	– na –	
Early Oct. counts*	+	0.0002					– na –	
Mid Oct. counts	– na –		– na –				– na –	
Late Oct. counts	+	0.0544	–	0.0024	–	0.1352	– na –	
Early Nov. counts	–	0.0278	+	0.0018			– na –	
Late Aug.:Migr.Cat.							– na –	
Early Sep.:Migr.Cat.	–	0.0023					– na –	
Mid-Sep.:Migr.Cat.	– na –		– na –				– na –	
Late Sep.:Migr.Cat.	+	0.0020	–	ns			– na –	
Early Oct.:Migr.Cat.*								
Mid-Oct.:Migr.Cat.	– na –		– na –				– na –	
Late Oct.:Migr.Cat.			+	0.0117	+	0.0244	– na –	
Early Nov.:Migr.Cat.			–	0.0070			– na –	
Fallout count	– na –		– na –		– na –		+	0.0002
Fallout count:Migr.Cat.	– na –		– na –		– na –			

\*Although the effect was not significant for Seal Island, there were problems with fitting the model, so it was included.

the 'best' variables selected from each dataset should indicate important determinants of transatlantic vagrancy. Together, the analyses give insights into the types of species crossing the Atlantic, and their seasonal and geographical origins in eastern North America.

### Comparisons among statistical approaches

The standard regressions have the most statistical shortcomings, as they are sensitive to outliers and

deviations from distributional assumptions. However, the results from the Fallout species using covariates from the other samples gave results that are generally reliable. The analysis using regression trees is a descriptive device, which gives insights into potentially complex relationships between the response and the covariates but does not provide a mechanism for inference. The great improvement of fits by the robust regressions is not surprising, but is at the expense of down-weighting the North American sample frequencies of those species that have been most often found in Britain and Ireland (Appendices 1 & 2).

**Table 5.** Large ( $t > |2|$ ) standardized residuals for species in the regressions of Tables 1 and 3. Included are their numerical representations on the UK and Ireland lists, and their migratory status (1 = wintering in North America; 2 = largely in North America, partly in Central America and/or West Indies; 3 largely in Central America and/or West Indies; 5 almost all in South America). Species unavailable for the Fallout-based residuals are entered as ‘–’ Residuals formally detected as residual outliers are shown in bold type.

Species	Sable Island	Seal Island	Florida	Fallout	Sable + Fallout	Seal + Fallout	Florida + Fallout	UK-Ireland	Migration category
Chimney Swift		<b>3.908</b>		–	–	–	–	19	5
Eastern Kingbird	<b>–4.731</b>			–	–	–	–	0	5
Red-eyed Vireo	3.164			2.558			2.224	128	5
Purple Martin		–2.891		–	–	–	–	0	5
Veery	2.202							4	5
Gray-cheeked Thrush		2.492						44	5
Hermit Thrush		2.462						6	2
American Robin		2.030		–	–	–	–	10	2
Cedar Waxwing	–2.083			–	–	–	–	0	3
Northern Parula	2.479	<b>3.647</b>	2.570			2.289	2.099	17	3
Cape May Warbler						–2.094		0	3
Yellow-rumped Warbler		2.031	3.293					23	2
Palm Warbler					–2.900			0	3
Blackpoll Warbler			2.247	2.206			2.699	36	5
Black-and-white Warbler	2.173	2.655	2.384		2.722	2.135		13	3
Connecticut Warbler	–3.165							0	5
Mourning Warbler			–2.143					0	5
Dark-eyed Junco		2.015		–	–	–	–	2	1
Baltimore Oriole	2.274	3.438	<b>3.399</b>			3.060	2.595	21	3

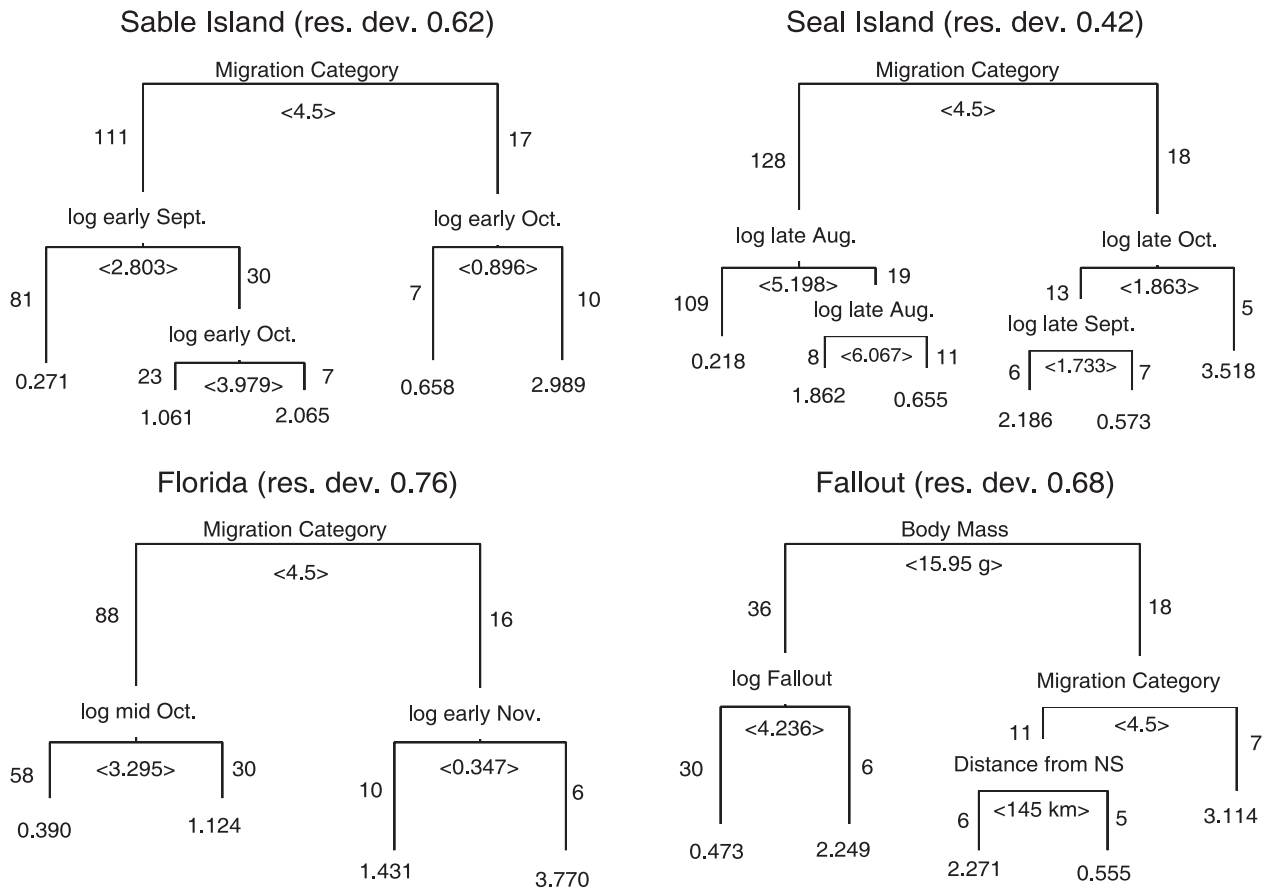
These down-weightings would have to be even more extreme if the original counts, rather than logs, were used. This indicates that the variables used in the regressions offer an incomplete explanation of the tendencies of species to undertake transatlantic crossings. The weightings may also reflect the possibility that some vagrants are more, or less, easy to find, identify and describe satisfactorily for accepted lists. Nevertheless, all the analyses, including the standard regressions, add insights from comparisons of variables (see below).

### Comparisons among sources of counts

Among the regressions, the frequencies and other features of birds in the Florida sample gave the best fit to the overseas counts, startlingly so in the robust form (Table 2, 92.7% of variance explained). By contrast, the results from the Fallout were statistically the least problematic and not much improved by the robust analysis (cf. explained variance, Tables 1 & 2). Furthermore, using the Fallout species along with the seasonal abundances from the other three samples produced large increases of explained variances (especially using Sable Island counts) and greatly improved statistical behaviour (Table 3), which was not further improved by robust analysis (Table 4).

These results may reflect characteristics shared by the birds in the Florida and Fallout samples. Both samples consisted of birds that had already migrated long distances at night: the Fallout birds arriving from offshore had certainly travelled by night (McLaren *et al.* 2000), and migrants from the north in Florida (the bulk of the transatlantic vagrants) had already come a long way, to be killed at night. The especially good fit using Fallout species with numbers from Sable Island suggests that the island produced the best seasonal samples of those species. Sable Island may be uniquely situated to avoid statistical ‘clutter’ from birds not willing or able to fly over water. In addition, an attempt had been made to avoid repeated counts of the same individuals on Sable Island, but not on sequential days on Seal Island, where estimated frequencies could be distorted by species-specific stopover tendencies.

The classification and regression trees (Figs 1 & 2) reflect some of the same properties shown by the standard GLMs. Although interaction terms are not used, the branchings of seasonal counts within migration category can be viewed as analogous to interactions between them. The trees supplied the best fits (Fig. 1, smallest residual mean deviance) using the two island datasets, unlike the standard GLM regressions (smallest  $R^2$  and/or significant



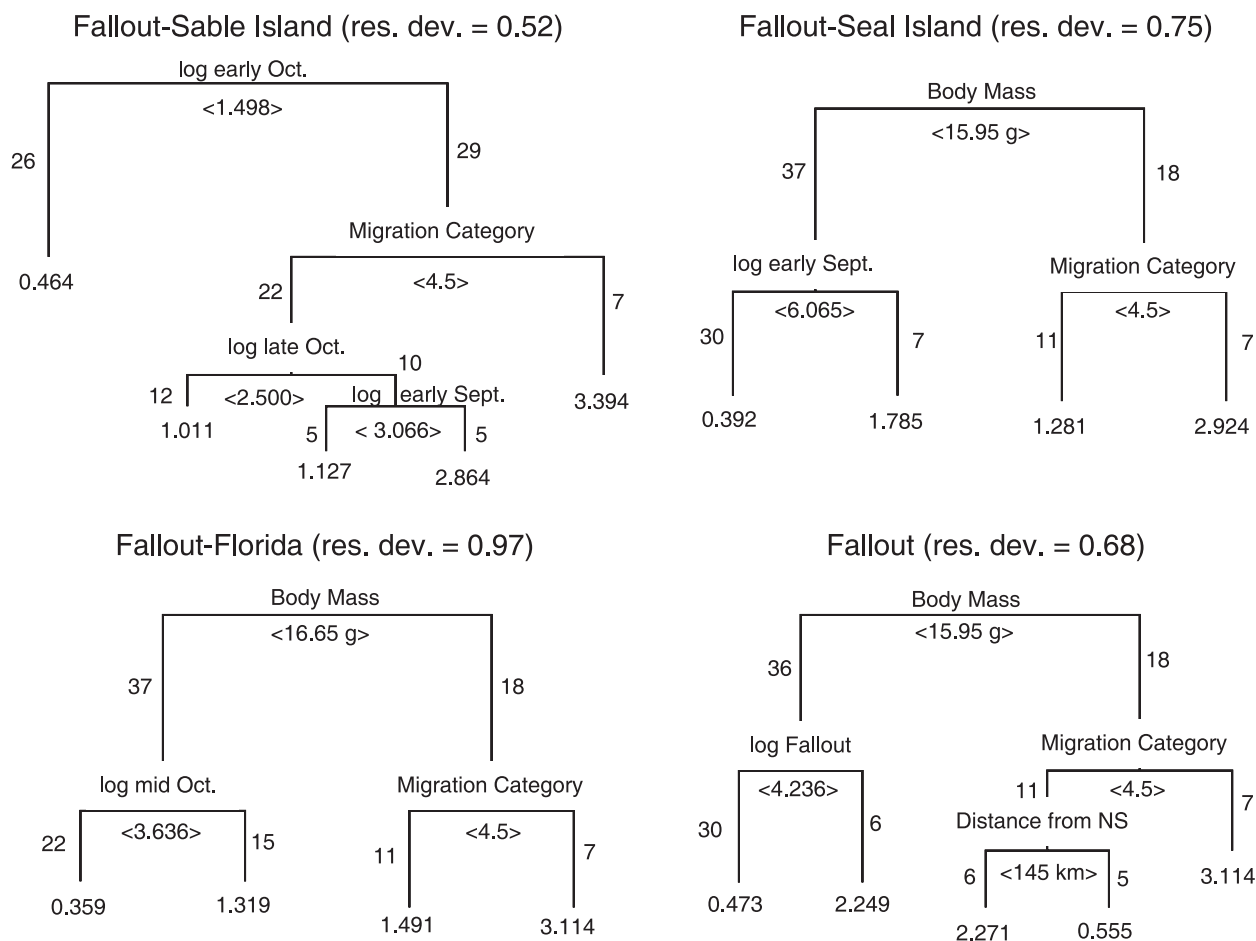
**Figure 1.** Pruned regression trees for the four datasets, with residual mean deviance (res. dev.) for each tree. The variable above each internal node was used to split the data using the values below each node. The non-uniform vertical branch lengths indicate the relative change in deviance between the parent and child nodes. The numbers alongside each vertical branch (in italics) are the numbers of species within that grouping. The terminal numbers are the predicted responses of each group.

Kolmogorov–Smirnov tests in Table 1). This may relate to the severe pruning of variables that were significant in the regressions. The trees do, however, indicate that higher proportions of species in the Florida and Fallout samples have large effects on the transatlantic counts. That is, 46/104 (44%) of the Florida species, 19/54 (35%) of Fallout species and 40/128 (31%) from Sable Island, but only 19/146 (13%) of those from Seal Island, have predicted responses > 1.0 (Fig. 1). This matches with the above conclusions from the standard GLM regressions (Table 1) that the Florida and Fallout samples may be most representative of long-distance, nocturnal migrants. When the analyses are explored further by combining the Fallout species with the larger seasonal counts, the tree for Sable Island proves to be the best fit (mean residual deviance 0.52), and 29/55 (53%) of species groups selected from Sable Island,

25/55 (45%) from Seal Island and 33/55 (60%) from Florida have predicted responses > 1.0 (Fig. 2).

### Comparisons of variables within analyses

Species frequencies in North American samples, as indicated in the Introduction, are a priori likely to be correlated among the samples and with the transatlantic frequencies. In the standard regressions (Table 1), only the counts from the Fallout (strongly at < 0.01) and two seasonal intervals on Sable Island (weakly) had direct effects. There were more strong direct effects (after extreme down-weightings) in the robust regressions (Table 2), but without clear seasonal patterns. Combining the Fallout species and the frequencies from the other sources (Table 3) produced strong positive effects of early October and early November, and a negative effect of late



**Figure 2.** Pruned regression trees using the species in the Fallout and the numbers of these species in the three larger datasets. The original tree for Fallout (from Fig. 1) is included for comparison. Variables and values as on Figure 1.

August. The robust versions (Table 4), which may actually eliminate some real influences, produced a variety of patterns. The seasonal effects of bird frequencies in their interactions with migration category were generally strongest later in the season in the standard regressions (Table 1; all with lowest  $P$  values for October), more variably in the other analyses (Tables 2–4). The interactions may be best captured in the more selective regression trees (Fig. 1), in which the larger predicted responses are all to groups of more abundant species in October (including the Fallout species) and early November. The effects of species frequencies were more complex in the versions using the Fallout species with counts from the other samples (Fig. 2), although species groups with larger counts in October predominated.

In summary, all the analyses indicate that the frequencies of the North American species later in

the season, especially October, had a predominant influence on their occurrence overseas.

Migration category as a main effect was significant among the standard regressions only for Seal Island (Table 1), but became so in the robust versions using samples from both islands and the Fallout (Table 2). It was also significant using the Fallout species combined with numbers from the two islands. The effect was always positive: longer-distance migrants were more likely to cross the Atlantic. The regression trees (Figs 1 & 2) selected migration to South America (i.e. category  $> 4.5$ ) as the major determinant of transatlantic vagrancy, although body size was a basic factor for the preselected long-distance migrants in the Fallout.

Body size is expected to influence the ability of a landbird to cross the ocean, through flight speed, metabolic capacity and general robustness. Accordingly,

it is not surprising that significant positive effects of wing length or body mass appeared in the regressions using the original datasets, especially in the robust regressions (Table 2), in which the effects of species frequencies are constrained. Perhaps because the species involved had demonstrated capacity for long flights, the effect of size was less marked in the regressions of the Fallout species combined with frequencies from the other samples (Tables 3 & 4); in the Fallout and Sable Island combination, the strong negative effect of wing length, combined with a strong positive effect of body mass (Table 3), seems inexplicable. The regression trees also reflect this issue. Body mass remains the primary basis of classification of species in the Fallout, with larger birds leading to the highest predicted response, but size measures are absent from the other trees (Fig. 1). Using the Fallout species supplied with counts from Seal Island and Florida evokes a primary role of body size, with larger size again leading to the largest predicted responses (Fig. 2). The absence of size as a variable using the Sable Island frequencies (Fig. 2) matches its mixed effects in the equivalent regression (Table 3).

Fat storage capacity is expected to have a positive influence on endurance for transatlantic flights. The proxy index of CV of body mass apparently had a strong influence using the original Fallout sample (Tables 1 & 2) and in the regressions using the Fallout species with numbers from the island samples (Table 3). Interestingly, the effect was eliminated from the latter by the robust regressions (Table 4), which also produced lower  $R^2$  values, presumably from down-weighting of many species in which the effect was important. The regression trees did not select CV of mass as important.

Geographical origins of the species in the North American samples were used to address an insight by Robbins (1980) that migrants (and vagrants) reaching the East Coast from more westerly breeding ranges might be more likely to carry on across the ocean. We extended the hypothesis by including the distance of the nearest normal range from Nova Scotia as a general indication of the 'willingness' for vagrancy. In several regressions (Tables 1–3), notably that for Fallout, there were significant ( $P < 0.05$ ) negative effects. The regression tree using the Fallout sample (Fig. 1) showed the same effect: species with ranges within 145 km of southwest Nova Scotia were more likely to reach Britain and Ireland. This result is contrary to those (weakly supported) by Robbins (1980), but might be tempered by the fact that some vagrant birds reaching Atlantic Canada from the

south or west are excluded from the accepted lists in Britain and Ireland because of perceived possibilities of their escape from captivity. These include (as per Mitchell & Young 1997) Spotted Towhee *Pipilo maculatus*, Blue Grosbeak *Guiraca caerulea*, Lazuli Bunting *Passerina amoena*, Painted Bunting *Passerina ciris* and Yellow-headed Blackbird *Xanthocephalus xanthocephalus* (see also Proctor & Donald 2003). The exclusion of such birds from our analysis could contribute to a negative influence of tendency for western birds to occur overseas. However, choosing among the various unaccepted records seemed more arbitrary than excluding them all.

Nocturnal vs. diurnal migration was not considered for the Fallout and Florida data, which selectively represented night migrants. It was tested, perhaps crudely, as a two-value category using the island data, and proved significant ( $P = 0.0199$ ), but negative (night migrants under-represented overseas), only in the robust regression for Sable Island (Table 2). This effect is inexplicable, but could reflect the artificiality of classing some transatlantic vagrants among day migrants (e.g. American Robin, sparrows).

Population change was considered in comparing the datasets from Florida (1955–80) and the Fallout (1998) with the long-term (1956–2002) records from Britain and Ireland. This proved to be a highly significant factor for the former but not the latter (Tables 1, 2 & 4). Birds that have increased in eastern North America since 1980 were more prevalent in the long-term records from Britain and Ireland.

## GENERAL CONCLUSIONS

Together, our various results using a variety of statistical approaches add up to patterns of transatlantic vagrancy that confirm and extend earlier insights of Robbins (1980), Elkins (1979) and others. Transatlantic bird vagrants were best represented by larger-bodied species among long-distance migrants (especially to South America) that were common in late autumn (especially October) in the North American samples, and notably those in the unusual Fallout of early October 1998 in southwestern Nova Scotia. All, or a large proportion, of the populations of the four most abundant species in the UK and Ireland – Yellow-billed Cuckoo, Gray-cheeked Thrush, Red-eyed Vireo and Blackpoll Warbler – winter primarily in Brazil (Stoltz *et al.* 1992). It is well established (e.g. Elkins 1979, 1988, 1999) that October is the peak month for arrivals of such birds in Britain and Ireland.

McLaren *et al.* (2000) gave strong statistical and meteorological evidence that the birds in the unusual Fallout in southwestern Nova Scotia had departed offshore following a cold front in the southeastern United States. Some then became entrained in strong southwest winds in the warm sector beyond the front, to be carried rapidly northeast and flung ashore by strong easterlies ahead of a deepening low at the northeastern end of the front. The Fallout birds moving northeast in late autumn were nominally 'reverse migrants', but this may be an inappropriate category for their behaviour. Although Thorup (2004) found a greater propensity for 'reverse migration' among eastern vagrants than southern vagrants in northwest Europe, Gilroy and Lees (2003) argued that autumn migratory 'misorientation' in general may occur in any direction but differential survival of such individuals may lead to the founding of new wintering subpopulations. Although nearctic vagrants in Europe have been construed as following the reverse great circle of the southwest trend of the east coast of the United States (Alerstam 1990, Cottridge & Vinicombe 1996, Elkins 1999), our evidence supports the conclusion by Elkins (1979, 1988, 1999) that they are actually entrained by North Atlantic wind-flow patterns. The mechanisms of these weather phenomena in eastern Canada were explored by Richardson (1972), who found from radar studies that 'offshore flights to the SE or S were most common and densest when there were W or NW winds, immediately after the passage of cold fronts.' By contrast, ahead of such cold fronts, there can be marked downwind migration, although variable in direction and intensity (Richardson 1982).

The tendency of autumn night migrants finding themselves at daybreak over the ocean off eastern Canada is to fly northwest (Richardson 1972), which is an adaptive direction for landfall along the SW-NE coast. However, when faced with strong south-westerly winds, there is much movement northeast (Richardson 1972), which may explain the regular appearance of 'southern' vagrants in Nova Scotia in autumn (McLaren 1981a). Although downwind flight may be generally adaptive for birds fleeing undesirable circumstances, it would not be so off eastern North America, where many land birds must face a watery end. This is hinted at in McClintock *et al.* (1978), who regularly encountered passerines up to 2100 km offshore during research cruises in the Atlantic, and by ship-based radar observations that detect a considerable volume of offshore passage (Larkin *et al.* 1979). Indeed, Butler (2000) found a relationship

between NABBS population sizes of widespread North American passerines and frequency of storms in the Gulf of Mexico and off the southeastern United States in the previous autumn. Many landbirds on Sable Island during October are unseasonable migrants and vagrants (McLaren 1981b). The island's role as a last refuge for some birds displaced far northeastwards in late autumn may be reflected by the particularly strong and statistically untroublesome fits from using the Fallout species and their frequencies on Sable Island in the standard regression (Table 3) and the strong responses to abundances in early October in the regression tree (Fig. 2).

Downwind flight by belated migrants from the unsuitably colder interior of the continent may also explain the regular occurrence in Atlantic Canada of vagrants from the far west in late autumn and early winter, after the establishment of vigorous westerly airflow across central North America (McLaren 1981a). Durand (1963) gives an instructive example of birds entrained by strong westerly flow at higher latitudes, following the northeastward passage of a hurricane. He found numerous birds aboard ship, most arriving overnight some 600+ km east of New York. The ten most abundant were: White-throated Sparrow (20+), Northern Flicker (10+), Blackpoll Warbler (10+), Song Sparrow (9+), Golden-crowned Kinglet (8+), Swamp Sparrow *Melospiza georgiana* (7), Dark-eyed Junco (6+), Ruby-crowned Kinglet (6), Savannah Sparrow (6) and Field Sparrow *Spizella pusilla* (5). Apart from the Blackpoll Warbler and White-throated Sparrow, none of these birds is among the 20 most abundant transatlantic vagrants (cf. Appendix 1), and four have never occurred. This suggests that birds swept offshore by westerlies at higher latitudes contribute little to the transatlantic list. Nevertheless, such westerlies might be the source of some winter appearances of transatlantic vagrants that have not been included in the present analyses; those of American Robins, for example, are clustered over the mid-winter period. (However, some nearctic vagrants first found during winter in the UK and Ireland may have arrived in autumn and escaped detection until they appeared at garden feeding stations or other well-watched sites.)

Ralph (1981) investigated age ratios at different banding sites to determine migration routes of North American passerines. He assigned different species to 14 routes; of these, the major categories and the proportion of species to have occurred in the UK in autumn are: 'broad front migrants' (3/12); 'coastal plain migrants' (17/20); 'Appalachian migrants'

(3/9) and 'west of Appalachian' (2/5). The higher proportion of 'coastal plain migrants' occurring is perhaps intuitive but there remains debate about which species of passerines and near-passerines use a direct transoceanic crossing from mid-latitudes of North America to northern South America. There is strong evidence that at least part of the Blackpoll Warbler population uses this route (Nisbet *et al.* 1995), which is also suggested by the above list from Durand (1963). Ralph (1981) adds another 14 species as 'Possible Western Atlantic Migrants.' Stoddard *et al.* (1983) calculated that the range of permissible headings (assuming a constant compass orientation) in order for birds to make a successful over-water journey when departing Nova Scotia is low. They must either have headings greater than 150° or must re-orientate their flights to the south *en route*. Radar studies suggest that it is the latter scenario that occurs frequently, considering the number of birds heading in apparently fatal directions. Even so, there is little margin for error with migratory headings.

Some insights on these questions may come from species that are statistically under- or over-represented in the overseas list (Table 5). In general, there is no pattern among the under-represented species; they all appear in different regressions, and none is on the overseas list, which makes 'predicted' estimates less reliable. Some putatively under-represented species have been the subject of past speculation. For example, tyrant flycatchers are among the more common migrants on North American lists, yet have not occurred in Britain and Ireland, although there are records of *Empidonax* spp. in Iceland. However, apart from the Eastern Kingbird, which is severely under-represented overseas (exaggerated by positive skew of the residuals) according to the Sable Island list (Table 5), the tyrant flycatchers do not rate as outstandingly deviant. The fact that they are generally early migrants, with peak counts on our North American lists in late August to mid-September, may be sufficient explanation, as those lists have smaller impacts on the overseas lists than those from October (see above).

By contrast, six species are substantially over-represented in the UK and Ireland by two or more regressions (i.e. absolute residuals > 2 in Table 5). Among them, the overseas frequency of Blackpoll Warbler is adequately predicted by its relative abundance on the Nova Scotian islands (standardized residuals = 1.335 for Sable Island and -1.492 for Seal Island), but not by the Florida or Fallout data (Table 5). This may reflect its known capacity (see

above) to migrate from northern latitudes non-stop over the ocean to South America, avoiding the southern USA. Three other species are strongly over-represented in all regressions except those for Fallout and its combinations with the other counts. Of these, the Northern Parula and the Black-and-white Warbler are rated as 'possible western Atlantic migrants' (i.e. over-ocean) by Ralph (1981), and both winter largely in the West Indies. The over-represented Baltimore Oriole also winters partly in the West Indies or migrates through the islands to northern South America. The Yellow-rumped Warbler, another 'possible western Atlantic migrant' (Ralph 1981), is especially over-represented based on the Florida regression, but not that for Sable Island. It does winter as far north as Nova Scotia, and may be one species that is propelled overseas by the strong westerly airflows developing at mid-latitudes in late autumn (see above). Finally, the Red-eyed Vireo, over-represented in three regressions (Table 5), is rated by Ralph (1981) as a 'broad front migrant'; it is not classed by him as a 'possible western Atlantic migrant', but some must fly over water to reach their wintering grounds, which include northeastern South America.

It would be unwise to speculate beyond these possible associations between characteristics of a few species and their statistical representations on the UK and Ireland list. Much of the unexplained variance may be reduced as we learn more about the ease of discovery and identification, seasonal timing, migratory routes, and other characteristics of species in eastern North America that have appeared overseas. Until then, our results are best used for their insights into the shared properties of the broad groups of species involved.

## REFERENCES

- Akaike, H.** 1974. A new look at statistical model identification. *IEEE Trans. Automat. Control* **19**: 716–723.
- Alerstam, T.** 1990. *Bird Migration*. Cambridge: Cambridge University Press.
- Breiman, L., Friedman, J.H., Olshen, R.A. & Stone, C.J.** 1983. *Classification and Regression Trees*. Pacific Grove, CA: Wadsworth.
- Bryant, D.** 1997. Population trends of American vagrants. *Birding World* **10**: 340–349.
- Butler, R.W.** 2000. Stormy seas for North American songbirds: are declines related to severe storms during migration? *Auk* **117**: 518–522.
- Clark, L.A. & Pregibon, D.** 1992. Tree-based models. In Chambers, G.M. & Hastie, T.J. (eds) *Statistical Models in S*: 377–419. Pacific Grove, CA: Wadsworth and Brooks/Cole Advanced Books & Software.

- Cottridge, D. & Vinicombe, K.** 1996. *Rare Birds in Britain and Ireland, a Photographic Record*. London: Harper Collins/Hayman.
- Crawford, R.L.** 1981. Bird casualties at a Leon County, Florida TV tower. *Bull. Tall Timbers Res. Sta.* **22**.
- Dunning, J.B.** 1993. *CRC Handbook of Avian Body Masses*. Boca Raton, LA: CRC Press.
- Durand, A.J.** 1963. A remarkable fall of American land-birds on the 'Mauretania', New York to Southampton, October 1962. *Br. Birds* **56**: 157–164.
- Elkins, N.** 1979. Nearctic landbirds in Britain and Ireland: a meteorological analysis. *Br. Birds* **72**: 417–433.
- Elkins, N.** 1988. Recent transatlantic vagrancy of landbirds and waders. *Br. Birds* **81**: 484–491.
- Elkins, N.** 1999. Nearctic landbirds in Britain and Ireland. *Br. Birds* **92**: 83–95.
- Elkins, N. & Yésou, P.** 1998. Sabine's Gulls in western France and southern Britain. *Br. Birds* **91**: 386–397.
- Gilroy, J.J. & Lees, A.C.** 2003. Vagrancy theories: are autumn vagrants really reverse migrants? *Br. Birds* **96**: 427–438.
- Hampel, F.R., Ronchetti, E., Rousseeuw, P. & Stahel, W.** 1986. *Robust Statistics*. New York: Wiley.
- Howell, S.N.G. & Webb, S.** 1995. *A Guide to the Birds of Mexico and Northern Central America*. Oxford: Oxford University Press.
- Larkin, R.P., Griffin, D.R., Torre-Bueno, J.R. & Teal, J.** 1979. Radar observations of bird migration over the western North Atlantic Ocean. *Behav. Ecol. Sociobiol.* **4**: 225–264.
- McClintock, C.P., Williams, T.C. & Teal, J.M.** 1978. Autumnal bird migration observed from ships in the Western North Atlantic Ocean. *Bird Banding* **49**: 262–273.
- McLaren, I.A.** 1981a. The incidence of vagrant landbirds on Nova Scotian islands. *Auk* **98**: 243–257.
- McLaren, I.A.** 1981b. The birds of Sable Island, Nova Scotia. *Proc. Nova Scotian Inst. Sci.* **31**: 1–84.
- McLaren, I.A., Maybank, B., Keddy, K., Taylor, P.D. & Fitzgerald, T.** 2000. A notable autumn arrival of reverse migrants in southern Nova Scotia. *N. Am. Birds* **54**: 4–10.
- Mitchell, D. & Young, S.** 1997. *Rare Birds of Britain and Europe*. London: New Holland Publishers Ltd.
- Morris, S.R., Holmes, D.W. & Richmond, M.E.** 1996. A ten-year study of the stopover patterns of migratory passerines during fall migration on Appledore Island, Maine. *Condor* **98**: 395–409.
- Moss, S.** 1998. Predictions of the effects of global climate change on Britain's birds. *Br. Birds* **91**: 307–325.
- Nisbet, I.C.T.** 1963. American passerines in western Europe, 1951–62. *Br. Birds* **55**: 139–158.
- Nisbet, I.C.T., McNair, D.B., Post, W. & Williams, T.C.** 1995. Transoceanic migration of the Blackpoll Warbler: summary of scientific evidence and response to criticisms. *J. Field Ornithol.* **66**: 612–622.
- Poole, A. & Gill, F. (eds)** 1992–2002. *The Birds of North America*. Nos. 1–716. Philadelphia, PA: Academy of Natural Sciences; Washington, D.C.: American Ornithologists' Union.
- Proctor, B. & Donald, C.** 2003. Yellow-headed Blackbirds in Britain and Europe. *Birding World* **16**: 69–81.
- Pyle, P.** 1997. *Identification Guide to North American Birds. Part 1. Columbidae to Ploceidae*. Bolinas, CA: Slate Creek Press.
- Raffaele, H., Wiley, J., Garrido, O.A., Keith, A. & Raffaele, J.** 1998. *A Guide to the Birds of the West Indies*. Princeton, NJ: Princeton University Press.
- Ralph, C.J.** 1981. Age ratios and their possible use in determining autumn routes of passerine migrants. *Wilson Bull.* **93**: 164–188.
- Richardson, W.J.** 1972. Autumn migration and weather in eastern Canada: a radar study. *Am. Birds* **26**: 10–17.
- Richardson, W.J.** 1982. Northeastward reverse migration of birds over Nova Scotia, Canada, in autumn. A radar study. *Behav. Ecol. Sociobiol.* **10**: 193–206.
- Ridgley, R.S.** 1981. *A Guide to the Birds of Panama*. Princeton, NJ: Princeton University Press.
- Ridgley, R.S. & Tudor, G.** 1989. *The Birds of South America, Vol. 1. The Oscine Passerines*. Austin, TX: University of Texas Press.
- Ridgley, R.S. & Tudor, G.** 1994. *The Birds of South America, Vol. II. The Suboscine Passerines*. Austin, TX: University of Texas Press.
- Robbins, C.S.** 1980. Predictions of future Nearctic landbird vagrants to Europe. *Br. Birds* **73**: 448–457.
- Robbins, C.S., Bystrak, C. & Geissler, P.H.** 1986. The Breeding Bird Survey: its first 15 years, 1965–1979. *US Fish Wildl. Serv. Resour. Publ.* **157**: 1–196.
- Sauer, J.R., Hines, J.E. & Fallon, J.** 2005. *The North American Breeding Bird Survey; Results and Analysis 1966–2004. Version 2005.2*. Laurel, MD: USGS.
- Sharrock, J.T.R. & Sharrock, E.M.** 1976. *Rare Birds in Britain and Ireland*. Berkhamsted: Poyser.
- Sibley, D.A.** 2003a. *The Sibley Field Guide to the Birds of Eastern North America*. New York: Alfred A. Knopf, Inc.
- Sibley, D.A.** 2003b. *The Sibley Field Guide to the Birds of Western North America*. New York: Alfred A. Knopf, Inc.
- Stoddard, P.K., Marsden, J.E. & Williams, T.C.** 1983. Computer-simulation of autumnal bird migration over the western North Atlantic. *Anim. Behav.* **31**: 297–306.
- Stotz, D.F., Bierregaard, R.O., Cohn-Haft, M., Petermann, P., Smith, J., Whittaker, A. & Wilson, S.V.** 1992. The status of North American migrants in Central Amazonian Brazil. *Condor* **94**: 608–621.
- Thorup, K.** 2004. Reverse migration as a cause of vagrancy. *Bird Study* **31**: 228–238.

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## APPENDIX 1

Significantly down-weighted coefficients (< 0.3) applied to (log + 1) species counts for use in the robust GLM regressions of Table 2. Species names and order are from the AOU (2004). An 'X' indicates that the species occurred in the count but was not down-weighted, or was down-weighted by > 0.3. Also included in the list are species that were not significantly down-weighted, but that have occurred in the British and Irish lists. Species that did not occur in or were excluded from some North American counts are denoted with a dash.

Species	Sable Island	Seal Island	Florida	Fallout	Britain/Ireland
Mourning Dove <i>Zenaida macroura</i>	0.0639	0.1462	X	–	2
Black-billed Cuckoo <i>Coccyzus erythrophthalmus</i>	0.2211	X	0.0357	0.0085	10
Yellow-billed Cuckoo <i>Coccyzus americanus</i>	0.0053	0.0091	0.0004	0.0155	45
Com. Nighthawk <i>Chordeiles minor</i>	X	X	0.0186	–	16
Chimney Swift <i>Chaetura pelagica</i>	0.0628	0.0156	0.0255	–	19
Belted Kingfisher <i>Ceryle alcyon</i>	0.0206	X	X	–	4
Yellow-bellied Sapsucker <i>Sphyrapicus varius</i>	0.2892	X	0.2680	–	2
Downy Woodpecker <i>Picoides pubescens</i>	X	0.0015	–	–	0
Northern Flicker <i>Colaptes auratus</i>	0.0072	0.1877	X	–	0
Eastern Wood-Pewee <i>Cotopus virens</i>	X	0.0999	X	0.4950	0
Acadian Flycatcher <i>Empidonax virescens</i>	–	–	0.0384	–	0
Alder Flycatcher <i>Empidonax alnorum</i> *	0.1766	0.0408	0.2217	–	0
Great Crested Flycatcher <i>Myiarchus crinitus</i>	0.1107	X	0.2616	–	0
Eastern Kingbird <i>Tyrannus tyrannus</i>	0.0254	0.0335	X	–	0
Yellow-throated Vireo <i>Vireo flavifrons</i>	X	X	X	X	1
Philadelphia Vireo <i>Vireo philadelphicus</i>	X	X	X	X	2
Red-eyed Vireo <i>Vireo olivaceus</i>	0.0040	0.0027	X	0.0037	128
Purple Martin <i>Progne subis</i>	0.0642	0.1509	–	–	0
Tree Swallow <i>Tachycineta bicolor</i>	0.2602	0.1590	X	–	0
Cliff Swallow <i>Petrochelidon pyrrhonata</i>	0.0642	0.1326	0.0605	–	10
Red-breasted Nuthatch <i>Sitta canadensis</i>	X	X	X	–	1
Ruby-crowned Kinglet <i>Regulus calendula</i>	0.2957	X	X	X	0
Veery <i>Catharus fuscescens</i>	0.2887	X	0.0177	0.1502	4
Gray-cheeked Thrush <i>Catharus minimus</i>	0.0054	0.0108	0.0055	0.0221	44
Swainson's Thrush <i>Catharus ustulatus</i>	0.0232	X	0.0018	0.1442	24
Hermit Thrush <i>Catharus guttatus</i>	0.0645	0.0844	X	0.0970	6
Wood Thrush <i>Hylocichla mustelina</i>	X	X	X	–	1
American Robin <i>Turdus migratorius</i>	0.0072	0.0635	0.0652	–	10
Varied Thrush <i>Ixoreus naevius</i>	X	X	X	0.1915	1
Grey Catbird <i>Dumatella carolinensis</i>	X	X	X	0.1120	3
Northern Mockingbird <i>Mimus polyglottos</i>	0.1020	X	0.2172	–	1
Brown Thrasher <i>Toxostoma rufum</i>	X	X	0.2915	X	1
American Pipit <i>Anthus rubescens</i>	X	0.2239	X	–	3
Cedar Waxwing <i>Bombycilla cedrorum</i>	0.0495	0.0195	X	–	0
Blue-winged Warbler <i>Vermivora pinus</i>	X	X	X	X	1
Tennessee Warbler <i>Vermivora peregrina</i>	X	0.1793	0.2631	X	4
Northern Parula <i>Parula americana</i>	0.0588	0.0486	0.0408	0.0449	17
Chestnut-sided Warbler <i>Dendroica pennsylvanica</i>	X	0.2395	X	X	2
Yellow Warbler <i>Dendroica petechia</i>	0.1583	0.0751	0.0476	0.2386	5
Magnolia Warbler <i>Dendroica magnolia</i>	X	X	X	X	1
Yellow-rumped Warbler <i>Dendroica coronata</i>	0.0041	0.0174	0.0234	0.0350	23
Blackburnian Warbler <i>Dendroica fusca</i>	X	X	X	X	2
Palm Warbler <i>Dendroica palmarum</i>	X	X	X	X	1
Bay-breasted Warbler <i>Dendroica castanea</i>	0.1382	0.0744	X	X	1
Blackpoll Warbler <i>Dendroica striata</i>	0.0222	X	0.0126	0.0212	36
Cerulean Warbler <i>Dendroica cerulea</i>	X	X	0.1893	–	0
Black-and-white Warbler <i>Mniotilta varia</i>	0.0656	0.0547	0.0605	0.1168	13
American Redstart <i>Setophaga ruticilla</i>	X	X	0.0299	0.2797	7
Ovenbird <i>Seiurus aurocapillus</i>	0.2895	0.2789	X	X	5
Northern Waterthrush <i>Seiurus novaboracensis</i>	0.1386	0.0672	0.0255	X	7
Connecticut Warbler <i>Oporornis agilis</i>	0.2160	0.1231	–	X	0
Mourning Warbler <i>Oporornis philadelphia</i>	0.1865	0.0862	X	X	0
Common Yellowthroat <i>Geothlypis trichas</i>	X	X	0.2067	X	4

## Appendix 1. Continued.

Species	Sable Island	Seal Island	Florida	Fallout	Britain/Ireland
Hooded Warbler <i>Wilsonia citrina</i>	X	X	X	X	2
Wilson's Warbler <i>Wilsonia pusilla</i>	X	X	X	X	1
Canada Warbler <i>Wilsonia canadensis</i>	0.2924	0.0733	X	X	0
Summer Tanager <i>Piranga rubra</i>	X	X	0.0437	X	1
Scarlet Tanager <i>Piranga olivacea</i>	X	0.1096	0.0039	X	7
Chipping Sparrow <i>Spizella passerina</i>	X	0.2673	X	X	0
Savannah Sparrow <i>Passerculus sandwichensis</i>	0.1060	–	X	–	1
Fox Sparrow <i>Passerella iliaca</i>	0.1966	X	X	–	0
Song Sparrow <i>Melospiza melodia</i>	X	0.1360	X	–	1
White-throated Sparrow <i>Zonotrichia albicollis</i>	0.0657	0.1048	0.1050	–	9
White-crowned Sparrow <i>Zonotrichia leucophrys</i>	X	X	X	–	2
Dark-eyed Junco <i>Junco hyemalis</i>	0.0278	0.0394	X	–	2
Rose-breasted Grosbeak <i>Pheucticus ludovicianus</i>	0.0270	0.0093	0.0208	0.0342	27
Indigo Bunting <i>Passerina cyanea</i>	X	0.2619	X	X	2
Dickcissel <i>Spiza americana</i>	0.1468	X	X	–	0
Bobolink <i>Dolichonyx oryzivorus</i>	X	0.0005	0.0044	–	26
Rusty Blackbird <i>Euphagus carolinus</i>	X	0.13	–	–	0
Baltimore Oriole <i>Icterus galbula</i>	0.0478	0.0262	0.0340	0.0435	21

\*Not discriminated from Least Flycatcher, *Empidonax minimus*, in the Sable Island counts.

**APPENDIX 2**

Significantly down-weighted coefficients (< 0.3) applied to (log + 1) species counts for use in the robust GLM regressions of Table 4. Species names and order are from AOU (2004). An 'X' indicates that the species occurred in the count but was not down-weighted, or was down-weighted by > 0.3. Also included in the list are species that were not significantly down-weighted, but that have occurred in the British and Irish lists. Species that did not occur in or were excluded from some North American counts are denoted with a dash.

Species	Sable Island	Seal Island	Florida	Fallout	Britain/Ireland
Black-billed Cuckoo	< 0.0001	< 0.0111	X	0.0085	10
Yellow-billed Cuckoo	0.0415	0.0416	0.0226	0.0155	45
Eastern Wood-Pewee	X	< 0.0001	X	0.4950	0
Least Flycatcher*	X	0.0002	X	X	0
Yellow-throated Vireo	X	0.1487	X	X	1
Philadelphia Vireo	X	X	X	X	2
Red-eyed Vireo	< 0.0001	0.0035	0.0088	0.0037	128
Ruby-crowned Kinglet	< 0.0001	X	X	X	0
Veery	0.0004	< 0.0001	X	0.1502	4
Gray-cheeked Thrush	0.0048	< 0.0001	0.0055	0.0221	44
Swainson's Thrush	0.0095	0.0169	X	0.1442	24
Hermit Thrush	0.0364	0.0567	0.0465	0.0970	6
Varied Thrush	X	0.0110	X	0.1915	1
Gray Catbird	< 0.0001	0.3177	X	0.1120	3
Brown Thrasher	0.1448	X	0.3534	X	1
Blue-winged Warbler	X	X	X	X	1
Tennessee Warbler	0.0095	< 0.0001	X	X	4
Northern Parula	0.0632	< 0.0001	0.0706	0.0449	17
Chestnut-sided Warbler	0.0161	X	X	X	2
Yellow Warbler	X	X	X	0.2386	5
Magnolia Warbler	< 0.0001	X	X	X	1
Cape May Warbler	< 0.0001	0.1138	X	X	0
Yellow-rumped Warbler	0.0038	0.0155	0.0103	0.0350	23
Black-throated Green Warbler	X	< 0.0001	X	X	0
Blackburnian Warbler	< 0.0001	0.0765	X	X	2
Palm Warbler	0.1656	X	X	X	1
Bay-breasted Warbler	X	X	X	X	1
Blackpoll Warbler	< 0.0001	< 0.0001	0.02312	0.0212	36
Black-and-white Warbler	0.0244	0.0601	0.0849	0.1168	13
American Redstart	< 0.0001	X	0.1660	0.2797	7
Ovenbird	< 0.0001	X	X	X	5
Northern Waterthrush	0.0978	0.0030	0.2716	X	7
Connecticut Warbler	X	< 0.0001	–	X	0
Mourning Warbler	X	< 0.0001	X	X	0
Common Yellowthroat	0.1836	0.1802	X	X	4
Hooded Warbler	X	0.2158	X	X	2
Wilson's Warbler	X	0.0707	X	X	1
Canada Warbler	X	< 0.0001	X	X	0
Summer Tanager	X	< 0.0001	X	X	1
Scarlet Tanager	0.0965	0.0464	X	X	7
Rose-breasted Grosbeak	< 0.0001	0.1617	0.0241	0.0342	27
Indigo Bunting	X	< 0.0001	X	X	2
Baltimore Oriole	0.0148	0.0111	0.0407	0.0435	21

\*Not discriminated from Alder Flycatcher in the Sable Island counts.