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Short communication

Assessing conservation trade-offs: identifying the effects of flooding rice fields for waterbirds on non-target bird species

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Abstract

I examined how winter flooding of post-harvest rice fields—a management practice used to benefit waterbirds—affects field use by other birds. In addition to waterbirds previously studied, I recorded 56 bird species in rice fields. Of these, five were more abundant in flooded fields, ten were more abundant in unflooded fields, no difference was detected for 19, and the remainder were too rare to draw any conclusions. Species that were more common in unflooded fields were all carnivorous or granivorous in winter, whereas species that were more common in flooded fields were mostly insectivores commonly associated with aquatic habitats. The net effects of the responses by individual species were fewer raptor species in flooded fields, but no difference in the species richness of other landbirds. Winter flooding potentially has negative effects for some birds, but has no discernible effects on most species studied and may benefit some passerines.

Keywords: Raptor; Landbird; Passerine; Agriculture; California Central Valley

1. Introduction

Land management strategies typically are developed with a particular species or assemblage of species in mind. When assessing the effectiveness of these strategies, it is rare to consider the impacts on non-target species. That every management action adversely affects some taxa, however, is inevitable. Identifying trade-offs before extensive implementation of a new management policy can reduce the chance of undesirable consequences and provide a framework for managing multiple species at large spatial scales.

Rice fields are increasingly seen to provide important wildlife habitats in many parts of the world, including southern Europe (Fasola and Ruíz, 1996, 1997), Japan (Lane and Fujioka, 1998; Maeda, 2001), and North America (Elphick and Oring, 1998). Usually, attention has focused on the large numbers of waterbirds that use flooded fields and on ways that field management methods either benefit or harm these species. In California, for example, much attention has been paid to winter flooding of post-harvest stubble as a way to improve conditions for waterbirds (Day and Colwell, 1998; Elphick and Oring, 1998, 2003). In another case, Japanese ecologists have studied ways in which the design of the irrigation ditches that deliver water to fields affect wading birds and their prey (Fujioka and Lane, 1997; Lane and Fujioka, 1998).

The growing knowledge about the potential value of rice fields to wildlife has resulted in explicit recommendations to alter management practices to benefit waterbirds (e.g. Elphick and Oring, 1998). Little attention, however, has been paid to the effects of proposed and ongoing management changes on other species that use rice fields (Maeda, 2001). For most parts of the world, information on landbird use of rice fields is restricted to a few species that are perceived to be crop pests. Nonetheless, the few studies that have described the entire avifauna of rice fields in an area have shown that a wide variety of raptors, passerines and other landbirds occur in both flooded and dry paddies (e.g. Remsen et al., 1991; Maeda, 2001; Fujioka and

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Yoshida, 2001; see also Fujioka et al., 2001 for data from fallow rice fields).

Approximately 140,000 to 180,000 ha of rice is grown in California annually, mostly in the Sacramento River drainage in the northern half of the Central Valley (Hill et al., 1992). California legislation has mandated that rice growers reduce the extent to which they burn residual straw while clearing fields after harvest (Rice Straw Burning Act, AB 1378, 1991). Many farmers have responded by flooding fields in winter, which aids in straw disposal by increasing decomposition rates (Bird et al., 2000). Conservation groups have recognised the potential value of this practice in mitigating against the extensive wetland losses that have occurred in California since European settlement, and rice field flooding is now viewed as an important conservation strategy because of the region's importance for wintering waterbirds (Brouder and Hill, 1995). The Central Valley, however, is an important wintering area for many species and also supports a diverse array of raptors, passerines and other "landbirds", which feed in both flooded and unflooded fields. Here I examine the effects of flooding fields on these birds. Specifically, I tested whether the abundance and variety of non-target species differed between fields that had been intentionally flooded by farmers and fields that had not been flooded.

2. Methods

Data were collected throughout the Sacramento Valley during winter. In 1993/94, I sampled 37 fields (total area = 797.2 ha; mean area ± SE = 21.5 ± 4.1 ha) that had been intentionally flooded to promote straw decomposition and attract waterbirds and 16 fields (486.5 ha; 30.4 ± 7.1 ha) that had not been intentionally flooded. In 1994/95, 25 flooded fields (699.3 ha; 28.0 ± 5.4 ha) and 15 unflooded fields (398.3 ha; 26.6 ± 6.4 ha) were surveyed. Fields that held standing water for short periods after heavy rain or river flooding, rather than management, were considered unflooded. Fifteen flooded fields and five unflooded fields were sampled during both winters and were used to compare the two winters, which experienced very different weather conditions; 1994/95 was much wetter than 1993/94 (Elphick and Oring, 1998).

2.1. Data collection

The abundance of non-target species was assessed while conducting waterbird surveys of the sample fields during a larger study of the management of rice fields for waterbirds (Elphick and Oring, 1998, 2002). Waterbirds were defined as members of the orders Podicipediformes, Ciconiiformes, Anseriformes, Gruiformes, and Charadriiformes. All other bird species, except for those introduced to North America by humans, were included in the surveys reported here.

Surveys involved walking the perimeter of each field and scanning continuously. All raptors (defined as the Accipitridae, Falconidae, and Strigidae, plus the scavengers of the Cathartidae) seen in, or flying over, any part of a field during a census were recorded. For each survey, I recorded the maximum number of each raptor species seen at any one time, plus any other individuals that clearly differed, based on plumage or moult. In addition, I tallied the total number of sightings for each species. These two measures represent the minimum and maximum number of each species seen, respectively. In all analyses, minimum values were used to ensure that estimates were conservative. When analyses were repeated using the maximum counts I found no qualitative differences, and only minor quantitative differences to those reported.

Less detailed numerical information was collected for other species. To balance accuracy with efficiency, I simply assigned order-of-magnitude abundance scores to each species based on the number of birds recorded in a field: 0 = 0 birds, 1 = 1–10 birds, 2 = 11–100 birds, 3 = 101–1000 birds, and 4 = 1001–10,000 birds. In other words, I used a $\log_{10}$ scale and rounded up to the nearest integer. For these species, I included only birds seen in a field or along its margin; those only seen flying overhead were excluded. Fields were surveyed approximately every ten-days, except during the hunting season when spacing between visits occasionally varied due to hunting. Fields were visited in an arbitrary order that changed randomly among surveys.

2.2. Data analysis

All dependent variables were corrected to account for search effort before analysis. I used the distance walked during a survey as a measure of effort. Survey duration was inappropriate because it included time spent counting waterbirds, during which other species were rarely seen. Distances were calculated from 1:24,000 topographic maps. Raptor numbers were corrected for search effort by dividing the number of birds recorded by the distance walked. Since abundance categories followed a log scale this correction was not appropriate for other species. Instead, I divided abundance scores by log(distance), which is expected to increase as a linear function of log(abundance). Species richness also increases as a non-linear function of search effort if sampling is sufficient to begin to exhaust the potential species pool (Magurran, 1988). For my data, however, linear regressions of richness on distance provided a better fit than curvilinear models suggesting that sampling on a single survey was insufficient to approach the asymptotic species richness. Thus, I divided richness by distance to correct for search effort. Once the search effort was accounted for, I calculated the mean value of each variable across all census periods for every field. Using data for the 20 fields censused both winters, I tested for annual differences in each measure. If no difference was detected, I pooled data for the two winters. For fields that were sampled in both years, I randomly chose data for 1 year only for the pooled data set. When there were significant differences between winters, I analysed data for each year separately.

I used t-tests to compare raptor numbers in flooded and unflooded fields. When Levene's tests (Levene, 1960; Milliken and Johnson, 1992) revealed that the assumption of homoscedacity was violated, I used separate variance t-tests. To test for differences in the abundance of other species, I used nonparametric tests because logarithmic abundance categories lack high precision and functionally give only a ranked measure of bird numbers. Patterns of species richness were examined using analysis of variance to test for differences between flooded and unflooded fields. Since data were collected over a large region, I subdivided my study sites into three geographic groups (see Elphick and Oring, 1998, for a map) and verified that the habitat differences found could not be attributed to geographic variation in species abundance (C.S. Elphick, unpublished data). If heteroscedacity was detected, data were log transformed. If the transformation failed to resolve the problem, nonparametric tests were used instead.

I decided a priori that the nature of this study justified an increased risk of making Type I errors (i.e. concluding a treatment effect where none existed), in exchange for a reduced risk of making Type II errors (i.e. concluding no treatment effect where one existed), and set $\alpha = 0.10$. For tests with $P > 0.1$, I determined power using tables in Cohen (1988). For nonparametric tests, I adjusted sample sizes to their parametric equivalents to obtain conservative power estimates (Siegel and Castellan, 1988). I viewed power > 0.8 as evidence for no difference among treatments and determined power for small, medium and large effect sizes (after Cohen, 1988).

3. Results

During the surveys we detected 52 non-waterbird species, including 18 raptors. Of these species, 34 were seen often enough to warrant testing for habitat use differences. Four more species were seen in rice fields during the study, bringing the total number of native non-target species to 56. For most species no differences in abundance were detected between winters. Significant differences between years were found for three raptors: northern harrier (paired-$t_{19} = 3.55$, $P = 0.002$), Cooper's hawk (paired-$t_{19} = 2.26$, $P = 0.036$), and prairie falcon (paired-$t_{19} = 2.10$, $P = 0.049$). All were seen more often in 1994/95. Overall raptor density was greater in 1994/95 (paired-$t_{19} = 2.72$, $P = 0.014$), largely because northern harriers were the commonest raptor in the area. Six passerines also differed in abundance between winters. American crows (Wilcoxon $z = 2.10$, $P = 0.036$) and American pipits ($z = 2.69$, $P = 0.007$) were more common in 1993/94 while song sparrow ($z = 2.42$, $P = 0.016$), Lincoln's sparrow ($z = 2.09$, $P = 0.037$), house finch ($z = 1.86$, $P = 0.063$), and American goldfinch ($z = 2.20$, $P = 0.028$) were more abundant in 1994/95.

As a group, raptors occurred at significantly higher densities in unflooded fields than in flooded fields (Table 1). A similar difference was found in at least 1 year for four species. In contrast, Cooper's hawks were more common in flooded fields, although only in 1994/95. No differences were found for the other seven raptors. Power estimates for these tests indicated a high chance ($1-\beta$ ranged from 0.78 to 0.94) of detecting a large treatment effect ($d = 0.8$) if one existed, but only a moderate chance of detecting a medium effect ($d = 0.5$; $1-\beta$ ranged from 0.45 to 0.64). I found significant

Table 1
Comparison of the mean raptor abundance in flooded and unflooded rice fields using t-tests[a,b]

Species	Winter	Mean (±SE) birds/km		t (df)	P
		Flooded	Unflooded		
Turkey vulture (*Catharus aura*)	Both	0.122±0.024	0.332±0.108	1.89 (27.6)	0.070
White-tailed kite (*Elanus leucurus*)	Both	0.027±0.010	0.087±0.020	2.11 (32.3)	0.042
Northern harrier (*Circus cyaneus*)	93/94	0.355±0.056	0.990±0.174	3.48 (18.2)	0.003
Cooper's hawk (*Accipiter cooperii*)	94/95	0.063±0.017	0.010±0.007	2.82 (31.0)	0.008
Red-tailed hawk (*Buteo jamaicensis*)	Both	0.203±0.027	0.348±0.042	3.03 (71)	0.003
All raptors	93/94	0.762±0.096	1.629±0.222	3.58 (20.8)	0.002
	94/95	1.446±0.090	2.257±0.263	2.86 (17.2)	0.011

[a] Sample sizes for flooded and unflooded fields, respectively, were 37 and 16 (1993/94), 25 and 15 (1994/95), 47 and 26 (both years combined). Separate tests were conducted for species that occurred at significantly different densities in the two winters. Separate-variance t-tests were used whenever the assumption of equal variances was violated.

[b] Results are given only for significant tests; no significant differences were found for: bald eagle (*Haliaeetus leucocephalus*), sharp-shinned hawk (*Accipiter striatus*), rough-legged hawk (*Buteo lagopus*), American kestrel (*Falco sparverius*), peregrine falcon (*Falco peregrinus*), prairie falcon (*Falco mexicanus*) or short-eared owl (*Asio flammeus*).

differences in abundance between flooded and unflooded fields for 10 of the remaining species (Table 2). Four species were more abundant in flooded fields and six in unflooded fields. Power of these tests ranged from 0.76 to 0.93 for a large effect size ($d = 0.8$).

On average, more non-target species were seen in rice-fields during 1994/95 than 1993/94 (paired-$t_{19} = 3.49$, $P = 0.002$). Similar results were found for both raptors and non-raptors when tested separately (paired-$t_{19} = 2.09$, $P = 0.051$ and paired-$t_{19} = 3.20$, $P = 0.005$, respectively). Richness data for the 2 years, therefore, were analysed separately. When all species were considered, richness was higher in unflooded fields (mean ±SE: 4.70±0.60 in 1993/94; 5.31±0.54 in 1994/95) than flooded fields (3.35±0.27 in 1993/94; 4.47±0.36 in 1994/95). In 1993/94, this difference was highly significant ($F_{1,47} = 10.82$, $P = 0.002$), whereas in 1994/95 it was only marginally so ($F_{1,34} = 3.89$, $P = 0.057$). Separating species into raptors and non-raptors revealed that differences between habitats were caused largely by raptors. Raptor richness was greater in unflooded fields than flooded fields (1993/94: $F_{1,47} = 13.43$, $P = 0.001$; 1994/95: $F_{1,34} = 9.43$, $P = 0.004$), while richness of other non-target species did not differ significantly between habitats (1993/94: Mann–Whitney $U = 246$, $P = 0.333$; 1994/95: $F_{1,34} = 1.35$, $P = 0.253$).

4. Discussion

Previous studies have demonstrated that California rice fields are used by a numerous and diverse assemblage of waterbirds (Day and Colwell, 1998; Elphick and Oring, 1998). Clearly, however, waterbirds are only a subset of the entire avifauna that occupies rice field habitats. During the course of this study, I recorded 56 additional bird species, 60% of which were common enough to allow a detailed analysis of occurrence patterns.

Research on waterbirds has focused on testing the supposition that increasing the extent of winter flooding will have widespread benefits, and on quantifying the gains. Broadening the range of species under study raises the question of whether increased flooding will have harmful effects on a portion of the avifauna that uses fields. Of the 34 species considered in this study, five were significantly more common in flooded fields, 10 were more common in unflooded fields, and no difference was found for the remaining 19 species (Tables 1 and 2). The net effect was fewer raptors in flooded fields, but no difference in the species richness of other landbirds.

Species that were more common in flooded fields were primarily insectivorous passerines that are usually found near water. Of these, black phoebes, marsh wrens and song sparrows were almost always seen in the vegetation that fringed flooded fields, while American pipits were found in the open centres of fields when conditions were wet, but the water not so deep as to cover the surface. Species that were less common in flooded fields separate into two groups. The first includes four large meat-eating species: red-tailed hawk, northern harrier, white-tailed kite, and turkey vulture (Table 1). The second consists of a dove, a lark, a sparrow, a finch and two icterids (Table 2); all species that feed on seeds in open habitats during winter (Ehrlich et al., 1988).

The remaining group, for which no differences could be detected, included a mixture of species differing

Table 2
Comparison of the mean abundance of non-raptor species in flooded and unflooded rice fields using Mann–Whitney tests[a,b]

Species	Winter	Mean abundance rank[c]		Flooding effect	
		Flood	No flood	U	P
Mourning dove (*Zenaida macroura*)	Both	35.0	40.6	517.0	0.006
Black phoebe (*Sayornis nigricans*)	Both	42.8	26.6	881.5	0.001
Horned lark (*Eremophila alpestris*)	Both	34.0	42.3	469.0	0.024
Marsh wren (*Cistothorus palustris*)	Both	47.7	17.7	1112.5	<0.001
American pipit (*Anthus rubescens*)	93/94	32.2	14.9	489.0	<0.001
	94/95	23.0	16.3	250.5	0.078
Savannah sparrow (*Passerculus sandwichensis*)	Both	26.5	56.0	116.0	<0.001
Song sparrow (*Melospiza melodia*)	94/95	24.6	13.6	291.0	0.004
Red-winged blackbird (*Agelaius phoeniceus*)	Both	32.1	45.8	381.0	0.008
Western meadowlark (*Sturnella neglecta*)	Both	26.1	56.7	98.0	<0.001
House finch (*Carpodacus mexicanus*)	93/94	25.2	31.2	229.0	0.047

[a] Separate tests were conducted for species that differed significantly in abundance in the two winters. Sample sizes are given in Table 1.

[b] Results are given only for significant tests; no significant differences were found for: loggerhead shrike (*Lanius ludovicianus*), yellow-billed magpie (*Pica nuttalli*), American crow (*Corvus brachyrhynchos*), northern mockingbird (*Mimus polyglottos*), yellow-rumped warbler (*Dendroica coronata*), Lincoln's sparrow (*Melospiza lincolnii*), white-crowned sparrow (*Zonotrichia leucophrys*), golden-crowned sparrow (*Zonotrichia atricapilla*), dark-eyed junco (*Junco hyemalis*), Brewer's blackbird (*Euphagus cyanocephalus*), brown-headed cowbird (*Molothrus ater*), or American goldfinch (*Carduelis tristis*).

[c] Relative abundance is given as the mean rank for fields of each habitat type.

taxonomically and ecologically. In general, species for which no differences were found tended to be encountered less often than those for which differences were detected. This observation, combined with my use of rank-transformed data for many species, suggests that these non-significant results should be viewed with some caution in the absence of more extensive sampling conducted with greater precision. Results for rare and sparsely distributed species should be viewed with greatest care. For example, bald eagles and peregrine falcons occur regularly but at low densities in California rice fields. These species might benefit from flooding because they feed on waterbirds (Ehrlich et al., 1988), and flooding both increases waterbird numbers locally and has potential to increase waterbird population levels. Both raptors were sufficiently rare, however, that they were never seen in most fields in the study, making it difficult to draw inferences from the non-significant test results. Without dedicated studies focused on rare species it is hard to form conclusions about their responses to flooding.

Two-thirds of the species for which we found habitat use differences were more common in unflooded fields. This result contrasts with that for waterbirds, most (but not all) of which are more abundant in flooded fields (Elphick and Oring, 1998). Five of the passerine species in this group have experienced significant long-term declines throughout their North American ranges over recent decades (Sauer et al., 2001). Extensive flooding of rice fields, thus, may have more detrimental effects on the region's avifauna than previously recognised. Several points, however, temper this concern. First, water is generally expensive and in short supply in the Sacramento Valley (Lee et al., 1999) and it is unlikely that winter flooding will ever include all rice fields. Second, rice is only one of many crops grown in the region, and land on which other crops are grown is rarely flooded. Third, we currently know little about the extent to which Central Valley bird populations are limited by habitat availability, and it is thus unclear whether habitat loss will result in reduced bird numbers. Finally, most birds for which detrimental effects appear possible are abundant generalists, occurring in a wide variety of habitats over a large range (e.g. red-tailed hawk, mourning dove, red-winged blackbird, house finch). Only the white-tailed kite does not match this description. Another study of kite habitat use in the Sacramento Valley suggests that rice stubble is used more often than expected based on the relative abundance of different habitat types (Erichsen et al., 1996) adding to concerns about the effects of habitat change on kites.

Several conclusions emerge from this study. First it is clear that rice fields are not used only by waterbirds and that a complete picture of their value to bird conservation will only be obtained when the entire avifauna is considered. As similar results emerge from rice field studies around the world (e.g. Maeda, 2001), it is becoming apparent that there is potential for land farmed for rice to contribute even more to bird conservation than has been previously recognised. Given the large proportion of the Earth's surface that is devoted to agriculture (Urban and Vollrath, 1984), and the difficulty of achieving conservation goals in protected lands alone (Soulé and Sanjayan, 1998), the ability to provide habitat for a wide diversity of species on land used for intensive food production will become increasingly important. Whether the potential value to be gained from rice fields is met, however, will depend on field management, and the directions taken as the rice industry develops. A second important result is that flooding fields during winter will not benefit all birds. Several species are significantly less common in fields that remain unflooded during the winter. Mostly these are relatively common species of low conservation concern, but several of them are also experiencing range-wide declines. To fully evaluate the impact of increased field flooding it will be necessary to determine the extent to which other habitats can support these species. Moreover, it is clear that a mix of management approaches needs to be maintained in farming areas to ensure that the landscape can support extant species assemblages in their entirety (see also Fujioka and Yoshida, 2001).

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References

Bird, J.A., Pettygrove, G.S., Eadie, J.M., 2000. The impact of waterfowl foraging on the decomposition of rice straw: mutual benefits for rice growers and waterfowl. Journal of Applied Ecology 37, 728–741.

Brouder, S.M., Hill, J.E., 1995. Winter flooding of ricelands provides waterfowl habitat. California Agriculture 49, 58–64.

Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences, second ed. Lawrence Erlbaum Associates, Hillsdale, New Jersey.

Day, J.H., Colwell, M.A., 1998. Waterbird communities in rice fields subjected to different post-harvest treatments. Colonial Waterbirds 21, 185–197.

Ehrlich, P.R., Dobkin, D.S., Wheye, D., 1988. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. Simon and Schuster Inc, New York.

Elphick, C.S., Oring, L.W., 1998. Winter management of California rice fields for waterbirds. Journal of Applied Ecology 35, 95–108.

Elphick, C.S., Oring, L.W., 2003. Conservation implications of flooding rice fields on winter waterbird communities. Agriculture, Ecosystems, and Environment 94, 17–29.

Erichsen, A.L., Smallwood, S.K., Commandatore, A.M., Wilson, B.W., Fry, M.D., 1996. White-tailed Kite movement and nesting patterns in an agricultural landscape. In: Bird, D.M., Varland, D.E., Negro, J.J. (Eds.), Raptors in Human Landscapes: Adaptations to Built and Cultivated Environments. Academic Press, London, UK, pp. 165–176.

Fasola, M., Ruíz, X., 1996. The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean region. In: Crivelli, A.J., Hafner, H., Fasola, M., Erwin, R.M., McCrimmon, D.A. (Eds.). Ecology, Conservation and Management of Colonial Waterbirds in the Mediterranean Region. Colonial Waterbirds 19 (Special Publication 1), pp. 122–128.

Fasola, M., Ruíz, X., 1997. Rice farming and waterbirds: integrated management in an artificial landscape. In: Pain, D.J., Pienkowski, M.W. (Eds.), Farming and Birds in Europe: the Common Agricultural Policy and its Implications for Bird Conservation. Academic Press, San Diego, California, pp. 210–235.

Fujioka, M., Lane, S.J., 1997. The impact of changing irrigation practices in rice fields on frog populations of the Kanto Plain, central Japan. Ecological Research 12, 101–112.

Fujioka, M., Armacost Jr, J.W., Yoshida, H., Maeda, T., 2001. The value of fallow farmlands as summer habitat for waterbirds in a Japanese rural area. Ecological Research 16, 555–567.

Fujioka, M., Yoshida, H., 2001. The potential and problems of agricultural ecosystems for birds in Japan. Global Environmental Research 5, 151–161.

Hill, J.E., Robert, S.R., Brandon, D.M., Scardaci, S.C., Williams, J.F., Wick, C.M., Canevari, W.M., Weir, B.L., 1992. Rice Production in California. Cooperative Extension, University of California, Davis, Publication 21498.

Lane, S.J., Fujioka, M., 1998. The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in rice fields of central Japan. Biological Conservation 83, 221–230.

Lee, H., Sumner, D.A., 1999. Economic impacts of irrigation water cuts in the Sacramento Valley. UC Agricultural Issues Center, University of California, Davis, CA.

Levene, H., 1960. Robust tests for equality of variance. In: Olkin, I., Gharge, S.G., Hoeffding, W., Madow, W.G., Mann, H.B. (Eds.), Contributions to Probability and Statistics. Stanford University Press, Palo Alto, California, pp. 278–292.

Maeda, T., 2001. Patterns of bird abundance and habitat use in rice fields of the Kanto Plain, central Japan. Ecological Research 16, 569–585.

Magurran, A.E., 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, New Jersey.

Milliken, G.A., Johnson, D.E., 1992. Analysis of Messy Data. Volume I: Designed Experiments. Van Nostrand Reinhold, New York.

Remsen Jr., J.V., Swan, M.M., Cardiff, S.W., Rosenberg, K.V., 1991. The importance of the rice-growing region of south-central Louisiana to winter populations of raptors, waders, and other birds. Journal of Louisiana Ornithology 1, 35–47.

Sauer, J.R., Hines, J.E., Fallon, J., 2001. The North American Breeding Bird Survey, Results and Analysis 1966–2000. Version 2001.2, USGS Patuxent Wildlife Research Center, Laurel, MD (Accessed 5 September 2002).

Siegel, S., Castellan Jr., N.J., 1988. Nonparametric Statistics for the Behavioral Sciences, second ed. McGraw-Hill, Inc, New York.

Soulé, M.E., Sanjayan, M.A., 1998. Conservation targets: do they help? Science 279, 2060–2061.

Urban, F., Vollrath, T., 1984. Patterns and trends in world agricultural land use. Foreign Agricultural Economic Report, No. 198, International Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.