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SPECIAL PROFILE: BIRDS AND AGRICULTURE

Editors' Introduction: Birds and Agriculture

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Summary

1. Around 10% of recent papers in the *Journal of Applied Ecology* have examined interactions between birds and agriculture. This statistic reveals the important role now played by ecologists in assessing the effects of agricultural development worldwide. It also reflects the position of birds as both indicators and targets of agricultural change: their patterns of behaviour, distribution, seasonal phenology and demography track closely onto the spatial and temporal scales of agricultural intensification.

2. Papers in this Special Profile illustrate how research in this sphere has shifted towards assessing the processes by which birds are affected ecologically by agricultural change. The works examine spatial patterns in extinction; assess long-term trends in bird abundance and agricultural practice; reveal how foraging and breeding performance in farmland birds varies between habitats; and evaluate the role of large-scale modelling in examining hypotheses about the influences of land management on birds. The final paper shows that birds can have intrinsically positive value in agricultural systems.

3. All the papers propose management prescriptions for agricultural areas that blend the microscopic – for example, how to modify local land structure to benefit birds – and the macroscopic – for example, by suggested inputs into land-use policy. Perhaps most pertinent is the key conclusion that agricultural change is multivariate, so that straightforward univariate effects on birds are unlikely. Restoration of impacted populations might therefore require holistic strategies that encourage appropriately scaled agricultural extensification. Success would be most likely if farmers, conservationists and other key players were engaged collaboratively in the process.

4. Current ideas about restoring farmland bird populations share a common assumption: if agricultural practice has reduced populations hitherto, then agricultural practice can restore the losses. We suggest that this assumption carries a range of predictions that now require testing through sustainable farm management – a situation ideally suited to 'BACI' style experiments.

5. We reiterate the need to expand work on other groups of organisms affected negatively or positively by agricultural management to allow a broader perspective of impacts or benefits.

Key-words: biodiversity, farming, habitat management, land use.

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Introduction

Those of us following the applied ecological literature over the last few years cannot have failed to notice the large volume of work that has examined interactions between birds and agriculture. The *Journal of Applied Ecology* alone published 26 studies on this issue between 1998 and 2000, contributing 10% of our total output, and representing 10 countries on five continents (Table 1). Other journals have also carried large numbers of similar papers (e.g. Browne, Vickery & Chamberlain 2000; Chamberlain, Vickery & Gough 2000; Fewster *et al.* 2000;

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Table 1. Recent papers on birds and agriculture in the *Journal of Applied Ecology* in chronological order

Region	Birds involved	Type of study	Journal reference
Brazil	Frugivores	Compared communities between contrasting agro-forestry	Galetti & Aleixo (1998)
Britain	General farmland birds	Assessed population trends among ecologically similar species	Siriwardena *et al*. 1998;
California	Waterbirds	Analysed bird use of fields flooded to speed straw decomposition	Elphick & Oring (1998)
Britain	Skylark *Alauda arvensis*	Compared territory size and breeding between land uses	Poulsen, Sotherton & Aebischer (1998)
India	Rainforest bird community	Assessed community and population in shifting cultivation	Shankar Raman, Rawat & Johnsingh (1998)
Spain	Red-billed chough *Pyrrhocorax pyrrhocorax*	Assessed foraging habitat in different land uses, habitats and crops	Blanco, Tella & Torre (1998)
Britain	Redshank *Tringa tetanus*	Assessed changes in density with changes in grazing intensity	Norris *et al*. (1998)
Britain	Skylark *Alauda arvensis*	Compared bird and invertebrate density between land uses; experiments on grazing exclusion	Wakeham-Dawson & Aebischer (1998)
Britain	Farmland and other birds	Assessed large-scale habitat use	Gregory & Baillie (1998)
Greece	Short-toed eagle *Circaetus gallicus*	Analysed habitat use and prey distribution	Bakaloudis, Vlachos & Holloway (1998)
France	Wildfowl	Analysed bird numbers and agricultural change	Duncan *et al*. (1999)
N. Ireland	Curlew *Numenius arquata*	Assessed interaction between predator numbers and agriculture	Grant *et al*. (1999)
Spain	Diurnal raptors	Assessed nest-site selection and land use	Sanchez-Zapata & Calvo (1999)
Britain	Wood pigeon *Columba palumbus*	Assessed avoidance of pesticide-treated seed	McKay *et al*. (1999)
Britain	Reed bunting *Emberiza schoeniclus*	Assessed long-term demography and agriculture changes	Peach, Siriwardena & Gregory (1999)
Britain	Skylark *Alauda arvensis*	Analysed abundance and land use	Chamberlain *et al*. (1999)
Australia	Red-capped robin *Petroica goodenovii*	Analysed density and phenology in relation to landscape structure	Major *et al*. (1999)
Britain	Farmland birds	Analysed demographic processes involved in population change	Siriwardena *et al*. (2000)
Spain	Booted eagle *Hieraatus pennatus*	Assessed nest selection and land use	Suarez, Balbontin & Ferrer (2000)
Britain	Farmland birds	Compared abundance between land uses	Henderson *et al*. (2000)
Britain	Farmland birds	Compared trends among birds and food plants	Smart *et al*. (2000)
France	Grey partridge *Perdix perdix*	Analysed demographic processes in population change	Bro *et al*. (2000)
Denmark	Grey plover *Pluvialis apricaria*	Compared time budgets and habitat selection between land use	Whittingham, Percival & Brown (2000)
Britain	Thrushes *Turdus* spp.	Analysed pattern in breeding performance	Paradis *et al*. (2000)
Theoretical	Any	Modelled effects of dispersal and fragmentation effects	Baillie *et al*. (2000)

Soderstrom & Part 2000). The largest fraction has been from Europe, and the United Kingdom in particular, from where we have published 14 studies on birds and agriculture in the last 3 years. These statistics, in part, reveal the value placed by specialist ornithologists on publishing in prestige journals, like this one, that reach a wide ecological audience. But much more, they reveal the importance now afforded to the ecological effects of agricultural change not only in Europe – where the Common Agricultural Policy continues to be a major influence (Bignal 1998) – but throughout the populated world (Watson 1999). Perhaps more importantly, the whole thrust of these publications reveals the growing role of ecologists in assessing the effects of agricultural change worldwide, inputting in turn into land-use policy.

Estimates vary, but probably around one-third of the earth's exploitable surface is now dominated by agriculture. In Europe, this value is often much higher, and Denmark (64%), Britain (75%) and Ireland (81%), for example, have around two-thirds or more of their total surface in 'agricultural utilization' (see Ostermann 1998). Of course, large surface cover alone might not have prompted such intense research activity into the ecological consequences, nor raised concern among so many conservationists. Indeed, the quality of much of Europe's protected space – national parks and other areas set aside for landscape or nature conservation – is widely recognized as being the result of an agrarian heritage (Ostermann 1998). This is true also of many biologically rich environments outside protected areas (e.g. Webb 1998). One clear lesson is that, as skilled agents of land management, biologically rich agricultural systems in future will require good farmers as much as good conservationists.

Instead, unease among many conservationists has arisen from large changes in the management of agricultural land over the last few decades. Policy, incentives, technology and economics have acted in concert to cause rapid and major change. In Britain, for example, intensification has been reflected in the increased use of agro-chemicals, and widespread switching on lowland farms to crops such as oilseed rape, while spring-sown cereals, root crops, hay crops and periods with bare fallow have all declined (Chamberlain *et al.* 2000). Although the exact details differ, similar stories characterize other areas of Europe, with the economic and agricultural consequences spreading outwards in complex ways to affect agriculture on more marginal areas, such as the uplands (e.g. Zervas 1998). Beyond Europe, not only intensification but also increased conversion to semi-natural habitat, continue as necessary consequences of population growth and global patterns of trade (Watson 1999). With large fractions of some species' populations occupying agricultural land, and many characteristic assemblages of organisms represented, the risks to biodiversity are real.

The possible ecological effects of changing agricultural practice or land conversion are many. Some arise as a direct consequence of structural or composition changes to vegetation and the associated faunal communities (Hansson & Fogelfors 1998; Hald 1999; Sternberg *et al.* 2000). Others are mediated more subtly, for example through the changing phenology of crops. In addition, a wide array of indirect influences arise, for example through changing predator–prey dynamics or the chemical influences of agro-chemicals on species composition. There are also knock-on effects on other ecosystems, for example downstream (Painter 1999; Manel, Buckton & Ormerod 2000) or in adjacent bordering areas (Jansen & Robertson 2001). Moreover, the major restructuring of land surfaces that accompanies agriculture is one of the principal ways through which the remaining semi-natural habitats are fragmented, with consequences for species' populations and dispersal (Hargis, Bissonette & Turner 1999; Anciães & Marini 2000; Palomares 2001).

New challenges are only now on the horizon. While conventionally driven changes in crop varieties have probably impacted on farmland biodiversity (Beringer 2000), switches to genetically modified crops will carry many unknowns. Impacts on birds will be difficult to address through field-scale trials, so that modelling approaches are under development (Freckleton & Watkinson 1998; Lintell-Smith *et al.* 1999; Watkinson *et al.* 2000). They indicate that scale is a critical issue, but also show that we need to understand how different agricultural practices affect weed numbers, and consequently the availability of weed seeds for seed eating birds.

Why birds?

While many groups of organisms, and many ecological processes, have been affected by agricultural change, there is little doubt that birds have been among the major foci of research activity and conservation concern. Why, when so many other organisms will also have been strongly affected, should this be?

Ornithologists indicate, with much justification, that birds are popular and charismatic organisms, attracting much public interest. This is well illustrated by the large array not only of amateur ornithologists, but also of governmental, non-governmental and academic organizations, with special interest in birds. This convergence of interest is illustrated by the multi-authored papers in this Special Profile (see also Table 1). But far beyond popularity, a range of more explicitly scientific features emphasize the simultaneous position of birds as both major targets, and major indicators, of agricultural change; the UK government, for example, now accepts bird populations as indicators of the 'quality of life'. Their diversity provides valuable comparisons of processes affecting ecologically similar or contrasting species, illustrated here for example by the work on two closely related buntings (Bradbury *et al.* 2000; Brickle *et al.* 2000). Birds – by virtue of their conspicuous nature – are easily researched. More importantly with respect to the agricultural issue, their patterns of behaviour, distribution, seasonal phenology and demography track closely onto the spatial and temporal scales of agricultural change. Foraging, nest-site selection or breeding performance reflect features within the patchwork of agricultural habitats (Bradbury *et al.* 2000; Brickle *et al.* 2000). The pattern of events in the annual farming calendar interact with key events in their own lives such as breeding or migration (see Bird, Pettygrove & Eadie 2000; Chamberlain *et al.* 2000). Their populations or communities vary in ways that reflect local, regional or international variations in land use or management (Manel, Buckton & Ormerod 2000; Milsom *et al.* 2000). The effects of year-to-year drift in their demography means that their population trends match the march of agricultural change (Gates & Donald 2000). Perhaps most importantly of all, the availability of well-organized and geographically extensive data on bird populations over time has drawn our attention to the major environmental changes that have occurred on agricultural land. When coupled with equally valuable long-term monitoring of land use, these data have special importance in illustrating how ecological trends and agricultural practices are so closely linked (Chamberlain *et al.* 2000; Gates & Donald 2000). While other taxonomic groups share some of these characteristics, few others have been researched with such co-ordination and profit: ornithologists working on birds and agriculture reveal just how much can be achieved when individuals and institutions combine their research resources around key themes.

A Special Profile: birds and agriculture

This Special Profile of seven papers on the theme of 'birds and agriculture' further emphasizes the importance that the *Journal of Applied Ecology* accords to understanding the ecological effects of global changes in land use. Together, these papers provide a state-of-the-art perspective on this major issue from ornithologists and associated researchers.

Increasingly, ecologists and policy specialists involved with birds and agriculture have called for a shift from work identifying trends among birds towards greater understanding of the processes involved (McCracken & Bignal 1998; Siriwardena *et al.* 1998). We wholly concur with this need. However, the exact processes changing vertebrate populations are seldom easily resolved. On the one hand, the complex nature of real environments mean that there can be many competing explanations of population trend even where demographic pattern is clear (e.g. Paradis *et al.* 2000). On the other hand, even where the ultimate causes of change seem clear, a range of demographic responses are possible, and the results often debated over long periods (e.g. Sibly, Newton & Walker 2000). Under these circumstances, single definitive studies of how birds respond to agricultural intensification have been elusive, and instead there has been a steady evaluation of accumulating evidence.

To add to this accumulation, the search for cause–effect links between birds and agricultural change in Europe is now taking several forms (see also Table 1). For example, following previous classic assessments in this Journal of population trend or survival (Siriwardena *et al.* 1998; Peach, Siriwardena & Gregory 1999), one of the studies here addresses the long-term risks of local extinction among farmland species: Gates & Donald (2000) show how losses have been more likely in less suitable habitats, and least likely in traditional lowland arable locations. Moreover, extinction risk for any one species was less when other farmland species were present, probably because overall habitat suitability for all of them was greater. In a conceptually similar paper, Chamberlain *et al.* (2000) seek evidence of cause–effect links between farmland bird abundance and agriculture by illustrating how both have changed through time. Bird numbers tracked the effects of changing agricultural practice, with occasional lagged responses. In what is likely to become yet another classic study in its genre, Chamberlain *et al.* (2000) show how agricultural trends have been truly multivariate: we can have no guarantee that birds have responded univariately to individual agricultural factors. This observation is of great management relevance (see below). Finally, among the papers considering processes, Bradbury *et al.* (2000) and Brickle *et al.* (2000) compare the breeding performance and foraging of buntings on contrasting farmland habitats in ways that allow them to test hypotheses about what happens when such habitats are lost. The results of these dominantly autecological studies clearly follow expectations.

We should remember, of course, that not all the effects of agricultural practice on birds are negative, and some practices attract large numbers of birds to special feeding opportunities. Such is the case in the Californian waterfowl example provided here by Bird, Pettygrove & Eadie (2000). More novel is their illustration that birds in large numbers can have positive benefits to agriculture – in this case by aiding the decomposition of straw in rice fields. With great perspicacity, Bird, Pettygrove & Eadie (2000) take us to the view that bird communities and agriculture can coexist in a win–win situation. There are likely to be other examples where birds, by virtue of their predatory activity or physical bioturbation, provide similar ecosystem services while benefiting from farmland habitats.

All of the studies in this Special Profile involve issues at large spatial scales – in keeping with the large proportion of papers published on this topic by this Journal (Ormerod, Pienkowski & Watkinson 1999; Ormerod & Watkinson 2000). But it is that very issue – of scale – that has prompted some researchers on birds to address the broader conceptual dimension involved. In this Special Profile, Manel, Buckton & Ormerod (2000) question the extent to which surveys, so often the mainstay of large-scale ornithological research, can satisfy the needs of hypothesis testing about large-scale factors such as the conversion of semi-natural habitats to agricultural land. Along with many contributors to this Journal, the study by Manel, Buckton & Ormerod (2000) continues to emphasize the value of distribution models for birds, at least when supported by validation and processes studies. Milsom *et al.* (2000) also use this approach here to positive applied effect by illustrating how the management of grazing marshes affects the distribution of lowland waders. Along with farmland passerines, this group has also shown dramatic population declines in parts of Europe, so that this contribution is timely.

Management relevance, new questions and testable predictions

In addition to its history of publishing papers on birds and agriculture, the *Journal of Applied Ecology* has a history of illustrating how ecological science informs environmental management and policy. This is particularly true with respect to agriculture (e.g. Bignal 1998; Ovenden, Swash & Smallshire 1998). These Special Profile papers each raise major management issues that are both microscopic – for example how to modify local land structure – and macroscopic – for example in relation to land-use policy. At the micro-scale, the recommendations are about how to attract or benefit bird populations by modifying local farm- or plot-scale features, such as grazing, flooding or field margin management (Bradbury *et al.* 2000; Brickle *et al.* 2000; Milsom *et al.* 2000). At the macro-scale, several workers point to issues ranging from subsidy and fiscal support for sensitive management (Bradbury *et al.* 2000), set-aside and cropping patterns (Brickle *et al.* 2000), to the identification of areas appropriate for conservation incentives or designation (Gates & Donald 2000). In Europe, science input into policy of this type is particularly timely now, with the next review of the CAP due in roughly 5 years. Perhaps most pertinent of all is the key conclusion from Chamberlain *et al.* (2000): if single agricultural factors cannot be held responsible for effects on bird populations, then conservationists might profitably consider holistic strategies that encourage whole-farm, or broad-scale, agricultural extensification. Agri-environment schemes often move part way towards this end, but whether this is sufficient to restore whole bird communities requires fuller appraisal (Ovenden, Swash & Smallshire 1998). Moreover, because funding available for agri-environmental schemes in some European countries is still considerably less than the CAP permits, the number of farms able to participate is currently small.

Intriguingly, all these notions of positive agricultural management for birds are rooted in a common assumption: if farming and agricultural practice has been responsible for reduction in bird populations hitherto, then farming and agricultural practice should be able to restore the losses. Within this assumption, however, are several key questions: Can there be reversal in land use and land management? Will habitats and food resources revert dynamically to former conditions? Will bird populations then change in expected ways? Will population and community pattern among birds indicate population and community pattern among other groups of organisms (e.g. Joyce, Holland & Doncaster 2000)? Although supported by evidence from studies on set-aside (Henderson *et al.* 2000), investigations of organic farming (Wilson *et al.* 1997) and from scarce species such as cirl bunting *Emberiza cirlus* L. (Ovenden, Swash & Smallshire 1998; Wotton *et al.* 2000), these questions still require further examination. This is particularly true at large spatial scales, and with respect to previously abundant and widespread farmland species for which assessments of viable population sizes are still few. We suggest that, with so much evidence now accumulated on how intensification affects many birds negatively, demonstrations of the positive value of extensification and restorative techniques is one of the key needs. Not only is this a situation ideally suited to 'BACI' style (= before-after-control-intervention) experiments, but also it benefits from what is now an enviably well-described set of baseline ornithological conditions. Inputs from researchers on other taxa into any such experimental approaches would ensure that costs or benefits for a wider array of taxa than birds were appraised. Increasingly wide-scale agro-environmental policy, if sufficiently bold to encompass and encourage real environmental benefit, make investigations of this type a real possibility.

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References

Anciães, M. & Marini, M.A. (2000) The effects of fragmentation on fluctuating asymmetry in passerine birds of Brazilian tropical forests. *Journal of Applied Ecology*, **37**, in press.

Baillie, S.R., Sutherland, W.J., Freeman, S.N., Gregory, R.D. & Paradis, E. (2000) Consequences of large-scale processes for the conservation of bird populations. *Journal of Applied Ecology*, **37** (Suppl. 1), 88–102.

Bakaloudis, D.E., Vlachos, C.G. & Holloway, G.J. (1998) Habitat use by short-toed eagles *Circaetus gallicus* and their reptilian prey during the breeding season in Dadia Forest (north-eastern Greece). *Journal of Applied Ecology*, **35**, 821–828.

Beringer, J.E. (2000) Releasing genetically modified organisms: will any harm outweigh any advantage? *Journal of Applied Ecology*, **37**, 207–214.

Bignal, E.M. (1998) Using an ecological understanding of farmland to reconcile nature conservation requirements, EU agriculture policy and world trade agreements. *Journal of Applied Ecology*, **35**, 949–954.

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.

Blanco, G., Tella, J.L. & Torre, I. (1998) Traditional farming and key foraging habitats for chough *Pyrrhocorax pyrrhocorax* conservation in a Spanish pseudosteppe. *Journal of Applied Ecology*, **35**, 232–239.

Borg, C. & Toft, S. (2000) Importance of insect prey quality for grey partridge chicks *Perdix perdix*: a self-selection experiment. *Journal of Applied Ecology*, **37**, 557–563.

Bradbury, R.B., Kyrkos, A., Morris, A.J., Clark, S.C., Perkins, A.J. & Wilson, J.D. (2000) Habitat associations and breeding success of yellowhammers on lowland farmland. *Journal of Applied Ecology*, **37**, 789–805.

Brickle, N.W., Harper, D.G.C., Aebischer, A.J. & Cockayne, S.H. (2000) Effects of agricultural intensification on breeding success of corn buntings *Miliaria calandra*. *Journal of Applied Ecology*, **37**, 742–755.

Bro, E., Sarrazin, F., Clobert, J. & Reitz, F. (2000) Demography and the decline of the grey partridge in France. *Journal of Applied Ecology*, **37**, 432–448.

Browne, S., Vickery, J. & Chamberlain, D. (2000) Densities and population estimates of breeding skylarks *Alauda arvensis* in Britain in 1997. *Bird Study*, **47**, 52–65.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. & Shrubb, M. (2000) Patterns of change in the abundance of farmland birds in relation to the timing of recent intensification of agriculture in England and Wales. *Journal of Applied Ecology*, **37**, 771–788.

Chamberlain, D.E., Vickery, J.A. & Gough, S. (2000) Spatial and temporal distribution of breeding skylarks *Alauda arvensis* in relation to crop type in periods of population increase and decrease. *Ardea*, **88**, 61–73.

Chamberlain, D.E., Wilson, A.M., Browne, S.J. & Vickery, J.A. (1999) Effects of habitat type and management on the abundance of skylarks in the breeding season. *Journal of Applied Ecology*, **36**, 856–870.

Duncan, P., Hewison, A.J.M., Houte, S., Rosoux, R., Tournebize, T., Dubs, F., Burel, F. & Bretagnolle, V. (1999) Long-term changes in agricultural practices and wildfowling in an internationally important wetland, and their effects on the guild of wintering ducks in winter. *Journal of Applied Ecology*, **36**, 11–23.

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

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R. & Wilson, J.D. (2000) Analysis of population trends for farmland birds using generalized additive models. *Ecology*, **81**, 1970–1984.

Freckleton, R.P. & Watkinson, A.R. (1998) Predicting the determinants of weed abundance: a model for the population dynamics of *Chenopodium album* in sugar beet. *Journal of Applied Ecology*, **35**, 904–920.

Galetti, M. & Aleixo, A. (1998) Effects of palm heart harvesting on frugivores in the Atlantic rain forest of Brazil. *Journal of Applied Ecology*, **35**, 286–293.

Gates, S. & Donald, P.F. (2000) Local extinction of British farmland birds and the prediction of further loss. *Journal of Applied Ecology*, **37**, 806–820.

Grant, M.C., Orsman, C., Easton, J., Lodge, C., Smith, M., Thompson, G., Rodwell, S. & Moore, N. (1999) Breeding success and causes of breeding failure of curlew *Numenius arquata* in Northern Ireland. *Journal of Applied Ecology*, **36**, 59–74.

Gregory, R.D. & Baillie, S.R. (1998) Large-scale habitat use of declining British birds: implications for conservation. *Journal of Applied Ecology*, **35**, 785–799.

Hald, A.B. (1999) The impact of changing the season in which cereals are sown on the diversity of wild flora in rotational fields in Denmark. *Journal of Applied Ecology*, **36**, 24–32.

Hansson, M. & Fogelfors, H. (1998) Management of permanent set-aside on arable land in Sweden. *Journal of Applied Ecology*, **35**, 758–771.

Hargis, C.D., Bissonette. J.A. & Turner, D.L. (1999) The influence of forest fragmentation and landscape pattern on American martens. *Journal of Applied Ecology*, **36**, 157–172.

Henderson, I.G., Cooper, J., Fuller, R.J. & Vickery, J.A. (2000) The relative abundance of birds on set-aside and neighbouring fields in summer. *Journal of Applied Ecology*, **37**, 335–347.

Jansen, A. & Robertson, A.I. (2001) Relationship between livestock management and the ecological condition of riparian habitats along an Australian floodplain river. *Journal of Applied Ecology*, **38**, in press.

Joyce, K.A., Holland, J.M. & Doncaster, C.P. (2000) Influences of hedgerow intersections and gaps on the movement of carabid beetles. *Bulletin of Entomological Research*, **89**, 523–531.

Lintell-Smith, G., Freckleton, R.P., Firbank, L.G. & Watkinson, A.R. (1999) The population dynamics of *Anisantha sterilis* in winter wheat: spatial and temporal variability, and the role of management. *Journal of Applied Ecology*, **36**, 455–471.

Major, R.E., Christie, F.J., Gowing, G. & Ivison, J. (1999) Age structure and density of red-capped robin populations vary with habitat size and shape. *Journal of Applied Ecology*, **36**, 901–908.

Manel, S., Buckton, S.T. & Ormerod, S.J. (2000) Testing large-scale hypotheses using surveys: the effects of land use on the habitats, invertebrates and birds of Himalayan rivers. *Journal of Applied Ecology*, **37**, 756–770.

McCracken, D.I. & Bignal, E.M. (1998) Applying the results of ecological studies to land-use policies and practices. *Journal of Applied Ecology*, **35**, 961–967.

McKay, H.V., Prosser, P.J., Hart, A.D.M., Langton, S.D., Jones, A., McCoy, C., Chandler-Morris, S.A. & Pascual, J.A. (1999) Do woodpigeons avoid pesticide-treated cereal seed? *Journal of Applied Ecology*, **36**, 283–296.

Milsom, T.P., Langton, S.D., Parkin, W.D., Peel, S., Bishop, J.D., Hart, J.D. & Moore, N. (2000) Habitat models of bird species' distribution: an aid to the management of coastal grazing marshes. *Journal of Applied Ecology*, **37**, 706–728.

Norris, K., Brindley, E., Cook, T., Babbs, S., Brown, C.F. & Yaxley, R. (1998) Is the density of redshank *Tringa totanus* nesting on saltmarshes in Great Britain declining due to changes in grazing management? *Journal of Applied Ecology*, **35**, 621–634.

Ormerod, S.J., Pienkowski, M.W. & Watkinson, A.R. (1999) Communicating the value of ecology. *Journal of Applied Ecology*, **36**, 847–855.

Ormerod, S.J. & Watkinson, A.R. (2000) Large-scale ecology and hydrology: an introductory perspective from the editors of the *Journal of Applied Ecology*. *Journal of Applied Ecology*, **37** (Suppl. 1), 1–5.

Ostermann, O. (1998) The need for management of nature conservation sites designated under Natura 2000. *Journal of Applied Ecology*, **35**, 968–973.

Ovenden, G.N., Swash, A.R.H. & Smallshire, D. (1998) Agri-environment schemes and their contribution to the conservation of biodiversity in England. *Journal of Applied Ecology*, **35**, 955–960.

Painter, D.J. (1999) Macroinvertebrate distributions and the conservation value of aquatic Coleoptera, Mollusca and Odonata in the ditches of traditionally managed and grazing fen at Wicken Fen, UK. *Journal of Applied Ecology*, **36**, 33–48.

Palomares, F. (2001) Vegetation structure and prey abundance requirements in the Iberian lynx: implications for the design of reserves and corridors. *Journal of Applied Ecology*, **37**, in press.

Paradis, E., Baillie, S.R., Sutherland, W.J., Dudley, C., Crick, H.Q.P. & Gregory, R.D. (2000) Large-scale spatial variation in the breeding performance of song thrushes *Turdus philomelos* and blackbirds *T. merula* in Britain. *Journal of Applied Ecology*, **37** (Suppl. 1), 73–87.

Peach, W., Siriwardena, G.R. & Gregory, R.D. (1999) Long-term changes in overwinter survival rates explain the decline of reed buntings *Emberiza schoeniclus* in Britain. *Journal of Applied Ecology*, **36**, 798–811.

Poulsen, J.G., Sotherton, N.W. & Aebischer, N.J. (1998) Comparative nesting and feeding ecology of skylarks *Alauda arvensis* on arable farmland in southern England with special reference to set-aside. *Journal of Applied Ecology*, **35**, 131–147.

Sanchez-Zapata, J.A. & Calvo, J.F. (1999) Raptor distribution in relation to landscape composition in semi-arid Mediterranean landscapes. *Journal of Applied Ecology*, **36**, 254–262.

Shankar Raman, T.R., Rawat, G.S. & Johnsingh, A.J.T. (1998) Recovery of tropical rainforest avifauna in relation to vegetation succession following shifting cultivation in Mizoram, north-east India. *Journal of Applied Ecology*, **35**, 214–231.

Sibly, R.M., Newton, I. & Walker, C.H. (2000) Effects of dieldrin on population growth rates of sparrowhawks 1963–86. *Journal of Applied Ecology*, **37**, 540–546.

Siriwardena, G.M., Baillie, S.R., Buckland, S.T., Fewster, R.M., Marchant, J.H. & Wilson, J.D. (1998) Trends in the abundance of farmland birds: a quantitative comparison of smoothed Common Birds Census indices. *Journal of Applied Ecology*, **35**, 24–43.

Siriwardena, G.M., Baillie, S.R., Crick, H.Q.P. & Wilson, J.D. (2000) The importance of variation in the breeding performance of seed-eating birds in determining their population trends on farmland. *Journal of Applied Ecology*, **37**, 128–148.

Smart, S.M., Firbank, L.G., Bunce, R.G.H. & Watkins, J.W. (2000) Quantifying changes in abundance of food plants for butterfly larvae and farmland birds. *Journal of Applied Ecology*, **37**, 398–414.

Soderstrom, B. & Part, T. (2000) Influence of landscape scale on farmland birds breeding in semi-natural pastures. *Conservation Biology*, **14**, 522–533.

Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E.D. & Kigel, J. (2000) Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. *Journal of Applied Ecology*, **37**, 224–237.

Suarez, S., Balbontin, J. & Ferrer, M. (2000) Nesting habitat selection by booted eagles *Hieraaetus pennatus* in southern Spain and implications for management. *Journal of Applied Ecology*, **37**, 215–223.

Wakeham-Dawson, A. & Aebischer, N.J. (1998) Breeding skylarks *Alauda arvensis* on Environmentally Sensitive Area arable reversion grass in southern England: survey-based and experimental determination of density. *Journal of Applied Ecology*, **35**, 635–648.

Watkinson, A.R., Freckleton, R.P., Robinson, R.A. & Sutherland, W.J. (2000) Predictions of biodiversity response to genetically modified herbicide-tolerant crops. *Science*, **289**, 1554–1557.

Watson, R. (1999) Common themes for ecologists in global issues. *Journal of Applied Ecology*, **36**, 1–10.

Webb, N.R. (1998) The traditional management of European heathlands. *Journal of Applied Ecology*, **35**, 987–990.

Whittingham, M.J., Percival, S.M. & Brown, A.F. (2000) Time budgets and foraging of breeding golden plover *Pluvialis apricaria*. *Journal of Applied Ecology*, **37**, 632–646.

Wilson, J.D., Evans, J., Browne, S.J. & King, J.R. (1997) Territory distribution and breeding success of skylarks *Alauda arvensis* on organic and conventional farmland. *Journal of Applied Ecology*, **34**, 1462–1478.

Wotton, S.R., Langston, R.H.W., Gibbons, D.W. & Pierce, A.J. (2000) The status of the cirl bunting *Emberiza cirlus* in the UK and the Channel Islands in 1998. *Bird Study*, **47**, 138–146.

Zervas, G. (1998) Quantifying and optimizing grazing regimes in Greek mountain systems. *Journal of Applied Ecology*, **35**, 983–986.