Galliformes science and species extinctions: what we know and what we need to know

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McGowan, P. J. K., Owens, L. L. & Grainger, M. J., 2012. Galliformes science and species extinctions: what we know and what we need to know. *Animal Biodiversity and Conservation*, 35.2: 321–331.

Abstract

Galliformes science and species extinctions: what we know and what we need to know.— In early 2010, the 193 Parties that had signed up to the Convention on Biological Diversity all acknowledged that they had failed to meet the target that they had set themselves in 1992 of significantly reducing species extinctions by 2010. At the end of the year they set a new and more ambitious target of preventing species extinctions by 2020. Achieving that target will require much greater efficiency in the use of resources and research has a very significant role to play in making this happen. There are 290 species of Galliformes of which 26% are considered at risk of extinction, compared with 12% of all 10,000 bird species. At the same time there is significant research literature on the group that stretches back decades for some species. It is timely, therefore, to consider whether it is possible to increase the efficiency and global impact of gamebird research so that, with careful planning that involves more strategic direction and sharing of lessons learnt, game biologists can play a significant role in achieving the 2020 target for species adopted by the Convention on Biological Diversity. Specific areas in need of this lesson sharing approach are population estimation and threat assessment, analysis of exploitation and determining the ecological basis of successful interventions.

Key words: Galliformes, Conservation, Policy, Convention on Biological Diversity, Extinction risk.

Resumen

Extinciones de especies de Galliformes y conocimientos científicos: lo que sabemos y lo que necesitamos saber.— A principios de 2010, las 193 partes que habían firmado el Convenio sobre la Diversidad Biológica reconocieron que no habían cumplido el objetivo que ellas mismas habían fijado en 1992 de reducir de forma significativa las extinciones de especies en 2010. Al final del año establecieron un objetivo nuevo y más ambicioso que consistía en evitar las extinciones de especies en 2020. Lograr dicho objetivo requerirá una utilización mucho más eficiente de los recursos y la investigación tiene un papel fundamental en hacer que esto ocurra. Existen 290 especies de Galliformes, de las cuales el 26% se considera en peligro de extinción, en comparación con el 12% del total de las 10.000 especies de aves. Al mismo tiempo, hay numerosos estudios publicados sobre el grupo que abarcan décadas para algunas especies. Por consiguiente, es oportuno analizar si es posible aumentar la eficiencia y las repercusiones a escala mundial de la investigación sobre aves de caza, de forma que, con la planificación meticulosa que conlleva más orientación estratégica e intercambio de experiencias, los biólogos especializados en este tipo de aves puedan desempeñar una función destacada en la consecución del objetivo de 2020 para las especies aprobado por el Convenio sobre la Diversidad Biológica. Los ámbitos específicos que necesitan este planteamiento de intercambio de experiencias son la estimación de la población y la evaluación de las amenazas, el análisis de la explotación y la determinación de la base ecológica de las intervenciones que hayan obtenido buenos resultados.

Palabras clave: Galliformes, Conservación, Políticas, Convenio sobre la Diversidad Biológica, Riesgo de extinción.

Received 19 III 12; Conditional acceptance: 25 V 12; Final acceptance: 8 VI 12

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ISSN: 1578–665X

Introduction

The deteriorating conservation status of the world's species is well documented (Barnosky et al., 2011). Conservation science is responding to this decline by offering increasing knowledge about species distributions and life history and the pressures on them, the actions that can address these pressures, and how conservation can then be implemented. The global policy context is arguably more sympathetic to species conservation than it has ever been. At the same time, however, public funds that are targeted explicitly for species conservation are being cut on a significant scale. Taken together this means that if those concerned with conservation are to find ways of capitalising on new opportunities to prevent species extinctions, it is imperative to significantly increase the efficiency with which resources are deployed for research, management and monitoring.

A fundamental requirement for greater efficiency is increased communication both about developments that improve the translation of money into sound science and also how to turn scientific findings into meaningful action (management or policy). The urgent need to enhance the communication between conservation scientists and those who can implement management has been acknowledged (Memmott et al., 2010; Milner–Gulland et al., 2010). The geographical imbalance in opportunities for developing conservation science seems to have drawn less attention (but see McGowan, 2010a). There is much to gain by enhancing the communication between research cultures where there is a decades–long tradition of ecological study with those parts of the world that have much younger research traditions, but where numbers of species (especially those at risk of global extinction), is generally far higher.

Nowhere are these opportunities for increasing communication more apparent than amongst those who study and manage Galliformes, widely known as the gamebirds. This avian Order contains some of the most intensively and extensively studied species in the world (such as grey partridge *Perdix perdix*, willow ptarmigan [= red grouse] *Lagopus lagopus*, bobwhite quail *Colinus virginianus*) as well as a very high proportion of threatened species (see below). This knowledge provides two exceptional opportunities to use lessons learnt from a relatively small number of very well studied and intensively managed species for much wider conservation benefit. The first of these is to use knowledge of conservation science of the better–studied species to enhance the survival prospects of the more poorly known species and, second, to accelerate the translation of science into management, especially for species where intervention is most needed to prevent population or species extinctions.

Put simply, there is a significant body of information that is not being used for the widest possible benefit. The consequence of this is that extinctions (local or global) are more likely to result because appropriate knowledge is not being applied to address pressing challenges. Here we suggest how the gamebird science community can make a significant contribution to preventing species extinctions and improving the status of threatened species through better communication leading to wider application of appropriate approaches and techniques. We will do this by outlining the current global policy context, and by reviewing the threat status of Galliformes and the actions necessary to reduce their risk of extinction. Finally, we suggest ways in which scientific efficiency may be enhanced by indentifying key issues in understanding the status of the most threatened species and determining the context–specific action necessary.

Global policy context

Convention on Biological Diversity 2020 targets

In 2002, the 193 Parties to the Convention on Biological Diversity (CBD) agreed to reduce the rate of biodiversity loss significantly by 2010 (CBD, 2002). The wider importance of biodiversity to human well–being was recognised by the adoption of this target contributing towards Millennium Development Goal 7: Environmental sustainability (UN, 2005).

In early 2010, there were a variety of analyses that showed this target, vague as it was, had not been met. Most important was the CBD's own assessment *Global Biodiversity Outlook 3* (Secretariat of the Convention on Biological Diversity, 2010). Later that year, the Parties to the Convention adopted 20 new targets for biodiversity conservation that were much more specific and highly ambitious. The target for species was agreed as: "By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained". (CBD, 2010)

At the same time, the importance of Galliformes as wild relatives of significant food species received attention at the 6th Session of the Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture (see McGowan, 2010b). The United Nations' Food and Agriculture Organisation is charged with implementing the *Global Action Plan for the Conservation of Animal Genetic Resources* and although this emphasizes the need for action to conserve rare breeds and domesticated varieties, the importance of wild relatives is touched upon (FAO, 2007). There are clear linkages between the implementation of this plan and CBD (2010), in which target 13 states: 'By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio–economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity'.

Three factors (wild relatives of species important to humans, long history of research and management in some species, and overall threat status), therefore, place Galliformes in a unique position to advance not only their own conservation, but as a model for increasing the efficient application of scientific and management developments to species most at risk.

Fig. 1. Global distribution of the 290 Galliformes species.

Fig. 1. Distribución mundial de las 290 especies de Galliformes.

Galliformes and their habitats

It is obvious that a range of research, management and monitoring approaches and techniques will be needed in different circumstances. For example, assessing the status of difficult to detect species inhabiting lowland rainforest in Indonesia provides very different challenges compared with Himalayan forest species that are often seen and heard regularly. Therefore, when understanding how best to exploit the opportunities for learning from the better studied and more intensively managed species it is necessary to understand the diversity of habitats and ecological requirements of the more threatened species.

For conservation purposes the most convenient list of species is that on the IUCN Red List and this describes 290 species of Galliformes (IUCN, 2011). The Order is made up of the following families: Phasianidae (181 species), Odontophoridae (31), Cracidae (51), Numididae (6) and Megapodidae (21) (BirdLife International, 2012a). They have a worldwide distribution (fig. 1) with concentrations of species in eastern and southern Asia and in South America.

As the species occur in all major habitat types and from sea level to high mountains and from the equator to high latitudes (McGowan, 1994), the range of ecological contexts in which they occur is considerable. This has direct implications for the sort of survey, research and management approaches that can be applied, depending upon how readily species are detected, how easy it is to work in each habitat and terrain, and the nature of interactions with human communities.

Threat status

The global index of species threat status is the IUCN Red List (www.iucnredlist.org) which documents the extinction risk of all assessed species (see Mace et al., 2008; Vié et al., 2009). In 2011,

Table 1. Number of Galliformes in each Red List category in 2011: N (toward extinction, from bottom to top); P (cumulative percentage, from top to bottom).

Tabla 1. Número de Galliformes en cada categoría de la Lista Roja en 2011: N (hacia la extinción, de abajo a arriba); P (porcentage acumulado, de arriba a abajo).

N	Category	P
2	Extinct since 1600	0.7%
1	Extinct in the wild	1.0%
5	Critically endangered	2.8%
24	Endangered	11%
44	Vulnerable	26%
37	Near–threatened	39%
177	Least concern	100%

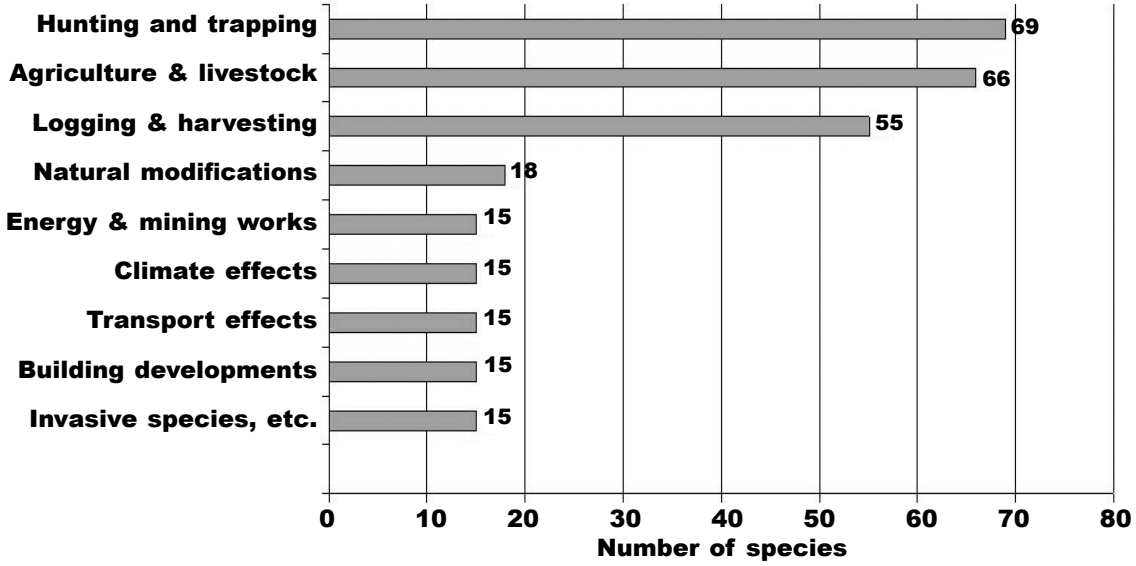

Fig. 2. The threats facing Galliformes listed as threatened on the IUCN Red List.

Fig. 2. Las amenazas a las que se enfrentan las Galliformes catalogadas como amenazadas en la Lista Roja de la UICN.

the 9,920 species of bird recognised by BirdLife International had been evaluated against the IUCN Red List criteria and 1,253 (12.5%) were considered threatened with extinction (BirdLife, 2012b). In contrast, 76 (26%) of the 290 species of Galliformes were included on the Red List. Table 1 shows that species do move towards extinction and that at present there is one species that only survives in captivity. The last wild record of the Alagoas curassow *Mitu mitu*, which inhabits the Atlantic Forest of Brazil, was in the late 1980s and it is now considered 'Extinct in the Wild'. A further example of a species that is moving closer to extinction is the uplisting of Edwards's pheasant *Lophura edwardsi* from Central Vietnam from Endangered to Critically Endangered that will take place on the forthcoming 2012 IUCN Red List (BirdLife International, 2012c).

Given the intense pressures and scarcity of resources it is critical to use the time, funds, expertise and people that are available to best possible effect. To achieve this, action therefore, falls within two extremes: broad–based policy interventions intended to address widespread issues and species–specific programmes designed to counter the particular pressures and constraints that are threatening individual species.

Two points are clear: 1) some issues are best addressed at a policy level, and 2) the resources needed to develop and implement detailed conservation strategies for all 76 threatened Galliformes are beyond reasonable expectations.

Taking action

Policy

Assessment of the pressures listed for the threatened species shows that over–exploitation and habitat change are the overwhelming issues (fig. 2; derived from IUCN, 2011). It is clear that there is a need to promote policy to reduce overexploitation and the worst effects of habitat change at various political and administrative levels. As this involves the advocacy of Galliformes science rather than increasing its efficiency and quality, it is not considered further here.

Species priorities

Critically Endangered species

In 2003, the World Pheasant Association reviewed the species that were then listed as Critically Endangered and concluded that there was little concerted action underway for three of them: Djibouti francolin *Francolinus ochropectus*, gorgeted wood quail *Odontophorus strophium,* and Trinidad piping–guan *Pipile pipile*. This led to a population survey of a key site for the wood quail in 2003 (Turner & Donegan, 2006) and the resulting population estimates, together with information from other sites, led to the gorgeted wood quail being downlisted to Endangered in 2008 (BirdLife International, 2012d). This left two Critically Endangered species requiring directed conservation action.

Table 2. The 31 countries in which the 24 Endangered Galliformes occur.

Tabla 2. Los 31 países en los que se encuentran las 24 Galliformes en peligro.

14 single country endemics	
	Angola, Brazil, Cameroon, China (2 species), Colombia (2 spp.), Indonesia (2 spp.), Tanzania, Tonga, US, Vietnam (2 spp.)
10 remaining endangered species occur in 17 further countries	
	Argentina, Bolivia, Cambodia, Congo DR, Ecuador, Guatemala, Lao PDR, Malaysia, Mexico, Myanmar, Northern Mariana Islands, Palau, Paraguay, Peru, Thailand, Uganda, Venezuela

Several activities have been undertaken to gather information and promote the conservation of both the Djibouti francolin and the Trinidad piping–guan and these led to the development of Species Conservation Strategies (see IUCN/SSC, 2008) in 2010. These strategies seek to bring together both those who can affect the species' conservation status and those who may be affected by the resulting action (or lack of it). This group of stakeholders then develops a vision for the species and the practical goals, objectives and actions necessary to realise that vision (IUCN/SSC, 2008). These are resource intensive activities, as they involve bringing together a variety of people and require a significant amount of time if the planning process is be comprehensive and thus allow the resulting strategy to stand the best chance of successful implementation. Success should, in due course, be measured by the downlisting of the target species and, ultimately, its removal from the Red List.

Endangered species

Critically Endangered species merit the most intensive attention as they are, by definition, those most at risk of extinction. This is more manageable because there are relatively few species in few countries. In contrast, there are 24 Endangered species spread across 31 countries (table 2, fig. 3),

Fig. 3. Distribution of single–country endemic Endangered Galliformes.

Fig. 3. Distribución de las Galliformes en peligro, endémicas de un único país.

making it a significant challenge to provide sufficient research, management and monitoring effort for these species not only because they are widely dispersed, but also because they are found in countries where capacity is often limited compared with conservation science needs. These are the species, therefore, where increased efficiencies have the biggest potential to contribute towards averting species extinctions.

The first step is to ensure that the species is appropriately categorised on the Red List. The five criteria against which each species is assessed are (IUCN, 2001): (i) Reduction in population size ≥ 70% over the last 10 years or 3 generations whichever in the shorter; (ii) Geographic range small (Extent of Occurrence of < 5,000 km^2 or Area of Occupancy < 500 km^2) and fragmented, declining and extreme fluctuations; (iii) Population size < 2,500 mature individuals and declining; (iv) Population size < 250 mature individuals; and; (v) Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations.

Eight species are currently listed under Criterion A, 14 under B, 13 under C and one under D. None of these species are listed as a result of an acceptable quantitative population viability analyses. As species should be listed under all criteria that they meet, the total above (36) is greater than the number of species (24).

Science

Assessing status

Recent advances in methods of assessing population sizes (Buckland et al., 1993; MacKenzie et al., 2002), geographic ranges sizes (Phillips et al., 2006) and in viability analyses (Lacy, 2000; Akçakaya & Root, 2002) offer considerable potential for generating appropriate and reliable data on poorly known Endangered species. Gamebird ecologists have a significant opportunity to contribute because some of these techniques have been very widely applied to a few highly studied galliform birds. For example, methodological arguments about how, when and what index to use when counting Galliformes have already been largely resolved in North America and Europe (Warren & Baines, 2011; Willebrand et al., 2011; Calladine et al., 2009). Distribution modelling (for example, Aldridge et al., 2012; Graf et al., 2009; Gottschalk et al., 2007) and population viability analysis (Lu & Sun, 2011; Johnson & Braun, 1999; LaMontagne et al., 2002) have become key to assessments of gamebird populations. This practical experience and an understanding the biological requirements of the species suggest that lessons are being learnt which can now be applied to Endangered species, most of which have been subject to little or no quantitative field study.

Insights generated by using these methods in field studies of Endangered species can be combined with remotely gathered data to produce powerful approaches to understanding species status in remote and challenging habitats. Even where location data are scarce, techniques such as Resource Selection Functions (Boyce et al., 2002) combined with high quality satellite images can produce predicted distribution maps which in turn allow the selection of priority areas and the efficient targeting of survey effort (*e.g.* Gottschalk et al., 2007). All of this would allow better understanding of two key issues. Firstly, do we have reasonable assessments of extinction–risk for each species? If we do, this would ensure that effort is targeted where it is most needed and the downlisting of the gorgeted wood–quail as a result of new knowledge is an example of this. Secondly, generating quantitative data for the parameters used to determine extinction risk will help to determine the factors that have led to species being considered to have a high risk of extinction.

Understanding threats

IUCN has developed a standardised classification for threats to species (IUCN, 2012a) and all new assessments specify threats according to these schemes. Although a wide range of threats have been documented for Endangered Galliformes, three stand out because of the number of species that they affect: agriculture involving annual and perennial non–timber crops, hunting and trapping, and logging and wood harvesting (fig. 4). There is extensive literature from intensively managed species, typically from Europe and North America, which explores these threats, both in terms of their impacts on particular galliform species and the actions that are necessary to mitigate those impacts (Bunnefeld et al., 2011; Dallimer et al., 2010; Pearce & Higgins et al., 2007).

Conversion of habitat to intensive agriculture has been responsible for declines in species such as red grouse and black grouse in Europe (Patthey et al., 2012; Dallimer et al., 2010; Ludwig et al., 2009) and prairie grouse in North America (Riley, 2004). Habitat reclamation and management such as set aside schemes offer potential to halt these declines (Riley, 2004; Patthey et al., 2012).

Sustainable harvesting of gamebirds has a long established tradition in Europe and North America. Management techniques that have been applied to these species successfully could be applied to threatened species elsewhere that are hunted in unsustainable numbers. These techniques include bag limits (Sandercock et al., 2011), habitat management (Patthey et al., 2012) and predator control (Summers et al., 2004).

The effects of management practices on gamebird populations by timber harvesting in North America and Europe are well known. The effects of logging rotations, remnant forest strips and fragmentation have all been addressed (for example, Potvin & Courtois, 2006; Giroux et al., 2007; Pearce–Higgins et al., 2007; Borchtchevski et al., 2009) leading to robust and testable habitat management recommendations.

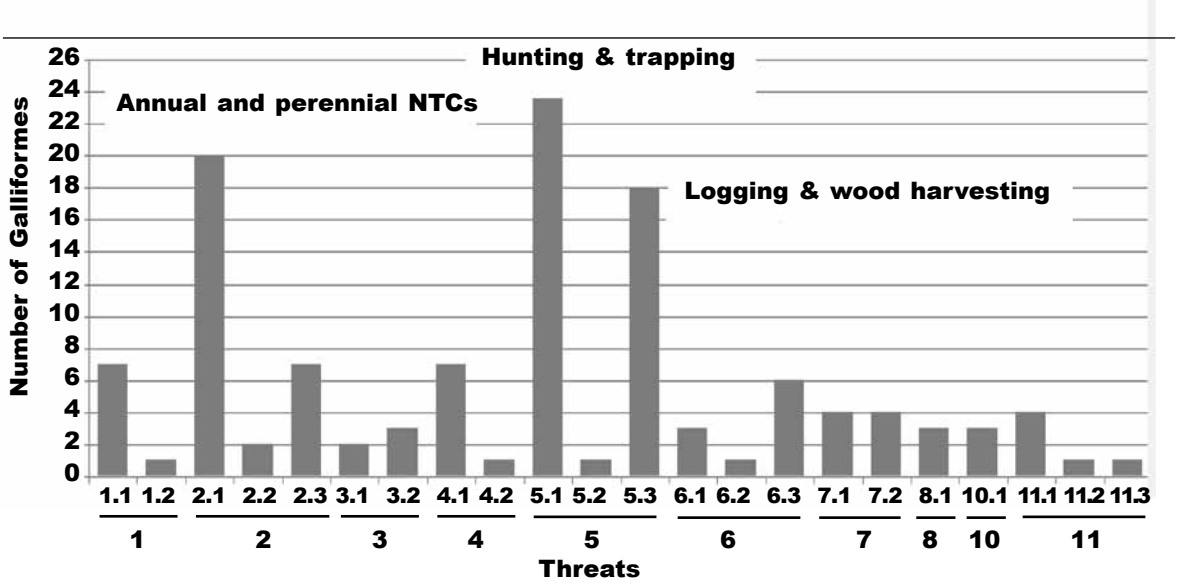

Fig. 4. Threats to Endangered Galliformes categorised by IUCN Red List Threats Classification Scheme: 1. Residencial and commercial development; 2. Agriculture and aquaculture; 3. Energy production and mining; 4. Transportation and service corridors; 5. Biological resource use; 6. Human intrusions and disturbance; 7. Natural system modifications; 8. Invasive and similar; 10. Geological events; 11. Climate change and severe weather.

Fig. 4. Amenazas para las Galliformes en peligro catalogadas según el sistema de clasificación de amenazas de la Lista Roja de la UICN: 1. Desarrollo residencial y comercial; 2. Agricultura y acuicultura; 3. Producción de energía y minería; 4. Transporte y servicio de corredores de transporte; 5. Uso de los recursos biológicos; 6. Intrusiones y perturbaciones humanas; 7. Modificaciones naturales del sistema; 8. Invasoras y similares; 10. Eventos geológicos; 11. El cambio climático y clima adverso.

Underpinning action

Understanding the probable consequences of action and the nature of threats are pre–requisites for defining as precisely as possible the action to be undertaken to mitigate threats. At present, the actions proposed for Endangered Galliformes are primarily site–based (fig. 5). In many cases, however, these proposals, classified under the IUCN Actions Classification Scheme (IUCN, 2012b) are based on very limited information and will benefit significantly from both better knowledge of the species as described above and comparison with management actions that have been tried and are documented in other galliform species.

Some Galliformes species have been subject to relatively well–researched and documented interventions and these may provide powerful lessons for poorly known Endangered species in capacity–limited areas of the world. Already, habitat fragmentation, a dominant paradigm in bird ecology, is becoming a major focus in the study of Galliformes in capacity–limited areas of the world (*e.g.* Cabot's tragopan in China, Deng & Zheng, 2004; chestnut–breasted hill–partridge in Indonesia, Nijman 2003). The application of these same techniques to Endangered galliform species must now be the next step.

Discussion

The 290 species of Galliformes are a remarkable group of birds. As a whole they are very important to humans and contain some of the most studied species in the world, but for many reasons they are highly threatened. These factors provide a valuable opportunity to both translate lessons from well studied to poorly studied species, especially those most at risk of extinction, and also in turning science into effective management. As global policy provides a context that explicitly promotes threatened species conservation, this offers an additional incentive to enhance the efficiency of research, management and monitoring for the most threatened species.

The wealth of applied research that has been conducted on partridges, quail, pheasants and grouse in Europe and North America has provided extensive literature that can be drawn on by those working on the most threatened species. Areas where such research offers especial insights include methods of population estimation (Warren & Baines, 2011), habitat use assessment (Dzialak et al., 2011), breeding ecology and success (Draycott et al., 2008; Kurki et al., 2000) and measuring and understanding mortality (Stephenson et al., 2011). Management has been explored in a wide variety of contexts and

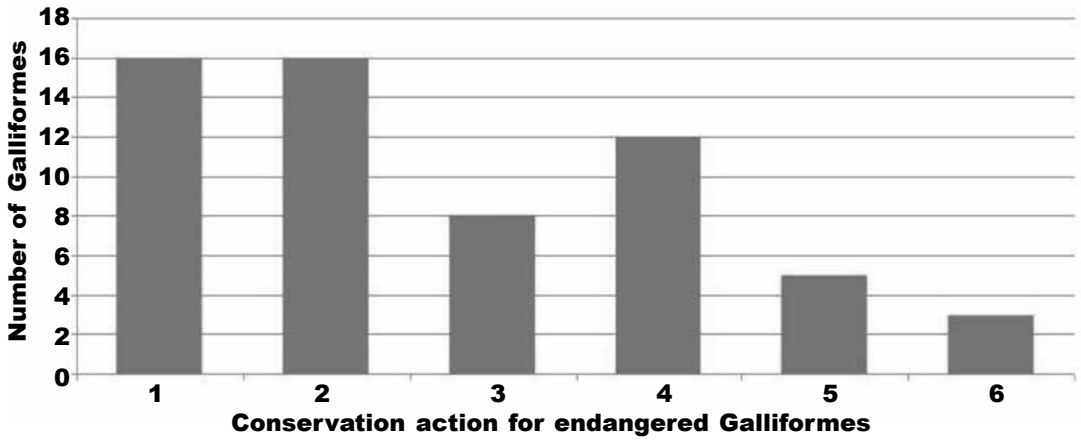

Fig. 5. Actions proposed for Endangered Galliformes categorised using the IUCN Red List Actions Classification Scheme: 1. Land/water protection; 2. Land/water management; 3. Species management; 4. Education and awareness; 5. Law and policy; 6. Livelihood, economic and other incentives.

Fig. 5. Medidas propuestas para las Galliformes en peligro catalogadas según el sistema de clasificación de medidas de la Lista Roja de la UICN: 1. Protección tierra/agua; 2. Gestión tierra/agua; 3. Gestión de las especies, 4. Educación y concienciación; 5. Legislación y política; 6. Sustento, incentivos económicos y de otro tipo.

although there are clear insights to be gained, these will be largely in understanding the ecological issues that management is designed to tackle, rather than socio–economic context in which each intervention will take place. For example, there are clear lessons to be drawn from past reintroduction efforts (World Pheasant Association and IUCN/SSC Re–introduction Specialist Group, 2009) in terms of numbers for release strategy, but where recovery programmes are community based, the involvement of the local community where the project will take place in developing and implementing the project is a key factor in its success (Waylen et al., 2010).

Specific needs

There are several areas that are immediate priorities for exploring what lessons can be learnt from combining knowledge from the well–understood species with developments in conservation science approaches (such as assessing the impact of off–take) and applying them to species with the most pressing needs (*i.e.* those that are Critically Endangered and Endangered). A key constraint in promoting knowledge and action for the most threatened species is simply encouraging researchers and conservationists to get out into the field to undertake status assessments and determine what needs to be done.

Conducting basic status assessments often seems very daunting for researchers in countries where there is limited capacity and little tradition of ornithological field work because the effort that must be expended in order to gather sufficient data on species can be perceived to be considerable. Therefore, clearer guidance on field techniques and their application in various circumstances (habitat, topography and species detectability) would make a significant contribution in both demonstrating that gathering meaningful data is possible and outlining how it might be done. New methods for population estimation are typically developed in countries that are relatively resource–rich and which have easier access across study areas and explicit efforts to test these on some of the most threatened species that inhabit areas where research is logistically more difficult would contribute significantly to Galliformes conservation. If this can be combined with greater support for new researchers through the mentoring of individuals or small groups, the increase in field effort on the most threatened species would be marked.

The main threat that makes Galliformes more highly threatened than most other avian Orders is over–exploitation. At present this is based on a perception that observations of snaring or wild meat extraction are indicative of removal outstripping recruitment. Whilst this may be suitably precautionary, further information on the scale of exploitation, allied to a better understanding of the genetic and demographic consequences of exploitation on hunted populations with various ecological characteristics (large population sizes, geographically restricted, habitat specialists etc). This is an area where significant contextual lessons could be learnt from the well–studied species to those that are poorly known and/or considered to be threatened with global extinction.

Finally, learning lessons about successful interventions may result in improving the efficiency of management for the most threatened species. Interventions

have both an ecological and social component, with the latter varying from place to place. There are now sufficient assessments of management interventions (some formally written up, others not) from the well–studied galliform species that general principles should be explored. It may lead to important conclusions about basic characteristics of management that may have especially positive impacts, such as stage of life history or reproductive cycle impacted or the needs of suites of particular species. Such findings may help develop more effective management approaches and methods for the most threatened species with greater efficiency.

As a way of approaching the analysis of a species conservation status and working to achieve its conservation, an Adaptive Resource Management (ARM) approach (Walters, 1986) offers a potential model to link scientific research and management outcomes for the benefit of Galliformes conservation (Conroy & Peterson, 2006). ARM acknowledges uncertainty inherent in ecological data collection and allows for managers to learn about ecosystems at the same time as managing them (Lancia et al., 1996). This approach is being used to manage populations of well–known Galliformes, particularly in North America (*e.g.* sage grouse in Canada, Canadian Sage Grouse Recovery Team, 2001). More formal incorporation of ARM into other areas of gamebird conservation could significantly enhance our ability to meet the CBD 2020 target for species conservation.

References

Akçakaya, H. R. & Root, W., 2002. RAMAS Metapop: viability analyses for stage–structured metapopulations (version 4.0). *Applied Biomathematics*, Setauket, NY, USA.

Aldridge, C. L., Saher, D. J., Childers, T. M., Stahlnecker, K. E. & Bowen, Z. H., 2012. Crucial nesting habitat for Gunnison sage–grouse: A spatially explicit hierarchical approach. *Journal of Wildlife Management,* 76:391–406.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., Mersey, B. & Ferrer, E. A., 2011. Has the Earth's sixth mass extinction already arrived? *Nature*, 471: 51–57.

BirdLife International, 2012a. Data Zone. Available at www.birdlife.org/datazone/species/search. Accessed on 15 March 2012.

– 2012b Birds on the IUCN Red List. www.birdlife.org/action/science/species/global_species_programme/red_list.html Accessed 15 March 2012.

– 2012c. Final decisions for the 212 IUCN Red List. Available at www.birdlife.org/globally–threatened–bird–forums. Accessed 15 March 2012.

– 2012d. Gorgeted wood–quail *Odontophorus strophium*. www.birdlife.org/datazone/speciesfactsheet.php?id=333. Accessed 15 March 2012.

Borchtchevski, V. G., Hjeljord, O., Wegge, P. & Sivkov, A. V., 2003. Does fragmentation by logging reduce grouse reproductive success in boreal forests? *Wildlife Biology*, 9: 275–282.

Boyce, M. S., Vernierb, P. R., Nielsena, S. E. & Schmiegelow, F. K. A., 2002. Evaluating resource selection functions. *Ecological Modelling,* 157: 281–300.

Buckland, S. T., Anderson, D. R., Burnham, K. P. & Laake, J. L., 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. London: Chapman and Hall

Bunnefeld, N., Reuman, D. C., Baines, D. & Milner–Gulland, E. J., 2011. Impact of unintentional selective harvesting on the population dynamics of red grouse. *Journal of Animal Ecology*, 80: 1258–1268.

Calladine, J., Garner, G., Wernham, C. & Thiel, A., 2009. The influence of survey frequency on population estimates of moorland breeding birds. *Bird Study*, 56: 381–388 .

Canadian Sage Grouse Recovery Team, 2001. *Canadian sage grouse recovery strategy*. http://www.srd.alberta.ca/FishWildlife/SpeciesAtRisk/LegalDesignationOfSpeciesAtRisk/RecoveryProgram/documents/SageGrousePlan.pdf. Unpublished strategy of Alberta Sustainable Resource Development's Fish and Wildlife Division, Canada. Accessed 30 May 2012.

CBD (Convention on Biological Diversity), 2002. *Conference of the Parties 6, Decision VI/26*. www.cbd.int/decision/cop/?id=7200. Secretariat of the Convention on Biological Diversity. Accessed 15 March 2012.

– 2010. Strategic plan for biodiversity 2011–2010, including Aichi biodiversity targets. Secretariat of the Convention on Biological Diversity. http://www.cbd.int/sp/. Accessed 31 May 2012.

Conroy, M. J. & Peterson, J. T., 2006. Integrating management, research, and monitoring: Balancing the 3–legged stool. Proceedings of Gamebird a joint conference of Quail VI and Perdix XII 31 May to 4 June 2006: 2 – 10

Dallimer, M., Marini, L., Skinner, A. M. J., Hanley, N., Armsworth, P. R. & Gaston, K. J., 2010. Agricultural land–use in the surrounding landscape affects moorland bird diversity. *Agriculture, Ecosystems & Environment*, 139: 578–583.

Deng, W. & Zheng, G., 2004. Landscape and habitat factors affecting Cabot's tragopan *Tragopan caboti* occurrence in habitat fragments. *Biological Conservation*, 117: 25 32.

Draycott, R. A. H., Hoodless, A. N., Woodburn, M. I. A. & Sage, R. B., 2008. Nest predation of common pheasants *Phasianus colchicus*. *Ibis*, 150, 37–44.

Dzialak, M. R., Olson, C. V., Harju, S. M., Webb, S. L., Mudd, J. P., Winstead, J. B. & Hayden–Wing, L. D., 2011. Identifying and Prioritizing Greater Sage–Grouse Nesting and Brood–Rearing Habitat for Conservation in Human–Modified Landscapes. *PlosOne*, 6: e26273.

FAO, 2007. *Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration.* FAO, Rome. Available at www.fao.org/docrep/010/a1404e/a1404e00.htm.

Giroux, W., Blanchette, P., Bourgeois, J. & Cabana, G., 2007. Ruffed grouse brood habitat use in mixed softwood–hardwood Nordic-temperate forests,

Quebec, Canada. Journal of Wildlife Management, 71: 87–95.

Gottschalk, T. K., Ekschmitt, K., Isfendiyaroglu, S., Gem, E. & Wolters, V., 2007. Assessing the potential distribution of the Caucasian black grouse *Tetrao mlokosiewiczi* in Turkey through spatial modelling. *Journal of Ornithology*, 148: 427–434.

Graf, R. F., Mathys, L., Bollmann, K., 2009. Habitat assessment for forest dwelling species using LiDAR remote sensing: Capercaillie in the Alps. *Forest Ecology and Management*, 257: 160–167.

IUCN, 2001. *IUCN Red List Categories and Criteria: Version 3.1*. IUCN Species Survival Commission, IUCN, Gland, Switzerland and Cambridge, UK.

– 2011. *IUCN Red List of Threatened Species. Version 2011.2.* Available at www.iucnredlist.org. Accessed on 15 March 2012.

– 2012a. IUCN Red List Threats Classification Scheme Version 3.0. www.iucnredlist.org/technical–documents/classification–schemes/threats–classification–scheme–ver3. Accessed 15 March 2012.

– 2012b. IUCN Red List Actions Classification Scheme Version 2.0. http://www.iucnredlist.org/technical–documents/classification–schemes/conservation–actions–classification–scheme–ver2. Accessed 15 March 2012.

IUCN/SSC, 2008. Strategic Planning for Species Conservation: A Handbook. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission. Available at http://cmsdata.iucn.org/downloads/scshandbook_2_12_08_compressed.pdf.

Johnson, K. & Braun, C. E., 1999. Viability and conservation of an exploited sage grouse population. *Conservation Biology*, 13: 77–84.

Kurki, S., Nikula, A., Helle, P. & Lindén, H., 2000. Landscape fragmentation and forest composition effects on grouse breeding success in boreal forests. *Ecology*, 81: 1985–1997.

Lacy, R., 2000. Considering threats to the viability of small populations using individual–based models. *Ecological Bulletins*, 48: 39–51.

LaMontagne, J. M., Irvine, R. L. & Crone, E. E., 2002. Spatial patterns of population regulation in sage grouse (*Centrocercus* spp) population viability analysis. *Journal of Animal Ecology*, 71: 672–682.

Lancia, R. A., Braun, C. E., Collopy, M. W., Dueser, R. D., Kie, J. G., Martinka, C. J., Nichols, J. D., Nudds, T. D., Porath, W. R. & Tilghman, N. G., 1996. *Wildlife Society Bulletin*, 24: 436–442.

Lu, N. & Sun, Y. H., 2011. Population viability analysis and conservation of Chinese grouse Bonasa sewerzowi in Lianhuashan Nature Reserve, north–west China. *Bird Conservation* International, 21: 49–58.

Ludwig, T., Storch, I. & Gärtner, S., 2009. Large–scale land use change may explain bird species declines in semi–natural areas: the case of black grouse population collapse in Lower Saxony, Germany. *Journal of Ornithology*, 150: 871–882.

Mace, G. M., Collar, N. J., Gaston, K. J., Hilton–Taylor, C., Resit Akçakaya, H., Leader-Williams, N., Milner–Gulland, E. J. & Stuart, S., 2008. Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology*, 22: 1424–1442.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B. , Droege, S., Royle, J. A. & Langtimm, C. A., 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology,* 83: 2248–2255.

McGowan. P. J. K., 1994. Phasianidae (Pheasants and partridges). In: *Handbook of the birds of the world. Volume II:* 434–552 (J. Hoyo, A. Elliott & J. Sargatal, Eds.). Lynx Edicions, Barcelona.

– 2010a. The urgent need to address geographical imbalance in the publication of conservation science. *Oryx,* 44: 328–329.

– 2010b. Conservation status of wild relatives of animals used for food. *Animal Genetic Resources,* 47: 115–118.

Memmott, J., Cadotte, M., Hulme, P. E., Kerby, G. Milner–Gulland, E. J. & Whittingham, M. J., 2010 Putting applied ecology into practice *Journal of Applied Ecology*, 47: 1–4.

Milner–Gulland, E. J., Fisher, M., Browne, S., Redford, K. H., Spencer, M. & Sutherland, W. J., 2010. Do we need to develop a more relevant conservation literature? *Oryx*, 44: 1–2.

Nijman, V., 2003. Distribution, habitat use and conservation of the endemic Chestnut–bellied Hill–partridge (*Arborophila javanica*) in fragmented forests of Java, Indonesia. *Emu.,* 103: 133–140.

Patthey, P., Signorell, N., Rotelli, L. & Arlettaz, R. l., 2012. Vegetation structural and compositional heterogeneity as a key feature in Alpine black grouse microhabitat selection: conservation management implications. *European Journal of Wildlife Research*, 58: 59–70.

Pearce–Higgins, J. W., Grant, M. C., Robinson, M. C. & Haysom, S. I., 2007. The role of forest maturation in causing the decline of Black Grouse *Tetrao tetrix. Ibis,* 149: 143–155.

Phillips S. J., Anderson R. P. & Schapire R. E., 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, 190: 231–259.

Potvin, F. & Courtois, R., 2006. Incidence of spruce grouse in residual forest strips within large clear–cut boreal forest landscapes. *Northeastern Naturalist*, 13: 507–520.

Riley, T. Z., 2004. Private–land habitat opportunities for prairie grouse through federal conservation programs. *Wildlife Society Bulletin*, 32: 83–91.

Sandercock, B. K., Nilsen, E. B., Broseth, H., & Pendersen, H. C., 2011. Is hunting mortality additive or compensatory to natural mortality? Effects of experimental harvest on the survival and cause–specific mortality of willow ptarmigan. *Journal of Animal Ecology*, 80: 244–258.

Secretariat of the Convention on Biological Diversity 2010. *Global Biodiversity Outlook 3*: *Executive Summary*. Convention of Biological Diversity, Montréal. http://gbo3.cbd.int/resources.aspx. Accessed 14 May 2010.

Stephenson, J. A., Reese, K. P., Zager, P., Heekin,

P. E., Nelle, P. J. & Martens, A., 2011. Factors influencing survival of native and translocated mountain quail in Idaho and Washington. *Journal of Wildlife Management*, 75: 1315–1323.

Summers, R. W., Green, R. E., Proctor, R., Dugan, D., Moncrieff, R., Moss, R. & Baines, D., 2004. An experimental study of the effects of predation on the breeding productivity of capercaille and black grouse. *Journal of Applied Ecology*, 41: 513–525.

Turner, C. & Donegan, T. M., 2006. Study of gorgeted wood–quail *Odontophorus strophium* in Serranía de los Yariguíes. In: *Colombian EBA Project Rep. Ser*. 7: 105–120 (B. Huertes & T. M. Donegan, Eds.) Downloaded from www.proaves.org on 15 March 2012.

UN, 2005. *Resolution adopted by the General Assembly 60/1. 2005 World Summit Outcome.* United Nations, New York. Available at http://daccess–dds–ny.un.org/doc/UNDOC/GEN/N05/487/60/PDF/N0548760.pdf?OpenElement. Accessed 15 March 2012.

Vié, J.–C., Hilton–Taylor, C. & Stuart, S. N. (Eds.), 2009. *Wildlife in a changing world: an analysis of the 2008 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland.

Walters, C. J., 1986. *Adaptive management of renewable resources*. MacMillan Pres, New York, USA.

Warren, P. & Barnes, D., 2011. Evaluation of the distance sampling technique to survey red grouse *Lagopus lagopus scoticus* on moors in northern England. *Wildlife Biology*, 17: 135–142.

Waylen, K. A., Fischer, A., McGowan, P. J. K., Thirgood, S. J., Milner–Gulland, E. J., 2010. The effect of local cultural context on the success of community–based conservation interventions. *Conservation Biology,* 24: 1119–1129.

Willebrand, T., Hörnell–Willebrand, M. & Asmyhr, L., 2011. Willow grouse bag size is more sensitive to variation in hunter effort than to variation in willow grouse density. *Oryx*, 120: 1667–1673.

World Pheasant Association & IUCN/SSC Re–introduction Specialist Group (eds.) 2009. Guidelines for the Re–introduction of Galliformes for Conservation Purposes. IUCN, Gland, Switzerland and World Pheasant Association, Newcastle–upon–Tyne, UK.