

The Interactions between Forest Quality, Reproduction and Social Stability in White-handed Gibbons as a Model for Understanding the Consequences of Habitat Changes in other Forest Species

Tommaso Savini¹, George A. Gale¹ and Philip D. Round²

¹King Mongkut's University of Technology Thonburi, Bangkok, Thailand, ²Mahidol University, Bangkok, Thailand

During the past few decades researchers have been documenting global climate change and its impacts on wildlife and their habitats around the world. Changes in habitat can directly impact on the diversity and interspecific interactions within many animal communities, yet the effects of these environmental changes have in most cases not been investigated in detail, particularly in the tropics. It is the goal of our work to model the influence that a given habitat has on its animal inhabitants in order to trace the effects of future environmental changes both on the animal itself and on the role this animal plays in the maintenance of the ecosystem in which it lives. In a three-year study of seven white handed gibbon groups conducted at Khao Yai National Park, Thailand, the role of forest productivity in the shaping of gibbon social structure and their reproductive performances was conducted. Forest productivity was defined by analyzing in detail the spatio-temporal distribution of potential food resources within each of the seven home ranges. Significant variation in forest productivity occurred among home ranges, but the significance disappeared when we compensated forest productivity with the size of each home range. For our model we found no significant relationship between home range productivity and the number of surviving offspring for each study female. However, the study found that females could maintain optimal reproductive performance by increasing their access to resources by manipulating three environmental/behavioral parameters: (1) home range size (2) group size, and (3) group social stability. Home range size variation was hypothesized to be a consequence of forest productivity. As predicted, large home ranges were associated with low quality forest, whereas in high quality forest small home ranges prevailed. Group size was hypothesized to be a direct consequence of resource availability. We found that larger groups were associated with higher quality forest while smaller groups were found in poor quality forest. We also found that group social stability was a consequence of different territorial costs associated with variable home range sizes. The second step of our work is to apply this model to the Khao Yai pheasant community which in the past two decades has shown a significant change in its structure with the number and proportion of detections of the lowland-inhabiting Siamese Fireback (*Lophura diardi*) increasing significantly, while the number of detections of the higher elevation inhabitant Silver Pheasant (*L. nycthemera*) showed no significant increase. This change in the community composition has been hypothesised to be a long-term consequence of a change in vegetation structure associated with regional climate change.

Key words: climate change, pheasant, micro habitat, inter-species competition

Introduction

Detailed analysis on climatological data, run over the past 100 years, has shown increases of approximately 0.6°C in the global average temperature and is expected to continue to rise rapidly (Houghton et al. 2001). Simultaneously, a large amount of recent scientific work has highlighted the general biological impacts of climate change (Penuelas and Flella, 2001; Walther et al., 2002). Although animal species have been responding to climatic changes on an evolutionary time scale, a critical question for wild species is how they will cope with this rapid rate of change (Root et al., 2003).

Animals groups have shown to react differently to global increase in temperature (Forcchammer, 1998). In the past thirty years warmer springs have resulted in earlier nesting activity in temperate areas (Crick et al., 1997; Crick and Sparks, 1999), earlier spring arrival dates in breeding visitors (Butler, 2003) and northward and altitudinal range expansions (Thomas and Lennon, 1999).

Although little work has been so far conducted in tropical habitats on the effects of global warming data suggest that animal species react to habitat changes by moving along climatic gradients (Karr and Freemark, 1983) with colonization of montane habitat by non-montane species (Pounds et al., 1999). In the tropics, as seasonal variations are of lower intensity, we can assume that in these habitats, humidity rather than temperature will play an important role in differentiating microhabitats.

Recent ecological work, combined with long term data on socio-reproduction (Brockelman et al., 1998), conducted on the gibbon population at Khao Yai National Park, has highlighted a tight interaction between animals and the quality of forest productivity (Savini, 2005). A marked degree of home range size variation between different groups was recorded and a significant negative correlation between home range size and habitat quality, with home range size increasing when the forest quality, measured as spatio-temporal distribution of food resources, decreased (Savini et al., submitted). Moreover, female gibbons synchronized their reproduction by clustering higher cost breeding activity during periods of higher food productivity (Savini et al., accepted). In the end, home range productivity influenced social variability with a larger chance for a gibbon group to develop a non-monomogamous social structure in larger and poorer home ranges than in smaller richer ones (Savini et al., submitted).

In the Mo Singto Long Term Biodiversity Research Plot, Khao Yai National Park (Brockelman et al., 2002), two species of pheasant live in an increasing syntopy. Recent analysis conducted by Round and Gale (in revision) over a period of more than twenty years on the relative abundance of two pheasant species show an increase in the population of Siamese Fireback (*Lophura diardi*), a lowland species, over Silver Pheasant (*L. nycthemera*), a species that commonly inhabits higher elevations. The proportions of sightings contributed by each species varied markedly through the period 1980 to 2005. Before 1993 *L. diardi* contributed only 18.6% of pheasant individuals seen in the area. From 1994 to the present, *L. diardi* contributed more than half of all pheasants observed (60.1%). Overall, there was a significant increase in the detection rate of Siamese Fireback throughout the survey period, both as measured by the number of individuals per unit effort, and the number of sightings per unit effort. In contrast neither the number of individuals detected nor the number of sightings per unit effort increased significantly in the Silver Pheasant. The authors suggest that the most possible reason for the increase in the numbers of Siamese Fireback over the “resident” population of Silver Pheasant is to be found in the rising temperature and consequently evapotranspiration (higher in the lowlands than in montane and upper submontane areas). Microhabitat changes consequence of rising temperature, which reflect in an increased evapotranspiration, will benefit plant and animals living in lowland habitats at the expenses of montane species Karr and Freedmark (1983).

Here we will present preliminary data on the distribution of two species of pheasant living in syntopy in the Mo Singto Long Term Biodiversity Plot, Khao Yai National Park and predict how the effect of forced syntopy coexistence can influence the conservation of both species.

Methodology

Study site and animals

The study, initiated in January 2006, is being conducted at the Mo Singto Biodiversity Research Plot (Brockelman et al., 2002), Khao Yai National Park, Thailand (2,168 km²; 101°22' E, 14°26' N; ~ 130 km NE of Bangkok), in slightly hilly terrain 725 - 815 m above sea level. Khao Yai is largely a seasonally wet, evergreen forest (Kerby et al., 2000; Kitamura et al., 2004a). The area experiences a distinct dry season (November – April) and wet season (May – October). In the period 2001 to 2004, precipitation averaged 2697 mm (range 2297 to 2976 mm), which closely corresponded to rainfall records of other researchers at the site during the years 1993 to 2001: 2326 mm (Kitamura et al., 2004b); 2030 mm in 1993 (Poonswad et al., 1998); 2695 mm in 1994 (Bartlett, 1999); and 2127 mm in 2004 (Kanwatanakid-Savini, unpublished data). Average daily temperature varied annually between 18.7° C and to 28.3° C and mean humidity ranged from 64.6% during the dry season to 77.1% during the wet season.

Monthly visits were made to the Mo-Singto study plot during the period running from June 2003 to August 2005 covering eight transects, each of 500 m in length. Only one transect was walked per morning so that two mornings were necessary to cover the entire plot. Distance and bearing to each pheasant seen or heard within 80 m was recorded, so as to render the data amenable to analysis both by spot-mapping and variable width line transect sampling. The locations of all birds heard or seen were located with reference to the nearest peg or nearest labelled tree. Distance from the observer (m) was estimated, and the bearing measured with a sighting compass. Most species were only recorded if judged to be within 80 m of the observer. Numbers of individuals in flocks or small groups were recorded, and other relevant information such as call-type, feeding behaviour was recorded when relevant. The tree numbers of those trees from which birds were seen taking fruit were also recorded.

From January 2006 onwards pheasants were caught using mist-nets and snare traps. Mist nets were set on the ground to a height of approximately 3 m. All pheasants caught were ringed with Royal Forest Department (RFD) metal rings, and colour-banded with a two-colour combinations so as to facilitate individual identification in the field. Each bird was additionally weighed, measured and examined for stage of moult.

Home range size for each individual of both species was estimated based on re-sightings of ringed birds referenced to either marked trees/grid pegs (Brockelman et al., 2002) or GPS readings. Locations were used to define minimum convex polygons (White, 1996; Linnell et al., 2001) drawn on ArcView 3.0a software.

Results

Density

During line transect surveys from June 2003 to August 2005 we recorded 13 observations of 23 adult *L. nycthemera* and 15 sightings of 34 adult *L. diardi*. Mean flock size was not significantly different (mean flock size 1.77 and 2.27 respectively, *t*-test, $t = 1.128$, $P = 0.135$). For density estimation, due to small sample size and as detection distances between species appeared to be similar, data from both species were pooled to generate a single detection function following Buckland et al. (2001) using DISTANCE 5.0 software (Thomas et al., 2004). The density estimate for *L. diardi* was greater (10.0 groups or 22.8 individuals / km², versus 8.0 groups or 14.7 individuals / km²). However, due to the small sample size the variances of the estimates were large (95% confidence limits, 4.7-21.5 groups / km² for *L. diardi* and 2.6-24.5 groups / km² for *L. nycthemera*) suggesting that the estimates should be treated with caution (Buckland et al., 2001).

Data collected on pheasant presence and group structure collected along trails and in the plot suggested an overall population of three groups per species inhabiting the 30 ha plot, equal to 1 group per 10 ha, remarkably similar to the estimates obtained from distance sampling. Average group size was estimated at 5 animals which was roughly equal to one animal every 2 ha suggesting that group size was probably underestimated using the more rapid survey methods. Additional detailed observations of marked birds are necessary to confirm this figure.

Birds ringed and definition of home ranges

A total of 4 birds belonging to the two pheasant species were ringed up to September 2006 (see table 1 for details).

Preliminary estimates of home range size indicate that Siamese Fireback male had a range of at least 7.5ha while the range was 3.8 ha for Silver Pheasant male (Figure 1). The two home ranges had a large overlap of 2.21 ha, equal to 29.5% of its estimate home range for Siamese Fireback and 58% for Silver Pheasant.

Table 1. Ringing details

Species	Sex	Left	Right	Waight
SPH	M	Y/DG	DB/M	1475
SPH	F	LB/DG	DB/-	1035
SMF	M	DB/Y	DG/M	1190
SMF	M	LB/F	DG/M	1210

Discussion and Conclusion

Round and Gale (in review) demonstrate a shift in the balance of an assumed competitive interaction between two species, with a lowland species, Siamese Fireback, increasing its abundance in the range of a higher elevation species, Silver Pheasant. Altitudinal range changes have been observed in several other species of both plants and animals (Pounds et al., 1999) and the authors hypothesise that the changing abundance of two pheasants is attributable to changing climate, although this cannot yet be proved. The two pheasants nevertheless maintain a substantial difference in the microhabitat use within the study site, with Silver Pheasants occurring mainly on ridges and Fireback in flatter and lower-lying areas. This difference in habitat use is presumably related to subtle variations in forest floor conditions, consequence of forest topography (Figure 2). These findings correspond to what was observed by Pounds and coauthors (1999) for which habitat expansion in the tropics might be a direct consequence of changes in humidity induced by global warming rather than temperature change *per se*. Lowland species might move to higher elevations as a consequence of changes in lowland microhabitat structure. With an increase in temperature lowland habitat may lose moisture with the effect that lowland species may migrate to higher altitudes where moisture level increases.

Future work will be conducted to test the hypothesis that microhabitat structure might naturally separate the two species within the same, and relatively small, study site. We predict that Siamese Fireback will prefer flat habitat while Silver Pheasant will prefer slopes. Moreover, detailed observations are needed to highlight the impact of syntopy on each species as both species appear to overlap greatly in feeding ecology.

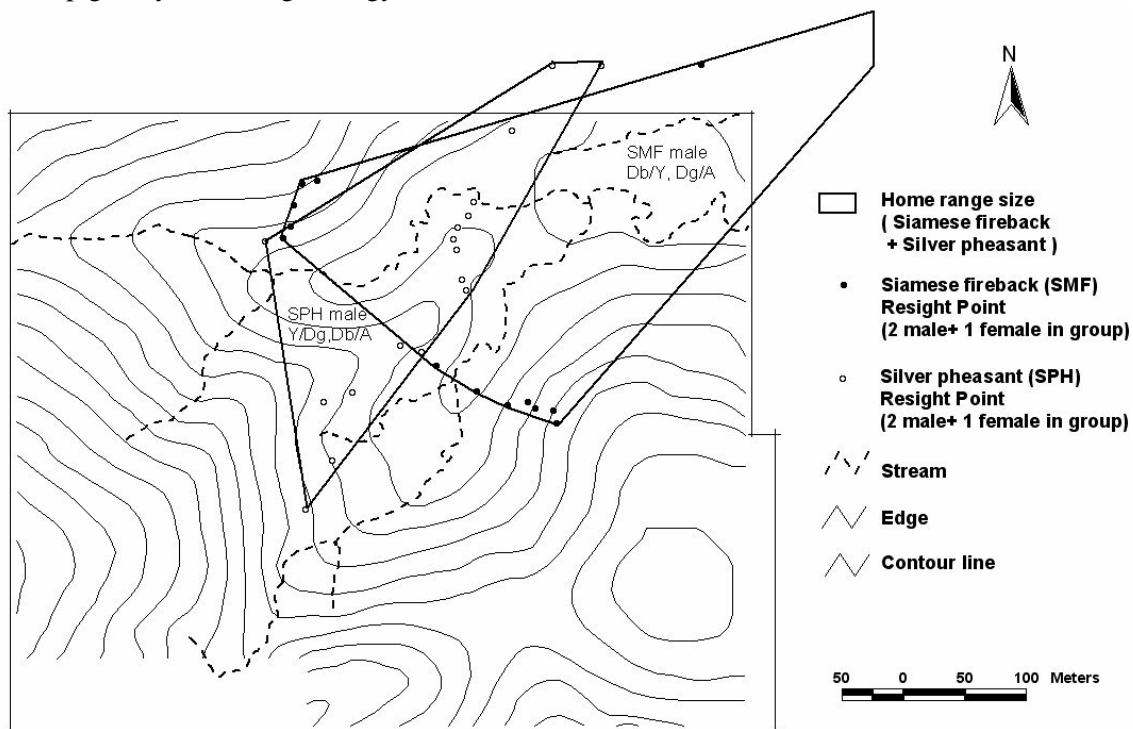


Figure 1. Preliminary home ranges of a ringed siamese fireback male and silver pheasant male.

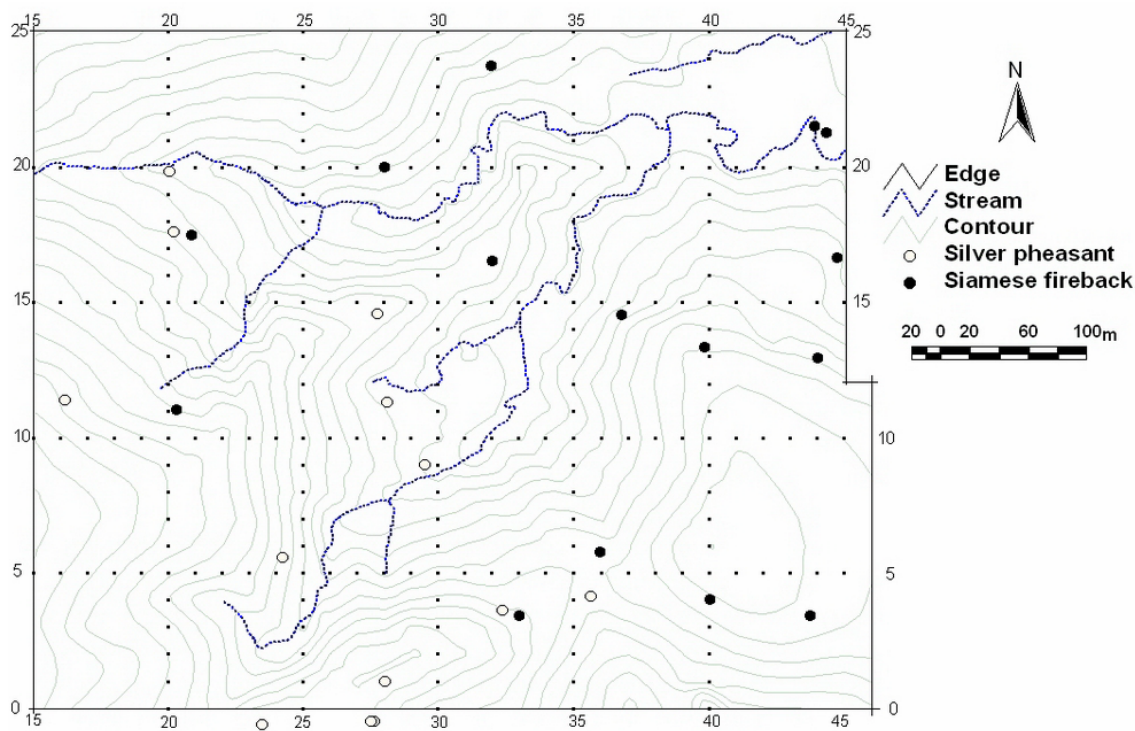


Figure 2. Observation from line transect survey (June 2003- August 2005)

In the few cases where *Lophura* species occur in syntopy they are usually ecologically segregated by microhabitat variations (Davison, 1981; Lekagul and Round, 1991; Bird Life International, 2001). However, preliminary results on the movement and home range location of ringed males of both pheasant species show a relatively extended overlap between the microhabitat used by each species forcing them into more direct contact resulting in an increase in resource competition for each species (Figure 1). If climate-induced changes in resource distribution and availability increase spatial overlap of these two species, and if this overlap leads to increased competition then, this might also affect the socio-reproductive stability of each species, with the potential consequence of causing hybridization. Physical clashes between both pheasants in Khao Yai have been observed (Praditsup, 2004) while hybridization between sympatric *Lophura* species is already known from Vietnam where a formerly recognized species, the Imperial Pheasant (*L. imperialis*) is now known to represent a hybrid between Silver Pheasant and the scarce and globally endangered Edwards's Pheasant *L. edwardsi* (Hannache et al., 2003).

Detailed investigations will be conducted on a larger number of ringed birds in order to determine the extension of overlap and the type of microhabitat shared between the two syntopic species. The use of similar microhabitat, together with a similar feeding and reproductive ecology, could lead to hybridization between the two species which may cause additional risks to the survival of both populations.

Acknowledgements

We would like to thank A.J. Pierce, N. Sukumal, M. Kinklai, M. Pliu-sungnoen, K. Pobprasert, W. Sankamethawee, K. Tokue, D. Khamcha, S. Nimnuan, A. Pattanavibool, W.Y. Brockelman, C. Mungpoonklang for their assistance in the field and in the analysis of the preliminary results. C. Kanwatanakid-Savini shared with us her weather data for 2004. Permission to conduct research in Khao National Park was granted by the Thai Royal Forestry Department and the National Research Council of Thailand. Research was sponsored by Biodiversity Research and Training Programme (BRT R_349004 and R_346004), the Wetland Trust (U.K.), the Max-Planck Institute for Evolutionary Anthropology (Germany) and the Christian Vogel Fond (Germany).

References

- Bartlett, T.Q. 1999. Feeding and ranging behavior of the white-handed gibbon (*Hylobates lar*) in Khao Yai National Park, Thailand. Unpublished PhD Dissertation. Washington University, Saint Louis, MI, USA.
- BirdLife International. 2001. Threatened birds of Asia: the BirdLife International Red Data Book. BirdLife International Cambridge, UK.
- Brockelman, W.Y., T. Santisuk, C. Nan and C. Suckaseam. 2002. Monitoring plant-animal relations on the Mo-singto Long Term Biodiversity Research Plot. Final report to the Biodiversity Research & Training Program, Thailand Research Fund, and BIOTEC, NSTDA.
- Brockelman, W.Y., U. Raichard, U. Treesucon and J.J. Raemaekers. 1998. Dispersal, pair formation and social structure in gibbons (*Hylobates lar*). *Behavioral Ecology and Sociobiology* 42: 329-339.
- Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.
- Butler, C.J. 2003. The disproportionate effect of global warming on the arrival dates of short-distance migratory birds in North America. *Ibis* 145: 484-495.
- Crick, H.Q.P. and T.H. Sparks. 1999. Climate change related to egg-laying trends. *Nature* 399: 423-424.
- Crick, H.Q.P., C. Dudley, D.E. Glue and D.L. Thompson. 1997. UK birds are laying eggs earlier. *Nature* 388: 526.
- Davison, G.W.H. 1981. Habitat requirements and the food supply of the Crested Fireback. *World Pheasant Assoc. Journal* 6: 40-52.
- Forcchammer, M., E. Post and N.C. Stenseth. 1998. Breeding phenology and climate. *Nature* 391: 29-30.
- Hannache, A., P. Rasmussen, V. Lucchini, S. Rimondi and E. Randi. 2003. Hybrid origin of the imperial pheasant *Lophura imperialis* (Delacour and Jabouille, 1924) demonstrated by morphology, hybrid experiments, and DNA analyses. *Biological Journal of the Linnean Society* 80: 573-600.
- Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden and D. Xiaosu. 2001. Climate Change 2001: The Scientific Basis: Contribution Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.
- Karr, J.R. and K.E. Freemark. 1983. Habitat selection and environmental gradients: Dynamics in the "stable" tropics. *Ecology* 64: 1481-1494.
- Kerby, J., S. Elliott, J.F. Maxwell, D. Blakesley and V. Anusarnsunthorn. 2000. Tree Seeds and Seedlings. FORRU Publishing Project.
- Kitamura, S., T. Yumoto, P. Poonswad, N. Noma, P. Chuailua, K. Plongmai, T. Maruhashi and C. Suckasam. 2004a. Pattern and impact of hornbill seed dispersal at nest trees in a moist evergreen forest in Thailand. *Journal of Tropical Ecology* 20: 545-553.
- Kitamura, S., T. Yumoto, P. Poonswad, N. Noma, P. Chuailua, K. Plongmai, T. Maruhashi and C. Suckasam. 2004b. Dispersal of *Aglaia spectabilis*, a large-seeded tree species in a moist evergreen forest in Thailand. *Journal of Tropical Ecology* 20: 421-427.
- Lekagul, B. and P.D. Round. 1991. A guide to the birds of Thailand. Saha Karn Bhaet Co., Bangkok.
- Linnell, J.D.C., R. Andersen, T. Kvam, H. Andrén, O. Liberg, J. Odden and P.F. Moa. 2001. Home-range size and choice of management strategy for lynx in Scandinavia. *Environmental Management* 27: 869-879.
- Penuelas, J. and I. Flella. 2001. Responses to a warming world. *Science* 294: 793-795.
- Poonswad, P., P. Chuailua, K. Plongmai and S. Nakkuntod. 1998. Phenology of some *Ficus* species and utilisation of *Ficus* sources in Khao Yai National Park, Thailand. In Poonswad, P. (ed.), *The Asian Hornbills: Ecology and Conservation*, pp. 227-244. Biodiversity Research and Training Program, National Center for Genetic Engineering and Biotechnology.
- Pounds, J.A., M.P.L. Fogden and J.H. Campbell. 1999. Biological response to climate change on a tropical mountain. *Nature* 398: 611-615.
- Praditsup, N. 2004. Social Behaviour and Ecology of the Siamese Fireback *Lophura diardi* in Khao Yai National Park, Thailand. Unpublished MSc. Thesis, Faculty of Graduate Studies, Mahidol University, Bangkok.
- Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig and J.A. Pounds. 2003. Fingerprints of global warming on animals and plants. *Nature* 421: 57-60.
- Round, P.D. and G.A. Gale. Changes in the status of *Lophura* pheasants in Khao Yai National Park, Thailand: a response to warming climate? *Biotropica* (in review).
- Savini, T. 2005. Socioecology and reproduction in white-handed gibbons (*Hylobates lar*) at Khao Yai National Park, Thailand. Unpublished PhD. Dissertation. Liege University, Belgium.
- Savini, T., C. Boesch and U.H. Reighard. Home range characteristics and the influence of seasonality on female reproduction in white-handed gibbons (*Hylobates lar*) at Khao Yai National Park, Thailand. *American Journal of Physical Anthropology* (accepted).
- Savini, T., C. Boesch and U.H. Reighard. Varying ecological quality influences the development of polyandry in white-handed gibbons (*Hylobates lar*). *Behavioural Ecology and Sociobiology* (submitted).
- Thomas, C.D. and J.J. Lennon. 1999. Birds extend their ranges northwards. *Nature* 399: 213.
- Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley and J.H. Pollard. 2002. Distance 4.0. Release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. <http://www.ruwpa.st-and.ac.uk/distance/>
- Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, J.H. Pollard and J.R.B. Bishop. 2004. Distance 5.0. Release Beta 3. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. <http://www.ruwpa.st-and.ac.uk/distance/>
- Walther, G.-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J.-M. Fromentin, O. Hoegh-gulberg and F. Bairlein. 2002. Ecological responses to recent climate changes. *Nature* 416: 389-395.
- White, P.C.L., G. Saunders and S. Harris. 1996. Spatio-temporal patterns of home-range use by foxes (*Vulpes vulpes*) in urban environments. *Journal of Animal Ecology* 65: 121-125.