The Effects of Climate Change on Migratory Birds:

an annotated bibliography

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Introduction

There is a general consensus among the world's scientific community that anthropogenic activities are enhancing the planet's natural 'greenhouse effect' thereby accelerating global warming, with many consequences for climate. Climate change is currently regarded as a serious environmental problem by many scientists and governments.

The possible effects of such changes on global biodiversity are extremely difficult to anticipate. It is clear from the fossil record that the earth has experienced many severe changes both in overall climate, and in the distribution of climatic regions, with concomitant extinctions (and consequent speciation bursts) in many taxa. The general observation that biodiversity as a whole has proved capable of adapting to climate change, cannot justify either ignoring the problem, or concluding that it is trivial. First, unlike previous periods of rapid climatic change, organisms are now subject to many other stresses inflicted upon them by human activity, that are likely to reduce their capacity to respond through natural evolutionary adaptation. Second, the rate of climate change predicted to occur through human alteration of the atmosphere is much faster than past natural changes, e.g. 50 times faster than at the start of the present interglacial period (Gribbin 1990). Further, it is not particularly helpful to rely on the innate capacity of living organisms in general to adapt to environmental change, if we want to predict impacts on particular species in which we have an interest.

Birds are potentially useful as indicators of broader ecological effects of climate change (or, indeed, any other kind of environmental change) because they occupy a wide range of habitats, are generally close to the top of food chains (few birds are exclusively vegetarian), and because they are diurnal, often brightly coloured, and vocal, they have attracted the interest and affection of many students, amateur and professional alike. Consequently there is far better information on the distribution, numbers, and biology of birds than of any other group of organisms.

This annotated bibliography is part of a continuing literature review on known and potential impacts of climate change on birds, with a particular emphasis on those breeding in Canada. It provides a synthesis of about 100 key recent scientific papers and reports relevant to climate change and birds. We include some works referring to species that do not occur in Canada (e.g. penguins) because there are ecologically similar taxa that do breed in Canada but for which there have not been equivalent studies on effects of climate. Our main aim is to include work which captures (i) the climatic variables (temperature,

rainfall etc.) to which birds seem most likely to respond; and (ii) the most likely ways in which birds will respond to those changes (e.g. breeding season, clutch size, etc.).

Four main databases were searched to locate these papers: Agricola, Biological Abstracts, Aquatic Fisheries and Sciences, and Forestry Abstracts. For each database search, keywords - such as birds, seabirds, songbirds, shorebirds, waterfowl, penguins, ducks, and geese - were searched in combination with the terms 'global warming' and 'climate change'.

The climatic variables most often identified as influencing bird responses included: air temperature rise, sea surface temperature rise, sea level rise, drying of wetlands, and sea ice variability. Approximately 65% of the literature reviewed referred to recent advances in breeding season that were correlated with warmer air temperatures in spring.

Much of the literature reviewed, especially the older works, consists of what might best be termed 'informed speculation'. The recent explosion of interest in global climate change has had a 'bandwagon effect' in which researchers are tempted to 'see climatic change behind every shift in an animal's distribution' (Burton 1995). Consequently, many publications include the terms 'climate change' or 'global warming' but do not provide convincing evidence of such relationships; rather, climate effects have been added to (or are now the focus of) speculative discussion on possible causes of changes observed in birds' biology. In general we have not included such works, though a few early examples that may be regarded as stimulating later work have been included (e.g. Brown 1991).

References are presented (i) in reverse chronological order, by year, i.e. all references dated 2001 first, back to 1990; earlier papers are combined as '1989-1972'; and (ii) in alphabetical order by first author, within each year or group of years. This demonstrates the very recent origin of most of this literature. In most cases the abstract we provide is our own, but in a few cases we have used that provided by the authors.

References

Brown, R.G.B. 1991. Marine birds and climatic warming in the northwest Atlantic. *in* Montevecchi, W.A. and Gaston, A.J. (eds.) Studies of high-latitude seabirds. 1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology. Occasional Paper Number 68. Canadian Wildlife Service, Ottawa.

Burton, J.F. 1995. Birds and climate change. Christopher Helm, London.

Gribbin, J. 1990. Hothouse earth: the greenhouse effect and Gaia. Bantam Press, London.

2001

Both, C.; Visser, M.E. 2001. Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. *Nature* 411(6835):296-298.

Spring temperatures in the temperate regions have increased over the past 20 years. In this report, the researchers showed that the adaptation to climate change in a long-distance migrant is constrained by the timing of its migration journey. For long-distance migrants, climate change may advance the phenology of their breeding areas, but the timing of some species' spring migration relies on endogenous rhythms that are not affected by climate change. Thus, the spring migration for these species will not advance even though they need to arrive earlier on their breeding grounds to breed at the appropriate time.

The researchers showed that the migratory Pied Flycatcher *Ficedula hypoleuca* has advanced its laying date over the past 20 years in the Netherlands. This temporal shift has been insufficient, however, as indicated by increased selection for earlier breeding over the same period. The shift is hampered by its spring arrival date, which has not advanced.

Some of the numerous long-distance migrants will suffer from climate change, because either their migration strategy is unaffected by climate change, or the climate in breeding and wintering areas are changing at different speeds, preventing adequate adaptation.

Martin, T.E. 2001. Abiotic vs. biotic influences on habitat selection of coexisting species: climate change impacts? *Ecology* 82 (1): 175-188.

Species are commonly segregated along gradients of microclimate and vegetation. The question of whether segregation is the result of microhabitat partitioning (biotic effects) or choice of differing microclimates (abiotic effects) was explored in this study. The question was explored for four ground-nesting bird species that were segregated along a microclimate and vegetation gradient in Arizona.

Birds shifted position of their nests on the microhabitat and microclimate gradient in response to changing precipitation over nine years. Similarly, annual bird abundance varied with precipitation across 12 yr. Those shifts in abundance and nesting microhabitat with changing precipitation demonstrated the importance of abiotic influences on bird distributions and habitat choice. However, nest-site shifts and microhabitat use also appeared to be influenced by interactions among coexisting species.

Moreover, shifts in habitat use by all species caused nest predation (i.e., biotic) costs that increased with increasing distance along the microclimate gradient. These results indicate that abiotic and biotic costs can strongly interact to influence microhabitat choice and abundances of coexisting species. Global climate change impacts have been considered largely in terms of simple distributional shifts, but these results indicate that shifts can also increase biotic costs when species move into habitat types for which they are poorly adapted or that create new biotic interactions.

Pennisi, E. 2001. Early Birds Miss the Worms. *Science Now* p.4.

A long-term study published in the 30 March issue of Science confirmed the toll that breeding can take if nature doesn't cooperate. Each spring since the 1970s, evolutionary ecologist Jacques Blondel of the Centre of Functional and Evolutionary Ecology in Montpellier, France, has studied Blue Tits in Corsica. Typically, Blue Tits in the two locales breed in different habitats--evergreen oak trees in Corsica, and deciduous oaks around Montpellier. Yet some of the continental birds were atypical and nested in local evergreen oak forests, like the ones in Corsica.

Four years prior to this report, Blondel and Donald Thomas, a physiological ecologist at the University of Sherbrooke in Quebec, Canada injected isotopes, and the researchers learned that the Montpellier birds breeding in evergreen oak forests used almost twice as much energy in rearing their young as the birds in Corsica did. The birds hopped about at a rate that they couldn't sustain for long periods of time.

The reason was inaccurate timing on the part of the Montpellier birds. The Corsica Blue Tits breed in June, when new leaves come out and leaf-munching caterpillars are most abundant. On the continent, most birds breed 3 weeks earlier, coinciding with the greening of the deciduous oaks and, again, an abundance of caterpillars. That puts the atypical population nesting in evergreen oaks near Montpellier at a disadvantage. Those trees are not budding, and caterpillars have not yet emerged in May. Out of synchrony with their food source, those birds had to work much harder. That would burn fat reserves, leaving the birds more vulnerable to starvation during the winter.

The new work confirmed that breeding too early had negative consequences. Thus, the work hinted that as climate changes and the timing of the seasons shifts, more populations of birds will become maladapted to breeding.

United States Environmental Protection Agency 2001. http://www.epa.gov/globalwarming/ impacts/birds/index.html. April 6, 2001.

Global warming was expected to primarily affect birds in both direct and indirect ways. Directly, higher temperatures could alter their life cycles. Indirectly, food may be become less available to birds, and habitat loss could occur, which may include beaches and wetlands.

With the progression of global warming, birds of the Northern Hemisphere have been able to inhabit more northerly areas. Data collected by the National Audubon Society's Christmas Bird Count show that during years with warmer temperatures, the majority of birds do not have to fly as far south for the winter. Warmer temperatures also allowed birds to spend their summers farther north.

A 1997 study examined the impact of warmer summers on the bobolink (a North American songbird). During summer, this bird can be found throughout New England, the states that border the Great Lakes, and north of a line stretching from Missouri to Idaho. With a doubling of carbon dioxide, the bobolink will be expected to only be found north of the Great Lakes.

Warmer temperatures have also been found to affect how birds respond to the change in seasons. For instance, many species that fly north in the spring to states such as Michigan arrive two or three weeks earlier than they did in 1960. Similarly, data from the British Trust for Ornithology have indicated that 20 of 65 species in Britain have been initiating egg-laying an average of 9 days earlier today than in 1971.

The long term consequences of these changes may be visible in only some cases. The earlier nesting trend seemed to be linked to earlier arrival of flowering plants and insects in spring; this change allowed birds to initiate nesting sooner because of earlier food availability. On a positive note, earlier nesting meant that juveniles would be a week or two older than usual when the time for southern migration would arrive. Being older and thus stronger could improve their odds of survival during the trip and the first winter. On a negative note, the changing climate could impair the degree to which a bird's life cycle is in synchrony with that of its food. Furthermore, as birds fly further north to deal with the global warming trend, their prey and/or vegetation upon which they feed may take years or decades to also adjust.

Bird habitat (characterized somewhat by landscape and vegetation) may also fail to migrate as quickly north as do the birds. As an example, the loss of estuarine beaches caused by sea level rises could decrease available habitat for the Least Tern, an endangered species. The loss of estuarine beaches would also decrease feeding areas for shorebirds that rely on horseshoe crabs found in intertidal areas. The loss of Louisiana's wetlands could have an adverse impact on international migratory birds that use the Mississippi flyway for travel. Similarly, the decline in prairie potholes would decrease duck populations. A drier climate would decrease the amount of open water ponds in the prairie potholes in the Northern Great Plains, and thus the number of ducks able to breed there. A 1© C warming would decrease duck populations by 25% if rainfall were to remain constant. A 8% increase in rainfall would be required to offset the deleterious effect of a 1^{o}C warming. In addition, a study at the University of Michigan revealed that a 15% increase in rainfall along with the 1^{o}C warming would actually increase duck populations by 25%. Realistically, however most climate change models have suggested that rainfall in the Great Plains will actually decrease (and perhaps far less than 8%). This state of climatic conditions would not sustain the ducks' habitat in the Great Plains. Therefore, it would seem likely that duck populations would actually decline in the future.

Yom-Tov, Y. 2001. Global warming and body mass decline in Israeli passerine birds. *Proceedings of the Royal Society of London Series B – Biological Sciences* 268(1470):947-952.

In Israel, minimum summer temperatures increased by an average of 0.26^{o}C per decade during the second half of the 20th century. Bergmann's rule predicts that, in warm-blooded animals, races from warm regions are smaller than races from cold regions. Numerous studies have reported general correlations between body mass in fossil animals and independently established

palaeoclimatic changes from various parts of the world in accordance with this rule.

Using museum specimens, the researcher tested the prediction that the body mass and tarsus length of five resident passerine species in Israel declined between 1950 and 1999. The body mass of four species (Graceful Warbler *Prinia gracilis*, House Sparrow *Passer domesticus*, Yellow-vented Bulbul *Pycnonotus xanthopygos* and Sardinian Warbler *Sylvia melanocephala*, but not Crested Lark *Galerida cristata*) declined significantly during this period. Tarsus length also declined significantly during this period in two species (Graceful Warbler and House Sparrow). Body condition (body mass-to-tarsus length ratio) decreased in Sardinian Warbler, Yellow-vented Bulbul and Crested Lark.

It was suggested that the above declines in body mass and tarsus length were due to global warming and also in accordance with Bergmann's rule. The above explanation does not exclude the possibility that other factors, such as a decrease in food availability, contributed to the decline in body mass. These declines may have serious implications for community structure and competition among bird species and may affect the survival of small passerines.

Zalakevicius, M. and Zalakeviciute, R. 2001. Global climate change impact on birds: a review of research in Lithuania. *Folia Zoologica* 50(1):1-17.

The aim of this paper was to demonstrate the effect of climate change on different migratory processes: spring arrival, migratory take-off, spring and autumnal migration. The analysis of arrival dates of 128 bird species registered in Zuvintas and 48 species registered in Vilnius showed that, under the effect of global warming, spring arrival became markedly earlier both for short- and long-distance migrants. The difference between these arrival dates was more pronounced at the beginning of the arrival season, and it was less at the end of the season for short-distance migrants but more constant for long-distance migrants.

The researchers tried to explain the effect of climate change mechanisms controlling migratory movements. The article presented material confirming the impact of global climate change on different breeding bird species and populations, changes of their ranges and population state. It was established that the impact of global warming upon birds of terrestrial and wetland complexes was more evident than upon waterfowl.

They also attempted to explain changes in bird staging and wintering concentrations areas due to climate change. Attention was focused on aspects of the effect of climate change upon birds in environmental protection, aviation flight safety and other branches of economy.

2000

Budd, G.M. 2000. Changes in Heard Island glaciers, king penguins and fur seals since 1947. *Papers and Proceedings of the Royal Society of Tasmania* 133 (2): 47-60.

The changes in glaciers, king penguins and fur seals reported by the nine wintering parties and 11 summer expeditions that have visited Heard Island since 1947, were discussed and summarized, with emphasis on those of the years between 1947 and 1971. These early years were notable for an initial period (1947-1955) of minimal change, and a subsequent period (1963-1971) of rapid change, in which a complex pattern of asynchronous glacier retreat and re-advance was observed and the main features of the island's recolonization by king penguins and fur seals were established.

Subsequent expeditions (1980-1993) have reported continuing glacier recession, evidently in response to warmer air temperatures, and a continuing exponential increase in numbers of king penguins and fur seals. The glacier observations show that the Heard Island glaciers are sensitive indicators of climate change in the Southern Ocean, and of the interactions between climate and glacier topography. The island's recolonization by king penguins and fur seals is attributed mainly to an improved food supply which may itself, like the glacier recession, be a response to changes in atmospheric and oceanic circulation.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent? *Trends in ecology and evolution* 15(2): 56 – 61.

Recent patterns of warming, which have been described as human-induced and anomalous with past natural climatic variability, have already affected the distribution and abundance of species in ways consistent with theoretical predictions. Marine birds have been sensitive to ocean warming, even to short-term sea surface temperature changes.

The Sooty Shearwater (*Puffinus griseus)* population of western North America had declined by 90% between 1987 and 1994 presumably due to increased sea surface temperature that decreased the availability and distribution of their prey, zooplankton. Distribution of terrestrial birds has also been affected by ocean warming. Ocean warming, especially in the tropics and at higher elevations, has accelerated global warming by increasing the amount of latent heat released from warmed waters that condenses. This process has caused a lifting cloud base as well as decreased dry mist frequency. Results of a study conducted on a 1540 m plot at Monteverde, Costa Rica revealed that numbers of birds have declined and that "cloud-forest intolerant" bird species have migrated upslope in association with decreased dry mist frequency.

The northern limits of distribution for 59 bird species in the south of Britain had expanded on average by 19 km over a 20 year period (1988-1991 compared with 1968-1972). Similarly, 14 bird species in western USA had expanded northward in their nesting distributions, 4 had expanded southward, 5 expanded westward, and one expanded radially. This northward expansion had presumably occurred because of decade-long increase in summer rainfall

beyond their former ranges. 20 out of 65 species monitored in in Britain displayed trends in earlier egg laying in 1995 than in 1971; on average, they were found to lay eggs 8.8 days earlier than in 1971. A more extensive study of 57 years with British birds showed that 19 out of 36 species laid their eggs late in the 1960s and 1970s and earlier in the 1980s and 1990s. Long-term studies of individual bird species in Europe and USA showed trends towards earlier reproduction, larger clutch sizes, and quicker development times

Huyser, O.; Ryan, P.G.; and Cooper, J. 2000. Changes in population size, habitat use and breeding biology of Lesser Sheathbills *Chionis minor* at Marion Island: impacts of cats, mice and climate change? *Biological Conservation* 92:299-310.

The Lesser Sheathbill *Chionis minor* is restricted as a breeding species to the Antarctic and sub-Antarctic; they are found at four sub-Antarctic island groups in the southern Indian Ocean. One island group, the Prince Edward Islands, comprising Marion and Prince Edward Island, support the Lesser Sheathbill, but marked differences have developed over the last 20 years in winter habitat use and population trends of sheathbills between the two islands. In 1978, for instance, studies found that Lesser Sheathbills at Marion Island left penguin colonies in the winter and either 1) moved inland to feed on macroinvertebrates occurring in vegetation of the coastal plain, or 2) moved to the coastline to forage in the intertidal zone and among washed up seaweed on the shore. The picture in the 1980s and 1990s became much different on Marion Island. Almost all sheathbills occurred on the coast, where they fed almost exclusively on the shoreline or in association with the remaining penguin species (ie, King Penguin *Aptenodytes patagonicus* and Gentoo Penguin *Pygoscelis papua*). This switch in winter foraging behaviour had not occurred on the adjacent Prince Edward Island. On the latter island, the Lesser Sheathbills, occurred at higher densities and forage mostly throughout the coastal plain. Compared to the 1970s, in a most recent study, sheathbills at Marion Island are now less abundant around most of the island, forage proportionately less in the coastal plain vegetation, commence breeding with a lower body mass and lay smaller clutches.

The main biological difference between the two islands is the presence of many more introduced species at Marion Island than at Prince Edward Island. At Marion Island, there has been a decrease in terrestrial macro-invertebrates, a former important prey item in winter for Lesser Sheathbills. In addition, Marion Island had an introduction of house mice *Mus musculus* that were accidentally brought to the island by sealers 180 years ago. Feral cats were then brought to Marion Island to control the mice problem, but then were eradicated in the early 1990s. At present researchers are hypothesizing that house mice are consuming the macro-invertebrate prey items of the sheathbills in the winter, thus impacting their current population status. This impact has only been intensified with the recent eradication of the feral cats and the massive reduction in burrowing petrels; these birds promote invertebrate populations through manuring. Global warming was also suggested as a possible culprit in the lesser sheathbill decline

on Marion Island, which may be a promoter of higher densities of mice. Given the likelihood of further climatic warming, this complex web of interactions between sheathbills, introduced species, invertebrates and burrowing petrels needs further study as the exact nature of the interactions remains unclear.

Inouye, D.W.; Barr, B.; Armitage, K.B.; and Inouye, B.D. 2000. Climate change is affecting altitudinal migrants and hibernating species. *Proceedings of the National Academy of Sciences of the United States of America* 97 (4): 1630-1633.

Calendar date of the beginning of the growing season at high altitude in the Colorado Rocky Mountains is variable but has not changed significantly over the past 25 years. This result differs from growing evidence from low altitudes that climate change is resulting in a longer growing season, earlier migrations, and earlier reproduction in a variety of birds.

At this study site, the beginning of the growing season was controlled by melting of the previous winter's snowpack. Despite a trend for warmer spring temperatures, the average date of snowmelt has not changed, perhaps because of the trend for increased winter precipitation. This disjunction between phenology at low and high altitudes may create problems for species of birds that migrate over altitudinal gradients.

Data were presented indicating this already may be true for American Robins, which are arriving 14 days earlier than they did in 1981; the interval between arrival date and the first date of bare ground has grown by 18 days. Migrants may experience problems as a consequence of these changes in phenology, which may be exacerbated if climate models are correct in their predictions of increased winter snowfall in this study area.

Kitaysky, A.S. and Golubova, E.G. 2000. Climate change causes contrasting trends in reproductive performance of planktivorous and piscivorous alcids. *Journal of Animal Ecology* 69:248-262.

Oceanographic changes in Tauyskaya Bay led to differences in prey availability for two families of alcids that had opposite effects on their reproductive success. Specifically, planktivorous auklets and piscivorous puffins differed significantly in their reproductive response to the oceanographic variable, sea surface temperature (SST). SST had fluctuated by +/- 1.2^{o}C in from 1987-1994; the direction of wind driven vectors was important in determining fluctuations in SST in the Tauyskaya Bay ecosystem. A positive SST was characterized by warm temperatures in the summer and associated with a pattern of early ice disappearance during the 8-year study; a negative SST was characterized by cold temperatures and late ice disappearance.

Planktivorous auklets, Crested Auklets *Aethia cristatella* and Parakeet Auklets *Cyclorrhynchus psittacula*, demonstrated higher reproductive success during cold years than did piscivorous puffins, Horned Puffins *Fratercula corniculata* and Tufted Puffins *Fratercula cirrhata*. Conversely, Crested Auklets and Parakeet Auklets were less reproductively successful than were Horned Puffins and Tufted Puffins during warm years. Reproductive success was

evaluated by the mean number of chicks fledged per occupied nest. Differences in reproductive success were a reflection of the accessibility of prey to foraging parent alcids.

The prey of the auklets – macro-zooplankton, such as oceanic copepods - were particularly accessible during cold years due to their high density within cold eddies, which were close to the auklet breeding island in the middle of Tauyskaya Bay. However, during warm years, cold, oceanic water was separated from bay water by the Kuril-Jamskoe oceanographic fronts, thus making oceanic inflow and macro-zooplankton less available to parent auklets.

The fish prey of puffins were abundant during warm temperature regimes due to the increase of meso-plankton, upon which fish feed. *Acartia sp.* and *Pseudocalanus sp.* - two abundant genera of meso-plankton - were too small for the auklets to capture and deliver to their young. Probably the prey of the auklets were too dispersed and/or isolated in cold waters away from their breeding island, which made foraging less optimal for these species of auklets.

Kraaijeveld, K.; and Nieboer, E.N. 2000. Late Quaternary paleogeography and evolution of arctic breeding waders. *Ardea* 88 (2): 193-205.

This review linked published data on mitochondrial DNA phylogeography of three wader species breeding in the Arctic to the availability of suitable breeding habitat during the past 250 000 years. These researchers argued that the breeding ranges of arctic waders were most restricted in size during warm phases in the earth's climate (interglacials), resulting in population bottlenecks in species breeding in the high arctic zone, such as Red Knot *Calidris canutus* and Ruddy Turnstone *Arenaria interpres*, and population contraction and the initiation of genetic divergence in low arctic species, such as Dunlin *Calidris alpina*. When the climate cooled, all species could spread over larger areas. However, large ice-sheets fragmented tundra habitat, which resulted in more differentiation. Subspecies of Dunlin that became isolated during or before the last glacial period were genetically distinct, while those that originated after the glacial could not be distinguished using mitochondrial DNA. The sensitivity of waders breeding in the high Arctic to increases in global temperature raises concerns over the effect of possible global warming due to anthropogenic factors on these species.

Lennon, J.J.; Greenwood, J.J.D.; and Turner, J.R.G. 2000. Bird diversity and environmental gradients in Britain: a test of the species-energy hypothesis. *Journal of Animal Ecology* 69 (4): 581-598.

The species diversity-energy hypothesis was tested using British bird fauna. This predicts that temperature patterns should match diversity patterns. Also, the hypothesis that the mechanism operates directly through effects of temperature on thermoregulatory loads was tested; this further predicts that seasonal changes in temperature cause matching changes in patterns of diversity, and that species' body mass is influential.

Four assemblages were defined using migration status (residents or visitors) and season (summer or winter distribution). Records of species' presence/absence in a total of 2362, 10 x 10-km, quadrats covering most of Britain were used, together with a wide selection of habitat, topographic and seasonal climatic data. A logistic regression model was fitted to each species' distribution using the environmental data. Then, these individual species models were combined mathematically to form a diversity model.

Analysis of this composite model revealed that summer temperature was the factor most strongly associated with diversity. Although the species-energy hypothesis was supported, the direct mechanism, predicting an important role for body mass and matching seasonal patterns of change between diversity and temperature, was not supported. However, summer temperature was the best overall explanation for bird diversity patterns in Britain. It was a better predictor of winter diversity than winter temperature. Winter diversity is predicted more precisely from environmental factors than summer diversity. Climate change was likely to influence the diversity of different areas to different extents; for resident species, low diversity areas may respond more strongly as climate change progresses. For winter visitors, higher diversity areas may respond more strongly, while summer visitors are approximately neutral.

Minin, A.A. and Gutnikov,V. 2000. A Pheno-indication of current fluctuations in climate in the European part of Russia, as exemplified by some forest-forming species and birds. *Lesovedenie* 2: 68-71.

Studies have been made over the last 30 years, recording the dates of leaf flushing of *Betula pendula*, flowering of *Prunus padus* and *Sorbus aucuparia*, the arrival of starlings *Sturnus vulgaris*, and the first song of the cuckoo *Cuculus canorus* on the territory of the Russian plain. Analysis of these phenological records indicated an increase in mean annual air temperature. Leaf flushing and flowering in trees is occurring earlier, especially in the north of the region, leaf fall is later, and the growing season is becoming longer. However, there are specific regional features for these phenomena which cannot be explained merely by changes in air temperature. Changes in seasonal bird behaviour were not correlated with the observed climate warming.

Najjar, R.G.; Walker, H.A.; Anderson, P.J.; Barron, E.J.; Bord, R.J.; Gibson, J.R.; Kennedy, V.S.; Knight, C.G.; Megonigal, J.P.; O'Connor, R.E.; Polsky, C.D.; Psuty, N.P.; Richards, B.A.; Sorenson, L.G.; Steele, E.M.; and Swanson, R.S. 2000. The potential impacts of climate change on the mid-Atlantic coastal region. *Climate Research* 14 (3): 219-233.

This paper assessed the potential impacts of climate change on the mid-Atlantic coastal (MAC) region of the United States. In order of increasing uncertainty, it was projected that sea level, temperature and streamflow will increase in the MAC region in response to higher levels of atmospheric CO_2. A case study for Delaware based on digital elevation models suggested that, by the end of the 21st century, 1.6% of its land area and 21% of its wetlands will be

lost to an encroaching sea. Sea-level rise will also result in higher storm surges, causing 100 yr floods to occur 3 or 4 times more frequently by the end of the 21st century. Increased accretion in coastal wetlands, however, which may occur in response to increases in CO_2, temperature, and streamflow, could mitigate some of the flooding effect of sea-level rise.

Warming alone will result in northward displacements of some mobile estuarine species and will exacerbate the already low summer oxygen levels in mid-Atlantic estuaries because of increased oxygen demand and decreased oxygen solubility. Streamflow increases could substantially degrade water quality, with significant negative consequences for submerged aquatic vegetation and birds.

Peacock, L.; Paulin, M.; Darby, J. 2000. Investigations into climate influence on population dynamics of Yellow-eyed Penguins *Megadyptes antipodes*. *New Zealand Journal of Zoology* 27(4): 317-325.

Since 1980, the Yellow-eyed Penguin *Megadyptes antipodes* has had three seasons of poor breeding success or low adult survival. Causes for poor seasons are not identified but could be related to climate - in particular, the El Nino-Southern Oscillation event, which affected ocean currents and climate over the penguins' range.

These researchers carried out an exploratory analysis to determine whether fluctuations in penguin population variables were correlated with fluctuations in climate variables. Population variables across breeding areas showed consistently strong correlations with rainfall and sea surface temperature. They modelled changes in climate variables and penguin population variables to test whether the effect could be explained as a chance correlation.

Investigations using these models indicated that the observed relationship was unlikely to have been due to chance. The models also suggested that fledgling success increased in seasons that were slightly cooler and wetter than average. Modeling studies were also carried out on a historical dataset of penguin population variables in the 1930s. It was found that the population tended to increase in seasons that were warmer and drier than average. Average temperatures have risen and average precipitation levels have become highly variable in the study area during this time. Therefore, long term climate change in general, rather than the El Nino Southern Oscillation events in particular, could be among the underlying causes of gradual decline in Yellow-eyed Penguin numbers.

Przybylo, R.; Sheldon, B.C.; and Merila, J. 2000. Climatic effects on breeding and morphology: evidence for phenotypic plasticity. *Journal of Animal Ecology* 69:395-403.

Cross-sectional studies were conducted over a 16 year period on Collared Flycatchers *Ficedula albicollis* in Gotland, Sweden, to observe how different values of the North Atlantic Oscillation (NAO) index had affected breeding

performance and cohort-specific morphology (both sexes) within and across individuals. Sweden had experienced significantly warmer, moister winters during the 16-year study, which were largely associated with positive winter NAO-index values. Collared Flycatchers had experienced at least two winters with positive NAO-index values during the 16 years.

NAO-index values did not influence wing length significantly. Systematic decreased male tarsus length was attributed to undernourishment during the nestling stage, which was the result of increased population density during the 16 year period. A longitudinal study showed that following positive winter NAO-index values, female flycatchers laid eggs earlier as well as larger clutches; however, NAO indices did not influence fledging success within individuals. Similar patterns were observed across individuals in the cross-sectional analyses suggesting that the population level response to NAO indices was the result of environmentally-dependent genotype expression.

Saether, B.E.; Tufto, J.; Engen, S. 2000. Population dynamical consequences of climate change for a small temperate songbird. *Science* 287(5454):854-6.

Predicting the effects of an expected climatic change requires estimates and modeling of stochastic factors as well as density-dependent effects in the population dynamics. In a population of a small songbird, the Dipper *Cinclus cinclus,* environmental stochasticity and density dependence both influenced the population growth rate. About half of the environmental variance was explained by variation in mean winter temperature.

Including these results in a stochastic model showed that an expected change in climate will strongly affect the dynamics of the population, leading to a nonlinear increase in the carrying capacity and in the expected mean population size.

Sillett, T.S.; Holmes, R.T.; and Sherry, T.W. 2000. Impacts of a global climate cycle on population dynamics of a migratory songbird. *Science* 288 (5473): 2040-2042.

Progress toward understanding factors that limit abundances of migratory birds, including climate change, has been difficult because these species move between diverse locations, often on different continents. For Black-throated Blue Warblers *Dendroica caerulescens*, demographic rates in both tropical winter quarters and north temperate breeding grounds varied with fluctuations in the El Nino Southern Oscillation.

Adult survival and fecundity were lower in El Nino years and higher in La Nina years. Fecundity, in turn, was positively correlated with subsequent recruitment of new individuals into winter and breeding populations. These findings demonstrated that migratory birds can be affected by shifts in global climate patterns and emphasize the need to know how events throughout the annual cycle interact to determine population size.

Stempniewicz, L.; Goc, M.; Bzoma, S.; Nitecki, C.; Iiszko, L. 2000. Can timing and synchronisation of breeding affect chick mortality in the Great Cormorant *Phalacrocorax carbo*? *Acta Ornithologica* 35(1):33-39.

In 1996, following a relatively severe and prolonged winter, Great Cormorants started to breed at the Katy Rybackie colony (NE Poland) one month later than in 1995 but breeding finished at the same time in both years. The estimated total food consumption of the Cormorants was lower during the shorter and more synchronised 1996 breeding season (737 tonnes) than in 1995 (805 tonnes) despite the larger population present in 1996 (5929 pairs) than in 1995 (4942). However, during the period of peak energy need in June the estimated total daily food consumption of Cormorants present in the colony was about 2 tonnes higher in 1996.

In June 1996, after a couple of windy days, 24.3% of chicks died and the total fledging success was lower (2.19 fledglings/nest) than in 1995 (2.45). The observed mass chick mortality could be due to the combined effect of strong breeding synchronisation, decreased food availability, and increased costs of foraging due to strong winds. Large breeding colonies of Cormorants can function successfully only when the suitable breeding period is prolonged and breeding can start early.

Long-term climate change due to global warming could have favoured the observed Cormorant population increase during the last decades and its expansion into NE Europe. Asynchrony could be adaptive towards alleviating the food requirements of both individual broods and the whole colony.

Stevenson, I.R. and Bryant, D.M. 2000. Climate change and constraints on breeding. *Nature* 406:366-367.

This study described an energy trade-off between reproduction and maintenance that occurred during cold weather in Great Tits *Parus major*, pointing to a thermal constraint on the timing of egg laying. The researchers used the doubly labelled water technique to study the daily energy expenditure (DEE) of laying Great Tits in central Scotland during 1997 and 1998.

DEE increased as ambient temperatures fell, probably as a result of increased thermostatic requirements or temperature-dependent food availability. After controlling for temperature, high DEE was also associated with the production of large eggs in 1997. The association of high energy-expenditure with both low temperatures and production of large eggs suggested that there were energetic constraints on the fitness benefits of earlier laying. Large eggs increase fitness because they produce heavier fledglings, which in turn, have a higher recruitment rate, but low temperatures may hamper the formation of such eggs. In 1997, the largest eggs were associated with DEE at or above four times the basal metabolic rate (BMR), a widely-recognised ceiling for cost-free sustained metabolism.

Using data on body mass and on laying advancement in response to increased temperature, the researchers also found that laying was most

advanced in the smallest species. In the smaller species, their thermoregulatory costs would be relatively higher and more sensitive to temperature.

For the UK population of great tits, temperature consistently increased throughout spring, maintaining synchrony between nestlings and their food. However in a Dutch population, the laying date did not advance during 1973-95 but the peak of nestling food availability did, leading to reduced breeding success. By contrast, an Oxford population experienced parallel advances in both laying and hatching dates, with no decline in breeding success. If temperature acts as a cue to anticipate caterpillar emergence, selection may refine the use of this and other cues to resynchronize chicks with their food. This cannot happen, however, if temperature constrains laying date and egg size. The authors emphasise that "The fine-scale pattern of climate change could be critical to the reproduction of some species and underlies previously unexplained variation in the breeding success of other temperate birds….. to predict effects of climate change on populations and communities, we must understand the cues and constraints that determine the timing of breeding."

Sydeman, W.J. 2000. Climate change and the population biology of Common Murres and other seabirds of the California Current Marine Ecosystem. *Dissertation Abstracts International Part B: Science and Engineering* 60 (7): 3079.

The influence of physical and biological oceanographic processes on the biology of Common Murres *Uria aalge* and other seabirds in the California Current marine ecosystem was investigated. Proximate and ultimate factors influencing timing of breeding of murres from 1972-1997 were considered. Mean breeding date became earlier through time even though ecological conditions appeared to deteriorate. Based on the probability of fledging young, there appeared to be directional selection for early breeding throughout most years of study, and stabilizing selection in 3 years corresponding to a period when mean breeding date also appeared to stabilize.

The effects of low-frequency marine climate change on the reproductive performance of 11 species of marine bird from southern and central California, 1969-1997 were also studied. Change in the birds' abilities to provision young during May-July each year appeared closely related to temporal changes in reproductive performance. Changes in diet, possibly related to ocean warming, are likely responsible for changes in performance in both oceanographic domains.

Whipple, D. 2000. Sand County revisited. *Audubon* 102 (2):14-15.

Between 1936 and 1947, Leopold recorded the spring arrivals of birds and the blossoming of plants. In 1976, Leopold's daughter, plant ecologist Nina Leopold Bradley, returned to the Leopold Preserve is Wisconsin to carry on her father's work and has been keeping similar records ever since. The data showed that global warming is transforming the very mark of spring. By tracking 300 different natural events, Bradley is finding that at least one-third of these happen

earlier due to rising temperatures. Some species of birds and plants are adapting to temperature changes, but others are not and may be more vulnerable to extinction.

Wolf, B. 2000. Global warming and avian occupancy of hot deserts; a physiological and behavioral perspective. *Revista Chilena de Historia Natural* 73 (3): 395 - 400.

Avian adjustments to desert environments are characterized by an integration of behavior and physiology. These responses serve to maintain homeostasis and conserve vital resources such as water. The small size of birds confers a close coupling to the thermal environment and demands rapid adjustments to environmental challenges. Physiological responses to heat stress include hyperthermia, and increased evaporative cooling as environmental temperatures approach body temperature. Behaviorally, desert birds respond to heat stress by drastically reducing activity during the hottest parts of the day and selecting cool shaded microsites. This characteristic behavioral response presents a potential problem in the face of global warming. If birds totally forgo foraging during extremely hot periods, increased evaporative water loss rates due to higher environmental temperatures could lead to significant episodes of direct mortality for birds in these regions. A simple model was presented which integrated behavior and physiology to predict survival times based on dehydration tolerance, microsite selection and environmental temperature.

Wuethrich, B., 2000. How climate change alters rhythms of the wild. *Science* 287(5454): 793-794.

Author discussed the conclusions of biologists with respect to connection between changing bird phenology and populations and changing climate. Earlier breeding times of Mexican Jays *Aphelocoma ultramarina* of Chiricahua Mountains, Arizona may be a response to global warming. Average minimum spring temperatures had risen in Arizona by 2.7^{o}C between 1971 and 1998 during the months prior to the birds' breeding season. Interestingly, Mexican Jays had laid their eggs 10 days earlier by 1998.

From a reproductive standpoint, higher temperatures promoted earlier breeding by allowing the jays to stay warm and conserve energy during an energetically costly time. It also triggered an earlier appearance of insects, which provided extra calories for the Mexican Jays.

The high phase of the North Atlantic Oscillation (NAO) may be positively correlated with the increased population of dippers (*Cinclus cinclus)* observed in southern Norway between 1978 and 1997. The mild winter conditions associated with the NAO high phase prevented freeze over of stream beds from which dippers primarily caught their food. The favourable food supply probably promoted the high immigration and birth rate of dippers in this local population. If temperatures rise 2.5^{o}C in the decades ahead, dipper numbers are expected to soar by 58%.

1999

Agler, B.A.; Kendall, S.J.; Irons, D.B.; and Klosiewski, S.P. 1999. Declines in marine bird populations in Prince William Sound, Alaska coincident with a climatic regime shift. *Waterbirds* 22(1):98-103.

The population levels of marine bird species were compared in July 1972 to July 1989, 1990, 1991 and 1993 in Prince William Sound and were related to changes in prey type. In total, the marine bird community declined by 50% between these study periods. Seventeen piscivorous taxa that fed on schooling fish were compared between the two study intervals and were as follows: Red-throated Loon *Gavia stellata*; Pacific Loon *Gavia pacifica*; cormorants *Phalacrocorax* spp.; Surf Scoter *Melanitta perspicillata*; White-winged Scoter *Melanitta fusca*; mergansers *Mergus* spp.; Bonaparte's Gull *Larus philadelphia*; Mew Gull *Larus canus*; Glaucous-winged Gull *Larus glaucescens*; Black-legged Kittiwake *Rissa tridactyla;* terns *Sterna* spp.; Pigeon Guillemot *Cepphus columba*: *Brachyramphus* murrelets (*Brachyramphus marmoratus* and *Brachyramphus brevirostris*); Parakeet Auklet *Cyclorrhynchus psittacula*; Tufted Puffin *Fratercula cirrhata*; Horned Puffin *Fratercula corniculata*; and Northwestern Crow *Corvus caurinus*.

In the same study area, the population levels of eight non-piscivorous taxa were compared between 1972 and 1989-1993, which were as follows: Fork-tailed Storm Petrel *Oceanodroma homochroa*; Harlequin Duck *Histrionicus histrionicus*; Goldeneyes *Bucephala clangula* and *islandica*; Bald Eagle *Haliaeetus leucocephalus*; Black Oystercatcher *Haematopus bachmani*; jaegers *Stercorarius* spp.; murres *Uria* spp.; and Ancient Murrelet *Synthliboramphus antiquus*.

Data indicated that more piscivorous than non-piscivorous taxa declined between 1972 and 1989-1991. Of the seventeen piscivorous taxa studied, 14 declined. Of the eight non-piscivorous taxa studied, 5 increased. The *T/V Exxon Valdez* oil spill in 1989 contributed to the decline of some taxa, but a climatic regime shift in 1976-1977 was also related to the population declines found in this study. Marine bird declines occurred before the 1989 *Exxon Valdez* oil spill. Therefore, population declines caused by the climatic regime shift were exacerbated by the oil spill, although the oil spill was solely responsible for the die-off of selected species (loons, cormorants, mergansers, Black-legged Kittiwakes, murres, and Pigeon Guillemots)

Sea temperatures (upper 250 m) in the Gulf of Alaska had shifted from colder than average temperatures in the 1970s to warmer than average temperatures in the 1980s. These changes coincided with a change in forage fish abundance throughout the Gulf of Alaska.

Ahas, R. 1999. Long-term phyto-, ornitho- and ichthyophenological time-series analyses in Estonia. *International Journal of Biometeorology* 42 (3): 119-123.

This study analyzes a long-term phenological time series for the impact assessment of climate changes on Estonian nature and for the methodological study of the possible limitations of using phenological time series for climate trend analyses. These limiting factors can influence the results of studies more than the real impact of climate changes, which may have a much smaller numeric value. The 132-year series of the arrival of the skylark *Alauda arvensis* and the white wagtail *Motacilla alba*, the 78-year series of the blossoming of the wood anemone *Anemone nemorosa*, the bird cherry *Padus racemosa*, apple trees *Malus domestica* and lilacs Syringa vulgaris, and the 44-year series of the spawning of pike *Esox lucius* and bream *Abramis brama* were studied at three selected observation points in Estonia.

The study of the phenological time series shows that Estonian springs have, on the basis of the database, advanced 8 days on average over the last 80-year period; the last 40-year period has warmed even faster.

Anderson, P.J.; and Piatt, J.F. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. *Marine Ecology Progress Series* 189: 117-123.

A shift in ocean climate during the late 1970s triggered a reorganization of community structure in the Gulf of Alaska ecosystem, as evidenced in changing catch composition on long-term (1953 to 1997) small-mesh trawl surveys. Forage species such as pandalid shrimp and capelin declined because of recruitment failure and predation, and populations have not yet recovered. Total trawl catch biomass declined >50% and remained low through the 1980s. In contrast, recruitment of high trophic-level groundfish improved during the 1980s, yielding a >250% increase in catch biomass during the 1990s. This trophic reorganization apparently had negative effects on piscivorous sea birds and marine mammals.

Bergmann, F. 1999. Long-term increase in numbers of early-fledged Reed Warblers *Acrocephalus scirpaceus* at Lake Constance (Southern Germany). *Journal fur Ornithologie* 140 (1): 81-86.

Data from a standardized mist-netting programme (the so-called "MRI-Programm") were used to assess the timing of breeding in Reed Warblers *Acrocephalus scirpaceus* at Lake Constance (South Germany). The number of Reed Warblers fledged early in the season increased significantly between 1976 and 1997 ($r(s) = 0.614$; $p < 0.01$). This was most probably due to a long-term increase in spring temperature as suggested by the high correlation between the number of early-fledged Reed Warblers and mean temperature in the first half of May ($r(s) = 0.416$; $p < 0.01$).

While in the period from 1961 to 1980 the mean date of spring arrival was on the 26(th) of April, it shifted towards the 19(th) April from 1981 to 1997. However, the number of early-fledged Reed Warblers and the date of spring arrival were not significantly correlated. The lack of a significant correlation may be due to a number of reasons, for instance early arriving birds did not belong to the local population or there could be an observational bias among years. Yet,

the most likely explanation is that the timing of breeding in Reed Warblers was triggered by vegetation growth and food supply rather than by the timing of spring arrival.

There is growing body of evidence from this and other studies that the recent climate change is responsible for the shift in both the timing of migration and breeding in birds.

Bradley, A.L.; Leopold, A.C.; Ross, J.; and Huffaker, W. 1999. Phenological changes reflect climate change in Wisconsin. *Proc. Natl. Acad. Sci. USA* 96: 9701-9704.

A phenological study of springtime events was made over a 61-year period at one site in southern Wisconsin. The records over this long period at one site presented an opportunity to examine changes in the dates of occurrences of various phenophases over a period of climate change. Within the 61-year period, the surface temperatures of the planet had warmed. The records showed that several phenological events had been increasing in earliness.

Seventeen phenophases (values of 95% probability of significance) showed significant advances in springtime occurrence, eight of which were regression analyses of the changes in bird phenophases. In order of probability of significance, these included: Geese arrival (*Branta canadensis*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), Phoebe arrival (*Sayornis phoebe*), House Wren arrival (*Troglodytes aedon*), Cardinal first song (*Cardinalis cardinalis*), Robin arrival (*Turdus migratorius*), Whip-poor-will arrival (*Caprimulgus vociferus*), and Redwinged Blackbird arrival (*Agelaius phoeniceus*).

The data also indicate that 20 phenophases did not appear to be increasing in earliness with minimal divergence from the date of occurrence; 4/20 were phenophases of birds. These included: Bluebird arrival (*Sialia sialis*), Fox Sparrow arrival (*Passarella iliaca*), Towhee arrival (*Pipilio erythrophthalamus*), and Brown Thrasher arrival (*Toxostomum rufum*). These phenophases may be regulated by photoperiod or a physiological signal other than local temperature. Alternatively, they might require a stronger climate signal or may be unable to adapt to climatic warming. If the latter case is true, these birds may experience greater stress or even extinction during extended climatic change.

The remaining 18 phenophases showed intermediate regressions, and were statistically not assignable to the responder or the nonresponder class; 5/18 were phenophases of birds that included: Meadowlark arrival (*Sturnella magna*), Woodcock first peent (*Scolopax minor*), Great Blue Heron arrival (*Ardea herodias*), Kingfisher arrival (*Ceryle alcyon*), Cowbird arrival (*Morothrus ater*), Northern Oriole arrival (*Icterus galbula*),and Wood Thrush arrival (*Hylocicla mustelina*).

Brown, J.L.,; Li., S.H.; and Bhagabati, N. 1999. Long-term trend toward earlier breeding in an American bird: A response to global warming? *Proc. Natl. Acad. Sci, USA*. *Ecology* 96: 5565 – 5569.

For a population of Mexican Jays *Aphelocoma ultramarina* breeding in southeastern Arizona, trends in earlier egg laying and nesting were observed in a study conducted between 1971-1998. Mean laying date of the first egg per clutch had become earlier by 10.1 days. Similarly, the date of the first nest had advanced by 10.8 days. Earlier laying was weakly correlated with the amount of precipitation in the previous monsoon and the minimum temperatures in the months preceding breeding, namely March and April.

Buse, A.; Dury, S.J.; Woodburn, R.J.W.; Perrins, C.M.; and Good, J.E.G. 1999. Effects of elevated temperature on multi-species interactions: the case of Pedunculate Oak, Winter Moth and Tits. *Functional Ecology* 13:74-82.

The effects of temperature on the Oak-Winter Moth-Tit food chain were studied at Wytham Wood, Oxford, and experimentally in the controlled environment solardomes at the institute of Terrestrial Ecology, Bangor. Moth eggs laid later or maintained at cooler temperatures than average required fewer heat units to hatch. Caterpillars took up to 50 days to complete growth at field temperatures but did so in only 20 days at a constant 15 °C. The mass of Tit chicks at day 15 (day 1 = egg hatch) was positively correlated with temperature and negatively correlated with rainfall during the growing period. At elevated temperature, budburst and moth egg hatch were synchronized, but earlier. Late feeding larvae and larvae fed on leaves from trees grown at elevated temperature produced smaller pupae. Pupal mass was unaffected when caterpillars and trees were maintained together under the same conditions.

Delaying egg hatch in Tits, to simulate conditions at elevated spring temperatures, resulted in reduced chick mass, body size and fledging success. This occurred because chicks were fed later and prey quality was poorer, because the peak of caterpillar biomass was missed. It was predicted that moth reproductive output will be retained at elevated temperatures because both leaves and caterpillars develop faster. Brood size in birds may be reduced because they cannot lay early enough to coincide with the narrower peak of food abundance.

Crick, H.Q.P. and Sparks,T.H. 1999. Climate change related to egg-laying trends. *Nature* 399(6735): 423-4.

Evidence that egg-laying trends in U.K. breeding birds are related to climate change was provided. Analysis of a 57-year data set revealed that laying date is related to temperature or rainfall for 31 of 36 species. Furthermore, 53 percent of species showed long-term trends in laying date over time, of which 37 percent can be statistically accounted for by changes in climate.

Dunn, P.O.; Winkler, D.W. 1999. Climate change has affected the breeding date of tree swallows throughout North America. *Proceedings of the*

***Royal Society of London Series B - Biological Sciences* 266 (1437): 2487-2490.**

To explore for large-scale effects of climate change on avian reproduction, 3450 nest records of tree swallows *Tachycineta bicolor* were examined from across North America. The egg-laying date in tree swallows advanced by up to nine days during 1959-1991, which was consistent with advances of vegetation in the north. Studies of growing seasons have suggested that most of this change has occurred recently and at higher latitudes. Similarly, most Tree Swallows breed above 35°N and the advancement of their egg-laying date was stronger during the 1980s than the 1970s.

This advance in phenology was associated with increasing surface air temperatures at the time of breeding. The mechanism for earlier laying in Tree Swallows was probably an advancement in the date of emergence or peak abundance of aerial insects.

The analysis controlled for several potentially confounding variables such as latitude, longitude, breeding density and elevation. In conclusion, tree swallows across North America were breeding earlier and the most likely cause was a long-term increase in spring temperature.

Finney, S.K.; Wanless, S.; and Harris, M.P. 1999. The effect of weather conditions on the feeding behaviour of a diving bird, the Common Guillemot *Uria aalge. Journal of Avian Biology* 30 (1): 23-30.

A detailed investigation of the effects of weather conditions on the feeding behaviour of a pursuit diving seabird, the Common Guillemot *Uria aalge*, was carried out during the chick-rearing period at a colony in southeast Scotland in 1997. There was no evidence that the rate at which adults brought back fish for their chicks was related to weather conditions but the type of prey delivered was affected with birds bringing in smaller sandeels *Ammodytes marinus* in stormy weather. This resulted in a significant decrease in the mean energy value of a prey load and in the overall rate of energy intake of chicks.

The attendance behaviour of adults also varied in response to the prevailing weather conditions. The proportion of sites with chicks which had both adults present was significantly lower in stormy conditions indicating that, although the frequency at which Common Guillemots provisioned their chicks was not affected, birds were spending longer away foraging. Furthermore, information on diving behaviour collected using radio telemetry suggested that birds were working harder when conditions were bad with the number of dives in a bout, and hence the amount of time spent underwater, increasing significantly and the interval between consecutive diving bouts decreasing significantly.

Analysis of long-term data on chick provisioning and adult attendance for the study colony indicated that the observed reductions in the mean energy value of loads and the proportion of chicks attended by both adults in stormy weather, which were evident in the 1997 data, were also apparent across years. If the current climate change prediction of an increase in the frequency and/or intensity of storms at mid to high latitudes proves correct, such trends could have marked

energetic consequences for Common Guillemots in terms of increased foraging costs of adults and reduced energy intake of chicks.

Fortescue, M. 1999. Temporal and spatial variation in breeding success of the Little Penguin *Eudyptula minor* on the east coast of Australia. *Marine Ornithology* 27: 21-28.

A 10-year study of the Little Penguin *Eudyptula minor* on Bowen Island has revealed comparatively high breeding success for this large colony towards the northern limit of the species' range. Similarly high success has been found at nearby Lion Island. The colony is prone to episodic broad-scale changes of ocean and climate, including the global-scale El Nino Southern Oscillation (ENSO). These climatic changes influence to varying degrees the breeding success of colonies on the east coast of Australia.

The mean breeding success for first broods of the Bowen colony was 1.23 chicks/pair. This is the highest recorded for the species, and 20% of pairs lay second broods in the same season. Lion and Bowen Islands are characterised by distinctive native vegetation assemblages which provide high quality, formally protected, nesting habitat for penguins, and a marine environment predominantly influenced by the East Australia Current, contributing to higher breeding success.

Reduced foraging range of Bowen Island penguins during critical stages of the breeding cycle compared with other colonies in the south suggested regional oceanographic characteristics may influenced distribution of major diet items. There appeared to be a correlation between breeding success and latitude of breeding colonies.

Holmes, B. 1999. Heads in the clouds. *New Scientist* 162(2185):32-36.

Global warming may be to blame for the unusual behavior of birds in the cloud forests of Costa Rica. The forests grow on the sides of a mountain range that rises 1,500 meters above sea level and are notable for their high level of moisture. However, the number of dry days in each winter dry season has increased steadily since 1973, and evidence indicated a strong link between climate and movement of lowland bird species to higher altitudes.

Mason, C.F.; and Macdonald, S.M. 1999. Estuarine feeding by Lapwings *Vanellus vanellus* and Golden Plovers *Pluvialis apricaria*. *Wildfowl* 50: 205-207.

Preliminary observations were presented on intertidal feeding by Lapwings and Golden Plovers in eastern England. It is considered that the use of estuaries for foraging may be more prevalent than is realised. Warmer autumns resulting from global warming may make traditional feeding areas in cereal fields unsuitable due to rapid crop growth. More systematic data on estuarine feeding are required to determine if this is a developing habit.

Morgan, K.H. 1999. Impact of the 1997/98 El Nino on seabirds of the northeast Pacific. PCES Scientific Report No. 10. Proceedings of the 1998 Science Board Symposium on the Impacts of the 1997/98 El Nino Event on the North Pacific Ocean and its Marginal Seas, March 1999. pp. 83 – 87.

Six seabird surveys – May and August 1996, February and June 1997, and February and June 1998 – were conducted along a repeated 1500-km track in order to examine the impact of the 97/98 El Nino event on the pelagic seabird community. It was predicted that the warming of the coastal waters, the depression of the thermocline, and the northward displacement of the Subarctic Boundary would significantly influence their composition, abundance and distribution.

Results that tended to support this hypothesis were as follows:

- The overall bird density and species diversity during the three early summer cruises were lowest in June 1997, which also had the highest sea surface temperatures.
- In June 1997, bird species frequently associated with the continental shelf, such as Common Murre *Uria aalge*, Cassin's Auklet *Ptychoramphus aleuticus*, and Rhinoceros Auklet *Cerorhinca monocerata* were completely absent.
- In June 1997, Fork-tailed Storm Petrels *Oceanodroma furcata* - usually most abundant along the outer edge and over the slope - ranged considerably farther offshore. This finding suggested that this species was travelling greater distances to obtain food probably absent within their typical range.

Results that tended to contradict the original hypothesis were as follows:

- Densities of Dark Shearwaters (Sooty *Puffinus griseus* and Short-tailed Shearwaters *P.tenuirostris)*, and Leach's Storm-Petrel *Oceanodrama leucorhoa* surpassed the long-term summer densities. This observation is noteworthy, because warm sea surface temperatures persisted to at least June 1998. Also, dark shearwaters apparently "rebounded" from low counts in February 1997 to high counts in June 1997.
- Diversity of species returned to pre El Nino levels in June 1998 in contrast to the preceding year.
- There was no statistically significant relationship between species densities and the water characteristics tested (surface temperature, salinity, chlorophyll-*a* and nitrate levels).

In light of these observations, Morgan speculated that, during this three year study, perturbations in climatic/oceanographic conditions outside of the survey route may had altered normal migration routes leading to a depressed seabird abundance and altered species mix. Furthermore, a time lag could have existed between the changing physical characteristics of ocean and climate and the local seabird assemblage that would probably negate simple correlation tests between seabirds and water characteristics (that had been measured concurrently). Before the commencement of this study, the seabird community of the tested region may have been dramatically altered from a regime shift step change or because of inter-decadal fluctuations.

Norment, C.J.; Hall, A,; and Hendricks, P. 1999. Important bird and mammal records in the Thelon River Valley, Northwest Territories: range expansions and possible causes. *Canadian Field-Naturalist* 113 (3): 375-385.

This paper indicated changes in avifaunal records along the Thelon River Valley that were documented in 1971-1996. Out of the 50 bird species whose status was annotated, 9 had been newly reported breeding north of treeline as follows: Mallard *Anas platyrhynchos*, Green-winged Teal *Anas crecca*, American Wigeon *Anas americana*, Surf Scoter *Melanitta perspicillata*, Common Merganser *Mergus merganser*, Bald Eagle *Haliaeetus leucocephalus*, American Kestrel *Falco sparverius*, Mew Gull *Larus canus*, and Bonaparte's Gull *Larus philadelphia*. Recent warming during the 1970s and 1980s at the northern treeline may explain this northerly shift in breeding ranges.

Conversely, 3 tundra breeding species had extended their southern breeding ranges (Tundra Swan *Cygnus columbianus*, Greater White - fronted Goose *Anser albifrons*, and Long -tailed Jaeger *Stercorarius longicaudus*). Reported were 24 new species breeding in the Thelon Wildlife Sanctuary; these included Mallard, Green - winged Teal, American Wigeon, Mew Gull, and Yellow-rumped Warbler *Dendroica coronata*. Although these species had been noted previously in the Thelon Wildlife Sanctuary, they were outside of their normal breeding ranges. Also, the Sandhill Crane *Grus canadensis*, Long - tailed Jaeger, Parasitic Jaeger *Stercorarius parasiticus*, Short-eared Owl *Asio flammeus*, Gray-cheeked Thrush *Catharus minimus*, and Blackpoll Warbler *Dendroica striata* had extended their breeding ranges to include, not only the Thelon River area, but the Thelon Wildlife Sanctuary.

16 new species of birds were noted in the Thelon Wildlife Sanctuary. One included the American Kestrel, which also was confirmed to have bred in the sanctuary. Others included the Yellow Warbler *Dendroica petechia*, Wilson's Warbler *Wilsonia pusilla*, and Smith's Longspur *Calcarius pictus*, all of which were not confirmed breeders of the sanctuary.

It was hypothesized that Mallard, American Wigeon, Surf Scoter, Gyrfalcon *Falco rusticolus*, Yellow-rumped Warbler, and Rusty Blackbird *Euphagus carolinus* had colonized the middle Thelon River area since the 1930s due to climatic change in the forest-tundra. For boreal species that had colonized the Thelon Valley, warmer summer temperatures may have provided moderate climatic conditions for breeding birds. This would be beneficial in an area such as this, where severe weather would delay breeding or cause high mortality among breeding species.

An alternate hypothesis suggested that increased bird colonization of the Thelon River Valley was due to the spread of excess birds from southerly habitats into northerly uncolonized habitats.

Piatt, J.F.; Drew, G.; Van Pelt, T.; Abookire, A.; Shultz, M.; and Kitaysky, A. 1999. Biological effects of the 1997/98 ENSO in Cook Inlet, Alaska. PICES

Scientific Report. No. 10, 1999. Proceedings of the 1998 Science Board Symposium on the Impacts of the 1997/98 El Nino Event on the North Pacific Ocean and its Marginal Seas, March 1999. 93-99.

In lower Cook Inlet, Alaska, detailed studies of seabird biology were conducted in relation to oceanography and forage fish ecology since 1995. Seabird productivity (chicks/pair) was analyzed at Chisik Island and Gull Island in Kachemak Bay from 1995-1998. The two species evaluated were the Common Murre *Uria aalge* and Black-legged Kittiwake *Rissa tridactyla*.

At Gull Island murres maintained relatively high productivity during all 4 years of study. Their breeding success was highest during1996. Analyses of time budgets of Common Murres suggested that they had no difficulty in finding food during the 1997/98 ENSO; there was little variance in their diet during the 4 years.

By contrast, at Chisik Island Common Murres' breeding success approached 0, clutch initiation was delayed, and clutch attendance was erratic. Stress hormones were higher in murres in 1998 than in 1997, especially at the onset of breeding season. These results were significant, because Common Murres' breeding success and thus productivity are not usually sensitive to fluctuations in food supply. Murres are able to ability to adjust their foraging trip duration and "loafing time" to compensate for food variability.

As with Common Murre, Black-legged Kittiwake breeding success (chicks fledged/nest) was most reduced in 1998 at Gull Island in Kachemak Bay. During this event there was low laying and hatching success, and egg-laying was delayed by 3 weeks. Once hatched, fledgling survival was high. Past studies have indicated that low production events in past years have corresponded to ENSO warming events during Alaskan winters.

On Chisik Island, Black-legged Kittiwakes underwent a complete breeding failure (produced zero chicks). Clutch initiation was delayed by 2-3 weeks and birds failed during incubation earlier than usual.

Also, during the four-year study, a significant seabird die-off was noted in the summer of 1997; the phenomenon was common to the southern Bering Sea and Aleutians of Alaska. There was a high mortality of surface feeders, such as shearwaters (and kittiwakes to a lesser extent), that peaked in August of 1997 when sea surface temperature anomalies were highest.

In the northern Bering sea, common murre die-offs were reported in May and June of 1997. The Gulf of Alaska also experienced high sea-surface temperature anomalies during the summer of 1997, but no murre die-offs were reported. In 1998, a moderate die-off of murres was reported in the northern part of the Gulf of Alaska, where moderate numbers of dead murres were recorded from March to May of 1998. In mid April 1998, this murre die-off peaked. The die-off of this seabird followed a long period of positive sea-surface temperature anomalies. The reported dead murres were mostly sub-adult and apparently died of starvation.

Pounds, J.A.; Fogden, M.P.L.; and Campbell, J.H. 1999. Biological response

to climate change on a tropical mountain. *Nature* 398(6728): 611-615.

This article gave supporting evidence to the popular hypothesis that recent climatic events have altered the distribution and abundance of wildlife communities - including those of birds. Populations of birds in the highland forests of Monteverde, Costa Rica, had shifted in response to changing climatic gradients, such as increased air temperatures with increasing altitude. Recent rises in sea surface temperature (SST), decreased dry mist frequency, and a lifting cloud base have contributed to hotter, drier conditions on this tropical mountain. The drying trend remained significant even after El Nino/ Southern Oscillation fluctuations were taken into account.

Their data showed that the abundance of lower montane bird species had remained stable since the first assessment between 1979-1981. Yet, the abundance of premontane species - those absent from cloud forest - had increased by 1998 within a 1, 540 m study plot. Most species had shifted their distribution upslope in response to the changing climatic gradient. For instance, Keel-billed Toucans *Ramphastos sulfuratus* previously nested in lowlands but shifted upslope by 1998. New species to the plot had increased in density by 1998; those included Golden-crowned Warblers *Basileuterus culicivorus* and Lesser Greenlets *Hylophilus decurtatus*. During some years of the study, species had shifted their distributions back downslope. The best predictor of upslope movements in a given year was the number of warm episodes in a preceding year.

Reuter, H.; and Breckling, B. 1999. Emerging properties on the individual level: modelling the reproduction phase of the European robin *Erithacus rubecula. Ecological Modelling* 1211(2): 199-219.

It has proven difficult to integrate more than a limited number of internal as well as environmental factors governing the reproductive success of birds into a simulation model. The authors developed an individual-based model of the reproductive phase of the European robin *Erithacus rubecula* extending the given possibilities. A priority value driven activity scheduling mechanism permitted the inclusion of a variety of behavioural as well as physiological aspects in relation to the local environmental situation represented by a grid map, food availability and microclimate data sets. The life history patterns of the individual robins emerge as a result of the interaction of their behavioural repertoire, activity selection mechanism, temperature and food availability.

The model integrated energy-budgets, activity scheduling on the individual level and reproductive success as well as spatial distribution patterns on the integration level of the population in a coherent way. One of the main aims of the model was to identify constraints occurring during the reproductive phase. The intensity and extent of critical situations were analyzed during the time when the males have to feed the young at the utmost possible level and at the start of breeding in late spring. Investigation of the effects of a possible climate change in Northern Germany emphasized the very critical timing of reproductive activities in relation to temperature and caterpillar emergence.

These effects are detectable on the individual level more precisely than on the population level. They are levelled out by averaging the state of the whole population. Similarly, a simpler model basing on differential or difference equations would not suffice to explain the reproductive success as the result of the diverse interrelated influences and decision schemes.

Rimmer, C.C.; and McFarland, K.P. 1999. Sky island songbirds: Bicknell's thrush. *Natural History* 108(7):34-38.

Studies of Bicknell's Thrush in the Green Mountains of Vermont were described. This bird, first discovered in 1881, has received little scientific attention and had been considered a subspecies of the Gray-cheeked Thrush until 1995. One reason for its neglect has been the inaccessibility of its breeding sites, on top of steep slopes surrounded by thickets.

Global climate change and human activities are threatening the spruce-fir habitat of Bicknell's thrush, although studies so far indicate that the birds can tolerate moderate human traffic and favor the dense growth often found at the edges of ski slopes and mountain roads. Both males and females seem to have a high survival rate and return to the same breeding sites each year. Other studies indicate that female Bicknell's thrushes may be in short supply.

Robards, M.D.; Piatt, J.F.; Kettle, A.B.; and Abookire, A.A. 1999. Temporal and geographic variation in fish communities of lower Cook Inlet, Alaska. *Fishery Bulletin* 97 (4): 962-977.

Nearshore and shelf fish communities were studied in three areas of lower Cook Inlet, Alaska: the Barren Islands (oceanic and well-mixed waters), Kachemak Bay (mixed oceanic waters with significant freshwater run-off), and Chisik Island (estuarine waters). Fish were sampled with beach seines (n=413 sets) and midwater trawls (n=39 sets). We found that lower Cook Inlet supported a diverse nearshore fish community of at least 52 species. Fifty of these species were caught in Kachemak Bay, 24 at Chisik Island, and 12 at the Barren Islands. Pacific sandlance dominated Barren Islands and Kachemak Bay nearshore habitats, comprising 99% and 71% of total individuals, respectively. The nearshore Chisik Island fish community was not dominated by any one species; instead it exhibited higher diversity. These spatial differences appeared linked to local oceanographic regimes and sediment influx. Analysis of historical data revealed that the nearshore Kachemak Bay fish community changed significantly between 1976 and 1996, showing increased diversity and abundance in several taxa, notably gadids, salmanids, pleuronectids, and sculpins. Decadal differences appeared to be related to large-scale climate changes in the North Pacific. Catches of most taxa peaked in May-August, and were low during other months of the year. Several species were present for only part of the summer. Species composition of seine catches differed significantly between consecutive high and low tides, but not between consecutive sets or years. Midwater trawls took 26 species, 14 of which were present in Kachemak Bay, 19 near Chisik Island,

and 7 at the Barren Islands. Community structures in shelf and nearshore waters were similar: diversity was high and abundance low at Chisik Island, whereas a few abundant species dominated at both Kachemak Bay and the Barren Islands. In addition, the low fish abundance near Chisik Island appeared to be related to declining seabird numbers at this colony.

Rodl, T. 1999. Environmental factors determine numbers of over-wintering European Stonechats *Saxicola rubicola* - a long term study. *Ardea* 87(2): 247-259.

This paper focused on environmental constraints on the number of wintering European Stonechats *Saxicola rubicola* in Negev, Israel, using data from seven non-breeding seasons (1989/90 and 1993/94 to 1998/99). The relationship between the number of European Stonechats and the local rainfall, air temperature, and arthropod abundance was examined. In 1996/97, population size declined to about one third of the initial size until the end of December, while in 1994/95 it remained almost constant. The decline of bird numbers was mainly due to the disappearance of young, unpaired individuals.

The amount of rain during early winter correlated significantly with population size. The data showed that the timing of the rain also had a strong impact on the population size. The effect of rain on the birds' environment was cumulative (unless the rain was totally erratic and unevenly distributed). Once the rain season had started, every additional rainfall increased the magnitude of this environmental factor. An early start of rain resulted in the lush development of vegetation and arthropods. The decline in numbers was also correlated with arthropod density in pitfall traps. The proportion of vanishing birds declined with the average number of arthropods in early winter and possibly as well with the average number of species during the early phase of the winter.

Early winter rainfall had a much stronger impact than total winter rain. There was a significant relationship between rain until the end of December and the vanishing proportion of birds.

Smith, R.C.; Ainley, D.; Baker, K.; Domack, E.; Emslie, S.; Fraser, B.; Kennett, J.; Leventer, A.; Mosley-Thompson, M.; Stammerjohn, S.; and Vernot, M. 1999. Marine ecosystem sensitivity to climate change. *BioScience* 40 (5): 393-404.

Summarized climatic variability in the Western Antarctic Peninsula (WAP) and discussed in the context of long-term climatic variability during the last 8000 years of the Holocene period. Historical records and paleoclimate records, such as those derived from Antarctic ice sheet marine sediment cores, showed that the WAP was a relatively cold region between 2700-100 BP, during the Little Ice Age. Yet, it had rapidly warmed during the 20th century; consequently, seabirds, like penguins, had changed in terms of their population numbers and breeding distributions – thus, served as ecological indicators of this climatic shift.

Two penguin species representative of climate change in the WAP region

included the Adelie Penguin *Pygoscelis adeliae* and Chinstrap Penguin *Pygoscelis adeliae*. Populations of the former, closely associated with winter pack ice, have slowly decreased in the WAP region. Melting of pack ice had occurred more rapidly on the WAP than any other region in the Antarctic, due to increased air temperatures; pack ice melting was especially prevalent in the summer. During this current century, the Adelie Penguin had incurred habitat loss on the WAP. They had shown a southerly shift in breeding ranges since the 1980s to the Ross Sea and populations there had remained stable ever since. At the Ross Sea, polar, dry conditions still existed, but if the warming trend ensues in the future, then Adelie Penguin populations in the Ross Sea can expect to peak in numbers and then, subsequently, decline. Then, the locus of their distribution will be forced further southward.

By contrast, Chinstrap Penguins, which occurred almost exclusively near open sea, increased by several hundred percent on the WAP, since this peninsula had become milder and warmer – reminiscent of subpolar conditions. Anvers Island was hypothesized to be the northern boundary for the distribution of Adelie Penguins, and approximately the southern boundary for Chinstrap Penguins. In the future, it was predicted that at Ross Sea Chinstrap Penguins will conversely increase in numbers, when unsuitable, warm conditions become inhabitable for Adelie Penguins.

Adelie Penguins may not have responded to climatic warming as much as to changes in the dynamics of their prey, for example, krill. Krill had shifted southward possibly because of the similarly-oriented shift in sea ice. Krill abundance was closely correlated with areas of high primary production; this was most prevalent in areas with sufficient ice coverage.

For Adelie Penguins, studies suggested that long-term survival and colony location were associated with ice-mediated factors. Relatively ice-free coastal areas were needed to set up breeding colonies in late spring. Recent warming was postulated to have increased the nesting success of Adelie penguins and food availabilty for them.

Sokolov, L.V.; Markovets, M.Y.; Shapoval, A.P.; and Morozov, Y.G. 1999. Long-term monitoring of spring migration time in passerines in the Courish Spit (the Baltic Sea). 2. Influence of temperature on migration terms. *Zoologichesky Zhurnal* 78 (9): 1102-1109.

The terms of spring migration were analyzed in 20 migrating Passerines species in relation to mean spring temperatures. The mean terms of migration in 6 species arriving predominantly in April were significantly related to the April temperature: the higher temperature, the earlier are terms of migrating birds through the Courish Spit. A significant negative correlation was found between the terms of migrating and May temperature. The long-term and significant changes in terms of spring migration in birds, especially in Passerines, due to climatic fluctuations in the northern hemisphere, were revealed based on published data and the authors' own.

The observed increase of the average annual air temperature in the 1930s, 1940s and then in the 60s and the 80s caused a shift in terms of spring

migration to the earlier dates. A decrease of the average annual temperature in the 1950s, 1970s, and probably in the 1940s, moved the terms to the later time. The climatic changes were reflected in the terms of spring migration in the species wintering in Europe and Africa.

Thomas, C.D.; and Lennon, J.J. 1999. Birds extend their breeding ranges northwards. *Nature* 399: 213.

In Great Britain, a 20-year study on the breeding distributions of selected birds was conducted; analyzing breeding data within a 100 km^2 grid between 1968-72 and 1988-91.

Results indicated that increases in distribution size of southerly species; their northern margins shifted northward. This was the case for such species as Cetti's Warbler *Cettia cetti*; this and other species were estimated to have migrated northward by 18.9 km on average during the 20-year study. In contrast, declines in range size of southerly-restricted species resulted in a southward retraction of their northern limits. This pattern was represented by the change in breeding ranges over the 20-year study by Turtle Doves S*treptopelia turtur*.

Increases in distribution size for northerly bird species of Great Britain, resulted in a southerly extension of their breeding ranges as was the case for Common Merganser *Mergus merganser.* Yet, declines in range size caused the breeding ranges of northerly species to retract northwards towards their core. This phenomenon was exemplified by the behaviour of Black Grouse *Tetrao tetrix*.

Climate change was the explanation for the average 18.9km northward migration of southern species. The shifted southern margins of northerly species were not consistent during the 20-year study; explanatory reasons were lacking. Perhaps, the warm margins of temperate species would be more responsive to rainfall than to thermal variation?

Wingfield, J.C.; Ramos-Fernandez, G.; Nun ez-de la Mora, A.; and Drummond, H. 1999. The effects of an "El Nino" Southern Oscillation event on reproduction in male and female blue-footed boobies, *Sula nebouxii*. *General and Comparative Endocrinology* 114:163-172.

On Isla Isabel in the Pacific Ocean off San Blas, Nayarit, Mexico, mean sea surface temperature was maintained at 25.63^o for an 11-year period of study. As a result of an El Nino event in 1992, mean sea surface temperatures increased to 26.69^o; in 1993, mean sea surface temperature decreased to 25.75^o.

In 1992, there was a complete reproductive failure in Blue-footed Boobies *Sula nebouxii* on Isla Isabel that was associated with the 1992 El Nino southern oscillation event. In 1993, the El Nino event waned and reproductive success was high. In 1992, 139 clutches were laid, of which 124 (89%) were then abandoned during incubation. Furthermore of 21 chicks that did hatch, all had died within a week. Therefore, reproductive success was zero in 1992. Also in

1992, large numbers of Blue-footed Boobies were present on the island and some were courting actively. However, many did not attempt to breed. On the other hand, in 1993, 589 clutches were laid, and only 230 (39%) were abandoned during incubation. The remaining 359 clutches produced 251 chicks.

Plasma levels of testosterone approached similarity in courting and non-breeding birds in 1992 and 1993, indicating that the mechanism underlying failure to initiate a nesting cycle did not involve androgens. Adult Blue-footed Boobies had adequate food to sustain themselves in both years (as indicated by body mass), but clearly in 1992 there were not adequate food resources to feed chicks as well as nourish adults.

Baseline circulating levels of corticosterone, a hormone often used as a measure of environmental stress, increased in females in 1992 compared with 1993. There is evidence that suggests corticosterone may play a role in inhibiting reproductive function including territorial behaviour and courtship. Plasma levels of corticosterone rose following capture and restraint in both sexes and at every stage in the breeding cycle in each year. Female responses to the capture stress protocol were greater during the parental phase of 1992.

There was a trend for corticosterone plasma levels to be higher in males than females in the earlier stages of breeding in 1992 compared with 1993. If all levels were combined within years, then females showed significantly higher corticosterone levels in the El Nino year. This was especially the case of the nonbreeding and courtship phases when a decision to initiate the nesting cycle occurred. In females, maximum corticosterone levels were greatest during the parental phase of 1992, when all nests had failed. Following capture and restraint in both sexes, corticosterone plasma levels increased markedly and at every stage of the breeding cycle during each year. There was no variation in the adrenocortical responses to stress with year or stage of nesting in males. Therefore, in the El Nino year, baseline circulating concentrations of corticosterone may have suppressed the initiation of breeding in Blue-footed Boobies by an elevation of corticosterone secretion. In contrast, after the nesting cycle has been initiated, increased adrenocortical sensitivity to acute stress may be involved in nest abandonment.

1998

Boersma, P.D. 1998. Population trends of the Galapagos penguin: Impacts of El Nino and La Nina. *Condor* 100 (2): 245-253.

The Galapagos Penguin *Spheniscus mendiculus* population probably has always been small and largely restricted to the islands of Fernandina and Isabela. Counts suggest the current population of Galapagos Penguins is likely between 4,250 and 8,500, half of what it was in the early 1970s. Population size has varied and declined probably because of substantial changes in oceanic conditions.

Body condition as evidenced by weight is enhanced during cold surface water conditions, La Nina, and deteriorates when surface waters are warmed, El Nino, and under the most severe conditions, penguins starve. Analysis of a long-term data set from counts of the population suggests that the population has fluctuated, dropping precipitously after the 1982-1983 El Nino and has since then been recovering very slowly.

This parallels the overall warming in the Pacific during the last 20 years associated with the more frequent El Nino and less frequent La Nina events. These trends suggest that long-term global climate warming is likely to threaten the Galapagos Penguin population particularly because the population is small and its distribution restricted. New threats from climatic warming and increasing human perturbations such as fishing, inadvertent discharge of petroleum products, and transport of potential predators and pathogens to islands, increase the risk of extinction.

Emslie, S.D.; Fraser, W.; Smith, R.C.; and Walker, W. 1998. Abandoned penguin colonies and environmental change in the Palmer Station area, Anvers Island, Antarctic Peninsula. *Antarctic Science* 10 (3): 257-268.

Six abandoned colonies of Adelie Penguin *Pygoscelis adeliae* were excavated near Palmer Station, Anvers Island, Antarctic Peninsula, to investigate the occupation history of this species. Sediments from each site yielded abundant fish bones and otoliths and squid beaks that represented prey remains deposited by penguins during the nesting period. Radiocarbon analyses indicate that colony occupation began prior to the Little Ice Age (LIA; 1500-1850 AD), with the oldest site dating to 644 yrs before present (BP; average reservoir-corrected date with 1s range, 603-679 yr BP). Food remains indicated that the non-euphausiid prey of penguins consisted primarily of a mesopelagic squid *Psychroteuthis glacialis* and two species of fish *Pleuragramma antarcticum* and *Electrona antarctica*. The relative abundance of the first two prey taxa varied significantly among six sites ($\chi^2 > 34.6$; df = 1011; $P < 0.001$) with colonies dating prior to the LIA having greater representation of squid, and less of silverfish, than those occupied during the LIA.

Data from control excavations at three modem colonies indicated a diet similar to that of the pre-LIA sites. These results suggest that Adelie Penguins may have changed their diet in response to warming and cooling cycles in the past. In addition, only Adelie Penguins are known to have nested in the Palmer Station area prior to the 1950s; Gentoo *Pygoscelis papua* and Chinstrap *P. antarctica* penguins now breeding in this region have expanded their ranges southward in the Peninsula within the past 50 yrs, in correlation with pronounced regional warming.

Hansell, R.I.C. 1998. Atmospheric change and biodiversity in the arctic. *Environmental Monitoring and Assessment* 49 (2-3):303-325.

Observations, as well as predictions of large-scale climate models which include ocean circulation, have revealed an anomalous cooling of northeastern

Canada in recent decades, in contrast to the overall significant increase in average annual temperature in the Northern Hemisphere. The presence of sea ice in Hudson Bay and other coastal areas is a major factor affecting interactions between the marine and terrestrial ecosystems. Further, the undersurface of sea ice is a major site for the growth of algae and marine invertebrates which in turn act as food for the marine food web. A rise in sea-level may flood coastal saltmarsh communities leading to changes in plant assemblages and a decline in foraging by geese and other consumers.

The anomalous cooling in the eastern Arctic, primarily in late winter and early spring, has interrupted northern migration of breeding populations of geese and ducks and led to increased damage to vegetation in southern arctic saltmarshes as a result of foraging. It is likely that there has been a significant loss of invertebrates in those areas where the vegetation has been destroyed.

The year of 1991 was the coldest year in a 50 yr dataset due to a cold water perturbation. This cold water resulted in breeding failure of Black-legged Kittiwakes *Rissa tridactyla* and other surface feeders. In contrast, birds that were able to forage deeper in the column of water (such as Common Guillemots [*Uria aalge*]) reproduced successfully. The presence of cooler surface waters in the past several years, has been linked to a general loss of migrant warm-water species, and the birds have been forced to rely increasingly on cold-water prey. Researchers also noted a three-to four-week delay in inshore migration and spawning of capelin *Mallotus villosus* – a very important food resource for seabirds.

Kruse, G.H. 1998. Salmon run failures in 1997-1998: a link to anomalous ocean conditions? *Alaska Fishery Research Bulletin* 5(1): 55-63.

Light winds, low nutrients, and high solar radiation prevailed in the Bering Sea during the summer of 1997. This unusual combination of conditions was thought to be a result of the strong 1997/98 equatorial El Nino and global warming. These conditions led to an unprecedented coccolithophore bloom in the Bering Sea in summer 1997; a second, stronger bloom of coccolithophores occurred again from as early as February until summer of 1998. During this time, turquoise water was observed from Bristol Bay north through the Bering Strait to the Chukchi Sea.

In alignment with the timing of these conditions (1997/98) was a high mortality of selected seabirds. Seabird corpses were prevalent in areas of turquoise water, and foraging birds seemed to avoid turquoise water where probably prey was more difficult to see.

In particular, Short-tailed Shearwaters *Puffinus tenuirostris* died from the western Gulf of Alaska to the Chukchi Sea. These shearwaters, 20-30% underweight, had died of starvation. Possibly, the poor water nutrients precipitated the coccolithophore bloom that affected the productivity of euphausiids – a prey species of shearwaters. Black-legged Kittiwakes *Rissa tridactyla* died on the Alaska Peninsula, and Common Murres *Uria aalge* died in western Alaska.

Levy, S. 1998. Where the sea meets the sky. *New Scientist* 160(2154): 40 – 44.

A study along the eastern Pacific coast assessed the impact of the 1998 El Nino event on the marine ecosystem. This study used seabirds as bio-indicators of changing prey availability and distribution.

Seabirds have suffered as a result of lack of prey abundance caused by the El Nino event. Specifically, this event suppressed primary production at sea - the basic foundation of the marine food web. Cold water carrying phosphorous and nitrogen for photosynthesis was trapped under a layer of warm water that had moved in from the south and west.

In response, Brown Pelicans *Pelecanus occidentalis* at Ano Neuvo and the Farallon Islands had either nested late or not nested at all. Mortality rate was high in chicks that were produced. Brown Pelicans abandoned their nesting colonies in southern California. Reproductive failure reflected a poorly productive marine food web from the time of mating to the fledging of chicks. Also in California, the planktivorous Cassin's Auklets *Ptychoramphus aleuticus* showed a delay in breeding. On the Farallon Islands, only half of the population of this species attempted to breed, and those that bred laid eight weeks late. 75% of the population of Common Murres *Uria aalge* atttempted to breed and delayed egg-laying by four weeks. On these islands, the majority of Rhinoceros Auklets *Cerorhinca monocerata* tried to breed and were only two weeks late laying their eggs. Delayed breeding and late egg laying were probably overt signs of decreased food resources in late winter and early spring for these species of birds.

The Cassin's Auklet was the most disadvantaged of all three alcids in this El Nino study. Planktivorous alcids, unlike piscivorous alcids, were restricted in diet and could not as easily switch to a different prey type, although Cassin's Auklets were documented carrying fish rather than phytoplankton to their chicks on Triangle Island in British Columbia. Compared with the other two alcids, the Cassin's Auklet was also smaller and more of a surface feeder due to its inability to dive to great depths. During the El Nino event, plankton had not flourished in the upper water column for Cassin's Auklets to capture.

Since the spring and summer of 1998, the diets of these three birds had changed in some areas. For instance, the Rhinoceros Auklets off central California had switched from anchovies to saury, and Common Murres had switched from rockfish and anchovies to sardines.

Some behaviours displayed by these seabirds during the year of El Nino had unexplainable patterns, which appear to be more the exception than the rule, but still need addressing. At Triangle Island, Cassin's Auklets laid their eggs 10 days later than usual, used only half the usual number of burrows, and 50% of chicks died. By contrast, Rhinoceros Auklets laid their eggs earlier, fewer nested, and chick growth rate was faster during the year of El Nino than in two years. Common Murre nesting behaviour had not changed, but like Rhinoceros Auklets, they were eating more sand eels. Common Murres on Tatoosh Island, however, had enough energy stores to lay replacement eggs after they were

scavenged by Bald Eagles; this implied that murres of Tatoosh Island were not greatly suffering as a result of El Nino. In fact, cold water upwellings from the oceanic bottom still persisted off Tatoosh Island, despite El Nino. Similarly, seabirds as far north as Alaska may not be suffering as a result of El Nino, as their breeding schedule at the time of this study was not noticeably altered.

McCleery, R.H. & C.M. Perrins. 1998. …temperature and egg - laying trends. *Nature* 391: 30-31.

Since 1947, records of annual laying dates for Great Tits *Parus major* in Marley Wood as well as spring temperatures for each year had been kept. As with similar, previous studies on bird breeding biology, the laying dates of great tits had become earlier since 1970. However, from 1947-1970, such a significant trend did not exist. The earlier laying trend co-existed with higher spring temperatures since 1970. Today's evidence does not suggest these birds are breeding earlier than they were formerly, relative to spring weather although high spring temperatures have accelerated since 1985. Presumably, earlier warm temperatures allow energy-rich foods to become available earlier to females. Earliest breeders have been found to produce the most surviving offspring.

Mortsch, L.D. 1998. Assessing the impact of climate change on the Great Lakes shoreline wetlands. *Climatic Change* 40 (2): 391-416.

Wetlands were affected by the local hydrology of the Great Lakes, whose levels, in turn, were a reflection of climatic variability. Fluctuations in water table levels were crucial to wetland formation and maintenance, and the wetlands were particularly adapted to water variability, yet concern surrounded the issue of the rate and magnitude of climatic change, especially wetlands near man-made structures, whose presence impedes wetlands' adaptability.

Survival and productivity of waterfowl, which depend on wetland resources, were hypothesized as one of many wetland species to be sensitive to climatically-induced changes in their wetland environment.

This assessment investigated two scenarios of water level fluctuations in wetlands and their effects on waterfowl populations: prolonged and frequent low water levels, as well as changes in temporal distribution and amplitude of seasonal water levels. Wetlands near the Great Lakes were crucial stopovers and breeding grounds for migratory and marsh birds.

Emergent, aquatic vegetation, used as food and cover by waterfowl, was lost when water table levels were high; the latter was caused by increased flooding and precipitation over evapotranspiration. In the spring, feeding was particularly important as waterfowl prepared to breed, and, therefore, were forced into upland farms in search of food during such times of scarcity. In addition, increased habitat loss due to high water table levels caused increased competition for territory between waterfowl. Predation, during the breeding season, was high due to the shifted position of nests on high ground and dikes, as well as flooding of nests.

Mulvaney, K. 1998. Can't take the Heat. *New Scientist* 159(2153): 12.

Rising air temperatures in Arctic which allowed the successful colonization of Black Guillemots 25 years ago were found to now be causing their decline in numbers. Temperature rise from the late 1960s onward caused snow to melt earlier in the spring and for Black Guillemots to breed and nest for a longer period. Between 1975 and 1990, the number of guillemots recorded on Cooper Island, near Barrow increased to a peak of 225 nesting pairs.

However, since 1990 the numbers have dropped dramatically to a recent recording of only 110 pairs. A hypothetical reason may be the reduction of sea ice in the area – caused by higher air temperatures. Black Guillemots feed on Arctic cod that live beneath the floes; ice-free areas harbour fewer fish, forcing guillemots to fly farther in search of food.

Prop, J.; Black, J.M.; Shimmings, P.; and Owen, M. 1998. The spring range of barnacle geese *Branta leucopsis* in relation to changes in land management and climate. *Biological Conservation* 86: 339 - 346.

A population of Barnacle Geese *Branta leucopsis* breeding at Svalbard, Norway, has expanded to numbers that exceed 13, 000. During spring migration trips, these geese have switched from staging on traditional, small islets 30 - 40 km offshore to larger agricultural islands only 15 km from the mainland; this trend began in the early 1980s. The smaller islands once inhabited by barnacle geese could no longer sustain their evergrowing numbers, because of the vegetation change and explosion of numbers that occurred. The type of vegetation on the smaller islets switched from hay-meadow towards herb-meadow - a type with a low density of grass shoots. The carrying capacity on this type of meadow was limited and could not sustain as many geese. The vegetation change on the traditional smaller islands coincided with an abandonment of agricultural practice and emigration of people.

Later, in 1988, a northerly shift in the distribution of barnacle geese was observed, which coincided with increases in spring temperatures. In this scenario, northern vegetation that was once frozen and unattainable by barnacle geese, became an available resource with warmer spring temperatures. If the recent warming trend continues in the future, further distribution of geese to the north should occur.

To deflect barnacle geese away from larger agricultural islands back to their traditional islands, one of two management practices needs to be implemented. The grasslands of traditional islands could be restored; and/or the attractiveness of salt marshes on the larger islands could be enhanced.

Sorenson, L.G.; Goldberg, R.; Root, T.L.; and Anderson, M.G. 1998. Potential effects of global warming on waterfowl populations breeding in the Northern Great Plains. *Climatic Change* 40 (2): 343 – 369.

Between 1955-1996, changes in May Palmer Drought Severity Index (PDSI) were positively correlated with the sizes of breeding duck populations and

numbers of ponds within the Prairie Pothole Region (PPR). Based on this relationship, researchers determined future pond and duck numbers from PDSI values that were determined by sensitivity simulations and two GCM scenarios. GCM scenarios suggested a significant increase in drought conditions, as reflected by lower average PDSI values, by 2060 AD. From the GCM scenario, this study predicted duck populations could decline from 5.0 million to 2.1-2.7 million ducks. Sensitivity analyses indicated that PDSI was more sensitive to temperature, because of increased evaporation, than to precipitation changes.

With increasing frequency of drought, which was enhanced by increasing temperature, migrating pairs were predicted to bypass the dry areas of the PPR and settle northward into parkland, boreal forest, and tundra habitats to breed. There, the waterfowl would be less productive, which may reduce the continental duck population on the prairies after many successive years of drought. Although an alternative habitat to breeding birds, in the long term, melting of permafrost could result in lowered water tables and drying of northern wetlands. Therefore, northern breeding habitats may prove to be unstable for these birds.

Alternatively, waterfowl may shift their migration and breeding schedules to earlier in the season in response to warmer temperatures and earlier wetland availability. Wetland quality may also decline in a warmer climate. If reduced wetland availability becomes a widespread phenomenon in the PPR, ducks may start to crowd together in a less desirable habitat. In such situations, competition for resources would increase as well as sexual harassment by males.

In general terms, drought could reduce available wetland habitat to breeding ducks, population size and their reproductive performance.

Visser, M.E.; Van Noordwij, A.J.; Tinbergen, J.M.; and Lessells, C.M. 1998. Warmer springs lead to mistimed reproduction in great tits *Parus major*. *Proceedings of the Royal Society of London Series B: Biological Sciences* 265 (1408): 1867-1870.

In seasonal environments, the main selection pressure on the timing of reproduction (the ultimate factor) is synchrony between offspring requirements and food availability. However, reproduction is initiated much earlier than the time of maximum food requirement of the offspring. Individuals should therefore start reproduction in response to cues (the proximate factors), available in the environment of reproductive decision making, which predict the later environment of selection. With increasing spring temperatures over the past decades, vegetation phenology has advanced, with a concomitant advancement in the reproduction of some species at higher trophic levels. However, a mismatch between food abundance and offspring needs may occur if changes in the environment of decision making do not match those in the environment of selection. Date of egg laying in a great tit *Parus major* population has not advanced over a 23-year period, but selection for early laying has intensified.

This was believed to be the first documented case of an adaptive response being hampered because a changing abiotic factor affected the environment in which a reproductive decision was made differently from the environment in which selection occurred.

1997

Crick, H.Q.P.; Dudley, C.; Glue, D.E.; and Thomson, D.L. 1997. UK birds are laying eggs earlier. *Nature 388(6642): 526.*

For northern latitudes, the egg-laying dates of birds in the United Kingdom were, on average, 8.8 days earlier between 1971-1995. This advancement was positively correlated with high spring temperatures. The types of birds to which this trend applied were water birds, resident insectivores, migrant insectivores, corvids, and seed-eaters. Only the stock dove *Columba oenas* showed a later trend in egg-laying. This was, perhaps, due to its opportunistic reproductive cycle.

Earlier flowering and leafing dates were associated with an increased number of arthropods, which implied more available food for earlier breeding birds. Potentially, earlier breeding could enhance juvenile survival, since young would be exposed to a longer warm period before winter. Conversely, the earlier breeding may have negative consequences on future food supply for birds. Their breeding dates may not coincide with the phenology of their prey.

Environment Canada, 1997. The Canada country study : climate impacts and adaptation, highlights for Canadians. Ottawa.

This study provided another important piece of knowledge on how climate change could impact our communities. It alerts Canadians to what scientists expect will happen and suggests ways in which Canadians can adapt to climate changes. The study looks at climate trends, the study itself, how climate change will affect Canada, weather extremes, people & traditional lifestyles, water resources, the natural environment (wetlands, aquatic life), snow geese in Hudson Bay lowlands & decline of breeding grounds, and the economy (energy, transportation, agriculture, fisheries, forestry, building & construction, insurance, recreation & tourism).

Erskine, A.J. 1997. Climate in relation to Canada Goose staging and wintering in the Maritime Provinces. pp.164-169 *in* Erskine, A.J. (ed.). 1997. Canada Goose studies in the Maritime Provinces 1950-1992. Environment Canada-Atlantic Region, Occasional Report No. 7.

Widespread impressions of milder winters and warmer springs in the Maritimes correlated plausibly with recent observed changes in goose distributions at those seasons. Preliminary examination of climatological data gave little support to the impression of milder and less snowy winters, although there was evidence of greater variation in winter weather. Climate change was unlikely to have cause the changes in goose distribution. Mean monthly temperatures in April were generally higher after 1975 than before, and snowfall

was lower despite higher total precipitation. The recent shift of spring-staging geese to Prince Edward Island may be associated with recent warmer springs.

Gratto-Trevor, C.L. 1997. Climate change: Proposed effects on shorebird habitat, prey, and numbers in the outer Mackenzie Delta*. Mackenzie Basin Impact Study: Final report* pp. 205-210.

Shorebirds (Charadriiformes) are dependent on shallow water habitats for foraging, so their populations are vulnerable to even small changes in climate. Most North American species of shorebirds breed in the arctic, and ten species breed commonly in the outer Mackenzie Delta. This paper discussed the implications of the potential changes in abiotic factors for shorebirds breeding in the outer Mackenzie Delta. It appeared that there will be little priority shorebird habitat lost in the area through coastal erosion during the next 50 years. An increase in the active layer, potentially less frequent inundations of the delta, and an increased evaporation rate may eventually result in fewer shallow wetlands throughout the outer delta, particularly in late summer.

With warmer temperatures, a greater proportion of insects are likely to be Culicidae rather than Chironomidae, but both are shorebird prey. Populations of species nesting in drier habitats of sparse vegetation, may increase slightly. Numbers of other species are expected to remain fairly constant. Many Mackenzie Delta shorebirds stage in Prairie Canada during spring and/or fall migration. With drier conditions in that region there may be some loss of habitat, particularly in the fall, but large shallow lakes and managed wetlands should be able to support these shorebird populations for some time.

Kont, A.; Ratas, U.; and Puurmann, E. 1997. Sea-level rise impact on coastal areas of Estonia. *Climatic Change* 36: 175 – 184.

The geomorphically diverse coastline of Estonia was a projected area of endangerment for bird species that use this habitat for breeding. Moderate sea-level rises associated with global warming will lead to disappearance of shoretypes along Estonia's coast. Case study areas of Estonia were assessed for vulnerability and adaptation in the case of a sea level rise of 1.0 m by 2075. Each area contained some of the representative shoreline types characteristic of Estonia. In Hiiumaa, a low-lying island off of the mainland of Estonia, the shoreline types most vulnerable to sea level rise were shoaly sandy and silty shores. In the past, highest sea level rises were reported along eastern and southern coasts, and these areas possessed the greatest number of shoals and were subjected to the greatest storm surges and wave action. Shoreline recession here was associated with storminess in the eastern Baltic Sea. The slow uplift of the earth's crust in Hiiumaa today has not stopped erosion of its sandy beaches; sandy beaches prevailed along the western coast of Hiiumaa.

The results of the case study for Hiuumaa indicated that its silty shorelines would be most vulnerable to inundation in the event of a moderate sea level rise of 1.0 m by 2075. A total of 38 km^2 of its territory would submerge. This included

coastal ecosytems, like the Hiiumaa Biosphere Reserve, which contains rich breeding grounds for birds.

The second case study area included was Parnu-Ikla, situated in SW Estonia on the western coast of the Gulf of Riga. Sandy shorelines with an extensive ridge of coastal formations covered by foredunes and dunes, characterized this study area. The results of the case study indicated that coastlines of the northern part of the study were most vulnerable to moderate sea level rise; here, silty shoreline was prevalent.

In conclusion, silty and sandy shore types of SW Estonia would be most vulnerable to inundation in the future; whereas, cliff, scarp, and till shores, which are typical of northern Estonia, would be better protected areas. Not only shore types, but the rate of isostatic land uplift, will be determine the degree of inundation and the best strategies employed to protect them.

Maarouf, A., and Boyd, H. 1997. Influences of climatic conditions in the Mackenzie Basin on the success of northern-nesting geese*. Mackenzie Basin Impact Study: Final report* pp. 211-216.

The breeding success of four species of Arctic-nesting geese (Anatidae), that breed in the north of the Mackenzie Basin, or stop in it while on migration, was examined in relation to climatic conditions during 1971-1993. The breeding success of northern geese had to be estimated indirectly, by field observations on goose flocks in autumn and by identifying young among the tails of geese contributed each year by hunters in Canada and USA.

Discriminant Function Analysis showed that breeding success was associated with monthly and seasonal variations in temperature and precipitation in two climate regions covering the Mackenzie Basin area. Above normal precipitation in spring and summer, and above normal temperature in summer, in the Northwest Forest climate region were found to be favourable for geese. Above normal temperature in May and below normal precipitation in June in the Mackenzie District were also favourable conditions. Future changes in climate in the Mackenzie Basin were more likely to be detrimental than beneficial to geese, due to a northward shift of the treeline, delayed expansion of the tundra regions, and destabilization of permafrost and vegetation in the geese feeding areas.

Mehlman, D. 1997. Change in avian abundance across the geographic range in response to environmental change. *Ecological Applications* 7 (2) 614-624.

The abundance changes of three North American passerine bird species (Carolina Wren *Thryothorus ludovicianus,* Eastern Bluebird *Sialia sialis,* Field Sparrow *Spizella pusilla*) in the late 1970s were analyzed to determine relationships between proportional abundance change and prewinter abundance, position within the geographic range, and winter severity. Analyses were made between both the prewinter period and a period of declining abundance

immediately after the winters and between this decline period and a later period of recovery in which abundance increased.

The proportional declines in abundance showed no relationship to prewinter abundances. Proportional abundance change was greatest at sites closer to the range edge and, for two species (Carolina Wren and Eastern Bluebird), at sites with a more severe winter. Proportional abundance increases of these two species between the decline and recovery periods similarly were greatest at sites near the range edges and with previously more severe winters. Abundance increases were greater at sites with the lowest predecline abundance. Geographic range structures showed changes parallel to the abundance changes, including overall contraction and expansion. In addition, there was evidence of fine-scale range dynamics, including extinction and colonization events toward the range margins and a roughening of the range boundary with abundance decrease followed by a smoothing of the boundary with abundance increase.

Periods of major environmental change, such as these severe winters, may provide insight into how populations of organisms will respond to global climate change. In particular, this study suggests that population declines will be accompanied by a contraction toward core areas of the range that formerly had the highest abundance.

1996

Jarvinen, A. 1996. Correlation between egg size and clutch size in the Pied Flycatcher *Ficedula hypoleuca* in cold and warm summers. *Ibis* 138 (4): 620-623.

The correlation between egg size and clutch size was studied in the Pied Flycatcher *Ficedula hypoleuca* in Finnish Lapland from 1975 to 1994. The hypothesis tested was that the tradeoff phenomenon is masked by warm weather. When data for 20 years were pooled, there was no correlation. However, when years were analysed separately, a negative correlation was observed for five of the years. Over 12 years, the correlation coefficient between egg size and clutch size was not significant, and for 3 years it was significantly positive. The size and magnitude of the correlation were related to temperature during the pre-laying and egg-laying periods.

Of the annual variation, 34% was explained by the mean temperature in early summer. It is suggested that trade-off between egg size and clutch size may not be apparent in central (southern) parts of the distribution area of the species where climate is warmer. In the future, global warming may alter reproductive strategies of birds. Long-term data may thus be useful in the analysis of such effects and in testing of theoretical questions in ecology.

Miller, M.W,; and Nudds, T.D. 1996. Prairie landscape change and flooding in the Mississippi River Valley. *Conservation Biology* 10 (3) 847-853.

Extensive landscape alteration of prairie in the U.S. from agricultural expansion has reduced waterfowl populations and increased precipitation runoff into regional river basins. Satellite imagery shows that prairie landscapes have been less altered in Canada than in the U.S. Long-term, broadscale precipitation data indicate that in both countries precipitation has varied widely but has not increased over time. Nevertheless, flow rates of unregulated U.S. rivers have increased, but there have been no detectable changes inflow rates of Canadian rivers. Neither of two competing hypotheses advanced to explain increasing flood magnitudes - climate change and channel confinement - can account for these results. Thus, the increased magnitudes of floods in the Mississippi River Valley over the last several decades may be at least partially related to extensive changes in agricultural land use resulting in reduction of natural upland vegetation and wetland drainage in the upper reaches of this watershed.

Patten, M.A.; and Marantz, C.A. 1996. Implications of vagrant southeastern vireos and warblers in California. *Auk* 113 (4): 911-923.

An unprecedented influx of vagrant vireos and wood-warblers into California occurred in the spring and summer of 1992. The seven species involved (White-eyed Vireo (*Vireo griseus*), Yellow-throated Vireo (*V. flavifrons*), Northern Parula (*Parula americana*), Yellowthroated Warbler (*Dendroica dominica*), Worm-eating Warbler (*Helmitheros vermivorus*), Kentucky Warbler (*Oporornis formosus*), and Hooded Warbler (*Wilsonia citrina*)) all breed primarily in the southeastern United States, suggesting a common factor for the influx. Furthermore, all seven species have been recorded in California with increasing frequency over the past two decades, suggesting a common trend in the populations of these species. Anomalous weather conditions (including global warming and El Nino-Southern Oscillation) probably accounted for 1992 magnitude influx of California records of these species. Range expansions into the western United States and/or dramatic population increases in the southeastern United States explained the overall trend. Although available data are not sufficient to distinguish between summer distributional shifts and population increases within the “normal” breeding ranges of these species, the possibility of westward range expansion is intriguing.

Percy, J.A.; Wells, P.G.; and Evans, A.J. (eds.). 1996. Bay of Fundy issues, a scientific overview: proceedings of a workshop. Fundy Marine Ecosystem Science Project Workshop. Occasional report no. 8. Environment Canada, Atlantic Region, Sackville, NB. 191 pp.

Proceedings of a workshop held to bring together Atlantic region scientists and managers interested in the Bay of Fundy ecosystem to discuss the current state of scientific understanding of the principal ecosystem components and processes. Proceedings are presented in seven chapters, beginning with an overview of the Fundy Marine Ecosystem Science Project. Topics covered are: the physical environment of the Bay, including its physical oceanography and

sedimentological processes; the chemical environment, including water and sediment quality, and chemical contaminants in food chains and tissues; the biological environment (primary production, plankton, benthos, fish, birds, marine mammals); marine resources and potential constraints on resource development; and ecosystem issues such as fish stock declines, climatic changes, and coastal development. The final chapter is a workshop synthesis.

Sutter, G.C. 1996. Habitat selection and prairie drought in relation to grassland bird community structure and the nesting ecology of Sprague's pipit, *Anthus spragueii*. Ph.D. thesis, University of Regina. 167 p.

Birds of North American grassland are adapted to withstand drought; however, little is known about how they might be effected if severe prairie drought starts to occur more frequently because of global climate change. The aim of this study was to determine whether responses to drought affect habitat selection in grassland songbirds. In chapter one, the researcher tested whether spatial patchiness affected the ability of a habitat to buffer drought effects by comparing the bird, plant and arthropod communities of native and introduced (Eurasian) vegetation at sites that represent moderate (Last Mountain Lake) and more arid conditions (Matador). Native vegetation was richer and more diverse than introduced vegetation in terms of plant species, but there was no evidence that one habitat was acting as a better buffer at the bird-community level.

Sprague's Pipit *Anthus spragueii* was significantly more common in native prairie at both sites, however, and appeared to be attracted to habitat with intermediate levels of cover. In chapter two, the researcher tested whether Pipit nests were located in relatively dense vegetation to maximize the amount of shelter available and whether the nest entrance was oriented to offset the effects of day-time heating. Compared to random location, Pipit nest-sites were generally associated with dense vegetation, but there was no strong directionality in nest orientation, suggesting that the well-concealed nests of this species may offset selective pressure associated with heat stress. In chapter three, he tested whether Pipit nest attentiveness depended on nest temperature, and estimate energy costs associated with artificially elevated nest temperatures. Pipits did not adjust their incubation rhythm in response to heat stress, but they paid a clear energetic penalty for tending hot nests. They followed a "Goldilocks" strategy by defending the nest against both heat and cold, and taking recesses when nest conditions were between 30-35°C. These results support the view that drought can act like an ecological crunch through increased heat stress at the nest site. They also indicate that physiological and behavioural traits can provide a "crunchable" range of phenotypic variation.

Veit, R.R.; Pyle, P.; and McGowan, J.A.. 1996. Ocean warming and long-term change in pelagic bird abundance within the California current system. *Marine Ecology Progress Series* 139: 11 – 18.

To detect whether long-term variability in sea surface temperature and zooplankton abundance within the California current system were reflected by

pelagic bird abundance, repeated, quantified sampling of bird abundance was undertaken over 300, 000 km^2 of open ocean between 1987-1994. These results were then studied against the pattern of temperature anomaly for the period of 1987-1994, which was one of sharp increase during the early years followed by comparatively small fluctuations. One large temperature anomaly in October 1992 likely represented the 1992-1993 El Nino Southern Oscillation. On the whole, the eight years were represented by alternate warm and cold periods that each last beyond one year.

Results indicated that the abundance of birds declined significantly by 40 % over the period 1987-1994. Furthermore, anomalies of bird abundance were significantly correlated with temperatures recorded 9 months previously. This suggested that bird abundance declined in response to marine conditions typical of preceding months and that their decision to return to the California Current System was based on their estimation of resources there the previous year.

Largely, the overall decline in bird abundance was mirrored by a 90% decline of Sooty Shearwaters *Puffinus griseus*, which comprised 50% of all observed birds on study cruises. Sooty Shearwater decline was not uniform and depicted an inverse pattern of sea surface temperature; during 1987 and 1988, Sooty Shearwater abundance was high and declined to low levels for the remainder of the study. Due to lack of data on changes in their breeding colony sizes on islands off New Zealand, researchers could not conclude whether Sooty Shearwater declines off southern California were a result of a distributional shift, population decline, or gill-net mortality in the north Pacific.

Similarly, numbers of other inshore species that seek cold waters for foraging were negatively related to temperature anomaly, but depicted no significant trend in abundance. Rhinoceros Auklets *Cerorhinca monocerata* and Cassin's Auklets *Ptychoramphus aleuticus*, like Sooty Shearwaters, declined unevenly since 1987. Both species were abundant in 1987 and subsequently declined to low levels that were maintained until 1994 with the exception of a large count of Cassin's Auklets in spring 1990. The decline of the two species of alcids off southern California was particular to their winter distributions rather than reflective of overall population size.

In contrast, Xantus' Murrelets *Synthliboramphus hypoleuca*, a resident of southern California and most numerous along the offshore slopes of the channel islands, showed an increased abundance with SST anomaly. Their abundance increased until late 1991/ early 1992 and then decreased; the correlation between murrelet abundance and temperature anomaly was highest at a lag of 9 months. Leach's Storm-Petrels *Oceanodroma leucorhoa* showed a positive correlation temperature anomaly at a lag of zero and until 1992, at which time they declined in abundance. Also, Black-vented Shearwaters *Puffinus opisthomelas* showed a positive correlation with temperature anomaly that was highest at a a lag of 3 months; their abundances increased twice during the 8-year study, in the fall of 1990 and winter 1993. Warm sea temperatures followed periods of increased abundance for Least *Oceanodroma microsoma* and Black *Oceanodroma melania* Storm-Petrels; thus, both species' abundances were correlated with sea surface temperature, but at a positive lag. These two species

also peaked in abundance during late summer 1992, or just before the October peak of the El Nino off southern California; this phenomenon likely reflected northward dispersal following reproductive failure within the Gulf of California and was not correlated with temperature anomaly. This was also the explanation for the invasion of Brown Pelican *Pelecanus occidentalis* and Heerman's Gull *Larus heermani* in the fall of 1991.

Resident pelagic species of the California Current System, such as the Brandt's Cormorant, Pelagic Cormorant *Phalacrocorax pelagicus*, and Western Gull *Larus occidentalis*, showed no significant decline in abundance during the 8-year study.

Yates, M.G.; Goss-Custard, J.D.; and Rispin, W.E. 1996. Towards predicting the effect of loss of intertidal feeding areas on overwintering shorebirds (Charadrii) and shelduck (*Tadorna tadorna*): refinements and tests of a model developed for the Wash, east England. *Journal of Applied Ecology* 33: 944 – 954.

A previous model was developed to predict how recent reductions in shore width due to salt marsh reclamation affected the numbers of overwintering shorebirds – the Shelduck *Tadorna tadorna* and seven wader species (Charadrii) - feeding on the Wash, England. The predictive value of this model was revisited in this article, as new limitations were considered. Subsequent refinements, such as the reformulation to include quadratic relationships, were made to the model; an additional study was conducted at another geographical area with the revised version.

The previous model, also called the 'shore width and sediment model', related feeding bird distributions to that of their prey which, in turn, were determined by the particle size distribution of the sediments and shore profile. Yet, this model's predictions were based on the averages of three censuses – autumn, winter, and spring – during a single year. Therefore, as a revision, interannual censuses were taken in each of four winters: 1985-87, 1989-90, 1990-91, 1991-92. The model also used simple linearity to describe the relationship between bird numbers and sediments, yet a curvilinear relationship would have been more suitable for some bird types. To correct for this limitation, replicate counts were made of birds on wide shores, because their numbers were often highly variable. This allowed for a better evaluation of the hypothesis of curvilinearity. Lastly, the previous model's predictive value was not tested in localities other than the Wash. In this paper, the revised model was tested in another estuary system for the determination of overwintering birds along the Essex coast of south-east England.

The interannual censuses indicated that bird distribution around the Wash was as constant between years as between months of the same year in the previous study; this reaffirmed the degree of constancy and predictability of the model. Grey Plover *Pluvialis squatarola* and Curlew *Numenius arquata* distribution remained the most constant of the species studied between years, while red knot *Calidris canutus* distributions remained the least constant.

The average counts of birds during the four winters were significantly and positively correlated with shore-width; however, Shelduck counts were negatively correlated. Shelduck counts were also negatively correlated with the area of sand, as in the previous study. Similarly, the log-transformed 4-year averages of all species were significantly and positively correlated with both muddy and sandy shores, but numbers of Bar-tailed Godwit *Limosa lapponica* were negatively correlated. Both sediments, mud and sand, similarly affected the variations in counts of Dunlin *Calidris alpina*, Redshank *Tringa totanus*, Red Knot, Oystercatcher *Haematopus ostralegus*, and Shelduck. However, the area of mud had a greater affect on Curlew, while the area of sand had a greater effect on the numbers of Grey Plover and Bar-tailed Godwit.

As hypothesized, the relationship between bird numbers of some species and shore width on both sediments was one of curvilinearity. Quadratic expressions were more suitable descriptions for at least one sediment type for four out of eight species considered: Dunlin, Redshank, Grey Plover and Shelduck.

The predictions within the Wash showed improvement yearly, as each year's census was incorporated and as predictions were made for areas of increasing size. Outside of the Wash, along the Essex coast of southeast England, the model reasonably predicted bird numbers. With these results, the model may be applied to a wide range of geographical areas and shorelines that have undergone some disturbances, such as sea level rise due to climate change.

1995

Bethke, R.W. and Nudds, T.D. 1995. Effects of climate change and land use on duck abundance in Canadian-prairie parklands. *Ecological Applications* 5(3): 588-600.

This study found population declines of breeding ducks in Canadian Prairie Parklands were not solely the result of climate change, such as drought, between 1975-1989. Availability of breeding habitats for a number of ducks has also declined due to agricultural expansion. This practice has been more intense since the mid-1970s in western areas than in eastern ones and, on the best breeding grounds for dabbling ducks. Therefore, deficits in duck abundance have been greatest in western regions. There, the deficits in duck abundance were the greatest among the 10 species* investigated. To restore a healthy abundance of breeding ducks to these regions, habitat restoration should be implemented in regions where the best breeding grounds and poorest agricultural land coincide.

*The species of ducks that underwent annual deficits between 1975 - 1989 were: Mallard *Anas platyrhynchos*, Northern Pintail *Anas acuta*, Blue-winged Teal *Anas discors*, American Wigeon *Anas americana*, Northern Shoveler *Anas clypeata*, Gadwall *Anas strepera*, Green-winged Teal *Anas crecca*, Canvasback *Aythya valisineria*, Lesser Scaup *Aythya marila*, Redhead *Aythya americana.*

Berthold, P. 1995. Microevolution of migratory behaviour illustrated by the Blackcap S*ylvia atricapilla. Bird Study* 42 (2): 89-100.

The view on how rapidly morphological, physiological, and behavioural traits may change as a result of microevolutionary processes (i.e. genetic variation and directional selection) has changed considerably in the recent past. Observations on selection of morphological traits in Darwin's Finches on the Galapagos Islands and results of a 2-way selection experiment on migratory behaviour of Blackcaps *Sylvia atricapilla* have indicated that substantial changes can occur within short periods. A striking case was represented by Blackcaps breeding in continental Europe. Within the past 30 years, a subpopulation has developed a 'new' migratory direction to the WNW to novel wintering areas on the British Isles. Experimental analysis of migratory orientation behaviour demonstrated that behavioural changes can result from microevolutionary processes. Similar microevolutionary processes are likely to occur commonly, as both recent field observations and experimental results suggest. One outcome of this, which is of particular interest, involved the effects of continued global warming. Global warming was likely to favor obligate partial and short-distance migrants at higher latitudes and to be disadvantageous to long-distance migrants, and may lead to further reduction of species diversity.

Burton, J.F. 1995. *Birds and climate change*. Christopher Helms, London.

This book reviews changes in distribution of birds in Europe, especially the British Isles, with occasional references to North America. It takes a long-term view of climate change, with chapters on the Ice Age, From the Ice Age to AD 1250, the Little Ice Age of 1250-1850, and climatic amelioration from 1850-1950. Most of the book covers the period 1850-1950, both because most information is for this period, and because this period represents a time of global 'amelioration ' (i.e. warming) which might provide useful lessons for anticipated future global warming. There are separate chapters on seabirds, waterfowl, and passerine and non-passerine landbirds. The author points out that there was considerable climatic cooling from 1950-1980, and traces the effects of this cooling on European (especially British) birds. Recent expansions of range to the north, north-west and west are attributed mainly to anthropogenic climatic warming. Although the book concerns European birds, many species are found also in Canada and could provide useful models for bird responses in North America. The author is aware of the tendency to attribute all changes to climatic change, and in most cases is careful to consider alternative explanations. In an Appendix, each European bird species is listed, and its apparent changes in distribution

summarised (by symbols) and categorised as either 'advancing' or retreating' ,for each major period of climatic change: 1850-1950, and 1950-1993. In another Appendix, summarising distribution changes in relation to climatic warming or cooling, 191 species are categorised as 'temperate breeding species advancing northwards'; 64 as 'temperate breeding species advancing westwards'; 32 as 'temperate breeding species retreating southwards'; 7 as 'temperate breeding species retreating eastwards'; 52 as 'northern breeding species retreating northwards'; 9 as 'northern breeding species advancing southwards', all in response to *climatic warming*; and 24 species as 'temperate breeding species retreating southwards' and 55 as 'northern breeding species advancing southwards' in response to climatic *cooling*. Many species are found in more than one category, illustrating the complexity of possible responses and the difficulties of attributing complex changes to climatic influences.

Mason, C.F. 1995. Long-term trends in the arrival dates of spring migrants. *Bird Study* 42: 182-189.

Data on the spring arrival dates of 23 species of migrants in Leicestershire over a 50-year period were presented. Four species showed a significant trend towards earlier arrival over the period: Chiffchaff *Phylloscopus collybita,* Sand Martin *Riparia riparia,* Blackcap Warbler *Sylvia atricapilla,* and Sedge Warbler *Acrocephalus schoenobaenus.* For each species, correlations were made between arrival dates and mean annual March and April temperatures for England and Wales. Conversely, the following species showed a trend towards later arrival during the period: Tree Pipit *Anthus trivialis,* Cuckoo *Cuculus canorus,* Whinchat *Saxicola rubetra,* Whitethroat Warbler *Sylvia communis,* and Garden Warbler *Sylvia borin.* Arrival dates of the earliest species were much more variable than those arriving later, while species arriving in the second half of April showed a generally synchronous arrival.

Fifteen species arrived noticeably earlier in the 1940s – a period of higher April temperatures than in later decades: Swallow *Hirundo rustica*, Willow Warbler *Phylloscopus trochilus*, Yellow Wagtail *Motacilla flava*, Tree Pipit, Cuckoo, Redstart *Phoenicurus phoenicurus*, Whitethroat, Grasshopper Warbler *Locustella naevia*, Lesser Whitethroat *Sylvia curruca*, Whinchat, Garden Warbler, Wood Warbler *Phylloscopus sibilatrix*, Nightingale *Luscinia megarhynchos*, Reed Warbler *Acrocephalus scirpaceus*, and Spotted Flycatcher *Muscicapa striata.* Eight species showed earlier arrivals in the 1980s: Chiffchaff, Sand Martin, Blackcap, House Martin *Delichon urbica*, Sedge Warbler, Grasshopper Warbler, Wood Warbler, and Nightingale.

A number of species showed later arrival dates in the 1960s and 1970s, when April temperatures were colder than average. Sand Martin, Blackcap, House Martin, Grasshopper Warbler, Lesser Whitethroat, Wood Warbler, Nightingale, Turtle Dove *Streptopelia turtur,* Reed Warbler, and Spotted Flycatcher. A number of species showed significant correlations between arrival date and air temperature.

Clearly, spring temperature had a major effect on the arrival dates of

spring migrants. Future global warming may present many advantages and disadvantages to birds, including: the potential of the population to rear more second broods if earlier arrival dates persist; the associated biological effects with temperature; the asynchrony between migrants and events on their breeding grounds since temperature increases and associated biological effects may become more pronounced at higher latitudes than in the tropics.

1994

Bohning-Gaese, K.; Taper, M.L; and Brown, J.H. 1994. Avian community dynamics are discordant in space and time. *Oikos* 70 (1) 121-126.

The threat of global climate change has challenged community ecologists to predict long-term and continental-scale changes in the structure of ecological communities. However, the vast majority of studies have been done at small temporal and spatial scales. Can conclusions about community dynamics based on small-scale studies be extrapolated to larger spatial and temporal scales? This study compared the dynamics of regionally coexisting bird species over different spatial and temporal scales using data from the North American Breeding Bird Survey. It found that such extrapolation is suspect. Bird species that had similar local year-to-year population fluctuations did not have similar long-term population trends. Additionally, species that had similar population dynamics in one region rarely exhibited similar dynamics in the different regions where they occurred together.

Emslie, S.D.; and Morgan, G.S. 1994. A catastrophic death assemblage and paleoclimatic implications of Pliocene seabirds of Florida. *Science* 264: 684 – 685.

In 1989, a deposit of fossil seabirds was discovered in Sarasota County, Florida that included 137 skeletons of a single extinct cormorant *Phalacrocorax* sp.. The site was of late Pliocene age dating back to 20 – 2.5 million years BP. The fossil site, located within the marine Pinecrest Beds in the upper Tamiami Formation, also produced 48 bones collectively of two species of grebe (Podicipedidae), egret *Egretta* sp., extinct pygmy goose *Anabernicula* sp., avocet *Recurvirostra* sp., Sanderling *Calidris* cf. *C. alba*, Red Knot *Calidris* cf. *C. canutus*, jaeger *Stercorarius* sp., and two gulls *Larus* spp.. It was speculated that a catastrophic event, such as a red tide or El Nino Southern Oscillation event, led to the addition of a large number of skeletons to the deposits.

Similarity in the morphology of the nasal gland depression and other cranial features revealed that the extinct cormorant was phylogenetically a relative of the living Brandt's Cormorant *Phalacrocorax penicillatus* and the recently extinct Pallus' Cormorant *Phalacrocorax perspicillatus*. The latter became extinct in the mid-1800s and was known only from the Bering Sea and Commander Islands; Brandt's Cormorant is restricted currently to the eastern

north Pacific – an area of cold-water upwelling. The environment in which the extinct cormorant and the other marine mammals were found was concluded to be shallow marine and coastal; preserved barnacle and oyster shells, which were inhabitants of coastal areas, were attached to the surface of the cormorant bones. The habitat of the extinct cormorant, the Florida Gulf Coast, was associated with cool ocean temperatures or upwelling systems, as molluscan evidence has suggested about the Pliocene.

Gratto-Trevor, C.L. 1994. Potential effects of global climate change on shorebirds in the Mackenzie Delta lowlands. pp.360-371 i*n*: Cohen, S.J. (ed.) Mackenzie Basin Impact Study (MBIS) Interim Report #2. Proceedings of the Sixth Biennial AES/DIAND Meeting on Northern Climate & Mid Study Workshop of the Mackenzie Basin Impact Study. Yellowknife, Northwest Territories, April 10-14, 1994.

Migratory shorebirds (sandpipers, plovers, phalaropes, snipe, godwits, and curlews) have used arctic breeding areas for only a few months of the year in the past. Their preferred nesting habitat in the outer edge of the Mackenzie Delta is damp sedge, low centre polygons, and low upland tundra: areas with shallow ponds for feeding, and drier sites with some cover for nests.

Global warming in the arctic (higher air temperatures) would be expected to affect shorebirds primarily through changes in food availability and habitat. If global warming causes insects to emerge earlier in the breeding season, then shorebirds may not be able to adequately time their spring migration routes and obtain enough energy to lay eggs early enough for the young to hatch at peak insect emergence. In other words, their life cycles could become out of synchrony. Furthermore, if temperatures in the arctic increase more rapidly than temperatures in the more southern area, then food may not be yet available in central or coastal North American spring staging sites by the time birds must be in the arctic in order to have eggs to hatch in time for peak insect emergence there.

Increased air temperatures are expected to increase the depth of the soil's active layer, with a decrease in permafrost. This might allow water to penetrate deeper into the substrate, decreasing standing water in shallow ponds. Alternatively, slumping sediments might increase shallow tundra ponds in low centre polygon habitats. Shorebirds, at present, are most common in poorly drained habitats.

Increased evaporation and evapotranspiration due to higher temperatures and decreased July precipitation could result in a net decrease in wetland habitats, and an earlier drying out of tundra ponds.

Ice break-up in the Mackenzie River is expected to be earlier. If flooding regimes are changed, changes in vegetation type are expected. The Beaufort Sea coastline is already submerging, and sea levels are expected to rise faster with an increasing melting of ice cap and glaciers, resulting in greater and/or more frequent inundation of the outer delta. At the point of this study, extensive areas of sparse willow/*Equisetum*/bare ground in northern Elice Island were found – an area more frequently exposed to saltwater submersion. This kind of

habitat was not conducive to successfully nesting shorebirds, and very few were seen feeding there.

Jarvinen, A. 1994. Global warming and egg size of birds. *Ecography* 17(1): 108-110.

Using a long-term data set, this study demonstrated how egg size of birds may respond to increasing summer temperatures in the north. The results also suggested that long-distance migrants, such as the Pied Flycatcher *Ficedula hypoleuca* may benefit from "greenhouse warming".

Egg size and other reproductive data were collected in Kilpisjarvi area in northwestern Finnish Lapland (69°03'N, 20°50'E). In northern Lapland, spring and early summer temperatures, but not mid-summer temperatures, have increased during 1966 – 1993. On average, mean temperature in May increased by 0.07°C/yr.

In 1975-1993 mean egg volume of the Pied Flycatcher showed a trend toward an increase. Egg size correlated with mean air temperature during the mean egg-laying period of the population. After deleting the two extreme years (1981 and 1992), the correlation was no longer significant.

At the same time, egg size correlated with relative hatching success but not with relative fleging success (%) of the population. In 1975-1983 the mean hatching percentage of the population was 70; in 1984-1993, 86%. The corresponding percentages for fledging success were 85 and 84. Summarising these primary data; mean air temperature during the mean egg-laying period of a Pied Flycatcher population correlated positively and significantly with mean egg volume of that population. Warm weather during the egg-laying period was the probable cause of an increase in egg volume.

Large eggs protect developing embryos against cooling better than small eggs. If mid-summer temperatures rise in the future, the larger eggs of the Pied Flycatcher will probably help to improve the overall fledgling productivity of the population; warmer weather may allow females to invest more resources in reproduction. This in turn may help birds rapidly conquer new areas when they become available and compensate for rising mortality rates to be expected elsewhere where warming means dessication.

Young, B.E. 1994. The effects of food, nest predation and weather on the timing of breeding in tropical house wrens. *Condor* 96 (2) 341-353.

Three hypotheses were tested that could explain variation in the timing of breeding in populations of House Wrens *Troglodytes aedon* at four sites in Costa Rica. The sites were located at 200-1,500 m elevation on both sides and on top of the central mountain range, and had climates differing in temperature, the severity of the dry season, and total rainfall. For the first hypothesis, that breeding was timed to coincide with peaks in food availability, the monthly abundance of arthropod prey and wren clutch initiations at the four sites was monitored. Cross-correlation analysis showed that at three sites, wrens initiated

clutches several months prior to when prey levels were high. Indeed, breeding began when prey levels were at their annual low. At the fourth site, prey levels varied little throughout the year and House Wrens nested nearly year round. These results indicate that sufficient food to produce eggs or feed nestlings may have been available throughout the year. Breeding appeared to be timed so that juvenile dispersal and molt occurred when food was most plentiful.

The second hypothesis, that breeding was timed to avoid seasons when nest predation was high, was not supported because the rate of nest predation did not vary temporally. The third hypothesis, that breeding was timed to avoid climatic events that can increase the physiological costs of reproduction, was not supported at the three lower elevation sites. Clutch initiation at the highest site, however, did not commence until the early dry season wind and mist subsided. The termination of breeding was not correlated with climatic changes at any of the sites. Thus reproduction in tropical House Wrens seemed generally to be timed to facilitate post-breeding activities, not activities associated with nesting itself.

1993

Bost, C.A.; and Le Maho, Y. 1993. Seabirds as bio-indicators of changing marine ecosystems; new perspectives. *Acta Oecologica* 14(3): 463 – 470.

Emphasized the importance of monitoring seabirds, through aspects of their breeding and feeding ecology, as a way to detect subtle changes in the overall marine ecosystem. Demographic parameters of seabirds - population size, breeding success, duration of foraging trips, body mass changes, and offspring growth rate - may be correlated to changes in either physical environment or prey availabilty.

Seabird populations and reproductive performances have been regulated partially by prey through density dependent responses. The abundance of seabirds has been linked not only to relative availability of prey, but also to the preference shown by predators. For seabird monitoring to have predictive value, an in-depth understanding of the interplay between prey availability, spatial and temporal abundance and seabird foraging ecology is necessary. Nevertheless, variation in seabird feeding and breeding ecology was, in part, a reflection of seasonal and inter-annual changes in ocean productivity. Breeding performance was not limited to only oceanographic changes, but may also be a reflection of other factors - predation, parasites, and extreme weather.

Daniels, R.C.; White, T.W.; and Chapman, K.K. 1993. Sea-level rise: Destruction of threatened and endangered species habitat in South Carolina. *Environmental Management* 17 (3): 373-385.

Concern for the environment has increased over the past century, and the U.S. Congress has responded to this concern by passing legislation designed to protect the nation's ecological biodiversity. This legislation, culminating with the Endangered Species Act of 1973, has been instrumental in defining methods for identifying and protecting endangered or threatened species and their habitats. Current legislation, however, assumes that the range of a protected species will stay constant over time. This assumption may no longer be valid, as the unprecedented increase in the number and concentration of greenhouse gases in the atmosphere has the potential to cause a global warming of 1.0-4.5 °C and a sea-level rise (SLR) of 31-150 cm by the year 2100. Changes in climate of this magnitude are capable of causing shifts in the population structure and range of most animal species.

This article examined the effects that SLR may have on the habitats of endangered and threatened species at three scales. At the regional scale 52 endangered or threatened plant and animal species were found to reside within 3 m of mean sea level in the coastal stages of the U.S. Southeast. At the state level, the habitats of nine endangered or threatened animals that may be at risk from future SLR were identified. At the local level, a microscale analysis was conducted in the Cape Romain National Wildlife Refuge, South Carolina, U.S.A., on the adverse effects (destruction of nesting and feeding habitats) that SLR may have on the habitats of the American alligator, brown pelican *Pelecanus occidentalus*, loggerhead sea turtle, and wood stork *Mycteria americana*.

Dean, R. 1993. The Red Lark in the greenhouse world. *African Wildlife* 47 (5): 211, 213-214.

Vegetation is expected to change with precipitation changes due to climatic warming, which may have marked effects on the Red Lark *Certhilauda burra* – a species living in a specialized and restricted range in the the north-western Cape Province of South Africa. Its most common habitat is red sand dunes in the Koa River Valley.

Within their distribution range, Red Larks may be useful indicators of changes in dune vegetation. The birds occur on dunes or plains where tussock grasses predominate. Perennial vegetation cover in Red Lark habitats ranges between 5 - 25%, of which less than one-third is woody shrubs, although cover increases to about 40% after rains. Red sand dunes with vegetation cover that falls outside this range, often as a result of heavy grazing, do not support Red Larks.

Direct effects of increasing carbon dioxide on plants may become extremely important to Red Larks. With increasing carbon dioxide, plants using a C_3 photosynthetic pathway have a competitive advantage over plants using C_4 photochemistry. Therefore, with increasing carbon dioxide and rainfall, C_3 plants (mainly shrubs) may increase at the expense of C_4 plants (mainly grasses).

The removal of vegetation by any of: heavy grazing; changes brought about by increases in carbon dioxide; or changes in vegetation as a result of climatic change, will all make habitats unsuitable for Red Larks. Since Red Larks live in a special area and cannot adapt to changes in vegetation structure and diversity, it seems probable that they will not be able to meet the challenge of global warming.

Grant, B.R.; and Grant, P.R. 1993. Evolution of Darwin's finches caused by a rare climatic event. *Proceedings of the Royal Society of London Series B Biological-Sciences* 251 (1331): 111-117.

In this study, it was shown that Darwin's finches on a Galapagos island underwent two evolutionary changes after a severe El Nino event caused changes in their food supply. Small beak sizes were selectively favored in one granivorous species when large seeds became scarce. The effects of selection were transmitted to the next generation as a result of high trait heritabilities. Hybridization between this species and two others resulted in gene exchange, but only after the El Nino when hybrid fitness was much enhanced under the altered feeding conditions. These observations implied that if global warming increases the frequency or severity of El Nino events on the Galapagos, microevolutionary changes in animal and plant populations are to be anticipated.

Marshall, V. (compiler). 1993. Forest Ecosystem Dynamics Workshop: proceedings. Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II: 210 Victoria. 98 p.

Summary of the work completed from the establishment of the Forest Ecosystem Dynamics Program to the time of its full-scale review, along with recommendations of the review panel. The workshop covers coastal forest chronosequences, environmental changes, stand characteristics, changes in plant diversity after converting old growth to second growth, variations in community structure, effect of logging on salamanders, nematodes in different soil habitats, terrestrial molluscs, use of old growth patches by forest birds, the effects of forestry practices on carbon and nutrient dynamics, use of fertilizers, genetic diversity and its conservation, research and management strategies, and climate changes.

Park, R.A.; Lee, Jae K.; and Canning, D.J. 1993. Potential effects of sea-level rise on Puget Sound wetlands. *Geocarto International* 8 (4): 99-110.

Remote sensing and simulation modeling of coastal areas around Puget Sound, Washington (U.S.A.) suggest that sea-level rise due to global warming could lead to a large loss of tidal flats with a significant decrease in shellfish and habitat loss for diving ducks and geese. In contrast, if small dikes enclosing most of the former salt- and brackish marshes are allowed to deteriorate, saltmarshes will gradually reclaim these lowlands; if the dikes are strengthened, saltmarshes will disappear. Freshwater marshes and swamps could exhibit a slight increase

in area as the base level changes and the water table rises adjacent to the shoreline.

Poiani, K.A.; and Johnson, W.C. 1993. Potential effects of climate change on a semi-permanent prairie wetland. *Climatic Change* 24 (3): 213-232.

The potential effects of a greenhouse gas-induced global climate change on the hydrology and vegetation of a semi-permanent prairie wetland were investigated using a spatially-defined, rule-based simulation model. An 11-yr simulation was run using current versus enhanced greenhouse gas climates. Projections of climatic change were from the Goddard Institute for Space Studies (GISS) general circulation model. Simulations were also run using a range of temperature (+2 and +4 degree C) and precipitation change values (-20,10.0, +10, +20%) to determine the responsiveness of wetland vegetation and hydrology to a variety of climate scenarios.

Maximum water depths were significantly less under the enhanced greenhouse gas scenario than under the current climate. The wetland dried in most years with increased temperature and changes in precipitation. Simulations also revealed a significant change in the vegetation, from a nearly balanced emergent cover to open water ratio to a completely closed basin with no open water areas. Simulations over a range of climate change scenarios showed that precipitation changes (particularly increases) had a greater impact on water levels and cover ratios when the temperature increase was moderate (+2 degree C). These potential changes in wetland hydrology and vegetation could result in a dramatic decline in the quality of habitat for breeding birds, particularly waterfowl.

Poiani, K.A.; and Johnson, W.C. 1993. A spatial simulation model of hydrology and vegetation dynamics in semi-permanent prairie wetlands. *Ecological Applications* 3 (2): 279-293.

The objective of this study was to construct a spatial simulation model of the vegetation dynamics in semi-permanent prairie wetlands. A hydrologic submodel estimated water levels based on precipitation, runoff, and potential evapotranspiration. A vegetation submodel calculated the amount and distribution of emergent cover and open water using a geographic information system. The response of vegetation to water-level changes was based on seed bank composition, seedling recruitment and establishment, and plant survivorship. The model was developed and tested using data from the Cottonwood Lake study site in North Dakota. Data from semi-permanent wetland P1 were used to calibrate the model. Data from a second wetland, P4, were used to evaluate model performance. Simulation results were compared with actual water data from 1979 through 1989.

Test results showed that differences between calculated and observed water levels were within 10 cm 75% of the time. Open water over the past decade ranged from 0 to 7% in wetland P4 and from 0 to 8% in submodel simulations. Several model parameters including evapotranspiration and timing of seedling germination could be improved with more complex techniques or

relatively minor adjustments. Despite these differences the model adequately represented vegetation dynamics of prairie wetlands and can be used to examine wetland response to natural or human-induced.

Root, T.L. 1993. Effects of global climate change on North American birds and their communities. Pp. 280-292 *in* Karieva, P.M.; Kingsolver, J.G.; and Huey, R.B. (eds.). Biotic interactions and global change. Sinauer Associates, Sunderland, MA.

Between the last glacial and present interglacial periods, vegetation communities exhibited major disruptions due to differential expansion and contraction of ranges, and there were many extinctions. Predicted impending climate change is at least an order of magnitude faster, so dramatic disruption of communities can be expected in the next century. This paper reviews author's own work on winter distribution of North American birds (using Christmas Bird Count data from 1962 through 1972). The northern boundary of many species' winter range was correlated with mean minimum January temperature (60.2% of all species examined), mean length of frost-free period (50.4%), and vegetation (i.e. habitat) (63.7%). Habitat was also frequently associated with eastern (62.8%) and western (46.0%) range boundaries, as was mean annual precipitation (39.7% and 36.0%, respectively). Because global cimate changes are expected to shift the geographic position of temperature and rainfall regimes, the boundaries of bird distributions in winter are predicted to change accordingly.

Studies of the winter physiology of 14 songbird (Passeriform) species showed that the metabolic rate at the northern boundary of the range was a multiple of 2.5 times Basal Metabolic Rate (BMR), with little variation among species (95% confidence intervals 1.95-2.93). Since body mass is inversely related to BMR, larger birds should winter further north, as indeed they do; exceptions are found in species such as black-capped chickadees (*Poecile atricapilla)* with behavioural specialisations for mitigating effects of low temperature (e.g. hypothermia, communal roosting, food-caching). Review integrates this physiological work with geographic distribution studies, and argues for a research agenda linking single-species studies of ecology, behaviour and physiology, of plants as well as birds, with information from climatologists, geologists and others to better forecast possible biological consequences of global climate change.

Safina,C. 1993. Population trends, habitat utilization, and outlook for the future of the Sandhill Crane in North America: A review and synthesis. *Bird Populations* 1: 1-27.

This paper reviewed historical range changes, population trends, and habitat requirements of the Sandhill Crane *Grus canadensis* and broadly predicted future population changes. Although habitat loss and consequent range contraction during the recorded history of North America have been great, Sandhill Cranes in the latter part of the 20th century have benefitted from agriculture and protection, and their numbers have increased impressively. Sandhill Crane numbers are currently high for most populations. However, the

continuing rate of loss of freshwater wetlands and human development of their wintering areas threaten their future. Sandhill Cranes are dependent on shallow, easily-drained marshes for roosting and nesting habitat almost everywhere in their range. This general habitat requirement, which probably evolved as security from predation, is now their vulnerability. Wetland preservation and enhancement are the most important issues in Sandhill Crane conservation. Because Sandhill Cranes gather in large numbers during winter and migration, continued wetland destruction may cause sudden, large-scale population declines. Increasing human populations are draining most of the Sandhill Crane's wintering habitat. At present, only the Rocky Mountain Greater Sandhill Crane population (approximately 3% of the total population) appeared secure. Climate changes that make present ranges more arid will be deleterious to cranes, but temperature rise per se ought not, because breeding Sandhill Cranes have adapted to temperature regimes ranging from that of Siberia to that of Cuba. Whether migratory populations will be able to adapt to an altered distribution of suitable wet habitat consequent to climate changes will depend on the rate of habitat change, the crane's rate of adaptation, and altered patterns of human habitat use, which are all unknowns.

Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D. (eds.). 1993. The status, ecology and conservation of marine birds of the North Pacific: proceedings of a symposium. Environment Canada, Canadian Wildlife Service, Special publication. Ottawa: 263 p.

Proceedings of a symposium covering bird distribution in the Bering Sea, in the central North Pacific, off the coasts of British Columbia and Washington, and in the California current, and explores the effects of climate changes such as the El Nino/Southern Oscillation and potential global warming on seabirds and their prey. The second section includes chapters on nesting and visiting seabirds in the North Pacific, from the Tropic of Cancer in the south to the Bering Sea in the north. Bird groups covered are albatrosses, fulmars, gadfly petrels and storm petrels, shearwaters, gulls, kittiwakes, terns, guillemots, murrelets, murres, puffins, and auklets. The third section includes chapters on the effects of environmental hazards such as gillnetting, introduced predators, human disturbance, plastic ingestion, contamination by trace metals and chlorinated hydrocarbons, and oil spillage on marine birds.

1992

Browning, M.R.1992. A new subspecies of *Chamaea fasciata* (Wrentit) from Oregon (Aves:Timaliinae). *Proceedings of the Biological Society of Washington* 105 (3): 414-419.

Geographic variation in plumage color of *Chamaea fasciata* (Wrentit) from northern California and southern Oregon was related to climate in this study. A new subspecies, *Chamaea fasciata margra*, was described from a disjunct population of southern interior Oregon.

Past studies suggested that populations of *C. fasciata* occurring in regions of dense vegetation and high humidity were darker and richer in color, and those populations of less dense vegetation and lower humidity were paler. In this study, the six subspecies of *C. fasciata* also varied by tail length, crown color, back and upper tail color, color of lower parts, and color of flanks according to this hypothesis; the specimens were from coastal Oregon, western coastal California, and northern interior California.

Colonization of *C. fasciata* in interior Oregon was perhaps from birds crossing coniferous forests via isolated patches of *Ceonothus*. Recent increases of Wrentits in interior Oregon may be in response to habitat alterations (deforestation, fires) and concurrent global warming.

Cooper, J.; and Lutjeharms, J.R.E. 1992. Correlations between seabird breeding success and meteorological conditions on Marion and Gough Islands. *South African Journal of Science* 88(3):173-178.

Information on the breeding success of surface-nesting seabirds of several species has been collected annually by the FitzPatrick Institute from 1981/82 to 1989/90 on Marion and Gough Islands in the southern Indian and Atlantic Oceans, respectively. Meteorological stations on these two islands have collected data over the same period, so that researchers could try to find relationships between weather conditions and seabird breeding success.

Year-to-year variations in breeding success varied the greatest in the Macaroni Penguin *Eudyptes chrosolophus* and Southern Giant Petrel *Macronectes giganteus* at Marion Island and lowest in the Northern Giant Petrel *M. halli* at Gough Island and Yellownosed Albatross *Diomedea chlororhynchos*.

Relationships between seabird breeding success and meteorological conditions were as follows. There was a negative correlation between Macaroni Penguin annual breeding success and seasonal rainfall at Marion Island and a positive correlation between Yellownosed Albatross breeding success and seasonal windiness at Gough Island. There was a weak positive relationship between the breeding suces of Wandering Albatross *Diomedea exulans* and rainfall and windiness at Mation Island.

At Marion Island, runoff from heavy rain can cause local flooding and peat slides around penguin breeding colonies and can lead to nest failure by chilling of wetted eggs or nest failure. Seasons of high rainfall could have, therefore, resulted in poor breeding seasons of the Macaroni Penguin. At Gough Island, annual variations in windiness may be correlated with variations in pelagic conditions which, in turn, may affect foraging success and timing of nest reliefs for Yellownosed and Wandering Albatrosses.

Given these relationships, it may be possible by inference to predict the

effects of such climatic changes, such as global warming, on southern seabirds. Such predictions will help when decisions are to be made relating to the conservation management of southern islands and their biota.

Fraser, W.R.; Trivelpiece, W.Z.; Ainley, D.G.; and Trivelpiece, S.G. 1992. Increases in Antarctic penguin populations: reduced competition with whales or loss of sea ice due to environmental warming? *Polar Biology* 11: 525-531.

Past studies have suggested that increases in in the abundance of Chinstrap Penguins *Pygoscelis antarctica* during the last four decades has resulted from an increase in prey availablility brought on by a decrease in baleen whale stocks; both organisms share krill as a prey item. However, the increase in Chinstrap Penguin abundance has not been mirrored by their close relative, the Adelie Penguin *Pygoscelis adeliae*. Both share a common habitat on the Antarctic Peninsula and islands of the Scotia Sea and exhibit a predominance of krill in their diets, yet population increases in Adelie Penguins have not been substantial and they have, in fact, decreased at several locations on the Antarctic Peninsula.

In this study, the whale reduction hypothesis was challenged with new evidence suggesting that increases in Chinstrap Penguin numbers were due to a gradual decrease in the frequency of cold years with extensive winter sea ice cover resulting from environmental warming. Supporting data were derived from a winter expedition to the Scotia and Weddell Seas in 1988; recent satellite images of ocean ice cover; and the analysis of long-term surface temperature records and penguin demography.

Demographic data on Chinstrap and Adelie Penguins were initiated at Admiralty Bay, King George Island in 1977 and had continued until the point of this study. Large annual increases in Adelie numbers were coincident with large annual decreases in Chinstrap numbers. These changes were also related to the extent of winter and spring sea ice cover, with Chinstraps increasing when sea ice extent diminished and vice versa. The importance of the winter expedition in 1988 was uncovering the fact that Chinstraps and Adelies resided in completely different habitats. Chinstrap Penguins occurred almost exclusively in open water, while Adelie Penguins were obligate inhabitants of the pack ice.

Analysis of long-term surface temperature records revealed that mean surface air temperatures had been increasing in the Antarctic Peninsula since approximately 1950. Also, satellite images of ocean ice cover revealed that since 1973, sea ice has been minimal along the western edge of the Antarctic Peninsula during years when surface air temperatures averaged at four stations had been warmer than $-4.3^{o}C$.

The frequency of cold/warm years, and thus extensive/reduced ice years, had changed sufficiently and over a long enough time period to influence resident penguin populations. The frequency of cold years had in fact changed during the last 45 years from an average of 4 out of 5 during mid-century to an average of only 1 or 2 out of five during the last 20 years.

Meekes, H.T.H.M. 1992. An inventory of the possible effects of climatic change on western palearctic migratory birds. *Wetlands Ecology and Management* 2(1-2):31-36.

This paper presented an assessment of the possible effect of future climatic change on migratory birds. An inventory was made of the environmental factors that may change which directly affect migratory birds. These factors included physical (temperature, hydrology, ocean and air streaming patterns) as well as biological (floral and faunal composition of ecosystems) and landuse aspects of the environment.

Temperature regulation in birds may become difficult if temperatures become too high, although increasing rainfall may counteract this effect, at least for waders. Dessication of freshwater wetlands due to higher evaporation and possibly lower precipitation could become an important threat. Long-distance migrants that are wetland-dependent may be faced with reduced stopover options in southern Europe. 'Skippers" and 'jumpers' , wader species which depend on few stopover sites, such as the Bar-tailed Godwit *Limosa lapponica* and the Knot *Calidris canutus,* may lose vital staging areas, which would considerably hamper their migration.

Wind patterns may change, and this may have consequences for birds presently using prevailing winds during migration to save energy. Stronger winds may lead to higher energy requirements for flight; some birds may be able to adapt. Aberrant prevailing winds may guide birds to new areas – both suitable and unsuitable. Oceanic streaming patterns may change which may lead to displacement of food resources for pelagic birds. Longer feeding trips may be required of them, which could reduce reproductive performance.

Birds breeding in the arctic and those depending on reed vegetation may especially encounter great changes in breeding areas. The tundra area is expected to decline significantly, leading to decreasing populations of arctic geese (*Branta* spp., *Anser* spp.) and waders (*Calidris* spp., *Limosa lapponica*).

Annual dessication of wetlands, which might be expected especially in southern Europe, will reduce the surface covered by reed vegetation and favour drought-tolerant plant species. This will lead to decreasing numbers of reed-inhabiting warblers (*Acrocephalus* spp.) and crakes (*Porzana* spp.).

Increased disturbance caused by size reduction of suitable areas due to dessication of wetlands and increased accessibility for predators, as well as reduced food availability, will enhance the vulnerability of swans, geese, ducks, and waders during moult, which often requires absence of disturbance combined with good food resources to make flight possible.

Short-distance migrants may shift their routes or begin wintering at higher latitudes. The migratory behaviour of the Blackcap *Sylvia atricapilla* is flexible enough to achieve this.

Mediterranean inland wetlands, which currently form the last possible stopover for herons, ducks, crakes, and warblers migrating to tropical Africa, may disappear due to desertification of the area.

It was concluded that many migratory bird species will be influenced by climatic change, leading to adaptations in the birds' annual cycles.

Norman, F.I.; Cullen, J.M.; and Dann, P. 1992. Little penguins *Eudyptula minor* in Victoria: Past, present and future. *Emu* 91 (5): 402-408.

Colonies of Little Penguins *Eudyptula minor* on Phillip Island, Victoria, (Australia) have declined in both breeding areas and numbers. Breeding periods have shortened in the past 20 years, and hence reduced potential recruitment, and there are increased losses in the pre-breeding age group. Some losses are due to continuing predator activities (mainly fox) but studies suggested that climate changes, reflected in sea temperature, may play a role in population regulation presumably through food availability. Off Phillip Island, Little Penguins take a range of prey, principally small schooling clupeoids, and breeding can be delayed if these are unavailable. Fish sampling showed the changing abundance and patchy distribution of food and the birds' distribution sometimes related to that of prey.

Vermeer, K. 1992. The diet of birds as a tool for monitoring the biological environment. pp. 41-50 *in* Vermeer, K, Butler, R.W. and Morgan, K.H. (eds.). The ecology, status and conservation of marine and shoreline birds on the west coast of Vancouver Island. Occasional paper no. 75. Canadian Wildlife Service, Ottawa, ON.

A review of the diet of marine birds in nesting colonies, in estuaries, in inlets, and over offshore banks along the west coast of Vancouver Island indicates that little is known of the diet of most nesting seabirds. An analysis of the diet of a small sample of pelagic birds over offshore banks revealed that they foraged on the same main food categories as elsewhere in the North Pacific, although there were geographic differences in prey species. Herring spawn constitutes a major food source for piscivorous and nonpiscivorous birds. Monitoring of the diets is providing biologists with an important tool to determine the effects of yearly physical variation in surface waters as well as those of major irregularities, such as El Ninos and global warming, on both prey and seabirds. It is necessary to monitor pollutants from mines and pulp and paper mills in tissues of both estuarine and marine birds and their prey.

1991

Botkin, D.B.; Woodby, D.A.; and Nisbet, R.A. 1991. Kirtland's Warbler habitats: a possible early indicator of climatic warming. *Biological Conservation* 56: 63-78.

If the projections of global climate models are correct, jack pine *Pinus banksiana* forests in central Michigan, the primary nesting habitat for the endangered species Kirtland's Warbler *Dendroica kirtlandii*, will soon be growing at a significantly slower rate than they have in the recent past. This endangered species nests only in the lower peninsula of Michigan and only in young jack pine stands exclusively where these grow on a single soil type – Grayling sands (a coarse sand found only at the southern edge of the jack pine's range in the lower northern peninsula of Michigan).

As a result, even though jack pine forest may move north as the climate warms, if it is not on sandy soil it will be unsuitable for Kirtland's warbler because this species nests on the ground and nests are flooded on poorly-drained soils. Thus these forests may become unsuitable for the warbler within 30 – 60 years. This projection was based on results from a global climate applied to a forest growth model. The robustness of these projections was discussed.

To explore the consequences for jack pine in Michigan of projected rapid climatic warming, climate projections for a transition from current conditions to that under twice CO_2 atmospheric concentration from a general circulation model were used. As the climate changes, the forest model predicts that jack pine will not persist through the next century and will become replaced by other species such as quaking aspen *Populus tremuloides* and oaks *Quercus* spp. by 2040. Although aspen and oak come in to replace jack pine, only stems of oaks are common by 2070; therefore a mature forest will never develop.

Species such as the Kirtland's Warbler that have highly restricted ranges may indeed become extinct in the next century , and management of such habitats might need revision in light of a projected global warming.

Brown, R.G.B. 1991. Marine birds and climatic warming in the northwest Atlantic. pp. 49-54 *in* Montevecchi, W.A. and Gaston, A.J. (eds.) Studies of high-latitude seabirds. 1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology. Occasional Paper Number 68. Canadian Wildlife Service, Ottawa.

Global warming has instigated a rise in worldwide rise in sea level that has caused a northerly expansion of breeding and feeding sites for many North Atlantic seabirds. Ornithologists have expected a northward expansion in the breeding ranges of low Arctic and high Arctic seabirds, such as the Common Murre *Uria aalge* and Thick-billed Murre *Uria lomvia*, respectively, from their coinciding breeding ranges at southeast Labrador. A similar northerly shift was expected with the Cory's Shearwater *Calonectris diomedea* and Great Shearwater *Puffinus gravis*, which summer off eastern Canada. At present, the former's geographical distribution lies within the Gulf Stream, while the latter's distribution extends beyond the Gulf Stream to southeast Labrador.

Murres, auks and other North Atlantic seabirds, feed on fish like capelin *Mallotus villosus* and Arctic cod *Boreogadus saida*, which may move to colder, northern waters as the warming trend progresses. Although difficult to ascertain at this point, these low Arctic and boreal seabirds most likely will shift to more

northerly ranges only after their prey have shifted. Therefore, they will alter their feeding grounds before they alter their breeding grounds.

As polar regions of the world continue to warm faster than any other, so will the species of this area react the fastest. For instance, one can expect that the migratory range of high Arctic seabirds, such as of the Ivory Gull *Pagophila eburnea*, will be squeezed northward. The southernmost limit of their route will retreat northward as their southern feeding habitat off the coast of Newfoundland becomes diminished. This habitat is pack ice, upon which their prey, harp seals *Phoca groenlandica* and hood seals *Cystophora cristata*, are captured. As this pack ice is expected to melt quickly, both of gulls and seals will move to more favorable northerly limits.

By contrast, other high Arctic birds, like the Dovekie *Alle alle*, will find this warming trend favorable with respect to their feeding ecology. At present, these seabirds are distributed along polynyas of southwest Greenland; Dovekie feeding habitats are associated with these open oceanic areas. In the future, they will expand their geographical range into northern Greenland where further polynyas will expect to develop. Further breeding grounds will also be exposed for Dovekies along slopes as snow melts earlier in the spring.

Thawing of permafrost may have long-term consequences for Red Phalaropes *Phalaropus fulicarius* and Red-necked Phalaropes *P. lobatus*. The thawing could cause extensive flooding along Arctic tundra, upon which areas they breed. Such flooding will cause long-term habitat damage for these breeding birds.

Red Phalaropes and Red-necked Phalaropes may respond negatively to differences in copepod levels as they journey through the Bay of Fundy during their migration route to Peru and West Africa. Such differences may arise as surface upwellings of copepod levels change; the ability of upwellings to occur may be compromised by an increased sea level in the future. These species of phalaropes may incur a further depletion of zooplankton levels as they reach the southern point of their migratory routes - off Peru and West Africa. Upwellings fail to occur every few years for these birds and are replaced by surges of warm water caused by El Nino. This leads to death of a large number of seabirds by starvation every year; the phenomenon may intensify as climatic warming progresses.

Meekes, H.T.H.M. 1991. The possible impact of climatic change on the avian community of dune ecosystems. *Landscape Ecology* 6 (1/2):99-103.

The possible effects of climatic change on the avifauna of dunes, especially in the Netherlands, were analyzed with two different approaches – the general and specific approaches. With the general approach, probable changes in dune habitats were translated to changes in functions these habitats serve to various bird groups or species. Sea level rise and coastal erosion were not thought to pose a problem to birds. In a number of situations with positive sedimentation budgets, disappearing dunes will be replaced by newly formed dunes at the new beaches. A special problem may arise if coastal erosion proceeds quickly and results in total disappearance of the present dunes.

If soil moisture content and the ground water level decrease due to climatic change, then problematic situations will arise for shorebirds that use these habitats for resting at high tide (Gulls *Laridae* and Waders *Charadriidae.*) On the other hand, the reverse development in other areas may create new alternative opportunities for these species.

The specific approach involved studying distribution maps from the Netherlands of breeding birds and selecting those species that have key populations in the dunes.

Poiani, K.A. & W.C. Johnson. 1991. Global warming and prairie wetlands. *BioScience* 41(9): 611 – 618.

Climate models have predicted a hot, dry regime for the North American Great Plains, which could adversely affect the habitat quality for breeding waterfowl. Climate affects the quality of habitat by controlling wetland hydrology and vegetation patterns.

The number of wetlands plays a role in determining waterfowl production. For example, Mallard (*Anas platyrhynchos*) breeding densities and brood numbers were greatest during years of increased numbers of ponds holding water. The permanence types within a wetland complex also have played significant roles in determining the quality of habitat for waterfowl such as dabbling ducks. They have used the early food resources of temporary and seasonal wetlands in spring. Similarly, both dabbling and diving ducks have nested and reared their broods in seasonally flooded wetlands, particularly when water levels were high. Then, they re-nested and reared broods in open areas of semipermanent wetlands after seasonal wetlands dried.

However, with the recent warming trend, the numbers of seasonal and temporary ponds are predicted to decline; subsequently, these dried-out breeding grounds may be used for agricultural purposes. In response to an expected drought, waterfowl may remain on permanent wetlands but not breed, fail to renest, or migrate to semipermanent wetlands. However, if global warming progresses, the density of emergent vegetation in semipermanent wetlands may exceed what is normal, and therefore exceed the normal cover:water ratio that would support optimal waterfowl production. Salinity of ponds may also rise as global warming continues. Saline conditions support the growth and production of invertebrate communities and submergent vegetation – the prey of many waterfowl species. Yet, such conditions do not promote the growth of emergent vegetation that produces a desirable cover:water ratio for breeding waterfowl. Hence, a saline environmemt would not be one selected by waterfowl.

To offset the loss of wetland habitat due to increasing cover:water ratios and loss of temporary and sesaonal ponds, the northern limits of prairie habitats may expand in response to increased temperatures, especially at higher latitudes.

Siegel-Causey, D., Lefevre, C.,and Savinetskii, A.B. 1991. Historical diversity of cormorants and shags from Amchitka Island, Alaska. *Condor* 93: 840 – 852.

In two large Aleut middens dating back to the Holocene period, the skeletal remnants of 6 species of shags and cormorants were excavated. 78% of 2, 025 bones recovered were of Pelagic Shag *Stictocarbo* [*Phalacrocorax*] *pelagicus*; 16% were of Red-faced Shag *Stictocarbo urile*; 5% were of Kenyon's Shag *Stictocarbo kenyoni*; and 1% were of Double-crested Cormorant *Hypoleucus* [*Phalacrocorax*] *auritus*. In addition, two elements of Japanese Cormorant *Phalacrocorax capillatus* and one element of Pallas's Cormorant *Compsohalieus* [*Phalacrocorax*] *perspicillatus* were found.

The Japanese and Pallas's Cormorants were most likely chance arrivals to Amchitka Island. The results of the analysis of the Kenyon's Shag remnants were inconclusive. The distribution of the Double-crested Cormorant was discovered to have changed throughout the past 2, 600 years. Analysis revealed that their numbers were low during this course of time; comparatively, the numbers are even lower today on Amchitka Island. Their changes in abundance through time reflected changes in distribution patterns, as cormorants and shags still are the commonest species of avifauna along Alaska. Three plausible explanations were given for the re-distribution of cormorants. The midden bones may have reflected chance occurrences of the cormorants during times of favourable conditions. Or, a switch to a colder climate in the past may had restricted cormorants from breeding in this area in later years. As a third possibility, cormorants may had always comprised a great part of the Amchitkan avifauna until eradication by predators, such as the Arctic foxes. Their flat-nesting habitat made them easy targets for such predators.

From the analysis of Pelagic and Red-faced Shag bones, temporal changes in their distribution have also been elucidated. The two have maintained numbers of constant proportion, as was represented in all of the strata of middens since the last Holocene, although their abundances have changed considerably on Amchitka Island. At present, the Pelagic Shag and the Red-faced Shag are the only two phalacrocoracids that breed on the Aleutian Islands, and the Pelagic Shag is about five times as numerous as the Red- faced shag on Amchitka Island. The changes in their distributions reflected their usage by early Aleuts, who used shags as a food item and as an exchange commodity.

Wilson, U.W. 1991. Responses of three seabird species to El Nino events and other warm episodes on the Washington coast, 1979-1990. *Condor* 93: 853 – 858.

Each of three major warm episodes (Jan.-Apr. 1981; Feb.-June 1983; Sept. 1987-Feb. 1988) along the Washington outer coast had peaked between 2.0 ^{o}C and 2.3^{o}C for each warm episode and were sustained at a minimum of 1^{o}C above climatological mean for four to six months. Within each warm episode, monthly SST data were compared with the nesting behaviour of the Double-crested Cormorant *Phalacrocorax auritus*, Brandt's Cormorant *Phalacrocorax penicillatus*, and Common Murre *Uria aalge*.

The negative correlation between SST and number of nests was lowest for Double-crested Cormorants during and after the 1982 - 83 El Nino event – the strongest event of this century. During the 1983 breeding season, 216 occupied nests were located; 7 were found in 1984. Numbers of nests were then restored after 1983 to pre-1983 nest numbers. Nest counts of Double-crested Cormorants plunged to a lesser degree in 1988 following the moderate 1987-1988 El Nino event. Oppositely, more nests were recorded during the 1981 warm episode than counted in 1979 and 1980. The effects of the 1981 event on number of nests of Double-crested Cormorants, which was not associated with an El Nino episode, were not well understood.

Comparatively, the number of Brandt's Cormorants nests declined during the 1983 El Nino event, and declined to 0 in 1984. Nest numbers then increased and were not significantly different to numbers prior to 1983. Similarly, nest counts were depressed following the 1981 episode and during 1987-1988 El Nino years. The annual counts of Brandt's Cormorant nests were significantly negatively correlated with the number of warm months (per calendar year, during January to June, and during March to August). The differences in timing of responses between Double-crested Cormorants and Brandt's Cormorants may be related to differences in their breeding chronologies.

The steepest decline in colony-attending Common Murres was associated with the 1983 El Nino event. During the 1983 El Nino year, their numbers declined by 87% of pre - 1983 counts. As with cormorants, the lowest numbers of murres were recorded in 1984. However, murres did not recover from the severe 1983 El Nino event and their numbers remained low from 1983-1986. Following the 1987-1988 El Nino event, murre numbers again declined to values similar to those during 1983-1986; these low numbers remained until 1990. The warm episode of 1981 also caused a decline in the number of colony-attending murres – approximately 20, 000. Annual murre numbers were significantly negatively correlated with the number of warm months during January-June.

1990

Taylor, R.H., Wilson, P.R. and Thomas, B.W. 1990. Status and trends of Adelie penguin populations in the Ross Sea region. *Polar Record* 26 (159): 293-304.

Aerial reconnaissance and photography were used in the Ross Sea sector of Antarctica to determine the breeding locations of Adelie penguins *Pygoscelis adeliae* , and to count the numbers of nests occupied during the early incubation period. From 1981 to 1987, all islands and sea coasts between 158 degree E and 175 degree E were searched, and 11 previously unreported breeding rookeries were discovered. Thirty-eight Adelie rookeries are now known from the region, with a total of about 1,082,000 breeding pairs—almost half the world

population. Some rookeries were photographed in all, or most, of the seven seasons to study the pattern of natural fluctuations in Adelie populations, and comparisons have been made with earlier counts. Populations at nearly all rookeries have increased in size over the last 10-20 years. Possible reasons for this, and for annual fluctuations in numbers breeding, include seasonal variations in sea ice and weather conditions, and longer-term climatic change.

1989 - 1972

Ball, T. 1983. The migration of geese as an indicator of climate change in the southern Hudson Bay region between 1715 and 1851. *Climatic Change* 5 (1): 85-93.

Observations and records maintained by the Hudson's Bay Company at York Factory and Churchill Factory on Hudson Bay between 1714 and 1825, served as the source of information for a study of changes in the date of arrival of geese (Anatidae) as a phenological indicator of climatic change. Changes in the migration pattern of geese were reflected in the changing date of arrival at the same location over a long period of time. Variations in this date were determined to be a function of southerly or tailwinds in the northward spring migration.

Cuthbert, F.J. 1989. Tern populations and changing lake levels: Implications for management and conservation. 32nd Conference On Great Lakes Research p. 40.

The breeding biology of Common *Sterna hirundo* and Caspian *S. caspia* Terns has been studied in lakes Michigan and Superior since 1975. This paper summarized the impact of fluctuating water levels on selected aspects of the behavior and ecology of both species and recommended methods for minimizing water level related impacts. Research indicated that Great Lakes water levels are a major variable influencing where birds nest, who they mate with, and whether individual reproductive effort is successful. A major question confronting colonial waterbird biologists is how populations will respond to lake levels lowered by predicted climatic change or from mandated regulation or diversion. To preserve the current diversity of water birds in the Great Lakes, federal and state agencies should monitor breeding sites annually and prioritize species or populations for special management efforts as needed. Methods to enhance populations include: attraction to alternate sites, minimizing gull/tern competition for habitat, reducing human disturbance and site specific predator control.

Kiel, W. H., Hawkins, A.S., and Perret, N.G.D. 1972. Waterfowl habitat trends in the aspen parkland of Manitoba Canadian Wildlife Service Report no. 18. Ottawa: Environment Canada, Canadian Wildlife Service, 63 p.

This study described natural and man-made changes in waterfowl habitat in the Minnedosa district of the aspen parkland of Manitoba. The study began with a review of the history of the prairie area from Aboriginal times to European settlement, the abundance of wildlife and waterfowl, prairie weather and floods, and precipitation fluctuations within the Minnedosa study area. It then described investigations over 1946-66, which included years both of intensive study and of brief reconnaissance. Ground transects and study blocks were established, potholes were selected along transects for waterfowl breeding and production surveys, vegetative cover maps were prepared, and aerial photographs were studied to determine changes in the area over the years. Waterfowl habitat changes were described, including those due to water level fluctuations, vegetation cover changes, climatic conditions, abundance of predators, road building, land clearing, and agricultural drainage. Finally, waterfowl density, species composition, and trends were estimated for the area for 1949-60 and the production potential of the study area were assessed. Little evidence was presented for direct response of waterfowl populations to climate, other than the well-known association between spring counts of ducks, numbers of wetlands, and rainfall.

Koskimies, P. 1981. The expansion of the Great Reed Warbler *Acrocephalus arundinaceus* into Finland. *Ornis Fennica* 58:151-158.

All known records of the Great Reed Warbler in Finland were collected for this study to elucidate some general questions concerning bird dispersal. The earliest record dated back to 1930 near Helsinki. The Reed Warbler population remained small up until the 1960s; the mean annual number of birds recorded was 3.6 in the 1950s, 7.5 in the 1960s and 30.2 in the 1970s. These figures somewhat exaggerate the increase, since observation activity has intensified. Until the beginning of the 1970s, the range was restricted to the south coast but covered the SW coast and SE Finland by the time of this study.

Springer, A.M.; Vernon Byrd, G.; Melteff, B. (coord). 1989. Seabird dependence on walleye pollock in the southeastern Bering Sea. Proceedings Of The International Symposium on the Biology and Management of Walleye Pollock, Anchorage, Alaska U.S.A., November 14-16, 1988. Lowell Wakefield Fisheries Symposium, Pp. 667-677, Alaska Sea Grant Rep. no. 89-1.

Piscivorous seabirds nesting on the Pribilof Islands and on St. Matthew-Hall Islands in the southeastern Bering Sea feed chiefly on walleye pollock in summer. During the 1980s, the reproductive success of kittiwakes has been poor in most years, apparently because of inadequate food availability. The reproductive success of black-legged kittiwakes was significantly correlated with

estimates of the abundance of age 1 pollock in the southeastern Bering Sea during a period of decline of both from 1975-1982. Numbers of kittiwakes and murres have decreased significantly on the Pribilof Islands since the mid-1970s. These observations were discussed in relation to 1) recent climate changes that might have affected the availability of pollock to seabirds during summer, 2) trends in recruitment data that indicate a decline in the abundance of juvenile pollock during the 1970s and early 1980s, and 3) population trends at other colonies in the southern Bering Sea where seabirds are supported by different prey species. Population declines are associated with cyclic changes in sea surface temperature between 3°C and 13°C over this period, that may have caused changes in numbers of young pollock.

Taylor, R.H; Wilson, P.R; and Thomas, B.W. 1988. Status and trends of Adelie penguin populations in the Ross Sea region. *Cormorant* 16: 134-135.

Aerial reconnaissance and photography are being used in the Ross Sea sector of Antarctica to determine the breeding locations of Adelie Penguins *Pygoscelis adeliae* , and to count the numbers of nests occupied during the early incubation period. Over the years 1981 to 1987, all islands and sea coasts (of Victoria Land and part of Oates Land) between 158E and 175E were searched, and 10 previously unreported breeding sites discovered.

The region now has 38 known Adelie Penguin colonies with a total of over 1,000,000 breeding pairs: almost half of the world population. A sample of colonies selected for different size, topography, and latitude was photographed in each of the seven seasons to study the pattern of natural fluctuations in Adelie Penguin populations. Most other colonies have been surveyed more than once, and comparisons have been made with population estimates in earlier accounts. Nearly all colonies have increased in size over the last 10-20 years. Possible reasons for this trend and for annual fluctuations in the numbers of penguins breeding, include climatic change, weather conditions, and the seasonal distribution of sea ice.

Tovar, H. 1983. Fluctuations of guano bird populations in the Peruvian littoral, 1960-1981. Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, San Jose, Costa Rica, 18-29 April 1983. A Preparatory Meeting for The FAO World Conference on Fisheries Management and Development.,876-957, FAO Fish. Rep./FAO, Inf. Pesca., no. 291, v.3.

The fluctuations of guano bird populatons and proportional compositions of guanay, boobies and pelicans are analysed for the years 1960 to 1981. These fluctuations are related with climatic phenomena, El Nino and the amount of anchoveta (Engraulis ringens) captured as causes of reduced food available to the birds and the rates of mortality of adults and chicks.

Weslkawski, J.M. ; and Adamski, P. 1987. Cold and warm years in South Spitsbergen coastal marine ecosystem.

Compares a notably cold year (1981/1982) with a notably warm year (1984/85); temperature differences were most marked in fall and winter. Despite the longer winter in the cold year, the timing of the plankton bloom was similar in both years. The species of plankton found in the diets of 2 species of seabird (little auk *Alle alle* and black-legged kittiwake *Rissa tridactyla*) were diifferent in the two years; in the warm year the plankton species were characteristic of subarctic (*Themisto* spp.) or boreal (*Thysanoessa inermis*) waters, compared with the characteristically cryopelagic (Arctic) species *Apherusa glacialis, Gammarus wilkitzkii)* in the cold year.