1. Climate Change 2001. Third Assessment Report of the Intergovernmental Panel on Climate Change

IPCC (WG I & II) (Cambridge Univ. Press, Cambridge, 2001).

2. Hughes, L. Biological consequences of global warming: is the signal already apparent? Trends Ecol.

Evol. 15, 56±61 (2000).

3. Wuethrich, B. How climate change alters rhythms of the wild. Science 287, 793±795 (2000).

4. McCarty, J. P. Ecological consequences of recent climate change. Conserv. Biol. 15(2), 320±331 (2001).

5. Ottersen, G. et al. Ecological effects of the North Atlantic Oscillation. Oecologia 128, 1±14 (2001).

6. Walther, G.-R., Burga, C. A. & Edwards, P. J. (eds) ``Fingerprints'' of Climate ChangeÐAdapted

Behaviour and Shifting Species Ranges (Kluwer Academic/Plenum, New York, 2001).

7. Bairlein, F. &Winkel,W. in Climate of the 21st Century: Changes and Risks (eds Lozan, J. L.,Graûl,H.&

Hupfer, P.) 278±282 (Wissenschaftliche Auswertungen, Hamburg, 2001).

8. Menzel, A. & Estrella, N. in ``Fingerprints'' of Climate ChangeÐAdapted Behaviour and Shifting Species

Ranges (edsWalther, G.-R., Burga, C. A. & Edwards, P. J.) 123±137 (Kluwer Academic,NewYork, 2001).

9. Gatter, W. Timing and patterns of visible autumn migration: Can effects of global warming be

detected? J. Ornithol. 133(4), 427±436 (1992).

10. Menzel, A., Estrella, N. & Fabian, P. Spatial and temporal variability of the phenological seasons in

Germany from 1951±1996. Glob. Change Biol. 7, 657±666 (2001).

11. Menzel, A. & Fabrian, P. Growing season extended in Europe. Nature 397, 659 (1999).

12. Myneni, R. B., Keeling, C. D., Tucker, C. J., Asrar, G. & Nemani, R. R. Increased plant growth in the

northern high latitudes from 1981 to 1991. Nature 386, 698±702 (1997).

13. Keeling, C. D., Chin, J. F. S. & Whorf, T. P. Increased activity of northern vegetation inferred from

atmospheric CO2 measurements. Nature 382, 146±149 (1996).

14. Forchhammer, M. C., Post, E. & Stenseth, N. C. Breeding phenology and climate. Nature 391, 29±30

(1998).

15. Post, E. & Stenseth, N. C. Climatic variability, plant phenology, and northern ungulates. Ecology 80,

1322±1339 (1999).

16. Ahas, R. Long-term phyto-, ornitho- and ichthyophenological time-series analyses in Estonia. Int. J.

Biometeorol. 42, 119±123 (1999).

17. Bradley, N. L., Leopold, A. C., Ross, J. & Huffaker, W. Phenological changes re¯ect climate change in

Wisconsin. Proc. Natl Acad. Sci. USA 96, 9701±9704 (1999).

18. Sparks, T., Heyen, H., Braslavska, O. & Lehikoinen, E. Are European birds migrating earlier? BTO

News 223, 8±9 (1999).

19. Huin, N. & Sparks, T. H. Spring arrival patterns of the cuckoo Cuculus canorus, nightingale Luscinia

megarhynchos and spotted ¯ycatcher Musciapa striata in Britain. Bird Study 47, 22±31 (2000).

20. Hoffman, A. A. & Parsons, P. A. Extreme Environmental Change and Evolution (Cambridge Univ.

Press, Cambridge, 1997).

21. Woodward, F. I. Climate and Plant Distribution (Cambridge Univ. Press, Cambridge, 1987).

22. Crick, H. Q. P. & Sparks, T. H. Climate change related to egg-laying trends. Nature 399, 423±424

(1999).

23. Easterling,D. R. et al. Climate extremes: observations, modeling, and impacts. Science 289, 2068±2074

(2000).

24. Grabherr, G., Gottfried, M. & Pauli, H. Climate effects on mountain plants. Nature 369, 448

(1994).

25. Parmesan, C. et al. Poleward shifts in geographical ranges of butter¯y species associated with regional

warming. Nature 399, 579±583 (1999).

26. Parmesan, C. Climate and species' range. Nature 382, 765±766 (1996).

27. Karl, T. R., Knight, R. W., Easterling, D. R. & Quayle, R. G. Indices of climate change for the United

States. Bull. Am. Meteorol. Soc. 77, 279±292 (1996).

28. Nehring, S. Establishment of thermophilic phytoplankton species in the North Sea: biological

indicators of climatic changes? ICES J. Mar. Sci. 55, 818±823 (1996).

29. Walther, G.-R. Climatic forcing on the dispersal of exotic species. Phytocoenologia 30(3±4), 409±430

(2000).

30. Chisholm, J. R. M., Jaubert, J. M. & Giaccone, G. Caulerpa taxifolia in the northwest Mediterranean:

introduced species or migrant for the Red Sea? C. R. Acad. Sci. Life Sci. 318, 1219±1226 (1995).

31. Nieder, J., La Mesa, G. & Vacchi, M. Blenniidae along the Italian coasts of the Ligurian and the

Tyrrhenian Sea: Community structure and new records of Scartella cristata for northern Italy. Cybium

24(4), 359±369 (2000).

32. Dukes, J. S. & Mooney, H. A. Does global change increase the success of biological invaders? Trends

Ecol. Evol. 14(4), 135±139 (1999).

33. Smith, R. I. L. Introduced plants in Antarctica: potential impacts and conservation issues. Biol.

Conserv. 76, 135±146 (1996).

34. Pugh, P. J. A. Non-indigenous Acari of Antarctica and the sub-Antarctic islands. Zool. J. Linn. Soc. 110,

207±217 (1994).

35. Epstein, P. R. et al. Biological and physical signs of climate change: focus on mosquito-borne diseases.

Bull. Am. Meteorol. Soc. 79(3), 409±417 (1998).

36. Brown, J. H., Valone, T. J. & Curtin, C. G. Reorganization of an arid ecosystem in response to recent

climate change. Proc. Natl Acad. Sci. USA 94, 9729±9733 (1997).

37. Sagarin, R. D., Barry, J. P., Gilman, S. E. & Baxter, C. H. Climate-related change in an intertidal

community over short and long time scales. Ecol. Monogr. 69, 465±490 (1999).

38. Pounds, J. A., Fogden, M. P. L. & Campbell, J. H. Biological response to climate change on a tropical

mountain. Nature 398, 611±615 (1999).

39. King, J. C. & Harangozo, S. A. Climate change in the western Antarctic peninsula since 1945:

observations and possible causes. Ann. Glaciol. 27, 571±575 (1998).

40. Bergstrom, D. M. & Chown, S. L. Life at the front: history, ecology and change on southern ocean

islands. Trends Ecol. Evol. 14, 472±476 (1999).

41. Hoegh-Guldberg, O. Climate change, coral bleaching and the future of the world's coral reefs. Mar.

Freshwat. Res. 50, 839±866 (1999).

42. Reaser, J. K., Pomerance, R., Thomas, P. O. Coral bleaching and global climate change: scienti®c

®ndings and policy recommendations. Conserv. Biol. 14, 1500±1511 (2000).

43. Convey, P. in ``Fingerprints'' of Climate ChangeÐAdapted Behaviour and Shifting Species Ranges (eds

Walther, G.-R., Burga, C. A. & Edwards, P. J.) 17±42 (Kluwer Academic, New York, 2001).

44. Bryant,D., Burke, L., McManus, J. & Spalding, M. Reefs at Risk: a Map-based Indicator of Threats to the

World's Coral Reefs (World Resources Institute, Washington DC, 1998).

45. Smith, R. I. L. Plant colonisation response to climate change in the Antarctic. Folia Fac. Sci. Nat. Univ.

Masarykianae Brunensis, Geographia 25, 19±33 (2001).

46. Convey, P., Smith, R. I. L., Hodgson, D. A. & Peat, H. J. The ¯ora of the South Sandwich Islands, with

particular reference to the in¯uence of geothermal heating. J. Biogeogr. 27, 1279±1295 (2000).

47. Glynn, P.W. Coral reef bleaching in the 1980s and possible connections with global warming. Trends

Ecol. Evol. 6, 175±179 (1991).

48. Wilkinson, C. R. (ed.) Status of Coral Reefs of theWorld: 2000 (Global Coral ReefMonitoring Network,

Australian Institute of Marine Science, Townsville, Australia, 2000).

49. Brown, B. E. Coral bleaching: causes and consequences. Coral Reefs 16, 129±138 (1997).

50. Spencer, T., Teleki, T. A., Bradshaw, C. & Spalding, M. Coral bleaching in the southern Seychelles

during the 1997±1998 Indian Ocean warm event. Mar. Poll. Bull. 40, 569±586 (2000).

51. Mumby, P. J. et al. Unprecedented bleaching-induced mortality in Porites spp. at Rangiroa Atoll,

French Polynesia. Mar. Biol. 139(1), 183±189 (2001).

52. Loya, Y. et al. Coral bleaching: the winners and the losers. Ecol. Lett. 4, 122±131 (2001).

53. Cunningham, D. M. & Moors, P. J. The decline of rockhopper penguins Eudyptes chrysocome at

Campbell Island, Southern Ocean and the in¯uence of rising sea temperatures. Emu 94, 27±36

(1994).

54. Barbraud, C. & Weimerskirch, H. Emperor penguins and climate change. Nature 411, 183±186

(2001).

55. Chown, S. L. & Gaston, K. J. Exploring links between physiology and ecology at macro-scales: the role

of respiratory metabolism in insects. Biol. Rev. 74, 87±120 (1999).

56. Saetre, G.-P., Post, E. & Kral, M. Can environmental ¯uctuation prevent competitive exclusion in

sympatric ¯ycatchers? Proc. R. Soc. Lond. B 266, 1247±1251 (1999).

57. Fromentin, J.-M. & Planque, B. Calanus and environment in the eastern North Atlantic. 2. In¯uence

of the North Atlantic Oscillation on C. ®nmarchius and C. helgolandicus. Mar. Ecol. Prog. Ser. 134,

111±118 (1996).

58. Cushing, D. H. Population Production and Regulation in the Sea: a Fisheries Perspective (Cambridge

Univ. Press, Cambridge, 1995).

59. Wespestad, V., Fritz, L.W., Ingraham, J.W. &Megrey, B. A. On the relationship between cannibalism,

climate variability, physical transport, and recruitment of Bering sea walleye pollock (Theragra

chalcogramma). ICES J. Mar. Sci. 57, 272±278 (2000).

60. Loeb, V. et al. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. Nature

387, 897±900 (1997).

61. Polovina, J. J. Decadal variation in the trans-Paci®c migration of northern blue®n tuna (Thunnus

thynnus) coherent with climate-induced change in prey abundance. Fish Oceanogr. 5, 114±119

(1996).

62. Bakun, A. in Reinventing Fisheries Management (eds Pitcher, T. J., Hart, P. J. B. & Pauly, D.) 331±358

(Kluwer Academic, Dordrecht, 1998).

63. McGowan, J. A., Cayan, D. R. & Dorman, L. M. Climate-ocean variability and ecosystem response in

the Northeast Paci®c. Science 281, 210±217 (1998).

64. Planque, B. & FreÂdou, T. Temperature and the recruitment of Atlantic cod (Gadus mohrua). Can. J.

Fish. Aquat. Sci. 56, 2069±2077 (1999).

65. Janzen, F. J. Climate-change and temperature-dependent sex determination in reptiles. Proc. Natl

Acad. Sci. USA 91, 7484±7490 (1994).

66. Rhen, T. & Lang, J. W. Among-family variation for environmental sex determination in reptiles.

Evolution 52, 1514±1520 (1998).

67. Beebee, T. J. C. Amphibian breeding and climate change. Nature 374, 219±220 (1995).

68. Kiesecker, J. M., Blaustein, A. R. & Belden, L. K. Complex causes of amphibian population declines.

Nature 410, 681±684 (2001).

69. Both, C. & Visser,M. E. Adjustment to climate change is constrained by arrival date in a long-distance

migrant bird. Nature 411, 296±298 (2001).

70. Visser, M. E. & Holleman, L. J. M. Warmer springs disrupt the synchrony of oak and winter moth

phenology. Proc. R. Soc. Lond. B 268, 289±294 (2001).

71. Visser,M. E., van Noordwijk, A. J., Tinbergen, J.M. & Lessels, C. M.Warmer springs lead tomistimed

reproduction in great tits (Parus major). Proc. R. Soc. Lond. B 265, 1867±1870 (1998).

72. Milner, J. M., Elston, D. A. & Albon, S. D. Estimating the contributions of population density and

climatic ¯uctuations to interannual variation in survival of Soay sheep. J. Anim. Ecol. 68, 1235±1247

(1999).

73. Post, E., Stenseth, N. C., Langvatn, R. & Fromentin, J.-M. Global climate change and phenotypic

variation among red deer cohorts. Proc. R. Soc. Lond. B 264, 1317±1324 (1997).

74. Forchhammer, M. C., Clutton-Brock, T. H., LindstroÈm, J. & Albon, S. D. Climate and population

density induce long-term cohort variation in a northern ungulate. J. Anim. Ecol. 70, 721±729 (2001).

75. Grenfell, B. T. et al. Noise and determinism in synchronized sheep dynamics. Nature 394, 674±677

(1998).

76. Post, E. & Forchhammer, M. C. Pervasive in¯uence of large-scale climate in the dynamics of a

terrestrial vertebrate community. BMC Ecol. 1, 5 (2001).

77. Post, E., Peterson, R.O., Stenseth,N. C. &McLaren, B. E. Ecosystem consequences of wolf behavioural

response to climate. Nature 401, 905±907 (1999).

78. Pascual, M. & Levin, S. A. From individuals to population densities: searching for the intermediate

scale of nontrivial determinism. Ecology 80, 2225±2236 (1999).

79. Root, T. L. & Schneider, S. H. Can large-scale climatic models be linked with multiscale ecological

studies? Conserv. Biol. 7, 256±270 (1993).

80. Harrington, R.,Woiwod, I.& Sparks, T. Climate change and trophic interactions. Trends Ecol. Evol. 14,

146±150 (1999).

81. Pitelka, L. F. & The Plant Migration Workshop Group. Plant migration and climate change. Am. Sci.

85, 464±473 (1997).

82. Roy, D. B. & Sparks, T. H. Phenology of British butter¯ies and climate change. Glob. Change Biol. 6,

407±416 (2000).

83. Crick, H. Q. P., Dudley, C., Glue, D. E. & Thomson, D. L. UK birds are laying eggs earlier. Nature 388,

526 (1997).

84. Brown, J. L., Li, S.-H.& Bhagabati, N. Long-term trend toward earlier breeding in an American bird: A

response to global warming? Proc. Natl Acad. Sci. USA 96, 5565±5569 (1999).

85. Dunn, P. O. & Winkler, D. W. Climate change has affected the breeding date of tree swallows

throughout North America. Proc. R. Soc. Lond. B 266, 2487±2490 (1999).

86. Inouye,D.W., Barr, B., Armitage, K. B.&Inouye, B.D. Climate change is affecting altitudinal migrants

and hibernating species. Proc. Natl Acad. Sci. USA 97, 1630±1633 (2000).

87. Kullman, L. 20th century climate warming and tree-limit rise in the southern Scandes of Sweden.

Ambio 30(2), 72±80 (2001).

88. Meshinev, T., Apostolova, I. & Koleva, E. In¯uence of warming on timberline rising: a case study on

Pinus peuce Griseb. in Bulgaria. Phytocoenologia 30(3±4), 431±438 (2000).

89. Wardle, P. & Coleman, M. C. Evidence for rising upper limits of four native New Zealand forest trees.

NZ J. Bot. 30, 303±314 (1992).

90. Sturm, M., Racine, C.&Tape, K. Increasing shrub abundance in theArctic. Nature 411, 546±547 (2001).

91. Kennedy, A. D. Antarctic terrestrial ecosystem response to global environmental change. Annu. Rev.

Ecol. Syst. 26, 683±704 (1995).

92. Holbrook, S. J., Schmitt, R. J. & Stephens, J. S. Jr Changes in an assemblage of temperate reef ®shes

associated with a climatic shift. Ecol. Appl. 7, 1299±1310 (1997).

93. Southward, A. J., Hawkins, S. J. & Burrows, M. T. Seventy years' observations of changes in

distribution and abundance of zooplankton and intertidal organisms in the western English Channel

in relation to rising sea temperature. J. Therm. Biol. 20, 127±155 (1995).

94. Alheit, J. & Hagen, E. Long-term climate forcing of European herring and sardine populations. Fish.

Oceanogr. 6(2), 130±139 (1997).

95. Parmesan, C. in Evolution and Ecology Taking Flight: Butter¯ies as Model Systems (eds Boggs, C. L.,

Watt, W. B. & Ehrlich, P. R.) (Univ. Chicago Press, Chicago, in the press).

96. Thomas, C. D. & Lennon, J. J. Birds extend their ranges northwards. Nature 399, 213 (1999).

97. Hersteinsson, P. & MacDonald, D. W. Interspeci®c competition and the geographical distribution of

red and arctic foxes Vulpes vulpes and Alopex lagopus. Oikos 64, 505±515 (1992).