Table 1a: Impacts of level of temperature change on Ecosystems

Temp-erature rise above prein-dustrial	Year in which this occurs	Population scenario	Impacts to unique and threatened ecosystems	Region affected	GCM used where known	Source
			OBSERVED CHANGE			
0.6	2004		Analysis of 143 studies of species which showed changes in phenology, morphology, range of abundance shows that 80% of the changes are in the direction consistent with the expected physiological response to climate change	All regions	N/A	Root et al 2003, also Parmesan & Yohe 2003.
0.6	2004		50 species of frogs & toads locally extinct in area, including global extinction of Golden Toad	Monteverde, Costa Rica		Pounds et al 1999
0.6	1965 - 2004		Loss grassland & acacia, loss flora/fauna, shifting sands (not attributed)	Sahel	N/A	ECF 2004
0.6	1979 - 2004		Chinstrap penguins (ice-phobic) increased 400% whilst ice-dependent Adelie decreased 25%	West Antarctic (where T rise 4 to 5 C since 1954)	N/A	Fraser and Patterson, 1997; Smith et al., 1999
0.6	2004		Vascular plant range increases	Antarctica	N/A	Smith 1994
0.6	2004		Decline of Rockhopper Penguins correlated to sea surface temperature	S Ocean	N/A	Cunningham & Moors 1994
0.6	2004		Poleward migration plants; disappearance of species from S Europe	Europe	N/A	EEA 2004
0.6	2004		Spring phenology advanced by 5 days e.g.	All regions	N/A	Root et al 2003 &

		tree flowering, leaf unfolding, egg-laying date of birds, emergence date of insects, hatching date of birds, spring arrival of birds.			references therein
0.6	2004	Growing season lengthened 11 days	Europe	N/A	IPCC 2001
0.6	2004	N movement of warm water plankton of 1000 km in only 40 years	E Atlantic	N/A	??
0.6	2004	Major reorganisation of plankton ecosystems: Change in plankton distribution; increasing phytoplankton biomass; extension of the seasonal growth period; N shift of zooplankton	North Sea	N/A	EEA 2004; Richardson and Schoeman 2004
0.6	2004	Likely to have caused severe decrease in sandeel abundance due to reorganisation of plankton above	North Sea	N/A	Arnott and Ruxton 2002
0.6	2004	Likely to have caused large scale breeding failure of seabirds due to decline in sandeels above	UK	**N/A**	Lanchberry 2005
0.6	2004	Dramatic change in community composition of UK marine fish	English & Bristol Channels	N/A	Hawkins 2005
0.6	2004	Decreased alpine flora, migration to higher altitudes	Japan, Europe	N/A	Harasawa 2005, EEA 2004
0.6	2004	Altered distribution of trees, butterflies, birds, insects	Japan	N/A	Harasawa 2005
		50% of Southern Ocean krill stocks are found in SW Atlantic sector, where their density has declined since the 1970s, as a result of decreasing sea-ice extent??	Antarctic	N/A	
0.6 and above	2004	Climate change impacts such as rising sea levels, sea-surface	Globe, particularly coastal		BTO (unpublished)

	temperatures, droughts and storms are adding to threats to 18 endangered/vulnerable/ threatened birds	areas/low -lying islands	
	PREDICTED CHANGE		
0.6 and increasi ng with tempera ture	Since ecosystem species do not shift in concert as climate changes, predator-prey and pollinator-plant relationships are disrupted, leading to many extinctions and pest outbreaks	Globe	??
0.6 and increasi ng with tempera ture	Cloud forest ecosystems continue to shift to higher elevations, causing further extinctions of endemic species over and above the frogs mentioned previously	Tropical mountain ous areas	Still et al 1999
0.6 and increasi ng with tempera ture	More pronounced ecosystem disturbance by fire/pests	Globe	IPCC 2001
0.6 and increasi ng with tempera ture	Increased overwinter survival of resident and wintering birds	Europe	EEA 2004
0.6 and increasi ng with tempera ture	Northward extensions in ranges of European butterflies	Europe	EEA 2004
0.6 and increasi ng with tempera ture	Increased drought in the Sahel would cause many local fauna and flora to disappear		ECF 2004
0.6 and increasi ng with tempera ture	Decreased survival of long distance migrants crossing Sahel as climate change is predicted to increase	Eurasia	Ask BTO which of the 3 refs;

		drought ; global effects if long-distance migrants suffer phenological miscuing	Globe		Berthold 1990
0.6 and rising with T		Increased ecosystem disturbance by pest/disease, especially in Boreal forest, Australia, California	Globe		IPCC 2001, Hare 2003, ECF 2004
0.7	2015	Africa's last tropical glacier Kilimanjaro lost (not attributed)	Africa		Thompson et al 2002
< 1		Coral reefs at high risk			Hoegh-Guldberg 1999
< 1		Loss in extent of Australia's most biodiverse region, the Queensland World Heritage Rainforest	Australia		Hilbert et al 2001;
< 1		Loss in extent of Karoo, the richest floral area in world	S Africa	HadCM2 HADGGAX50 (CO2 doubling)	Rutherford et al 1999
< 1		Risk extinction of vulnerable species in Dryandra forest	SW Australia		Pouliquen-Young & Newman 1999
< 1		Range losses begin for animal species in S Africa, and Golden Bowerbird in Australia	S Africa, Australia	HadCM2 HadCM3 **	Rutherford et al 1999; Hilbert et al 2003
?		Snow leopards at risk	Russia		ECF 2004
1		Coral reefs 82% bleach including Great Barrier Reef	Globe, Australia		Hoegh-Guldberg 1999
1		10% Global Ecosystems transformed; only 53% wooded tundra remains stable, loss cool conifer forest. Ecosystems variously lose between 2 to 47% of their extent.	Globe	5 GCMS: HadCM2 GFDL ECHAM 4 CSIROMK2 CGCM1	Leemans & Eickhout 2003
1	2050	50% loss highland rainforest, range losses of endemics and 1 of these extinct	Queens-land Australia	Sens study covered range of precip	Hilbert et al 2001; Williams et al 2003

					Outcomes; **	
1.3	2020 IS92a		Risk extinction of Golden Bower bird : at 1C local temperature rise habitat reduced by 50%	Australia	**	Hilbert et al 2003
1.4			Extinction of coral reefs	Indian Ocean		Sheppard 2003
1.4			>50% loss Kakadu	Australia	HadCM2/3	Hare 2005
1 – 2			Risks for many ecosystems	Globe		Leemans & Eickhout 2003
1 – 2			Many eucalypts out of range	Australia		Hughes et al 1996
1 – 2			Large impacts to salmonid fish	N America	Range of GCMs	Hare 2005 based on Keleher and Rahel 1996
1 – 2			Significant loss Alpine zone	Australia		Busby 1988
1 - 2	2050		Severe loss of extent of Karoo	S Africa	HadCM2 HADGGAX50 (CO2 doubling)	Rutherford et al 1999
1-2			Risk extinction frogs/mammals (40% loss World Heritage Rainforest area)	Australia's most biodiverse region (Queensland wet tropics)		Williams et al 2003
1 - 2			Loss of aerobic capacity, potential for local extinction of key mollusc species from the Southern Ocean at local T rise of 2C.	Antarctic		Peck et al 2004
1 -2			Moderate stress Alpine zone	Europe		Hare 05
1 -2			Severe damage to Arctic ecosystem	Arctic		ACIA 2004
1- 2			60% loss lemming (for local T rise 4C) affecting whole ecosystem, including snowy owl	Arctic	GISS GCM; **	Kerr & Packer 1998
1.5	2050	B1	18% all species extinct	Globe		*Thomas 04

2		Coral reefs 97% bleached	Globe		Hoegh-Guldberg 1999
2	2100	Total loss Arctic summer ice, high risk extinction of polar bears, walrus, seals, whole ecosystem stressed	Arctic		ACIA 2004
2		16% global ecosystems transformed : ecosystems variously lose between 5 and 66% of their extent		5 GCMs: HadCM2 GFDL ECHAM 4 CSIROM K2 CGCM1	Leemans & Eickhout 2003
2		Further ecosystem disturbance by fire & pests	Globe		IPCC 2001
2		50% loss of Sundarbans wetlands	Banglade sh	HadCM2 /3 to convert local T to global	Hare 2005, Qureshi & Hobbie, 1994, Smith et al 1998
2		Only 42% existing Arctic tundra remains stable	Arctic		Folkestad 2005
2		Millions of the world's shorebirds nest in Arctic, from the endangered Spoon-billed Sandpiper and very common Dunlin and would lose between 10% and 45% of breeding area; high arctic species most at risk	Globe		Folkestad 2005
2		Millions of Geese eg Whitefront and endangered Red-breasted Goose lose up to 50% breeding area	N hemisphe re		Folkestad 2005
2		60% N American wood warblers ranges contract, whilst only 8% expand, such that between 4 and 13 (34%)		Sensitivity analysis	Price 200x

			(range allows for uncertainty in precipitation change) reach "vulnerable" conservation status			
2			Severe damage to boreal forest	China		Ni 2001
2			> 50% salmonid fish habitat loss	N America	Range of GCMs	Hare 2005 based on Keleher and Rahel 1996
2	IS92a	2050	Transformation of ecosystems e.g. 32% of plants move from 44% European area with potential extinction of endemics/specialists	N Europe		ECF 2004; Bakkenes et al 2002
2			High risk extinctions of forest mammals; inflexion point at which extinction rates take off	Australia (Queensland)		Williams et al 2003
~2			Cloud forest regions lose hundreds of metres of elevational extent	Central America, tropical Africa & Indonesia	GENESIS GCM 2XCO2	Still et al 1999
2			Extinctions of endemics such as Hawaiian honeycreeper birds	Hawaii		Benning et al 2002
2			50% loss of Chinese boreal forest ecosystem	China		Hare 2005 based on Ni 2001
2			Loss of 9%-62% mammal species from mountainous areas	USA Great Basin	**	Hannah et al 2002
2.2	A1F1		15-37% species extinct	Globe		*Thomas 04
2.3	2050 IS92a		High risk extinction of Golden Bower bird : at 2C local temperature rise habitat reduced by 90% and at 3C by 96% to 37 km2	Australia	**	Hilbert et al 2003
2.4	2055 IS92a		Large range loss animals & risk extinctions of 11% species	Mexico	HadCM2 HADGGAX50 (CO2 doubling)	Peterson et al 2002
2.4	2050		Succulent Karoo	S Africa	HadCM2	Rutherford et

	IS92 a	reduced to 20% of area and fragmented, threatening 2800 plants with extinction; 5 S African parks lose > 40% animals		HADGG AX50 (CO2 doubling)	al 1999, Hannah et al 2002
2.4		66% animals lost from Kruger; 29 endangered species lose >50% range; 4 species becomes locally extinct	S Africa	HadCM2	Erasmus et al 2002; Hare 2005
2 – 2.5		Fish populations decline strongly with drought, wetland ecosystems dry and disappear		Malawi, African Great Lakes	ECF 2004
2-3		Amazon collapse	S America, globe		Cox et al 2004
2 - 3		Total loss Kakadu	Australia	HadCM2 /3	Hare 2005
2 -3		Extinctions of alpine flora	New Zealand		Halloy & Mark 2003
2 – 3		Large impacts eg permafrost shifts N by 1 to 2 degrees latitude, acceleration of desertification	Tibetan plateau	HadCM2 500 ppm CO2	Ni, 2000
2.5 HadCM 2n and s (Check T)	2050	Extinctions 10% endemics in Fynbos hotspot for plant biodiversity; 51-65% loss of Fynbos area.	S Africa	HadCM2 CSM	Midgley et al 2002
2.5		Complete loss alpine zone	Australia		Hare 2005 based on Pouliquen-Young & Newman 1999
2 - 2.5		Cold temperate forest e.g. maple (responsible for New England fall colours) at risk	USA		ECF 2004
2.6	2100	20-70% loss (avg 44%) migratory & wintering shorebird habitat at 4 major sites	USA both coasts		Galbraith et al 2002; Hare 2005
3		Few ecosystems can adapt to temperature increases of 3C and above	Globe		Leemans & Eickhout 2003

3	2080 IS92 a	Increase of fire frequency converting forest and macquis to scrubland, increased vulnerability to pests	Mediterr anean	HadCM3 for T; reduced low and increased high intensity rainfall events	Mouillot et al 2002
3		50% all nature reserves cannot fulfil their conservation objectives	Globe	5 GCMs: HadCM2 GFDLLR ECHAM 4 CSIROM K2 CGCM1	Leemans & Eickhout 2003
3		Risk extinction of 90% Hawaiian honeycreeper birds	Hawaii		Benning et al 2002
3	2100	Risk of loss of up to 60% species	Europe especiall y South		ECF 2004
3		Complete loss of Chinese boreal forest ecosystem	China		Ni 2001
3		Large loss migratory bird habitat	Baltic, USA, Mediterr anean	HadCM3 IPCC 2001 IS92a sea level scenario	Nicholls et al 1999, Najiar et al 2000
3 (2.8 – 3.6)	2050	50% loss world's most productive duck habitat in prairie pothole region (38% HadCM3; 54% GFDL; others 0 -100% but 11 of 12 simulations show losses, loss even if precipitation increases	USA	GFDL HadCM2 Other GCM ranges covered via sen-sitivity analysis	Sorenson et al 1988
3		22% global ecosystems transformed: ecosystems variously lose between 7 and 74% of their extent	Globe	Range of GCMs (via IMAGE)	Leemans & Eickhout 2003
3		Alpine species near extinction	Europe	Explored range of regional climate	Bugmann 1997

				outcomes	
3		50% loss eucalypts	Australia		Hughes et al 1996
3		60% species loss	Mediterranean		Hare 03
3.3	2050	>50% range loss (and 80% current range loss) of 24 latitudinally restricted endemic butterflies	Australia	Median of 10 GCMs	Beaumont & Hughes 2002
3.3		77% loss low tundra	Canada		Neilson et al 1997
3.4		22% loss coastal wetlands	Globe	HadCM2 HadCM3	Nicholls et al 1999
3.8		60% loss tundra ecosystem	Globe		Neilson et al 1997
3.8		44% loss taiga ecosystem	Globe		Neilson et al 1997
4		Complete loss alpine zone	Australia		Pouliquen-Young & Newman 1999
4		38% European alpine species lose 90% range	Europe		Hare 2005
5.3	2100	Avg 79% loss at 4 key sites for migratory & wintering shorebird habitat (2C SF Bay?)	USA both coasts		Galbraith et al 2002; Hare 2005

*Thomas et al: this paper has been subject to debate (Thuiller et al 2004; Harte et al 2004; Buckley & Roughgarden 2004; Thomas et al reply 2004). Potential biases include (i) overestimation due to questions related to the validity of the particular application of the species-area relationship used, though Thomas et al contest this in their reply (ii) over or under estimation due to the use of a common formula for all species, since sparsely distributed species will be more vulnerable (iii) the potential effects of methodological uncertainty concerning niche models (iv) the validity of the relation between range reduction and extinction likelihood (v) underestimation due to ignoring genetic adaptation to climate at the population level. It has been suggested that endemics-area relationships might better be used. What is clear is that climate change and land use change together place enormous threats to biodiversity in the twenty-first century.

** the literature gives only the effects of local temperature rises, hence the author (RW) has used Hulme et al 1999's presentation of HadCM2 and HadCM3 scenarios to convert from local to global termperature rise, in which the IS92a scenario is simulated (see temperature table in accompanying "methodology" section).

Table 1b: Impacts of rate of temperature change on Ecosystems

Rate of Temp-erature rise above prein-dustrial	Population scenario	Impacts to unique and threatened ecosystems	Region affected	Source
0.6C over 20th century; now 0.17+/- 0.05C/decade		Fastest rise of millennium	Globe	IPCC 2001
0.05C/decade		Proposed threshold to protect ecosystems		Leemans & van Vilet 2005
0.1C/decade		Threshold above which ecosystems are damaged	Globe	Vellinga & Swart 1991
0.1C/decade		50% of ecosystems can adapt; forest ecosystems impacted first	Globe	Leemans & Eickhout 2003
General remark		Warming may require migration rates much faster than those in post-glacial times & therefore has potential to reduce biodiversity through selection for mobile/opportunistic species		Malcolm et al 2002; using 7 climate scenarios from GFDL and HadCM2
General remark		ecosystem response lags behind equilibrium, hence vulnerability to pests, diseases, fire is high, this is worse for higher rates of change	Globe	IPCC 2001, Leemans & Eickhout 2003
0.3C/decade		30% ecosystems can adapt; ecosystem response lags behind equilibrium, vulnerability to pests, diseases, fire is high	Globe	Leemans & Eickhout 2003
0.4C/decade		All ecosystems rapidly deteriorate, disturbance regimes, low biodiversity, aggressive opportunistic species dominate globe: resulting in release of carbon to the atmosphere	Globe	Leemans & Eickhout 2003; Neilson 1993

0.46C/decade		Current rate in Arctic (1977 – 2003)		**Folkestad 2005**

Table 1c: Impacts of sea-level rise on Ecosystems

Sea-level rise above 1961-1990 average (cm)	Year	Matching Temperature increase range (TAR) for this time period	Impacts to unique and threatened ecosystems	Region affected	Source
2.7	2004	0.6		Globe	Parry 1999
3-14	2025	0.4-1.1	Loss of some coastal wetlands likely, increased shoreline erosion, saltwater intrusion into coastal aquifers	Globe	IPCC 2001
30	Any		57% sandy beaches eroded	Asia	Harasawa 2005
5 - 32	2050	0.8-2.6	More extensive loss coastal wetlands, further shore erosion		IPCC 2001
34			20-70% loss of key bird habitat at 4 major sites	USA	Galbraith et al 2002
34			Large loss migratory bird habitat	Baltic, Mediterranean	Nicholls et al 1999, Najiar et al 2000
45	Any	Any	Mangroves cannot survive 45 cm sea level rise	Asia (and other world regions?)	Harasawa 2005

9 - 88	2100	1.4-5.8	More extensive wetland loss, further erosion of shorelines		IPCC 2001
100	Any	Any	90% sandy beaches eroded	Asia (and other world regions?)	Harasawa 2005
40	2080	3.4	5 – 22% world's coastal wetlands lost	Globe	HadCM2/3 Nicholls et al 1999
100	2100		25-55% world's coastal wetlands lost	Globe	HadCM2/3 Nicholls et al 1999; Hoozemans et al 1993
300-500	2300	3	With 3C temperature rise this will occur by 2300 even if Greenland and WA ice sheets do not melt	Globe	ECF 2004
300-500	2300	3	Widespread loss coastal and deltaic areas including Bangladesh, Nile, Yangtze, Mekong	Globe	ECF 2004

Table 1d Impacts of rate of sea-level rise on ecosystems

Rate of sea-level rise	Status	Impacts to unique and threatened ecosystems	Region affected	Source
1 to 2 mm/yr Between 0.8 and 3 mm/year	Observed in twentieth century		Globe	IPCC 2001
Between 0.8 and 3 mm/yr	Observed in twentieth century		Europe	EEA 2004
5 mm/yr		Coastal erosion, loss of coastal ecosystem such as mangroves and coral reefs thus destroying natural coastal defences; saltwater instrusion, dislocation of people, increased risk to storm surge, this being especially problematic in small island states	Globe, particularly Asia, N America, Latin America, and small island states.	IPCC 2001
6 mm/yr	Prediction	Wetlands lost	New England	Hare 2005 based on Donnelly & Bertness 2001

Table 1e. Effects of acidification on the oceans

[CO2]	Ocean pH		Impacts to marine ecosystems	Source
265	8.2		Marine biogeochemistry altered, disrupting carbonate chemistry and altering plankton composition	Riebesell 2000
750	7.82		Calcifying organisms at risk: Replacement of coccilithiphores, gastropods & formanifera by non-calcifying organisms	Turley et al 2005
			Calcifying organisms at risk: Corals growth rates reduced by up to 40% by 2065	Langdon et al 2000; Leclercq et al 2000
			Impacts on plankton grazers including economically important species such as shellfish and fish.	Turley et al 2005