Index

2025 time horizon 2
aapa mires (patterned fens, string bogs) 115, 116
abalone (*Haliotis* spp.) 215, 218
Acanthaster planci (crown-of-thorns starfish) 250, 251, 258
acid neutralizing capacity of streams and lakes 23
acid rain and river recovery 23–4
acidification
  oceans 6–7
  small freshwater lakes 71–3
adaptive management 26
African Great Lakes 81–2
  eutrophication 83–4
  Freshwater Protected Areas (FPAs) 92
  impacts of land-use changes 83
  invasive species 89
  overfishing 86
  pollution 85
  potential states in 2025 90, 91–2
  water diversion threats 89
Agenda 21, 301
agricultural irrigation, pressures on water resources 7
agriculture
  demand for groundwater 34
  impacts of fertilizer use 25
  pollution of groundwater 34–5
albedo 2
  polar surface albedo feedback mechanisms 322
alewife (*Alosa pseudoharengus*) 87
Alosa pseudoharengus (alewife) 87
amphibian species, declines and extinctions 11, 12
amphipod (*Echinogammarus ischnus*) 88
Antarctic ice sheet, effects of warming 5, 6
  see also polar and ice-edge marine systems
Antarctic krill (*Euphausia superba*) 322, 329–30, 331
antibiotic contamination of groundwater 35
Aplodinotus grunniens (sheepshead) 86
Aptenodytes forsteri (emperor penguin) 330
aquaculture, impacts on fishing pressure 10–11
aquarium fish, source 86
aquatic biodiversity, global trends 11–13
aquatic ecosystem trends
  coastal wetlands 357–8
  flowing waters 354–5
  freshwater wetlands 355–7
  human dependence on water 353–4
  projections to the year 2025 363–5
  rocky shores 358–9
  soft shores 359–61
  still fresh waters 355
  trends and prospects across systems 362–3
  vast marine systems 361–2
aquifers *see* groundwater
Aral Sea 82, 89, 98, 99, 101, 103, 104, 106
  conservation efforts 107
Arctic *see* polar and ice-edge marine systems
Arctic charr (*Salvelinus alpinus*) 69
Arctic Oscillation 322–3
Arctocephalus gazella (southern fur seal) 321, 331
Artemia (brine shrimp)
  harvest from salt lakes 97
  introduction into salt lakes 104
Asian carps (cyprinid fishes) 89
Asian clam (*Potamocorbula amurensis*) 199
Atlantic salmon (*Salmo salar*) 24, 83, 86
Atlantic thermohaline circulation 6
Atriplex (*Halimione*) *pedunculata* (pedunculate sea-purslane) 170
Aurelia aurita (moon jellyfish) 104
Avicennia spp. (mangroves) 173, 176, 182, 183

Bayesian modelling 26
beaches *see* sandy shores
biodiversity, global trends in aquatic ecosystems 11–13
biodiversity loss, impacts on streams and rivers 27–8
biological control agents 26–7
biome 2
biotope 2
blue pike (*Sander glaucum* formerly *Stizostedion vitreum glaucum*) 84
bogs *see* cool temperate peatlands
Boreogadus saida (polar cod) 329
brine shrimp *see Artemia*
brown mussel (*Perna perna*) 199, 216
Buccinum undatum (common whelk) 215
burbot (*Lota lota*) 86

California cordgrass (*Spartina foliosa*) 159, 163
Canadian water weed (*Elodea canadensis*) 89
capelin (*Mallotus villosus*) 331
carbon balance in cool temperate peatland 118–19
carbon dioxide (CO_2)
  acidification of the oceans 6–7
  greenhouse gas 3
carbon reservoir in cool temperate peatlands 114
carbon trading 186
Carcinus maenas (common shore crab) 216, 218, 219
Caribbean monk seal (*Monachus tropicalis*) 12
carp, *see* common carp
Caspian Sea 95, 98
  drilling for oil 102
  introduction of exotic species 104
  pollution 103
  sturgeon fishery 97, 103–4
Champsocephalus gunnari (icefish) 331
chemical pollutants of streams and rivers 25–6
chemical wastes, water pollution 7
Chen caerulescens caerulescens (snow goose) impact on marshes 165–6
Chilean abalone (*Concholepas concholepas*) 215, 216, 223
chlorofluorocarbons, greenhouse gases 3
cichlid fishes (African Great Lakes) 66, 84, 89, 92, 150
cisco (*Coregonus artedi*) 84, 86, 87
Cladophora 88, 90
climate change
  and floods 6
  drivers for change 2
  measures of change 2

climate change impacts 3–7 *see also specific ecosystems*
climate change projections
  Integrated Global System Model (IGSM) 3–5
  level of uncertainty 5
Clupea harengus (herring, Atlantic herring) 331
coastal development, ports and shipping facilities 8
coastal ecosystems, vulnerability to climate change 6
coastal systems, impacts of climate change 6
cod (*Gadus morhua*) 331
colonial hydroid (*Cordylophora caspia*) 88
common carp (*Cyprinus carpio*) 72, 86, 87
common cordgrass (*Spartina angelica*) 163, 167
common periwinkle (*Littorina littorea*) 199, 215, 218
common reed (*Phragmites australis*) 159, 160, 163, 164, 168, 199
common shore crab (*Carcinus maenas*) 216, 218, 219
common whelk (*Buccinum undatum*) 215
Concholepas concholepas (Chilean abalone) 215, 216, 223
continental-shelf benthic ecosystems
  changes induced by commercial fishing 297–9
  creating genuine value propositions 306
  ecologically sustainable development 301–6
  economic value 295
  eutrophication 300
  financial drivers of environmental management 305–6
  fishing down the food web 297–9
  global and sectoral agreements on 301–4
  human drivers of change 296–301
  impacts affecting biodiversity 296
  impacts of fishing subsidies 305
  implementation of goals and objectives 304–8
  implications of human welfare goals 303–4
  Marine Stewardship Council certification of fisheries 306
  sediment loading 300–1
  social dimensions of environmental management 304–5
  society's goals for 301–4
  water quality 299–301
Convention on Biological Diversity (1992) 11, 301
cool temperate peatland types
  aapa mires (patterned fens, string bogs) 115, 116
  Arctic polygon mires 115–16
  blanket mires 116
  lagg fen 116
  ombrotrophic (rain-fed) 115–16
  ombrotrophic mires (raised bogs) 115, 116
  palsa mires 116
  quaking mires 116
  rheotrophic (flow-fed) 115–16
  tundra mires 115, 116
cool temperate peatland
  accumulation of organic matter 114
  acrotelm (upper layer) 116–17
  age of 116
  biomass 117
  carbon balance 118–19
  carbon reservoir 114
  carbon sequestration 117–19
  catotelm (deeper layer) 116–17
  definition 113
  factors affecting decomposition rate 118–19
  formation 116
  fossil evidence of development 121
  gaseous emissions 119–20
  global distribution 113–14
  greenhouse gas emissions 119–20
  human impacts 120–1
  Late Holocene development 121
  long-term trends 121–5
  methane formation and release 114, 119–20
  nitrous oxides emissions 120
  pH 115
  primary productivity 117
  recent changes in vegetation 121–2
  rehabilitation efforts 120–1
  role of *Sphagnum* mosses 114–15, 117–18, 120, 121–2
  sensitivity to the physical environment 116–17
cool temperate peatlands in the future 122–6
  effects of airborne pollutants 123
  effects of climate change 123–6
  effects of destructive exploitation 122–3
coral bleaching 246, 249, 250, 251, 252, 256
coral bycatch in deep-water fisheries 339–40
coral reef predictions to 2025 252–8
  climatic oscillations and disturbances 252–4
  consumption 257–8
  diseases 258
  disturbance frequency and reef recovery 254
  fisheries 257
  herbivorous fish populations 257
  increase in ultraviolet light levels 256
  invertebrate populations 257
  nutrient enrichment 255–6
  oceanographic and environmental change 254–6
  physicochemical factors 252–4
  production 256
  Symbiodinium dinoflagellate coral symbiont 256–7
  symbiotic relationships 256–7
coral reefs
  Asian Pacific reef trends 250–1
  Atlantic reef trends 247, 249–50
  Australian reef trends 250–1
  biological forcing factors 247
  Caribbean reef trends 247, 249–50
  characteristics 242–3
  conditions for reef formation 243
  coral bleaching 246, 249, 250, 251, 252, 256
  crown-of-thorns starfish predation 250, 251, 258
  diseases 247, 249, 250
  Eastern Pacific reef trends 250
  effects of acidification of the oceans 6–7
  effects of aragonite saturation levels in seawater 245
  effects of seawater temperature increase 243–6
  environmental forcing factors 243–7
  factors affecting calcification rates 245
  impacts of fishing pressures 247
  impacts of global warming 243
  impacts of human development 246–7
  impacts of increasing CO_2 levels 242–3
  impacts of loss of *Diadema antillarum* (long-spined sea urchin) 247, 249
  impacts of nutrient enrichment 246–7
  impacts of sea-level changes 246
  origins and evolution 242–3
  physicochemical forcing factors 243–7
  recommendations for further research 258–9
  recommendations for management 259–60
  Red Sea reef trends 251–2
  temperature records from coral cores 246
  Western Indian Ocean reef trends 251–2
Cordylanthus maritimus ssp. *maritimus* (salt marsh bird's beak) 160, 163
Cordylophora caspia (colonial hydroid) 88
Coregonus artedi (cisco) 84, 86, 87
Coregonus autumnalis migratorius (omul) 87

Coregonus spp. (whitefish, Salmonidae) 86, 331
crab-eater seals, distemper infection 8
crown-of-thorns starfish (*Acanthaster planci*) 250, 251, 258
cyanobacteria (*Spirulina*) 97
cyanobacterium (*Microcystis*) 79, 88, 90
cyprinid fishes (Asian carps) 89
Cyprinus carpio (common carp) 72, 86, 87

dams
  breaching 24
  impacts of 23, 24–5
Daphnia (water fleas, Cladocera)
  factors affecting seasonal abundance (English lakes) 75, 76
  impact of removal of predatory fish 79, 80
DDT (dichlorodiphenlyltrichloroethane) pollution
  in the deep sea 344–5
  Lake Baikal 85–6
  spraying of saltmarshes 159
  St Lawrence Great Lakes 84–5
Dead Sea 96, 98, 100
deep-sea floor ecosystems
  anthropogenic forcing factors 337–45
  biological productivity 335
  climate change impacts to 2025 343–4
  coral bycatch 339–40
  deepwater MPAs 348–9
  disposal of sewage sludge and dredge spoils 343
  disposal of solid structures 342
  dumping of munitions and radioactive waste 342–3
  ecological characteristics 335–6
  extent and characteristics 334–5
  hydrothermal vents 335
  impacts of deepwater fisheries 337–40
  impacts of pollution 344–5
  importance of 336
  indirect impacts of fisheries 339
  levels of pollutants in deepwater organisms 344–5
  manganese nodule mining 341–2
  methane hydrate exploitation 341
  oil and gas exploitation 340–1
  persistence of toxic pollutants 344–5
  policy and solutions for anthropogenic impacts 348–9
  polymetallic sulphide mining 342
  regulation of high seas fishing 348–9
  sensitivity to human impacts 335, 336
  species ecology and life-history patterns 337
  United Nations Convention on the Law of the Sea (UNCLOS) 349
  waste disposal 342–4
deep-sea floor ecosystems research needs
  biogeography 345–6
  habitat distributions 345–6
  long time-series studies 348
  response to anthropogenic forcing factors 346–8
deepwater amphipod (*Diporeia hoyi*) 88, 89
deforestation, impacts on groundwater 35–6
Devil's Lake, USA 98
Diadema antillarum (long-spined sea urchin) 247, 249, 257, 258
Diporeia hoyi (deepwater amphipod) 88, 89
Dissostichus eleginoides (Patagonian toothfish) 331, 332
Dreissena bugensis (quagga mussel) 87, 88–9
Dreissena polymorpha (Zebra mussel) 8, 26, 87, 88–9, 90, 199
drought disturbances, impacts on streams and rivers 22–3
dryland salinity 57, 58
dunes *see* sandy shores

East African Rift Valley salt lakes 97, 100
Echinogammarus ischnus (amphipod) 88
ecohydrology 30–1
ecological units, terminology 2
economics, cost of setting aside land or fishing space 8
ecoregion 2
ecosystem, concept 2
ecosystem classification schemes 13–15
  freshwater systems 13–14, 15
  marine systems 13, 14, 15
ecosystem services *see specific ecosystems*
Eichhornia crassipes (water hyacinth) 84, 150
El Niño–Southern Oscillation (ENSO)
  impacts on coral reefs 246, 250, 252, 254–5, 256
  impacts on kelp forests 229, 230–1, 238, 239
  influence on nutrient upwellings 223, 229
  influence on temperature and precipitation 22, 36, 109, 151
  link with algal blooms 214
Elodea canadensis (Canadian water weed) 89
emperor penguin (*Aptenodytes forsteri*) 330
empirical regression models 26
endocrine disruptors
  pollution of small freshwater lakes 72
  pollution of streams and rivers 25
English Lake District, influence of the Gulf Stream 75, 76, 77
Esthwaite Water, England 75, 76, 77
Esthwaite waterweed (*Hydrilla*) 26
estuaries
  anthropogenic impacts 188–9, 190
  characteristics 188
  definition 188
  ecosystem characteristics 189–90
  phytoplankton blooms 194–5
  zones 188
estuarine environment forcing factors 190–201
  aquaculture 193–4
  boating damage 192–3
  chemical contaminants 195–6
  dredging 192
  estuarine embayment modification 192–4
  eutrophication 194–5
  fisheries overexploitation 196–7
  fishing-gear impacts 193
  freshwater diversions 197–8
  habitat loss and alteration 191
  impacts of human activities 190–201
  introduced/invasive species 198–9
  nutrient enrichment 194–5
  organic-carbon loading 194–5
  pollution impacts 194–6
  sea-level rise 199–200
  sediment contamination 195–6
  sediment input/turbidity 201
  shoreline development 192
  subsidence 200–1
  watershed changes 191–2
estuarine systems in the future
  anthropogenic threats 202–6
  chemical contaminants 204
  climate change effects 204
  coastal subsidence 205
  eutrophication 202
  fisheries overexploitation 202–3
  freshwater diversions and inputs 204
  habitat loss and alteration 202
  introduced/invasive species 204–5
  multiple-stressor effects 205–6
  sea-level rise 204
  sediment input/turbidity 205
Eucalyptus camaldulensis (red gum) 57
Eumetopias jubatus (Steller's sea lion) 331
Euphausia superba (Antarctic krill) 322, 329–30, 331
Eurasian water milfoil (*Myriophyllum spicatum*) 26, 74
European Union Marine Strategy 302–3
European Water Framework Directive (2000) 77, 78
eutrophication *see specific ecosystems*

extinctions of aquatic species
  causes of 11
  fish species 12–13
  freshwater animal species 12
  marine species 12–13
Exxon Valdez oil spill 214

fens *see* cool temperate peatlands
fertilizers
  pollution of groundwater 34–5
  pollution of streams and rivers 25
fish migration, impacts of dams 24
fisheries
  driver for change in aquatic ecosystems 3
  economic pressures 8–10
  fishing down marine food webs 8–9
  impacts of aquaculture 10–11
  impacts of overfishing 8–11
  marine fish biomass declines 8–9
  need for change in the industry 10, 11
  overfishing and declining catches 12–13
  vulnerable species 8–10
flood disturbances, impacts on streams and rivers 22–3
flood plains
  biodiversity 45, 51–2
  biodiversity decline 55
  biological productivity 45, 52
  cultural value 45, 54
  definition 46
  drivers of change 54–7
  drivers of river–floodplain ecology 51–2
  dryland salinity 57, 58
  dynamic nature 45
  ecological values 51–2
  economic value 45, 52–3
  ecosystem services and functions 52–3
  flood and flow pulses 51
  flood benefits 52–3, 53–4
  flood losses 53, 54
  flood management developments 54
  flow regime 51
  global distribution and extent 45–51
  hazards and benefits to humans 53–4
  human impacts on riparian zones 46, 47, 52
  hydrologic connectivity 51
  impacts of climate change 56
  impacts of flow modification 56–7
  impacts of human population growth 55
  invasive species 57
  Mesopotamian wetlands 55
  pollution of the parent river 57
  riparian obligate species 51–2
flood plains in the future 57–9
  impacts of land-use changes 59
  species population decline 58–9
  time lag between impact and response 58
flooding, effects of loss of wetlands 6
floodplain management requirements 59–61
  cost–benefit calculations 60
  environmental flow requirements 60
  floodplain restoration 60–1
  indicators of environmental conditions 59
  institutional framework 60–1
  inventory of level of anthropogenic impact 59
food production, pressures on water resources 7–8
forestry, impacts on groundwater 35–6
fragmentation of lotic habitats 24–5
Framework Convention on Climate Change 2
freshwater ecosystems, classification schemes 13–14, 15
Freshwater Ecosystems Index (FEI) 11–12
Freshwater Protected Areas (FPAs) 92
freshwater species, population trends 12
freshwater wetlands *see* temperate freshwater wetlands
Fundulus parvipinnis (California killfish) 166

Gadus morhua (cod) 331
Gentoo penguin (*Pygoscelis papua*) 330
glacial relict flora and fauna, large freshwater lakes 82
glaciers, retreat of 6
Gleotrichia (planktonic cyanobacterium) 79
global circulation models 22
global cooling, drivers 2
global warming, drivers 2
global warming impacts *see specific ecosystems*
golden mussel (*Limnoperna fortunei*) 151
granular limpet (*Scutellastra granularis*) 218
Great Lakes *see* African Great Lakes; St Lawrence Great Lakes
Great Salt Lake, USA 96, 97, 98, 100, 103
greenhouse effect 2
  radiative forcing 3
greenhouse gases 3
  emissions from cool temperate peatlands 119–20
  release from contaminated aquifers 36
Greenland ice sheet, effects of warming 5, 6
groundwater, importance of 30
groundwater ecosystems
  agricultural demand for water 34
  components 31–3
  freshwater reserves in aquifers 31, 32
  functions of microorganisms 32–3
  geological component 31–2
  groundwater–surface water interactions 33–4
  human dependence on water from aquifers 31
  human impacts 34–6
  impacts of climate change 36
  impacts of land use and deforestation 35–6
  industrial demand for water 34
  living organisms 32–3
  role in the hydrological cycle 31, 33–4
  sources of groundwater pollution 34–6
  stygobionts 33
  urban domestic water demand 34
  variations in size and structure 33
groundwater ecosystems projections to 2025 42–4
  biodiversity loss 43
  changes in surface ecosystems 44
  land subsidence 42–3
  lower water tables 42–3
  restriction in functionality 43
  salinization 43–4
groundwater management 36–42
  cultural attitudes to water use 38
  ecological engineering 39
  economic aspects of water use 37–8
  establishment of conservation areas 41–2
  human attitudes to groundwater use 37–9
  improved water-use efficiency 39–40
  integrated hydrological and ecological framework 30–1
  integrated water management 40–1
  need for sustainable management 36–7
  potential for future water crisis 36
  protection of groundwater systems 41–2
  reduction of poverty 41
  safe yield concept 36
  technological aspects of water use 38–9
  use of ecological risk assessment 41–2
Gulf porpoise (*Phocoena sinus*) 12
Gulf Stream, influence on lakes in the English Lake District 75, 76, 77

Haliotis spp. (abalone) 215, 218
heavy metals
  pollution of groundwater 35
  pollution of streams and rivers 25
herring (Atlantic herring, *Clupea harengus*) 331
high-latitude climate changes 324
horned turban snail (*Turbo truncatus*) 215
human population
  coastal settlements 2
  demand for fresh water 7
  impacts on aquatic ecosystems 2–3
  impacts on fresh water 7–8
  projected growth 7, 8

rate of growth 2
size 2
uneven global distribution 2
uses for fresh water 7–8
Hydrilla(Esthwaite waterweed) 26
Hydrodamalis gigas (Steller's sea cow) 12
hydrogeological setting (HGS) of wetlands 138
hydrogeomorphic (HGM) classification of wetlands 136, 137, 138

icefish (*Champsocephalus gunnari*) 331
industrial demand for groundwater 34
industrial waste, pollution of groundwater 35
inland aquatic systems, impacts of climate change 6
Integrated Global System Model (IGSM) 3–5
introduced alien species
effects on aquatic ecosystems 7–8
in small freshwater lakes 66, 72
invasion ecology 29
invasive species
flood plains 57
impacts on streams and rivers 26–7
models of establishment and dispersal 26–7
strategies for control 26
invasive/introduced species, estuaries 198–9
IPCC (International Panel on Climate Change) 3

kelp forest ecosystems
biodiversity and deforestation rates 235–7
characteristics 226
consequences of kelp deforestation 235–7
development of kelp forests 228–9
ecological processes 228–37
global distribution 227, 228–9
impacts of physical structure and biomass 227–8
kelp deforestation 229–37
loss of top predators 235
sea surface temperature effects 229
sea-urchin herbivory 230, 231–5
spatial and temporal scale of change 235, 236
species diversity 227
kelp forest ecosystems in the year 2025 238–40
changing coastal biodiversity 239–40
declining water quality 240
extrapolation of known trends 238
impacts of El Niño and La Niña events 238, 239
impacts of global warming 238–9
impacts of ocean-climate change 238–9
impacts of pollution 240
invading species 240
new apex predators 239–40
keystone species, loss to overfishing 9
killifish (California killifish, *Fundulus parvipinnis*) 166
Kyoto Protocol 2, 186

La Niña events 223, 239
Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) 96, 101
lake associations and citizen concern 72, 74
Lake Baikal 81–2
eutrophication 84
impacts of land-use changes 83
invasive species 89
overfishing 86–7
pollution 85–6
potential state in 2025 90, 92
water diversion 89
Lake Cantara South, Australia 98
Lake Corangamite, Australia 99, 101
Lake Erie *see* St Lawrence Great Lakes
Lake Finjasjön, Sweden 79, 80
Lake Huron *see* St Lawrence Great Lakes
Lake Issyk-kul, Kyrgyzstan 98
Lake Malawi *see* African Great Lakes
Lake Michigan *see* St Lawrence Great Lakes
Lake Naivasha, Kenya (case study) 66
Lake Ontario *see* St Lawrence Great Lakes
lake recreation culture 72, 74
Lake Superior *see* St Lawrence Great Lakes
Lake Tanganyika *see* African Great Lakes
lake trout (*Salvelinus namaycush*) 86, 90
Lake Van, Turkey 98
Lake Victoria *see* African Great Lakes
Lake Windermere, England 72, 75, 76, 77
lakes
cultural and inspirational aspects 64
definition of large and small 64
impacts of climate change 6
threat from water shortages 64
see also African Great Lakes; large freshwater lakes; salt lakes; small freshwater lakes; St Lawrence Great Lakes and *specific lakes*
land use, impacts on groundwater 35–6
landfill waste leakage, pollution of groundwater 35
large freshwater lakes
definition 81
endemism 82
eutrophication 83–4
glacial relict flora and fauna 82
glacial scour lakes 82 *see also* St Lawrence Great Lakes
impacts of land-use change 83
invasive species 87–9
major impacts 82–9
overfishing 86–7
pollution 84–6
potential states in 2025 89–93
tropical tectonic lakes 82 *see also* African Great Lakes
water diversion threats 89
large lakes, definition 64
Lates niloticus (Nile perch) 8, 12, 84, 86, 89, 150
Limnoperna fortunei (golden mussel) 151
limpet (*Scutellastra argenvillei*) 218, 219
Littoraria irrorata (marsh periwinkle) 164–5
Littorina littorea (common periwinkle) 215, 218, 199
Littorina saxatilis (rough periwinkle) 212
Living Planet Index (LPI) 11–12
Living Planet Report (WWF) 11
long-spined sea urchin (*Diadema antillarum*) 247, 249, 257, 258
Lota lota (burbot) 86
lotic ecosystems 18 *see also* streams and rivers

macrosystems approach to wetlands 136–7
Mallotus villosus (capelin) 331
management approach, acid rain and river recovery 23–4
mangrove ecosystems
basin mangroves 177, 178
characteristics 172–3
classification of mangrove formations 176–8
diversity of forms and species composition 176–8
economic valuation of mangroves 184
global area and distribution 173–6
mangroves as keystone species 172
palaeohistorical perspective on distribution 176
physiological adaptations in plants 173
potential expansion following climate change 183–4
potential for wastewater treatment 182
river-dominated mangroves 177–8
sustainable management for timber 180
tide-dominated (fringe) mangroves 176–7
trends in loss of area 174–6
values 173

mangrove ecosystems future threats
  climate change 182–4
  economic market failure 184–5
  effects of elevated CO_2 182–3
  heavy metal pollution 182
  human population demography 178
  hydrological change 180–1
  nutrient pollution 182
  oil pollution 181–2
  pollution 181–2
  response to sea-level rise 183, 184
  shrimp farming 179
  timber extraction for rayon 180
  tourism 178–9
  urban development 178–9
mangrove ecosystems mitigation 185–7
  carbon trading 186
  conservation areas 186
  educational role in ecosystem management 186–7
  management for sustainable use 186–7
  participation of local communities 186–7
  rehabilitation 185–6
  role of the international community 187
mangroves (*Avicennia* spp.) 173, 176, 182, 183
marbled rockcod (*Notothenia rossii*) 331
marine ecosystems, classification schemes 13, 14, 15
Marine Ecosystems Index (MEI) 11–12
marine life
  effects of acidification of the oceans 6–7
  population trends in marine species 12–13
  risk from introduced diseases 8
marine pelagic ecosystem
  alien species invasions 312
  disease epidemics 312
  impact of commercial fishing 312
  impacts of fish farming 313
  impacts on the pelagic food web 314–16
  indicators of decline in health 312
  natural variability of marine ecosystems 313
  numbers of endangered species 312
  phytoplanktonic blooms 312
  potential for fisheries collapse 312
  state of the ecosystem 312
  sustainability of human influence (fisheries example) 313
  timescale of changes 312
  'tragedy of the commons' 313
marine pelagic ecosystem to the year 2025
  anthropogenic impacts 313–16
  future issues 316–17
  integration across research sectors 316–17
  limitations of global ocean programmes 316
  natural oscillations 313–16
  philosophical perspective 318
  scientific perspective 317–18
  societal issues 316
Marine Protected Areas (MPAs)
  for deepwater ecosystems 348–9
  on the high seas 348–9
Marine Stewardship Council certification of fisheries 306
marsh periwinkle (*Littoraria irrorata*) 164–5
Mediterranean monk seal (*Monachus monachus*) 12
Mediterranean mussel (*Mytilus galloprovincialis*) 218, 219
mercury pollution
  African Great Lakes 85
  small freshwater lakes 72
  streams and rivers 25–6
Mesopotamian wetlands 55
methane (CH_4)
  formation and release in cool temperate peatlands 114, 119–20
  greenhouse gas 3
methylmercury pollution 344, 345
microbial resistance to antibiotics 26
Microcystis (cyanobacterium) 79, 88, 90
mires *see* cool temperate peatlands
Mnemiopsis leidyi (warty comb jelly) 104
Monachus monachus (Mediterranean monk seal) 12
Monachus tropicalis (Caribbean monk seal) 12
Mono Lake, California 96, 97, 98, 100, 101, 106–7
Moon jellyfish (*Aurelia aurita*) 104
Morone saxatilis (striped bass) 199
Myriophyllum spicatum (Eurasian water milfoil) 26, 74
Mysis relicta (opossum shrimp) 83
Mytilus galloprovincialis (Mediterranean mussel) 218, 219

Neogobius melanostomus (round goby) 87, 88
Nile perch (*Lates niloticus*) 8, 12, 84, 86, 89, 150
Nile tilapia (*Oreochromus niloticus*) 86, 89
nitrate pollution
  groundwater 34–5
  streams and rivers 25
nitrogen loading in rivers 7
nitrous oxide (N_2O)
  emissions from cool temperate peatlands 120
  greenhouse gas 3
  release from contaminated aquifers 36
North Atlantic Oscillation (NAO) 22, 222, 245, 252, 322
Northern Annular Mode 323
Notothenia rossii (marbled rockcod) 331
nutrient concentrations in streams and rivers 25

oceans, impacts of climate change 6–7
oil spills, impacts on rocky intertidal shores 213–14
omul (*Coregonus autumnalis migratorius*) 87
Oncorhynchus clarki henshawi (Lahontan cutthroat trout) 96, 101
Oncorhynchus spp. (salmon) 56
operational landscape unit (OLU) concept 133, 138, 139
Opossum shrimp (*Mysis relicta*) 82
Oreochromus niloticus (Nile tilapia) 86, 89
organic pollution of groundwater 35, 36
Osmerus mordax (smelt) 87
Owens Lake, USA 100–1
ozone hole over Antarctica 323–4

Pacific swampfire, pickleweed (*Sarcocornia pacifica*) 162
Patagonian toothfish (*Dissostichus eleginoides*) 331, 332
PCBs (polychlorinated biphenyls) pollution
  deep-sea ecosystems 344–5
  Lake Baikal 86
  St Lawrence Great Lakes 84–5
peatlands *see* cool temperate peatlands
Pedunculate sea-purslane (*Atriplex* (*Halimione*) *pedunculata*) 170
Perca flavens (yellow perch) 86
Perna perna (brown mussel) 199, 215
pesticide pollution *see specific ecosystems*
petroleum products, pollution of groundwater 35
Petromyzon marinus (sea lamprey) 87–8, 90
pharmaceuticals, pollution of streams and rivers 25
Phocoena sinus (Gulf porpoise) 12
Phragmites australis (common reed) 159, 160, 163, 164, 168, 199
Pickleweed, Pacific swampfire (*Sarcocornia pacifica*) 162
Planktonic cyanobacterium (*Gleotrichia*) 79
polar and ice-edge marine systems
  Antarctic sea ice 326–7
  Arctic Oscillation 322–3
  Arctic sea ice 324–6
  climate change effects in the future 322–4
  climate change impacts on higher predators 329–30
  collapse of Arctic fish stocks 331

decline in albatross and petrel populations 332
differences between the Arctic and Antarctic 319–20
ecosystem responses to loss of sea ice 328–30
feedbacks in the polar climate system 322
fishing impacts 330–2
food web responses to climate change 330
future sea-ice conditions 327–8
global thermohaline circulation 324
harvesting of Antarctic marine living resources 331–2
harvesting of Arctic marine resources 330–1
high-latitude climate changes 324
human impacts 320–2
illegal, unreported and unregulated fishing (IUU) 332
impacts of reduction in sea-ice 320
major Antarctic trends 321
major Arctic trends 320–1
marine mammal exploitation 330–1
North Atlantic Oscillation 322
Northern Annular Mode 323
ozone hole over Antarctica 323–4
predictions for 2025 332–3
primary production in the future 328
sea-ice reduction 324–8
sea ice seasonal variations 324
seabird bycatch in long-line fisheries 332
secondary production in the future 328–9
Southern Annular Mode 323–4
surface albedo feedback mechanisms 322
whaling 330–1
polar bears, impacts of sea-ice reduction 329
polar cod (*Boreogadus saida*) 329
polar regions
effects of warming 5, 6
projected temperature increase 5
pollution, sources of groundwater pollution 34–6
ponds *see* small freshwater lakes
population trends
Freshwater Ecosystems Index (FEI) 11–12
Marine Ecosystems Index (MEI) 11–12
Potamocorbula anurensis (Asian class) 199
Pygoscelis papua (Gentoo penguin) 330
Pyramid Lake, USA 96, 100, 101, 107
Pyura praeputialis (tunicate) 219

Quagga mussel (*Dreissena bugensis*) 87, 88–9

radiative forcing, greenhouse effect 3
radioactive waste burial, pollution of groundwater 35
rainfall, measure of change 2
raised bogs (ombrotrophic mires) 115, 116
Ramsar Convention on Wetlands 96, 106–7, 112, 152, 170, 187
Rastrineobola argentea (silver cyprinid) 86, 89
red gum (*Eucalyptus camaldulensis*) 57
Regional Seas Agreements 302
Rhizophora spp. 173, 176, 177, 180, 182, 183, 185–6
Rio 'Earth Summit' (1992) 11, 301
river systems, impacts of alteration and damming 11
rivers, human sources of pollution 7 *see also* streams and rivers
rockfish (*Sebastes* spp.) 337, 338, 339
rocky intertidal shores
actions to help preserve habitats 224–5
capacity for recovery 210–11
characteristics 210–11
ecosystem services 211
environmental gradients 212
factors which influence communities 212
interactions of physical and biological factors 212
management issues 210–11
vulnerability to human activities 210–11
rocky-shore impacts
actions to help preserve habitats 224–5
alien species 216–19
alteration of coastal geomorphological processes 219–20
co-management strategies 224–5
El-Niño–Southern Oscillation events 222–3
elevated ultraviolet radiation 222
endocrine disruptors 213
eutrophication 214
generation of power 220
global climate change 220–3
harvesting for human food 215–16, 217, 224–5
marine mollusc harvesting 215–16, 217, 224–5
mining activities 214–15
oil spills 213–14
pollution 212–15
present and future human impacts 212–23
projecting into the future 223–4
recreational uses 220
research and educational uses 220
responses to warming 221–2
sea defences 219–20
sea-level rise 222
sedimentation 220
storms and extreme weather events 222
toxic algal blooms 214
rough periwinkle (*Littorina saxatilis*) 212
round goby (*Neogobius melanostomus*) 87, 88

salinization
anthropogenic 101–2
future of salt lakes 109
land in Australia 57, 58, 99, 102
Salmo salar (Atlantic salmon) 24, 83, 86
salmon (*Onchorhynchus* spp.) 56
salmonids, escape of genetically modified or farm-selected fish 72
salt lakes 64
calcite branch point 94
conservation value 96
critical habitat for waterbirds 96
cultural value 96
definition 94
distribution and extent 94–5
ecological value 96
economic and non-economic values 95–7
likely status in 2025 108–10
recreational and aesthetic values 97
scientific value 96
salt lakes threats and impacts 97–105
biological disturbances 104
catchment area uses and development 104
changes in ultraviolet radiation 98
conservation threat of freshwater crisis 105–8
global climate change 97–8
groundwater pumping 101
introduction of exotic species 104
mining 102–3
overfishing 103–4
pollution 103
secondary (anthropogenic) salinization 101–2
surface inflow diversions 98–101
saltmarsh bird's beak (*Cordylanthus maritimus* ssp. *maritimus*) 160, 163
saltmarshes
disease risk to humans 159
ecological goods and services 158
functions 158
history of human impact 158–9
insect populations 159
old marshes 158
sedimentation and erosion 158
types of settings 157
values 158
wider linkages 158
zonation of vegetation 157–8

saltmarshes in the future 159–71
  actions required 170
  coastal development pressures 166–8
  conflicting environmental policies 169
  conservation of rare plant species 169–70
  consumer pressure 164–6
  effects of climate change 161–2
  effects of global warming 161–2
  effects of increased CO_2 levels 161–2
  effects of sea-level rise 160–1, 161–2
  eutrophication 163–4
  fish use of saltmarshes 166
  hybridization among saltmarsh plants 163
  impact of grazing by geese 165–6
  invading fish species 166
  invasive species 162–3
  managed coastal realignment 168–9
  mitigation of losses 168
  restoration of damage 168–70
  shoreline development 165
  value judgements about changes 160
Salton Sea, California 97, 102, 104, 107
Salvelinus alpinus (Arctic charr) 69
Salvelinus namaycush (lake trout) 86, 90
Sander glaucum formerly *Stizostedion vitreum glaucum* (blue pike) 84
Sander vitreus formerly *Stizostedion vitreum* (walleye) 86
sandy shore current trends
  coastal evolution 275–6
  evolutions of beach and dune environments 274–5
  improved coastal zone management 274
  pressure of human activities 274
sandy shore impacts of human actions 265
  altering external conditions 268, 273
  altering faunal viability or use patterns 267, 273–4
  altering landform mobility 267, 269–71
  altering through use 266–8
  creating landforms and habitats 271–2
  dams and stream mining 273
  nourishment and restoration 268, 271–2
  pollutants 273
  reshaping 267, 268–9
  trends in intensity of development 265–6
sandy shores
  impacts of climate change 265
  natural characteristics of beaches 264
  natural characteristics of dunes 264–5
  natural threats 265
  origins 263
  sediment transport 263–4
sandy shores to the year 2025 276–9
  direct human pressures 277–9
  global warming 276–7
Sarcocornia pacifica (pickleweed, Pacific swampfire) 162
sardines (Australia), herpes virus infection 8
Scutellastra argenvillei (limpet) 218, 219
Scutellastra granularis (granular limpet) 218
sea-fans (Caribbean), fungal infection 8
sea lamprey (*Petromyzon marinus*) 87–8, 90
sea-level rise
  factors affecting 6
  future effects on saltmarshes 160–1, 161–2
  projections 5–6
  see also specific ecosystems
seagrass ecosystems
  biodiversity 283
  characteristics 281–3
  conservation prospects 290
  cumulative impacts of multiple stressors 290
  ecosystem services 283
  global decline 281–2
  global impacts and losses 285–8
  global seagrass area 282
  human impacts 285–8
  impacts of climate change 288–90
  losses from natural causes 289–90
  management and protection 291–3
  mapping of global distribution 282–3
  monitoring programmes 291–3
  outlook for 2025 293–4
  productivity 282
  regional status and trends 283–5
  restoration practices 293
  seagrass species 282
  status of seagrass protection 291–3
  widespread decline 283
Sebastes spp. (rockfish) 337, 338, 339
sheepshead (*Aplodinotus grunniens*) 86
silver cyprinid (*Rastrineobola argentea*) 86, 89
small cordgrass (*Spartina maritima*) 163
small freshwater lakes
  acidification 71–3
  bass fishing 74
  clarity of pristine lake waters 67–8
  colonization of pristine lakes 68
  community structures 68
  connections in the landscape 65–6
  criteria of deterioration 70
  dam building 72
  deleterious factors 71–80
  drainage or infill 72
  effects of increased ultraviolet radiation 72
  eutrophication 71
  impact of fish 68, 69
  impacts of climate change 73, 75, 76, 77
  introduced species 66, 72
  lake associations and citizen concern 72, 74
  Lake Naivasha, Kenya (case study) 66
  lake recreation culture 72, 74
  liming of acidified lakes 71
  nature of primary producers 68
  nutrient scarcity in the pristine state 67
  oligotrophication process 67
  overfishing 72
  pH of pristine lakes 67
  pristine status determinants 66–8
  range of origins of natural lake basins 67
  restoration 74–80
  shoreline development and recreational damage 72, 74
  speciation and endemism 68
  tension between conservation and exploitation 66
  total ion concentrations in the pristine state 67
  toxic pollutants 72
  water abstraction 72
small islands, impacts of climate change 6
small lakes, definition 64
smelt (*Osmerus mordax*) 87
smooth cordgrass (*Spartina alternifolia*) 161, 163, 164, 165, 167, 199
snow goose (*Chen caerulescens caerulescens*), impact on salt marshes 165–6
South Africa, National Water Policy (1997) 77, 78
Southern Annular Mode 323–4
southern fur seal (*Arctocephalus gazella*) 321, 331
Spartina alternifolia (smooth cordgrass) 160, 163, 164, 165, 167, 199
Spartina anglica (common cordgrass) 163, 167
Spartina foliosa (California cordgrass) 159, 163
Spartina maritima (small cordgrass) 163
Spartina spp., hybridizations in saltmarshes 163
Sphagnum mosses (peat mosses), role in cool temperate peatlands 114–15, 117–18, 120, 121–2
Spirulina (cyanobacteria) 97
St Lawrence Great Lakes 81–2
  eutrophication 83
  impacts of land-use changes 83
  invasive species 87–9
  overfishing 86, 87
  pollution 84–5
  potential states in 2025 89–91, 92–3
  water diversion threats 89

Steller's sea cow (*Hydrodamalis gigas*) 12
Steller's sea lion (*Eumetopias jubatus*) 331
steroid contamination of groundwater 35
streams and rivers
  acid rain and river recovery 23–4
  chemical pollutants 25–6
  drought and flood disturbances 22–3
  ecologically informed future management 28–9
  ecosystem function and biodiversity 27–8
  ecosystem services 19
  effects of overexploitation 23
  endocrine disruptor pollutants 25
  forecasting future chemical impacts 26
  genetic implications of habitat fragmentation 25
  heavy metal pollution 25
  impacts of biodiversity loss 27–8
  impacts of climate change 22–3
  impacts of damming and fragmentation 23, 24–5
  impacts of fertilizer use 25
  impacts of water engineering projects 23
  invasive species 26–7
  large-scale forcing factors 20
  large-scale stressors 20
  local stressors 20–1
  loss of habitat patches 24–5
  metapopulation structure in freshwater species 24, 29
  nitrate pollution 25
  nutrient concentrations 25
  persistent (press) perturbations 21
  pesticide pollution 25
  pharmaceutical pollutants 25
  predictions from global circulation models 22
  predictive models 28–9
  pressures from human activities 19–22
  pulsed perturbations 21
  recolonization from refugia 21
  recolonization of habitat patches 25
  scales at which threats operate 20–1
  temporal variations in threats 21
  variation in threats along longitudinal profiles 21
striped bass (*Morone saxatilis*) 199
sturgeon fishery, Caspian Sea 97, 103–4
Symbiodinium dinoflagellate coral symbiont 256–7

Tamaricaceae (*Tamarix* spp.) 26
Tamarix spp. (Tamaricaceae) 26
TBT (tributyl tin) pollution 213
temperate freshwater wetlands
  approaches to wetland management 134–5
  arid climates 128–9
  assessment of condition 137
  barriers to management and protection 135
  biodiversity 130–1
  capacity for protection and restoration 134–5
  carbon accumulation 129–30
  core genera 129
  endemism 131
  extent of losses 132–3
  functions 129–31
  global distribution 127
  habitat classification approaches 136–7
  human-induced alterations to water flow 131–2
  humid climates 128–9
  hydrogeological setting (HGS) 138
  hydrogeomorphic (HGM) classification 136, 137, 138
  inter-basin transfers of water 131–2
  inventory and mapping 136–7
  macrosystems 136–7
  nutrient cycling rates 130
  operational landscape unit (OLU) concept 133, 138, 139
  organic matter accumulation 129–30
  patterns across moisture gradients 128–34
  patterns related to economics and culture 134–5
  potential evapotranspiration (PET) ratio 128–9
  prospects for the future 140
  public education 139–40
  requirements for effective management 136–40
  restoration in a landscape setting 137–8
  restoration practices 133–4
  training of scientists and resource managers 138–40
  types of wetlands 128–9
  vegetation 129
temperature
  global mean surface temperature projections 5
  latitudinal distribution of warming 5
  measure of change 2
terminology for ecological units 2
Torrey Canyon oil spill 214
toxic pollutants, small freshwater lakes 72
toxic waste burial, pollution of groundwater 35
tropical wetlands
  biophysical gradients 142–4
  climatic gradients 143
  definition of 'tropical' 142
  economic and political gradients 145–6
  ecosystem functions 147
  factors affecting degradation 147–8
  geomorphological gradient 143
  global distribution 142
  human-made or modified wetlands 143
  hydrological gradient 143
  hydrological regimes 147
  impact of human population density 144
  impacts of grazing by large herbivores 143–4
  impacts of human activities 147–8
  influence on human evolution 144
  Neotropics 142
  present state 146–7
  pressures to develop wetlands 148
  recent history of degradation and loss 148
  role in the growth of human civilization 144
  sociocultural gradients 144–6
  traditional management practices 147–8
tropical wetlands in the future 149–52
  challenges facing local people 152–3
  dependency of poor local people 153
  ecological economics 153–4
  global pressures on developing countries 152
  government pressures on local people 152
  impacts of global climate change 151
  invasion by exotic species 150–1
  land use and water quality 150
  pressures to cultivate wetlands 153
  sustainable use and management 151–2, 153–4
  value of non-economic goods 153–4
  water pollution 150
  water-resources management 149–50
  wetland restoration 154
tundra mires 115, 116
tunicate (*Pyura praeputialis*) 219
Turbo truncatus (horned turban snail) 215

ultraviolet (UV) radiation, effects in high-altitude lakes 72
uncertainty in climate change projections 5
United Nations Convention on the Law of the Sea (UNCLOS) 349
urban domestic demand for groundwater 34
urban waste, pollution of groundwater 35

Walker Lake, Nevada 100, 101, 107
walleye (*Sander vitreus* formerly *Stizostedion vitreum*) 86
water fleas, *Cladocera see Daphnia*

water hyacinth (*Eichhornia crassipes*) 84, 89, 150
water scarcity, threat to human populations 7
water stress, threat to human populations 7
water vapour, as greenhouse gas 3
wetlands
  definition 112
  impacts of climate change 6
  see also temperate freshwater wetlands; tropical wetlands
whales, globally endangered species 330–1
whaling 330–1
whitefish (*Coregonus* spp., Salmonidae) 86, 331
Winnemucca Lake, USA 100
World Summit on Sustainable Development 302

yellow perch (*Perca flavens*) 86

Zebra mussel (*Dreissena polymorpha*) 8, 26, 87, 88–9, 90, 199
Zuni Lake, New Mexico 96, 107