SPECIES AND CLIMATE CHANGE:

More than just the Polar Bear

The IUCN Red List of Threatened Species™

SSC
Species Survival Commission

Species and Climate Change: More than Just the Polar Bear

The Polar Bear has come to symbolise the impacts of climate change on the natural world. But it is only one of a multitude of species affected, and many of these are also well-known, much-loved and important to people. This report presents 10 new climate change flagship species, chosen to represent the impact that climate change is likely to have on land and in our oceans and rivers.

We cover some of the existing and anticipated threats to these 10 well-known species. They illustrate some of the many and varied ways that climate change impacts different regions of the world, from African deserts to the polar ice-caps. We hope these species can help to share the Polar Bear's burden in representing the effects of climate change on our natural world, and the millions of species with whom we share the planet.

Staghorn corals are severely impacted by bleaching and disease. They highlight impacts of rising sea temperatures and increasing ocean acidification due to climate change.

Ringed Seal reproduction is being disrupted as the ice upon which they live and breed melts. They highlight impacts of Arctic ice melt due to climate change.

Leatherback Turtle nesting beaches are being washed away, while rising sand temperatures during egg incubation lead to disproportionately lower numbers of males. They highlight impacts of increasing air and sea temperatures, rising sea levels and changing ocean currents due to climate change.

Emperor Penguins are predicted to lose sea ice platforms for breeding and face changes in food availability. They highlight impacts of rising sea temperatures and melting sea ice due to climate change.

Quiver Trees are losing populations in the equator-ward parts of their distribution range due to drought stress. They highlight problems that all plants and slow-moving species face in keeping up with rapidly accelerating changing climate.

Clownfish's coral reef habitats are under severe threat and their ability to find their protective host anemones is being disrupted. They highlight impacts of coral reef degradation, increasing ocean acidification and warming oceans due to climate change.

Arctic Foxes face habitat loss, competition and predation from Red Foxes, together with changes in population cycles of their prey. They highlight climate change's disruptive effects on interactions between species.

Salmon's freshwater habitats are facing warming and altered seasonal flows, while food availability in their marine ranges may shift. They highlight the effects of rising temperatures on both freshwater and marine ecosystems, and illustrate how climate change impacts on wild species can have a direct effect on economies.

Koalas are experiencing malnutrition as *Eucalyptus* leaves decline in nutrient richness. They highlight effects of elevated CO_2 levels on plants and on the animals that rely on them for food.

Beluga Whales are losing their refuges from humans as Arctic sea ice melts, and also face new competitors, predators and diseases. In addition to melting sea ice impacts, they highlight climate change's indirect effects of worsening existing threats from people.

Climate change does *not* commit these species to extinction. Species can usually adapt if conditions change sufficiently slowly. Worsening climate change effects are inevitable because of the lag-effects of the greenhouse gasses that we've already emitted. But it is not too late. If our governments commit to strong and timely targets to reduce emissions, and adhere to them, we can slow the pace of climate change and give these and other species a chance to survive.

What can you do to safeguard a future for these species?

1. Reduce *your* use of energy.
2. Ensure that your leaders make and adhere to strong commitments to cutting greenhouse gas emissions now.
3. Spread the word about the effects of climate change on the world's species.
4. Find a way to support conservation where you live, and support a conservation organisation working to safeguard species at risk from climate change.

For more information on IUCN's Species Survival Commission and our work on climate change, please contact:

Wendy Foden: Programme Officer - Climate Change, IUCN Species Programme
wendy.foden@iucn.org
http://www.iucn.org/about/work/programmes/species/our_work/climate_change_and_species/

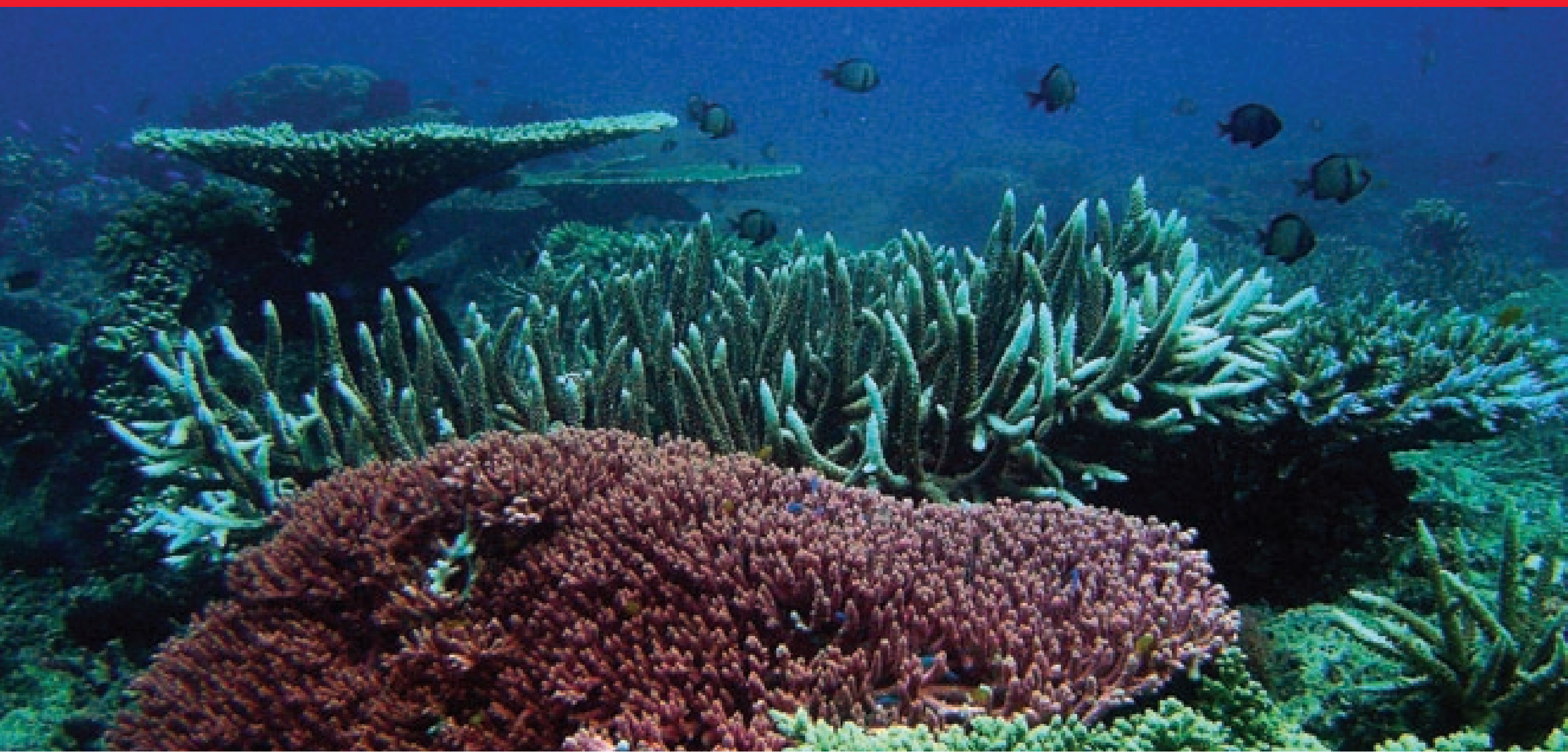
Simon Stuart: Chairperson, IUCN Species Survival Commission
simon.stuart@iucn.org
http://www.iucn.org/about/work/programmes/species/about_ssc/

Acknowledgements: species reports were compiled by Jamie Carr, Renuka Badhe, Chun Yuen Wong, Sarah Brooke and Wendy Foden with invaluable inputs from the experts named as contacts in each report, as well as Peter Cochrane, Ivan Lawler and William Foley (Koalas); and Peter Fretwell and Barbara Wienecke (Emperor Penguins). Thanks to Sarah Horsley for editing the reports and compiling the press release, and to Kathryn Pintus and Lynne Labanne for coordinating the layout.

© 2009 IUCN

STAGHORN CORALS AND CLIMATE CHANGE

Better to burn out than to pHade away?



© *Emre Turak*

Summary

- As well as being the most biodiverse ecosystems in the marine realm, coral reefs provide protein, livelihoods and services to tens of millions of people worldwide.

- Staghorn corals, the collective name for some 160 species representing approximately one-fifth of earth's extant reef-building corals, are critical to the processes of reef-building and provision of habitat for the remarkable array of associated reef life globally.

- These corals are extremely sensitive to high sea temperatures. They 'bleach' when warming forces them to expel the pigmented algae on which they rely for energy. Too much warming and they die, *en masse*.

- In addition, ocean acidification is causing weakening of coral skeletons, slower growth rates and, if unchecked, will contribute to the erosion of coral reefs in general.

- Corals are already threatened by human activities and disease; climate change interacts synergistically with these threats, reducing their chance of recovery. 33 percent of coral species are already listed as threatened on the IUCN Red List.

STAGHORN CORALS AND CLIMATE CHANGE

- Staghorn corals highlight the impacts of rising sea temperatures and increasing ocean acidification due to climate change. These changes directly or indirectly affect most species in the marine biome.

Coral reefs are the most biodiverse ecosystems in the marine realm. They are home to more than a third of all known marine species and are sometimes referred to as 'undersea cities' or 'oases'.

Staghorn corals are hard or 'stony' corals belonging to the genus *Acropora* and are so named for the antler-like colony forms of characteristic species. Other typical forms include intricate tables, expansive bushes and delicate 'bottle-brushes', among a bewildering variety of growth architectures. There are approximately 160 species of staghorn corals worldwide. Staghorn corals are thought to have evolved in the late Paleocene some 55-65 million years ago, and have dominated many reefs for the past 500,000 years.

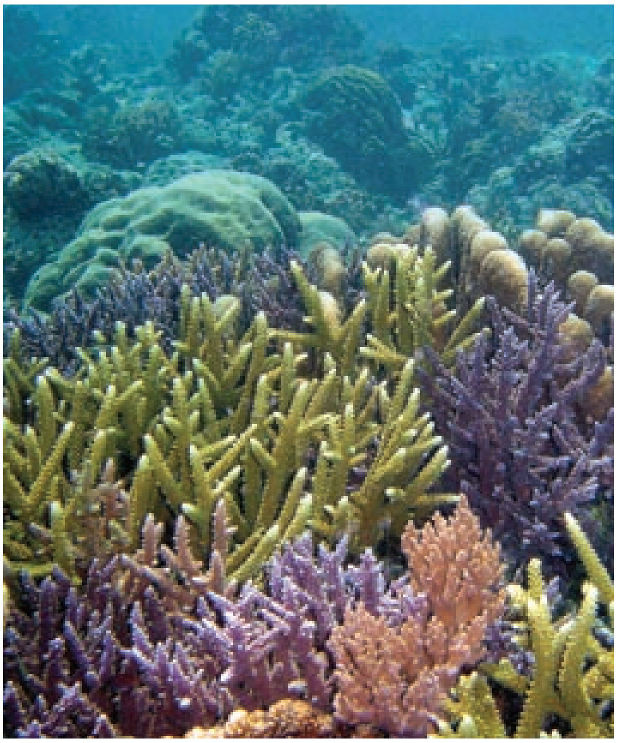
Staghorn corals play crucial roles in reef-building, and in providing food, shelter and other services to the remarkable array of associated species, a number of which are important to humans.

More than 100 countries have coastlines fringed by reefs, and almost 500 million people (about eight percent of world's population) live within 100km of a coral reef. Consequently, tens of millions of people depend on coral reefs for their protein. They also provide many important services to human societies. These include shielding thousands of kilometres of coastline from wave erosion, and protecting lagoons and mangroves, which are vital habitats for a range of commercial and non-commercial species.

Many medically active compounds are also created by or from corals and associated reef species. Reefs are also popular locations for snorkelling and SCUBA diving and as such have much value for ecotourism. Although valuation of all the goods and services provided by reefs is difficult, estimates range from $172 billion to $375 billion per year.

What do we know about staghorn corals?

Staghorn corals can be broadly divided into Atlantic and Indo-Pacific groups, and are generally located between 25˚N and 25˚S. The Atlantic group is by far the smaller of the two, being composed of only two extant species and a common hybrid, found along the Caribbean coasts of Central and South America, south-western Gulf of Mexico and the Bahamian archipelago. The Indo-Pacific group is distributed across the tropics in suitable habitat all the way from the west coast of Central America to the Red Sea and East Africa, with the centre of diversity in the 'Coral Triangle' region of the Solomon Islands, Papua New Guinea, Indonesia, East Timor, Philippines and Malaysia. Undisturbed staghorn corals normally form a distinct "staghorn zone" in shallow waters between 5 to 15m depth, though they do also occur in shallower and deeper water.



© Emre Turak

As with other stony corals, staghorn corals have a symbiotic relationship with photosynthetic single-celled algae called zooxanthellae. Staghorn corals are highly dependent on the oxygen and nutrients provided by these algae and the algae, in turn, receive carbon dioxide, nitrogen and other substances they need from the coral. Zooxanthellae are presently divided into six major clades and numerous sub-clades and different coral-zooxanthella combinations result in different coral physiology and colouration.

Staghorn corals reproduce both sexually (being hermaphrodites) and asexually (via budding and colony fragmentation). Sexual reproduction begins when, triggered by various environmental cues, including sea temperature, solar irradiance and lunar cycles, corals release vast numbers of sperm and eggs into the sea. In some regions hundreds of species do this simultaneously, (known as mass spawning). Eggs are fertilised in the open ocean and develop into free-living planktonic larvae that are carried by water currents. Larvae may drift on ocean currents for periods lasting several days to up to three months and may travel for up to hundreds of kilometres during this time. Upon maturing, they settle on a reef and undergo metamorphosis to transform into a single polyp.

Each staghorn polyp is approximately one to several millimetres in size and its body structure consists of a mouth and a saclike cavity called the coelenteron. The coral polyp secretes a calcium carbonate skeleton that serves as a home and helps to protects it from harm.

STAGHORN CORALS AND CLIMATE CHANGE

© *Emre Turak*

Polyps divide asexually by budding to make the colonies of thousands of polyps that form the antler-, bush- and table-like structures we recognise as staghorn corals. In addition to the energy provided by the zooxanthellae, polyps are also carnivorous and feed nightly on plankton by extending their tentacles, equipped with stinging cells called nematocysts, to capture prey. When coral polyps are threatened, they simply retract into their skeletons.

When pieces of a staghorn corals break off, they are often able to grow and form a new coral colony. This process of asexual reproduction is called fragmentation and is a common form of coral reproduction, particularly following severe storms.

How is climate change affecting staghorn corals?

Climate change has a wide range of impacts on corals and the reefs they build, the most important of which are bleaching, acid erosion and increased disease susceptibility.

Bleaching:

Bleaching occurs when corals experience environmental stress. Corals and their symbiotic zooxanthellae usually live only 1 to 2˚C below their upper temperature tolerance, and climate change is expected to cause seawater temperature to rise above this limit with greater frequency. Large-scale or 'mass' coral bleaching is a new phenomenon dating back to the 1980s; and is now the main cause of coral mortality and reef deterioration globally.

When water temperature increases, the algal symbionts photosynthesise more quickly. This increases the amount of oxygen they produce which can increase to toxic levels within the corals' tissues. To survive, corals expel most, if not all, of the algae from their tissues, thereby losing their source of energy. Corals appear white or 'bleached' because when the pigmented algae are gone, the white calcareous skeleton becomes visible through the transparent coral tissues.

Coral survival is contingent on a complex variety of factors that are both species- and colony-specific, including the type of zooxanthellae present. If seawater temperature returns to normal within a few weeks, the bleached corals sometimes regain their zooxanthellae populations and recover. Even so, these colonies still suffer from increased disease susceptibility, reduced growth rates and reproductive capability.

If high water temperatures persist for several weeks then bleaching causes coral tissues to die; bleaching mortality tends to be proportional to the intensity and length of unusually high temperature conditions. Once dead, coral skeletons break down over a period of years into grey 'rubble', which destroys the complex three dimensional structure and supports few other species. These reefs look eerily like flattened cities abandoned after a nuclear explosion. When high proportions of colonies on reefs bleach and die, this can lead to changes in the community structure of the entire coral reef ecosystem, severely impacting reef-dependent organisms and reducing overall biodiversity.

Coral vulnerability to bleaching varies between species, and staghorn corals are thought to be one of the most vulnerable groups. Temperature-induced mass coral bleaching has caused widespread mortality of staghorns and other corals worldwide, including the well-protected Great Barrier Reef in Australia. Globally, 20 percent of coral reefs are already damaged beyond recovery.

Ocean acidification:

Carbon dioxide (CO_2) emitted into the atmosphere by human activities is being absorbed by the oceans, making them more acidic. Because acidification affects the process of calcification, this directly impacts marine animals like corals and molluscs which have calcareous shells or plates. Ocean acidification causes weakening of coral skeletons, slower growth rates and, if unchecked, erosion of coral reefs in general. Recent studies have shown that if atmospheric CO_2 concentrations reach 560 ppm, coral calcification and growth will be reduced by 40 percent.

Disease:

Increasing water temperatures and acidification cause physiological stress, increasing corals' susceptibility to diseases. In addition, rising sea temperatures often present more suitable conditions for the pathogens themselves, and this also worsens outbreaks of coral diseases. The rapid, large-scale devastating loss of staghorn corals in the Caribbean is due to an unprecedented rise in coral diseases and this climate change related effect poses a very real threat to coral biodiversity.

Other threats:

Climate change introduces a host of other impacts which may act synergistically with bleaching, acidification and disease to threaten staghorns and other corals. These include sea level rise, changes to ocean circulation patterns, damage from increased storm intensity and frequency, and loss of light from increased river sediment loads.

Will corals adapt to climate change?

Corals' susceptibility to bleaching varies substantially between geographic locations, even for the same species. This is partly because some clades of symbiont algae photosynthesise at slower rates than others, thereby preventing oxygen levels in coral tissues from reaching toxic levels. Corals containing these algae are able to tolerate greater heat stress, though at the cost of slower growth rate during normal conditions.
In some coral-zooxanthella symbioses, several types of zooxanthellae can be present and 'shuffle' to better suit changing environmental conditions, and in some cases, switch completely between different algal clades or subclades. These mechanisms may provide an added, although not infinite, degree of flexibility and environmental tolerance to the association, and hence a small, if rapidly closing, window of opportunity to address climate change.

It has also been suggested that corals may be able to adapt to climate change by gradually evolving greater tolerance to higher oxygen levels in their tissues and hence to higher temperatures. In general, however, such adaptation is very slow and unlikely to be able to keep up with the current rates of climatic change.

Other threats

Of the 704 species of corals that were assessed in the IUCN Red List Assessment (2008), 33 percent are listed as threatened. Declines in their abundance are associated with bleaching and diseases driven by elevated sea surface temperatures, with extinction risk further exacerbated by local-scale anthropogenic disturbances. The proportion of corals threatened with extinction has increased dramatically in recent decades and exceeds that of most terrestrial groups.

Direct human impacts such as coastal developments can completely remove an entire reef, altering the flow dynamics and causing changes to nearby ecosystems. Dynamite fishing, vessel ground and anchoring, and tourism can also cause damage and scouring of corals.

Corals are also threatened indirectly by urban and agricultural runoff, and deforestation, which reduce water quality and increase sediment loads. This degrades habitat quality and exposes corals to further stress. Collection and removal of herbivorous fishes also result in corals becoming overgrown by macroalgae, preventing resettlement of new corals in damaged reefs.

"Both staghorn corals and coral reefs as a whole are canaries in the coal mine for human impacts from the local your local coastline, to the global scale of climate change. They serve up a lesson for what will happen to other less sensitive species and ecosystems. We must have consensus to reduce climate change to minimal levels to have a chance of having healthy coral reef ecosystems as long as we are on the planet."

- David Obura, IUCN SSC Coral Reef Specialist Group

Staghorn coral geographical distribution
© IUCN Red List

Contacts

David Obura
Co-Chairperson, IUCN SSC Coral Reef Specialist Group
dobura@cordioea.org
+254 733 851 656

Lyndon DeVantier
IUCN SSC Coral Reef Specialist Group
Ldevantier@aol.com

Emre Turak
IUCN SSC Coral Reef Specialist Group
emreturak@wanadoo.fr

The Coral Reef Crisis

Output of the Royal Society Technical Working Group meeting, London, 6th July 2009

- Temperature-induced mass coral bleaching is causing widespread mortality on the Great Barrier Reef and many other reefs of the world which started when atmospheric CO_2 exceeded 320 ppm.

- At today's level of 387 ppm CO_2, reefs are seriously declining and time-lagged effects will result in their continued demise with parallel impacts on other marine and coastal ecosystems.

- If CO_2 levels are allowed to reach 450 ppm (due to occur by 2030–2040 at the current rates of increase), reefs will be in rapid and terminal decline world-wide from multiple synergies arising from mass bleaching, ocean acidification, and other environmental impacts.

The full statement can be accessed at:
http://www.coralreefresearch.org/misc/Workshop%20statement%20and%20scientific%20justification.pdf

© 2009 IUCN

RINGED SEALS AND CLIMATE CHANGE

Arctic ice loss seals the deal

© Kit Kovacs and Christian Lydersen

Summary

- Ringed Seals live primarily in the high Arctic and are heavily dependent on Arctic ice, almost never coming onto land.

- Warming spring temperatures and early ice breakup are causing nursing young to be prematurely separated from their mothers and to be exposed both the elements and to predators.

- To cope with global warming, Ringed Seals will need to shift their territories to track suitable ice conditions. Increases in disease and disturbance by humans are also likely challenges.

- Marked decreases in Ringed Seal abundance are likely to have cascading effects in Arctic food webs. They are the most important species in the diet of Polar Bears.

- Ringed Seals highlight the direct impacts of climate change on polar habitats, including the effects ice loss has on other ice-adapted species.

RINGED SEALS AND CLIMATE CHANGE

© danielguip

What do we know about Ringed Seals?

Ringed Seals are known for the characteristic light-coloured ring marks on the dark grey pelt of adult animals. They are the smallest of all living seal species. Male Ringed Seals reach 1.5 m in length and females remain slightly smaller. Newborn pups are just 60 cm in length and weigh about 4.5 kg.

There are five sub-species of Ringed Seals and all live primarily in the Arctic Ocean, but are also found in more southern regions such as the Baltic and Bering Seas. They have a unique ability to create and maintain breathing holes in the sea ice by using sharp claws on their fore-flippers. This allows them to live in areas where even other ice-associated seals cannot reside.

The Ringed Seals are regarded as heavily ice-associated; they use ice year-round, for mating, birthing and pup rearing, moulting and even haul-out resting. Ringed Seal adults excavate lairs or snow dens on the surface of sea ice for giving birth to and rearing their young, as well as for protection from predators and their own shelter. The dens provide a warm micro-climate, reducing the energy required for keeping warm. The construction of such lairs is highly dependent on sufficient annual snowfall.

Ringed Seals are opportunistic feeders, but adults show a preference for small fish that tend to form dense shoals. Invertebrates such as krill and shrimp also form an important part of their diet. The Ringed Seal's diet overlaps considerably with the other higher predators (especially other seals) residing in the region.

Ringed Seals pup at low densities in March-April. The females lactate for about six weeks after birth and the pups are then weaned prior to the spring ice breakup in June. During lactation, both the mother and the pup are active, and spend considerable time making short feeding dives. Mating takes place a month after the pup is born, in preferred breeding habitats of land-fast ice or stable pack ice. After the breeding season ends in May, the seals haul out on the ice to moult until the ice breakup.

Polar Bears are Ringed Seals' most important predator, and they prey on little else. They are most successful at killing pups and sub-adult seals, though adults are also preyed up on. Other Ringed Seal predators include Walrus and Killer Whales which hunt both adults and pups, and Arctic Foxes, gulls and ravens, which predominantly hunt pups.

Humans hunt Ringed Seals in the Arctic, and have been doing so for millennia. Ringed Seals have traditionally formed a fundamental subsistence food item for most coast-dwelling northern peoples, and they are a source of cash income. Ringed Seals have never been the subject of large-scale commercial hunting but many tens of thousands of Ringed Seals are harvested annually by Inuit and other peoples of the Arctic Basin.

Population sizes of Ringed Seals are generally unknown because the seals and their pups spend a lot of their time under the snow in their lairs, and are practically invisible. Estimates of abundance from some areas have been derived by calculating the number of seals required to support known populations of Polar Bears and humans.

RINGED SEALS AND CLIMATE CHANGE

© Kit Kovacs and Christian Lydersen

How is climate change affecting Ringed Seals?

Many aspects of the Ringed Seal's life cycle are dependent upon their ice habitat, and many of their activities are governed by the timing of the formation and break-up of ice sheets. As a result, the most significant impact of climate change on Ringed Seals is the loss of the Arctic ice upon which they depend, although other less direct impacts have also been predicted.

Loss of ice habitat:

Ringed Seal breeding is dependent on the availability of sufficient ice, at the correct time of year in areas with sufficient food nearby. As the Arctic ice continues to melt earlier each year, more and more pups may be separated prematurely from their mothers. Both ice and snow must be stable enough in the spring season to successfully complete the six week period of lactation. If the land-fast ice breaks up too soon, pups may be separated prematurely from their mothers, resulting in high pup mortality.

Spring rains or warm spring temperatures can cause the roofs of lairs to prematurely collapse leaving Ringed Seals unsheltered and exposed to predators. Insufficient snow at the beginning of the breeding season can have the same effect.

Ringed Seals in some areas are already showing relatively long-term declines in reproductive rates and pup survival. Kovacs and Lydersen report: "During 2006 and 2007 many of the fjords on the west coast of Svalbard did not freeze for the first time in recorded history. Ringed Seal reproduction was virtually non-existent in areas where many hundreds of pups are normally born. It is not known if the seals that normally pup in this region established themselves elsewhere early enough to set up territories and build lairs, etc., but it seems highly unlikely."

Increases in disease:

Warmer ocean temperatures are likely to make conditions more favourable for Ringed Seal parasites and pathogens. Spread of these organisms is likely to be facilitated by the migration of seals as they are forced to seek more stable ice habitats. It is also possible that the added stresses from a changing climate will reduce the immunity of Ringed Seals, making them more susceptible to these natural threats.

Increases in human presence:

As Arctic conditions warm, a greatly increased presence of humans in previously inaccessible areas is anticipated. Activities such as shipping, agriculture and oil exploration are predicted to disturb and further degrade habitats and increased fishing in the area may reduce food availability.

RINGED SEALS AND CLIMATE CHANGE

Can Ringed Seals adapt to climate change?

To cope with global warming, Ringed Seals will need to shift their territories to track suitable ice conditions. Ringed Seals are known to have the capacity to move to new areas when required, although this can be restricted by geographical barriers and is ultimately dependent on the availability of sufficient new habitat. Their already high-latitude distribution range limits their potential for pole-ward migration.

According to some predictions, in the near future there could be very little summer sea ice in the Arctic. Ringed Seals do not normally haul out on land and performing this behaviour would be a rather dramatic change to the species' behavioural patterns. While closely related seals do perform this behaviour on islands and have survived at low population densities over an extended period of time, they face few or no predation risks in their ranges.

Ringed seal geographic distribution – © IUCN Red List

Other threats

Ringed Seals also face non-climate related threats. Subsistence hunting of Ringed Seals by indigenous peoples is unrestricted in most areas but the levels are thought to be sustainable. Pollutants have been shown to cause direct mortality to Ringed Seals, as well as increasing susceptibility to diseases. Accidental capture by commercial fisheries is a problem in some small lake populations. But the largest threat by far to Ringed Seals is climate change.

> *"If the extremes predicted for losses of sea ice do occur, it is difficult to envisage how this ice-breeding seal will survive beyond the small refugia-areas where ice-cover will remain, despite its currently broad range and high abundances."*
>
> *"Marked decreases in Ringed Seal abundance are likely to have cascading effects in Arctic food webs. They are the most important species in the diet of Polar Bears and are themselves top trophic consumers of significant magnitude.*
>
> **- Kit Kovacs and Christian Lydersen (2008)**

Contact

Kit Kovacs
Chairperson: IUCN SSC Pinniped Specialist Group
Kit.Kovacs@npolar.no

© 2009 IUCN

LEATHERBACK TURTLES AND CLIMATE CHANGE

Turtle-y exposed to climate change

© Brian J. Hutchinson

Summary

- The Leatherback Turtle is the largest of all the living turtles. Weighing in at over 500kg, it is often called the 'gentle giant' of the ocean.

- Higher sand temperatures during egg incubation lead to disproportionately higher numbers of female turtles. Increasing sand temperatures caused by climate change could threaten the stability of Leatherback populations in the future.

- Rising sea levels and increased storm activity may wash away turtle nests and decrease turtle nesting habitat.

- Leatherbacks are listed as Critically Endangered on the IUCN's Red List and already face a number of threats, including accidental capture by fisheries, coastal development and mistaken consumption of plastic debris.

- Leatherback Turtles highlight the impacts of increasing air and sea temperatures, rising sea levels and changing ocean currents. These changes are likely to affect all marine turtles and many other marine species.

Species Survival Commission

LEATHERBACK TURTLES AND CLIMATE CHANGE

The Leatherback Turtle *(Dermochelys coriacea)* is the largest of all the living turtles. Leatherbacks can reach lengths of nearly two metres and can weigh more than 500 kg. The largest specimen ever found weighed an astounding 916 kg, justifying the Leatherback's title as a 'gentle giant' of the oceans.

Leatherbacks are easily distinguished from other turtles by their smooth, leathery and comparatively softer shells. They can dive to depths of more than 1,000 metres, much deeper than any other marine turtle. Leatherbacks are the sole member of their family and are unique among reptiles in their ability to maintain a constant internal body temperature higher than the surrounding water.

What do we know about Leatherback Turtles?

The Leatherback's ability to regulate its body temperature has afforded the species the widest distribution of all the world's reptiles. Individuals have been found as far north as Alaska and Norway, and as far south as the Cape of Good Hope in South Africa, southern Chile and Argentina. They are found in three of the world's oceans: the Atlantic, Indian and Pacific. Leatherback nesting sites are found in many countries around the world, including those in the Americas, Africa, Asia and Australasia.

For nesting, Leatherbacks require soft, sandy beaches with wide entry from the ocean. The females emerge on to the beaches and dig holes with their rear flippers to create a nest. Female Leatherbacks deposit approximately 100 eggs into the nest and then carefully back-fill their nests, disguising it from predators with a scattering of sand. Female Leatherbacks can repeat this process at approximately 10-day intervals during the nesting season. Once nesting is complete, female turtles return to the open ocean to feed for the first time since the egg-laying season began. Females tend to nest at between two and seven-year intervals.

The incubation period of Leatherback Turtle eggs is approximately 60 days. During this time the gender of the hatchlings is determined by the average temperature at which the eggs develop; cooler temperatures produce males, while warmer temperatures produce females. Hatchlings are in immediate danger of predation from birds, crustaceans, other reptiles, and feral animals (dogs, pigs, etc). Once they reach the ocean they are generally not seen again until maturity and virtually nothing is known about this life stage. Very few turtles survive this period to become adults.

Jellyfish are the main food of Leatherbacks, although other food types include sea squirts and other soft-bodied animals. These floating animals are found in great numbers where ocean currents meet, and where cool, nutrient-laden water moves upwards from lower depths. These sites may be thousands of kilometres away from the turtles' nesting sites, and are the reason for their huge migratory distances - further than any other marine turtle species.

How is climate change affecting Leatherback Turtles?

Climate change is likely to affect Leatherback Turtles in at least three important ways.

Increasing feminisation:

Average global temperatures are predicted to increase by at least 2°C in the next 40 years due to climate change. The resulting increase in the temperature of the sand used for nesting could have serious consequences for Leatherbacks, as well as other species whose gender is determined by embryonic temperature. The predicted outcome of this change is an increase in the number of females relative to males in populations. This could threaten the stability of Leatherback populations in the future.

Increases in temperature have also been shown to lead to hatchling abnormalities and developmental and other health problems in young Leatherbacks.

© Roderic B. Mast

Beach erosion:

Ocean levels are thought to have risen at an average rate of 1.8 mm per year since 1961, and are predicted to rise even more rapidly in the future. Increases in storm frequency and severity have also been predicted. This is likely to lead to increased beach erosion and degradation, which could wash away turtle nests and decrease nesting habitat in the longer term.

While climate change adaptation measures, such as sea walls, help to prevent sea level rise impacts on human populations, their increased construction is likely to further reduce the availability of Leatherbacks' nesting habitat in the future.

LEATHERBACK TURTLES AND CLIMATE CHANGE

© *Roderic B. Mast*

Dispersal and food availability:

Ocean currents are important for both juvenile and adult Leatherbacks. Juveniles use them to aid dispersal following hatching and adults use them as aids to navigation and long-distance migration. In addition, changes to oceanic currents are likely to affect the abundance and distribution of jellyfish and other Leatherback prey species. While climate change impacts on ocean currents are likely, the nature of these changes, and hence their effects on Leatherbacks, remain uncertain.

Can Leatherback Turtles adapt to climate change?

Throughout their evolution, marine turtles have experienced climatic changes and have adapted accordingly. However, the current rates at which changes to the climate are occurring are believed to be faster than anything Leatherbacks and other marine turtle species have encountered previously. Such rapid changes, in combination with the Leatherbacks' long and slow-maturing life history, may limit the species' capacity to adapt quickly enough to prevent severe population impacts.

While physiological adaptation may be limited in Leatherbacks, there have been suggestions that the species may be able to adapt behaviourally in order to persist in the changing climate. While females are known to return to the same region and perhaps nesting beach, to nest each breeding year, Leatherbacks are among the most flexible turtle species in their nest site choice. Over time, Leatherbacks' flexibility may help them adapt their nesting site choice to select more favourable areas. Indeed, northward extensions of both nesting and feeding areas have been observed in the species.

For this to be possible, potentially suitable beaches need to be available in more favourable areas. Coastal developments and pressures from humans have already rendered many possible sites unsuitable, and increasing sea wall development and beach erosion are likely to further reduce beach availability.

Other threats

Leatherbacks' ability to adapt to climate change may be further limited by other factors already contributing to their Critically Endangered status. Leatherbacks already face a suite of threats, which include human harvesting, accidental capture by fisheries, coastal development and mistaken consumption of plastic debris. Such ongoing threats are likely to make Leatherbacks less resilient to further pressures, especially those arising from climate change. There is a clear need for greater protection of this species.

Contact

Roderic B. Mast
Co-Chairperson: IUCN SSC Marine Turtle Specialist Group
MTSG.Chairs@gmail.com
+1 703 341 2400

Brian Hutchinson
Conservation International
b.hutchinson@conservation.org

Bryan Wallace
Conservation International
b.wallace@conservation.org

Leatherback Turtle geographical range – © IUCN Red List

"Sea turtles are truly resilient creatures that have survived millions of years of global change, yet today they are in decline pan-globally due to the unprecedented pace of climate change and other human-generated impacts. Sea turtles are bellwethers, whose message to man is that slowing and reversing climate change is urgent."

"Healthy oceans are the underpinning of human well-being in coastal regions across the planet, and through ecosystem services like oxygen production and carbon sequestration, they are undisputedly critical to overall human survival. The bottom line in saving the seas lies in controlling what humans put into and take out of it – it is all about human behaviours as they relate to consumption and waste. Sea turtles have proven again and again to be exceedingly good flagships for engaging people and "selling" the concepts of ocean conservation to the public."

- Roderic Mast, IUCN SSC Marine Turtle Specialist Group

© 2009 IUCN

EMPEROR PENGUINS AND CLIMATE CHANGE

Tough times for hot chicks

© Ty Hurley

Summary

- Emperor Penguins are an iconic and charismatic species, highly adapted to living in the unforgiving conditions of the Antarctic .

- For much of the year, Emperor Penguins live on thick sea ice, which they use for mating, chick rearing and moulting.

- In some regions of the Antarctic, seasonal sea ice extent and thickness have reduced in recent decades following climate change. Continued warming will lead to further reductions in sea ice, impacting Emperor Penguins, with more northerly colonies being most at risk.

- The biomass of Antarctic krill has decreased in recent decades correlating with decreases in sea ice. Changes in krill abundance are likely to negatively affect Emperor Penguins and many other Antarctic species.

- Emperor Penguins highlight the possible impacts of rising sea temperatures and melting sea ice due to climate change. These changes directly or indirectly affect many other species in the Antarctic marine ecosystem.

Species Survival Commission

EMPEROR PENGUINS AND CLIMATE CHANGE

The Emperor Penguin's *(Aptenodytes forsteriis)* charismatic appearance and behaviour, as well as the feature documentary 'March of the Penguins', have made the species an icon of Antarctica. They inhabit shorelines all around Antarctica and are the largest, both in height and weight, of all the living penguin species.

Antarctica is an extremely harsh environment with temperatures dropping to below -40°C and winds reaching more than 140 km/h. While most other animals leave the region during the winter, Emperor Penguins remain to incubate their eggs.

Emperor Penguins keep warm by having a very high proportion of insulation feathers and, overall, the highest density of feathers of any bird (100 feathers per square inch). The thick layer of fat that they accumulate over the summer months insulates their bodies, but as this is gradually used up over the winter for energy, huddling and shivering become increasingly important for survival.

What do we know about Emperor Penguins?

For most of the year, Emperor Penguins live on the thick sea ice surrounding the continent of Antarctica. Because they incubate their eggs during the Antarctic winter, when scientists are unable access the colonies, much remains unknown about the location or total number of breeding colonies. Thirty-eight colonies are currently known to exist. This figure includes 10 new colonies that have recently been indentified using satellite images which highlighted reddish brown patches of penguin droppings (or guano) against the white ice.

Fish, squid and Antarctic krill form the main diet of Emperor Penguins. They hunt for food at sea in the open water or through cracks in the sea ice. Emperor Penguins are extremely accomplished divers that may remain submerged for up to 18 minutes and reach depths of up to 500m. They are able to do this due to their unusual blood haemoglobin composition, which allows them to function at low oxygen levels.

Emperor Penguins have a number of natural predators.. Chicks are vulnerable to predation by Giant Petrel and South Polar Skua, while Leopard Seals and Killer Whales frequently prey on adults.

In autumn, as the hours of daylight become shorter, Emperor Penguins begin the long journey to their breeding grounds. Leaving the open ocean behind, they walk distances of up to 200 km across the sea ice to reach their breeding sites.

Once at the breeding site, Emperor Penguins court and mate. Emperors are said to be serial monogamists, pairing and mating with the same mates for one season, but choosing a different mate each year. Females lay a single egg, which the males then incubate on top of their feet for the 2 month gestation period. Leaving her mate to care for the egg, the female immediately journeys back to the ocean to feed and recover the energy used for egg production and her long journey.

© Barbara Wienecke

The male remains on the ice for at least another two months without food, protecting the egg until it hatches. Throughout this period, males are exposed to severe weather conditions. Huddling together in large groups, individuals attempt to conserve body heat by constantly moving in an attempt to escape the worst of the wind, By the time the female returns, males could have fasted for up to 115 days and lost around 20kg, potentially more than half their original body weight.

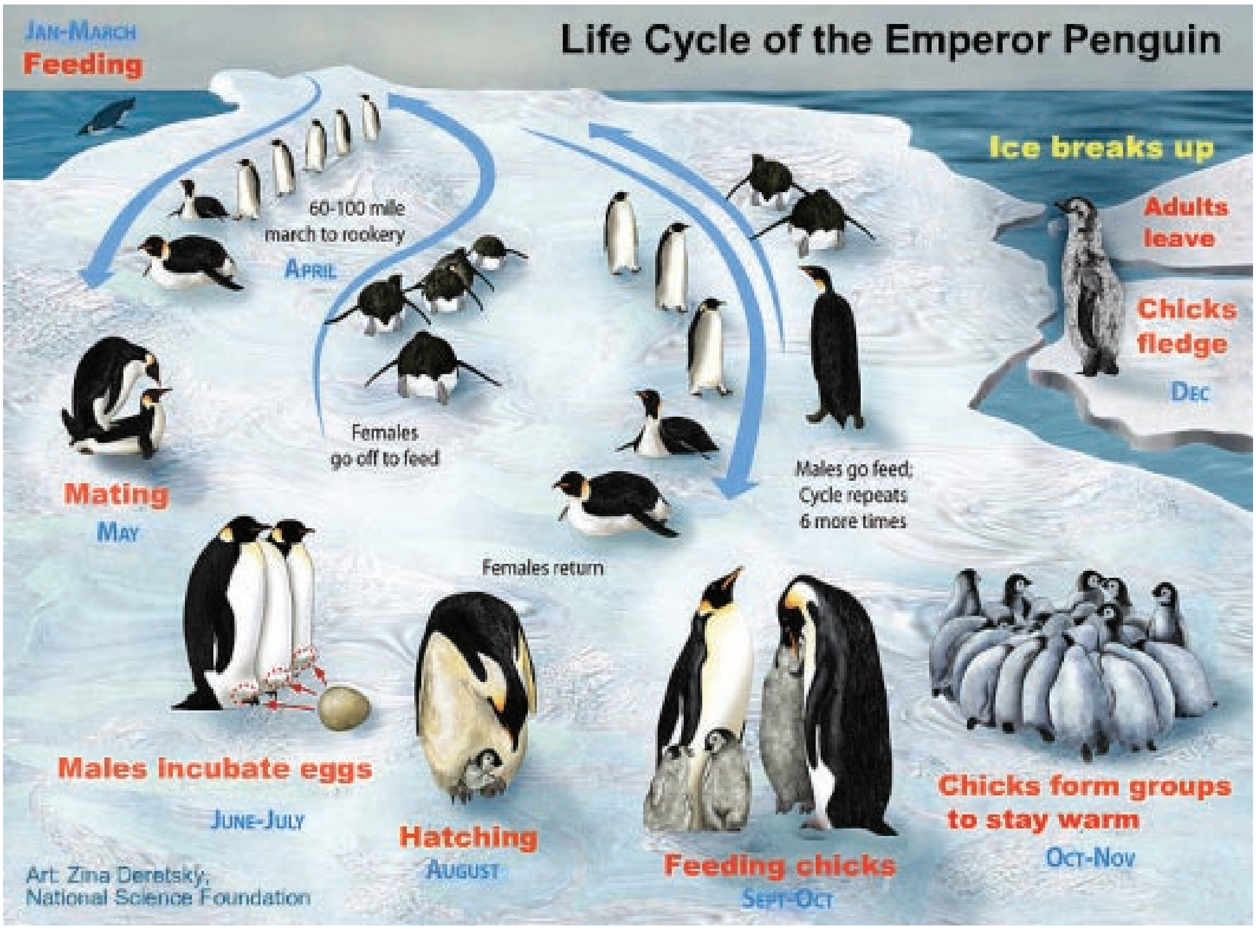
The females return to the breeding grounds as the eggs hatch, and feed the chicks by regurgitation. The pair then swaps roles; the female continues to brood the chick, while the male heads to the sea to feed. Both parents make multiple trips to feed their growing chick and, as the young penguins grow, the adults leave them in groups called crèches.

This shared parenting continues until the middle of the Antarctic summer, when the chicks fledge. By this time the melting ice edge is approaching the breeding colony and food is much more easily available. The adults then depart from the colonies and the chicks are able to feed for themselves.

How is climate change affecting Emperor Penguins?

Over the past 50 years, the west coast of the Antarctic Peninsula has been one of the most rapidly-warming parts of the planet, the British Antarctic Survey reports. Here, annual mean air temperatures have risen by nearly 3°C, with the greatest warming occurring in the winter season. This is approximately 10 times the mean rate

EMPEROR PENGUINS AND CLIMATE CHANGE



of global warming reported by the Intergovernmental Panel on Climate Change (IPCC). The east coast of the Peninsula has also warmed, though less rapidly, and here the largest warming has taken place in summer and autumn.

Significant warming has also been observed in the Southern Ocean, with upper ocean temperatures to the west of the Antarctic Peninsula having increased by over 1°C since 1955. As a result, sea ice cover may decline by around 25% (although there are considerable uncertainties associated with this prediction). Changes in seasonal sea ice have already been observed, including sea ice declines in the Antarctic Peninsula region.

Thinning sea ice:

Changes in seasonal sea ice are potentially a considerable threat to breeding Emperor Penguins. While it is sometimes argued that a reduction in sea-ice extent could actually benefit Emperor Penguins by reducing the distance adults have to travel to feed during the breeding season, there are also numerous and important negative effects that should be taken into consideration.

Pack ice extent reaches its minimum in late summer. A this time, however, ice is still essential as a platform for crèched chicks before they fledge, and later, for adults so that they can successfully moult. The platform is needed for growing chicks and for moulting adults as they are unable to survive without their waterproof feathers. Early ice break-up in warm years has caused chicks to be swept into the ocean and drowned.

Should global temperatures increase by 2°C, scientists estimate that colonies to the north of 70°S would probably become unviable. This means that 40 percent of all colonies, and almost 40 percent of the total breeding population of Emperor Penguins would be affected.

In 2001, a large iceberg collided with the Ross Sea ice shelf in the vicinity of a well-established Emperor Penguin breeding colony. The sea ice supporting a considerable proportion of the colony was broken. In addition to the direct impacts of the collision, the colony was affected for several years afterwards by the continued presence of the iceberg. Chick production was markedly reduced and remained lower than usual for some years. With increases in temperature and thinning of the sea ice, such incidences are likely to occur more frequently.

EMPEROR PENGUINS AND CLIMATE CHANGE

Reduced food availability:

Antarctic krill are small (maximum size 5.5 cm) shrimplike invertebrates that form the basis of much of the Antarctic food web. Krill make up an estimated biomass of over 500 million tonnes, which is about twice that of humans. Krill feed on phytoplankton or algae found in the open ocean, or on the underside of sea ice. Projected declines in sea ice extent are likely to reduce the number of krill in the Southern Ocean, which would, in turn, have profound effects on the Antarctic food chain. In addition to its direct effects on Emperor Penguins, krill availability is likely to have impacts on other penguin prey species abundance, such as of fish and squid, which also feed on krill.

Can Emperor Penguins adapt to climate change?

Little is known about Emperor Penguins' capacity to adapt to climate change. Emperor Penguin colonies exist at the edge of the Antarctic continent, so there is little potential for colonies to move southward. However, two Emperor Penguin colonies are known to occur on land rather than on ice, and these have remained stable over the last 20 years. This suggests that other colonies could potentially shift to land as sea ice decreases, though this would depend on finding land areas with suitable access to food resources. Access to reliable food sources is probably key to determining the location of Emperor Penguin colonies.

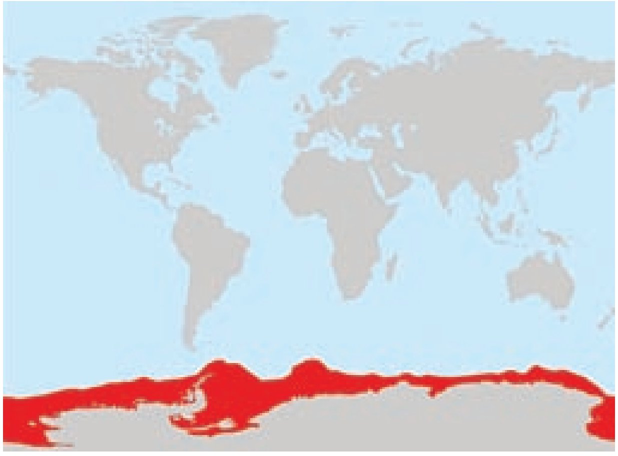
Other threats

Emperor Penguins are currently listed as 'Least Concern' on the 2009 IUCN Red List. Aside from climate change, they face few significant threats, but declines in food availability could become a concern if Southern Ocean krill fisheries become established.

Contact

Ben Lescalles
BirdLife International
Ben.Lascelles@birdlife.org
+44 1223 277 318

Phil Trathan
British Antarctic Survey
pnt@bas.ac.uk
+44 1223 221602



Emperor Penguin geographical range – © IUCN Red List

"Emperor Penguins are not only the largest penguins alive, they are also the oldest. Their forefathers inhabited Gondwana, the great super continent. When Gondwana spilt into the southern continents some 200 million years ago, some of the birds stayed on the part which is now Antarctica and started to evolve into Emperor Penguins about 130-160 million years later. As Antarctica drifted farther south and got colder, these birds adapted gradually to the harsh conditions that characterise Antarctica today. Having been successful on this planet for millions of years, Emperor Penguins now face the most serious challenge in their long history; in geological terms a very rapid warming of their home. They stand to lose their breeding grounds on the fast ice and potentially their main prey species. Will they be able to adapt rapidly to a completely altered southern Ocean ecosystem?
Their chances are slim."

- Barbara Wienecke, Australian Antarctic Division

© Barbara Wienecke

© 2009 IUCN

QUIVER TREES AND CLIMATE CHANGE

Desert giants feel the heat

© Wendy Foden

Summary

- The Quiver Tree, a long-lived giant tree Aloe, is iconic in the Namib Desert region of southern Africa. This region is projected to experience increasing droughts due to climate change.

- The Quiver Tree seems to be responding to this warming by shifting its distribution range towards higher latitudes (closer to the poles) and higher altitudes (tops of mountains), where conditions are typically cooler and moister.

- The Quiver Tree is slowly losing equator-ward parts of its range due to climate change, but populations are flourishing on its pole-ward range edge. This pattern is typical of species undergoing a pole-ward range shift.

- To keep up with a shifting climate, the Quiver Tree must, in time, colonise new pole-ward areas that are now becoming suitable. Sadly, no new populations have yet been found.

- The Quiver Tree highlights the problems that all plants and slow-moving species face in keeping up with rapidly accelerating changing climate.

SSC
Species Survival Commission

QUIVER TREES AND CLIMATE CHANGE

The Quiver Tree (*Aloe dichotoma*) is one of the best known desert plant species of southern Africa. Reaching heights of up to 10 metres, it is the largest, and arguably most striking, floral element of its native landscape.

Traditionally, Quiver Trees are used by indigenous San Bushmen hunters to construct quivers to carry their arrows. Due to their pulpy, water retentive 'wood', dead trunks are often hollowed out and used as natural refrigerators. Other reported uses include the use of the bark as building material and the wood pulp as a source of drinking water.

As far back as 1685 and 1861 eminent historic figures such as Simon van der Stel (the Dutch explorer and first governor of the Cape Colony) and Thomas Baines (the English artist and explorer) respectively noted Quiver Trees as being conspicuous and defining elements of the landscape. In more recent times Quiver Tree 'forests' have become popular tourist attractions. The Quiver Tree has been named the national plant of Namibia and appears on the country's 50c coins.

Within their ecosystem, the Quiver Trees' nectar-rich flowers provide food for a number of species including insects, birds and even large mammals such as baboons. Quiver Trees also provide important nesting sites for birds including perches for raptors and support for the massive nests of Sociable Weavers. Such roles are of particular importance in the Quiver Trees' otherwise often treeless and barren desert landscapes.

© Wendy Foden

What do we know about Quiver Trees?

Quiver Trees grow in arid regions of South Africa and Namibia. Within these two countries, the species is found predominantly in the west, and occurs throughout much of the Succulent Karoo Biodiversity Hotspot.

As a desert species, the Quiver Tree has well adapted to its environment through water-storing succulent leaves and shallow root systems that can quickly absorb water following rare rainfall events and even when condensed ocean fog drips from their own branches and leaves. Like other members of the *Aloe* genus, Quiver Trees use a special internal adaptation known as 'CAM metabolism', which allows them to photosynthesise without losing much water to the hot and dry environment.

How is climate change affecting Quiver Trees?

Weather station records from across the Quiver Tree's range show that average temperatures in the region have increased over past decades. Regional climate predictions suggest accelerating temperature increases and rainfall decreases in the near future.

Because they live so long (approximately 350 years) and continue to grow larger throughout their lives, Quiver Trees provide an invaluable living record of past climatic events. By examining the sizes of trees in a Quiver Tree population, it is possible to estimate when the infrequent wet periods suitable for seedling survival occurred. In addition, because the decay of dead trees happens slowly in the hot, dry desert conditions, the number of tree deaths can be reasonably accurately recorded. This makes Quiver Trees ideal for examining the ongoing impacts of climate change.

Distribution range shift:

By 2001, large die-offs of Quiver Trees were occurring, generating concern amongst the people of Namibia and South Africa. Scientists found that most of these die-offs were occurring in the hotter equator-ward areas of the Quiver Tree's range, and that these were most likely to be caused by drought stress. In contrast, populations on the pole-ward range areas and at the tops of high mountains were growing and reproducing.

Species are known to respond to climatic warming by shifting their ranges closer to higher latitudes and higher altitudes, where conditions are typically cooler and moister. For mobile species, this is apparent as individuals migrate away, but for plants and other immobile organisms, individuals that are 'left behind' by their shifting ranges are unlikely to reproduce successfully and eventually die.

QUIVER TREES AND CLIMATE CHANGE

© Wendy Foden

In contrast, pole-ward range areas that were previously unsuitably cold or wet can become newly suitable. Collectively, such areas may be known as the 'leading edge' of the species' range. Mobile species can quickly take advantage of these new conditions, but immobile species like plants rely on rare long distance seed dispersal events to colonise new areas.
Mapping patterns of population die-off across the Quiver Tree's range, revealed just such a pattern of a pole-ward range shift in response to warming. High die-offs are generally occurring on the equator-ward and low altitude parts of the species range, while populations on the 'leading edge' and on mountain tops have been flourishing increasingly over the past decades.

Can Quiver Trees adapt to climate change?

Genetic studies show that pole-ward, leading edge populations are generally more genetically poorer than equator-ward populations. This has two implications; firstly, it suggests that the pole-ward populations are younger and may have descended from the older equator-ward populations. This could be due to a range shift over a long time period such as following the last ice age, and suggests that, if pace of climate change is sufficiently slowed, the species may yet keep up.

Secondly, die-off of equator-ward populations would lead to loss of a disproportionate percentage of Quiver Trees' genetic diversity, including the lineages that are adapted to the hottest and driest conditions.

Scientists have not found any new Quiver Tree populations beyond the established pole-ward leading range edge, despite several decades of warmer, drier conditions. But Quiver Trees in gardens in these areas flourish, suggesting that climate is unlikely to be preventing colonisation, and rather that long distance dispersal may be limiting the Quiver Tree's migration.

This introduces an important and controversial conservation question: should scientists help Quiver Trees to migrate by planting new trees beyond their pole-ward leading range edge – a process known as 'assisted colonisation'? If so, should they simulate natural dispersal, spreading plants from pole-ward populations, or should they use plants from the genetically rich equator-ward populations, risking what some would call 'genetic pollution'? These questions remain the subject of as yet, unresolved debate, and highlight some of the challenges climate change brings to traditional scientific approaches and conservation practices.

Other threats

Very few other anthropogenic threats to Quiver Trees exist, although their popularity with gardeners makes the removal of juveniles, particularly in populations near towns or main roads, a marginal threat. Natural threats to the Quiver Trees include a fungal disease known as 'Aloe rust', and physical damage caused by baboons and porcupines.

Contacts

Wendy Foden
IUCN SSC Southern African Plant Specialist Group
wendy.foden@iucn.org
+44 793 280 4214

Guy Midgley
South African National Biodiversity Institute
g.midgley@sanbi.org.za

Quiver Tree geographical range – © IUCN Red List

"The Quiver Tree is noted for its drought tolerance and longevity, but in fact, like other desert organisms, it may be operating at the edge of its physiological tolerance.

If the Quiver Tree is declining as a result of climate change, then other smaller-ranged and more sensitive species are likely to be experiencing even worse impacts. But being inconspicuous, their declines may be passing unnoticed."

- Wendy Foden
IUCN SSC Southern African Plant Specialist Group

© Wendy Foden

© 2009 IUCN

CLOWNFISH AND CLIMATE CHANGE

Losing Nemo

© *Rita Vita*

Summary

- Clownfish live in tropical and subtropical ocean waters and have a mutualistic relationship with sea-anemones, upon which they rely for protection.

- Coral reefs are seriously declining globally and time-lagged effects and increasing CO_2 levels mean that rapid further declines are imminent. Clownfish and sea-anemones depend on coral reefs for their habitat.

- Clownfish are also affected by increasing ocean acidification. More acidic water disrupts their sense of smell, impairing their ability to find their specific host sea-anemone.

- There is some possibility that clownfish may adapt to these changes by changing their behaviour or the places they inhabit. However, their inability to move long distances and the rate at which their habitat is being degraded makes such an occurrence unlikely.

- Clownfish highlight the impacts of coral reef degradation, increasing ocean acidification and warming oceans due to climate change. These changes directly or indirectly affect most species in the marine biome.

SSC
Species Survival Commission

CLOWNFISH AND CLIMATE CHANGE

Clownfish (family: Pomacentridae), also known as anemonefish, are some of the most iconic marine fish in the world. They are highly popular among SCUBA divers due to their striking colour combinations of white, orange, yellow and brown.

There are a total of 28 species of clownfish, which are all very similar in their habits. Perhaps the most renowned of these is the Common Clownfish *(Amphiprion ocellaris)*, which was popularised in the Walt Disney movie 'Finding Nemo'.

What do we know about clownfish?

Clownfish are found in tropical and subtropical areas of the Pacific and Indian Oceans. The greatest diversity of clownfish is found close to Papua New Guinea, although the Great Barrier Reef in Australia is also known for a number of unique variants.

Within their range, clownfish are restricted to shallow waters due to their fascinating relationship with only a handful of specific sea-anemone species upon which they depend. While most fish are repelled by the anemones' poisonous stings, the clownfish acquires immunity to this defence, and is therefore able to use it for its own protection against predators. In return, clownfish keep their host anemone in a healthy state, and prevent them from being attacked by angelfishes and sea turtles, (which are also immune to the sea anemone's stinging tentacles).

A single sea-anemone may support several clownfish, all of which, excluding one single female, are males at various stages of development. Should the sole female die, then the largest male turns into a female and continues breeding.

Clownfish lay their eggs beneath the oral disc of their host sea anemone and these are guarded by the male. When the eggs hatch, larvae are carried away by ocean currents and most perish.

As a larva develops, it begins to use chemical signals present in the water to detect a suitable anemone to be used as its new home. These signals permit the young fish to select the right type of anemone, and ensure that it is different from its place of birth to avoid inbreeding. The period between hatching and seeking a new anemone 'home' is notably short (around 8–12 days), meaning that they do not disperse very far from their parents' anemone.

How is climate change affecting clownfish?

The most significant impacts of climate change on clownfish are those affecting their coral reef habitat, and water temperature and chemistry. Such changes may affect clownfish in a number of ways.

Loss of habitat as coral reefs decline:

At today's level of 387 ppm CO_2, coral reefs are seriously declining and time-lagged effects will result in their continued demise. If CO_2 levels are allowed to reach 450 ppm (due to occur by 2030–2040 at the current rates of increase), reefs will be in rapid and terminal decline world-wide from multiple synergies arising from mass bleaching, ocean acidification, and other environmental impacts (more details are available in the staghorn coral account).

© Alfonso Gonzalez

Clownfish depend on sea-anemones, which are most frequently found on coral reefs. Reef-dependent species such as the clownfish will undoubtedly be affected by the decline in coral reefs. In 1998, one of the most severe global coral bleaching events in recorded history led to the complete disappearance of several sea-anemone species used by clownfish in the corals reefs around Sesoko Island, Japan, causing local population declines.

Disruption of navigation as ocean acidity rises:

Increases in ocean acidity levels have been shown to affect clownfish's ability to detect the chemical signals necessary for navigating to and locating their anemone homes. This effect is known to be particularly severe in juvenile fish. Fish that are unable to locate a suitable hiding place are at a much higher risk of predation, and are much less likely to find other clownfish with which to mate.

Juvenile fish that are unable to locate new anemones to inhabit also have a much greater chance of returning to their original place of birth. While such individuals may be considered fortunate for at least finding protection, the likelihood of inbreeding in these fish is greatly increased.

Adult clownfish, although less susceptible to the loss of chemical cues, can still become confused and lost when venturing away from their host anemone. An extended period away from their host commonly leads to the loss of their immunity to their anemones' poison, and a much greater risk of predation. In order to regain this immunity, the fish must perform an elaborate 'dance', which may last up to several hours and further increases the chances of predation.

Ocean warming changes development rates:

All fish are 'cold-blooded' or ectothermic, which means that all aspects of their life-history are highly influenced by the surrounding water temperature. As ocean temperatures continue to increase we may expect to see a number of effects on clownfish.

Juvenile clownfish have been shown to develop faster as water temperatures increase (assuming sufficient food is available). There are potential immediate benefits to individuals such as faster reproductive turnover, but more rapid growth will generally mean that individuals disperse shorter distances from their parents' anemone before their development stage triggers the instinct to find their own anemone. The resulting decrease in dispersal distances means greater competition for local dwelling places, greater chance of predation and increased inbreeding.

A further threat to clownfish associated with warming ocean temperatures relates to their reproductive behaviour. Clownfish (as with many other fish species) are known to only reproduce within a very small temperature range. It follows, therefore, that an increase in temperature could discourage clownfish from breeding. High temperatures have also been shown to cause eggs to perish. Either of these outcomes, or a combination of the two, could have disastrous consequences for clownfish.

In summary, a combination of habitat loss, disruption of their olfactory senses and direct effects to their physiology makes clownfish particularly vulnerable to the effects of climate change.

Can clownfish adapt to climate change?

As ocean temperatures warm, clownfish may be forced to shift their ranges polewards to find cooler water. However, clownfish larvae travel only short distances from their parents' anemone, and increased development rates caused by warming, coupled with the need for parallel dispersal in interdependent sea-anemone species, is likely to limit dispersal further.

To avoid the negative effects of warming on reproduction and egg survival, clownfish could potentially adapt behaviourally to time such events during cooler periods or seasons. However, the potential for such changes in clownfish are, as yet, unexplored.

The problems caused to clownfish by habitat loss will require movement to new areas of suitable habitat. Obviously such areas will be limited in number and, once again owing to the poor mobility of the species, will only be accessible if they are relatively close by. One species of clownfish has recently been shown to use soft corals as an alternative habitat, something only ever previously witnessed in captivity. Whether such behaviour could be adopted by other species of clownfish, and, if so, whether it would serve to alleviate pressure on clownfish, is currently unclear.

Other threats

Both clownfish and their sea-anemone hosts are highly sought after by marine aquarists and they have become increasingly popular targets for collection. Reef destruction and degradation due to human activities remain its greatest threat at present.

Contact

Dr Terry Donaldson
Hawkfishes and Sandperches Red List Authority
University of Guam, Marine Laboratory
donaldsn@uguam.uog.edu

© Jonathan Beeston

© 2009 IUCN

ARCTIC FOXES AND CLIMATE CHANGE

Out-foxed by Arctic warming

© *Mark McLaughlin*

Summary

- The Arctic Fox is one of the top land-dwelling predators of the Arctic region. It is thought to be one of the first mammals to have colonised Sweden and Finland following the last ice-age.

- As the Arctic region warms, tundra habitat may slowly be replaced by boreal forest from the South. Forest habitat is unsuitable for Arctic Foxes.

- Red Foxes prey on and are superior hunters to Arctic Foxes. Northward encroachment of Red Foxes into the Arctic Fox's range has already been documented and is likely to continue as the tundra warms.

- Arctic Foxes prey largely on lemmings and voles. Milder and shorter winters are predicted to cause declines in the regularity of these rodents' population cycles, as well as decreases in their overall numbers.

- These factors are likely to cause declines in Arctic Fox numbers and range size. Arctic Foxes highlight the impacts of climate change on the ways that species interact with each other, both through competition and via changes in predator-prey relationships.

ARCTIC FOXES AND CLIMATE CHANGE

© Valerie

The Arctic Fox *(Alopex lagopus)* is the smaller 'cousin' of the perhaps more familiar Red Fox. As one of the top land-dwelling predators of the Arctic region, it may be regarded as a good indicator of the overall health of the tundra ecosystem.

This species is thought to be one of the first mammals to have colonised Sweden and Finland following the last ice-age. Thick fur, large fat reserves, specialised 'heat-retaining' circulatory systems in their feet and an ability to lower their metabolic rate to endure periods of starvation have allowed the Arctic Fox to colonise and prevail in these unforgiving regions.

What do we know about the Arctic Fox?

The Arctic Fox is native to the Arctic tundra and has a circumpolar distribution, occurring in Alaska, Canada, Greenland, Iceland, Russia and Scandinavia.

Arctic Foxes are opportunistic feeders and may both hunt and scavenge, depending on the food sources available. Inland populations prey mainly on lemmings and voles, while those at more coastal locations feed to a greater extent on seabirds and other elements of more 'marine-based' food chains. Additional items in the Arctic Foxes' diet may include Ringed Seal pups, Arctic Hare, fish and carrion.

The health of Arctic Fox populations is believed to be closely linked to that of lemming populations, and their numbers may fluctuate in accordance with the availability of this important prey species. Historically, lemming numbers have peaked every three to five years and then crashed to extremely low levels. Lemmings can reproduce only weeks after being born, so their numbers often increase very quickly. The cause of lemming cycles has long been debated, but is believed to result from the combined effects of pressure from predators, including skuas, owls and foxes, and the length of winter.

Arctic Foxes form monogamous pairs and breed at the end of winter, typically in the treeless high north or at higher altitudes. Birthing takes place in the early summer and the juveniles (or kits) are born in complex underground networks known as dens. A single den may host several generations of foxes. Arctic Foxes' litter sizes are thought to be linked to previous food consumption and so may vary greatly. While reports have been made of litters containing up to 25 kits, numbers between five and ten are more typical.

How is climate change affecting Arctic Foxes?

Regional warming is likely to affect Arctic Foxes in at least three important ways.

Habitat loss:

Perhaps the largest threat to the Arctic Fox arising from climate change is a loss of the tundra habitat that the species inhabits. As warming temperatures allow new plant species from the south to colonise the region, large extents of tundra habitat are expected to slowly be replaced by boreal forest. Forest habitat is known to be highly unsuitable for Arctic Foxes.

Increased competition with Red Foxes:

The Arctic Fox's greatest predator and competitor is the Red Fox. Red Foxes are superior hunters to Arctic Foxes and are known to prey on Arctic Fox kits and adults. While the northern limits of the Red Fox's range are determined by the productivity of the habitat, the southern limits of the Arctic Fox's range are determined

© Martha de Jong-Lantink

by the presence of the Red Fox. The encroachment of Red Foxes into more northern areas has already been documented and looks set to continue as the tundra warms.

Changes in prey abundance:

Numbers of Arctic rodents, particularly lemmings, are known to fluctuate greatly, but historically such fluctuations have been fairly regular and cyclical. There is now reason to believe that climate change will lead to instability in the population sizes of these and other important prey species.

Lemmings and voles do not hibernate through the winter. Instead they continue to forage in the space between the frozen ground of the tundra and the snow, almost never appearing on the surface. This is possible because the snow provides good insulation from the severe Arctic winter conditions. Mild weather and wet snow lead to the collapse of these under-snow spaces, destroying the lemmings' burrows, while ice crust formation reduces the insulating properties of the snow pack and may make food plants inaccessible. The combination of milder and shorter winters is predicted to decrease the regularity of lemming cycles, and population peaks in some populations have not occurred since the 1990s.

Any declines of important prey species are likely to have significant impacts on Arctic Fox populations. Declines of Arctic Fox numbers attributable to this very cause have already been observed in certain Scandinavian populations. It is argued by some, however, that although species such as lemmings may decrease in number, other potential prey species may begin to thrive in the new climate. Unfortunately, for the Arctic Fox, the associated arrival of species such as the Red Fox would almost certainly overshadow such benefits.

Arctic Foxes inhabiting coastal regions are likely to be less affected by declines of rodents than inland populations. But because Polar Bears and Ringed Seals are expected to decline due to climate change (see associated information), coastal populations are likely to face reductions in alternative food sources such as Ringed Seal pups and the remains of Polar Bear prey.

Can Arctic Foxes adapt to climate change?

Arctic Foxes are unable to persist in environments other than their native tundra habitat. This means that individuals living in southern parts of the species' range will probably need to move north if they are to survive. Arctic Foxes, however, already occur in some of the most northerly parts of the world and overall, their total available habitat is shrinking. In short, this means that that the number of Arctic Foxes that can be supported worldwide is likely to decrease.

Some positive outcomes of Arctic warming have been suggested for the Arctic Fox. For example, should larger herbivores such as Reindeer and Musk Ox lose potential forage material as a result of ice crust formation, Arctic Foxes may benefit from an increase in large herbivore carrion. Such benefits would be short-lived however, as the populations of these larger herbivores, along with the carrion they provide, eventually decline.

Arctic Foxes living on Arctic islands may ultimately prove to be the safest of all populations. Such locations are generally at very high latitudes and will be among the last to face changes in tundra habitat and invasion by Red Foxes. Further, the likely loss of the ice sheets currently connecting these islands to the continental landmasses will prevent access of Red Foxes. However, island populations often tend to be more vulnerable to losses of genetic variation and the associated affects on long-term population health. Island populations may also have poor recovery potential from other threats such as hunting and hybridisation with farm-bred foxes, which are currently the largest threats to the species.

Arctic Fox geographical range – © IUCN Red List

At present, the Arctic Fox is classified as 'Least Concern' on the IUCN Red List, although specific populations in Norway, Finland and Sweden are considered 'Critically Endangered'.

Contacts

Claudio Sillero-Zubiri
Chairperson: IUCN SSC Canid Specialist Group
claudio.sillero@zoo.ox.ac.uk

Anders Angerbjorn
Department of Zoology, Stockholm University
anders.angerbjorn@zoologi.su.se
+46 8 16 40 35

© 2009 IUCN

SALMON AND CLIMATE CHANGE

Fish in hot water

© Anita Scharf

Summary

- Salmon have a long historical association with human society and make a large contribution to economies. They also have important ecological roles.

- Some salmon populations have declined significantly in recent decades. While human activities are largely responsible, climate change could now exacerbate or even supersede these threats, particularly in the southern part of their natural range.

- Physical changes to freshwater ecosystems resulting from climate change will degrade and diminish available habitat, reduce reproductive success and jeopardise migration.

- Although not well understood, impacts on salmon's marine habitat could lead to temporal and spatial shifts in both their prey and predators. Possible changes to the timing of migration represents an important new threat.

- These species highlight the effects of rising temperatures on both freshwater and marine ecosystems, and illustrate how climate change impacts on wild species can have a direct effect on economies.

SSC
Species Survival Commission

SALMON AND CLIMATE CHANGE

© *Arthur Chapman*

Salmon have a long historical association with human society and represent one of the most valuable wild capture fisheries in the world. In a recent assessment in 2007, the salmon fishing industry contributed more than $2 billion to economies in Russia, Japan, the US and Canada and directly employed more than 35,000 people. Salmon are also harvested on a smaller scale, both for recreational and subsistence purposes, and many individuals, communities and small businesses are dependent on salmon for their livelihoods.

Salmon have important cultural and ceremonial associations. Such associations range from those of Native American tribes, who have held salmon with great reverence and believed that their annual returns were a 'self-sacrifice' to feed the people, to the many people who derive pleasure from viewing their captivating migrations.

Salmon play an extremely important role in the functioning of their ecosystems. They provide food for a suite of predators and scavengers, including seals, whales, otters, bears, birds and countless invertebrates. Salmon also transport essential nutrients from the marine environment to freshwater and terrestrial habitats. This occurs through the excretion of waste and the decay of carcasses, including those discarded by terrestrial predators.

What do we know about salmon?

Salmon belong to the family Salmonidae, which includes other well known fish such as trout, grayling and char. The salmon species covered here include Chinook, sockeye, pink, coho, cherry and chum (collectively belonging to the 'Pacific salmon'), as well as Atlantic salmon, all of which perform their renowned migrations from freshwater to marine habitats and back again. This behaviour is called 'anadromy'.

Pacific salmon live in coastal and river waters from Alaska and Russia in the north, to Japan and Mexico in the south, while Atlantic salmon inhabit areas in the North Atlantic Ocean and Baltic Sea, including associated river ways in USA, Canada, Iceland, Norway, Finland, Sweden and the United Kingdom.

One of the most intriguing aspects of salmon is their extraordinary life cycle. Salmon eggs are laid in small pits (called 'redds') that are excavated in gravel-based freshwater streams by egg-bearing females. These nesting sites are selected because of their specific temperature, currents and oxygen levels.

Salmon eggs hatch after about three months, although juveniles remain dependent on the yolk-sac for several weeks after hatching. Eventually the juveniles begin their downstream migration1 during which time they develop a tolerance to saline waters. Young salmon may remain in fresh water for up to four years, before entering the ocean. It is during this period that juveniles are thought to be most vulnerable to predation.

Entry into the ocean coincides with planktonic blooms, upon which the juveniles feed. Older individuals may feed upon small invertebrates, squid and a diversity of marine fishes.

SALMON AND CLIMATE CHANGE

© Craig Elliot

Depending on the species, salmon may spend between one and seven years at sea, where they continue to grow. Once sexually mature, the salmon migrate back to their original hatching grounds to reproduce. Such migrations (which can be extremely long) use a combination of chemical, magnetic and celestial cues for navigation. For most species this landward migration occurs throughout the summer and autumn months, with a few species, such as Chinook, coho and chum salmon, continuing to migrate through the winter months.

Salmons' spawning migration is both risky and energetically costly. Salmon must travel continually against the current and overcome numerous threats and barriers including predators, disease and waterfalls. As a result, many salmon die during the migration, and those that survive are often bruised and battered. Upon arrival at the nesting site a salmon will typically spawn several times before dying, although some species (notably Atlantic salmon) can survive and may even repeat spawn.

How is climate change affecting salmon?

Freshwater habitats:

As water temperatures increase, a number of negative effects on salmon may arise. Direct biological impacts on salmon include physiological stress, increased depletion of energy reserves, increased susceptibility and exposure to disease and disruptions to breeding efforts.

Such direct impacts on the biology of salmon may potentially lead on to further, less direct impacts. For example, as the developmental rate of salmon is directly related to water temperature, it is possible that increasing temperatures could cause the more rapidly developing juveniles to enter the ocean before their planktonic food source has reached sufficiently high levels.

Additional indirect effects to salmon, associated with increasing air and water temperatures, relate to negative changes to their habitat. It has been noted that areas of particularly warm freshwater can present a thermal barrier to migrating salmon that requires additional energy to navigate around. Such barriers can also delay or even prevent spawning.

As the air temperatures warm, much of the snow that feeds the river systems is expected to melt earlier. In many cases snow is predicted to be replaced by rain. This will lead to a reduction in the summer flows of many rivers, coupled with an increase in freshwater inputs during the winter.

A reduction in summer flow levels will serve to increase water temperatures further and is likely to reduce the overall habitat available to salmon. Increased winter flows are likely to scour the river beds, disturbing nests and causing physical damage to both salmon eggs and juveniles.

Coupled with an increase in freshwater inputs, is an increase in the sedimentation of river and stream beds. Such sedimentation is likely to reduce the amount of gravel substrate available for spawning, and to smother both eggs and juveniles.

Marine habitats:

Predicting the specific effects of climate change on salmon in their marine environment is extremely difficult. This is due to our limited knowledge of the marine habits of salmon, combined with uncertainties about how marine habitats will be affected by climate change.

It has been suggested that many of the food webs of which salmon are a part will be disrupted by climate change. For example, the timing of the planktonic 'blooms' required by the young is governed by climatic factors. Changes in the timing of these blooms could cause a scarcity of food at a critical stage of the salmon's life cycle.

Warmer ocean temperatures have been shown, in certain areas, to reduce the abundance of other smaller fish into these newly warmed areas. These two factors, when coupled together, could cause a significant rise in predation pressure on salmon.

Can salmon adapt to climate change?

Not all salmon populations will be affected by climate change in the same way, and some populations at higher latitudes may actually benefit from warmer temperatures through increased production. It is possible that a warmer climate could make new spawning habitats available, and this has been observed in parts of Alaska. Such changes are likely to lead to unexpected consequences and shifts in ecosystems and fisheries, and humans will need to be prepared to adapt to these new conditions.

It is important to note that a multitude of other threats to salmon currently exist. These include:

- Overexploitation by the fishing industry.
- Habitat destruction and degradation (particularly through activities such as mining, forestry, agriculture and/or urbanisation).
- Pollution and sedimentation of river waters
- Obstruction of migratory routes, (especially by dams and hydropower stations).
- Interbreeding and ecological interactions with artificially propagated salmon (originating from either farms or hatcheries).

This suite of threats will all serve to jeopardise salmon's chances of adapting to the new threats arising from climate change.

Contact

Pete Rand
Chairperson: IUCN SSC Salmonid Specialist Group
prand@wildsalmoncenter.org
+1 971-255-5546

"Continued research on how salmon will cope with climate change is important and should be emphasised. But we also need to support efforts to control greenhouse gases, do everything we can to help wild salmon adapt to a new, changing environment, and work on adapting to a new way of doing business through proactive, precautionary management and actively promoting wild salmon conservation."

- Pete Rand, IUCN SSC Salmonid Specialist Group

Salmon geographical range – © IUCN Red List

© 2009 IUCN

KOALAS AND CLIMATE CHANGE

Hungry for CO_2 cuts

© Daniele Sartori

Summary

- Koalas are iconic animals native to Australia. They are true habitat and food specialists, only ever inhabiting forests and woodlands where Eucalyptus trees are present.

- Increasing atmospheric CO_2 levels will reduce the nutritional quality of *Eucalyptus* leaves, causing nutrient shortages in the species that forage on them. As a result, Koalas may no longer be able to meet their nutritional demands, resulting in malnutrition and starvation.

- Increasing frequency and intensity of droughts can force Koalas to descend from trees in search of water or new habitats. This makes them particularly vulnerable to wild and domestic predators, as well as to road traffic, often resulting in death.

- Koala populations are reported to be declining probably due to malnutrition, the sexually-transmitted disease chlamydia, and habitat destruction.

- Koalas have very limited capability to adapt to rapid, human-induced climate change, making them very vulnerable to its negative impacts.

SSC
Species Survival Commission

KOALAS AND CLIMATE CHANGE

- Koalas are particularly vulnerable to the effects of elevated CO_2 levels on plant nutritional quality, as they rely on them for food. The potential impacts of these changes on the world's food chains are enormous.

Australian icon, the Koala (*Phascolarctos cinereus*), is a tree-dwelling marsupial found in eastern and southern Australia. Marsupials are mammals whose young are born at a very undeveloped stage before completing their development in a pouch. The Koala is not a bear, though this name has persisted outside Australia since English-speaking settlers from the late 18th century likened it to a bear.

What do we know about Koalas?

Koalas are native to Australia and are present in four Australian states: Queensland, New South Wales, South Australia and Victoria. They are commonly found in southern and eastern coastal regions from Adelaide to Cairns, and further inland where the landscape and climate can support woodlands. Koalas forage mainly at night and typically sleep and rest for a minimum of 16 hours a day.

Koalas are true habitat and food specialists, only ever inhabiting forests and woodlands where eucalypts are present. Of the 600+ eucalypt species present in Australia, Koalas feed only on the leaves of a few tens of species. Further, Koalas in different regions also show preferences for different species.

The nutritional quality of eucalypt leaves is very poor, and an individual Koala may have to consume 500g of leaves or more each day in order to grow and survive.
All *Eucalyptus* leaves contain tannins, which are chemicals that attach to leaf proteins and make them highly indigestible. Plants produce tannins to deter herbivores, and Koalas choose their preferred eucalypt species based on a trade-off between nutrient and tannin concentrations within their leaves.

The Koala's choice of specific eucalypt species may also allow it to minimize competition with other marsupials, such as the Greater Glider and Common Ringtail Possum, which also feed on *Eucalyptus* leaves.

Koalas usually live between 10 and 14 years. Females reach sexual maturity at about three years old and males at four. Mating takes place during the Australian summer between December and March, and usually just one juvenile, called a 'joey', is born each year per female. The joeys remain in the females' pouch and feed on her milk for about six months before beginning to explore the outside world.

Nursing mothers produce a special form of faeces, known as 'pap'. Pap contains the specific micro-organisms essential for digesting *Eucalyptus* leaves. After consuming the pap, the joey is able to slowly switch its diet from milk to leaves. Joeys usually stay with their mothers for about a year, or until a new joey is born and requires the pouch. The young Koala then disperses in order to find its own territory.

© Erik K. Veland

How is climate change affecting koalas?

Climate change is predicted to include an increase in drought frequency and high-fire-danger weather in many parts of Australia, owing to reduced rainfall levels, increased evaporation rates and an overall temperature increase of about 1ºC by 2030, according to a CSIRO report.

CO_2 concentrations globally have increased from 280 ppm to 387 ppm since the Industrial Revolution. Projections for 2050 suggest that CO_2 concentrations are likely to increase markedly to between 500 and 600 ppm, depending on future emissions scenarios.

Elevated CO_2 levels:

Increased atmospheric CO_2 levels tend to result in faster plant growth through a process known as 'CO_2 fertilisation'. However, while plants grow faster, experiments have shown that it also reduces protein levels and increases tannin levels in plants' leaves.
As CO_2 levels continue to rise, Koalas and other browsers will need to cope with increasingly nutrient-poor and

KOALAS AND CLIMATE CHANGE

© *Erik K. Veland*

tannin-rich *Eucalyptus* leaves. Scientists suggest that Koalas could respond in two ways.

Firstly, Koalas could meet their nutritional needs by spending more time feeding and thus eating more. However, there is a limit to how much Koalas can increase the size of their guts. In addition, eating more leaves causes them to pass more quickly through the Koala's digestive system, resulting in less thorough digestion and decreased nutrient uptake.

Secondly, the above strategy could be combined with greater selectivity in leaf and tree choice. Younger, more nutritious leaves, however, also tend to possess more tannins. Koalas could also be more selective about the trees they select, though this would involve greater travelling time to find the best trees.

Koalas travelling in search of food are at an increased risk of predation and road accidents. Dispersing Koalas often find themselves having to cross main roads and coming into contact with domestic animals. It is estimated that around 4,000 Koalas are killed each year by dogs and cars alone.

The difficulties of digesting *Eucalyptus* leaves, combined with limitations on how much Koalas can increase the size of their gut, means that Koalas may no longer be able to meet their nutritional demands, ultimately resulting in malnutrition and starvation.

The nutritional demands of breeding female Koalas are higher than non-breeding individuals, providing an insight into challenges faced by all Koalas under higher CO_2 conditions. Lactating female Koalas have already been observed adopting the above strategies in attempts to meet the extra nutritional requirements demanded for the production of milk for their young. Unfortunately, if the quality of their food declines, they have limited options for further changing their behaviour. If females are unable to produce joeys to replace Koalas that die of old age, populations will dwindle and eventually disappear.

Increasing droughts and bushfires:

Koalas' warm fur and thick skin enables them to endure cold conditions in southern Australia, but they do not cope well with extreme heat. Unlike most other arboreal marsupials, Koalas do not use nest hollows, which also contributes to their greater susceptibility to extreme temperatures and drought. During particularly hot periods, Koalas descend to the ground and go in search of water. When at ground level, Koalas are significantly more exposed to their predators, which include dingoes and dogs.

Bushfires, which have already wiped out considerable populations of Koalas, are likely to increase in both frequency and severity with climate change. Koalas are particularly vulnerable to bushfires as their slow movement and tree-dwelling lifestyle makes it difficult for them to escape and their food supply can be destroyed.

KOALAS AND CLIMATE CHANGE

Can Koalas adapt to climate change?

Koalas' possible behavioural adaptations to decreasing food quality are discussed above. However, scientists are not optimistic of the ability of this highly specialised species to adapt to a changing climate, particularly as changes are occurring faster than Koalas are likely to have experienced in the past.

Koalas' potential for adaptation is also limited by the low levels of genetic variation within their populations. This is primarily due to a large reduction in their numbers in the early 20th century due to hunting for the fur trade. This brush with extinction was followed by a subsequent increase from a very small founder population and, as a result, most current Koala populations are highly inbred.

On some islands, such as Kangaroo Island in southern Australia, Koalas can achieve very high population densities. However, current reductions in food quality mean that Koala habitats will become increasingly poor in quality. As these populations are unable to disperse to new habitats, current densities will ultimately become unsustainable and we may expect to see increased levels of starvation.

Other threats

Reports of large population declines over the past decade have prompted reassessments of the Koala's threat status by the Australian government. In addition to climate change-related declines in Koala nutrition, declines are attributed to disease and habitat destruction. *Chlamydia* is a sexually-transmitted disease that causes blindness, pneumonia, and urinary and reproductive tract infections and death in Koalas. Destruction and degradation of Koala habitat is particularly prevalent in the coastal regions of Australia where urban development is rapidly encroaching on *Eucalyptus* forests. In addition, habitat fragmentation limits Koalas' ability to disperse to suitable areas and can intensify inbreeding problems.

Koala geographical range – © IUCN Red List

"My view of koalas is that the strong connection between food quality and demography means that they are particularly vulnerable to climate change. Elevated atmospheric CO_2 reduces the amount of protein available from Eucalyptus *leaves for animals. This* Eucalyptus*-marsupial system is one of the very few examples in which the direct effects of CO_2 can be linked to populations of wild mammals."*

- William Foley, University of Sydney

Contacts

Chris Johnson
Australasian Marsupial and Monotreme Specialist Group
+61 7 47 814141
christopher.johnson@jcu.edu.au

Jane DeGabriel
Aberdeen University, United Kingdom
j.degabriel@abdn.ac.uk

Ben Moore
The Macaulay Land Use Research Institute,
United Kingdom
b.moore@macaulay.ac.uk

© 2009 IUCN

BELUGA WHALES AND CLIMATE CHANGE

© Bill Liao

Summary

- Beluga whales live in Arctic and sub-Arctic waters and are sociable and vocal animals. They are hunted by indigenous Arctic people for food and are captured alive on a relatively small scale in eastern Russia to supply the live animal display industry throughout the world.

- Climate change is likely to affect Belugas both directly through ecological interactions and indirectly through its effects on human activity.

- Among the ecological factors that may affect Belugas are changes in populations of their prey, changes in ice conditions (more ice entrapment is a possibility), greater competition with co-predators, more frequent predation by killer whales and exposure to novel pathogens.

- As Arctic ice cover rapidly declines and the passages across northern landmasses become more navigable, humans will gain easier access to formerly pristine areas that have long served as refuges for Belugas and other marine mammals.

- Belugas are increasingly at risk from vessel and industrial noise, ship strikes and toxin exposure.

SSC
Species Survival Commission

BELUGA WHALES AND CLIMATE CHANGE

The scientific name for the Beluga Whale *(Delphinapterus leucas)* means "white dolphin without wings". Adult Belugas are entirely white and their common name comes from the Russian word *belukha* or "white one".

Belugas are toothed whales that measure up to 4 (females) or 5.5 metres (males). Unlike most other whales and dolphins, they lack a dorsal fin.

Belugas are extremely vocal, producing whistles, squeals, chirps and clicks, prompting their nickname, "sea canaries". They use some of their sounds to communicate and others to locate objects. Some of their sounds can be heard from above the water.

Belugas were historically an important food resource for many indigenous Arctic communities and they were hunted by commercial whalers for oil and hides. Today they are hunted only by Inuit, primarily for their skin, which is considered a delicacy.

What do we know about Belugas?

Belugas live mainly in Arctic and sub-Arctic waters. Some populations (for example, the Cook Inlet and the St Lawrence River populations) are geographically isolated and live in those locations all year round. Other groups of Belugas inhabit fairly well-defined areas in the summer but may mix with other populations in the winter.

In spring and summer months Belugas are typically found in fjords, bays and estuaries where feeding opportunities are good and water temperatures are favourable for calves. As autumn progresses into winter these habitats usually freeze over, and the whales are forced into offshore waters, though their exact winter movements are not well known. Belugas are well adapted to living in ice-infested waters and are likely to benefit from the fact that Killer Whales, their main predators, are not.

Belugas are social animals and are usually found in groups known as "pods" of a few to a few tens of individuals. Pods generally consist either only of males, or only of females and young whales. Pods of Belugas often form large aggregations of numerous pods totalling hundreds of animals.

Mating takes place between late winter and early spring, and a single calf is born approximately 14 months later. Young Belugas depend on their mothers' milk for close to two years. Mature females generally reproduce once every three years.

Belugas rub and scrape against coarse sand and rocks, apparently to enhance the shedding of old skin. They return each year to favourite skin-shedding places, typically in shallow estuaries, and calves presumably learn the locations of these sites from their mothers.

Belugas' ages are estimated by counting the number of layers of dentine in their teeth. There has been considerable debate about how many layers are laid down per year and until recently, scientists calculated Beluga age assuming that two layers were laid down per year. But new evidence suggests that only one dentine layer is laid down per year, and as a result, estimates of Beluga longevity have at least doubled to 60 years or more, with significant implications for population growth projections.

© Jenny222

Belugas feed on a large variety of fish species including Arctic cod, polar cod, saffron cod, salmon and smelt, as well as invertebrates such as shrimp, crabs, octopuses and marine worms. Belugas themselves are preyed upon by Killer Whales and Polar Bears, the latter at cracks in sea ice where the whales become particularly vulnerable.

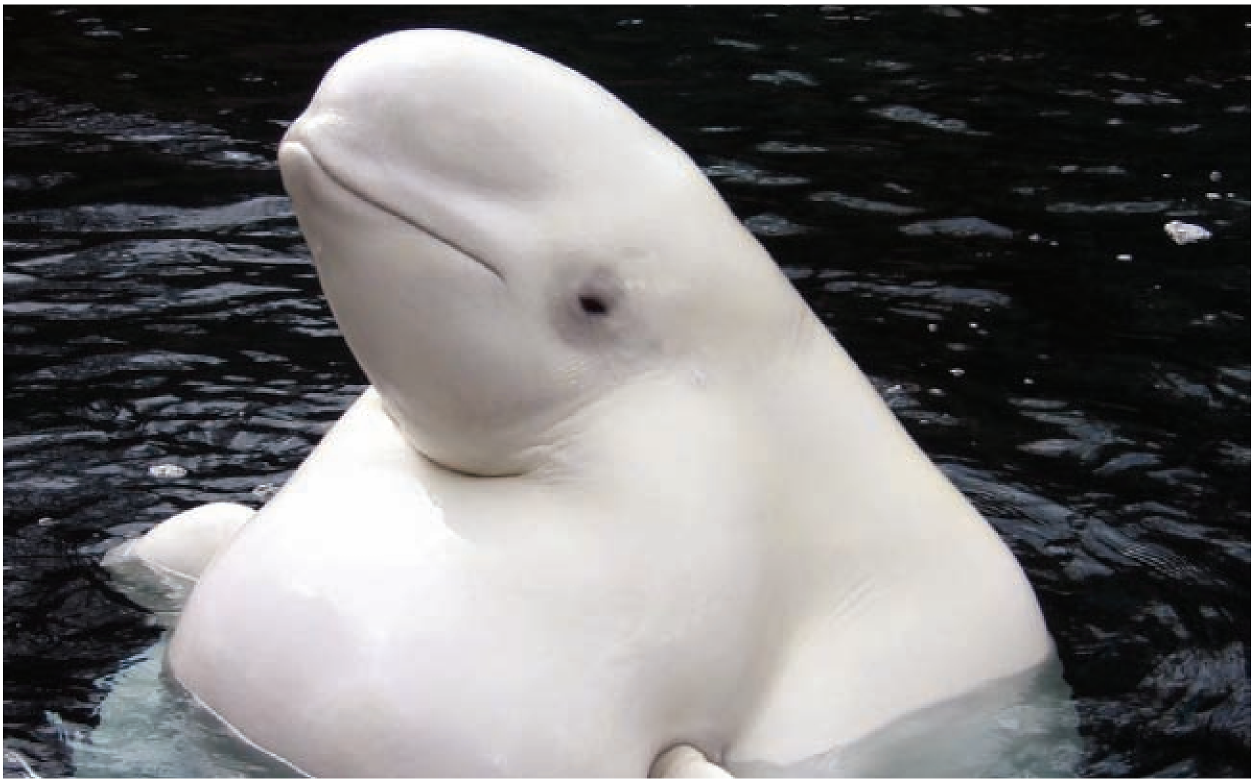
How is climate change affecting Belugas?

The most serious impacts of climate change on Belugas may not come directly from the effects of weather conditions, but rather indirectly from the role that regional warming and reduced sea ice play in changing human activities.

Extensive ice cover and extreme winter conditions (including both darkness and cold) have always limited human activities in the Arctic, and many regions have remained inaccessible to ships and other vessels. As Arctic ice cover declines and the passages between northern landmasses become more navigable, humans will gain easier access to formerly pristine areas that have long served as refuges for Belugas.

Ship strikes and noise:

The number of vessels sailing through the Arctic for gas and oil exploration/extraction, commercial shipping (for both transportation and tourism), and fishing has



© Jenny Spadafora

already increased. Further reductions in sea ice are likely to accelerate this trend in coming decades. With the increase in ship traffic, ship strikes are likely to become an increasingly significant cause of Beluga injury and death.

Belugas detect and respond to the presence of ice-breaking ships over great distances (up to 50 km). Industrial noise, for example from ships, seismic surveys and offshore drilling, likely disrupts Beluga behaviour and may impair their ability to communicate, forage efficiently and generally sense their environment. Noise-producing activities are already ongoing or planned in many areas used by large populations of Belugas, including the Beaufort and Chukchi seas, West Greenland and Hudson Bay.

Chemical pollution:

Some toxic contaminants become concentrated as they move up the food chain. Because Belugas and other cetaceans are at or near the top of the food chain and have long life spans, they accumulate relatively high concentrations of certain toxins in their blubber and other organs. These may contribute to a range of health problems in the animals themselves and are also of concern to the people who hunt Belugas for food. Industrialization and urbanization of the Arctic are bound to exacerbate the problem of pollution.

Changing prey availability:

Loss of sea ice and increased ocean temperatures will affect the distribution, composition and productivity of prey communities and in turn influence the ability of Belugas to find and catch suitable prey. Given the great uncertainties about how Arctic and sub-Arctic ecosystems function and about how Belugas will respond, it is impossible to make confident predictions of impacts.

Unreliable ice refuges:

As weather patterns become more unpredictable and extreme due to climate change, it is possible that Belugas and other Arctic whales will become more susceptible to ice entrapment. Such unfortunate events have always occurred and they are considered to contribute to natural mortality in most Beluga populations. However, it is feared that the frequency and scale of the mortality from ice entrapment will increase as the climate changes.

Competition and predation:

As Arctic waters become warmer and patterns of circulation, salinity and nutrient input change, species that previously were not present in the Arctic will be able to move further north and remain there for longer. This could have two major types of effects on Belugas. Firstly, species such as Minke and Humpback whales as well as seals and other predators may directly compete with Belugas for food resources. Secondly, species such as Killer Whales may have more opportunities to prey on Belugas. Both of these factors could negatively affect Beluga populations.

Can Belugas adapt to climate change?

Although the total number of Belugas throughout their range (well over 100,000) is fairly large, it is important to recognize that there are many fewer now than there were as recently as 100 years ago. Declines in some areas have been drastic, mainly due to overhunting but almost certainly exacerbated by habitat degradation from human activities.

Although we know very little about the ability of Belugas and other Arctic animals to adapt to changing environmental conditions, it is important to recognize that their resilience has already been compromised by the historical reductions in population sizes and ranges. Therefore, until we have evidence to the contrary, it is sensible and prudent to assume that the rapid changes associated with climate change will put their survival at ever-greater risk.

Other threats

In some parts of the species' range, particularly in Canada and Greenland, intensive hunting represents an ongoing threat to Belugas. In a few instances this is compounded by the less direct and less easily quantified threats of disturbance by vessel traffic (e.g. St. Lawrence estuary, river mouths in eastern Hudson Bay), habitat modification (e.g. large hydroelectric dams in rivers flowing into Hudson Bay and James Bay), contaminants (e.g. St. Lawrence estuary), and possibly incidental catch in fisheries (wherever entangling gear overlaps the animals' range).

Contact

Randall Reeves
Chairperson: IUCN SSC Cetacean Specialist GroupOkapi Wildlife Associates, Canada
rrreeves@okapis.ca

Beluga Whale geographical range
© IUCN Red List

"Climate change could prove to be catastrophic for Belugas (and Narwhals and Bowhead Whales) but the catastrophe could be either dramatic and rapid or very prolonged and subtle. At the same time, it is possible that some species of cetaceans, perhaps even one of these Arctic species, will adapt to some degree and persist and even flourish, at least locally or regionally."

- Randall Reeves
Chairperson: IUCN SSC Cetacean Specialist Group

© 2009 IUCN

Staghorn Coral

(2005) Atlantic *Acropora* Status Review Document. *Report to National Marine Fisheries Service, Southeast Regional Office*, 152pp+App.

Baker, A.C. *et al.* (2008) Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. *Estuarine, Coastal and Shelf Science* 80, 435-471

Buddemeier, R.W., and Fautin, D.G. (1993) Coral bleaching as an adaptive mechanism. *Bioscience* 43, 320-326

Diaz-Pulido, G. *et al.* (2009) Doom and boom on a resilient reef: climate change, algal overgrowth and coral recovery. *Public Library of Science ONE* 4, e5239

Douglas, A.E. (2003) Coral bleaching—how and why? *Marine Pollution Bulletin* 46, 385-392

Füssel, H.M. (2009) An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. *Climatic Change* 97, 1-14

Glynn, P.W. (1993) Coral reef bleaching: ecological perspectives. *Coral reefs* 12, 1-17

Goulet, T.L. (2006) Most corals may not change their symbionts. *Marine Ecology Progress Series* 321, 1-7

Goulet, T.L. (2007) Most scleractinian corals and octocorals host a single symbiotic zooxanthella clade. *Marine Ecology Progress Series* 335, 243-248

Harvell, C.D. *et al.* (2002) Climate warming and disease risks for terrestrial and marine biota. *Science* 296, 2158

Hoegh-Guldberg, O. (1999) Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50, 839-866

Hoegh-Guldberg, O. *et al.* (2007) Coral reefs under rapid climate change and ocean acidification. *Science* 318, 1737-1742

Hughes, T.P. *et al.* (2003) Climate change, human impacts, and the resilience of coral reefs. *Science* 301, 929-933

Kleypas, J.A. *et al.* (1999) Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. *Science* 284, 118-120

Sampayo, E.M. *et al.* (2008) Bleaching susceptibility and mortality of corals are determined by fine-scale differences in symbiont type. *Proceedings of the National Academy of Sciences* 105, 10444-10449

Thornhill, D.J. *et al.* (2006) Multi-year, seasonal genotypic surveys of coral-algal symbioses reveal prevalent stability or post-bleaching reversion. *Marine Biology* 148, 711-722

Wilkinson, C. (2002) *Status of coral reefs of the world: 2002*. Australian Institute of Marine Science

Willis, B.L. *et al.* (2006) The role of hybridization in the evolution of reef corals. *Annual Review of Ecology, Evolution, and Systematics* 37, 489-517

Ringed Seal

ACIA (2004) Impacts of a warming Arctic: Arctic climate impact assessment. Cambridge University Press

Bluhm, B.A., and Gradinger, R. (2008) Regional variability in food availability for arctic marine mammals. *Ecological Applications* 18, S77-S96

Born, E.W. *et al.* (2004) Habitat use of ringed seals (*Phoca hispida*) in the North Water Area (North Baffin Bay). *Arctic* 57, 129-142

Burek, K.A. *et al.* (2008) Effects of climate change on arctic marine mammal health. *Ecological Applications* 18, S126-S134

Carlens, H. *et al.* (2006) Spring haul-out behavior of ringed seals (*Pusa hispida*) in Kongsfjorden, Svalbard. *Marine Mammal Science* 22, 379-393

Ferguson, S.H. *et al.* (2005) Climate change and ringed seal (*Phoca hispida*) recruitment in western Hudson Bay. *Marine Mammal Science* 21, 121-135

Frost, K.J. *et al.* (2004) Factors affecting the observed densities of ringed seals, *Phoca hispida*, in the Alaskan Beaufort Sea, 1996-99. *Arctic* 57, 115-128

Holst, M. *et al.* (2001) Diet of ringed seals (*Phoca hispida*) on the east and west sides of the North Water Polynya, northern Baffin Bay. *Marine Mammal Science* 17, 888-908

Hovelsrud, G.K. *et al.* (2008) Marine mammal harvests and other interactions with humans. *Ecological Applications* 18, S135-S147

Kovacs, K.M. (2007) Arctic Marine Mammal Monitoring Framework workshop: Background Document for Development of a Circumpolar Ringed Seal (*Phoca hispida*) Monitoring Plan

Krafft, B.A. *et al.* (2006) Abundance of ringed seals (*Pusa hispida*) in the fjords of Spitsbergen, Svalbard, during the peak molting period. *Marine Mammal Science* 22, 394-412

Laidre, K.L. *et al.* (2008) Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. *Ecological Applications* 18, S97-S125

Lydersen, C. (1998) Status and biology of ringed seals (*Phoca hispida*) in Svalbard. *NAMMCO Science Publication* 1, 9-45

Moore, S.E., and Huntington, H.P. (2008) Arctic marine mammals and climate change: Impacts and resilience. *Ecological Applications* 18, S157-S165

Reeves, R.R. (1998) Distribution, abundance and biology of ringed seals (*Phoca hispida*): an overview. 9-45, NAMMCO Science publication

Walsh, J.E. (2008) Climate of the arctic marine environment. *Ecological Applications* 18, S3-S22

Leatherback Turtle

(1998) Recovery plan for U.S. Pacific populations of the leatherback turtle (*Dermochelys coriacea*). NMFS & USFWS (National Marine Fisheries Service & U.S. Fish and Wildlife Service)

(2009) *Dermochelys coriacea*. Department of the Environment, Water, Heritage and the Arts

(2009) Leatherback Turtles: Threats to Leatherbacks. http://www.conservation.org/learn/species/profiles/turtles/sea_turtles/leatherback/Pages/threats.aspx

Avise, J.C. *et al.* (1992) Mitochondrial DNA evolution at a turtle's pace: evidence for low genetic variability and reduced microevolutionary rate in the Testudines. *Molecular Biology and Evolution* 9, 457-473

Bindoff, N.L. *et al.* (2007) Observations: oceanic climate change and sea level. In *Climate Change 2007: The Physical Science Basis.* Cambridge University Press

Dutton, P. (2006) Building our knowledge of the leatherback stock structure. In *The State of the World's Sea Turtles Report* (Mast, R.B. *et al.*, eds), Conservation International

Fish, M.R. *et al.* (2008) Construction setback regulations and sea-level rise: Mitigating sea turtle nesting beach loss. *Ocean & Coastal Management* 51, 330-341

Hamann, M. *et al.* (2007) Vulnerability of marine reptiles in the Great Barrier Reef to climate change. In *Climate change and the Great Barrier Reef: a vulnerability assessment* (Johnson, J.E., and Marshall, P.A., eds), 465–496, Great Barrier Reef Marine Park Authority and Australia Greenhouse Office

Hawkes, L.A. *et al.* (2009) Climate change and marine turtles. *Endangered Species Research* 7, 137-154

Houghton, J.D.R. *et al.* (2007) Protracted rainfall decreases temperature within leatherback turtle (*Dermochelys coriacea*) clutches in Grenada, West Indies: Ecological implications for a species displaying temperature dependent sex determination. *Journal of Experimental Marine Biology and Ecology* 345, 71-77

Luschi, P. *et al.* (2003) Current transport of leatherback sea turtles (*Dermochelys coriacea*) in the ocean. *Proceedings of the Royal Society B* 270, S129-S132

Milton, S.L., and Lutz, P.L. (2003) Physiological and genetic responses to environmental stress. In *The biology of sea turtles* (Lutz, P.L. *et al.*, eds), CRC Press

Pike, D.A., and Stiner, J.C. (2007) Sea turtle species vary in their susceptibility to tropical cyclones. *Oecologia* 153, 471-478

Rabon Jr, D.R. *et al.* (2003) Confirmed leatherback turtle (*Dermochelys coriacea*) nests from North Carolina, with a summary of leatherback nesting activities north of Florida. *Marine Turtle Newsletter* 101, 4-8

Sarti Martinez, A.L. (2000) *Dermochelys coriacea*. In *IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2*, <www.iucnredlist.org>

Shillinger, G.L. *et al.* (2008) Persistent leatherback turtle migrations present opportunities for conservation. *Public Library of Science Biology* 6

Solomon, S. *et al.* (2007) *Climate Change 2007: the Physical Science Basis*. Cambridge University Press, Cambridge

WWF (2009) Leatherback turtle - Population & Distribution. In *Marine Turtles*, World Wide Fund for Nature, http://www.panda.org/what_we_do/endangered_species/marine_turtles/leatherback_turtle/lbturtle_population_distribution/

Emperor Penguin

Ainley, D. *et al.* (2008) The fate of Antarctic penguins when Earth's tropospheric temperature reaches 2°C above pre-industrial levels. WWF

Barbraud, C., and Weimerskirch, H. (2001) Emperor penguins and climate change. *Nature* 411, 183-186

Burns, J.M., and Kooyman, G.L. (2001) Habitat use by Weddell seals and Emperor penguins foraging in the Ross Sea, Antarctica. *Integrative and Comparative Biology* 41, 90

Clair, C.C.S., and Boyce, M.S. (2009) Icy insights from emperor penguins. *Proceedings of the National Academy of Sciences* 106, 1691-1692

Cook, A.J. *et al.* (2005) Retreating glacier fronts on the Antarctic Peninsula over the past half-century. *Science* 308, 541

Croxall, J.P., and Davis, L.S. (1999) Penguins: paradoxes and patterns. *Marine Ornithology* 27, 1-12

Croxall, J.P. *et al.* (2002) Environmental change and Antarctic seabird populations. *Science* 297, 1510

Forcada, J., and Trathan, P.N. (2009) Penguin responses to climate change in the Southern Ocean. *Global Change Biology* 15, 1618-1630

Fretwell, P.T., and Trathan, P.N. (2009) Penguins from space: faecal stains reveal the location of emperor penguin colonies. *Global Ecology and Biogeography* 18, 543-552

Jenouvrier, S. *et al.* (2005) Long-term contrasted responses to climate of two Antarctic seabird species. *Ecology* 86, 2889-2903

Jenouvrier, S. *et al.* (2009) Demographic models and IPCC climate projections predict the decline of an emperor penguin population. *Proceedings of the National Academy of Sciences,* 106, 1844

Kooyman, G.L. (2002) Evolutionary and ecological aspects of some Antarctic and sub-Antarctic penguin distributions. *Oecologia* 130, 485-495

Kooyman, G.L. *et al.* (2000) Moult of the emperor penguin: travel, location, and habitat selection. *Marine Ecology Progress Series* 204, 269-277

Lemaho, Y. (1977) The emperor penguin: a strategy to live and breed in the cold. *American Scientist* 65, 680-693

Robertson, G. *et al.* (1994) Diet composition of Emperor Penguin chicks *Aptenodytes forsteri* at two Mawson Coast colonies, Antarctica. *Ibis* 136, 19-31

St Clair, C.C., and Boyce, M.S. (2009) Icy insights from emperor penguins. *Proceedings of the National Academy of Sciences* 106, 1691

Tamburrini, M. *et al.* (1994) Adaptation to extreme environments: structure-function relationships in Emperor penguin haemoglobin. *Journal of Molecular Biology* 237, 615-621

Wienecke, B. *et al.* (2007) Extreme dives by free-ranging emperor penguins. *Polar Biology* 30, 133-142

Williams, T.D., and Wilson, R.P. (1995) *The Penguins: Spheniscidae.* Oxford University Press

Quiver Tree

Davis, M.B., and Shaw, R.G. (2001) Range shifts and adaptive responses to Quaternary climate change. *Science* 292, 673-678

Foden, W. *et al.* (2007) A changing climate is eroding the geographical range of the Namib Desert tree Aloe through population declines and dispersal lags. *Diversity and Distributions* 13, 645-653

Hulme, M. *et al.* (2001) African climate change: 1900-2100. *Climate Research* 17, 145-168

McCarthy, J.J. (2001) *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge

Midgley, G.F. *et al.* (2009) Are Quiver Trees a Sentinel for Climate Change in Southern Africa? , SANBI (South African National Biodiversity Institute)

Midgley, J.J. *et al.* (1997) Population ecology of tree succulents (Aloe and Pachypodium) in the arid western Cape: decline of keystone species. *Biodiversity and Conservation* 6, 869-876

Reynolds, T. (2004) *Aloes: the genus Aloe Medicinal and Aromatic Plants–Industrial Profiles.* CRC Press

Uys, N. *et al.* (2009) The status of *Aloe dichotoma* subsp. *dichotoma* (quiver tree) populations in Goegap Nature Reserve. *South African Journal of Botany* 75

van Wyk, P. (2001) *A Photographic Guide to the Trees of Southern Africa*. Struik Publishers

Clownfish

Arvedlund, M. (2009) First records of unusual marine fish distributions—can they predict climate changes? *Journal of Marine Biological Association of the UK* 89, 863-866

Arvedlund, M. *et al.* (2001) The embryonic development of the olfactory system in *Amphiprion melanopus* (Perciformes: Pomacentridae) related to the host imprinting hypothesis.

Journal of Marine Biological Association of the UK 80, 1103-1109

Arvedlund, M., and Takemura, A. (2005) Long-term observation in situ of the anemonefish *Amphiprion clarkii* (Bennett) in association with a soft coral. *Coral Reefs* 24, 698-698

Dixson, D.L. *et al.* (2008) Coral reef fish smell leaves to find island homes. *Proceedings of the Royal Society B* 275, 2831

Fautin, D.G., and Allen, G.R. (1992) *Field guide to anemonefishes and their host sea anemones.* Western Australian Museum

Frisch, A.J., and Hobbs, J.P.A. (2009) Rapid assessment of anemone and anemonefish populations at the Keppel Islands [electronic resource]: a report to the Great Barrier Reef Marine Park Authority. Great Barrier Reef Marine Park Authority

Jones, G.P. *et al.* (2005) Coral reef fish larvae settle close to home. *Current Biology* 15, 1314-1318

Munday, P.L. *et al.* (2009) Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. *Proceedings of the National Academy of Sciences* 106, 1848

Munday, P.L. *et al.* (2008) Climate change and the future for coral reef fishes. *Fish and Fisheries* 9, 261-285

Munday, P.L. *et al.* (2007) Vulnerability of fishes of the Great Barrier Reef to climate change. In *Climate Change and the Great Barrier Reef*, (Johnson, J.E., and Marshall, P.A., eds), 357–391, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia

Munday, P.L. *et al.* (2009) Climate change and coral reef connectivity. *Coral Reefs* 28, 379-395

Ochi, H. (1986) Growth of the anemonefish *Amphiprion clarkii* in temperate waters, with special reference to the influence of settling time on the growth of 0-year olds. *Marine Biology* 92, 223-229

Patzner, R.A. (2008) Ecological Studies on Two Amphiprion Species in Maldivian Coral Reefs. *The Open Fish Science Journal* 1, 8-10

Wellington, G.M., and Victor, B.C. (1989) Planktonic larval duration of one hundred species of Pacific and Atlantic damselfishes (Pomacentridae). *Marine Biology* 101, 557-567

Arctic Fox

Angerbjörn, A. (2008) *Alopex lagopus*. In *IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2*, <www.iucnredlist.org>

Fuglei, E., and Ims, R.A. (2008) Global warming and effects on the arctic fox. *Science Progress* 91, 175-191

Owen, J. (2007) 'Arctic fox may be left behind by warming, study suggests.' http://news.nationalgeographic.com/news/2007/04/070409-arctic-foxes_2.html.

Roth, J.D. (2002) Temporal variability in arctic fox diet as reflected in stable-carbon isotopes; the importance of sea ice. *Oecologia* 133, 70-77

Sillero-Zubiri, C. *et al.* (2004) *Canids: foxes, wolves, jackals, and dogs: status survey and conservation action plan*. World Conservation Union, IUCN/SSC Canid Specialist Group

Symon, C. *et al.* (2005) *Arctic climate impact assessment*. Cambridge University Press

WWF (2008) Climate change likely culprit as Arctic fox faces extinction. http://www.panda.org/what_we_do/where_we_work/arctic/news/?147581/Climate-change-likely-culprit-as-arctic-fox-faces-extinction, accessed on 10 November 2009

Salmon

(2007) 'This year's harvest was the 4th largest since statehood'. ADF&G (Alaska Department of Fish and Game) Press release: no. 07-27, November 7, http://www.adfg.state.ak.us/news/2007/11-7-07_nr.php

(2009) Water Quality in Salmon Spawning Gravels. Technical document. Fisheries Research Services, Freshwater Laboratory, Pitlochry, Perthshire, UK, http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/FW17Gravels.pdf

Anderson, D.M., and Scott, M.J. (1993) Valuing the salmon resource: Columbia River stocks under climate change and fishery enhancement. In *27th Annual Pacific Northwest Regional Economic Conference*, 83-88, http://economic-analysis.pnl.gov/pubs/proceedings/ValuSalmonResource.pdf

Augerot, X. *et al.* (2005) *Atlas of Pacific salmon: the first map-based status assessment of salmon in the north Pacific*. University of California Press

Babaluk, J.A. *et al.* (2000) First records of sockeye (*Oncorhynchus nerka*) and pink salmon (*O. gorbuscha*) from Banks Island and other records of Pacific salmon in Northwest Territories, Canada. *Arctic* 53, 161-164

Battin, J. *et al.* (2007) Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences* 104, 6720

Beacham, T.D., and Murray, C.B. (1990) Temperature, Egg Size, and Development of Embryos and Alevins of Five Species of Pacific Salmon: A Comparative Analysis. *Transactions of the American Fisheries Society* 119, 927-945

Ben-David, M. *et al.* (1998) Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. *Oikos* 83, 47-55

Bradford, M.J., and Irvine, J.R. (2000) Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 57, 13-16

Cederholm, C.J. *et al.* (2001) Pacific Salmon and Wildlife-Ecological Contexts, Relationships, and Implications for Management (Special Edition Technical Report). In *Wildlife-Habitat Relationships in Oregon and Washington*, Washington Dept. Fish and Wildlife, Olympia, WA, 138 pp

Crozier, L.G. *et al.* (2008) Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications* 1, 252-270

Crozier, L.G. *et al.* (2008) Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Global Change Biology* 14, 236-249

Groot, C., and Margolis, L. (1991) *Pacific salmon life histories*. University of British Columbia Press, Vancouver

Irvine, J.R. (2004) Climate Change, Adaptation, and 'Endangered' Salmon in Canada. In *Species at Risk 2004 Pathways to Recovery Conference* (Hooper, T.D., ed), Pathways to Recovery Conference Organizing Committee, Victoria, B.C.

Irvine, J.R. *et al.* (in press) Salmon in the Arctic and how they avoid lethal low temperatures. *NPAFC Bulletin* 5

Lisle, T.E. (1989) Sediment transport and resulting deposition in spawning gravels, north coastal California. *Water Resources Research* 25, 1303-1319

Mantua, N. *et al.* (2009) Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. Washington. In *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*, Climate Impacts Group, University of Washington, Seattle, Washington

Mantua, N.J. (2005) Impacts of Climate Change on Washington Resources. 23, Climate Impacts Group, Center for Science in the Earth System Joint Institute for the Study of the Atmosphere and Oceans. University of Washington.

Marine, K.R., and Cech Jr, J.J. (2004) Effects of High Water Temperature on Growth, Smoltification, and Predator Avoidance in Juvenile Sacramento RiverChinook Salmon. *North American Journal of Fisheries Management* 24, 198-210

McCullough, D.A. (1999) A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. 279, USEPA

Mote, P.W. *et al.* (2003) Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61, 45-88

Patz, J.A. *et al.* (2000) The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment. *Environmental Health Perspectives* 108, 367

Rand, P.S. *et al.* (2006) Effects of river discharge, temperature, and future climates on energetics and mortality of adult migrating Fraser River sockeye salmon. *Transactions of the American Fisheries Society* 135, 655-667

WWF (2001) The status of wild Atlantic salmon: a river by river assessment. World Wildlife Fund – European Freshwater Programme, Copenhagen, Denmark

Koala

(2009) Draft National Koala Conservation and Management Strategy 2009-2014 – Consultation Draft 6 June 2009. 34

(2009) The IUCN World Commission on Protected Areas (WCPA) Oceania; Australia, New Zealand, Pacific Islands and PNG. *IUCN - WCPA Newsletter* 3

DeGabriel, J.L. *et al.* (2009) The effects of plant defensive chemistry on nutrient availability predict reproductive success in a mammal. *Ecology* 90, 711-719

Gordon, G. *et al.* (2008) *Phascolarctos cinereus*. In *IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2*, <www.iucnredlist.org>

Lawler, I.R. *et al.* (1996) The effects of elevated CO_2 atmospheres on the nutritional quality of *Eucalyptus* foliage and its interaction with soil nutrient and light availability. *Oecologia* 109, 59-68

Moore, B.D., and Foley, W.J. (2000) A review of feeding and diet selection in koalas (*Phascolarctos cinereus*). *Australian Journal of Zoology* 48, 317-333

Moore, B.D., and Foley, W.J. (2005) Tree use by koalas in a chemically complex landscape. *Nature* 435, 488-490

Moore, B.D. *et al.* (2005) A simple understanding of complex chemistry explains feeding preferences of koalas. *Biology Letters* 1, 64-67

Beluga Whale

ACIA (2004) Impacts of a warming Arctic: Arctic climate impact assessment., Cambridge University Press

Bluhm, B.A., and Gradinger, R. (2008) Regional variability in food availability for arctic marine mammals. *Ecological Applications* 18, S77-S96

Brodie, P.F. (1989) The white whale *Delphinapterus leucas* (Pallas, 1776). In *Handbook of marine mammals* (Ridgway, S.H., and Harrison, R.J., eds), 119-144, Academic Press, London

Caron, L., and Smith, T.G. (1990) Philopatry and size tenacity of belugas, *Delphinapterus leucas*, hunted by the Innuit at the Nastapoka estuary, eastern Hudson Bay. *Canadian Journal of Fisheries and Aquatic Sciences* 224, 69-79

Erbe, C., and Farmer, D.M. (2000) A software model to estimate zones of impact on marine mammals around anthropogenic noise. *Journal of the Acoustic Society of America* 108, 1327 - 1331

Fordyce, R.E. (2009) Fossil Sites, Noted. In *Encyclopedia of Marine Mammals* (Perrin, W.F. *et al.*, eds), 459-466, Academic Press, San Diego, USA

Harington, C.R. (2008) The evolution of Arctic marine mammals. *Ecological Applications* 18, S23-S40

Hovelsrud, G.K. *et al.* (2008) Marine mammal harvests and other interactions with humans. *Ecological Applications* 18, S135-S147

Jefferson, T.A. *et al.* (2008) *Delphinapterus leucas*. In *IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2*, <www.iucnredlist.org>

Kuiken, T. *et al.* (2006) The 2000 Canine Distemper Epidemic in Caspian Seals (*Phoca caspica*): Pathology and Analysis of Contributory Factors. *Veterinary Pathology* 43, 321-338

Laidre, K.L., and Heide-Jørgensen, M.P. (2005) Arctic sea ice trends and narwhal vulnerability. *Biological Conservation* 121, 509-517

Laidre, K.L. *et al.* (2007) Background Document for Development of a Circumpolar Beluga (*Delphinapterus leucas*) Monitoring Plan. (http://arcticportal.org/)

Laidre, K.L. *et al.* (2008) Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. *Ecological Applications* 18, S97-S125

Lowry, L.F. *et al.* (2006) *Delphinapterus leucas* (Cook Inlet population). In *2006 IUCN Red List of Threatened Species*, IUCN

Luque, S.P., and Ferguson, S.H. (2009) Ecosystem regime shifts have not affected growth and survivorship of eastern Beaufort Sea belugas. *Oecologia* 160, 367-378

O'Corry-Crowe, G.M. *et al.* (2002) Molecular genetic studies of population structure and movement patterns in a migratory species: the beluga whale, *Delphinapterus leucas,* in the western Nearctic. In *Molecular and cell biology of marine mammals* (Pfeiffer, C.J., ed), Krieger, Malabar

Reeves, R.R. *et al.* (2003) *Dolphins, Whales and Porpoises: 2002–2010 Conservation Action Plan for the World's Cetaceans*. IUCN/SSC Cetacean Specialist Group

Simmonds, M.P., and Eliott, W.J. (2009) Climate change and cetaceans: concerns and recent developments. *Journal of the Marine Biological Association of the United Kingdom* 89, 203-210

Simmonds, M.P., and Isaac, S.J. (2007) The impacts of climate change on marine mammals: early signs of significant problems. *Oryx* 41, 19-26

Smetacek, V., and Nicol, S. (2005) Polar ocean ecosystems in a changing world. *Nature* 437, 362-368

Thomas, C.D. *et al.* (2004) Extinction risk from climate change. *Nature* 427, 145-148

Wolkers, H. *et al.* (2006) Accumulation, metabolism, and food-chain transfer of chlorinated and brominated contaminants in subadult white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) from Svalbard, Norway. *Archives of Environmental Contamination and Toxicology* 50, 69-78