Appendix 2 - Impacts of pressures on seabirds

Introduction

There are five main pressures, as listed in the Millennium Ecosystem Assessment (www.maweb.org): habitat change, climate change, invasive species, over-exploitation, pollution. For each of these pressures, JNCC, as part of strategy development, identified a series of human activities through which each of the pressures acts (e.g. a fishery is a human activity that causes over-exploitation). The potential or proven impacts to seabirds of each human activity identified by JNCC as creating each of the five MEA pressures are described in Table A2.1.

Using current knowledge in the literature, each human activity was scored on the magnitude of its impact (proven or suspected) on each seabird species, as follows (Table A2.2): 0 = proven or suspected to be absent or negligible; 1 = proven or suspected low impact; 2 = proven or suspected substantial impact. The presence of an impact (i.e. score of 1 or 2) was assessed in terms of whether or not the human activity would have a measurable effect at a regional or UK scale on the population of a particular species of seabird breeding in the UK. The activity that leads to the pressure need not necessarily originate in the UK or in UK waters, as long as the impacts are potentially detectable in UK breeding populations by the SMP. Hence the aim of the scoring was to determine which species should be monitored in order to monitor the impacts of certain pressures. In Table 4 of the main text we have used this scoring to indicate which pressures have a proven or suspected substantial impact on each of the species.

The impact scoring for each species in Table A2.2 reveals that those pressures and activities that have a substantial impact on seabirds breeding in the UK are:

- exploitation by fisheries, harvesting and illegal killing;
- habitat transformation by agriculture, energy production and recreation and tourism;
- pollution from waste disposal and industrial discharge;
- climate change through ecosystem simplification;
- unintentional or intentional movement of invasive alien species between ecosystems.

Our assessment is based on interpretative knowledge to date, which in the case of some pressures and activities is far less than conclusive. In the following sections we take each of the substantial impacts in turn and review the existing evidence and suggest how they could be monitored effectively.

Overexploitation by fisheries

There are three ways in which fisheries have impacted negatively on seabirds: a) by competing for seabird prey species e.g. lesser sandeel; b) by reducing the amount of food provided to seabirds through discards and offal discharge; c) by accidentally catching and killing seabirds in fishing gear.

It is extremely difficult to prove a link between fish stock reductions caused by fisheries and changes within populations of seabirds. To date, the strongest evidence for direct competition between seabirds and fisheries is from the Isle of May where the presence of the sandeel fishery over the Wee Bankie during 1990-99, was significantly associated with low breeding success of black-legged kittiwakes there (Frederiksen *et al.* 2004). Since 2000, a precautionary ban was imposed on sandeel fishing over the Wee Bankie (as part of an area from northeast Scotland to Northumberland) and kittiwake breeding success on the Isle of May showed some signs of improvement, up until 2004 when breeding success was poor (Harris *et al.* 2005). Most of the sandeel fishing elsewhere in the North Sea occurs beyond the foraging range of seabirds in UK colonies, apart from around Shetland. A precautionary ban was imposed on the Shetland fishery in 1990-95 and subsequent catches were limited to low levels, with a voluntary ban around south Shetland in 2004.

Sandeels are an important food source for other species of seabird breeding in the UK, particularly along the North Sea coast. But despite the bans or low-levels of fishing around Shetland and over the Wee Bankie, and the fact that west coast colonies appear more reliant on sprats and herring than sandeels, there have been recent breeding failures at UK colonies amongst those species that feed on small fish. The poorest breeding seasons since annual monitoring began in 1986 occurred in Orkney, Shetland and the North Sea coast of Britain in 2004 (Mavor et al. 2005) and in NW Scotland in 2005 and 2006 (Mavor et al. 2006, 2007). During all instances, birds were struggling to find enough food to feed their chicks.

Fishing is clearly not the sole constraint on the breeding success of these species. Indeed, Frederiksen *et al.*(2004) also found that in addition to the impact of the Wee Bankie fishery, the productivity and over-winter survival of adult Black-legged kittiwakes breeding on the Isle of May was strongly correlated with SST. They suggested that warming of the North Sea as a result of global climate change was affecting sandeel productivity, which in turn was reducing the food available to kittiwakes (see below). It is also likely that ocean acidification resulting from CO_2 emissions will cause changes to lower trophic levels of the marine ecosystem that will detrimentally impact on seabirds (see below for more detail).

It appears that the impacts of fishing for sandeels in the North Sea would exacerbate the effects of climate change already impacting significantly on seabirds, and future impacts of ocean acidification. Frederiksen *et al.* (2004) predicted that if SST in the North Sea continued to increase in the future and the Wee Bankie sandeel fishery resumed, the kittiwake population on the Isle of May (and perhaps other nearby colonies) would enter into a *"catastrophic decline*".

Detection of any impacts on seabirds of sandeel fishing in the North Sea would rely on effective monitoring to assess the impact of climate change-induced impacts before the additive effects of fishing and ocean acidification could be detected. Hence those species that feed on small fish including sandeels that may potentially compete with fisheries could be effective indicators of impacts from fisheries, climate change and ocean acidfification: European shag, Arctic skua, black-legged kittiwake, Arctic tern , common guillemot, razorbill and Atlantic puffin. Great cormorants and red-throated divers also feed on sandeels, so may suffer substantial impacts from fisheries (Table A2.2), but they also feed on a wider range of species and size of fish that the other species listed above and therefore may be a less clear indicator of fisheries impacts.

Arctic Terns and Black-legged Kittiwakes feed on sandeels just below the surface, while Arctic skuas steal sandeels from them and other species including auks and are dependant on the ability of these species to find food. Hence, arctic skuas tend to suffer poor breeding success in the same years as their hosts. Guillemots, razorbills, puffins and European shags can all reach food much deeper below the surface by pursuit diving and so tend to have a greater ability to obtain enough food to raise chicks even when fish stocks are low. However, diving species are by no means immune to the effects of food shortages. For instance, on the Isle of May, Firth of Forth, the breeding success of European Shags has been positively correlated with the size of the local sandeel stock (Rindorf *et al.,* 2000) and in 2004 and 2005, food shortages caused the worst breeding seasons on record for colonies guillemots and razorbills on the east and west coasts of Scotland respectively (Mavor *et al.* 2005, 2006).

Commercial fisheries do not always compete with seabirds over fish, and indeed fishing trawlers can be an important source of food for some species. Tasker & Furness (1996) estimated that in the North Sea, seabirds consume annually 100,000 tonnes of discards and 70,000 tonnes of offal, produced mainly by the demersal whitefish fishery (i.e. Haddock and Whiting). However, over the last 30 years there has been a general decline in commercial fishing around the UK, leading to lower quantities of offal and discards. Current and future fisheries management practices (i.e. increased mesh sizes, square meshed panels in trawl nets) will result in fewer discards, particularly of small fish. This is likely to impact most on smaller species of scavenging seabirds – northern fulmars, Great Skuas, Herring Gulls and Lesser Black-backed Gulls; but will have less of an effect on larger species such as Northern Gannet and Great Black-backed Gulls that can handle larger fish (Reeves & Furness, 2002). At some colonies, Great Skuas have taken to predating on other seabirds and the proportion of seabirds in their diet is higher in years when fewer discards are produced by the North Sea whitefish fishery and when sandeel stocks are low (another favoured prey of the Great Skua) (Votier *et al.,* 2004). The numbers of seabirds taken by Great Skuas can be considerable at some colonies (Phillips *et al.* 1999), and they are having a significant impact on some populations of Arctic Skuas, Black-legged Kittiwakes and Leach's Storm-petrel (Mitchell *et al.,* 2004). Furthermore, if both discards and sandeel stocks decrease in the future, as seems likely (see above), the impact of Great Skua predation on the populations of other species will increase, particularly on those already struggling to find food.

In order to detect the effects of fluctuations in food availability resulting from both fisheries and climate change we recommend that the following parameters be monitored, preferably annually in order to build up a detailed picture of how variation in fishing effort and climate variability relate to variation in seabird demography:

i. breeding numbers – if these are monitored regularly at individual colonies, as well as at a UK scale, they can be used to detect non-breeding events or reductions in attendance both caused by adults being in poor condition by the start of breeding in spring.

ii. Breeding success – the highest daily food requirements by seabirds is during chick rearing, so that any limitations in the availability during this time will be reflected in the level of breeding success.

iii. Survival – reductions in food supply over winter may cause lowered survival of adults and immatures.

iv. Diet – observations of prey species and chick provisioning rates can be used to indicate whether food availability is limited and identify the prey species that may be in short supply. More detailed analysis of prey specimens such as size or energy content may reveal changes in prey quality that may also limit chick growth rates and fledging success despite normal rates of provisioning (Wanless *et al.,* 2005).

v. Phenology – timing of breeding may be an important determinant of subsequent breeding success given that mismatches between spawning in prey species and hatching of chicks can lead to breeding failures.

The effects of food availability will be evident on a local, regional and national scale, with the effects of fishing policy on discards and offal likely to impact and be detected at a much larger scale than the effects on those species that catch living prey. Seabirds rely on different prey depending on local availability e.g. colonies in north-west Scotland feed on a higher percentage of sprat than colonies in eastern Scotland, which feed mostly on sandeels (Swann *et al.* 2005, Harris *et al.* 2005). Furthermore, Sandeel distribution in UK waters is patchy, with distinct spawning aggregations resulting from the availability of sandy sediments, and the fact that adult sandeels are relatively sedentary, showing only limited movements between areas (Proctor *et al.,* 1998, Pedersen *et al.,* 1999, Wright *et al.,* 2000). The varying fortunes of these distinct sandeel stocks may have led to the observed geographical variation in breeding success of black-legged kittiwakes (Frederiksen *et al.* 2006) and perhaps other species that rely on sandeels.

Northern fulmars appear to be most susceptible to becoming accidentally caught in fishing nets and on baited hooks on long-lines. The scale of the impact on the UK fulmar population is not known, but could be substantial given that Dunn & Steel (2001) estimated that the Norwegian offshore long-line fleet accidentally caught 20,000 Northern Fulmars in 1997-98 and further studies, involving the monitoring of survival of birds from UK colonies will be required to fully assess the extent of this bycatch across the fleets from Iceland and the Faeroes. Auks can be caught in considerable numbers in fixed salmon nets set close to cliffs and the resulting mortality has led to localised declines in breeding numbers in the past. Extensions to SPAs in the future will help to keep such mortality to minimum. Other species caught in nets include , European shags, great cormorants and red-throated divers.

Over-exploitation by harvesting and illegal killing

Seabird populations in the UK have increased in size over the last century as a direct result of increased protection from hunting and persecution in the UK and overseas.

In the UK largely takes the form of licensed lethal and non-lethal control of fish-eating bird species (i.e. great cormorant) and ‘pest’ species (i.e. herring, lesser black-backed and great black-backed gulls) and occasionally other species (i.e. common gull, Arctic skua, great skua). Licences may be issued by Defra under section 16(1) of the Wildlife and Countryside Act 1981 to kill or take wild birds, or to take, damage or destroy their nests and/or eggs for the purposes of: (i) preventing the spread of disease; (ii) preventing serious damage to livestock, foodstuffs for livestock, crops, vegetables, fruit, growing timber, fisheries or inland waters; (iii) preserving public health or public safety (including air safety); (iv) conserving wild birds; and (v) preventing serious damage to fisheries or inland waters.

During the 1970's and 1980s large colonies of herring and lesser black-backed gulls were partially culled to reduce impacts to public health and to conserve other seabird colonies e.g. terns. Some colonies were extirpated completely. However the number of gulls culled has reduced since the 1980s and there has been a greater use of non-lethal means to control gulls, particularly in urban areas.

Up until September 2004, around 300 great cormorants were shot annually in England under licence. Since then, new licensing procedures have been adopted by Defra that would allow the number of cormorants shot to rise to 2,000 per year and periodically up to 3,000 (http://www.defra.gov.uk/wildlife-countryside/vertebrates/piscivorous.htm). The aim of the new quota is to reduce the wintering population of an estimated 17-23,000 birds by 20% by 2010 and by no more than 40% in the longer term.

However, the population model used to set the quotas (http://www.defra.gov.uk/wildlife-countryside/vertebrates/reports/cormorant-removal.pdf) does not allow any assessment of the effect of the cull on the breeding populations that 'supply' the wintering birds in England. The UK breeding population holds around 13% of the sub-species *Phalacrocorax carbo carbo* and a few of the continental sub-speceies *P.c.sinensis* (Sellers 2004). The wintering population is bolstered by *sinensis* cormorants from mainland Europe. The cull will make no distinction race or age, and there are no plans to record these statistics in the birds that are shot. Therefore it is impossible to predict exactly what effect the cull will have on the UK breeding population. Furthermore the cull, which runs from 31 August until 15 April (or until 1 May in places where there is a salmon smolt run), overlaps considerably with the start of the breeding season, particularly on the south coast of England where cormorants start laying as early as February. Therefore it is important that the monitoring of cormorant colony size and breeding success is continued throughout the UK in order to detect any impact of the cull on the breeding population.

In addition to licensed culling of cormorants some may also be killed illegally. It remains to be seen if the new, more 'user friendly' licensing rules will reduce this number.

Other than licensed management practices, the only licensed harvesting of seabirds for food in the UK is the annual collection of 10,000 eggs from the black-headed gull colony at Bemersyde Moss in the Scottish Borders and the traditional annual 'guga' hunt of 2,000 gannet chicks on Sula Sgeir, where breeding numbers have declined in contrast to most other colonies that have been increasing in size for many years (Wanless *et al.* 2005).

Hunting outside the UK may impact on the number of some migratory species breeding in Britain. Most notably, trapping of Sandwich and roseate terns in west Africa during the 1980s and early 1990s resulted in significant declines in the numbers breeding in the UK, but conservation action has resulted in substantial declines in this practice (Newton, 2004, Ratcliffe, 2004a).

Habitat-transformation

The human activities that are likely to transform habitats and, in turn, impact substantially on seabirds are **agriculture** (black-headed gulls, common gulls), **renewable energy production** (red-throated divers) and **recreation and tourism** (red-throated divers, little terns).

Since the early 1970s, the number of black-headed gulls breeding in England and Wales has declined by 20%, but the area they occupy has declined by 60% (Dunn 2004). It appears that the area of suitable nesting habitat has shrunk considerably and more birds are now compressed into a much smaller area, tending to move away from inland colonies to a smaller number of larger colonies on coastal marshes. In Scotland and Northern Ireland, a similar shrinkage in distribution has occurred, but in Scotland, numbers breeding on the coast appear to have decreased while numbers breeding inland have increased. While predation from alien species may have been responsible for their disappearance in some areas it seems likely that the major changes in **agricultural** management and intensification of farming practices, that have caused major declines in other farmland bird species (Chamberlain *et al.* 2000), have also had an important impact. A decline in invertebrate prey through increased pesticide use and from a decrease in spring tillage may have made some areas effectively unsuitable for breeding black-headed gulls.

Common gulls breeding in the UK are restricted mainly to Scotland where their distribution has decreased by 40% since the early 1970s, but numbers breeding on the coast have apparently increased by 67% while the number breeding inland (where the majority nest) have probably decreased substantially (Tasker 2004).

Both black-headed and common gull species may be potential indicators of agricultural land-use changes. However, there is already a UK Farmland Bird Indicator that uses trends in population size of 19 species, but does not include common gull or black-headed gull (http://www.defra.gov.uk/environment/statistics/wildlife/kf/wdkf03.htm). The Indicator is tied in with UK Government's Public Service Agreement on Farmland Bird: "Care for our living heritage and preserve natural diversity by reversing the long-term decline in the number of farmland birds by 2020, as measured annually against underlying trends". Success in meeting this target is measured using the Farmland Bird Indicator. The question remains as to whether the Farmland Bird Indicator would be strengthened significantly by the inclusion of one or both gull species. However, a much firmer link between population size and agricultural practices needs to be determined before their inclusion should be considered.

The development of **renewable energy** sources, including onshore and offshore wind farms and other offshore projects such as wave and tidal, will have impacts on seabirds. For instance, offshore wind farms displace feeding seabirds, as a result of the movement of the turbines and boat based maintenance activities. Red-throated divers appear most susceptible to such disturbance and offshore wind turbines have been demonstrated to displace about 96% of Red-throated divers from their development footprint and adjacent waters up to 2-4km away from the turbines (Petersen *et al.* 2004, Petersen 2005). The extent of the displacement will depend on the size of the wind farm and where it is placed in relation to seabird feeding grounds. The locations of proposed and consented offshore wind farms are concentrated around the UK's major estuaries and within a few kilometres of the shore (http://www.thecrownestate.co.uk/34_round_1and2_project_map2.pdf), so will mostly affect inshore feeding species e.g. divers, shags, terns and gulls. The SMP has a potential role to play in predicting during the breeding season where the greatest impacts from renewable energy schemes are likely to occur as birds move between feeding and breeding sites. For instance onshore wind farms proposed on Shetland may disrupt the flight paths of gulls, skuas, arctic terns and red-throated divers heading from inland breeding sites to coastal feeding areas. However, impacts that occur during the non-breeding season may be difficult to link to any changes that might occur at colonies during the breeding season as a result. A substantial impact from offshore wind farms is likely to be felt by red-throated divers outside the breeding season, since their wintering distribution around the UK (O'Brien *et al.* in prep.) overlaps considerably with areas of proposed and consented and wind farm placement.

Recreation and tourism has the potential to impact on some seabird species, largely through disturbance to nesting sites or disturbance to feeding birds by recreational boat traffic. Little terns are particularly susceptible to disturbance from people as they nest on beaches used for recreation. Local conservation efforts such as fencing-in colonies and putting up warning signs have greatly reduced the impact. Red-throated divers that nest beside small lochans are also potentially susceptible to disturbance from walkers and also from boat users in nearby bays where they forage for food for their chicks. The role of the SMP is to put any localised impacts of recreation and tourism on little tern colonies and red-throated diver populations into a wider UK context and thereby help prioritise locally based mitigation measures.

Other activities that cause habitat transformation that may have an impact on UK seabirds are **aquaculture, forestry, transport infrastructure, urban and industrial development, water management and aggregate/mineral/peat extraction** (see Table A2.1). However none of these were considered to have a substantial impact.

Pollution

Of those human activities that have been identified in Table A2.2 as having a potential substantial impact on seabirds, pollution from **industrial discharge** (i.e. chemical or oil based effluent or leakages from land-based or offshore installations) and **transport derived from fossil fuels** (e.g. oil spills from fuel tanks of ships or large scale spills of petro-chemical cargoes at sea).

It is extremely difficult to predict the impact on seabirds from industrial discharge and transport derived form fossil fuels due to the stochastic nature of the resulting pollution events. Pollution from both activities causes surface pollution that will kill seabirds that become significantly contaminated. The scale of mortality resulting from such events will be highly dependant on the time of year at which the discharge occurs, since this will determine the number, age and species of the birds present in the area affected.

Mortality following an industrial discharge from land will probably be confined to species that predominantly feed and loaf close to the shore (see Table A2.2) and will probably be better contained and confined to a smaller area than discharges from offshore installation and from ships out at sea. For spills occurring a considerable distance offshore, the area of dispersal of the pollutant is often very large and can potentially affect all of the UK's breeding seabird species to some degree. The SMP has already proved useful in detecting the effects of oil spills that have occurred during its history. It has demonstrated the usefulness of good baseline data from which post-spill effects can be detected. In all of the oil spill disasters that have occurred during the SMP, guillemots and razorbills have predominated in the seabirds recovered. But despite large numbers of birds being killed, there does not appear to have been any substantial lasting effect on UK seabird populations.

The scale of baseline monitoring should be geographically broad since it is impossible to predict before a spill occurs which colonies will be most affected. Depending on where and when the spill occurs, the effects may be felt only by birds from colonies in the local area of the spill (e.g. Sea Empress and Braer disasters), but may also impact on wintering birds from colonies a long way from the spill that may be distributed over a large area. For instance, the Erika and Prestige disasters off the coast of France and Spain killed auks from colonies throughout the Celtic Sea area; and the Tricolor spill in the English Channel killed auks from colonies in Eastern Scotland.

In order to detect an effect of stochastic mortality from discharges and oil spills on breeding populations, the key parameters to monitor i) trends in population size (at a colony, regional and UK scales) and ii) trends in annual survival rates. For some species, trends in population size may be sufficient to detect an effect; for instance SOTEAG's monitoring of black guillemot numbers in Shetland has detected declines resulting from mortality following relatively minor oiling incidents (Heubeck 2000). However, despite tens of thousands of guillemots and razorbills being killed during oil spills, the SMP has not detected any subsequent declines in numbers of birds attending colonies (Mavor *et al.* 2006). This may in part be due to the majority of birds killed being immature. However following the Tricolor spill in the English Channel that was thought to have killed upwards of 8,000 razorbills and 25,000 guillemots (Camphuysen & Leopold 2004), over 70% of which were adults (Grantham 2004), no impact on numbers or adult survival was detected by the SMP in eastern Scotland (Mavor *et al.* 2004, Wilson *et al.* 2005), where most of the birds killed by the spill were thought to originate from (Grantham 2004). The only significant impact on guillemots following a spill as yet detected, was a drop in the annual adult survival rate of guillemots at the SMP Key Site on Skomer following the Erika spill (Birkhead 2001). Ringing birds to determine survival rates also has the added advantage that during oil spills, the breeding origins of the birds affected can be identified (e.g. Grantham 2004). It is also important that birds recovered from spills, whether ringed or not, are examined to record age and racial origin (if possible fro m plumage and/or biometrics) in order to predict those populations likely to be most affected (e.g. Camphuysen & Leopold 2004).

Disposal of waste has substantial positive and negative effects on lesser black-backed and herring gulls that predominate amongst the species feeding on domestic waste at rubbish tips. However, this once important food source is diminishing due to the closure of some landfill sites and changes in practices at others. But more significantly, landfill sites are a source of botulism – a fatal disease contracted by ingesting the bacterium *Clostridium botulinum.* Botulism is thought to have contributed significantly to the decline in the number of herring gulls breeding in Ireland by 81% since the mid 1980s and to more localised declines in western Britain (Madden & Newton 2004). Given that Herring Gull numbers in the UK are now less than half of what they were in 1970, they have been nominated to be included under UKBAP. A first step of any Species Action Plan for herring gull should be to investigate the relationship between waste management, botulism and survival of adult and immature herring gulls and how this ultimately affects the number of herring gulls breeding in the UK. In contrast, lesser black-backed gulls do not appear to have been affected by botulism by anything like the extent of herring gulls and have increased in number in both the UK and Ireland (Calladine 2004). The simultaneous comparative study of lessers may help to determine why herring gulls are apparently more susceptible to the disease.

Litter in the marine environment is ingested by northern fulmars and non degradable plastics accumulate in large quantities in their stomachs. So much so, that quantities of plastic in fulmar stomachs in the OSPAR area are being used as an Eco QO of the level of marine litter pollution (van Franeker *et al.* 2005). However it is unclear what effect this ingested litter has on the long-term survival and condition of fulmars. Simultaneous monitoring of survival of fulmars at UK colonies by the SMP, along with monitoring of plastics in their stomachs co-ordinated by OSPAR, could potentially identify a link if indeed there is one.

Ocean acidification results from increasing levels of CO_2 in the atmosphere, leading to CO_2 uptake across the air-sea interface and increased carbon concentrations in the ocean. The pH of the world's oceans has already fallen by 0.1 and is expected to reduce by a further 0.2-0.3 by 2100. The effect of this acidification on marine organisms comes from the fact that it reduces the concentration of carbonate ions and affects the carbonate saturation state of the seawater makes it more difficult for phytoplankton, zooplankton and corals to build their carbonate shells (OSPAR 2006). This will have highly significant knock-on effects through the marine ecosystem, not least to seabirds. As yet the implications of ocean acidification are not fully understood, but the effects on all seabird species are likely to be substantial (Table A2.2). Monitoring of ocean acidification effects on seabirds may be best achieved in tandem with the monitoring of the impacts of fisheries (see above) and climate change (see below) that also affect seabirds by directly impacting on lower trophic levels of the marine ecosystem on which seabirds depend.

Climate change

Long-term climate change is likely to impact significantly on seabird populations. The breeding behaviour of some seabird populations in the UK have been linked to large-scale climatic fluctuations in the North Atlantic, such as the North Atlantic Oscillation (NAO) (Thompson & Ollason 2001, Frederiksen *et al.* 2004b. Projected consequences of global warming in UK waters, such as sea level rises and increased storminess are likely to have a direct impact on seabird populations. For instance, rising sea levels may reduce the amount of breeding habitat available for shoreline nesting species such as terns; winter storms can cause large-scale mortality or 'wrecks' of seabirds and summer storms can wash whole colonies from cliffs.

Rises in sea temperatures have already caused significant changes lower down the food chain that may be having a serious knock-on effect on seabirds. Around the mid 1980s, rises in sea surface temperatures (SST) led to a complete change in species composition and biomass of the plankton community in the North Sea (Beaugrand *et al.* 2003) and consequently, a reduction in the recruitment of sandeels (Arnott & Ruxton 2002) - a major source of food for breeding seabirds and their young. The size of sandeels caught by (and available to) Atlantic puffins over the Wee Bankie off southeast Scotland decreased significantly over the period 1973-2002 (Wanless *et al.* 2004). Furthermore, the energy content of sandeels and sprats that adult common guillemots fed to their young in 2004 on the Isle of May, SE Scotland, was much lower than normal and resulted in lower growth rates of chicks and ultimately the worst breeding season on record for the colony (Wanless *et al.* 2005b). At the same site, over-winter survival of adult black-legged kittiwakes during 1986-2002 was lower following warmer winters (i.e. high SST) and breeding success one year later was significantly reduced – this is thought to be linked to variable recruitment of sandeels (Frederiksen 2004). There have been recent breeding failures at UK colonies amongst those species that rely on sandeels – the poorest breeding seasons since annual monitoring began in 1986 occurred in Orkney, Shetland and the North Sea coast of Britain in 2004 (Mavor *et al.* 2005) and in NW Scotland in 2005 (Mavor *et al.* 2006). While no direct link has been shown between SST increases, low sandeel biomass and poor seabird breeding performance, the circumstantial evidence is compelling.

While most species of seabirds will be affected substantially by climate change (see Table A2.2), we have suggested concentrating monitoring only those species that feed exclusively on small fish (including sandeels) that are likely be impacted via climate-induced changes to lower trophic levels in the marine environment (that may also be caused by ocean acidification and fishing) – see above.

Significant changes at the lower trophic levels may also be evident in the diet of Leach's storm-petrel, which consists of macro-zooplankton (Montevecchi et al. 1992). During the breeding season in the north-eastern Atlantic, away from the colonies, Leach's storm-petrels are concentrated in areas beyond the shelf break over deep water (1,000m to >2,000m) (Pollock et al. 2000); indeed the few breeding sites in the British Isles appear to have been chosen because of their proximity to deep oceanic water (Mitchell 2004). Therefore, by monitoring changes in the diet of Leach's petrel, we may more conveniently and more cheaply monitor changes in the macro zooplankton than by using plankton trawls. More work is needed to determine if the content of Leach's storm-petrel regurgitates is representative of the plankton communities in the north-east Atlantic.

Invasive alien species

The main impact on seabirds by invasive alien species comes from mammalian predators that have been introduced either intentionally or accidentally to areas that were naturally free of such animals. The main strategy adopted by seabirds to cope with mammalian predation is avoidance, and they tend to nest on cliffs or offshore island or remote beaches where predators are scarce or absent. For example, in Orkney and Shetland, black guillemots nesting on islands with rats and stoats appeared to avoid predation by nesting in crevices high off the ground on cliffs that were inaccessible to the rats and stoats, rather than in the boulder beaches that they used on islands free of mammals (Ewins & Tasker 1985). Hence, the distribution and availability of predator-free sites is an important determinant of seabird range and is likely to limit population size by preventing colonisation of areas that would otherwise be suitable for breeding. But not all species are as adaptable as the black guillemot and ground-nesting seabirds are particularly susceptible and some species are unable to coexist with mammalian predators. For example, European and Leach's storm-petrels are only found breeding on islands that are free of rats (Mitchell 2004, Newton & Mitchell 2004).

The brown rat (*Rattus norwegicus*), originally from south east Asia, was introduced to the British Isles by Russian ships in the early eighteenth century. Hence the presence of rats for almost 300 years in some places has lead to an equilibrium between the impact of rats and the number and distribution of seabirds. However on some islands, more recent introductions have led to recorded declines in seabird species (e.g. the demise of puffins on Ailsa Craig and Puffin Island and of Manx Shearwaters on Canna). The results of recent rat eradication programmes (e.g. on Ailsa Craig, Handa, Lundy and Canna) have been encouraging. However eradication is very expensive and has so far been restricted to independant, locally focused projects. A UK-wide initiative is required to reverse the impact of rats and other introduced mammals on islands and enable certain seabird populations to expand at a UK wide scale. The first step would be to produce an inventory of islands containing introduced mammalian predators in order to assess the scale of the problem. The SMP would provide advice on where eradication should be prioritised to obtain the greatest benefits to seabirds. The SMP would also provide pre- and post-eradication long-term monitoring data to assess the success of any work carried out.

The other alien mammal to have a UK-wide impact on seabirds is the American mink, which in contrast to the brown rat, was introduced much more recently in the 1950s for the fur trade. Mink that have since escaped from fur farms have colonised much of mainland Britain, and have so far reached just north of the Great Glen, but are continuing to spread northwards. They are adept swimmers and can easily reach seabird colonies on inshore islands, where they cause complete breeding failures, adult mortality and eventually site abandonment. This devastating impact means that seabird monitoring can provide a clear indicator of the presence of mink, arguably much more easily than by tracking the mink or by monitoring other species on which the mink also depredate (e.g. waterfowl, water voles, corncrake). Along the west coast of Scotland, mink predation within the last 10-20 years has led to the redistribution and decline in numbers of common and Artic terns, common and black-headed gulls and black guillemots (Craik 1997, Mitchell et al. 2004). Mink control has been implemented at specific colonies in western Scotland and has been effective at increasing productivity and preventing abandonment (Craik 1997, 1998). A five year project to eradicate mink from the Uists and reduce numbers on Harris has recently been completed. But as mink continue to spread through Scotland there is an urgent need to model where the mink are likely to eventually spread to and hence what the impact is likely to be on resident colonies of seabirds. This will enable control measures to be implemented in the most vulnerable areas, thus optimising limited resources. Seabird monitoring in areas not yet occupied by mink (e.g. Caithness, Sutherland and most of Rosshire) should be a future priority of the SMP to ensure that any impacts from mink can be detected quickly and mitigated against.

In contrast to rats and mink, other introduced species of predatory mammal appear to have a much more localised impact on seabirds e.g. feral cats in the Isles of Scilly, polecats on the Isle of Man, ferrets on Shetland and domestic cats on remote inhabited islands in Orkney and Shetland. However some of their impacts could be significant at a larger scale if left unchecked: for instance, most of the UK's red-throated divers breed in Shetland and are very susceptible to predation from mammals.

Table A2.1: The potential impacts of ecosystem pressures on breeding seabird populations in the UK.

Note: The impact assessment is divided into human activities through which each pressure acts (e.g. fisheries is an activity that causes over-exploitation)

Pressure	Human activities	Impacts on seabirds
Over-exploitation	Fisheries	a) competition for seabird prey species e.g. lesser sandeel; b) reduction in food provided to seabirds through discards and offal discharge; c) seabird mortality caused by accidental entrapment in fishing gear
Over-exploitation	Trade in species	None
Over-exploitation	Hunting	None
Over-exploitation	Harvesting	a) licensed culling of gulls and great cormorants under licence; b) Annual 'Guga Harvest' of northern gannet chicks on Sula Sgeir; c) egg collecting.
Over-exploitation	Recreation & tourism	Disturbance to nesting seabirds by wildlife tourism
Over-exploitation	Illegal killing	a) Unlicensed killing of gulls and great cormorants. b) trapping of roseate and Sandwich terns in W Africa.
Habitat transformation	Agriculture	Intensive agriculture can reduce food available for gulls reliant on arable land and pasture for feeding.
Habitat transformation	Aquaculture	a) Discharge of food from fish cages may create local aggregations of prey fish for some seabirds, b) seabird mortality caused by entanglement in fish cages
Habitat transformation	Forestry	a) encroachment of conifer plantations on upland nesting sites of some gull species; b) forests provide cover for land predators of seabirds and may result in elevated levels of predation and abandonment of colony.
Habitat transformation	Transport infrastructure.	Disturbance to foraging birds from shipping
Habitat transformation	Urban & industrial development	a) destruction of gull nest sites on the roof tops of old buildings, b) fencing can exclude land-predators from ground nesting colonies of gulls and common terns, creating new safe habitat and/or improved breeding success.
Habitat transformation	Water management	coastal defences can a) be used to create marshland nesting habitat for terns and gulls; or b) destroy soft shore nesting habitat of terns and gulls.
Habitat transformation	Aggregate/mineral/peat extraction	Peat extraction may destroy some upland nesting sites for gulls, skuas and divers.
Habitat transformation	Energy production	a) onshore windfarms can reduce available upland nesting habitat for gulls, skuas and divers; b) Offshore windfarms can exclude some seabirds from foraging areas; c) Some structures e.g. oil/gas platforms can create nesting habitat for gulls.

Pressure	Human activities	Impacts on seabirds
Habitat transformation	Recreation & tourism	a) Disturbance by people and their pets reduces available safe undisturbed nesting habitat; b) disturbance from watersports can exclude seabirds from good quality foraging areas.
Pollution	Increasing yield from non-animal food production Note 2,5,6,7,9	None
Pollution	Increasing production of animal protein Note 2,5,6,9	Discharge of livestock waste can cause eutrophication of upland water bodies and reduce prey abundance for red-throated divers
Pollution	Extraction of raw materials Note 7,9	None
Pollution	Industrial discharge Note 2,6,7	Surface pollutants may cause mortality to seabirds by poisoning or by clogging plumage. Most likely to impact species that spend the non-breeding season in inshore waters.
Pollution	Domestic sewage discharge Note 2,6	None
Pollution	Electricity generation from fossil fuels Note 3,4,8	None
Pollution	Heat generation from fossil fuels Note 3,4,8	None
Pollution	Transport derived from fossil fuels Note 3,4,8	Oil spills from fuel tanks of ships and large scale spillages of cargo creates surface pollutants that may cause mortality to seabirds by poisoning or by clogging plumage. .
Pollution	Control of human diseases Note 5	None
Pollution	Disposal of waste Note 9	Landfill sites provide food for gulls, so may improve survival and breeding success. Conversely, landfill sites are also a source of disease e.g. botulism and may therefore cause increased mortality. Plastic waste at sea is ingested by surface feeding species and can cause mortality.
Pollution	CO2 emissions Note 10	Ocean acidification could have a significant impact on marine ecosystems that may in turn impact on seabirds, but it is difficult to predict the species-specific impacts.
Climate change	Land use planning/zoning	None
Climate change	Ecosystem simplification (the effect of all other direct drivers)	This is likely to most affect more specialised species but the precise nature of the impacts is difficult to predict.
Climate change	Coastal development	Most likely to threaten nesting habitat of ground-nesting species along soft shores
Climate change	Landscape and habitat fragmentation	Most likely to impact on inland nesting species

Invasive alien species	Unintentional / intentional movement of species between ecosystems	The intentionally or unintentional introduction of alien predatory mammals (e.g. rats, cats, mink) to islands has and will continue to have the greatest impact on ground-nesting seabird species, through predation of adults, young and eggs.

Note 1: Sustaining life: the minimum food, water, shelter, healthcare, education, social and spiritual fulfilment to sustain a life. ‘Desire' is defined as anything that is not needed to sustain life - including an excess of something used to sustain life (too much food)
Note 2: Causing nutrient enrichment via run-off (see below)
Note 3: Causing nutrient enrichment via aerial deposition (see below)
Note 4: Causing acidification by sulphur discharge (see below)
Note 5: Causing biocide run-off
Note 6: Causing the release of chemicals causing disruption to endocrine systems (see below)
Note 7: Causing the release of heavy metals
Note 8: Ocean acidification
Note 9: Groundwater contamination
Note 10: Ocean acidification

Table A2.2: The magnitude of the potential impacts of pressures (listed in Table 2.2.1) on each breeding seabird species in the UK.

Note: 0 = impact absent or negligible; 1 = proven or suspected to have a low impact; 2 = proven or suspected to have a substantial impact

		Magnitude of impact on seabird species																									
Pressure	**Human activities**	**red-throated diver**	**northern fulmar**	**Manx shearwater**	**European storm-petrel**	**Leach's storm-petrel**	**northern gannet**	**great cormorant**	**European shag**	**Arctic skua**	**great skua**	**Med gull**	**black-headed gull**	**common gull**	**lesser black-backed gull**	**herring gull**	**great black-backed gull**	**black-legged kittiwake**	**Sandwich tern**	**roseate tern**	**common tern**	**Arctic tern**	**little tern**	**common guillemot**	**razorbill**	**black guillemot**	**Atlantic puffin**
Over-exploitation	Fisheries	2	2	1	1	0	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	2	1	2	2	0	2
	Trade in species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hunting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harvesting	1	0	0	0	0	1	2	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
	Recreation & tourism	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Illegal killing	0	0	0	0	0	0	2	0	0	0	0	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0
Habitat transformation	Agriculture	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aquaculture	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Forestry	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Transport infr.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban & industrial	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0

development

		Magnitude of impact on seabird species																									
Pressure	**Human activities**	**red-throated diver**	**northern fulmar**	**Manx shearwater**	**European storm-petrel**	**Leach's storm-petrel**	**northern gannet**	**great cormorant**	**European shag**	**Arctic skua**	**great skua**	**Med gull**	**black-headed gull**	**common gull**	**lesser black-backed gull**	**herring gull**	**great black-backed gull**	**black-legged kittiwake**	**Sandwich tern**	**roseate tern**	**common tern**	**Arctic tern**	**little tern**	**common guillemot**	**razorbill**	**black guillemot**	**Atlantic puffin**
Habitat transformation	Water mgmt	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
	Aggregate/mineral/peat extraction	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Energy production	2	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
	Recreation & tourism	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	2	0	0	0	0
Pollution	Increasing yield from non-animal food production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Increasing production of animal protein	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Extraction of raw materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Industrial discharge	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

		Magnitude of impact on seabird species																								
Pressure	**Human activities**	**red-throated diver**	**northern fulmar**	**Manx shearwater**	**European storm-petrel**	**Leach's storm-petrel**	**northern gannet**	**great cormorant**	**European shag**	**Arctic skua**	**great skua**	**Med gull**	**black-headed gull**	**common gull**	**lesser black-backed gull**	**herring gull**	**great black-backed gull**	**black-legged kittiwake**	**Sandwich tern**	**roseate tern**	**common tern**	**Arctic tern**	**little tern**	**common guillemot**	**razorbill**	**black guillemot**	**Atlantic puffin**
Pollution	Domestic sewage discharge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electricity generation from fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heat generation from fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Transport derived from fossil fuels	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1
	Control of human diseases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Disposal of waste	1	0	0	0	0	0	0	0	0	0	1	1	1	2	2	1	0	0	0	0	0	0	0	0	0	0
	CO2 emissions (Ocean Acidification)	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?	2?

Climate change	Land use planning/zoning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Ecosystem simplification (the effect of all other direct drivers)	2	1	1	1	2	1	1	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2

		Magnitude of impact on seabird species																									
Pressure	**Human activities**	**red-throated diver**	**northern fulmar**	**Manx shearwater**	**European storm-petrel**	**Leach's storm-petrel**	**northern gannet**	**great cormorant**	**European shag**	**Arctic skua**	**great skua**	**Med gull**	**black-headed gull**	**common gull**	**lesser black-backed gull**	**herring gull**	**great black-backed gull**	**black-legged kittiwake**	**Sandwich tern**	**roseate tern**	**common tern**	**Arctic tern**	**little tern**	**common guillemot**	**razorbill**	**black guillemot**	**Atlantic puffin**
Climate change	Coastal development	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0
	Landscape and habitat fragmentation	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Invasive Aliens	Unintentional / intentional movement of species between ecosystems	1	0	2	2	2	1	1	1	2	2	2	2	2	2	2	2	0	2	2	2	2	2	1	1	2	2

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