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The Arctic Species Trend Index

Tracking trends in Arctic marine populations

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Executive Summary

Due to the complex temporal dynamics of wildlife populations and fish stocks, long-term monitoring data measuring change in population trends is a necessary and revealing way to track the effect of environmental changes on wildlife.

The Arctic Species Trend Index (ASTI) tracks the temporal abundance in 890 populations of 323 vertebrate species. This represents an update of the index first reported on in 2010 (McRae *et al*. 2010) and shows that average species population abundance in the Arctic has increased over the time period between 1970 and 2007. This pattern, however, is not consistent among regions as vertebrate abundance has increased on average in the low Arctic but not in the high Arctic and sub Arctic. The marine component of the ASTI shows a greater increase – and evidence is presented that the trends in marine species are driving the pan-Arctic index. The marine trend varies according to taxonomic class and ocean basin, among other variables.

Marine mammal populations increased on average but there is a need to interpret the recovery in numbers in the context of the 1970 baseline, as some populations still remain heavily depleted after historical overexploitation. Recent declines were observed in the Bering Sea and Aleutian Islands for seven species: beluga whale, Steller sea lion, harbour seal, sea otter, Pacific walrus, northern fur seal, and gray whale. The reasons for the population declines are not uniform for all species; the associated threats include overharvesting, increased predation, loss of summer sea ice, and depleted prey resource.

Marine bird indices show either stable or declining trends depending on the Arctic region in question. Climate change, exploitation, and invasive species are anthropogenic threats that have been linked with negative trends for some of these populations—but there may also be an influence from natural changes in environmental and foraging conditions, especially affecting piscivorous species, particularly in the Bering Sea and Aleutian Islands.

The fish data set was dominated largely by benthic and commercially fished species from the Bering Sea. Among fish populations there were increases in the Pacific and Arctic basins of the study area, possibly due to increases in sea surface temperatures observed in regions such as the Bering Sea in the 1970s and 1980s. The average trend in seven pelagic fish species showed a variable pattern and was found to have a strong association with similar trends in the Arctic Oscillation.

Populations that were affected by at least one anthropogenic threat showed an overall increasing trend from 1970 to 2005 – but the upward trend was due to increases in abundance that occurred in the first 15 years of that period. In contrast, populations not identified as being under threat increased four-fold over the 35-year period.

For bird populations, there was a difference in trend depending on whether the population was located inside or outside a protected area. On average those outside protected areas declined slightly in abundance, which could be due in part to unsustainable harvesting of seabirds in some locations, but more information is needed in order to test this more fully.

The marine data set is dominated by fish species and by populations from the Bering Sea which, at times, have a large influence on some of the sub-indices. The current spatial extent of monitoring needs to be improved to better represent regions and species classes across the marine Arctic.

Introduction

The Arctic is one of the regions in the world experiencing the most rapid visible and measurable changes in its climate and environment (ACIA 2005; Stroeve *et al*. 2007). As a globally important area for biodiversity, it is vital that accurate wildlife monitoring systems are in place to measure how species in the Arctic are reacting both spatially and temporally to different types and magnitudes of pressure.

Evaluating trends in species abundance is one of the most revealing ways to examine broad-scale patterns of biodiversity change. The Arctic Species Trend Index (ASTI), developed for this purpose, uses population time series trend data from vertebrate species from 1970 until the present day. The first report on Arctic species trends (McRae *et al*. 2010; www.asti.is) revealed that trends in Arctic vertebrates show an overall increase in abundance over a 34-year period. Further analysis revealed that this pattern was not consistent within regions, systems or groups of species. In contrast to patterns in the terrestrial environment, marine vertebrate populations from this region show increasing trends in abundance on average since 1970 (McRae *et al*. 2010). Although this trend slowed in rate from 1986, the overall result suggests that by 2004 a 53% increase in abundance of Arctic marine vertebrates had occurred compared to a baseline year of 1970. Disaggregation of the marine data set into taxonomic and regional results across the Arctic indicate that there may be disparity in abundance trends (McRae *et al*. 2010).

One of the principal weaknesses of relying on a non-stratified monitoring network, which must be overcome to provide the best possible indicators of aggregated population trend, is the dominance of particular datasets due to the imbalance in monitoring focus (e.g., more monitoring of commercially exploited species) and the imbalance in distribution of monitoring sites (Bohm *et al*. 2012). The marine component of the ASTI data set, for example, is somewhat dominated by population time series of increasing trend from the Bering Sea and Aleutian Islands. It is likely that species from these locations are driving the marine and the pan-Arctic index whilst masking other important trends.

The importance of obtaining a clear picture and improving understanding of biodiversity trends in the Arctic marine environment cannot be overstated. A wealth of research into environmental patterns in the Arctic marine environment over recent years has brought to light changes in marine systems, both cyclical and long-term, and also interactions among species that occur in this system. Recent research shows, for example, impacts on biodiversity of declines in sea-ice extent (e.g., Heide-Jørgensen *et al*. 2010; Kovacs *et al*. 2010); warming sea surface temperatures in areas such as the Bering Sea and possible effects on species (e.g., Coyle *et al*. 2007; Stabeno *et al.* 2007; Irons *et al*. 2008); and, trophic interactions and cascades that can occur as a result of environmental changes in the marine habitat (e.g., Stempniewicz *et al*. 2007; Anthony *et al*. 2008).

In light of these changes, further investigation of the underlying trends in the marine index are now needed to establish whether the increasing trend is common to all marine species and regions and also to put these results in the context of environmental changes in the Arctic seas. In order to explore this, we present a number of sub-indices showing trends in groups of marine vertebrate populations disaggregated taxonomically, geographically, ecologically, and according to different types of conservation management. Finally, variables from these categories were tested in relation to population trends, using single trend values based on the total rate of change for each population. This gave us the option to look for significant factors in predicting marine population trends (see Appendix 1: Methods for details).

Results and Discussion

Pan-Arctic update

Following data collection, time series updates, and removal of redundant data sets, the ASTI was updated to cover 323 species monitored through 890 populations (Table 1). This is an addition of 17 species since the first ASTI report (McRae *et al*. 2010), increasing the representation of Arctic vertebrate species from 35% to 37% (Figure 1). Note that a population, for the purposes of the ASTI, is defined by a data set of annual measures of abundance of one species from a specific location.

				Species				Populations
	Mammals	Birds	Fishes	**Total**	Mammals	Birds	Fishes	**Total**
Terrestrial	30	132	-	**162**	182	256	-	**438**
Freshwater	1	44	14	**59**	3	64	75	**142**
Marine	22	34	55	**111**	60	152	98	**310**
Total (unique species)	**53**	**201**	**69**	**323**	**245**	**472**	**173**	**890**

Table 1. Number of species and populations in the ASTI
The updated ASTI covers a time period of 1970 to 2007.

Due to a large number of data updates we were able to extend the original ASTI by another three years to cover the period 1970 to 2007 (the 2010 ASTI included data only to 2004). This shows that the relatively stable trend at the pan-Arctic level that was evident in 2004 continued until 2007. Plotting ASTI values over the full time period (Figure 2) shows that vertebrate abundance trends increased from 1970 until 1990 when the index stabilised, remaining around the 1.2 index value level (20% above the baseline) for the rest of the time series.

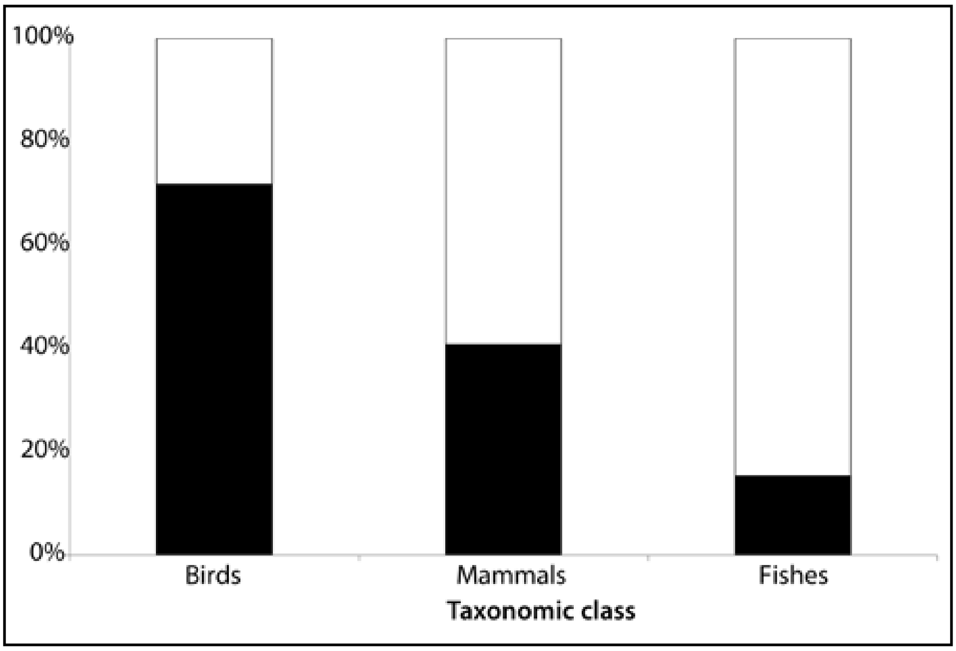


Figure 1. Data coverage by taxonomic class.

Black bars represent the proportion of Arctic species for each class for which population data are available

High Arctic species declined from 1970 to the mid-1990s and then remained fairly stable (Figure 3); low Arctic species account for most of the overall increase in abundance in the first two decades, with the trend levelling off in the mid-1990s. Sub Arctic species increased from 1970 to the mid-1980s and then declined at a steady rate. The three years of data added in this update of the ASTI (2005 to 2007) show marked differences to the preceding few years: a downward trend for low Arctic species and an upward trend for high Arctic species. These changes cancel each other out when all species are combined (Figure 2). This is too short a time to interpret as a significant change and points out the importance of frequent updates of the ASTI.

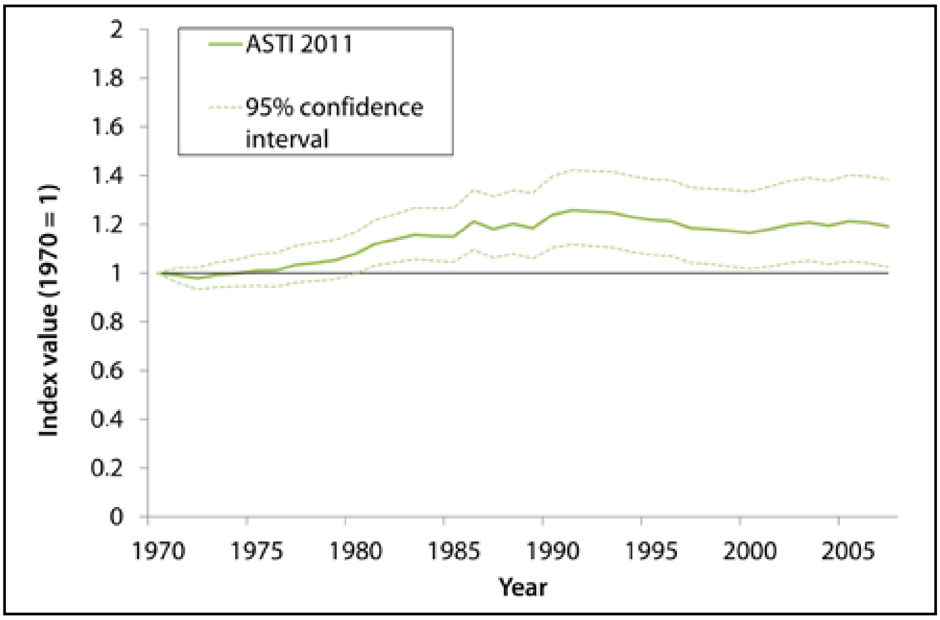


Figure 2. Index of abundance for 323 Arctic vertebrate species (890 populations), from 1970 to 2007. The figure plots the 95% confidence intervals and the number of populations contributing to each year of the index*. The 2007 index value is 1.19.

* Confidence intervals are not shown in the remaining figures to maintain clarity of the graphs. The values can be found in Appendix 4: Table of index values

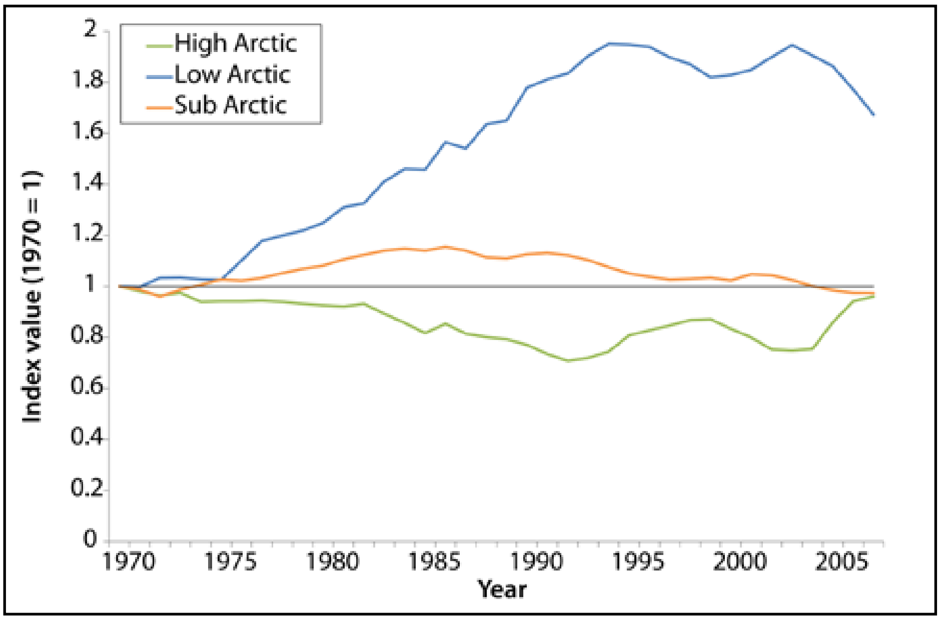


Figure 3: Index of abundance for Arctic vertebrate species from 1970 to 2007 grouped by high, low and sub Arctic.

Polar bear. Photo: Wild Arctic Pictures/Shutterstock.com

Marine results

Overview

The Arctic marine data set contains a total of 111 species and 310 population time series (Table 2) from 170 locations (Figure 4). Species coverage is about 34% of Arctic marine vertebrate species (100% of mammals, 53% of birds, and 27% of fishes) (Bluhm *et al*. 2011). At the species level, even though the representation of Arctic fish species is lower than that of mammals and birds, the data are dominated by fishes, primarily from the Pacific Ocean (especially the Bering Sea and Aleutian Islands). However, there are more population time series in total for bird species, which is reflective of this group being both better studied historically and also monitored at many small study sites compared to fish and marine mammal species, which are regularly monitored at a much larger scale through stock management (Table 2). Note that the time span selected for marine analyses is 1970 to 2005 (compared with 1970 to 2007 for the ASTI for all species, as discussed above).

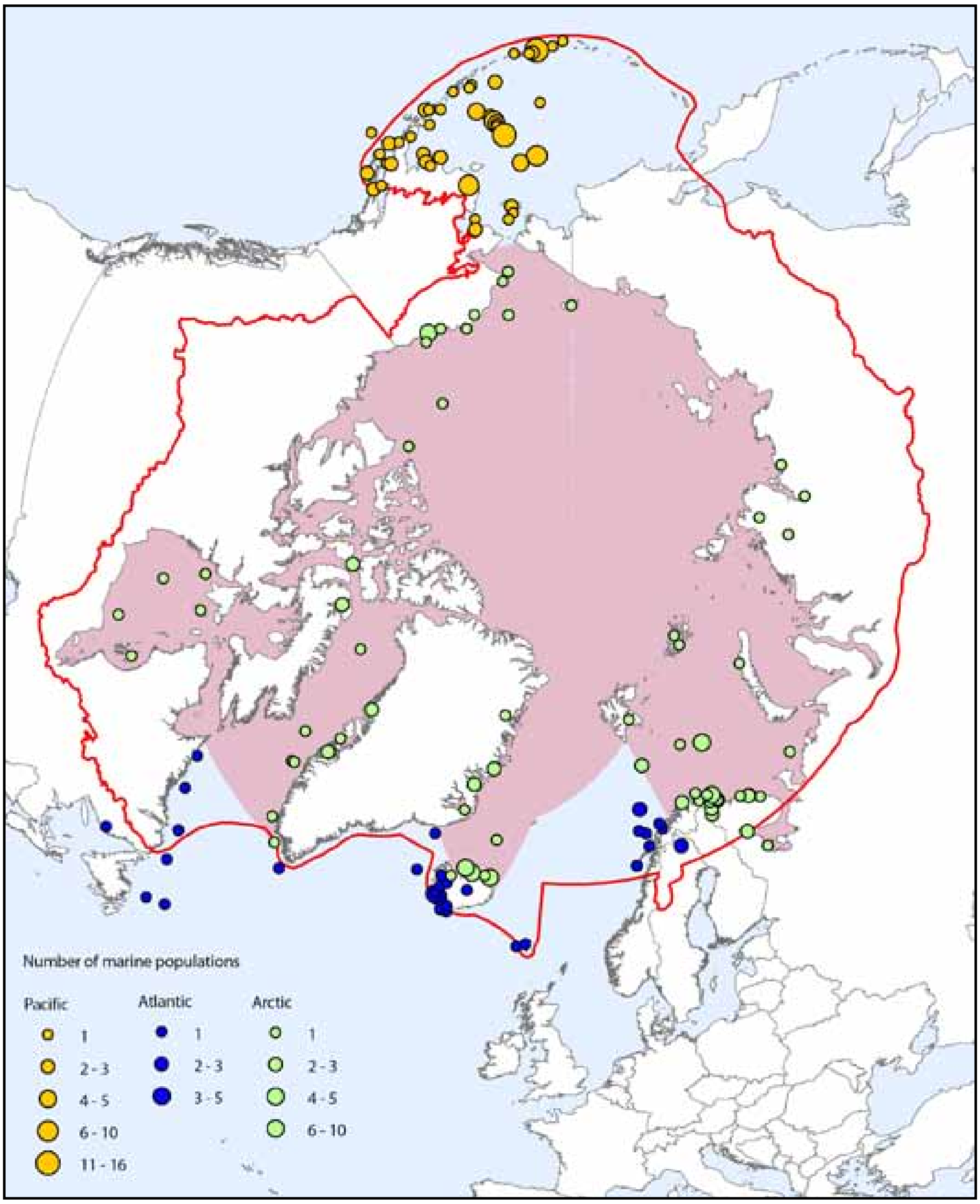


Figure 4. Spatial distribution of marine population data collected
The size of the circle denotes the number of population time series from that location.
For greater clarity in the division of populations by ocean region, the Arctic Ocean base map area used for all analyses is shown in pink.

Table 2. Number of Arctic marine species and populations by ocean basin and class
Marine analyses cover the time period 1970 to 2005.

				Species				**Populations**
	Mammals	Birds	Fishes	**Total**	Mammals	Birds	Fishes	**Total**
Pacific basin	13	22	40	**75**	32	59	62	**153**
Atlantic basin	2	13	7	**22**	3	25	16	**44**
Arctic basin	15	22	15	**52**	25	68	20	**113**
Total (unique species)	**22**	**34**	**55**	**111**	**60**	**152**	**98**	**310**

Population data spanned the years 1950 to 2011. However, the greatest contiguous period of data across all species lies between 1970 and 2005. This dictated the temporal limits set for the marine index.

The Arctic marine index (blue line in Figure 5) shows a very similar trend to the index for all Arctic vertebrates, exhibiting an increasing trend until 1990 and very little subsequent change. In contrast, the index for terrestrial vertebrate species shows very different pattern, with little change up to about 1990, followed by a slow decline. This suggests that the marine species are driving the overall Arctic index (see also McRae *et al*. 2010).

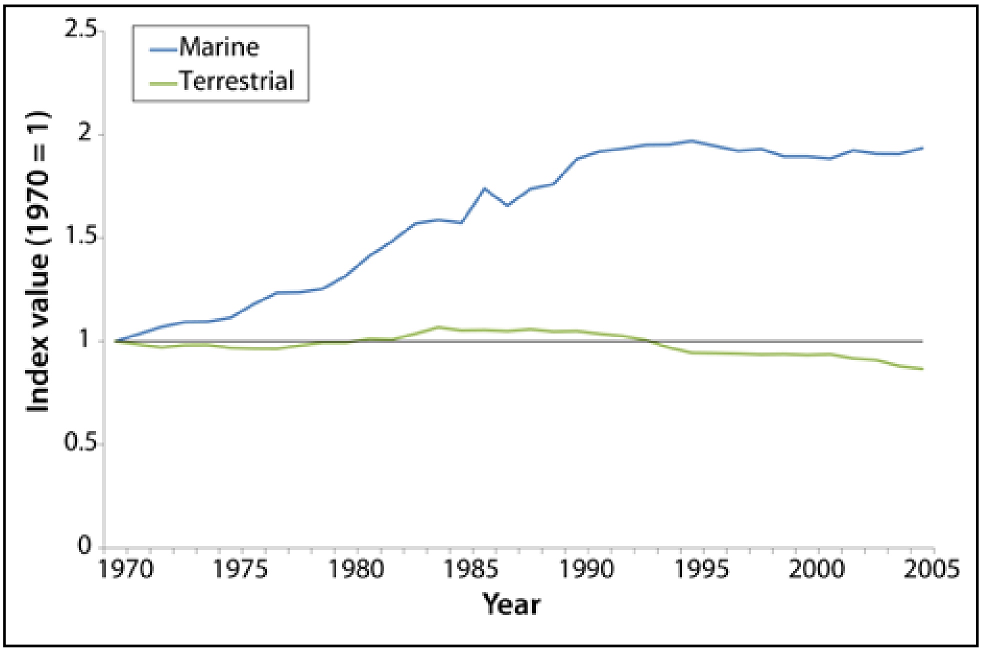


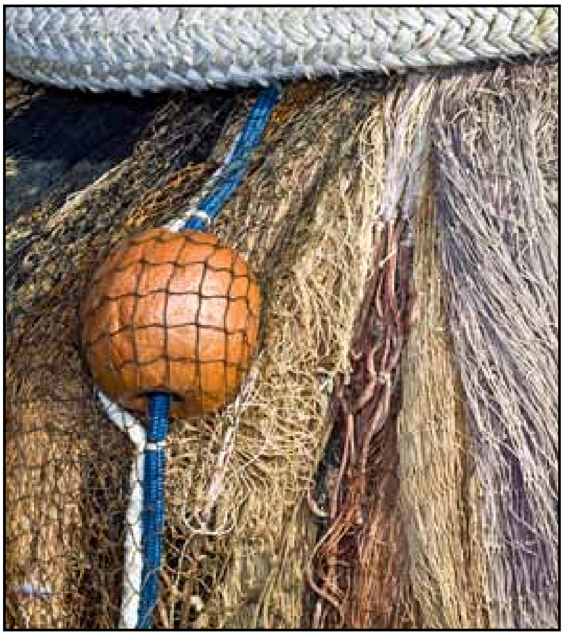
Figure 5. Indices of abundance for Arctic vertebrate species, grouped by marine and terrestrial species, 1970 to 2005.

Data sets for marine: 111 species, 310 populations

Kittewakes on sea ice. Photo: Gail Johnson/Shutterstock.com

Baselines

The concept of baselines is critical to interpreting an analysis such as the one reported here. Current trends in marine ecosystems need to be interpreted against a solid understanding of the magnitude and drivers of past changes (Lotze & Worm 2009). Due to the lack of widespread abundance data pre-1970, the approach taken here is to set the baseline to the year 1970 (Loh *et al*. 2005). However, an understanding of the historical changes in the system could likely yield a different interpretation and thus caution is needed when referring to the overall change in an index from 1970 to 2005.



Fishing nets. Photo: jele/Shutterstock.com

For certain populations that have increased in abundance since 1970, it can be meaningful to put the positive trend into an historical context. Anthropogenic threats such as exploitation may have had an impact on population size before this time and hence the recovery, although positive, may not be equivalent to the decline that occurred previously. Some techniques are being developed to try to reconstruct historical baselines, specifically for marine species (Lotze & Worm 2009), in order to obtain a more accurate picture of a species' current conservation status and as guidelines for future ecosystem restoration.

This concept is particularly pertinent to the marine mammals of the Arctic as there has been a long established practice of subsistence and commercial hunting of many species and severe population reductions of some species from historical, unsustainable commercial whaling Some marine mammal populations have increased dramatically—positive news when comparing trends against a 1970 baseline year. However, many populations are unlikely to have increased back to historical highs (Alter *et al*. 2007; Lotze & Worm 2009; Wade *et al.* 2011). For example, research on *Eschrichtius robustus* (gray whale) from the eastern Pacific suggested that, while abundance has increased dramatically, the whales have, at best, recovered to 28-56% of their original abundance levels (Alter *et al*. 2007). Similar findings have been documented for populations of *Odobenus rosmarus* (Greenland walrus) (Witting & Born 2005), the western Arctic population of bowhead whale (George *et al*. 2004), and for the highly commercial *Gadus morhua* (Atlantic cod) (Rosenberg *et al*. 2005).

Supply vessel entering Appilatoq, Greenland. Photo: Gentoo Multimedia Ltd./ Shutterstock.com

Taxonomic trends

The marine data set is dominated by fish species (Table 2) and as each species trend is equally weighted within the index, this means that this group carries the most weight in the overall index. A closer look at sub-indices of each taxonomic group supports this hypothesis as trends in marine fish increased up to an index value of 2.6 over the 35-year period (Figure 6). Marine mammals also showed an upward trend. Both mammal and fish indices increased to a much greater degree than the index for birds, which displayed a slower increasing trend to 1984, then remained stable, with indications of a slow decline starting after 1998.

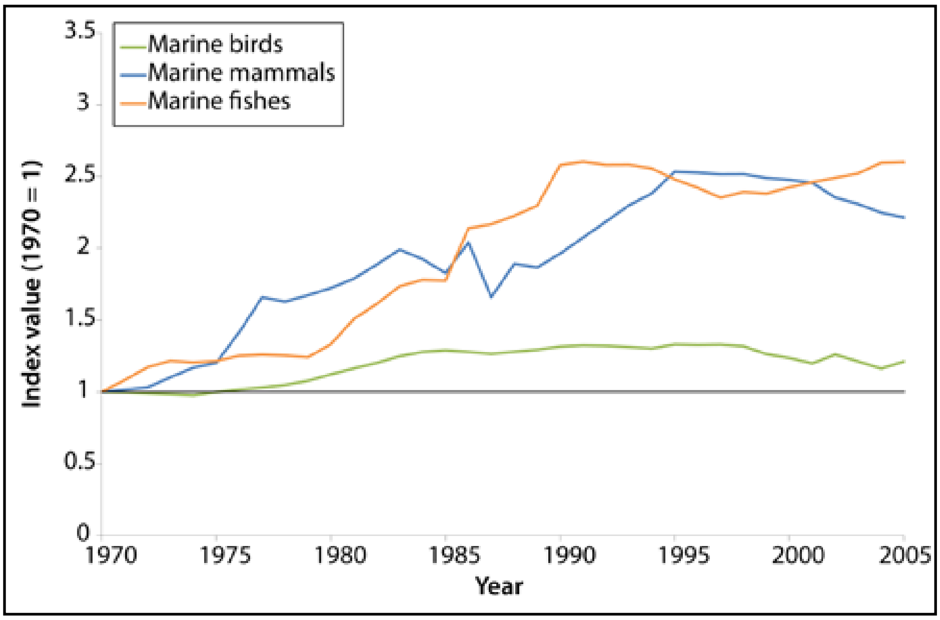


Figure 6. Indices of abundance by taxonomic class, 1970 to 2005. Indices are averaged for birds (34 species, 152 populations), fishes (55 species, 98 populations), and mammals (22 species, 60 populations).

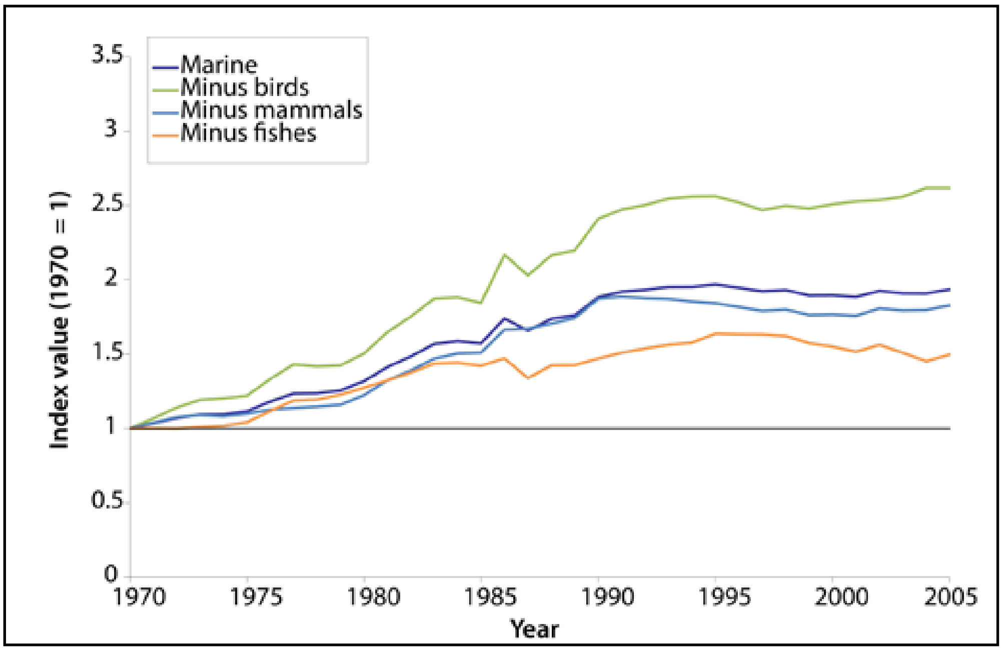


Figure 7. Effects of the removal of each class on the marine indices of abundance weighted at the species level.

Figure 7 shows the influence of each taxonomic group by plotting the marine index with the sequential removal of birds, mammals, and fishes. Mammals are indicative of the overall marine index—their removal from the analysis results in little change to the trend line. The magnitude of the influence of bird and fish trends appears to be largely the same, but in opposite directions. The presence of bird trends reduces the overall increase and the presence of fish trends raises it.

Overall, the taxonomic results suggest that there has been an average increase in abundance amongst Arctic mammal species. One explanation is that they have increased in abundance over this time period following sharp declines related to historical overharvesting (see discussion on this point in Baseline section above). Mammal species increased in abundance in all three regions of the marine Arctic—Pacific, Arctic, and Atlantic (results of the analysis grouped by ocean region not displayed). Marine mammal population trends are illustrated in more depth when we focus the analysis on the Bering Sea and Aleutian Island region as part of the regional trends section.

Guillemots. Photo: Ewan Chesser/Shutterstock.com

Marine bird populations have not increased by the same magnitude as mammals and fishes (Figure 6). The increase in bird abundance stabilises around 1984 and in 1998 starts showing a decline. The overall picture suggests that the abundance of marine birds was greater in 2005 compared to 1970 but was lesser than that in 1998. This recent trend may indicate the start of a longer term decline so it will be important to monitor this over the coming years and to investigate what may be driving these trends.

Recent studies have shown that population trends in some bird species may be influenced by changes in climate and sea-ice extent, as these environmental conditions dictate the availability of food and therefore bird abundance, which can have subsequent indirect effects on the composition of the terrestrial coastal environment (e.g., Stempniewicz *et al*. 2007). For example, some population declines researchers have observed in piscivorous seabirds are thought to be due to changes in foraging conditions determined by winter sea-ice (Byrd *et al.* 2008) and a link has been established between changes in sea-surface temperature across the Arctic and declines in seabird colony productivity (Irons *et al*. 2008). This is discussed further in the ecological trends section as part of the analysis on trophic level.

Fish feeding on zooplankton. Photo: Mareano Institute of Marine Research

Marine fish show a large overall increase in abundance which predominantly occurred in the 20-year period between 1970 and 1990 (Figure 6). The trends in fish species are contributing more to the positive trend in the marine index than the other two classes (Figure 7), so these results strongly suggest that an overall increase in fish abundance occurred over the 35-year period.

Identifying the drivers behind this change in abundance is complex as the data set comprises a broad range of species that could be responding differently to varying degrees of climatic, ecological, and management pressures. Commercial exploitation is a more important factor in fish populations (more so than for most bird and mammal populations), with a little over half the fish species in this data set being commercially exploited. The fish data set contains a large number of benthic species (two-thirds of the populations). This means that the data set for fish is somewhat dominated by the influence of commercial exploitation and the emphasis on benthic fishes.

Population trends are not noticeably different according to aspects of fish ecology such as trophic level and habitat (see Ecological trends section). Finally, regional differences were noticeable in fish population trends, most noticeably in the Atlantic Ocean where the average change was a continued and unabated decline (Appendix 4: Table of index values). This pattern is also evident in the regional disaggregation of the entire marine index, the underlying trends of which are discussed in the following section.

Regional trends

Three regions: were defined Pacific, Arctic, and Atlantic (see Figure 4 for boundaries) to evaluate regional trends in marine population abundance. These regions vary according to ecological processes and different management and political pressures.

Bird, mammal, and fish trends in each of these regions were examined in order to help interpret the results we found. The results of taxonomic analyses for each region did not produce reliable indices, largely due to the small size of each data set, so they have not been included in this report. However, the influence of birds, mammals and fish in each region is referred to in the discussion below.

The Arctic Ocean. Photo: George Burba/Shutterstock.com

The three oceanic regions differed significantly in average population trend (Figure 8 and Appendix 2: Table of ANOVA results). This difference seems to be largely driven by variation in fish population abundance—there were no significant regional differences for birds or mammals. Figure 9 shows the significant differences in rates of population change among the ocean regions ($F = 9.32$, $df = 2$, $p = 0.00$), highlighting, at the population level, the declining trend in the Atlantic, small average increase in the Arctic, and largest positive change in the Pacific Ocean. The pronounced increase in the Pacific Ocean index is not as apparent when looking at the mean rates of change and it is likely that the index is being driven by a few rapidly increasing mammal and fish species. This, and the clear differences in trends among the ocean basins, particularly from 1975 to 1995, can be explored further by looking at patterns in the Bering Sea and Aleutian Islands (Box 1).

Trends in the Atlantic Ocean, the smallest data set of the three Arctic regions, are driven predominantly by fish and birds. Arctic climate-driven regime shifts are thought to have occurred in the North Atlantic (Greene et al. 2008) but due to both northward and southward movement of species in response to the changing conditions, teasing out how this might have affected overall abundance trends is analytically complex. One possibility is that changes to environmental conditions may operate in tandem with exploitation effects to facilitate a population decline. Alternatively, they could impede an overexploited species' recovery, as suggested for the case of Atlantic cod (Beaugrand *et al*. 2008). In the Arctic Ocean index, the increase from 1987 is driven by fish and mammal species as the bird trends are largely stable across the time series (Appendix 4: Table of index values).

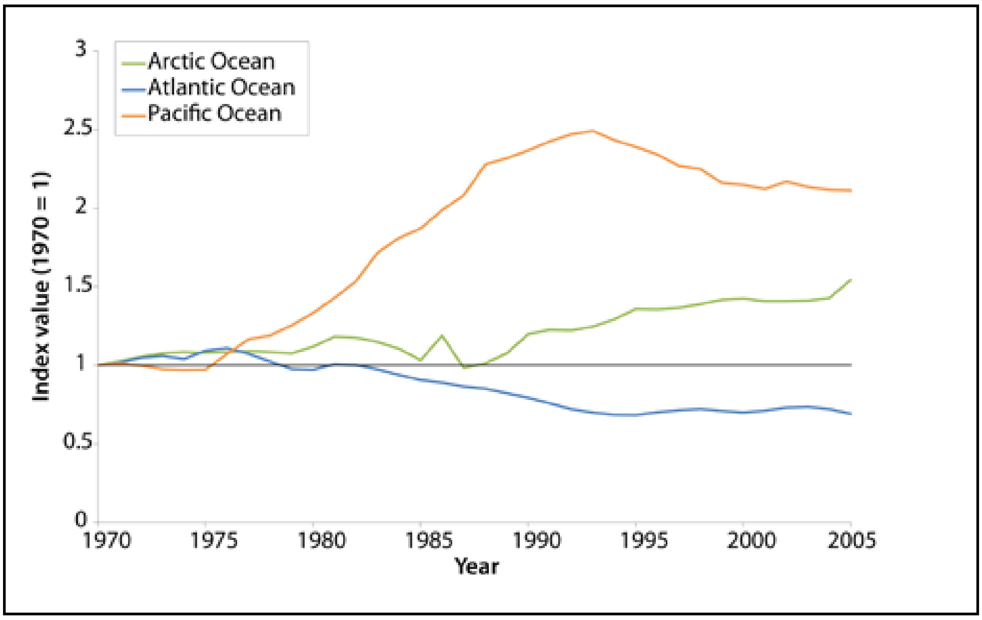


Figure 8. Indices of abundance by ocean region, 1970 to 2005. Indices are averaged for the Arctic Ocean (52 species, 113 populations), Atlantic Ocean (22 species, 44 populations), and the Pacific Ocean (75 species, 153 populations).

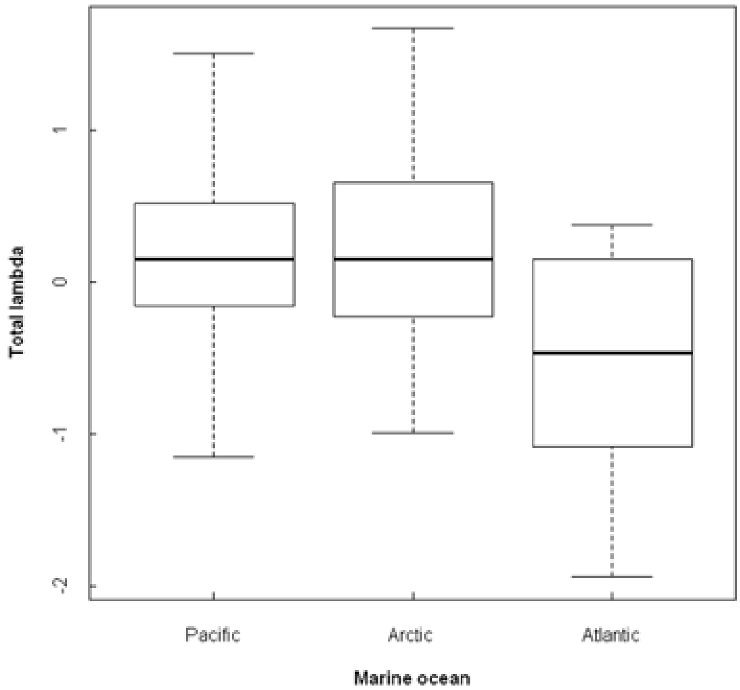


Figure 9. Box plot showing the median annual rate of change of fish species in each oceanic region from 1970 to 2005

Data sets – Arctic Ocean: 20 populations; Atlantic Ocean: 16 populations; Pacific Ocean: 62 populations.

Box plot interpretation: the horizontal lines are the medians; the tops and bottom lines of the boxes represent the 75th and 25th percentiles respectively; the top and bottom end-points to the vertical dashed lines represent the 95th and 5th percentiles respectively.

Total lambda is a measure of the rate of change over the entire time period.

Sea otter. Photo: TTphoto/Shutterstock.com

Bering Sea effect

The marine index shows an overall increase in vertebrate abundance from 1970 to 2005 but the spatial distribution of the population time series contributing to the index is not uniform across the Arctic marine environment (Figure 4). Much of the current monitoring effort appears to be largely clustered around the Bering Sea and Aleutian Island (BSAI) area. The number of populations from this region (n=138), which is a subset of the Pacific Ocean data set, outweighs the number of populations from the Arctic Ocean, Atlantic Ocean, and the rest of the Pacific Ocean individually, but not combined (n=172).

Northern fur seal. Photo: VasikO/Shutterstock.com

In order to investigate the extent to which populations from the BSAI drive the overall marine index trend, the populations from this region were analysed separately. The results (Figure 10) suggest that abundance trends from the BSAI do exert a large influence on the marine index, particularly from 1985 to 1995, but that an increase in abundance is still occurring in the remaining marine regions combined.

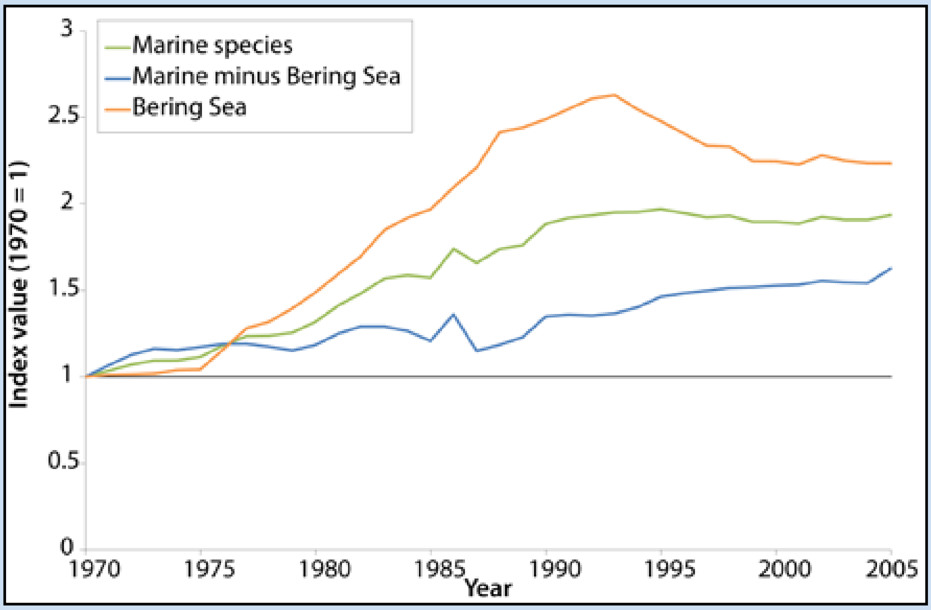


Figure 10. Indices of abundance for marine populations showing the effect of removing the Bering Sea and Aleutian Island populations. BSAI data sets comprised 71 species, 138 populations.

A closer examination of the BSAI region (Figure 11) reveals that fish and mammal trends show an overall increase, whereas bird trends show an overall decline. An overall cause of the declining bird trend is not evident as the presence and nature of threats vary among bird species. Even within species, identifying precise causes of decline is sometimes complicated by spatial and temporal fluctuations occurring simultaneously (Byrd *et al*. 2008). One example of a species from this region in decline is *Rissa brevirostris* (Red-legged kittiwake). The effects of a substantial fisheries industry mediated through habitat disturbance or disruption of the food web are a possible cause of decline (Byrd *et al*. 1997). Early declines of seabirds in the Aleutian islands in the 20th century were thought to be due to fox predation (Croll *et al*. 2005) but it is unclear whether this would be the major driver of trends after 1970.

The marine mammal increase (Figure 11) is not consistent across the entire time period, with a definitive shift in dynamics to a decline in 1988, which continues until 2005. This is a result of increasing population trends for six cetacean species for which monitoring ended in 1989 and highlights the importance of implementing long-term monitoring to avoid breaks in data sets that can influence the index to such a degree. If these six cetacean populations are removed from the data set, the index shows an overall decline in abundance of 43% from 1970 to 2005. This constant decline in trend is reflective of the following species: beluga whale, Steller sea lion, harbour seal, sea otter, Pacific walrus, northern fur seal, gray whale – for reasons including increased predation (Doroff *et al*. 2003), loss of summer sea ice (Kovacs *et al*. 2010), and depleted prey resource (Moore *et al*. 2003), (Trites & Donnelly 2003).

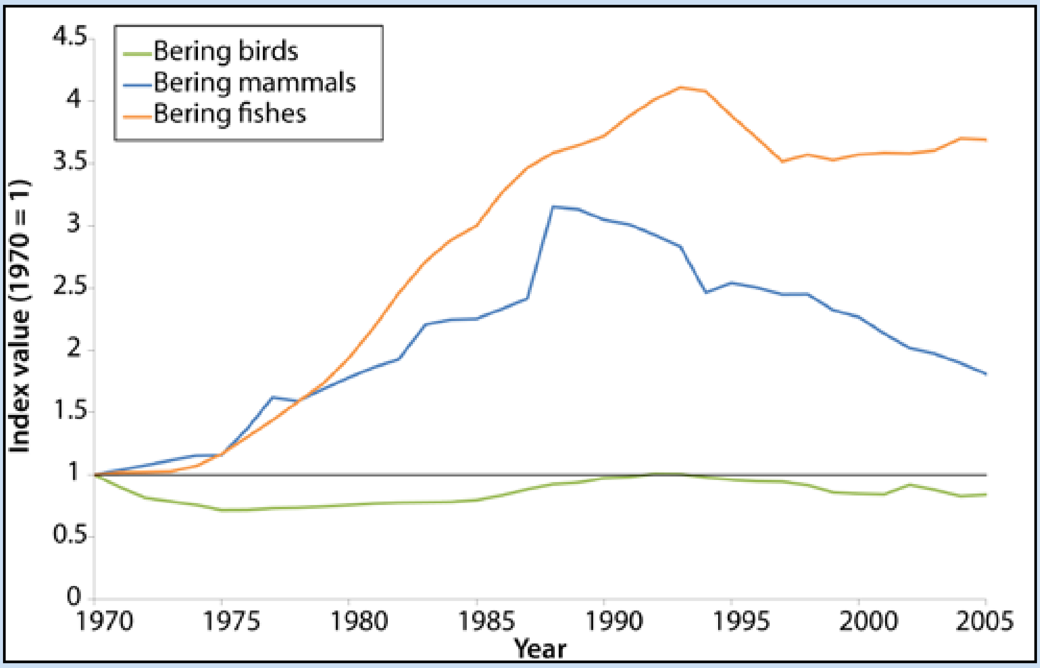


Figure 11. Indices of abundance for marine populations from the Bering Sea and Aleutian Island region (BSAI) for birds, fishes and mammals

BSAI data sets – birds: 21 species, 54 populations, fishes: 37 species, 53 populations, mammals: 13 species, 31 populations

Fish species from the BSAI, on average, increased in abundance from 1970 to 1993 (Figure 11) and this trend drives the overall fish index and, to a certain extent, the marine index. Another broad scale study (Hoff 2005) also found positive changes in biomass in the eastern Bering Sea shelf for all fish guilds in the 1970s and 1980s. This suggests that favourable environmental conditions are likely to be responsible for the increases. The change in trend after 1993 to a decline and then to a stable trend could be due to low productivity observed in groundfish in the eastern Bering Sea during the 1990s (Mueter & Megrey 2005).

Steller sea lions. Photo: Caleb Foster/Shutterstock.com

Ecological trends

Sea ice association

Recent changes in sea ice extent in the Arctic have been well documented (Stroeve *et al*. 2007; Polyak et al. 2010) and there is evidence emerging that this rapid shift is having, at times, adverse effects on biodiversity (Gleason & Rode 2009; Heide-Jørgensen et al. 2010; Kovacs et al. 2010). The nature of a species' association with sea ice is important and varies from the availability of ice algae as the basis of the food webs to the provision of suitable habitat for breeding and for use as a hunting platform (Marz 2010).

Sea ice associated seal. Photo: Irina Igumnova/Shutterstock.com

The ASTI data set contains population trends for nine species that have a strong association with sea ice (Arctic cod, ivory gull, thick-billed guillemot, bowhead whale, beluga whale, narwhal, Pacific walrus, ringed seal, polar bear). The data set for sea ice associated species was not sufficient to produce an overall trend index due to a large variation in time series lengths for each species, as well as discontinuous periods of monitoring. Looking at the population trends over the entire time period for each species, four ice-associated species—ringed seal, beluga whale, Pacific walrus and thick-billed guillemot—showed overall declines in abundance (a lower population at the end of the monitoring period than at the beginning). There were mixed trends among the 36 populations (Figure 12) but just over half showed an overall decline. In light of the paucity of available data and the warning sign of a number of negative trends, there is clearly an urgent need to monitor these key Arctic species.

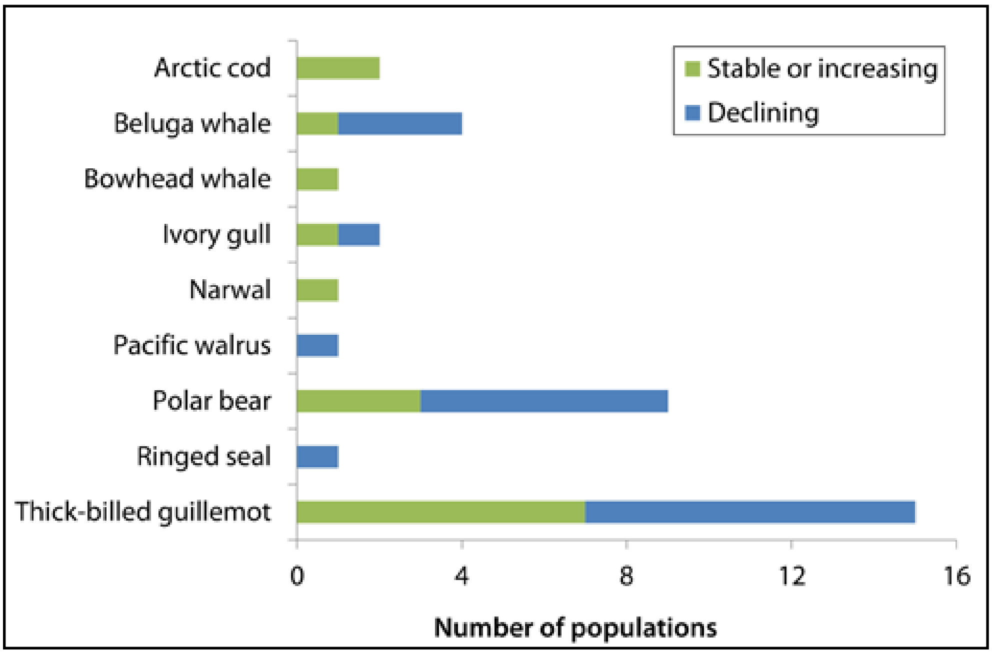


Figure 12: Known status of individual populations for nine ice associated marine species.

For a breakdown by species and populations, see Appendix 5: Table of population trends for nine sea ice associated species.

Note: the status shown for Pacific walrus represents the declining trend in recent decades (1980 to 2006) which followed a period of increase – the trend over the entire time period of monitoring was an increase.

Regime shift

Arctic ciso drying in the sun. Photo: Rumo/ Shutterstock.com

Environmental changes in the marine system are projected to lead to a shift in species composition from benthic to pelagic—this is thought to occur in response to warmer sea surface temperatures (Richter-Menge & J. Overland 2010) and associated reduction in summer sea ice extent. We investigated this by assigning each species to the benthic, pelagic or benthopelagic marine zone (see Appendix Table 1- B for definitions). Looking at the fish species broken down in this way (Figure 13) provides no evidence of such a shift. Both benthic and pelagic species exhibited an overall increase in abundance, with the pelagic fishes showing a distinct cyclical pattern throughout the time series. This cyclical pattern could be concomitant to changes occurring in the marine environment in similar cycles. The six species of benthopelagic fish also increased in abundance from 1970, but this increase continued only until about 1998, when a largely decreasing trend began and persisted until 2005. With only seven species of pelagic fish in the data set, the trend could be driven by a small number of these species. Natural resource management may also have an effect, especially considering that some of these species are of high commercial importance (Box 2).

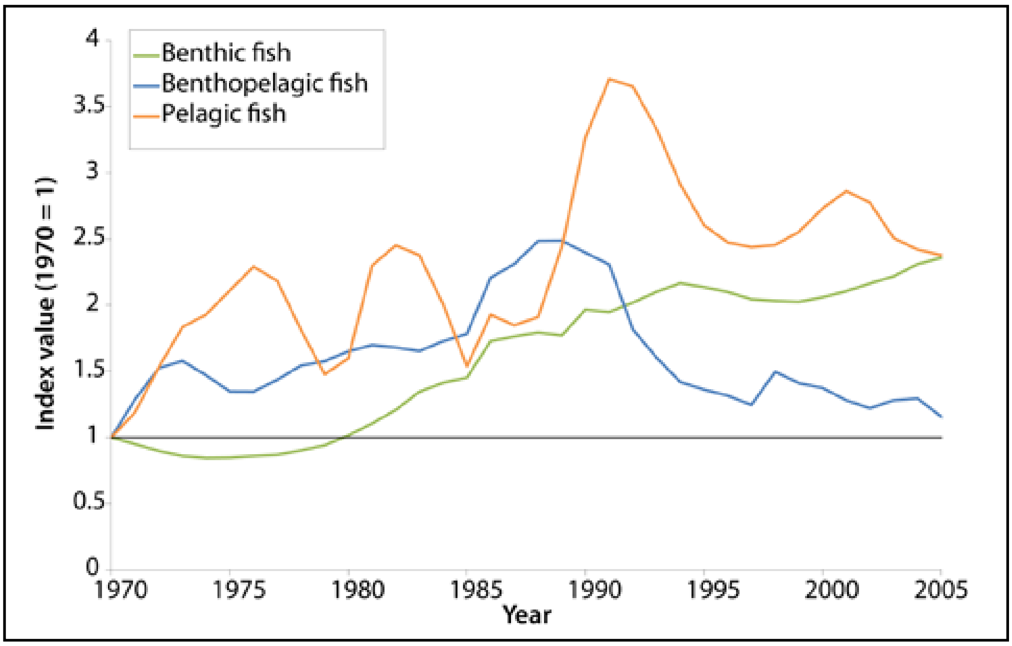


Figure 13. Indices of abundance for benthic, pelagic, and benthopelagic fish species from 1970 to 2005 .

Data sets comprised

- benthic fishes: 42 species, 63 populations;
- pelagic fishes: 7 species, 14 populations;
- benthopelagic fishes: 6 species, 21 populations.

Arctic char. Photo: Dan Bach Kristensen

Pelagic fish trends

To better understand the apparent cyclic pattern determined for the pelagic fish as shown in Figure 13, we compared the overall pelagic fish index to the established climate oscillations (Pacific, Decadal, Arctic, and North Atlantic). From this analysis there appeared to be a strong association between the overall pelagic fish index with the Arctic Oscillation index with peaks in the pelagic index in 1977, 1983, 1993, 2002, and 2009 generally tracking the peaks in the Arctic Oscillation. At this widespread scale, therefore, there does appear to be a link (Figure 14).

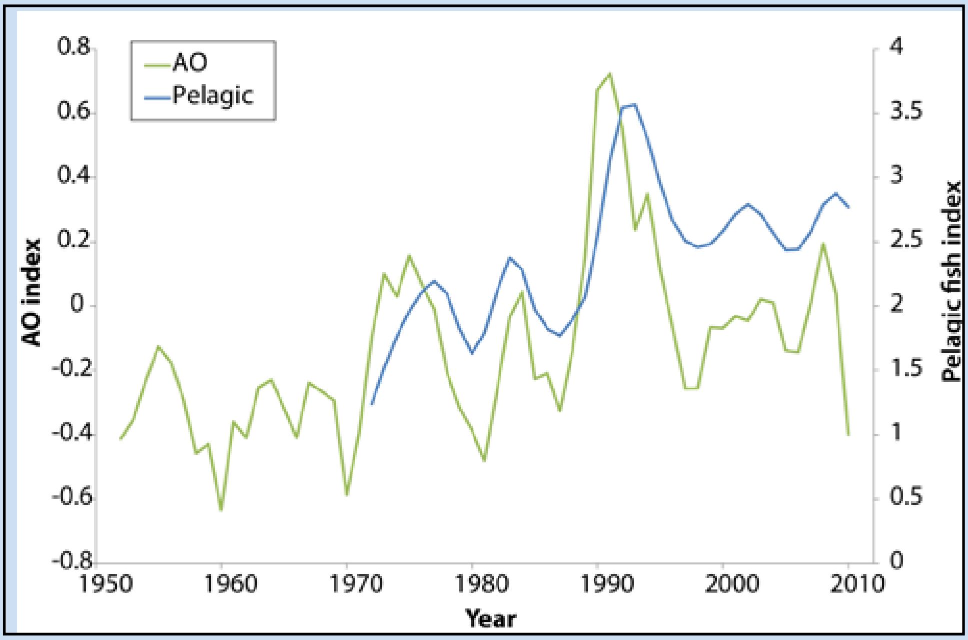


Figure 14. Comparison of the three year running average for the pelagic fish index and the Arctic Oscillation

Oscillation data from: http://www.esrl.noaa.gov/psd/data/correlation/ao.data

However, it is important to relate the pattern to habitat indicators that authors have identified as significant factors in the survival and thus productivity of pelagic species. For example, authors (NPFMC 2008) note that Pacific herring recruitment in the Togiak herring population (Bristol Bay, Alaska) is highly variable, with large year classes occurring at intervals of between nine and 10 years. Further, there is good evidence that environmental conditions—especially air and sea-surface temperature—relative to spawn run timing are important factors in determining Pacific herring recruitment in the Bering Sea (Williams & Quinn 2000).

Potential drivers of herring population change were examined in relation to the Togiak herring data set (NPFMC 2008). The indicators looked at were: sea-surface temperature (NOAA 2011); summer bottom temperature (Richter-Menge & J. Overland 2010); mean annual temperature (Geophysical Institute University of Alaska Fairbanks 2011); sea ice cover (Richter-Menge & J. Overland 2010). These were all highly variable and did not appear to peak on a nine to 10 year cycle as is suggested in the estimated herring population size. As an example, sea ice extent (plotted on a three year running average) is shown (Figure 15). This was the closest among the variables to

Herring. Photo: fanfo/Shutterstock.com relate to estimates of population abundance of herring in the Togiak region and illustrates that the drivers behind the herring cycles are not able to be explained by a single indicator but are influenced by a complex of factors.

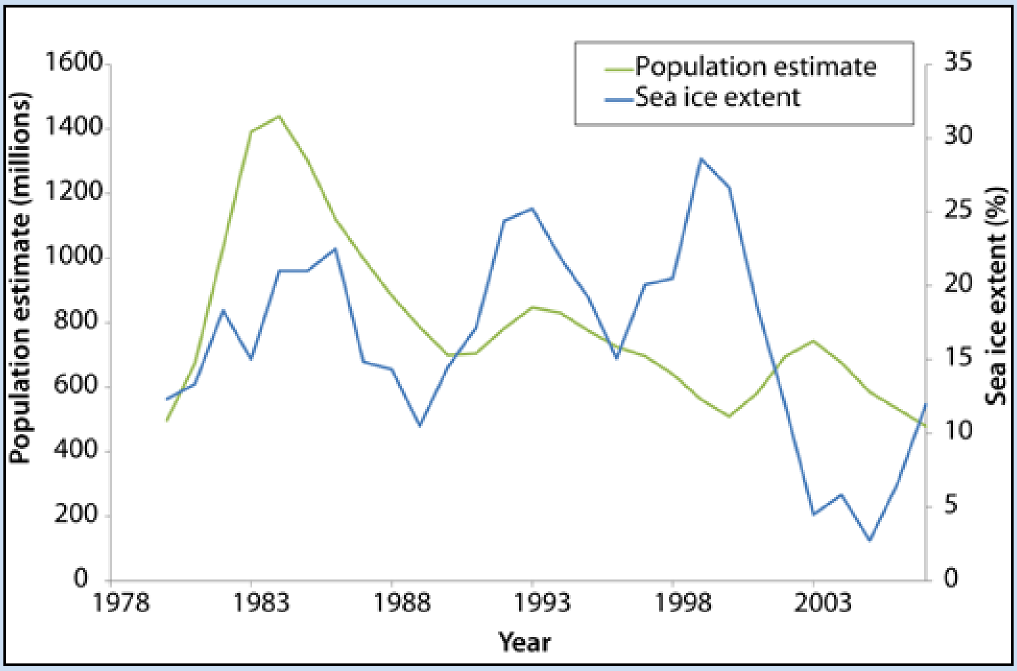


Figure 15. Comparison of estimated herring population size in the Bristol Bay area and the sea ice extent in the East Bering Sea

Both plotted as three year running averages. Herring data from NPFMC (2008) ; sea ice data from http://www.arctic.noaa.gov/reportcard

(Aydin & Mueter 2007)) provide a comprehensive overview of the complex interactions that may be responsible for the observed cyclical fish population trends in the southeastern Bering Sea. They report that the Bering Sea has experienced abrupt shifts in climatic conditions since the mid-1970s with associated food web shifts. The extent of sea ice and timing of ice retreat is critical for timing, overall biomass, and fate of primary production—which comprises mostly copepods, an important component of prey for various foraging fish species. Differences in bloom timing have favourable effects on either benthic or pelagic species. Cycles of density-dependent recruitment of various shorter-lived pelagic species, such as pollock are also likely to interact with the cycles in longer-lived, competitor benthic species such as flatfish.

Another factor not incorporated in these abiotic indicators is human harvest. The Bering Sea is one of the most productive fisheries in the world (Walsh *et al*. 1989) and its stocks have experienced a long history of exploitation, so the possible influence of fishing pressure should also be considered. The Pacific herring population discussed above is considered to be threatened by exploitation (NPFMC 2008). While overfishing is likely to directly cause a decrease in abundance of a fished species, the fishing pressure exerted on a stock could also have a more complex effect. Fishing effort and catch in the region are closely monitored, and adjustments are made to quota, based on past recruitment in the target species. It is possible that this adjustment of fishing pressure in response to recruitment could influence cyclical patterns observed (Williams & Quinn 2000). Furthermore, human pressures can and will interact in complex ways with the climatic changes observed in the Bering Sea.
This analysis is a good example of how a global scale index such as ASTI can reveal relationships with key drivers of species abundance when this is not possible through focussing on individual populations. The latter approach, however, is important in better understanding the mechanisms: how large-scale oscillations exert themselves on biodiversity and abundance and how factors not incorporated into simple global indices impact local populations.

Trophic level

Pursuing the theme of ecological interactions, Figure 16 shows the average rates of change broken down by the trophic level of the species. We might expect to see differences among the trophic levels in response to environmental fluctuations and the corresponding changes in foraging conditions. For example, impacts specific to piscivorous seabirds have been explored under scenarios of a changing climate (Stempniewicz *et al.* 2007). Therefore, we disaggregated the data for birds and fishes into fish-feeding and plankton-feeding species to see if there were any patterns in the rates of change.

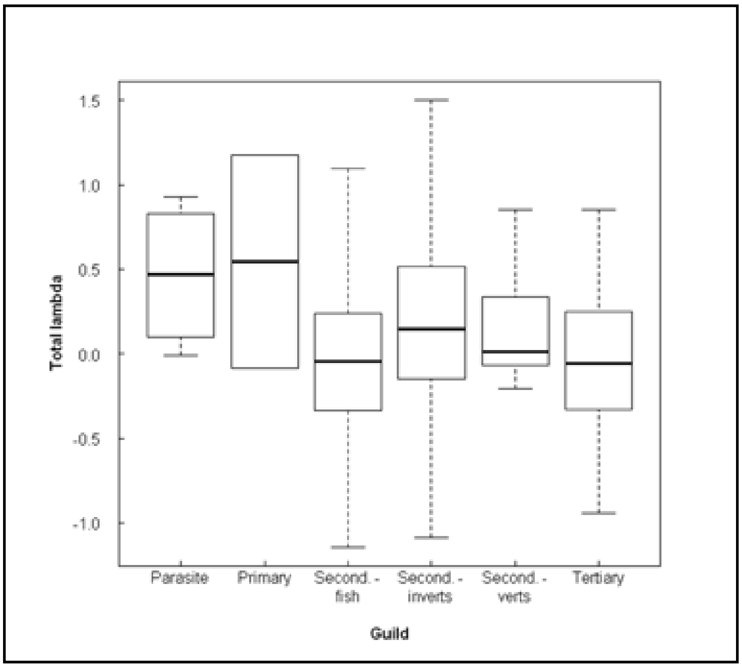


Figure 16. Box plot showing median rate of change by trophic level for parasites and for primary, secondary, and tertiary consumers

Data sets – parasites: 4 populations; primary consumers (Prim): 2 populations; secondary consumers of fish (Sec-fish): 183 populations; secondary consumers of invertebrates (Sec-inv): 68 populations; secondary consumers of other vertebrates (Sec-vert): 9 populations; tertiary consumers (Tert): 44 populations.

Box plot interpretation: the horizontal lines are the medians; the tops and bottom lines of the boxes represent the 75th and 25th percentiles respectively; the top and bottom end-points to the vertical dashed lines represent the 95th and 5th percentiles respectively.

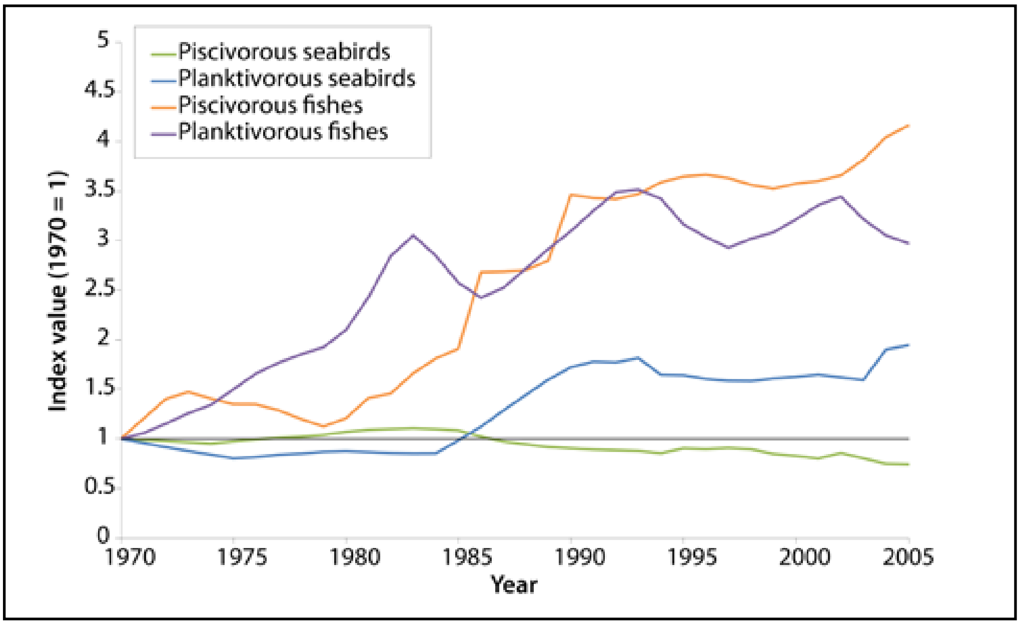
Total lambda is a measure of the rate of change over the entire time period

Figure 17 compares the resulting trends in fish and plankton feeding fish and birds. There is no clear difference in trends among the fish groups but the bird indices differ significantly after 1985. Unlike the fish, the trends in piscivorous birds are in concordance with the median negative rate of change for all secondary consumers of fish (Figure 16). The bird population declines in this data set could be a result of detrimental changes to foraging conditions as found in some species and locations (Byrd *et al*. 2008) or a response to an anthropogenic threat. The bird populations in question are affected by different threat types and levels, so it is not possible to make any overarching conclusions about the decline in piscivorous seabirds at this stage.

Figure 17. Trends in abundance indices for species of piscivorous and planktivorous birds and fishes from 1970 to 2005

Data sets

- piscivorous birds: 22 species, 116 populations;
- piscivorous fishes: 26 species, 44 populations;
- planktivorous birds: 4 species, 17 populations;
- planktivorous fishes: 15 species, 25 populations.



The underlying trends for tertiary consumers contrast with the common theme throughout these results of declines in bird populations and increases in mammals and fish (Appendix 2: Table of ANOVA results). The two eagle species in this category show an average increase whereas the populations of *Orcinus orca* (killer whale) and *Ursus maritimus* (polar bear) show an average decline. The fish data set is the largest in the tertiary consumer category and is dominated by *Gadus morhua* (Atlantic cod), *Sebastes marinus* (Ocean perch) and *Reinhardtius hippoglossoides* (Greenland halibut) populations which are driving the mean population rate of change in this group. The majority of populations of these species are threatened by exploitation so it is not surprising that the rate of change for tertiary fish and the overall average for the three classes is negative (Figure 16).

Conservation management trends

Anthropogenic threats

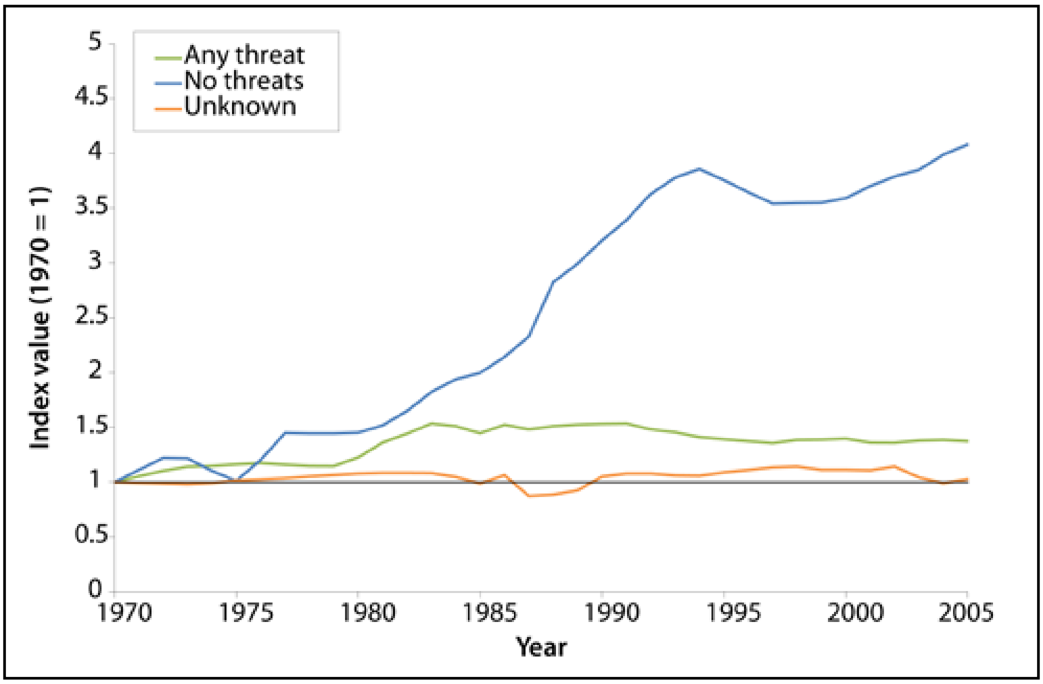
Examining anthropogenic threats to marine populations can give an indication of the predominant pressures affecting species abundance. For this analysis, populations that had an anthropogenic threat identified as being associated with them by the authors of the source document were considered to be under threat. Options for threat category are: 'habitat loss', 'habitat degradation', 'climate change', 'disease', 'pollution', 'exploitation', and 'invasive species'. Note that 'exploitation', which includes accidental mortality as well as harvesting, is therefore only associated with a population if it is identified as a threat to the population by the source author. Populations that were described as not currently threatened were placed in the 'no threats' category and the remaining ones with no information were tagged as 'unknown' (see data tagging in Appendix 1: Methods).

Figure 18 shows that, although encouragingly both threatened and non-threatened populations increased in abundance over the 35-year period, the trajectories of the two indices are substantially different. In addition, the populations under threat stabilised in abundance during the mid-1980s and have been in a slow decline ever since. The populations in the 'unknown' category have seen little change in abundance over this time but appear to be faring slightly worse than the threatened populations. This highlights the need to obtain more information on these data-poor species and locations.

Figure 18. Indices of abundance for populations by threat classification from 1970 to 2005

Data sets

- populations under any anthropogenic threat: 57 species, 110 populations;
- populations under no threat: 42 species, 57 populations;
- those for which no information is available: 49 species, 143 populations



For those populations that are identified as threatened, 'climate change' and 'exploitation' appear to be having the greatest effect on median rate of change (Figure 19). These results are significant; however the analysis includes data for populations where threat information is not known. When the 'unknown' and the 'no threat' categories are excluded from the analysis and the median rates of change are compared by taxonomic class, there are only significant differences by threat type for bird populations (Appendix 4: Table of index values). A negative rate of change is observed for populations threatened by 'climate change' and 'exploitation', which suggests that birds are driving the results for all classes in Figure 19.

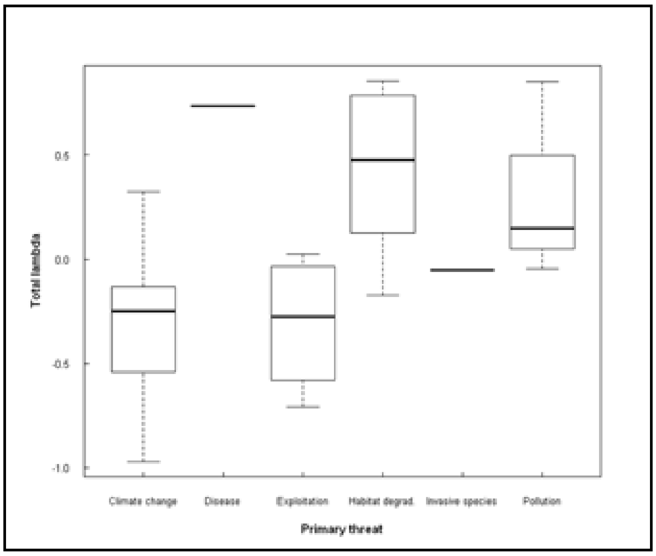


Figure 19. Box plot showing the median rates of change of bird populations for which a threat is identified , grouped by primary threat, 1970 to 2005.

Data sets – threats to bird populations: climate change (CC): 12 populations; disease: 1 population; exploitation (exploit) : 4 populations; habitat degradation (hab deg): 7 populations; invasive species (inv): 1 population; pollution: 3 populations.

Box plot interpretation: the horizontal lines are the medians; the tops and bottom lines of the boxes represent the 75th and 25th percentiles respectively; the top and bottom end-points to the vertical dashed lines represent the 95th and 5th percentiles respectively.

Total lambda is a measure of the rate of change over the entire time period.

Information on threats was collated from the data sources where the population data was published. Because the scope and objectives of each source document varied according to the subject the authors were tackling, there is some disparity in the amount of threat information that is available for each population. To make better use of the ASTI in tracking and understanding the impacts of these threats to Arctic biodiversity, it is therefore important to improve not only the animal population data, but also the quality, comparability, and coverage of data on threats to populations. Variables that can be used to predict changes in populations, including measures of anthropogenic threats, are discussed further in a report on spatial analysis of the ASTI data set (Bohm *et al.* 2012).

Protected areas

Table 3 shows the number of populations that occur within protected areas ('yes'), entirely outside protected areas ('no'), and not entirely within or without protected areas ('no – large survey area').
The trend analysis comparing protected and unprotected populations showed very similar levels of population change (Appendix 4: Table of index values). The protected populations are mainly bird species which would suggest that data are primarily from coastal locations. Most of the marine mammal and fish populations, however, are surveyed in such large areas that none of them are entirely protected.

Located within a protected area?	**Populations**		
	Mammals	Birds	Fishes
yes	21	95	4
no	7	30	12
no- large survey area	27	21	82
total "no"	34	51	94

Table 3. Total numbers of populations and species that are found inside and outside protected areas

Female and male common eiders. Photo: Micha Klootwijk/ Shutterstock.com

Although the overall indices of population change for vertebrates within protected areas and vertebrates not within protected areas are similar, if we look only at bird populations bird populations in protected areas are faring far better than their counterparts in unprotected areas (Figure 20). Bird populations in unprotected areas were found primarily along the west and northeast coast of Iceland, the Murmansk and Taimyr regions of Russia, and the northern part of Norway, including locations in the Barents Sea. Some of these regions have a long tradition of utilising seabird populations (Denlinger & Wohl 2001), although the number of species utilised and amount of harvest taken are often only a fraction of former levels (Merkel 2010). Hunting is strictly regulated in Norway and Svalbard and poses no particular threat (Bakken & Anker-Nilssen 2001). In Russia, Alcids can be hunted locally at particular times of the year, with no hunting allowed at sea in the Barents Sea region (Golovkin 2001).

One potential cause of decline (especially in past decades) of marine birds not in protected areas is the widespread utilisation of marine birds throughout the Arctic (Merkel & Barry 2008). Around the Arctic, the most common species harvested are Common murres and Common eiders, and the countries with the highest harvest levels are Iceland, Canada, and Greenland (Merkel 2010). The following section considers two measures recorded for each population time series in the data set: 1) is the population known to be utilised (through regular or systematic harvesting, including collection of eggs); and, 2) is the population thought to be impacted by exploitation (including both harvesting and accidental killing, for example though entanglement in fishing nets).

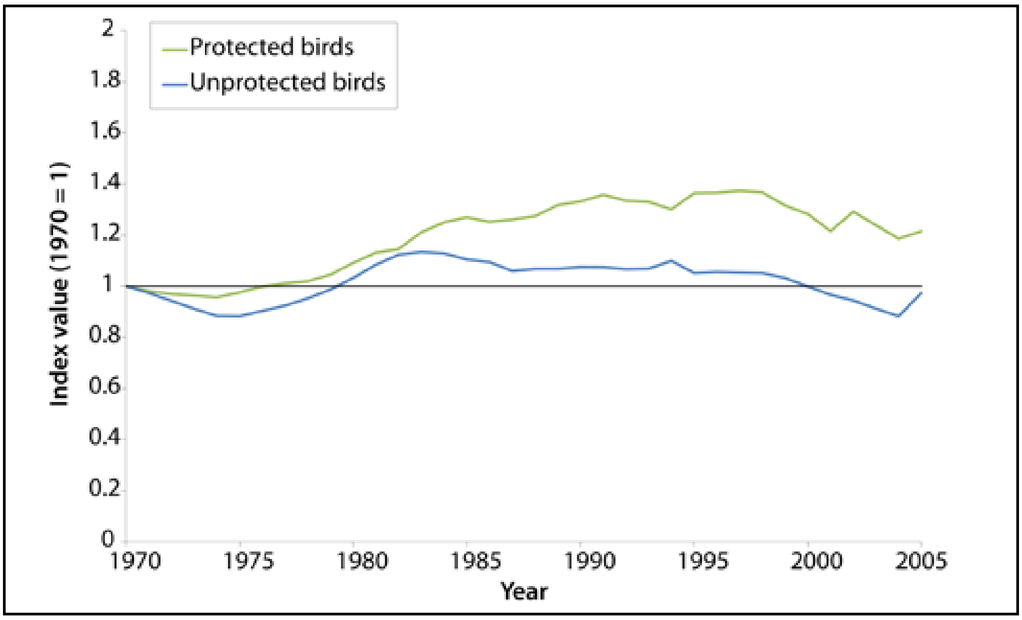


Figure 20. Indices of abundance for protected and unprotected bird populations from 1970 to 2005.

Data set

- protected: 30 species, 95 populations;
- unprotected: 17 species, 51 populations.

The harvest of seabirds used to be widespread in Norway and Svalbard but nowadays strict regulations and year-round protection of most species result in a very low harvest rate of an average of 5,000 birds per year, therefore not posing a particular threat (Merkel & Barry 2008). Of the 11 Norwegian populations, only two are threatened by exploitation (Steller's eider from Varangerfjord, and Common murre from Finnmark), but not being a target species and with no indication of being utilised could point to a potential impact from outside the country. In Russia, seabird harvest has never been of primary importance for the economy or local communities, with the exception of indigenous people inhabiting the north and far east of the country (Merkel & Barry 2008). No official figures on the harvest taken annually exist, but they are believed to be low, as most of the important bird colonies are now protected (Merkel & Barry 2008). Nevertheless, poaching could be a localized problem, especially in remote areas (Merkel & Barry 2008). Of the Russian populations in the data set, none are recorded as being utilised and only Steller's eider is considered to be threatened by exploitation. However, as this is a country-wide estimate, over-harvesting is unlikely to be the single reason for the observed decline in birds in unprotected areas.

One third of populations in the data set are explicitly not utilised; we only have information confirming utilisation for one population, which is *Somateria mollissima* (common eider) from southwest Iceland. The utilisation status for other populations is unknown. Interestingly, three different populations of black guillemot and northern fulmar are listed as being threatened by exploitation, although this is through bycatch and not intentional harvesting.

Overall, there is no evidence to suggest that unsustainable harvest could be the cause of declining trends in seabird populations outside of protected areas in the Arctic. But as the majority of population data sets are not accompanied by information on utilisation status or on exploitation as a potential threat (these sources are in languages other than English), this remains a possibility and could be further explored by improving the data on utilisation and exploitation and on focussing the analysis on species that are targeted for harvest or are vulnerable to other forms of exploitation.

Bird cliff. Photo: Maksimilian/Shutterstock.com

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Appendix 1: Methods

Population data

Time series trends for Arctic species were collated by CAFF´s CBMP and from the Living Planet Database (Loh *et al*. 2005; Collen *et al.* 2009; www.livingplanetindex.org). These data were collated from published scientific literature; online databases; Arctic researchers and institutions; and from grey literature.

Following Collen *et al*. (2009) data were only included if:

- measure or proxy measure of population size – e.g., full population count, biomass, catch per unit effort, density (Appendix Table 1- A) - was available for at least 2 years;
- information was available on how the data were collected and what the units of measurement were;
- the geographic location of the population was provided and lay within the defined Arctic boundaries;
- the data were collected using the same method on the same population throughout the time series; and,
- the data source was referenced and traceable.

Northern fulmar Photo: David Thyberg/Shutterstock.com

Appendix Table 1- A. Data type of populations by class

Data type	Mammals	Birds	Fish	Total
Biomass			68	68
Measure per unit effort	1		9	10
Populations estimate or count	34	86	9	129
Other	25	66	12	103

Data tagging

Ancillary information to the time series data was also collated at both the species and population level encompassing data on geographic, ecological and conservation management themes. Those tags used to disaggregate the marine data are detailed in Appendix Table 1- B.

Appendix Table 1- B. Population and species-based data tags

	Data tag	Details
	System	**Terrestrial; Freshwater; Marine**
Population based	Marine ocean	Atlantic; Pacific; Arctic
	Primary threat	Information on the primary anthropogenic threat to a population was recorded if available from the data source. Options for threat category are habitat loss, habitat degradation, climate change, disease, pollution, exploitation, invasive species, no threats, unknown
	Protected area	Yes; No (entirely outside protected areas); No – large survey area (population was surveyed in a large area and so not entirely inside or outside a protected area). The World Database on Protected Areas was used to discern protected area status (IUCN & UNEP-WCMC 2010)
	Sea ice association	Yes; No
Species based	Trophic level	Parasite; Primary consumer; Secondary consumer (fish); Secondary consumer (invertebrates); Secondary consumer (vertebrates); Tertiary consumer
	Marine zone	Benthic (living and feeding near the bottom of the ocean); pelagic (living and feeding in the open sea); benthopelagic (living and feeding near the bottom of the ocean as well as in midwater and near the surface or species which hover or swim just over the sea floor – (Froese & Pauly 2011))
	Taxonomic class	Birds; mammals; fish (as there are only three Elasmobranch species in the data set, we grouped these with Actinopterygii to create one fish class)

Trend analysis

For the marine ASTI, data were averaged at the species level (equal weight per species). ANOVA analyses, however, were conducted at the population level.

All analyses were carried out in R version 2.12.0 (R Development Core Team 2006). Indices of change in marine species abundance were calculated using a Generalised Additive Modelling (GAM) framework to obtain population trends and then a geometric aggregation method following Collen *et al.* (2009) to produce an index of change. The data set was disaggregated according to the data tags above to look for underlying trends in the marine data. In order to test the significance of several variables in association with population change, we first computed three measures from the raw population trend time series data. These were:

- slope of a linear regression of year against population size (LRS);
- mean annual change in population size calculated using a GAM framework (MAC); and
- total change in population size over time using a GAM framework (TC).

We obtained three change measures for each population and species by generating the logged trend values and mean logged trend values respectively from the individual population time series calculated by each of the methods above. We carried out ANOVAs to trial each of the three measures of population change against each of the discontinuous variables and linear regressions of population change against each of the two continuous variables. Very few significant results were produced at the species level so we have reported only those significant results at the population level (see Appendix 2: Table of ANOVA results) and as we were interested in the most variance, the trend value we selected to report on was measuring total change (TC), also referred to as total lambda over time as was used on similar analyses (Collen *et al.* 2011). We displayed box plots for significant results where relevant.

Appendix 2: Table of ANOVA results

Factor	Total lambda				
	df	Sum sq	Mean sq	F value	p value
Class	2	1.387	0.69344	1.5972	0.2041
Primary threat (incl Unknown/No; all spp)	8	11.893	1.48661	3.6444	0.0004551 ***
Primary threat (incl Unknown/No; birds)	8	6.415	0.8019	2.2363	0.02805 *
Primary threat (incl Unknown/No; fish)	4	5.321	1.33028	2.9809	0.02302 *
Primary threat (incl Unknown/No; mammals)	5	4.981	0.9962	2.2612	0.0612300000
Primary threat (excl Unknown/No; all spp)	5	2.687	0.53738	1.4981	0.1968000000
Primary threat (excl Unknown/No; birds)	5	4.1466	0.82931	4.3431	0.006696 **
Primary threat (excl Unknown/No; fish)	1	0.1133	0.11331	0.2265	0.6360000000
Primary threat (excl Unknown/No; mammals)	2	0.1311	0.065545	0.3734	0.6927000000
Protected location	3	2.276	0.75881	1.7538	0.1560
Protected vs unprotected - all spp (Yes and No only)	1	1.425	1.42516	3.1105	0.0796
Protected vs unprotected - birds (Yes and No only)	1	2.591	2.5911	6.9899	0.009265 **
Protected vs unprotected - fish (Yes and No only)	1	0.046	0.04597	0.1007	0.7556
Protected vs unprotected - mammals (Yes and No only)	1	0.5361	0.53614	0.7003	0.4103
Protected vs unprotected - all spp (Yes, No, Large=No)	1	0.621	0.62081	1.4107	0.2359
Protected vs unprotected - birds (Yes, No, Large=No)	1	0.003627	0.003627	4.3371	0.03906 *
Protected vs unprotected - fish (Yes, No, Large=No)	1	0.511	0.51113	1.0595	0.3059
Protected vs unprotected - mammals (Yes, No, Large=No)	1	0.5509	0.55085	1.1622	0.2859
Ocean basin	2	7.126	3.5631	8.5762	0.0002375 ***
Ocean - birds	2	1.974	0.98697	2.6393	0.0748
Ocean - fish	2	7.682	3.8409	9.3222	0.0002011 ***
Ocean - mammals	2	0.0798	0.03992	0.0793	0.9239
Bering Sea split (Bering vs Rest; all spp)	1	1.376	1.3763	3.1801	0.0755
Bering Sea split (Bering vs Rest; birds)	1	0.086	0.08641	0.225	0.6360
Bering Sea split (Bering vs Rest; fish)	1	1.74	1.74006	3.7052	0.0572
Bering Sea split (Bering vs Rest; mammals)	1	0.0024	0.00238	0.0048	0.9450
Trophic level	5	5.285	1.05703	2.4835	0.03176 *
Tertiary consumer by class	2	3.683	1.8415	5.0372	0.01106 *
Sea-ice association	1	0	0.00005	0.000100	0.9919
Marine zone - benthic, pelagic, benthopelagic	2	2.129	1.06443	2.465400	0.0867
Marine zone - fish	2	3.125	1.56266	3.3972	0.03758 *
Marine zone - birds	2	0.001112	0.000556	0.668100	0.5142
Protected location (all spp)	3	2.276	0.75881	1.7538	0.1560
PA type (all, incl unprotected)	3	1.111	0.37043	0.8487	0.4682
PA type (yes and both only)	3	2.138	0.71253	1.8886	0.1348
Depth stratum	2	2.782	1.391	3.2378	0.04060 *
Depth stratum (fish)	1	0.103	0.10285	0.2113	0.6468
Utilised (all spp)	2	0.304	0.15193	0.3471	0.71
Utilised (fish)	2	0.91	0.4551	0.9417	0.39

Highlighted cells denote significant results
* significant at $p<0.05$ level
** significant at $p<0.01$ level
*** significant at $p<0.001$ level

Appendix 3: List of monitored species and locations

Class	Binomial	Common name(s)	Country	Location of Population
Fishes	*Albatrossia pectoralis*	Giant grenadier	United States	Eastern Bering Sea
	Anoplopoma fimbria	Sablefish	United States	Bering Sea, Aleutian Islands and Gulf of Alaska
	Atheresthes evermanni	Kamchatka flounder	United States	Bering Sea
	Atheresthes stomias	Arrowtooth flounder	United States	East Bering Sea and Aleutian Islands
	Bathyraja parmifera	Alaska skate	United States	Bering Sea / Aleutian Islands
	Boreogadus saida	Arctic cod	United States	Sagavanirktok Delta, Alaska
			Norway	Barentshavet
	Brevoortia tyrannus	Herring	Iceland	Icelandic summer-spawning herring (Division Va)
	Brosme brosme	Tusk	Iceland	Icelandic shelf
	Clupea pallasii	Pacific herring	United States	East Bering Sea
			United States	Togiak district of Bristol Bay, Alaska
	Coregonus autumnalis	Arctic cisco	United States	Colville River delta
	Coryphaenoides acrolepis	Pacific grenadier	United States	Eastern Bering Sea
	Coryphaenoides cinereus	Popeye grenadier	United States	Eastern Bering Sea
	Eleginus gracilis	Saffron cod	United States	Sagavanirktok Delta, Alaska
	Embassichthys bathybius	Deepsea sole	Russian Federation	Northern Kuril Islands and Southeastern Kamchatka
	Gadus macrocephalus	Pacific cod	United States	Eastern Bering Sea and Aleutian Islands
	Gadus morhua	Atlantic cod	Canada	NAFO divisions 2GH, Northern Labrador cod stock
			Greenland	Greenland offshore component
			Iceland	ICES Division Va (Icelandic)
			Canada	NAFO 2J3KL
			Norway	North East Arctic
	Gasterosteus aculeatus	Three spined stickleback	Russian Federation	Gorelyi Island, Kandalaksha Bay, White Sea, Russia
			Russian Federation	Seldianaya Inlet, Kandalaksha Bay, White Sea, Russia
	Glyptocephalus stelleri	Korean flounder	Russian Federation	Northern Kuril Islands and Southeastern Kamchatka
	Glyptocephalus zachirus	Rex sole	United States	Aleutian islands
			United States	Eastern Bering sea shelf
			Russian Federation	Northern Kuril Islands and Southeastern Kamchatka

Class	Binomial	Common name(s)	Country	Location of Population
	Hemilepidotus jordani	Yellow Irish lord	United States	Aleutian islands
			United States	Bering Sea shelf
	Hemitripterus bolini	Bigmouth sculpin	United States	Aleutian Islands
			United States	Bering Sea shelf
	Hippoglossoides elassodon	Flathead sole	United States	Eastern Bering Sea
	Hippoglossoides platessoides	American plaice	Canada	Newfoundland region (3K)
			Canada	Newfoundland region (3Ps)
			Greenland	West Greenland
	Hippoglossoides robustus	Bering flounder	United States	Eastern Bering Sea
	Isopsetta isolepis	Butter sole	United States	Aleutian Islands
			United States	Eastern Bering Sea shelf
	Lepidopsetta bilineata	Rock sole	United States	East Bering Sea
	Lepidopsetta polyxystra	Northern rock sole	United States	Aleutian Islands
			United States	Bering Sea
	Limanda aspera	Yellowfin sole	United States	Eastern Bering Sea
			Russian Federation	W Kamchatka shelf
	Limanda proboscidea	Longhead dab	United States	Eastern Bering Sea shelf
			Russian Federation	W Kamchatka shelf
	Limanda sakhalinensis	Sakalin flounder	Russian Federation	West Kamchatka Shelf
			United States	Eastern Bering Sea shelf
	Liopsetta glacialis	Arctic flounder	United States	Sagavanirktok Delta, Alaska
	Malacocottus kincaidi	Blackfin sculpin	United States	Aleutian Islands
	Mallotus villosus	Capelin	Russian Federation	Barents Sea
			Norway	Barentshavet
			Iceland	Iceland-East Greenland-Jan Mayen area
			Canada	NAFO 0 to 4
	Melanogrammus aeglefinus	Haddock	Iceland	Division Va (Iceland)
			Faroe Islands	ICES Division Vb (Faroe)
			Norway	Northeast Arctic haddock (Sub-areas I and II)
	Microstomus achne	Slime flounder	Russian Federation	Northern Kuril Islands and Southeastern Kamchatka

Class	Binomial	Common name(s)	Country	Location of Population
	Microstomus pacificus	Dover sole	United States	Aleutian Islands
			United States	Eastern Bering Sea shelf
	Myoxocephalus jaok	Plain sculpin	United States	Bering Sea shelf
	Myoxocephalus polyacanthocephalus	Great sculpin	United States	Aleutian Islands
			United States	Bering Sea shelf
	Myoxocephalus verrucosus	Warty sculpin	United States	Bering Sea shelf
	Osmerus mordax	Atlantic rainbow smelt	United States	Sagavanirktok Delta, Alaska
	Parophrys vetulus	English sole	United States	Aleutian Islands
	Platichthys stellatus	Starry flounder	United States	Aleutian Islands
			United States	Eastern Bering Sea shelf
	Pleurogrammus monopterygius	Atka mackerel	United States	Aleutian Islands
			Russian Federation	Petropavlovsk-Commander zone, off Kamchatka Peninsula
	Pleuronectes quadrituberculatus	Alaska plaice	United States	Eastern Bering Sea
			Russian Federation	West Kamchatka shelf
	Pollachius virens	Pollock or Saithe	Faroe Islands	Faroe saithe (Division Vb)
			Iceland	Icelandic (Division Va)
			Norway	North-East Arctic saithe (Sub-areas I and II).
	Reinhardtius hippoglossoides	Greenland halibut	United States	East Bering Sea and Aleutian Islands
			Norway	ICES Subareas I & II.
			Greenland	ICES v and xiv
			Greenland	NW Atlantic
	Sebastes alutus	Pacific ocean perch	United States	Aleutian Islands
	Sebastes borealis	Shortraker rockfish	United States	Bering Sea / Aleutian Islands
	Sebastes marinus	Ocean perch	Iceland	Iceland
			Greenland	ICES v and xiv
			Canada	NAFO divisions 2J3K
			Norway	NE Arctic
	Sebastes mentella	Deepwater redfish	Norway	Norwegian Barents Sea and Svalbard
	Sebastes polyspinis	Northern rockfish	United States	Bering Sea / Aleutian Islands
	Somniosus pacificus	Pacific sleeper shark	United States	Aleutian Islands
			United States	Eastern Bering Sea shelf

Class	Binomial	Common name(s)	Country	Location of Population
	Squalus acanthias	Spiny dogfish	United States	Aleutian Islands
			United States	Eastern Bering Sea shelf
	Theragra chalcogramma	Walleye pollock	United States	Aleutian Islands
			United States	Bogoslof Island region
			Russian Federation	East Kamchatka
			United States	Eastern Bering Sea
			United States	Shelikof Strait, Gulf of Alaska
			Russian Federation	West Bering Sea
	Triglops scepticus	Spectacled sculpin	United States	Aleutian Islands
Birds	*Alca torda*	Razorbill	Iceland	Hafnaberg, South-West Iceland
			Norway	Hjelmsøy, Måsøy, Finnmark
			Iceland	Krisuvikurberg (Krisuvik), SW Iceland
			Iceland	Skoruvik, NE Iceland
	Cepphus Columba	Pigeon Guillemot	United States	Buldir Island, Alaska
			United States	Kasatochi Island, Alaska
	Cepphus grille	Black Guillemot	United States	Cooper Island, Alaska
			Iceland	Flatey Island, Breioafjorour Bay, Northwest Iceland
			Iceland	Strandasysla Coastline, NW-Iceland
	Clangula hyemalis	Long-tailed Duck	Russian Federation	Bering Island coast
			Canada	Southern Plain, Sirmilik National Park, Bylot Island, (Qarlikturvik Valley /main goose nesting colony)
			Russian Federation	Taimyr Peninsula
			Greenland	The Karupelv Valley Project, Traill O, Kong Oscars Fjord, North-East Greenland
			Greenland	Zackerbergdalen, Northeast Greenland
	Fratercula arctica	Atlantic Puffin	Russian Federation	Aynov Island, Murmansk, Russia
			Russian Federation	Bol'shoy Aynov Island
			Russian Federation	Gavriloski Island
			Norway	Hornøy,Vardø,Finnmark
			Russian Federation	Maly Aynov Island
			Norway	Rost Islands
			Russian Federation	Seven Islands
	Fratercula cirrhata	Tufted Puffin	United States	E. Amatuli Island, Alaska

Class	Binomial	Common name(s)	Country	Location of Population
	Fulmarus glacialis	Northern Fulmar	United States	Chowiet Island, Alaska
			Iceland	Hafnaberg, South-West Iceland
			United States	Hall Island, Alaska
			Iceland	Krisuvikurberg (Krisuvik), SW Iceland
			Canada	Prince Leopold Island, Nunavut
			Iceland	Skoruvik, NE Iceland
			United States	St George Island, Alaska
			United States	St. Paul Island, Alaska
	Gavia pacifica	Pacific Loon	United States	Yukon-Kuskokwim delta
	Haliaeetus albicilla	White-tailed Eagle	Finland	Northern Finland
			Sweden	Northern Sweden
			Iceland	West coast of Iceland
	Haliaeetus leucocephalus	Bald Eagle	United States	Adak Island, Rat Island group, Aleutian Islands, Alaska
			United States	Amchitka Island, Rat Island group, Aleutian Islands, Alaska
			United States	Kiska Island, Andreanof group, Aleutian Islands, Alaska
			United States	Tanaga Island, Andreanof group, Aleutian Islands, Alaska
	Haliaeetus pelagicus	Steller's Sea Eagle	Russian Federation	Kurilskoe Lake, Kamchatka
	Histrionicus histrionicus	Harlequin Duck	Russian Federation	Bering Island coast
	Larus argentatus	Herring Gull	Russian Federation	Agapa River Valley, Taimyr
			Iceland	Iceland
			Norway	Nordland (Sortlandssundet)
			Canada	Quebec
			Russian Federation	Seven Islands, Murmansk
	Larus canus	Mew Gull	Russian Federation	Bolshoi Ainov, Murmansk
			Norway	Pasvik naturreservat,Sør- Varanger,Finnmark
			Russian Federation	Seven Islands, Murmansk
			United States	Yukon-Kuskokwim delta
	Larus glaucescens	Glaucous-winged Gull	United States	Bogoslof Island, Alaska
			United States	Buldir Island, Alaska
			United States	Kasatochi Island, Alaska
			United States	Puale Bay, Alaska

Class	Binomial	Common name(s)	Country	Location of Population
	Larus glaucoides	Iceland Gull	Greenland	Nordre Strømfjord
	Larus hyperboreus	Glaucous Gull	Russian Federation	Kolguev Island, Russia
			Greenland	Region 2, central West Greenland
			Greenland	Region 3, central West Greenland
			Canada	Southern Plain, Sirmilik National Park, Bylot Island, (Qarlikturvik Valley /main goose nesting colony)
			United States	Yukon-Kuskokwim delta
	Larus marinus	Great Black-backed Gull	Norway	Nordland (Sortlandssundet
			Greenland	Nordre Strømfjord
	Morus bassanus	Northern Gannet, Gannet	Iceland	Austursvaeoio (Eastern Group) including Rauoinupur, Skoruvik, and Skruour
			Iceland	Eldey Island, Southwest Iceland
			Iceland	Vestmannaeyjar (Vestman Islands), Southwest Iceland
	Oceanodroma furcata	Fork-tailed Storm-petrel	United States	E. Amatuli Island, Alaska
	Pagophila eburnean	Ivory Gull	Russian Federation	Franz Josef Land
			Russian Federation	Various in Canada, Greenland, Russia, Norway (midpoint latitude below)
	Phalacrocorax aristotelis	European Shag	Norway	Sør- Varanger, Sør- Varanger, Finnmark
			Iceland	West Iceland, Iceland
	Phalacrocorax pelagicus	Pelagic Cormorant	United States	Buldir Island, Alaska
			United States	Cape Peirce, Alaska
			United States	Chiniak Bay, Alaska
			United States	Hall Island, Alaska
	Phalacrocorax urile	Red-faced Cormorant	United States	Chiniak Bay, Alaska
	Polysticta stelleri	Steller's Eider	Russian Federation	Bering Island coast
			Russian Federation	Taimyr Peninsula
			Russian Federation	Total species
			Norway	Varangerfjord, northern Norway
	Rissa brevirostris	Red-legged Kittiwake	United States	Buldir Island, Alaska
			United States	St George Island, Alaska
			United States	St. Paul Island, Alaska
	Rissa tridactyla	Black-legged Kittiwake	United States	Agattu Island, Alaska
			Russian Federation	Arkhangelskaya Bay, Novaya Zemya

Class	Binomial	Common name(s)	Country	Location of Population
			Svalbard and Jan Mayen Islands	Bear Island
			United States	Bluff, Alaska
			United States	Buldir Island, Alaska
			United States	Cape Lisburne, Alaska
			United States	Cape Peirce, Alaska
			United States	Chiniak Bay, Alaska
			United States	Chowiet Island, Alaska
			Iceland	Hafnaberg, South-West Iceland
			United States	Hall Island, Alaska
			Norway	Hjelmsøy, Måsøy, Finnmark
			Norway	Hornøy, Vardø, Finnmark
			Russian Federation	Kharlov, Murman coast, North-West Russia
			United States	Koniuji Island, Alaska
			Iceland	Krisuvikurberg (Krisuvik), SW Iceland
			Canada	Prince Leopold Island, Nunavut
			United States	Puale Bay, Alaska
			Norway	Røst, Røst, Nordland
			United States	Round Island, Alaska
			Russian Federation	Rubini Rock, Hooker Island, Franz Josef Land
			Iceland	Skoruvik, NE Iceland
			Norway	Sør- Varanger,Sør- Varanger,Finnmark
			United States	St George Island, Alaska
			United States	St. Paul Island, Alaska
	Somateria mollissima	Common Eider	Russian Federation	Bering Island coast
			Iceland	Nordurkot, Reykjanesbaer, southwest Iceland
			United States	Yukon-Kuskokwim delta
			Greenland	Zackerbergdalen, Northeast Greenland
	Stercorarius longicaudus	Long-tailed Jaeger	Canada	Southern Plain, Sirmilik National Park, Bylot Island, (Qarlikturvik Valley /main goose nesting colony)
			Greenland	The Karupelv Valley Project, Traill O, Kong Oscars Fjord, North-East Greenland
	Stercorarius parasiticus	Arctic Jaeger, Parasitic Jaeger, Arctic Skua	Russian Federation	Kharlov Island, Murmansk Coast

Class	Binomial	Common name(s)	Country	Location of Population
			Norway	Slettnes,Gamvik,Finnmark
	Sterna paradisaea	Arctic tern	Russian Federation	Oneshski Bay, White Sea, Russia
			Norway	Pasvik naturreservat,Sør- Varanger,Finnmark
			Russian Federation	Seven Islands, Murmansk Coast, Russia
			Greenland	The 4 islands of Gronne Ejland
			United States	Yukon-Kuskokwim delta
	Uria aalge	Common Guillemot	Iceland	Hafnaberg, South-West Iceland
			Russian Federation	Karlov Island, Murmansk, Russia
			Iceland	Krisuvikurberg (Krisuvik), SW Iceland
			Iceland	Skoruvik, NE Iceland
			Norway	Syltefjord, Finmark, Norway
			Svalbard and Jan Mayen Islands	Bear Island, Norway
			Norway	Hjelmsøy, Måsøy, Finnmark
			Norway	Hornnøy, Vardø, Finnmark
			Norway	Sor-Fugloy, Troms, Norway
			Norway	Vedøy, Vedøy, Nordland
			United States	Bluff, Alaska
			United States	Cape Peirce, Alaska
			United States	Hall Island, Alaska
			United States	Round Island, Alaska
			United States	St George Island, Pribilofs
			United States	St Paul Island, Pribilofs
			United States	St. Lawrence Island
	Uria lomvia	Thick-billed Guillemot	Canada	Coats Island, Nunavut
			Iceland	Hafnaberg, South-West Iceland
			Iceland	Krisuvikurberg (Krisuvik), SW Iceland
			Canada	Prince Leopold Island, Nunavut
			Iceland	Skoruvik, NE Iceland
			Russian Federation	Bezymyannaya bay
			Norway	Hornoya
			Greenland	Kap Brewster
			Russian Federation	Kharlov Island

Class	Binomial	Common name(s)	Country	Location of Population
			Svalbard and Jan Mayen Islands	Svalbard
			United States	Buldir Island
			United States	Hall Island, Alaska
			United States	St George Island, Pribilofs
			United States	St Paul Island, Pribilofs
			United States	St. Lawrence Island
	Xema sabini	Sabine's Gull	United States	Yukon-Kuskokwim delta
Mammals	*Balaena mysticetus*	Bowhead whale	United States	Western Arctic stock, Alaska (aka Bering-Chukchi-Beaufort stock).
	Balaenoptera acutorostrata	Minke whale	Norway	Barentshavet, Grønlandshavet, Norskehavet og Nordsjøen
			Iceland	Icelandic coastal waters
			United States	Pribilof Isalnds, Bering Sea
	Balaenoptera borealis	Sei whale	Iceland	Icelandic coastal waters
	Balaenoptera musculus	Blue whale	Iceland	Icelandic coastal waters
	Balaenoptera physalus	Fin whale	Greenland	Greenland
			Iceland	Iceland
			Iceland	Icelandic coastal waters
			Canada	Newfoundland
			United States	Pribilof Islands, Bering Sea
	Callorhinus ursinus	Northern fur seal	United States	St. George Island (in the Pribilof Islands part of the Aleutian Islands), Alaska
			United States	St. Paul Island (in the Pribilof Islands part of the Aleutian Islands), Alaska
	Delphinapterus leucas	Beluga	United States	Cook Inlet stock, Alaska
			Canada	Eastern Hudson Bay population
			United States	Eastern Chukchi Sea Stock, Alaska
			United States	Norton Sound, Alaska
	Enhydra lutris	Sea otter	United States	Adak Island, Aleutian Islands, Alaska
			Russian Federation	Bering Island, Russia
			United States	Delarof Islands, Aleutian Islands, Alaska.
			United States	Fox Island, Aleutian Islands, Alaska
			United States	Near Islands, Aleutian Islands, Alaska.

Class	Binomial	Common name(s)	Country	Location of Population
			United States	North Alaskan peninsula, northeast (offshore)
			United States	North Alaskan peninsula, southwest (offshore)
			United States	Rat Islands, Aleutian Islands, Alaska.
			United States	South Alaska peninsula, coastline of 22 islands.
			United States	South Alaska peninsula, False Pass to Cape Douglas, coastal
			United States	South Alaskan Peninsula from (offshore) from the Ikatan Peninsula to Shumagin Islands
	Eschrichtius robustus	Gray whale	United States	Northern Bering Sea including St Lawrence Island
			United States	Pribilof Islands, Bering Sea
	Eumetopias jubatus	Steller sea lion	United States	Alaska - Western stock
			United States	Central Aleutian Islands
			United States	Eastern Aleutian Islands
			Russian Federation	Kuril Islands
			United States	Western Aleutian Islands
	Globicephala melas	Long finned pilot whale	Iceland	Icelandic coastal waters
	Hyperoodon ampullatus	Northern bottlenose whale	Iceland	Icelandic coastal waters
	Megaptera novaeangliae	Humpback whale	Iceland	Icelandic coastal waters
			United States	Pribilof Islands, Bering Sea
	Monodon monoceros	Narwhal	Canada	Hudson Bay, Canada
	Odobenus rosmarus	Pacific walrus	United States	Bering and Chukchi seas of Alaska and Russia
	Orcinus orca	Killer whale	Iceland	Icelandic coastal waters
			United States	Pribilof Islands, Bering Sea
	Phoca vitulina	Harbour Seal	United States	Otter Island, Bering Sea, Alaska
			United States	Nanvak Island, Alaska
			Sweden	Northern Sweden
			United States	Tugidak Island, Alaska
	Phocoena phocoena	Harbour porpoise	Iceland	Icelandic coastal waters
	Phocoenoides dalli	Dall's porpoise	United States	Pribilof Islands, Bering Sea
	Physeter catodon	Sperm whale	Iceland	Icelandic coastal waters
	Pusa hispida	Ringed seal	Canada	eastern Beaufort Sea
	Ursus maritimus	Polar bear	United States	Alaskan Stock

Class	Binomial	Common name(s)	Country	Location of Population
			Canada	Baffin Bay
			United States	Chukchi/Bering Sea stock
			Canada	Davis Strait
			Canada	Northern Beaufort Sea population
			United States	Southern Beaufort population
			Canada	Southern Hudson Bay population
			Canada	Western Hudson Bay population
			Russian Federation	Wrangel Island State Nature Reserve

Appendix 4: Table of index values

The table presents five yearly index values and number of populations for each Arctic index shown in the report.

	1970	1975	1980	1985	1990	1995	2000	2005
ASTI 2011	1	1.009841	1.078684	1.150389	1.239031	1.218304	1.165219	1.21232
Lower confidence interval	1	0.948302	0.99796	1.04626	1.104754	1.075185	1.017745	1.048901
Upper confidence interval	1	1.076369	1.167175	1.266994	1.39765	1.385632	1.334767	1.402085
Number of populations	224	283	353	411	469	571	619	503
Marine								
Marine species	1	1.114247	1.317582	1.572679	1.882688	1.968758	1.895275	1.93523
Lower confidence interval	1	0.965039	1.113791	1.288609	1.474931	1.525575	1.453415	1.464981
Upper confidence interval	1	1.308125	1.589431	1.93303	2.413804	2.549569	2.471473	2.556968
Number of populations	68	99	145	195	216	231	222	165
Marine birds	1	0.997764	1.122378	1.28987	1.314885	1.331219	1.236808	1.211394
Lower confidence interval	1	0.91827	1.005529	1.125928	1.086834	1.061118	0.982468	0.8691
Upper confidence interval	1	1.095847	1.244867	1.450622	1.599749	1.643055	1.593717	1.56662
Number of populations	34	49	74	103	115	124	115	92
Marine mammals	1	1.202454	1.722755	1.827424	1.9627	2.533504	2.476332	2.214405
Lower confidence interval	1	1.027889	1.17436	1.237401	1.050436	1.270725	1.280015	1.055701
Upper confidence interval	1	1.389616	2.353404	2.643598	3.846035	4.651949	4.267893	3.836428
Number of populations	10	20	25	34	41	46	43	10
Marine fishes	1	1.215079	1.331957	1.77474	2.579227	2.479329	2.424314	2.600284
Lower confidence interval	1	0.946687	1.017399	1.284341	1.701527	1.640312	1.623004	1.753774
Upper confidence interval	1	1.946065	2.077843	3.020004	4.347044	4.332616	4.05346	4.443767
Number of populations	24	30	46	58	60	61	64	63
Taxonomic effect								
Marine	1	1.114247	1.317582	1.572679	1.882688	1.968758	1.895275	1.93523
Lower confidence interval	1	0.965039	1.113791	1.288609	1.474931	1.525575	1.453415	1.464981
Upper confidence interval	1	1.308125	1.589431	1.93303	2.413804	2.549569	2.471473	2.556968
Number of populations	68	99	145	195	216	231	222	165

	1970	1975	1980	1985	1990	1995	2000	2005
Minus birds	1	1.218977	1.50363	1.84363	2.4109	2.561966	2.5081	2.616509
Lower confidence interval	1	0.952601	1.117566	1.328514	1.641212	1.717797	1.663814	1.710984
Upper confidence interval	1	1.614112	2.088935	2.629027	3.649082	3.901905	3.83919	4.059243
Number of populations	34	50	71	92	101	107	107	73
Minus fishes	1	1.041276	1.273508	1.421223	1.46926	1.636768	1.550269	1.496136
Lower confidence interval	1	0.959672	1.111677	1.201662	1.152716	1.261503	1.176684	1.10393
Upper confidence interval	1	1.13158	1.481346	1.720099	1.908795	2.15271	2.058076	2.043897
Number of populations	44	69	99	137	156	170	158	102
Minus mammals	1	1.099438	1.223274	1.509501	1.871507	1.84258	1.766273	1.827372
Lower confidence interval	1	0.935411	1.021167	1.223764	1.457115	1.415932	1.342493	1.351402
Upper confidence interval	1	1.321133	1.492295	1.902881	2.433802	2.425199	2.351492	2.423714
Number of populations	58	79	120	161	175	185	179	155
Ocean basin								
Arctic Ocean	1	1.07794	1.118803	1.031441	1.19854	1.357803	1.424298	1.542828
Lower confidence interval	1	0.97856	0.967883	0.833491	0.761469	0.877838	0.933275	0.945517
Upper confidence interval	1	1.177113	1.28991	1.227842	1.621245	1.887448	1.917453	2.197517
Number of populations	32	39	50	64	83	76	71	47
Atlantic Ocean	1	1.092007	0.971313	0.905974	0.792417	0.682281	0.698429	0.690356
Lower confidence interval	1	0.698235	0.603564	0.575761	0.499334	0.40574	0.41927	0.419878
Upper confidence interval	1	1.568681	1.422385	1.311167	1.15544	0.994336	1.032576	0.979962
Number of populations	19	22	30	41	40	36	24	23
Pacific Ocean	1	0.971865	1.332155	1.870811	2.367528	2.389436	2.148445	2.113518
Lower confidence interval	1	0.799362	1.040441	1.426487	1.727317	1.730009	1.53118	1.512989
Upper confidence interval	1	1.225136	1.793921	2.582133	3.398477	3.491577	3.356503	3.160392
Number of populations	17	38	65	90	93	119	127	95
Bering Sea								
Bering Sea	1	1.042088	1.48759	1.967571	2.48797	2.47797	2.245908	2.235218
Lower confidence interval	1	0.824813	1.138795	1.445061	1.83258	1.862725	1.629392	1.589221
Upper confidence interval	1	1.220889	2.045222	2.667079	3.403583	3.340541	3.172907	3.33482
Number of populations	12	33	55	84	87	108	116	90

	1970	1975	1980	1985	1990	1995	2000	2005
Marine minus Bering Sea	1	1.171356	1.183236	1.206308	1.347492	1.462441	1.526446	1.626274
Lower confidence interval	1	0.981972	0.969959	0.900716	0.94351	1.006895	1.071785	1.183513
Upper confidence interval	1	1.443303	1.50594	1.537158	1.947833	2.111479	2.178463	2.46748
Number of populations	56	66	90	111	129	123	106	75
Bering birds	1	0.716961	0.756647	0.795857	0.972427	0.961084	0.848746	0.839834
Lower confidence interval	1	0.623031	0.652309	0.680874	0.748608	0.733071	0.62605	0.570575
Upper confidence interval	1	0.820872	0.871604	0.925849	1.260082	1.258951	1.159308	1.21743
Number of populations	1	10	21	34	37	49	54	37
Bering fishes	1	1.166061	1.937049	2.999204	3.719842	3.884403	3.573027	3.692198
Lower confidence interval	1	0.761074	1.216892	1.785645	2.195324	2.249615	2.028019	2.053039
Upper confidence interval	1	1.773337	3.082026	5.013473	6.349981	6.653324	6.305691	6.655616
Number of populations	5	8	18	30	30	35	41	48
Bering mammals	1	1.158352	1.781006	2.253052	3.049295	2.541555	2.267056	1.810252
Lower confidence interval	1	1.062601	1.277659	1.484669	1.624318	1.295382	1.145237	0.906043
Upper confidence interval	1	1.247532	2.57333	3.46961	5.746624	5.074001	4.574479	3.688465
Number of populations	6	15	16	20	20	24	21	5
Sea ice association								
Not associated	1	1.080857	1.294591	1.6134	1.935442	1.979779	1.892574	1.940091
Lower confidence interval	1	0.88611	1.099004	1.295827	1.464921	1.436947	1.442808	1.480081
Upper confidence interval	1	1.266706	1.569791	2.062277	2.462768	2.613275	2.498851	2.63102
Number of populations	64	92	132	171	191	205	198	148
Sea ice associated	1	1.438163	1.478786	1.215271	1.382608	1.823801	1.90005	1.847834
Lower confidence interval	1	1.213439	1.24378	0.848826	0.897862	0.990532	0.969511	0.978472
Upper confidence interval	1	1.691054	1.755737	1.694164	2.088947	3.271395	3.282895	3.403608
Number of populations	4	7	13	24	25	26	24	17
Marine zone								
Benthic fish	1	0.847484	1.015729	1.451804	1.967326	2.136922	2.060795	2.359461
Lower confidence interval	1	0.680872	0.780571	1.041065	1.322604	1.410522	1.340051	1.505985
Upper confidence interval	1	1.034374	1.30791	2.008178	2.979518	3.269703	3.202652	3.718174
Number of populations	10	13	22	32	34	41	46	47

	1970	1975	1980	1985	1990	1995	2000	2005
Benthopelagic fish	1	1.348473	1.651483	1.784157	2.398219	1.361894	1.375197	1.157641
Lower confidence interval	1	0.687768	0.780432	0.74494	0.894199	0.488127	0.436445	0.348927
Upper confidence interval	1	2.833867	3.627184	4.590298	6.673504	3.995494	4.580171	4.052748
Number of populations	9	10	13	16	16	13	11	11
Pelagic fish	1	2.111073	1.597818	1.538582	3.267538	2.604642	2.73313	2.378078
Lower confidence interval	1	0.818447	0.565143	0.461006	0.701132	0.546403	0.52764	0.455817
Upper confidence interval	1	5.907668	4.84943	5.627016	17.8833	14.59354	16.29361	14.54902
Number of populations	5	7	11	10	10	7	7	5
Planktivorous feeders								
Piscivorous seabirds	1	0.973779	1.068846	1.083051	0.903676	0.903919	0.826194	0.742729
Lower confidence interval	1	0.867834	0.945021	0.954432	0.746605	0.735827	0.624446	0.517759
Upper confidence interval	1	1.068693	1.17199	1.207084	1.015262	1.066673	0.994613	1.009821
Number of populations	28	42	61	82	91	91	83	66
Piscivorous fishes	1	1.348937	1.205521	1.908059	3.461609	3.644552	3.573729	4.161422
Lower confidence interval	1	0.928582	0.710118	0.966247	1.850307	2.042281	1.998049	2.256241
Upper confidence interval	1	2.152773	2.08003	3.270981	6.799244	7.22117	7.085897	7.726046
Number of populations	9	9	15	26	29	31	31	29
Planktivorous seabirds	1	0.803552	0.874373	0.983917	1.722304	1.641129	1.62533	1.943556
Lower confidence interval	1	0.803552	0.75156	0.836844	1.445102	1.331621	1.403463	1.542119
Upper confidence interval	1	0.803552	0.955237	1.304581	2.418211	2.330629	2.497926	3.877701
Number of populations	0	1	6	13	14	18	17	16
Planktivorous fishes	1	1.499526	2.096872	2.574555	3.094991	3.161776	3.212127	2.971525
Lower confidence interval	1	0.784903	1.105678	1.26009	1.436703	1.44644	1.535758	1.360954
Upper confidence interval	1	2.99681	4.616229	5.296864	5.894302	5.862755	6.871211	6.152875
Number of populations	6	11	16	14	14	15	17	15
Threats								
Unknown	1	1.014925	1.078858	0.987633	1.050691	1.089163	1.112435	1.027479
Lower confidence interval	1	0.918452	0.962793	0.839148	0.750054	0.747863	0.750306	0.659168
Upper confidence interval	1	1.123089	1.213615	1.148177	1.492938	1.604574	1.669382	1.612894
Number of populations	31	46	71	90	115	116	105	66

	1970	1975	1980	1985	1990	1995	2000	2005
No threats	1	1.011811	1.451504	1.996786	3.208091	3.757376	3.591975	4.080581
Lower confidence interval	1	0.70798	0.901846	1.174586	1.797852	2.073388	1.961934	2.171151
Upper confidence interval	1	1.39634	2.307871	3.360468	5.656222	6.642041	6.463931	7.562862
Number of populations	7	17	19	32	26	35	39	39
Any threat	1	1.162646	1.225217	1.44617	1.53271	1.390152	1.396481	1.372785
Lower confidence interval	1	0.925443	0.947447	1.058939	1.098914	0.981926	0.974464	0.938049
Upper confidence interval	1	1.507447	1.633341	2.026676	2.187835	2.007798	2.042104	2.041828
Number of populations	30	36	55	73	75	80	78	60
Protected areas								
Protected birds	1	0.975835	1.091298	1.269578	1.331779	1.363661	1.282401	1.21469
Lower confidence interval	1	0.783012	0.863271	0.959008	0.972525	0.963008	0.891771	0.798613
Upper confidence interval	1	1.176186	1.346428	1.666638	1.814192	1.902935	1.836861	1.832926
Number of populations	17	28	49	67	72	78	76	59
Unprotected birds	1	0.881982	1.032164	1.104786	1.074551	1.051463	0.998881	0.974174
Lower confidence interval	1	0.796747	0.891092	0.930566	0.886453	0.8426	0.789202	0.699173
Upper confidence interval	1	0.966151	1.204806	1.327638	1.312931	1.3192	1.263694	1.452495
Number of populations	15	19	21	31	39	41	35	30

Appendix 5: Table of population trends for nine sea-ice associated species

Trends are based on the overall change in population size.

Species	Common name	Location of monitored population	Reference	Population trend
Balaena mysticetus	Bowhead whale	Western Arctic stock, Alaska (a.k.a. Bering-Chukchi-Beaufort stock).	(Angliss & Outlaw 2006)	Stable / Positive
Boreogadus saida	Arctic cod	Barentshavet	(Michalsen 2004; Stiansen & Filin 2008)	Stable / Positive
		Sagavanirktok Delta, Alaska	(Griffiths *et al*. 1998)	Stable / Positive
Delphinapterus leucas	Beluga whale	Cook Inlet stock, Alaska	(MMC 2002; Angliss & Outlaw 2008; Allen & Angliss 2010)	Negative
		Eastern Chukchi Sea Stock, Alaska	(NOAA Fisheries: Office of Protected Resources 1999)	Negative
		Eastern Hudson Bay population	(DFO 2005)	Negative
		Norton Sound, Alaska	(DeMaster *et al*. 2001)	Stable / Positive
Monodon monoceros	Narwhal	Hudson Bay, Canada	(COSEWIC 2004)	Stable / Positive
Odobenus rosmarus	Pacific walrus	Bering and Chukchi Seas of Alaska and Russia	(Garner 1995; NOAA 2010a)	Negative
Pagophila eburnea	Ivory gull	Franz-Josef Land	(Anker-Nilssen *et al*. 2000)	Stable / Positive
		Various in Canada, Greenland, Russia, Norway (midpoint latitude below)	(CAFF 2008)	Negative
Pusa hispida	Ringed seal	Eastern Beaufort Sea	(Stirling 2002)	Negative
Uria lomvia	Thick-billed guillemot	Bezymyannaya bay	(Krasnov *et al*. 1995)	Stable / Positive
		Hornoya	(Anker-Nilssen *et al*. 2000)	Stable / Positive
		Kap Brewster	(Falk & Kampp 1997)	Negative
		Kharlov Island	(Krasnov *et al*. 1995)	Stable / Positive
		Svalbard	(Anker-Nilssen *et al*. 2000)	Stable / Positive
		Buldir Island	(Dragoo *et al*. 2000; Dragoo *et al*. 2008)	Stable / Positive
		St George Island, Pribilofs	(Dragoo *et al*. 2000; Dragoo *et al*. 2008)	Negative
		St Paul Island, Pribilofs	(Dragoo *et al*. 2000; Dragoo *et al*. 2008)	Negative
		Hafnaberg, South-West Iceland	(Garoarsson & Zocker 2006)	Negative
		Krisuvikurberg (Krisuvik), SW Iceland	(Garoarsson & Zocker 2006)	Negative
		Skoruvik, NE Iceland	(Garoarsson & Zocker 2006)	Negative
		Coats Island, Nunavut	(Gaston *et al*. 2008b)	Stable / Positive
		Prince Leopold Island, Nunavut	(Gaston *et al*. 2008b)	Stable / Positive

Species	Common name	Location of monitored population	Reference	Population trend
		Hall Island, Alaska	(Dragoo *et al*. 2008)	Negative
		St. Lawrence Island	(Dragoo *et al*. 2008)	Negative
Ursus maritimus	Polar bear	Chukchi/Bering Sea Stock	(U.S. Fish and Wildlife Service Marine Mammals Management 2002; NOAA 2010b)	Negative
		Alaskan Stock	(U.S. Fish and Wildlife Service Marine Mammals Management 2002)	Negative
		Wrangel Island State Nature Reserve	(Derocher *et al*. 1997)	Negative
		Southern Beaufort population	(IUCN 2001; IUCN/SSC Polar Bear Specialist Group 2010)	Negative
		Western Hudson Bay population	(Aars *et al*. 2005)	Negative
		Southern Hudson bay population	(Obbard *et al*. 2007)	Stable / Positive
		Northern beaufort sea population	(Stirling *et al*. 2007)	Stable / Positive
		Baffin Bay	(IUCN/SSC Polar Bear Specialist Group 2010)	Negative
		Davis strait	(IUCN/SSC Polar Bear Specialist Group 2010)	Stable / Positive

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