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The Arctic Species Trend Index 2011

Key findings from an in-depth look at marine species and development of spatial analysis techniques

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WWF

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Graphics by: Margrét Valmundsdóttir

For more information please contact:
CAFF International Secretariat
Borgir, Nordurslod
600 Akureyri, Iceland
Phone: +354 462-3350
Fax: +354 462-3390
Email: caff@caff.is
Internet: http://www.caff.is

Layout: Courtney Price
Editing: Courtney Price, Tom Barry

CAFF Designated Area

CBMP

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Key Findings List

1 The Arctic Species Trend Index (ASTI): 2011 update

1.1 Average abundance of Arctic vertebrates increased from 1970 until 1990 then remained fairly stable through 2007, as measured by the ASTI 2011.

1.2 When species abundance is grouped by broad ecozones, a different picture emerges, with low Arctic species abundance increasing in the first two decades much more than high Arctic and sub Arctic species abundance. The low Arctic index has stabilized since the mid-1990s while the high Arctic index appears to be recovering in recent years and the sub Arctic index has been declining since a peak in the mid-1980s.

1.3 The trend for Arctic marine species is similar to that of the overall ASTI, while the trend for terrestrial species shows a quite different pattern: a steady decline after the early 1990s to a level below the 1970 baseline by 2005.

2 Tracking trends in Arctic marine vertebrates

2.1 The trend for marine fish is very similar to the trend for all marine species, increasing from 1970 to about 1990 and then levelling off. This indicates that the ASTI is strongly influenced by fish trends. Overall, marine mammals also increased, while marine birds showed less change.

2.2 The three ocean regions, Pacific, Atlantic, and Arctic, differed significantly in average population trends with an overall decline in abundance in the Atlantic, a small average increase in the Arctic and a dramatic increase in the Pacific. These differences seem to be largely driven by variation in fish population abundance—there were no significant regional differences for birds or mammals.

2.3 Pelagic fish abundance appears to cycle on a time frame of about 10 years. These cycles showed a strong association with a large-scale climate oscillation.

2.4 The ASTI data set contains population trends for nine sea ice associated species. There were mixed trends among the 36 populations with just over half showing an overall decline.

2.5 The Bering Sea and Aleutian Island (BSAI) region of the Pacific Ocean is well studied, providing an opportunity to examine trends in more detail. Since 1970, BSAI marine fish and mammals showed overall increases, while marine birds declined. However, since the late 1980s, marine mammal abundance has declined while marine fish abundance has largely stabilized.

3 Tracking trends through space and time

3.1 Spatial analysis of the full ASTI data set (1951 to 2010) started with an evaluation of vertebrate population trend data from around the Arctic. The maps produced from this analysis provide information useful for identifying gaps and setting priorities for biodiversity monitoring programs.

3.2 Mapping trends in vertebrate populations provides information on patterns of biodiversity change over space and time, especially when examined at regional scales.

3.3 Understanding of the causes of Arctic vertebrate population change can be improved by expanding the spatial analysis of ASTI data to include spatial data on variables that represent drivers of biodiversity change.

Introduction

Evaluating trends in species abundance reveals much about broad-scale patterns of biodiversity change. The Arctic Species Trend Index (ASTI), developed for this purpose, uses population trend data from vertebrate species from 1970 until the present day. It is the Arctic component of a global index of vertebrate species trends, the Living Planet Index (LPI)[1]. Both the LPI and the ASTI, because they combine information on trends in many species into one measure that can be plotted over time, are useful for visualising change and tracking overall progress towards targets, such as those set through the Convention on Biological Diversity. The ASTI data sets are not just numbers of animals though—they contain, or can be associated with, additional information about the animals and their habitats and about threats to biodiversity and drivers of change. The ASTI data set can be used to dig deeper and look at patterns in species trends as well as to look at how these trends are related to other changes in Arctic ecosystems.

The Conservation of Arctic Flora and Fauna (CAFF) working group of Arctic Council facilitates cooperation on Arctic biodiversity conservation and management, information sharing, and knowledgeable decision-making. Work on the ASTI is part of a suite of projects and programs underway to assess biodiversity status and trends and to improve understanding of causes of change and of management options. Cooperation in monitoring and work on indices and indicators are coordinated through CAFF´s Circumpolar Biodiversity Monitoring Program. Results of monitoring and research are being synthesized through the Arctic Biodiversity Assessment. The ASTI provides trend analysis and an analytical framework that complements these initiatives.

This report builds on the CAFF report *The Arctic Species Trend Index 2010: Tracking trends in Arctic wildlife*[2]. This report provides an update of the overall index, an exploration of the data sets using spatial analysis techniques, and a more in-depth examination of the data sets for marine vertebrates. The report is based on two technical reports prepared for CAFF[3,4]. A plain language summary of the ASTI methods, as well as a table showing the time spans and sample sizes for the various analyses described in this report, are found in Appendix 1.

Tufted puffin: Photo: Maksimilian/Shutterstock.com

Key Findings

1 The Arctic Species Trend Index: 2011 update

The data set underlying the index was updated by acquiring new data, removing redundant data sets, and extending time series. New ASTI values were calculated for each year from 1970 to 2007.

1.1 Average abundance of Arctic vertebrates increased from 1970 until 1990 then remained fairly stable through 2007, as measured by the ASTI 2011.

Although the ASTI data set has been improved and the index has been extended by three years since the first ASTI report[2], the overall trend of the index (Figure 1) has not changed (but see Key Finding 1.2). The ASTI now includes data for 323 species, increasing representation of Arctic vertebrate species from 35% (in the 2010 index) to 37%. These species are represented by trend data from 890 populations.

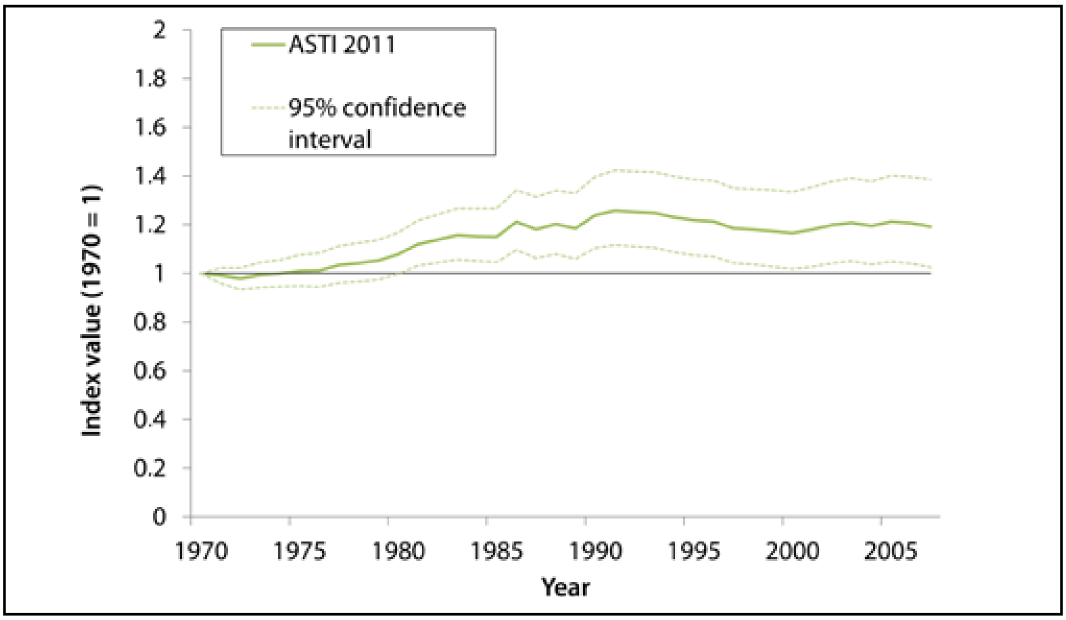


Figure 1. Index of abundance for 323 Arctic vertebrate species (890 populations) from 1970 to 2007. The figure plots the 95% confidence intervals and the number of populations contributing to each year of the index.

1.2 When species abundance is grouped by broad ecozones, a different picture emerges, with low Arctic species abundance increasing in the first two decades much more than high Arctic and sub Arctic species abundance. The low Arctic index has stabilized since the mid-1990s while the high Arctic index appears to be recovering in recent years and the sub Arctic index has been declining since a peak in the mid-1980s.

Muskox. Photo: Peter Krejzl/Shutterstock.com

High Arctic species declined from 1970 to the mid-1990s and then remained fairly stable (Figure 2). 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 1). This is too short a time to interpret as a significant change and points out the importance of frequent updates of the ASTI.

Some factors that influence these ecozone patterns[2]:

- Natural cycles, for example for lemmings and caribou, influence the index, especially for the high Arctic zone.
- Data for most high Arctic populations are quite sparse.
- The sub Arctic zone covers terrestrial and freshwater systems, with no marine species.
- Sub Arctic trends are the most susceptible to direct influence from human activities and land use.
- The low Arctic index values mainly reflect trends in marine species, especially fish.

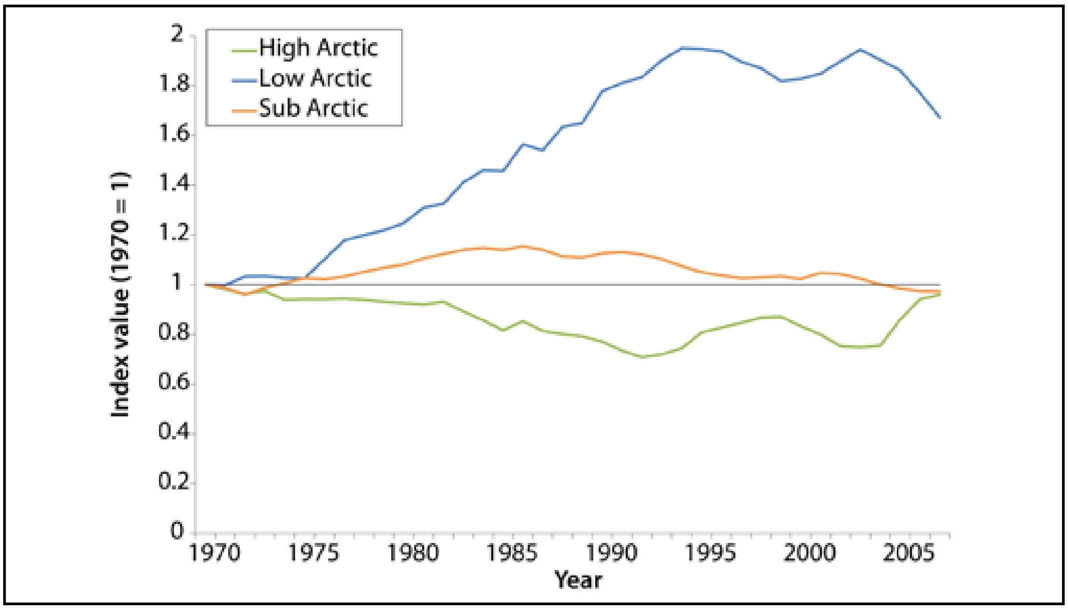


Figure 2. ASTI 2011 for species grouped by high, low, and sub Arctic from 1970 to 2007.

1.3 The trend for Arctic marine species is similar to that of the overall ASTI, while the trend for terrestrial species shows a quite different pattern: a steady decline after the early 1990s to a level below the 1970 baseline by 2005.

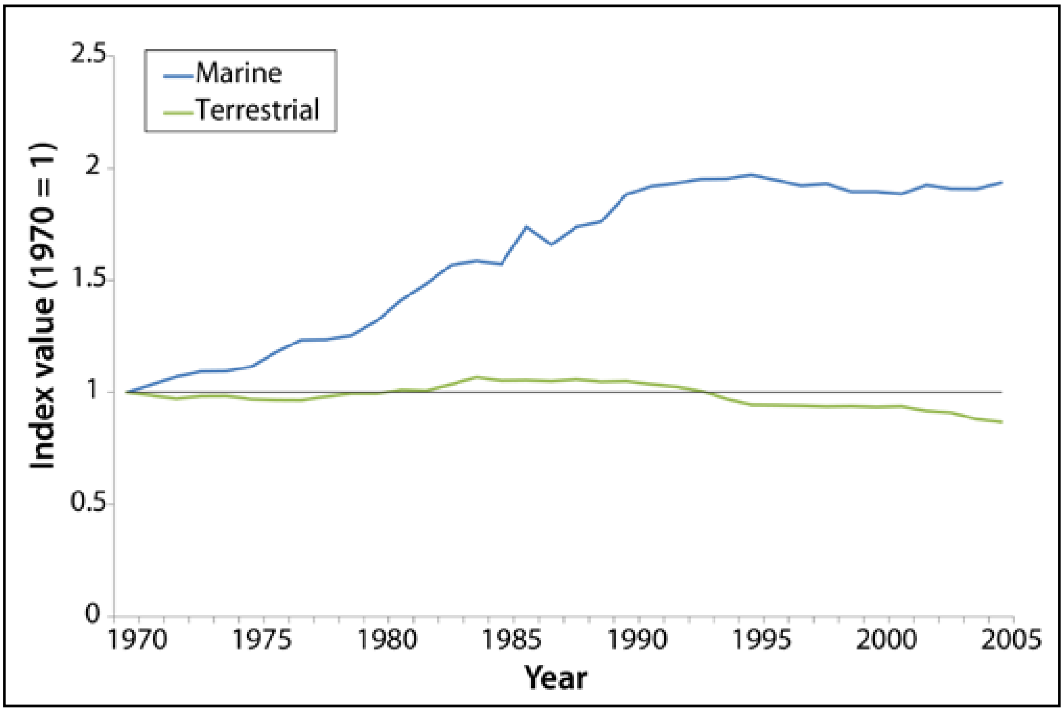


Figure 3.Trends for Arctic marine and terrestrial species from 1970 to 2005. This time span is based on the period of best data for the marine analyses which follow.

See Table A1 for details of data included in each analysis.

The decline in the terrestrial index over the past two decades reflects declines in high Arctic populations (Figure 3); the steepness of the decline is moderated by sharp increases in some species in the low and sub Arctic (notably geese) over this period[5]. The increase in marine species from 1970 to the mid-1980s is influenced by strong increases in some fishes[6] and marine mammals[7] during that period. The marine ASTI dataset contains 310 data sets recording trends in 111 species, providing an opportunity for deeper analysis to look at how trends differ among regions of the Arctic marine environment and among different types of marine vertebrates.

2 Tracking trends in Arctic marine vertebrates

The Arctic marine data set contains a total of 111 species and 310 population time series from 170 locations (Figure 5). Species coverage is about 34% of Arctic marine vertebrate species (100% of mammals, 53% of birds, and 27% of fishes)[8]. Although the representation of Arctic fish species is lower than that of mammals and birds, the increase in the marine index is strongly influenced by large increases in abundance for some fish species, primarily from the Pacific Ocean (especially the Bering Sea and Aleutian Islands). Note that the time span selected for marine analyses is 1970 to 2005 (compared with 1970 to 2007 for the ASTI for all species).

2.1 The trend for marine fish is very similar to the trend for all marine species, increasing from 1970 to about 1990 and then levelling off. This indicates that the ASTI is strongly influenced by fish trends. Overall, marine mammals also increased, while marine birds showed less change.

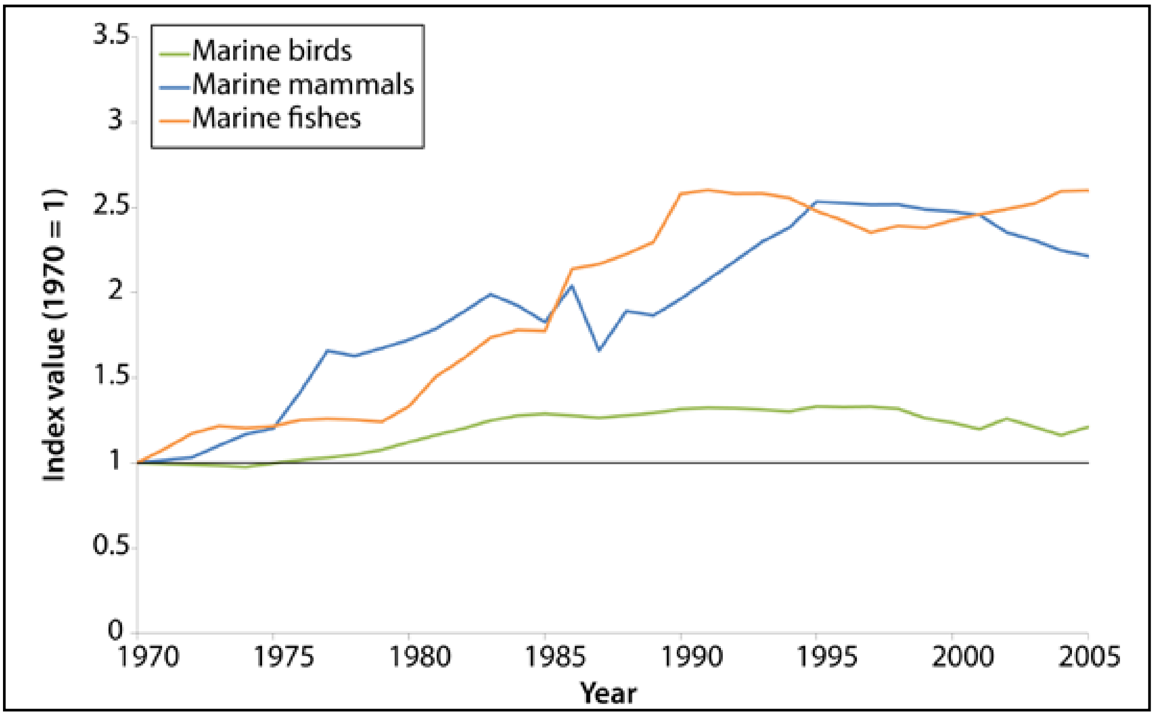


Figure 4. Indices of abundance by taxonomic class from 1970 to 2005 for marine birds, fishes, and mammals.

Indices are averaged for birds (34 species, 152 populations), fishes (55 species, 98 populations), and mammals (22 species, 60 populations).

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

Arctic char. Photo: Dan BachKristensen/Shutterstock.com

The ASTI index for marine fish dramatically increased over the 35-year period, with the increase occurring wholly within the first two decades (Figure 4). A comparison of the ASTI trend lines for: 1) marine fishes (orange line in Figure 4), 2) all marine species (blue line in Figure 3), and 3) all Arctic species (Figure 1), indicates that the rapid, two-decade increase recorded for fish has a strong influence on both the marine and the overall indices. Marine fish trends did not differ significantly among trophic levels (whether the fish feed on plankton or on fish), but were different depending on ocean region—the most noticeable difference being that there was a continued and unabated decline of fish in the Atlantic Ocean.

Marine mammals also showed an upward trend, leveling off in the mid-1990s (Figure 4). Additional analysis showed that the trends for marine mammals were similar for the Pacific, Arctic, and Atlantic ocean regions[4]. 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[9-11]. For example, research on gray whales from the eastern Pacific suggested that, while abundance has increased dramatically, the whales have, at best, recovered to 28 to 56% of their original abundance levels[9]. Similar findings have been documented for populations of Greenland walrus,[12] the western Arctic population of bowhead whale,[13] and for commercially fished Atlantic cod[14].

Gray whale. Photo: Jo Crebbin/Shutterstock.com

King eider. Photo: Daniel Prudek/Shutterstock.com

The index for marine birds displayed a slower increasing trend to 1984, then remained stable, with indications of a slow decline starting after 1998 (Figure 4). This recent trend may indicate the start of a longer term decline so it will be important to monitor this over the coming years. Recent studies have shown that population trends in some marine birds may be influenced by changes in climate and sea-ice extent, conditions that dictate the availability of their food[15].

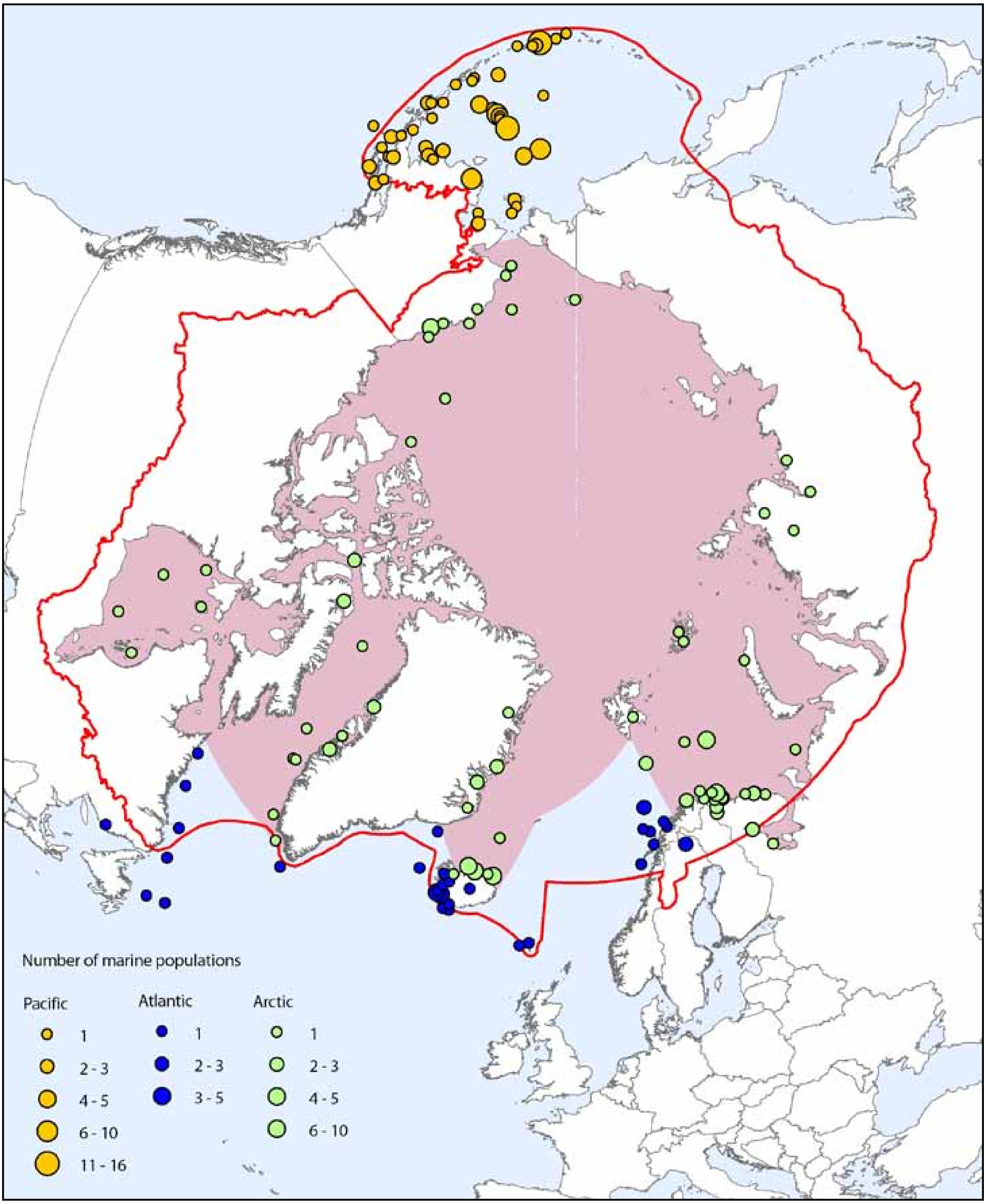


Figure 5. Spatial distribution of marine population data collected.
The size of the circle denotes the number of population time series from that location.
For greater clarity in the division of populations by ocean region, the Arctic Ocean base map area used for all analyses is shown in pink.

2.2 The three ocean regions, Pacific, Atlantic, and Arctic, differed significantly in average population trends with an overall decline in abundance in the Atlantic, a small average increase in the Arctic and a dramatic increase in the Pacific. These differences seem to be largely driven by variation in fish population abundance—there were no significant regional differences for birds or mammals.

Grouping all marine vertebrate populations by ocean region (Figure 6) shows an average decline in abundance in the Atlantic, a small average increase in the Arctic, and the largest increase in the Pacific Ocean. The dramatic increase from 1975 to the early 1990s in the Pacific Ocean index is likely driven by a few rapidly increasing mammal and fish species. This is further explored by looking at patterns in the Bering Sea and Aleutian Islands, which account for almost half of the marine populations (see Focus on the Bering Sea).

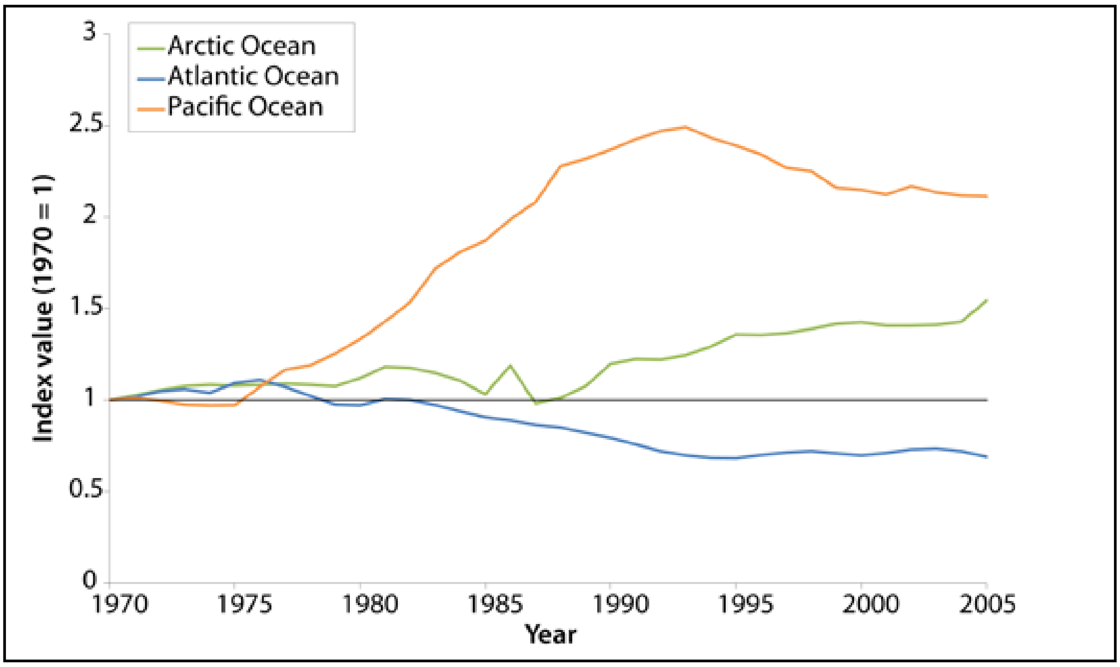


Figure 6. Indices of abundance by ocean region, 1970 to 2005.

Indices are averaged :

- Arctic Ocean (52 species, 113 populations)
- Atlantic Ocean (22 species, 44 populations)
- Pacific Ocean (75 species, 153 populations).

Trends in the Atlantic Ocean, the smallest data set of the three ocean regions, are driven predominantly by fish and birds. Arctic climate-driven regime shifts are thought to have occurred in the North Atlantic[16], and these may be operating in tandem with exploitation effects (commercial fishing), resulting in declines. 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[4].

2.3 Pelagic fish abundance appears to cycle on a time frame of about 10 years. These cycles showed a strong association with a large-scale climate oscillation.

Although environmental changes related to warmer sea temperatures are projected to lead to a shift in species composition from benthic (living near the ocean bottom) to pelagic (living in open water)[17], there is no evidence of such a shift at the scale of this analysis[4]. There was, however, a noticeable difference in the pattern of the trends for the two groups, with pelagic fishes showing a distinct cyclical pattern throughout the time series (blue line in Figure 7). To examine this pattern the trend in the overall pelagic fish index was compared to large-scale climate oscillations (Pacific, Decadal, Arctic, and North Atlantic), showing a relationship only with the Arctic Oscillation. The association was strong, with peaks in the pelagic fish index in 1977, 1983, 1993, 2002, and 2009 generally tracking peaks in the Arctic Oscillation (Figure 7).

To see if specific ocean conditions associated with the Arctic Oscillation could be identified as drivers of these cycles of pelagic fish, patterns in herring abundance in the Bering Sea[6] were examined in relation to patterns of variation in sea-surface temperature, summer bottom temperature, mean annual temperature, and sea-ice cover. Although studies show that environmental conditions relative to spawn run timing are important in determining herring recruitment in the Bering Sea[18], herring cycles were not closely associated with any of these indicators of ocean conditions when looked at one by one.

This analysis is a good example of how a global scale index such as ASTI can reveal relationships with large-scale 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 and in identifying the key factors that influence population trends.

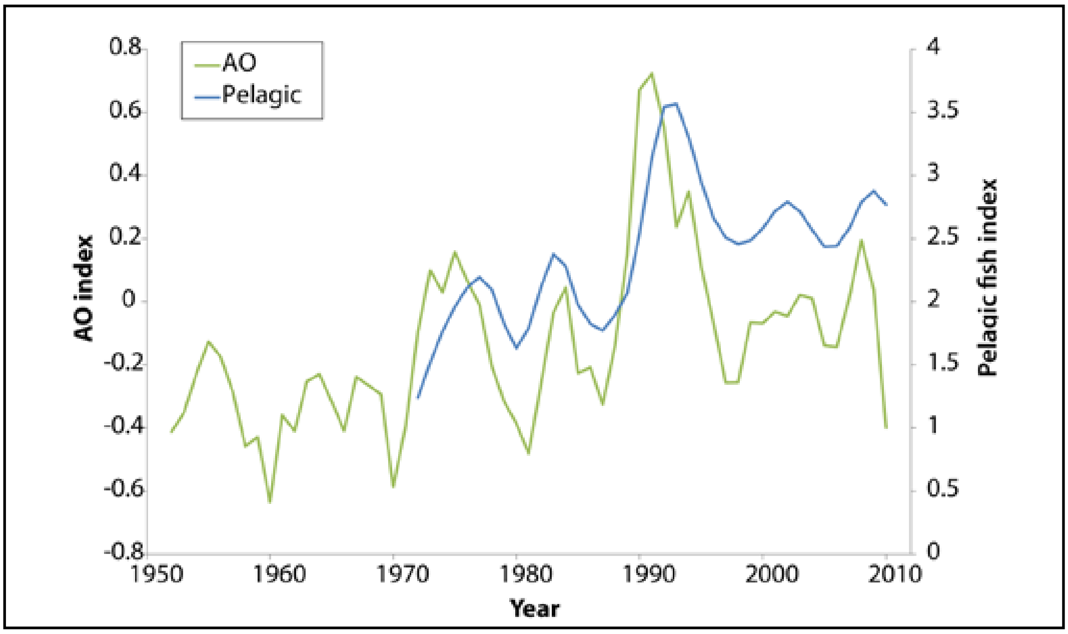


Figure 7. Comparison of the three year running average for the pelagic fish index and the Arctic Oscillation (AO).

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

Drying fish. Photo: MP cz/Shutterstock.com

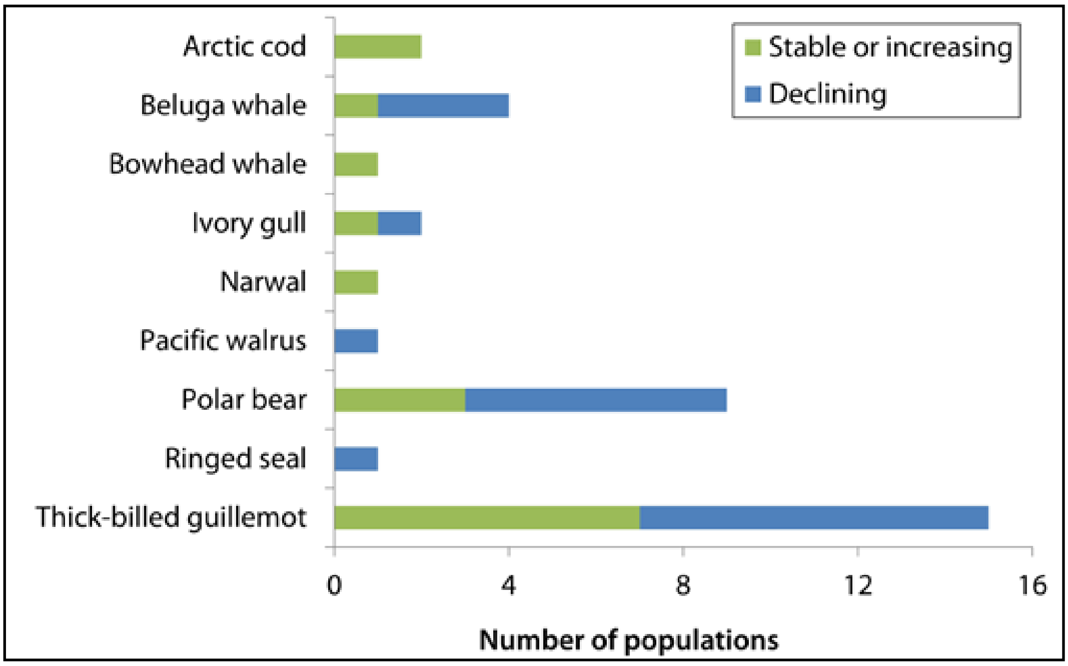
2.4 The ASTI data set contains population trends for nine sea ice associated species. There were mixed trends among the 36 populations with just over half showing an overall decline.

Recent changes in sea-ice extent in the Arctic have been well documented[19,20] and there is evidence emerging of adverse effects on biodiversity[21-23]. 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 chain to the provision of suitable habitat for breeding and for use as a hunting platform[24].

Data, available for two bird, six mammal, and one fish species of ice-associated vertebrates (Figure 8), are not adequate to calculate an overall trend index—this is because the length and the quality of the time series data sets vary greatly. Over the full period of monitoring for each species, three —ringed seal, beluga whale, and thick-billed guillemot—showed overall declines in abundance. In light of the paucity of available data, the rapid changes in sea ice, and the warning sign of a number of negative trends, sea-ice associated species are a priority for monitoring.

Figure 8. Known status of individual populations for nine ice-associated marine species.

Note that the status shown for Pacific walrus represents a possible declining trend in recent decades (1980 to 2006) which followed a period of increase (the trend over the entire monitoring time period was an increase although trend estimates are considered uncertain[25]).



Beluga whale. Photo: Maksimilian/Shutterstock.com

Focus on the Bering Sea

2.5 The Bering Sea and Aleutian Island (BSAI) region of the Pacific Ocean is well studied, providing an opportunity to examine trends in more detail. Since 1970, BSAI marine fish and mammals showed overall increases, while marine birds declined. However, since the late 1980s, marine mammal abundance has declined while marine fish abundance has largely stabilized.

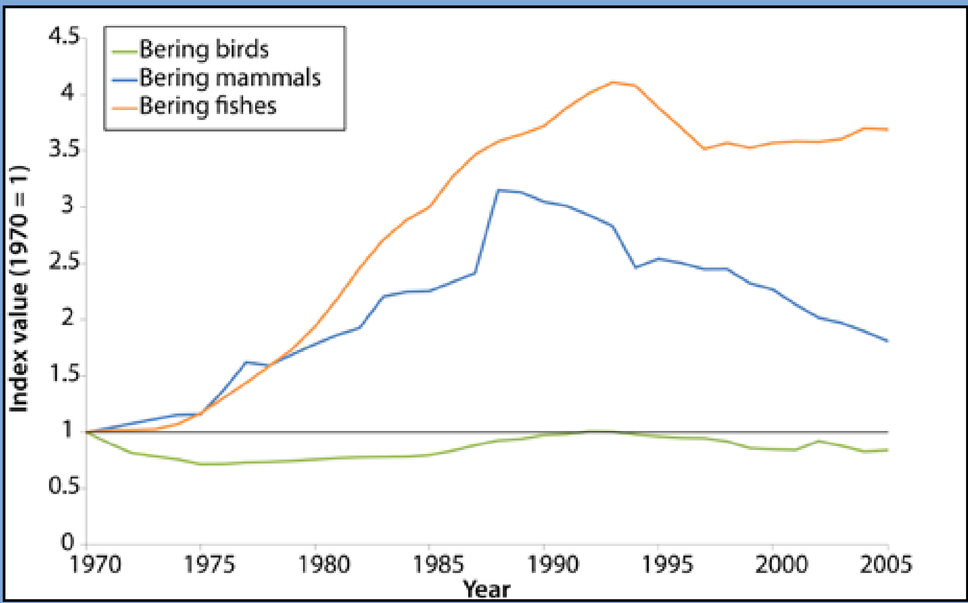


Figure 9. Indices of abundance for marine populations from the Bering Sea and Aleutian Island region for birds, fish, and mammals

Of the 310 marine vertebrate populations in the ASTI data set, 138 populations are from the BSAI region.

Birds

An overall cause of declining marine birds is not evident (Figure 9) as threats vary among species. Even within species, identifying precise causes of decline is sometimes complicated by fluctuations in abundance over time and space occurring simultaneously[26]. One example of a species from this region in decline is the red-legged kittiwake. The effects of a substantial fisheries industry, interacting with habitat disturbance or disruption of the food web, is a possible cause of decline[27].

Fish

Fish species from the BSAI, on average, increased in abundance from 1970 to 1993 (Figure 9), a trend that drives the overall fish index and, to a certain extent, the marine index. Another broad-scale study[28] found increases in fish biomass in the eastern Bering Sea shelf in the 1970s and 1980s, suggesting that favourable environmental conditions were likely responsible for the increases. The change 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[29].

Mammals

The marine mammal increase is not consistent across the entire time period, with a definitive shift in dynamics to a decline in 1988, which continues until 2005 (Figure 9). 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 constantly declining trend is reflective of the following species: beluga whale, Steller sea lion, harbour seal, sea otter, northern fur seal, and gray whale. Reasons for declines include increased predation[30], loss of summer sea ice[23], and depleted prey resource [31,32].

3 Tracking trends through space and time

The ASTI, as with most biodiversity indicators, looks mainly at trends over time in wildlife population abundance. Population trends also vary from place to place, but this spatial variation has not been examined to the same degree. The ASTI data set provides a good opportunity for spatial analysis as it consists of repeated measurements of abundance for 890 vertebrate populations, each associated with a specific location. While the distribution of these locations is not systematic or even, there is broad geographic coverage around the Arctic.

Spatial analysis has been used more in other fields, like epidemiology[33] and, in ecology, for modelling habitat characteristics at broad scales[34,35], but has not been widely applied in biodiversity monitoring at this scale. Other current Arctic projects employing spatial analysis techniques at regional or pan-Arctic scales include the Bering Sea Sub-Network (a CAFF project), which uses scientific and traditional knowledge to look at change in species important to indigenous communities [36], and WWF's Rapid Assessment of Circumarctic Ecosystem Resilience project, which is identifying areas of socioecological resilience under future climate change scenarios[37].

3.1 Spatial analysis of the full ASTI data set (1951 to 2010) started with an evaluation of vertebrate population trend data from around the Arctic. The maps produced from this analysis provide information useful for identifying gaps and setting priorities for biodiversity monitoring programs.

The ASTI spatial analysis[3] focused on developing and testing methodology. As a first step, the data set itself was evaluated and mapped, looking both at the spatial distribution and at the quality of abundance measurements of Arctic vertebrates.

Figure 10 shows the locations of 366 sites with trend information for a total of 890 vertebrate populations. Some sites have associated data for one or two populations, while several species were monitored at the same location at sites marked with darker squares. The Bering Sea and Aleutian Islands, as well as northern Scandinavia and Iceland, stand out as areas with more intense monitoring. Northern Russia, northern Greenland, and the islands and adjacent areas of the Canadian High Arctic stand out as regions with sparse monitoring coverage.

The maps in Appendix 2 allow a closer look. While data coverage is variable across space (Figure 10), high quality data in terms of time series length are much more equally spread among locations (Figure A1). Time series of 20 years or more are particularly concentrated around the Bering Sea, but coverage is also very good in Iceland and northern Scandinavia. Relatively few of the monitoring locations in Russia are long time series and the number of data points per time series is particularly low in this area (Figure A2).

Figure A3 shows very complete data sets (sets of annual measurements with few years missed) in the Bering Sea, Iceland, northern Scandinavia, as well as around the Kamchatka Peninsula. However, time series data in other areas are much less complete. For example, in Canada, many time series have only about half the number of possible annual data points, while in the westernmost Aleutian Islands, time series are even less complete (Figure A3).

The number of populations for which data are available for each year from 1970 to 2007 (Figure 11) varied from about 200 to about 600, with a steady rise in number of populations until the most recent decade, followed by a sharp decline. This recent decline may mean that data collected are not yet published, or it may reflect reductions in biodiversity monitoring efforts, or a combination. Changes in monitoring and reporting of results for specific regions are shown in Figure A4, which displays data availability for each of 366 locations, decade by decade, from 1951 to 2010.

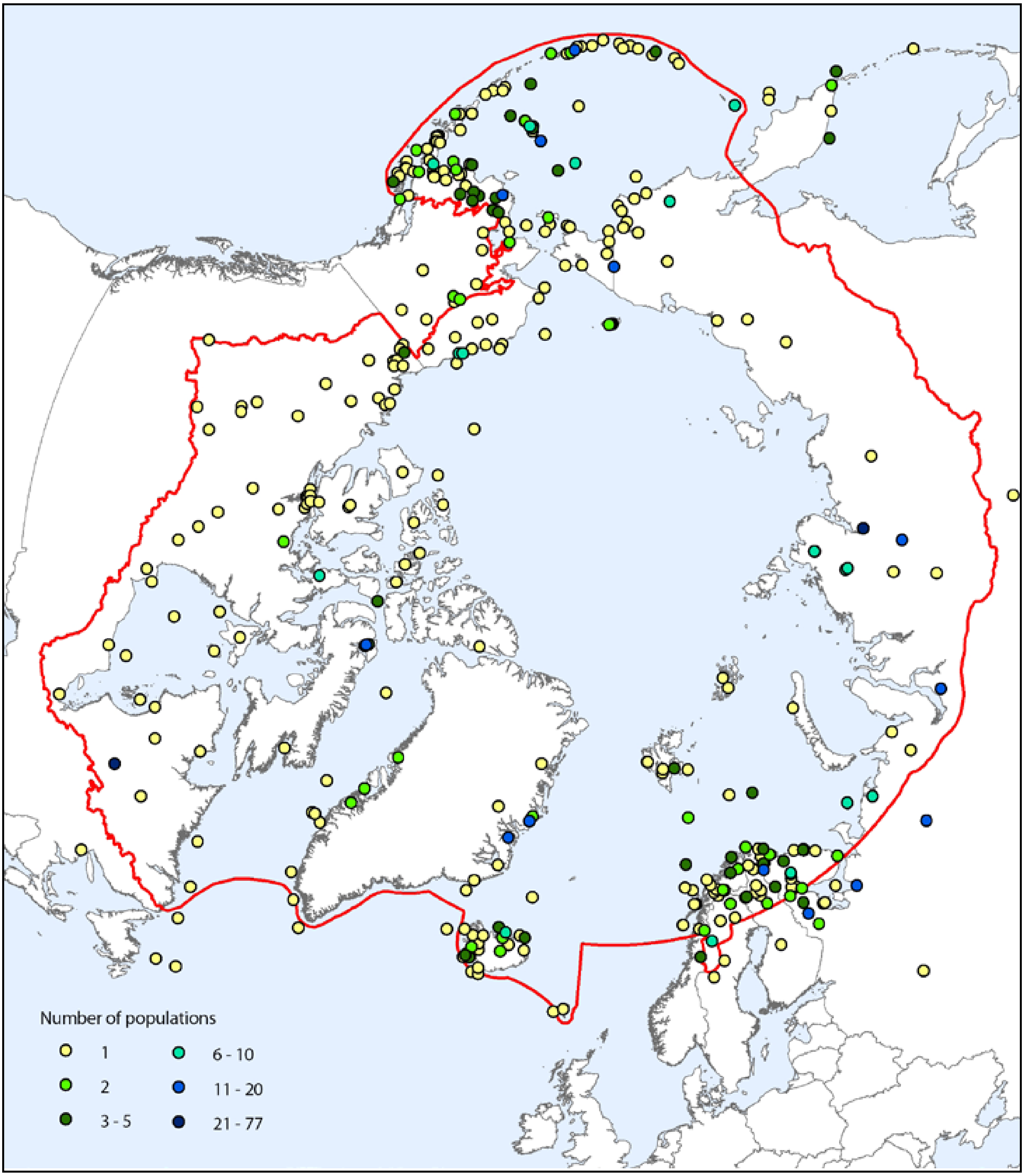


Figure 10. Distribution of population time series data across the Arctic.
Colours represent the number of populations (of different species) measured at each location. Locations with data over any period from 1951 to 2010 are shown.

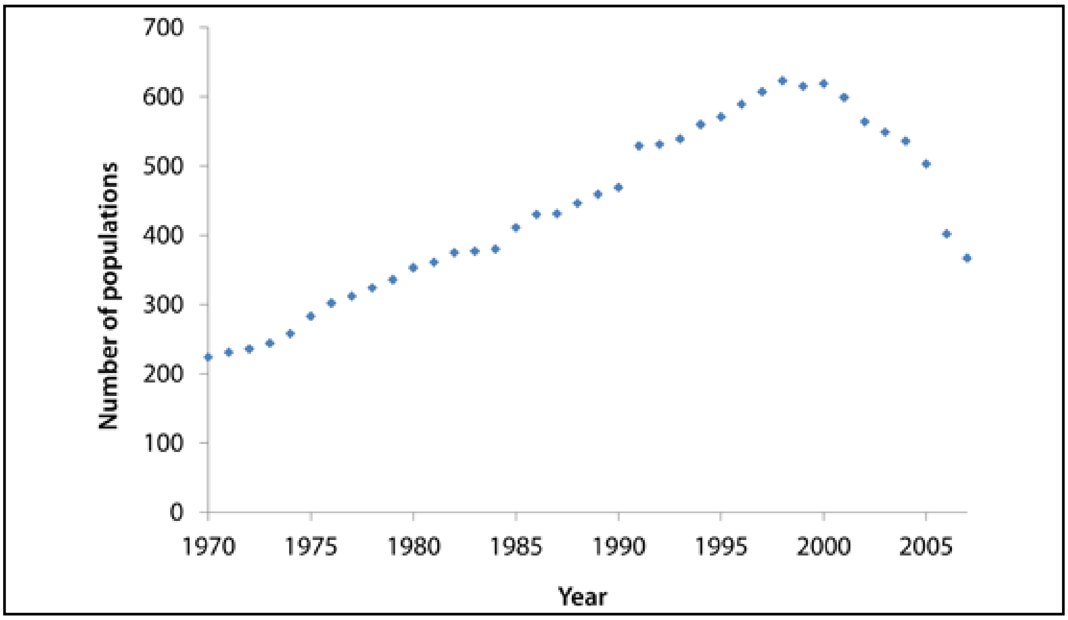


Figure 11. Number of populations for which data are available each year, 1970 to 2007

3.2 Mapping trends in vertebrate populations provides information on patterns of biodiversity change over space and time, especially when examined at regional scales.

While no clear, broad-scale pattern of spatial distribution of overall population trends is apparent, there are clusters of population growth and decline (Figure 12). Locations both in the Labrador Sea (with data mainly for cod, American plaice, herring, ocean perch, and Arctic char) and on the Queen Elizabeth Islands (with data mainly for caribou, lemmings, and shorebirds) show multiple populations undergoing marked declines.

Examining distribution of trends by taxonomic class (birds: Figure A5, mammals: Figure A6, and fish: Figure A7) highlights some additional patterns. While fish stocks appear to be declining rapidly in the Labrador Sea, many show a slight increase in the Bering Sea. Many bird and mammal populations along the Labrador Sea coast are showing declines. However, in the Bering Sea, both birds and mammals (mainly sea otters) are faring worse than fish. For birds, this is particularly true in the far north eastern reaches of Siberia where downward trends reflect declines in some terrestrial and shorebird populations on the mainland and some island-dwelling marine bird populations.

Red knot. Photo: John L. Absher /Shutterstock.com

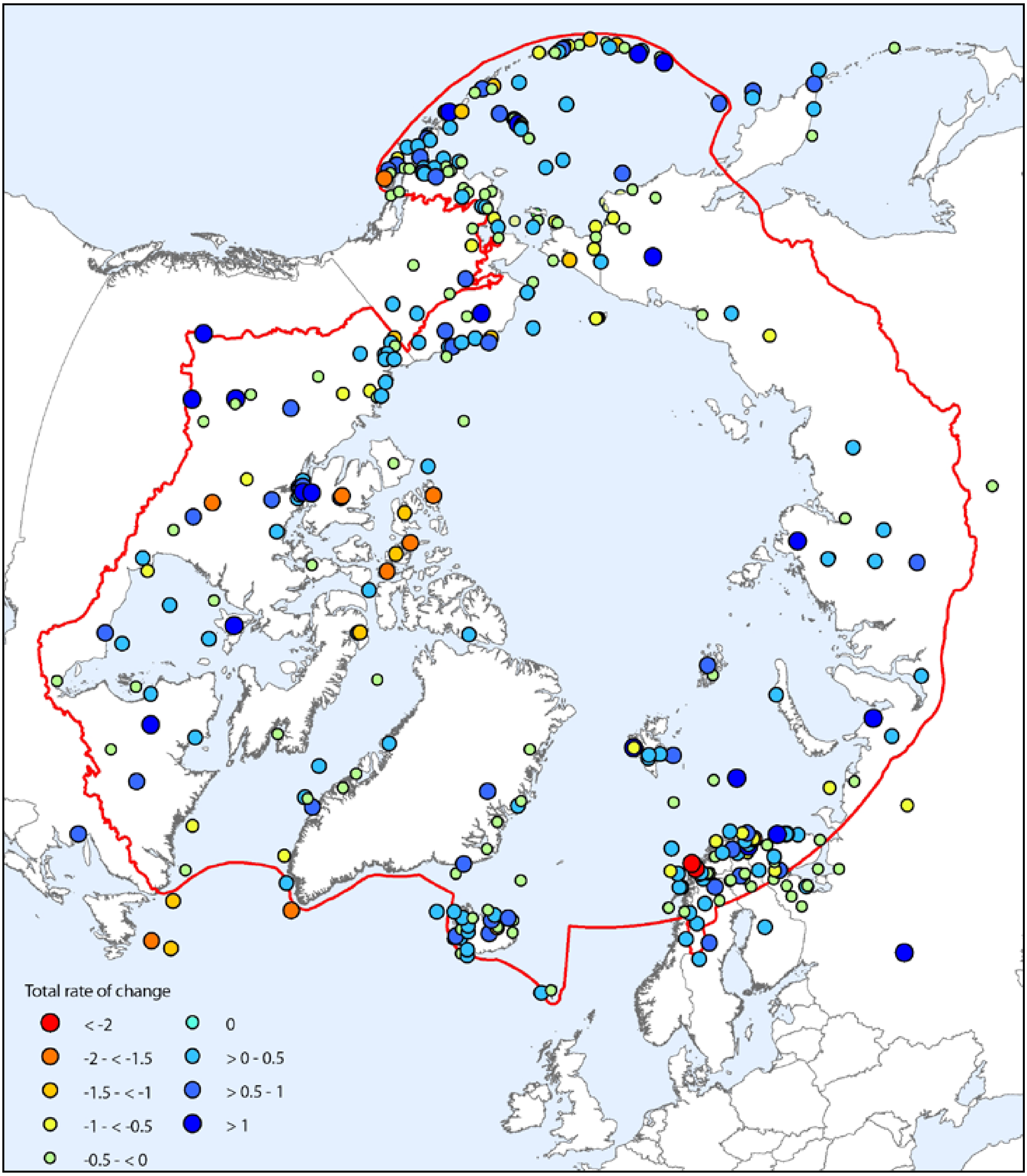


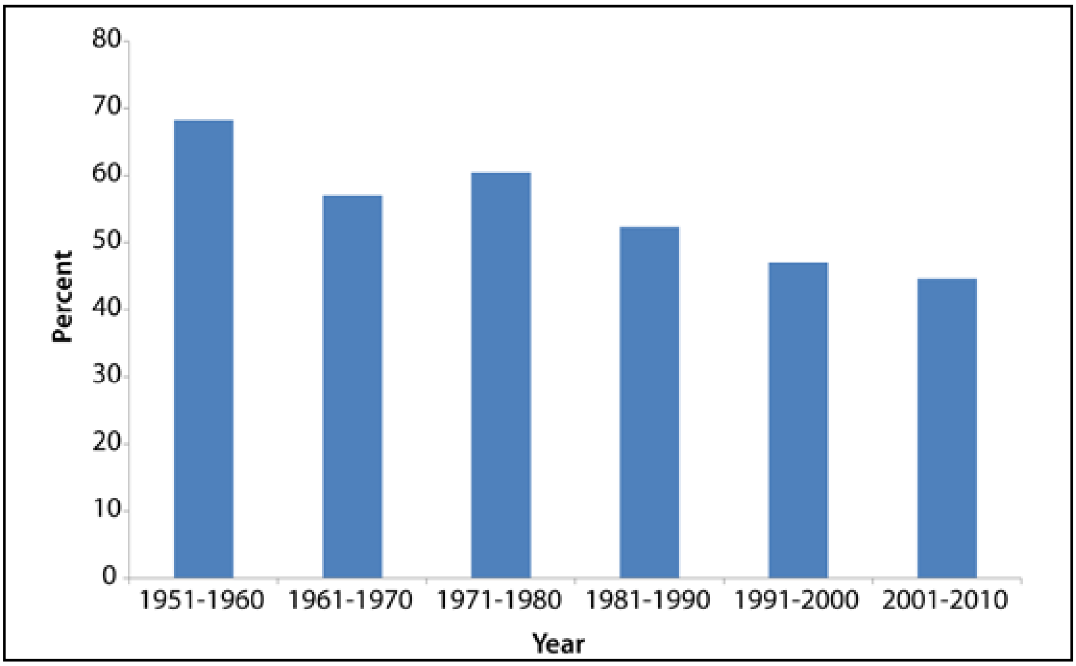
Figure 12. Spatial distribution of trends in the ASTI data set, for all populations, 1951 to 2010
Red circles indicate negative rates of change (i.e., declines), blue circles positive rates of change (i.e., increases).

Population trends for all vertebrates combined are shown by decade in Figure A8. While there are few population time series that date back to the 1950s and 1960s, monitoring increased substantially in the 1970s, particularly across northern Canada and Russia. Figure A8-F shows a recent gap in data coverage from northern Canada, particularly from populations that had previously reported declines.

These decadal trend maps (Figure A8) can be used to explore how trends have changed over time in specific regions. For example, in far eastern Russia, populations seem to have continued to decline over the 60-year period, while recent years have seen some recovery in at least two populations in the Labrador Sea.

Overall, the proportion of locations with increasing or stable populations has declined over time when the data are combined for all locations (Figure 13). This could reflect a change in the nature of the monitoring programs themselves—if there has been a shift in monitoring focus in recent decades from primarily monitoring more abundant, utilised species for management purposes to also monitoring more declining species for conservation purposes.

Figure 13. Percent of locations with increasing or stable populations, by decade from 1951 to 2010



Arctic environment. Photo: Roman Krochuk/Shutterstock.com

3.3 Understanding of the causes of Arctic vertebrate population change can be improved by expanding the spatial analysis of ASTI data to include spatial data on variables that represent drivers of biodiversity change.

The real benefits from spatial analysis come when you can associate, location by location, the trends in species abundance with the variables that may be driving the observed changes in biodiversity (for example, changes in climate and in land use). This allows for the testing of hypotheses. As the real world is complex, interactions among these drivers needs to be taken into account.

This type of analysis requires developing a model that incorporates, along with the population trend data, measures of factors that potentially drive changes in biodiversity (referred to as predictor variables). The model can then be used to look at which variables drive population increases, which ones have no significant effects, and which ones are associated with population declines. The model can help in detecting interactions, in estimating population trends in areas for which there are no data, and in predicting future biodiversity trends under different scenarios. For example, the model could be linked with climate models to predict biodiversity changes related to climate change scenarios. This would help in identifying regions where we would expect population declines, allowing better allocation of monitoring and management funds.

The methodology was tested by developing a preliminary model that incorporated a few readily available time series as predictor variables, including measures of air temperature, human density, and land cover. The resulting models (constructed using two different statistical techniques) explained only a modest amount of the variation in the population data (5 to 11%), indicating that a better suite of predictor variables is needed, as well as further work on methodology (see Looking ahead section for recommendations).

Herring. Photo: fanfo /Shutterstock.com

Looking ahead

Data coverage, quality and availability

In order to improve the spatial coverage of the data set, data collection efforts should be particularly focussed on areas where data are currently sparse, especially where declining trends are evident. This report provides tools for identifying significant gaps in data coverage (Key Findings 3.1 and 3.2 and related appendices).

The maps of data set characteristics (Key Findings 3.1 and 3.2 and related appendices) should be used to identify priority populations and areas for improvement of monitoring quality.

Two examples of how this can increase the utility of monitoring results:

- Establishing more multi-species monitoring programs in areas with mainly single species monitoring could help identify whether observed population trends are congruent among species.
- More frequent monitoring in areas with few data points in time series, especially where abundance may be declining or populations are potentially at risk, could be used to pinpoint inflection points in the time series and distinguish between naturally occurring fluctuations and actual population reductions in a more timely manner.

Arctic fox. Photo: Imagix/Shutterstock.com

The extensive and high quality time series data available for certain regions, such as northern Scandinavia and the Bering Sea, provide a basis for further analysis of underlying spatial patterns and factors influencing population trends. Regional analyses such as these are likely to improve our understanding of particular local factors that could exert a large influence on vertebrate population trends (Key Finding 2.5).

Snow bunting. Photo: Francis Bosse/Shutterstock.com

Measures to ensure consistent, timely reporting of monitoring results would improve the capacity of the ASTI and associated data analyses to provide up-to-date trend information and identify emerging changes in Arctic biodiversity. Data availability dropped sharply after 2000; in 2011 insufficient data were available to conduct analyses that extended past 2005 (for marine species) or 2007 (for all species combined). This may be the result of both a lag in reporting time and declining biodiversity monitoring efforts (Key Finding 3.1).

Drivers of population trends

The ASTI data set is suited for testing hypotheses and constructing predictive models using spatial analysis. To improve its capacity, work is needed in defining key drivers that impact northern populations and in developing data sets for variables that represent these drivers over space and time. These could include such variables as measures of habitat fragmentation, measures of impacts of climate change on habitat (such as changes in sea-ice conditions), and degree to which populations are harvested (Key Finding 3.3).

Steps that are likely to improve the power of these predictive models include (Key Finding 3.3):

- incorporating additional possible explanatory variables into future analysis using regional sub-sets as the basis for analysis;
- splitting analysis by species groups (numerically increasing versus decreasing; spatially expanding versus contracting populations); and,
- improved handling of multiple populations in a single area.

Caribou and industrial area. Photo: Wyatt Rivard/Shutterstock.com

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Appendix 1: Information on methods and data

The ASTI is an index calculated from monitoring data on abundance of vertebrates (fish, birds, and mammals) from around the Arctic. The data are from published literature and from unpublished monitoring records. Data sets are included if they have at least two well documented, comparable measurements of abundance taken in different years. Each of these data sets is referred to as a population.

Data sets have tags attached to them – examples: the taxonomic class, whether the population measured is in a protected area, and what part of the Arctic the data set is from. These tags allow indices to be calculated on subsets of the data and statistical tests to be used to look at patterns and relationships. This process is referred to as 'disaggregating' the index.

The index consists of one number calculated for each year from 1970 to 2007. This number is calculated from the overall average rate of change since the previous year for all the animals for which there are measures of abundance for those two years. Statistical models are used to estimate abundance for missing years between the start and end years of the time series, so some of the numbers used are estimates and some are measured values. The units are ASTI index units – starting at a value of 1 for 1970. A rise in the trend line connecting any two years of index values means that the average rate of change for all the species with data sets that spanned those two years was positive (an increase in abundance). The slope (steepness) of the line that connects any two values shows the magnitude of this increase in abundance. And, conversely, declining sections of the trend line show decreases in average species abundance.

Some aspects of the index to consider in interpreting the results

How data are combined influences the weight given to species in the analyses.

- ASTI: Where there are several data sets for one species, the annual rates of change are averaged so that only one value is used for each species for each index calculation. This means that each species has an equal weight in the value of the index. Thus, for example, all caribou populations are combined and have the same weight in the index as one species of fish.
- Marine analyses: Population statistics are not combined at the species level. This means that each population has an equal weight in the value of the index.

Results reflect the nature of the data set.

The ASTI data set is impressive in number of data time series and geographic coverage – but it is made up of data collected for various purposes, with different methods, time spans, and frequencies of abundance measurements. It does not come from a structured, thought-out, circumarctic monitoring program. This means that there are imbalances in the data coverage that influence the interpretations.

The timeframe of the analysis must be considered.

Current trends in marine ecosystems need to be interpreted against a solid understanding of the magnitude and drivers of past changes.[7] Due to the lack of widespread abundance data prior to 1970, that year is set as the baseline. However, an understanding of historical changes, including those related to overharvesting in the early to mid 20th century, could give rise to quite different interpretations of trends for some species.

Different species mixes are used to calculate the index each year.

This means that the index is not comparing the same mix of species along the length of the trend line.

Data.
The table below provides statistics on the data sets used for the various types of analyses described in this report.

Table A1: Data sets used for the various ASTI analyses

	2010 ASTI[2]	2011 ASTI update[4]	Marine ASTI (2011)[4]	Spatial analyses[3]
Time span	1970-2004	1970-2007	1970-2005	1951-2010
Number of populations	965	890	310	890
Number of species	306	323	111	323
Percentage of known vertebrate species	35%	37%	34%	37%

Kittiwakes Photo: Wild Arctic Photo /Shutterstock.com

Appendix 2: Maps of Arctic vertebrate data sets showing data coverage and quality over space and time

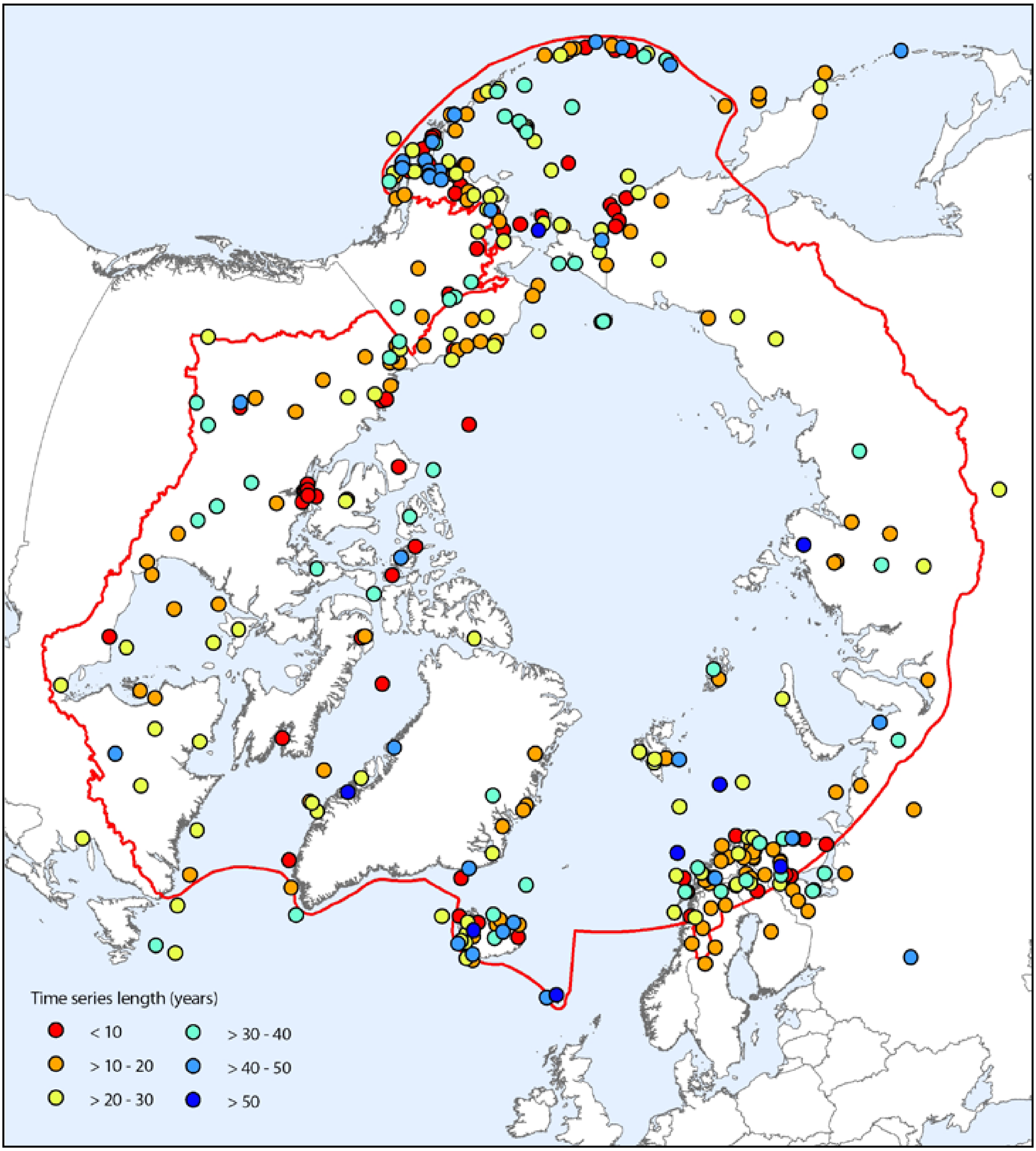


Figure A1. Quality of time series data across the Arctic by time series length, 1951 to 2010

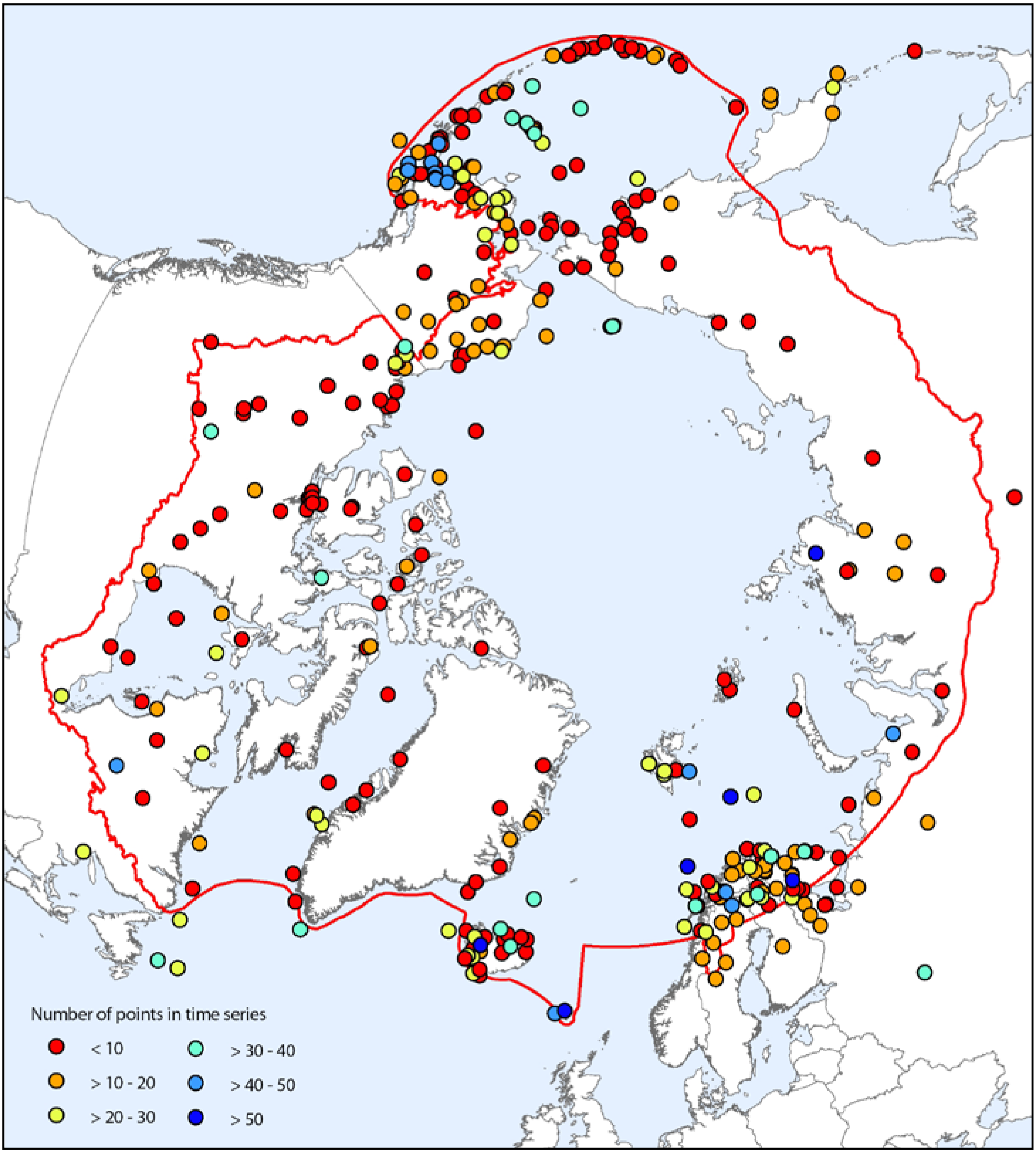


Figure A2. Quality of time series data across the Arctic by number of points in time series, 1951 to 2010

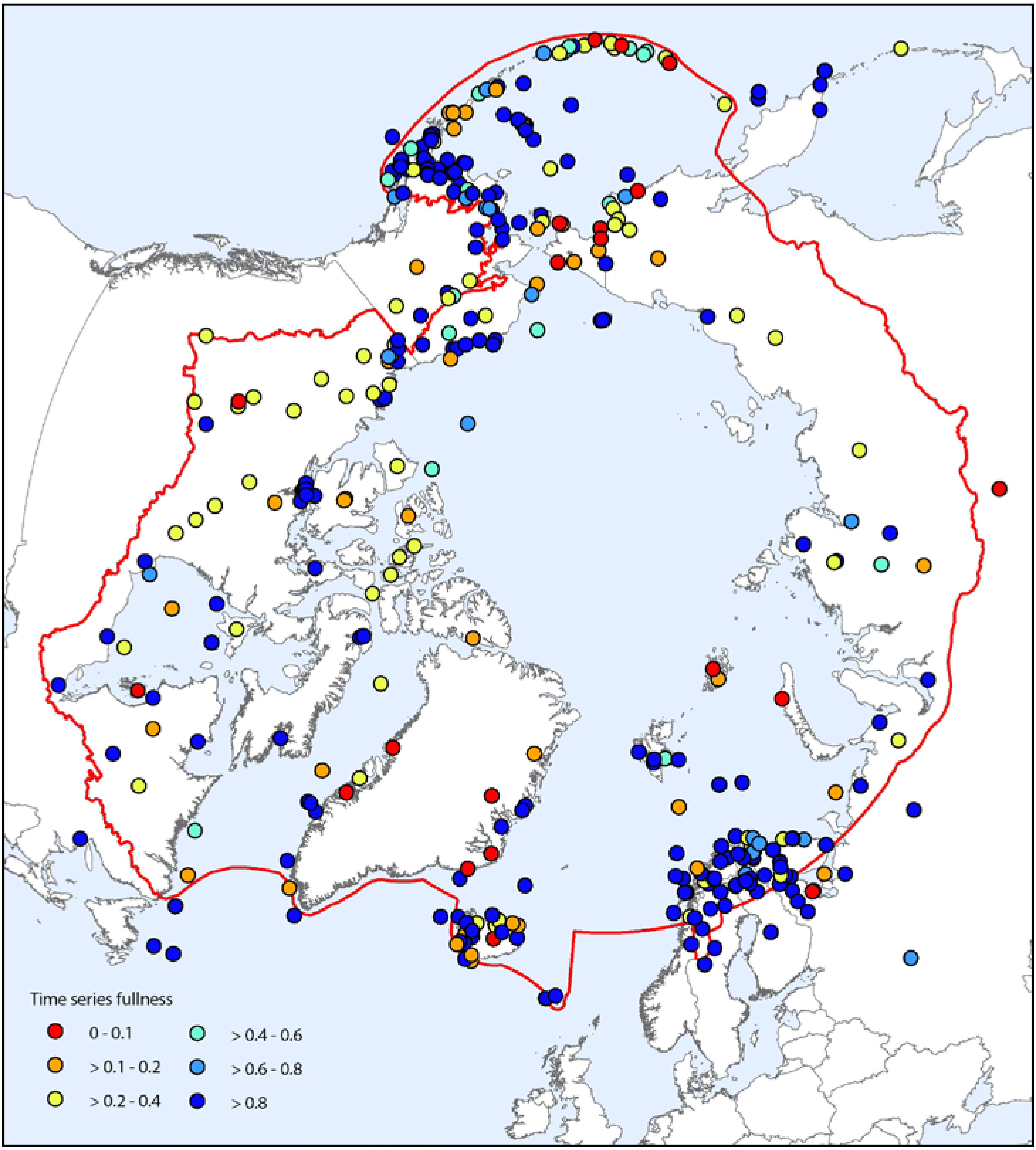


Figure A3. Quality of time series data across the Arctic in terms of time series fullness, 1951 to 2010
Calculated as Number of data points divided by time series length. 1.0 = complete time series.

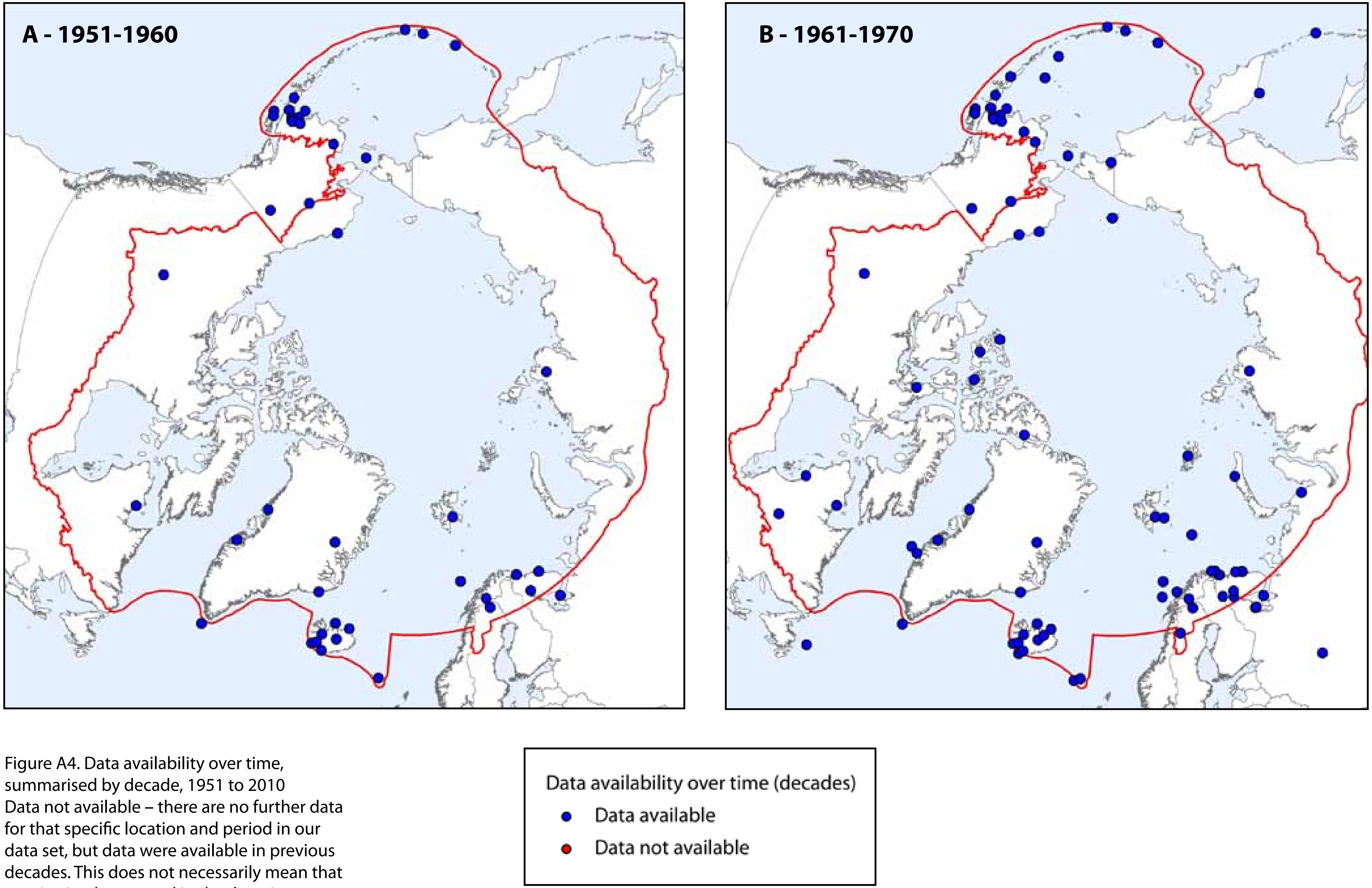
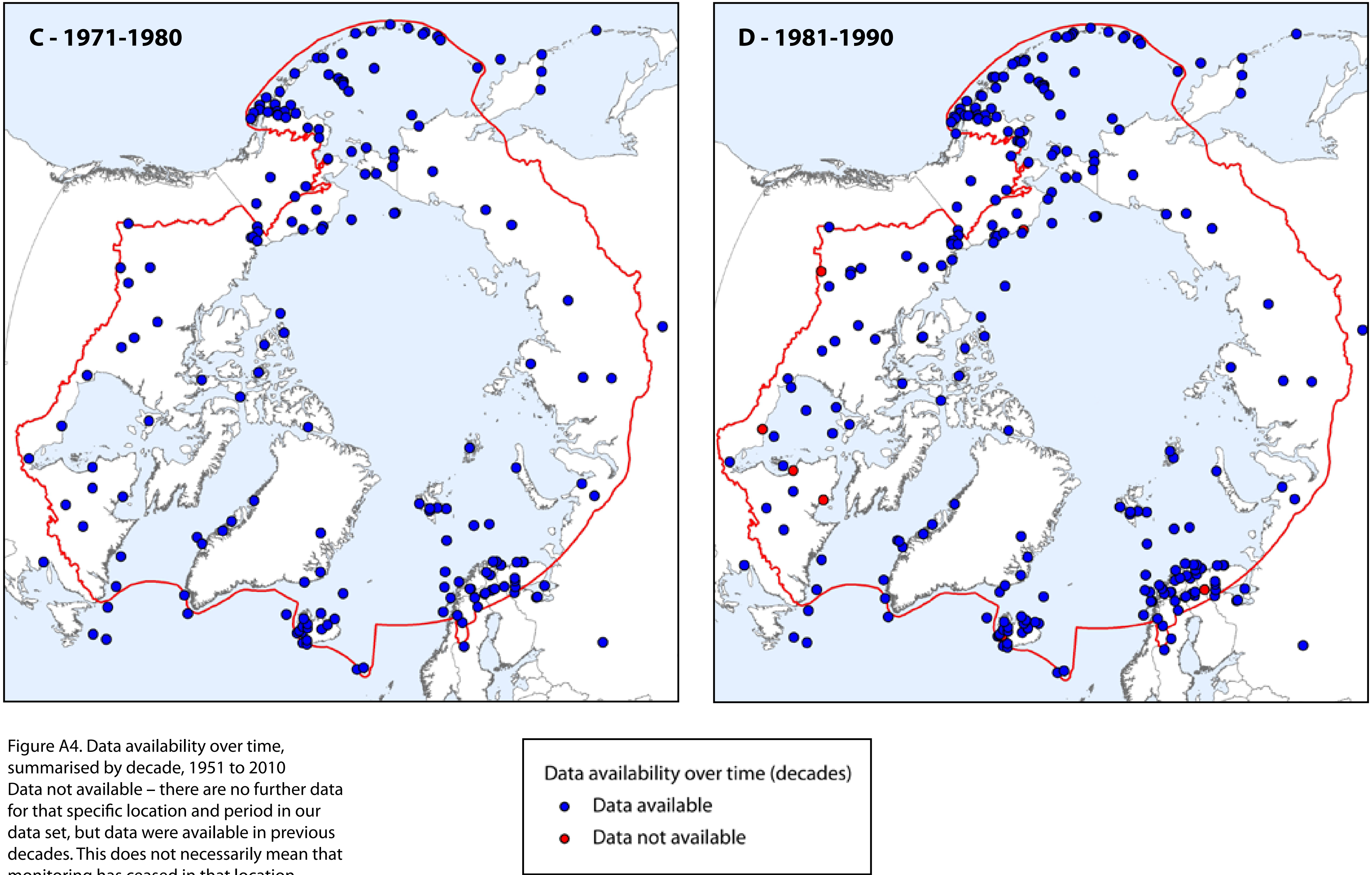


Figure A4. Data availability over time, summarised by decade, 1951 to 2010
Data not available – there are no further data for that specific location and period in our data set, but data were available in previous decades. This does not necessarily mean that monitoring has ceased in that location.



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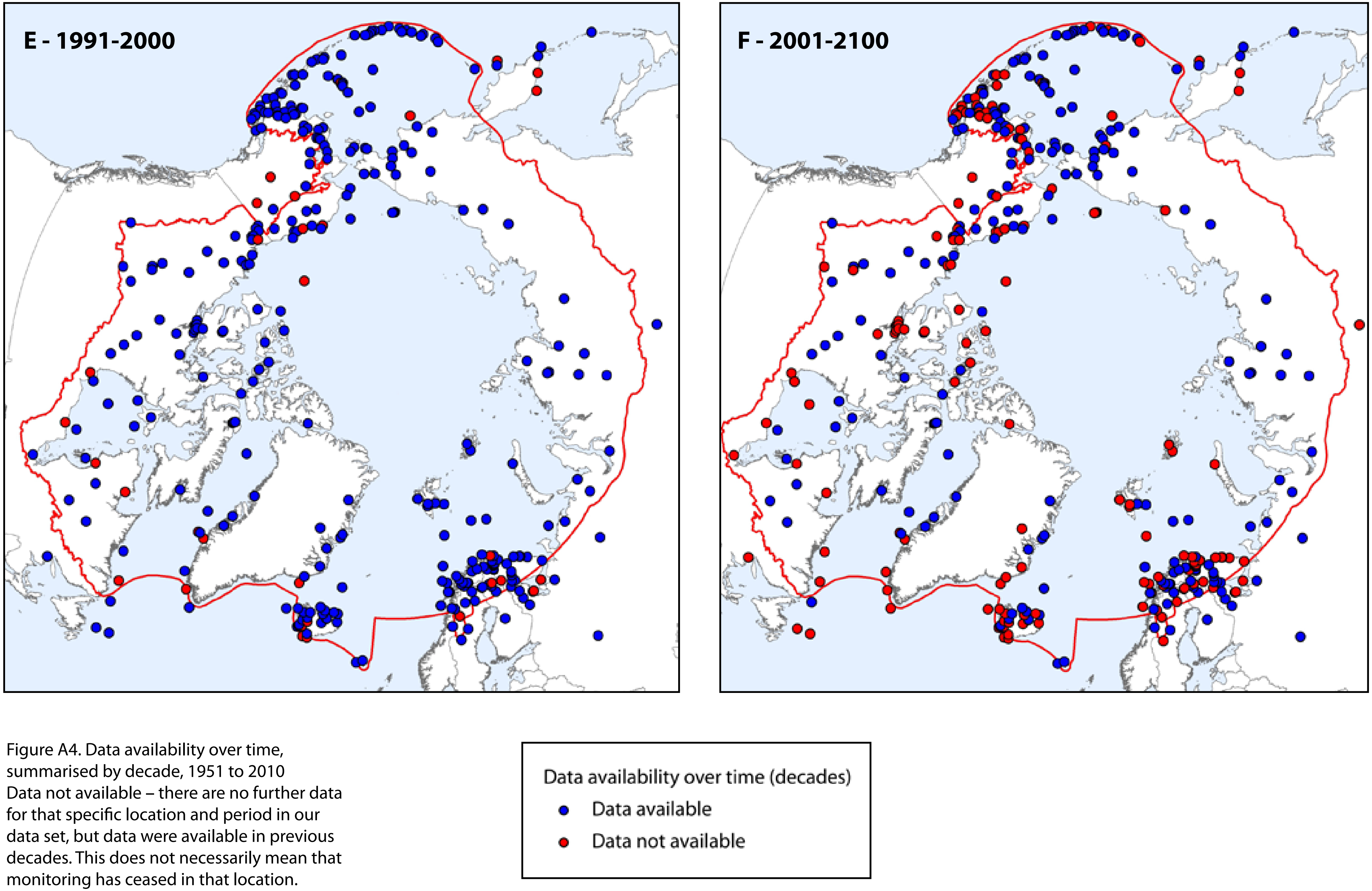

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Appendix 3: Maps of Arctic vertebrate data sets showing trends over space and time

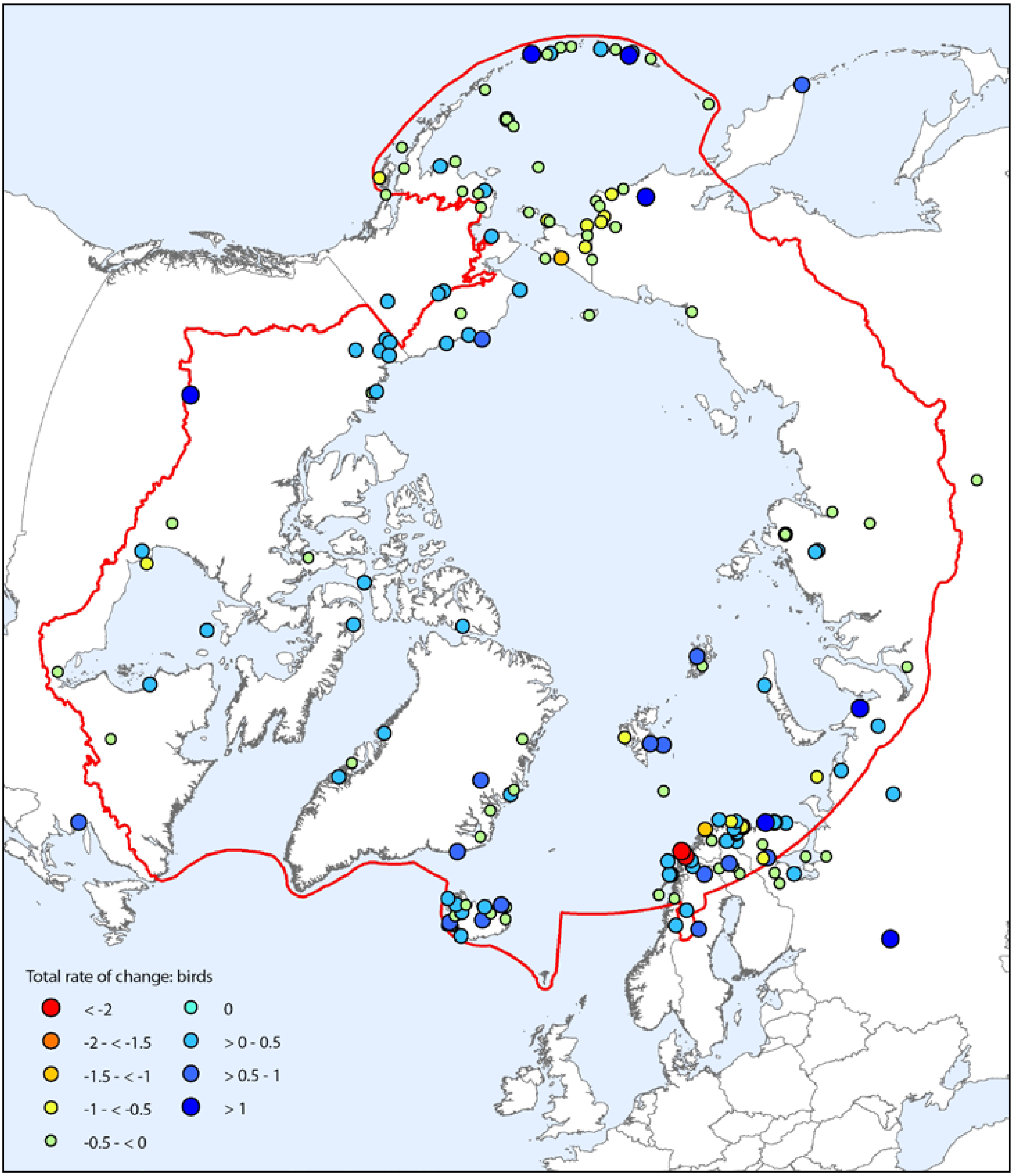

Figure A5. Spatial distribution of bird population trends in the ASTI data set, 1951 to 2010
Red circles indicate negative rates of change (i.e. declines), blue circles positive rates of change (i.e., increases). Total lambda is a measure of the rate of change over the entire time period.

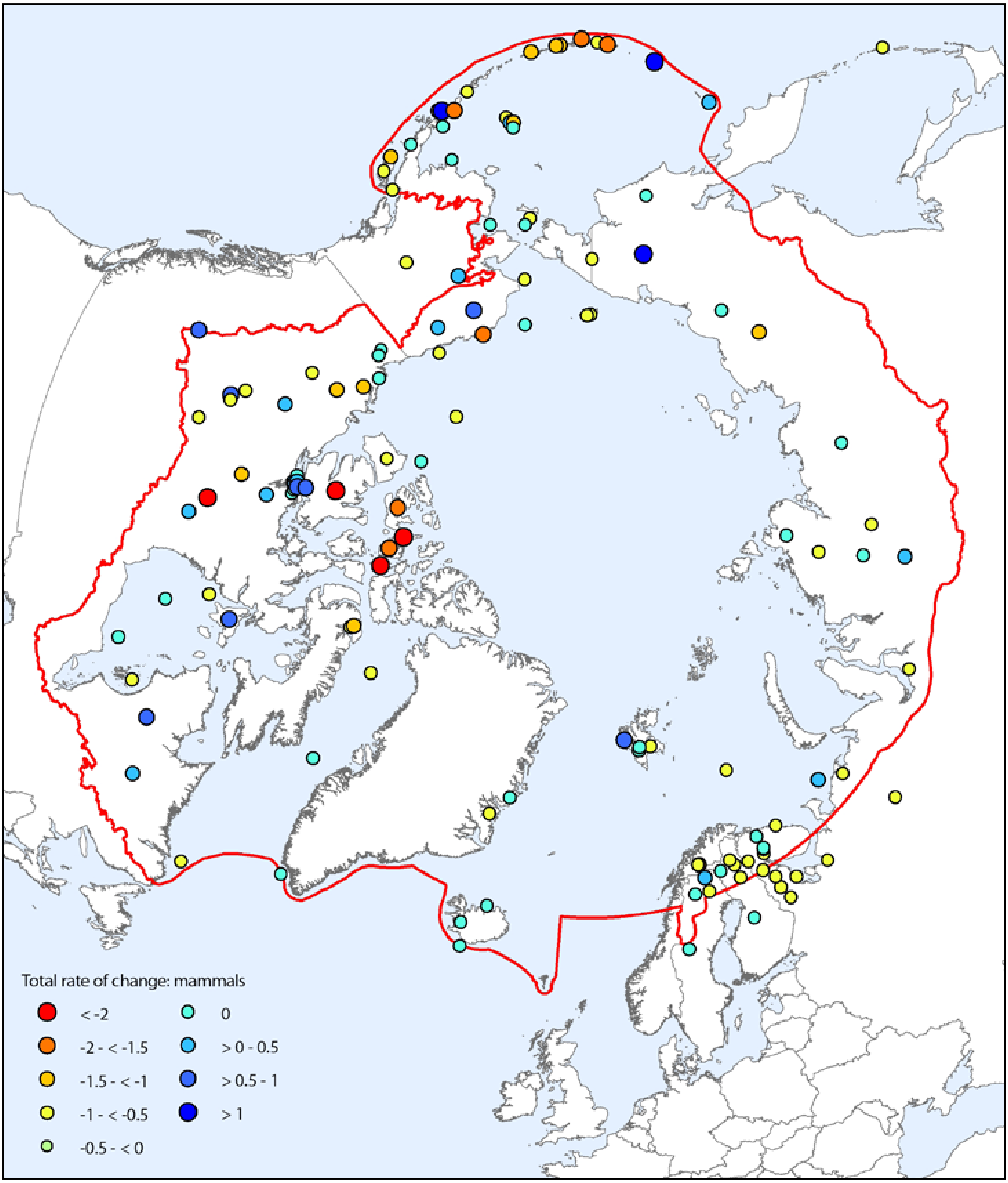

Figure A6. Spatial distribution of mammal population trends in the ASTI data set, 1951 to 2010
Red circles indicate negative rates of change (i.e. declines), blue circles positive rates of change (i.e., increases).
Total lambda is a measure of the rate of change over the entire time period.

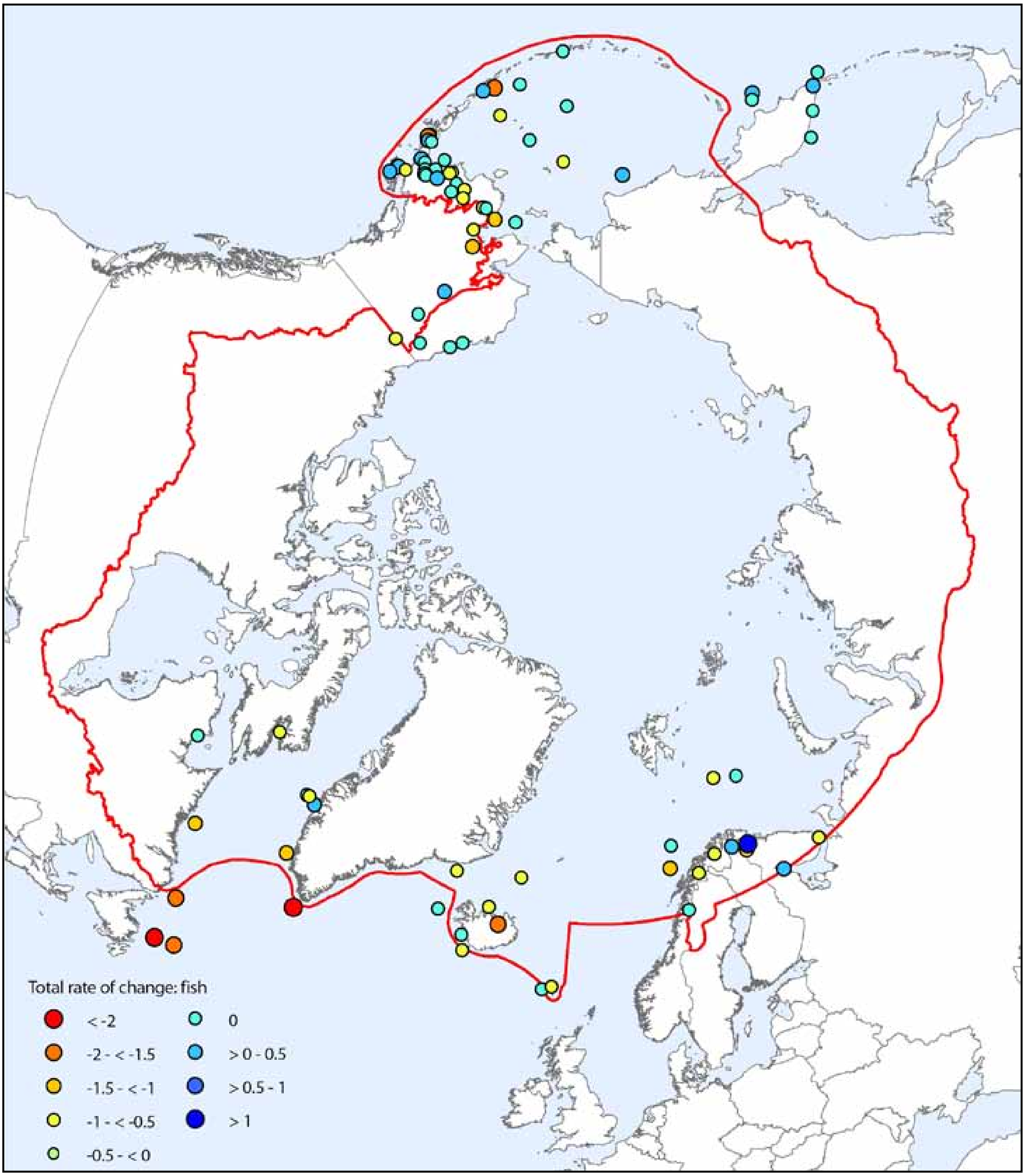

Figure A7. Spatial distribution of fish population trends in the ASTI data set, 1951 to 2010
Red circles indicate negative rates of change (i.e. declines), blue circles positive rates of change (i.e., increases).
Total lambda is a measure of the rate of change over the entire time period.

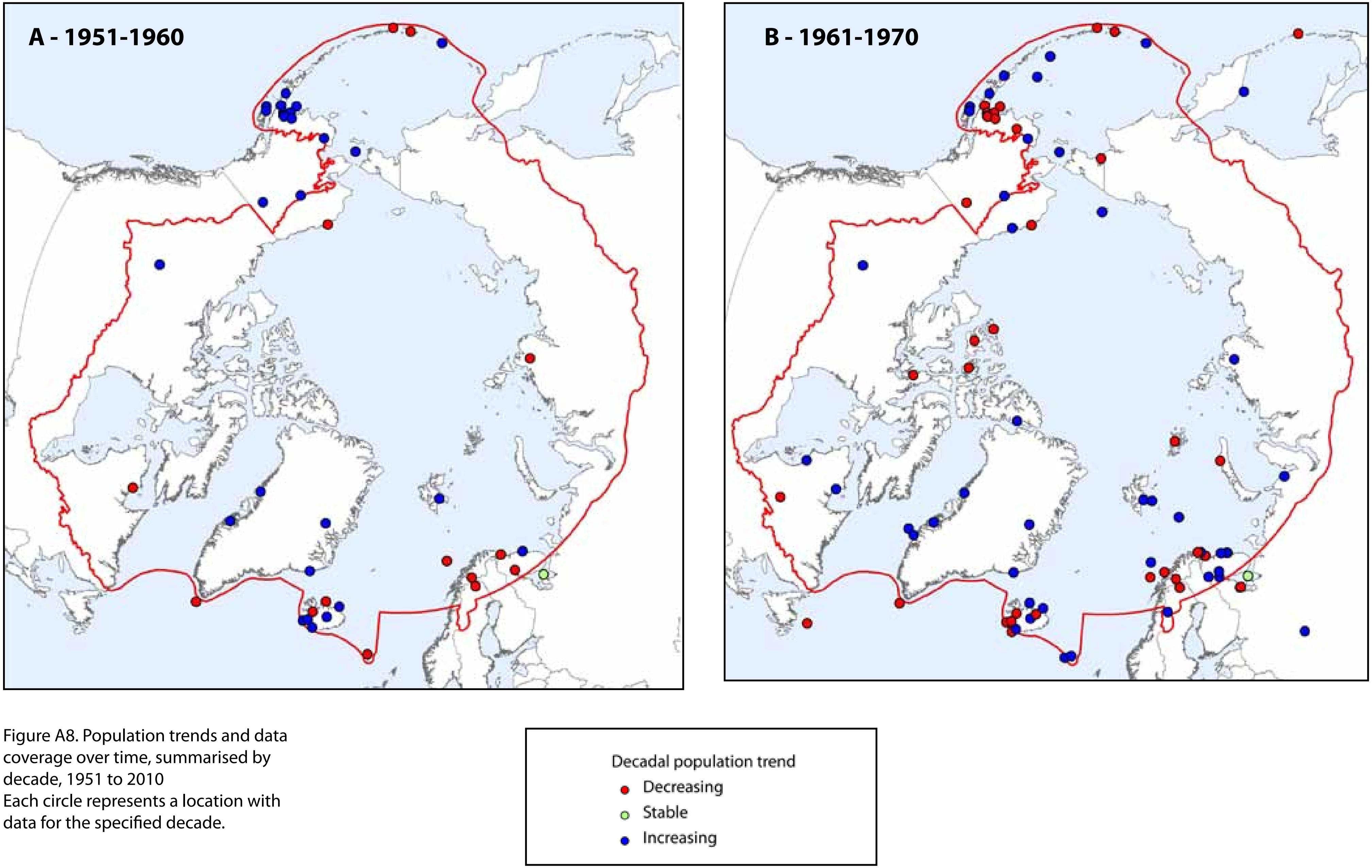

Figure A8. Population trends and data coverage over time, summarised by decade, 1951 to 2010
Each circle represents a location with data for the specified decade.

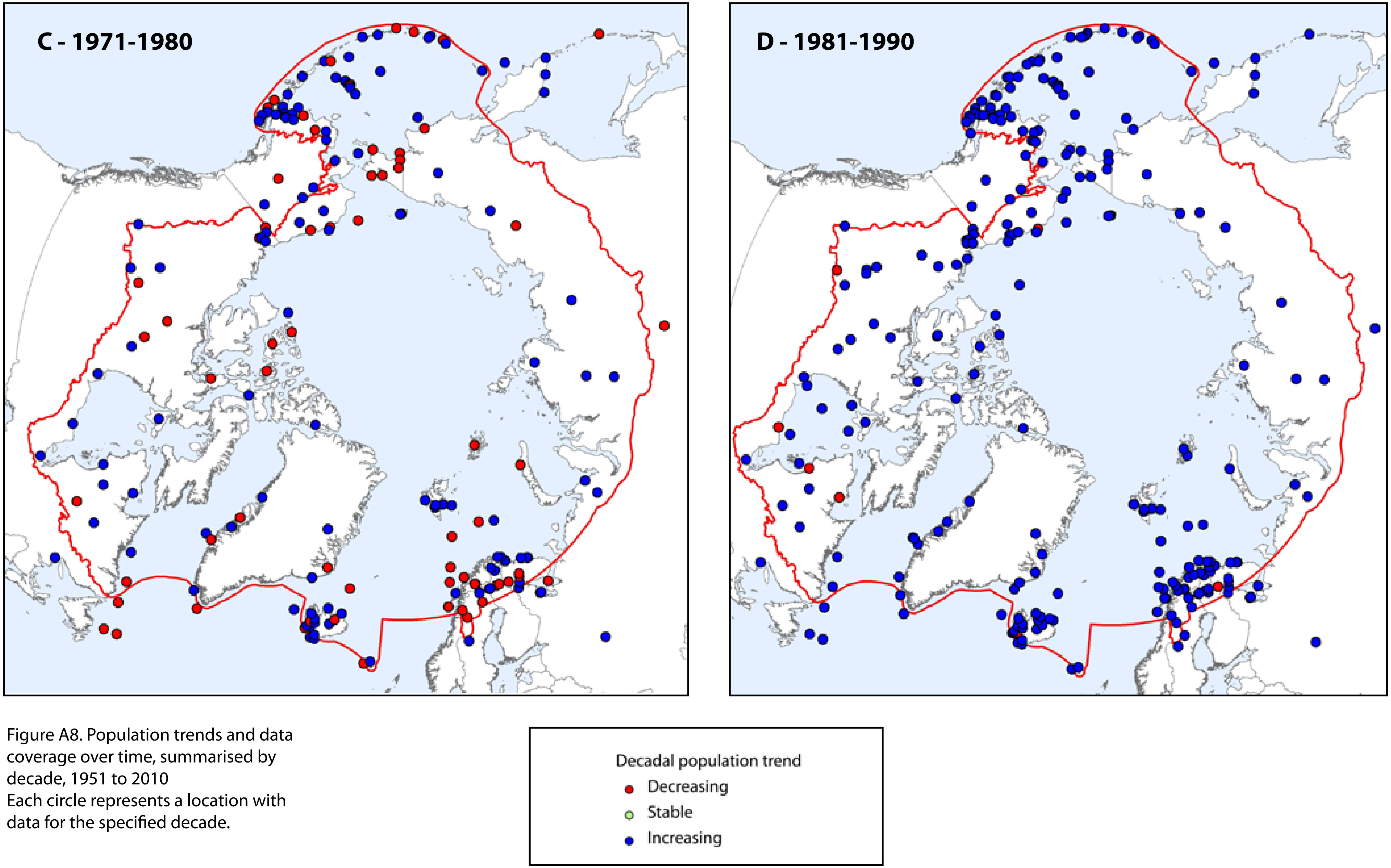

Figure A8. Population trends and data coverage over time, summarised by decade, 1951 to 2010
Each circle represents a location with data for the specified decade.

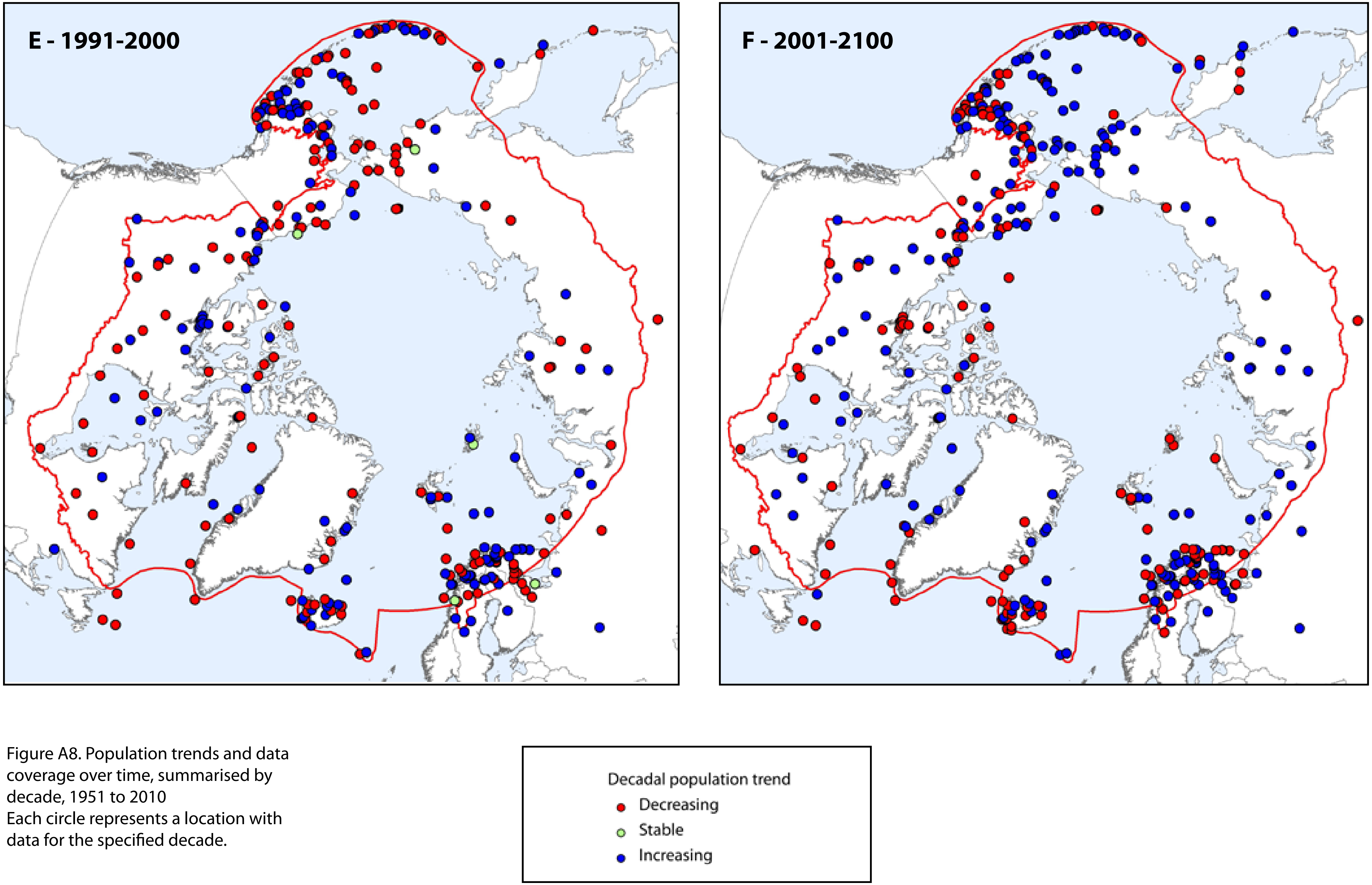

Figure A8. Population trends and data coverage over time, summarised by decade, 1951 to 2010
Each circle represents a location with data for the specified decade.

For further information and additional copies contact:

CAFF INTERNATIONAL SECRETARIAT
Borgir
Nordurslod
600 Akureyri
ICELAND

Telephone: +354 462 3350
Fax: +354 462 3390
E-mail: caff@caff.is
Internet: http: //www.caff.is

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