High Russian Arctic. Photo: Samantha Crimmin/Shutterstock.com

3.1 VEGETATION

Knowledge on different groups of vegetation, which includes plants and fungi, is very heterogeneous. Although the taxonomy of vascular plants is relatively well known, the checklists for both mosses and lichens are disparate with substantial knowledge gaps. Fungi and terrestrial algae are little known in the area. Plants are the main producers in Arctic ecosystems, while fungi, arthropods and different microorganisms are the main decomposers (Figure 2-4).

3.1.1 PATTERNS AND TRENDS OF FECS AND THEIR ATTRIBUTES

The CBMP–Terrestrial Plan identifies four FECs for monitoring vegetation: all plants (species, life-form groups and associated communities); rare species and species of concern; invasive alien species; and species that humans use as food (culturally important species). This section focuses on ‘all plants’—specifically those with existing monitoring data—and on ‘invasive alien species.’ Results for the ‘species of special concern’ FEC are included in Section 3.5. The ‘food species’ FEC was not included as data were too disparate.

Lead authors:
Virve Ravolainen, Anne D. Bjorkman

Contributing authors:
Donald Walker, Howard Epstein, Gabriela Schaepman-Strub

Forty key attributes (essential and recommended) that pertain to vascular plants, bryophytes and lichens were identified for monitoring (Table 2-1). This section focuses on the essential attributes for which sufficient data exist. For 'all plants,' this includes productivity, composition, abundance, and phenology. For 'invasive alien species' it includes abundance and distribution.

This summary is based on the overviews and references within Bjorkman et al. (2020), Ravolainen et al. (2020), Jenkins et al. (2020) and Wasowicz et al. (2020), as well as other recent relevant literature

3.1.1.1 All Plants/Vegetation

Productivity

Primary productivity can be assessed on a circumpolar scale using satellite imagery that provides vegetation indices; frequently using an index called the Normalised Difference Vegetation Index (NDVI). Analysis of temporal trends in the greenness indices include the maximum NDVI (MaxNDVI) and time integrated NDVI. The U.S. National Oceanic and Atmospheric Administration reports on these annually (e.g., Frost et al. 2020). Results show an overall increasing trend from 1982 to 2017 for both the MaxNDVI (Figure 3-1) and time-integrated NDVI. Nevertheless, some regions show a negative trend, such as the Yukon–Kuskokwim Delta of western Alaska, the high Arctic of the Canadian Archipelago, and the north-western and north coastal Siberian tundra. There is large heterogeneity in satellite-derived vegetation change, also found in recent studies (Myers-Smith et al. 2020). This result is supported by Jenkins et al. (2020) which found a circumpolar NDVI increase between 2000 and 2017 (see also Figure 3-1). While positive trends can be linked to climate change, the cause of the different positive and negative trends in different geographic areas over the same time period is not clear. It is thought to be at least partially linked to changes in the distribution of Arctic sea ice versus open water (Bhatt et al. 2010, 2017), to variation in climate and soil moisture (Berner et al. 2020). and to divergent NDVI data resulting from different sensors (Guay et al. 2014).

Composition and Abundance

Observations from plot-based studies of community composition and abundance also show heterogeneous trends (Elmendorf et al. 2012). A recent review (Bjorkman et al. 2020) found large variation among sites and species in the direction and magnitude of change in abundance. Forb, graminoid and shrub abundance changed significantly (increased or decreased) over time in roughly a third of published studies, while approximately half of the studies identified no significant trends (Figure 3-2). In contrast to mixed temporal trends, experimental warming led to clear changes in the abundance of lichens, which were far more likely to decrease in abundance in response to experimental warming than to increase or remain stable.

Shrub abundance is generally considered to be particularly sensitive to environmental change and the 'greening' observed in many areas of the Arctic is often attributed to the increased growth or expansion of shrubs. However, multiple aspects of shrub development (for example, area expansion, height change and upslope or northward movement) also demonstrate considerable heterogeneity, and no directional change in any variable consistent across the entire Arctic is evident (Myers-Smith et al. 2015).

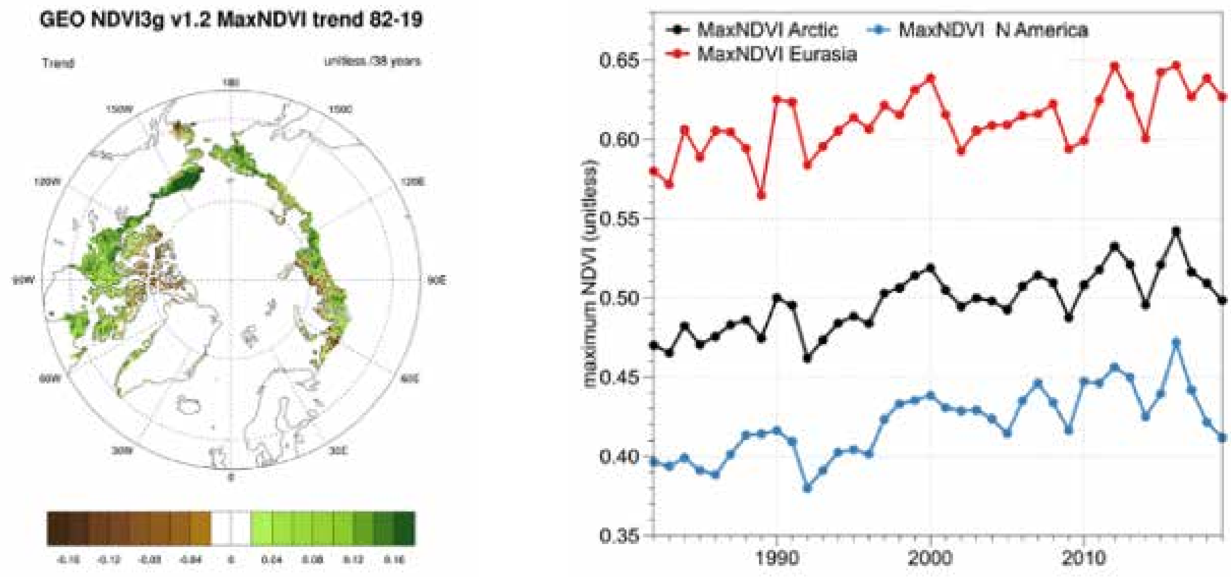


Figure 3-1. Circumpolar trends in primary productivity as indicated by the maximum Normalised Difference Vegetation Index, 1982–2017. (a) Brown shading indicates negative MaxNDVI trends, green shading indicates positive MaxNDVI trends. (b) Chart of trends for the circumpolar Arctic, Eurasia, and North America. Modified from Frost et al. 2020.

Phenology

Phenology—the timing of life events such as green up, flowering and leaf senescence—is identified by the CBMP–Terrestrial Plan as an essential attribute. Changes in phenology can influence the reproductive success of an individual plant and consequently the population size of a species, potentially leading to shifts in the composition of Arctic plant communities. Studies have shown that leaf emergence (green up) and flowering typically occur earlier in response to experimental warming (Bjorkman et al. 2020). Many plot-based monitoring studies also documented trends toward earlier flowering over the duration of the studies, which ranged from 9 to 21 years (Figure 3-3); however, this varied by site and species (Bjorkman et al. 2015). Phenological observations through remote sensing between 2000 and 2017 indicate an earlier start of the season (green update) in most southern and middle latitude regions (subzones E and C) while in other regions (subzones A, B and D) there was no change in green up (Jenkins et al. 2020).

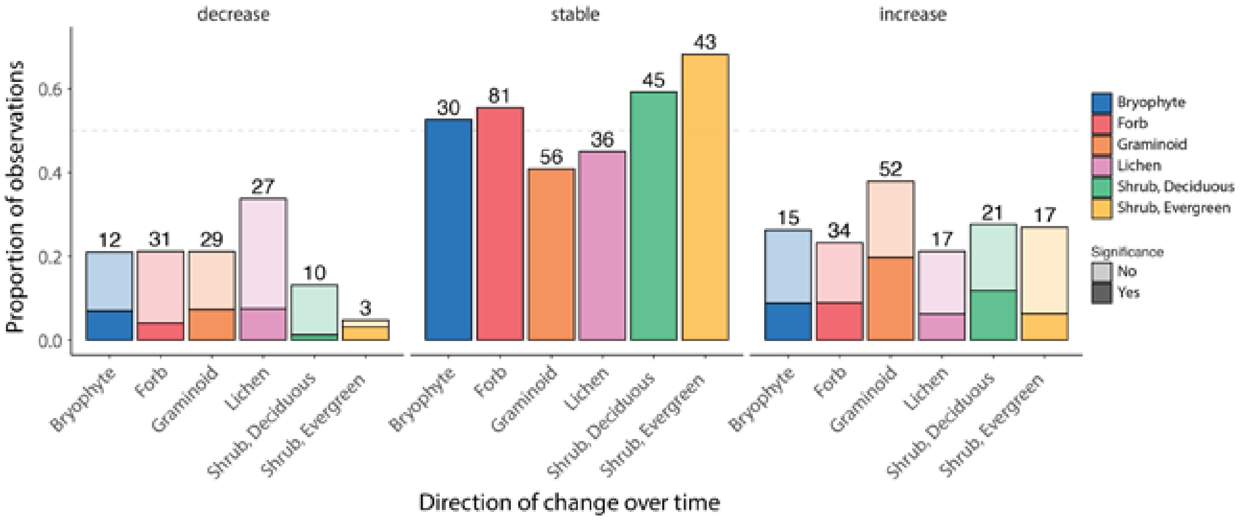


Figure 3-2. Change in forb, graminoid and shrub abundance by species or functional group over time based on local field studies across the Arctic, ranging from 5 to 43 years of duration. The bars show the proportion of observed decreasing, stable and increasing change in abundance, based on published studies. The darker portions of each bar represent a significant decrease, stable state, or increase, and lighter shading represents marginally significant change. The numbers above each bar indicate the number of observations in that group. Modified from Bjorkman et al. 2020.

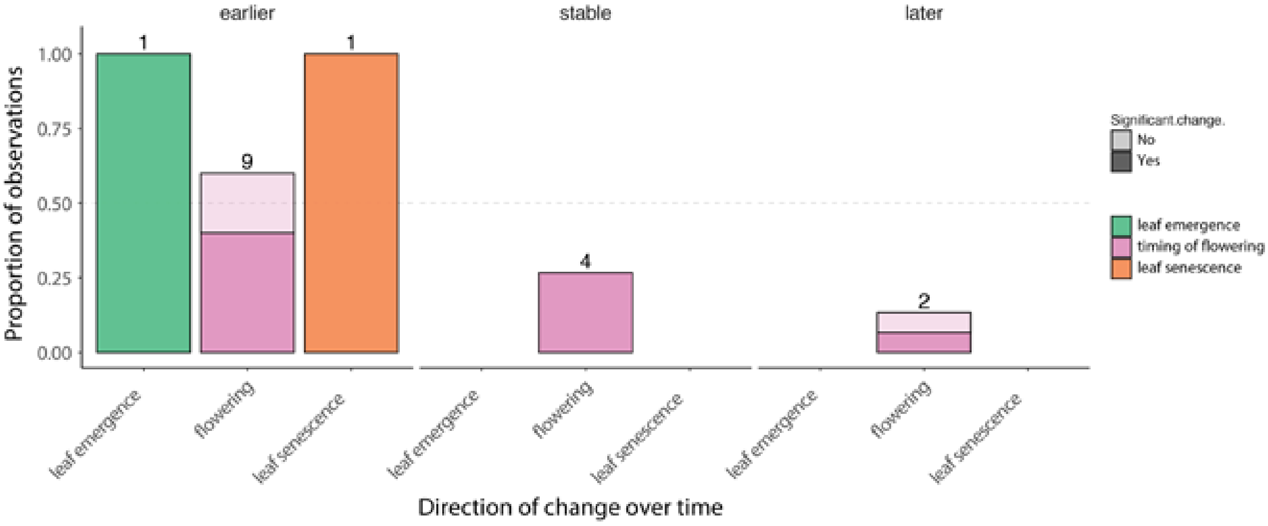


Figure 3-3. Change in plant phenology over time based on published studies, ranging from 9 to 21 years of duration.

The bars show the proportion of observations where timing of phenological events advanced (earlier) was stable or were delayed (later) over time. The darker portions of each bar represent visible decrease, stable state, or increase results, and lighter portions represent marginally significant change. The numbers above each bar indicate the number of observations in that group. Figure from Bjorkman et al. 2020.

At the end of the growing season, leaf senescence shows different patterns in experimental warming and in long-term monitoring studies (Bjorkman et al. 2020) for reasons currently unknown. These results correspond with a 2013 synthesis of leaf senescence (Oberbauer et al. 2013) finding mixed trends, as well as satellite records where no trend was observed in senescence date.

In addition to monitoring studies assessing change in vegetation over time, studies of vegetation change along spatial temperature gradients that traverse the Arctic, such as the Eurasia Arctic Transect (e.g., Walker et al. 2019), can also increase our understanding of how changing temperature might influence the plant communities.

3.1.1.2 Non-native Species

In 2019, 341 non-native vascular plant species were confirmed in the Arctic; 11 are considered invasive (Wasowicz et al. 2020). Regional and local studies indicate that invasive alien plant species are largely confined to areas close to human settlements (Wasowicz et al. 2020) and studies hitherto found that in natural habitats, they tend to disappear over the course of some years to a decade (Alsos et al. 2015).

Although non-native plant species are found throughout the Arctic, they show a clustered distribution pattern (Figure 3-4).

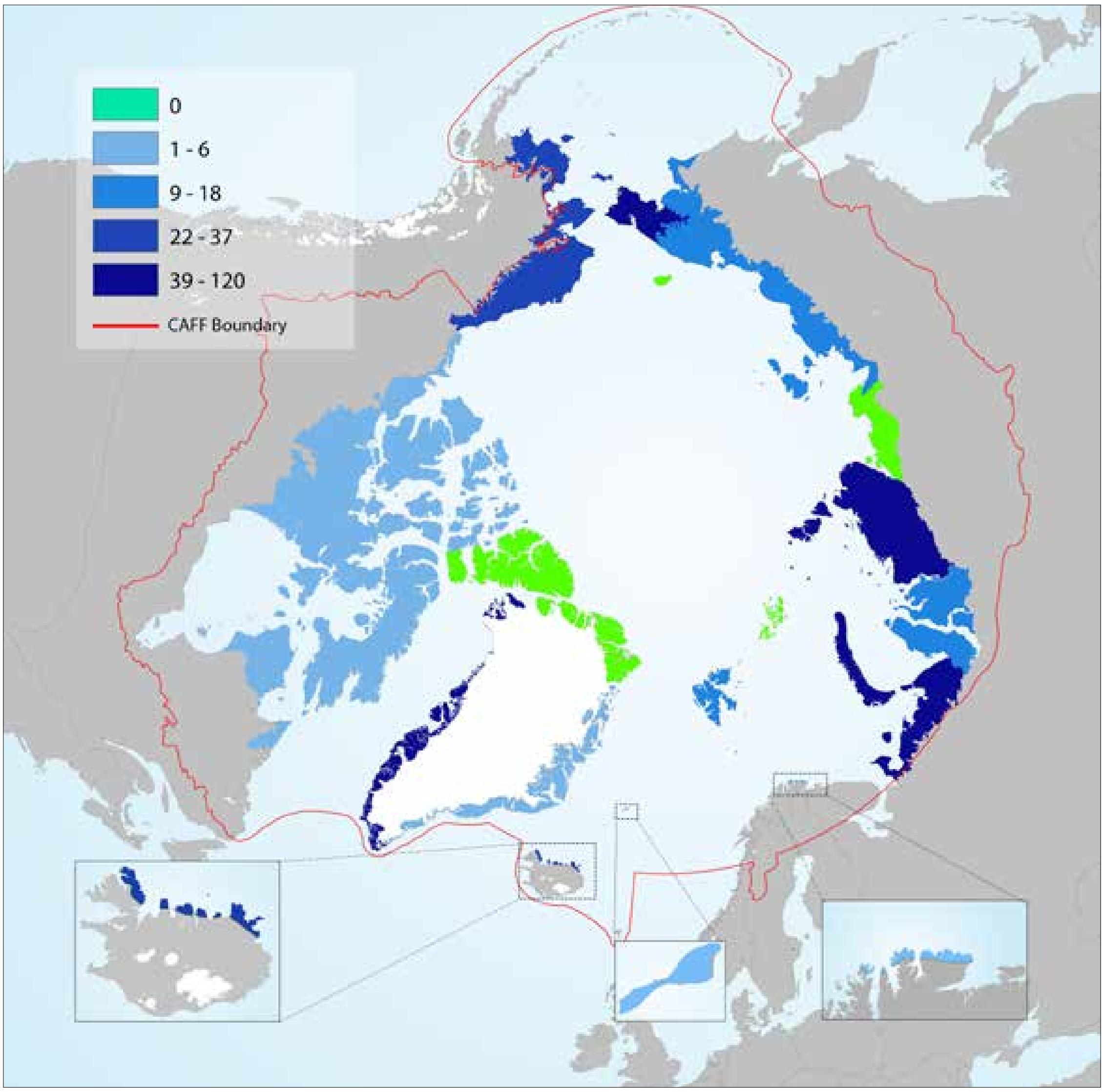


Figure 3-4. Number of non-native plant taxa that have become naturalised across the Arctic. No naturalised non-native taxa are recorded from Wrangel Island, Ellesmere Land – northern Greenland, Anabar-Olenyok and Frans Josef Land. Modified from Wasowicz et al. 2020.

Photo: Evgeniy Trufanov

3.1.2 EFFECT OF DRIVERS ON FECS AND THEIR ATTRIBUTES

The high inter- and intra-annual variability in vegetation parameters may give the impression that little general change in vegetation in the Arctic has occurred. This heterogeneity is, however, inherent to plant life in the Arctic, and a response to the drivers that influence plants on local and regional scales. Arctic plants are generally slow growing and long-lived, but they are also adapted to a highly variable environment. Their growth and abundance are tightly linked to summer temperature (van der Wal & Stien 2014), given sufficient moisture (Elmendorf et al. 2012, Myers-Smith et al. 2015). As temperature, moisture and other environmental conditions have varied greatly historically within and between seasons, a natural consequence is large variation in above ground plant abundance, phenology, and productivity between consecutive years at any given location.

Summer temperature is one of the most important drivers affecting plant above-ground abundance in the Arctic. Plant abundance strongly correlates with July temperature in the high Arctic as shown in Svalbard (van der Wal & Stien 2014); however, as demonstrated in Section 2.3.1, few, if any, spatially consistent, large-scale trends in documented plant responses to temperature drivers exist (Elmendorf et al. 2012). Locally, effects of summer and winter climate can be pronounced (Milner et al. 2016). In the winter, mild events followed by cold temperatures or ice layers on the ground can damage plants in some parts of the landscape. Shrubs are particularly vulnerable to winter damage and several studies have documented damage or mortality due to severe winter climate events (Bjerke et al. 2017). Effects of climate are modified both locally/regionally (Bråthen et al. 2017) and globally (Barrio et al. 2016) by biotic interactions and especially by grazing animals.

3.1.3 COVERAGE AND GAPS IN KNOWLEDGE AND MONITORING

Vegetation change may be more pronounced at particular locations, habitats within landscape, or within vegetation types, and may not be uniform among similar habitat types across different regions. Vegetation parameters can be decreasing or increasing at hyper-local scales, even if compound measures that average the parameters over several ecological contexts show no change. The spatial heterogeneity in vegetation change over time and in response to environmental drivers suggests that effects of change in drivers needs to be investigated and interpreted in the context of each ecosystem and even in habitat-specific contexts (Ravolainen et al. 2020).

To accommodate changes in vegetation in response to outside influences—that is, context dependency—monitoring programmes and long-term ecological research should include conceptual models on expected vegetation responses and their drivers, for example, the International Tundra Experiment (ITEX) (2020). These would help decipher which vegetation parameters are expected to change in a given ecosystem or habitat, what drivers are likely to play an important role, and how they can be monitored to provide information on trends and causal relationships.

Vegetation monitoring occurs across the Arctic, but the duration of monitoring efforts is variable and is dependent upon both study design and access to resources. Although many field studies on vegetation have been conducted in the Arctic (Figure 3-5), not all can be considered monitoring since some recorded only select measurements over limited time frames. Studies reporting on abundance and composition of vegetation reflect a larger and more widespread geographical coverage than the typically more site-limited and time-consuming phenology studies (Figure 3-5). Geographical gaps in coverage of Siberia and large parts of the Canadian Arctic are evident.

Relatively few time series are maintained with annual or nearly annual recording in the Arctic. These time series are restricted to a handful of sites, including Svalbard (e.g., van der Wal & Stien 2014), the Norwegian mainland (e.g., Soininen et al. 2018), Greenland (e.g., Westergaard-Nielsen et al. 2017), the Canadian high Arctic (e.g., Hudson & Henry 2009) and the U.S. Arctic (e.g., Wahren et al. 2005). In most cases, the vegetation monitoring at these sites is integrated with monitoring of other ecosystem components and environmental conditions, as well as climate. The International Tundra Experiment (ITEX) and other relevant networks, contribute valuable information to long-term studies of plants and their responses to climate change. Great variability in the frequency and duration of measurements occurs within these networks. Only recently have ecosystem-based monitoring programmes been developed in some of the Arctic states, such as Norway and Greenland (Ims et al. 2013).

Whilst used over large areas, the resolution of the satellite imagery and computational and analytical power sets limits on what kind of information is available for the largest scale, such as Arctic-wide studies. Currently, circumpolar studies use 250 metres or larger units in the analysis. This scale limits the parameters to compound measures such as vegetation indices that give no or little information about which vegetation type is changing. Vegetation models can be used for spatial studies of vegetation change, but with the same limitations regarding spatial resolution, precision, and accuracy as with satellite imagery.

3.1.3.1 Recommended Revisions to FECs and Attributes

Based on experience obtained from producing the START, there are no revisions recommended for vegetation FECs. The FECs in themselves cover a broad spectrum of topics but are largely lacking in monitoring (see below).

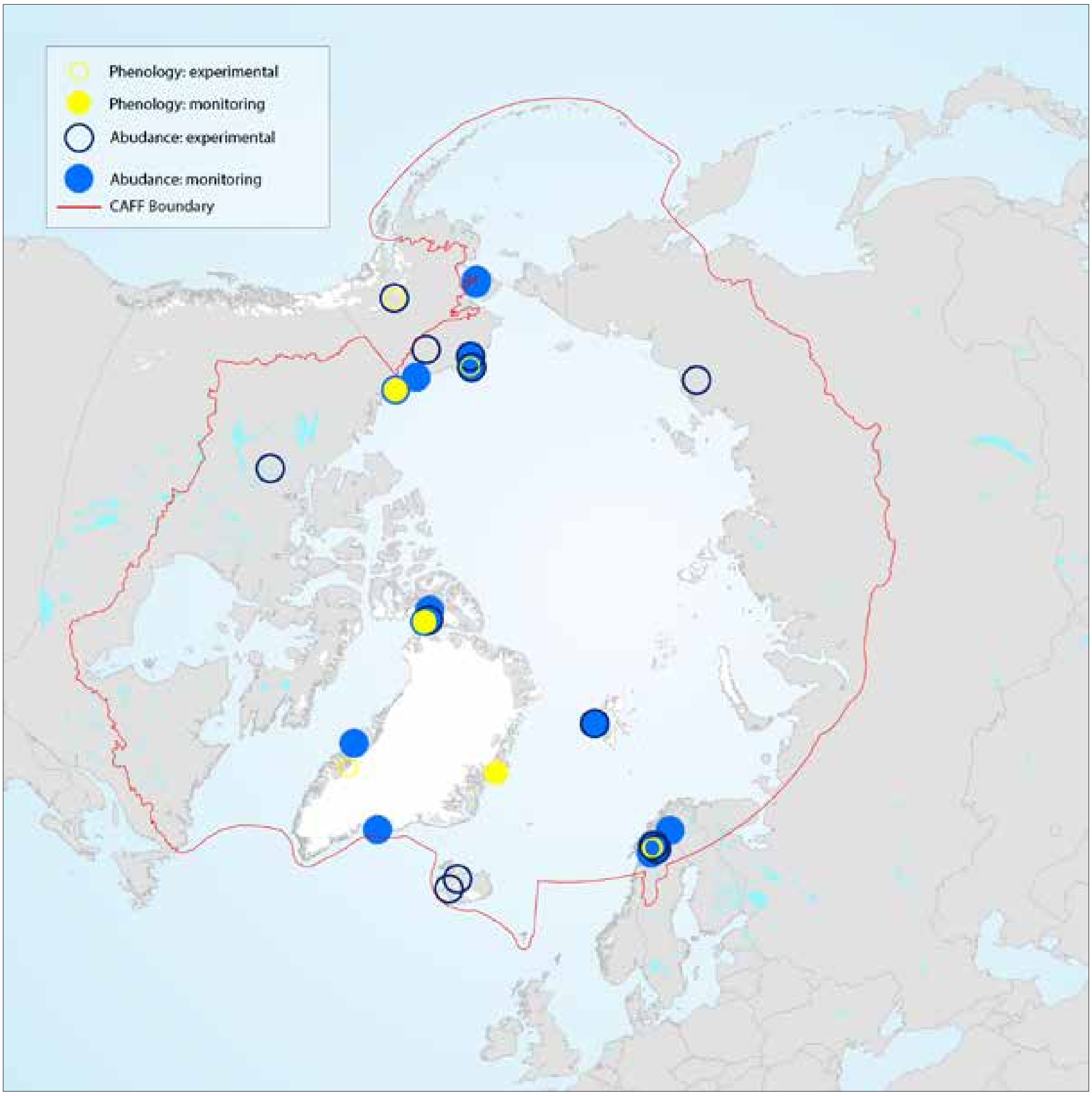
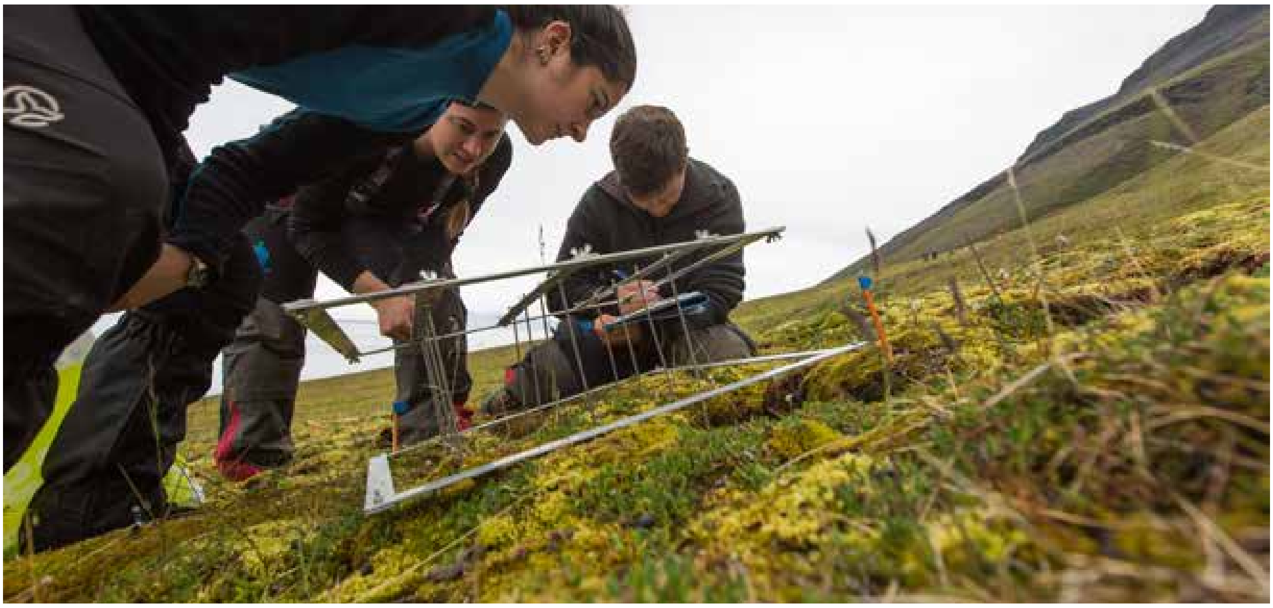


Figure 3-5. Geographic distribution of long-term studies or monitoring sites of abundance and phenology of plants in the Arctic. Modified from Bjorkman et al. 2020.



Vegetation monitoring, Svalbard, Norway. Photo: Lawrence Hislop

3.1.4 CONCLUSIONS AND KEY FINDINGS

Many of the physical and ecological parameters that drive terrestrial vegetation have experienced significant change over the past decades; for example, seasonal land surface temperature has increased significantly since 2001 (Jenkins et al. 2020). These rapid changes in the physical environment highlight the importance of a systematic approach to monitoring across the Arctic, including ecological responses associated with Arctic vegetation.

The plant productivity FEC attribute measured with remote sensing, had a general positive trend from the early 1980s to 2017. Some relatively large regions in the Arctic showed a negative trend, although the reasons are not fully understood. Plot-based studies of the 'community composition' and 'abundance' attributes show large variation among sites and species in the direction and magnitude of change. In the majority of the studies, abundance of different plant groups remained stable. Amongst the responsive groups, shrub and graminoid abundance often increased, while lichen abundance commonly decreased over time. Shrub abundance increased more often in southern parts of the tundra than in the northern parts. Experimental warming studies and observational long-term studies show somewhat different trends. Invasive plant species are largely confined to human settlements, and, when observed in natural habitats, have been found to disappear in less than a decade.

Climate is one of the most important environmental drivers for vegetation. Plant abundance is closely linked to summer temperature and variable climate is reflected in variable above ground biomass. In some regions, damage to vegetation from the increasingly mild winters and especially ground-ice formation has been reported. Effects of climate can be modified by biotic interactions. Changes to vegetation occur in the context of each ecosystem and there can be strong local effects of environmental drivers on vegetation even if averaged trends may seem heterogenous or stable.

Key Findings

- There is considerable spatial and temporal heterogeneity in vegetation development in the Arctic; some areas show increases in production and abundance, while others are decreasing or remaining stable. However, remote sensing shows that since 2001 there has been a significant increase in vegetation productivity across the entire Arctic.
- Responses to climate change include an increase in the abundance of shrubs and grasses and a decrease in lichens and mosses.
- Non-native plant species are increasingly moving into the Arctic and are largely found localised in areas with human activity. Between 2013 and 2019 the numbers of non-native plants detected increased by 80%, to 341. Most are still non-invasive.
- Experimental warming has shown that green-up and flowering can happen earlier. This trend has also been found in many plot-based monitoring studies, although not as conclusively. Remote sensing indicates an earlier start of the season in the most southern and middle latitude regions of the Arctic.
- There is a need for more long-term monitoring on all FECs.