Appendix 1 Supplementary information on indicators

Contents

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1 General methods

This section describes methods for how indicator values are calculated based on the available datasets. We describe the overall analytical framework used to estimate rates of change in abiotic indicators and indicators based on time-series (see Williams et al. 2021 for an example). The appendix includes graphical representations of all indicator values and background data for these values, as well as supplementary methods for estimating indicator values where required. All statistical analyses were conducted in R (R Core Team 2021).

1.1 Abiotic indicators (climate and hydrology) - rates of change after the reference period 1961–1990

To estimate linear rates of change, relative to the climatic reference period 1961–1990, a two-step bootstrap (i.e. a statistical method that resamples a dataset many times) has been used: 1) Non-parametric bootstrapping data for the first 30 years (1961–1990) as basis for estimating uncertainty around the mean for the reference period, 2) bootstrapping of data for all remaining years after the climatic reference period (1991–present) used to fit a linear regression model with the intercept given by the bootstrapped mean for the reference period. We also fitted segmented models with trends in both the reference period and the most recent period (1991 onwards) in case changes started before 1990. However, not all abiotic indicators can be estimated based on linear relationships. For some indicators, which have linear rates of change on a log scale and Poisson distributions or a variance proportional to the mean (for instance counts such as the number of days), log-linear models were used, using quasi-likelihood methods in case of overdispersion. The difference between this approach and the default linear model is that the average for the reference period 1961–1990 was included as an offset in a generalised linear model (glm function). See Figure A1 for details on how to interpret results.

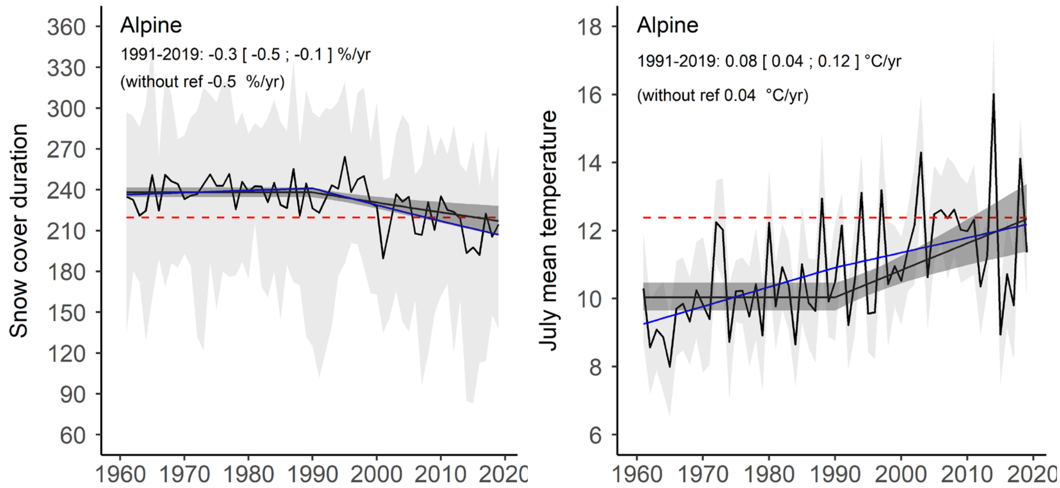

Figure A1. *Example of how rates of change are estimated for the time-series for abiotic indicators (here illustrated by the indicators Snow cover duration and July mean temperature for alpine areas). The fluctuating black line with light grey error envelopes show the mean and SD of indicator values for Trøndelag weighted by ecosystem proportion (see Ch. 1.3.). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period. When there is no trend before 1990 (Snow cover duration), using the "no-trend" model (black line) is adequate, but using the trends models for both periods should be preferred for July mean temperature (blue line).*

1.2 Other indicators - rates of change in time-series

To estimate linear rates of change, regression models with different structure for the residuals were used. The best fitting model was chosen based on Akaike Information Criterion (AIC). The possible models included in the model selection were: 1) AR0, a standard linear regression with independent residuals, 2) AR1, a 1st order autoregressive model, 3) AR2, a 2nd order autoregressive model, 4) AR3, a 3rd order autoregressive model, 5) ARMA11, a 1st order autoregressive model with a 1st order moving average. Models were estimated using the function gls() in the nlme library (Pinheiro et al. 2020) in R. The predictions based on the best AIC selected model were calculated using the function predictSE.gls() in the AICmodavg library (Mazerolle 2020) in R. The REML method was used for the estimates, except in cases where the model failed to converge, in which case the ML method was used. In cases where the model was based on transformed data (log for counts or logit for proportions), back transformed predicted values are shown (see Fig. 2 for details). R^2 was calculated as the squared correlation between the predicted and the observed values, and 95 % confidence intervals of regression coefficients were estimated using the function intervals() in the nlme library (Pinheiro et al. 2020). For time series with a known AR-structure, for instance small rodent abundance, AR2-models were used by default (Bjørnstad et al. 1995, Henden et al. 2009). The best (AIC selected) model for each individual indicator is indicated on the figures of indicator values and background data.

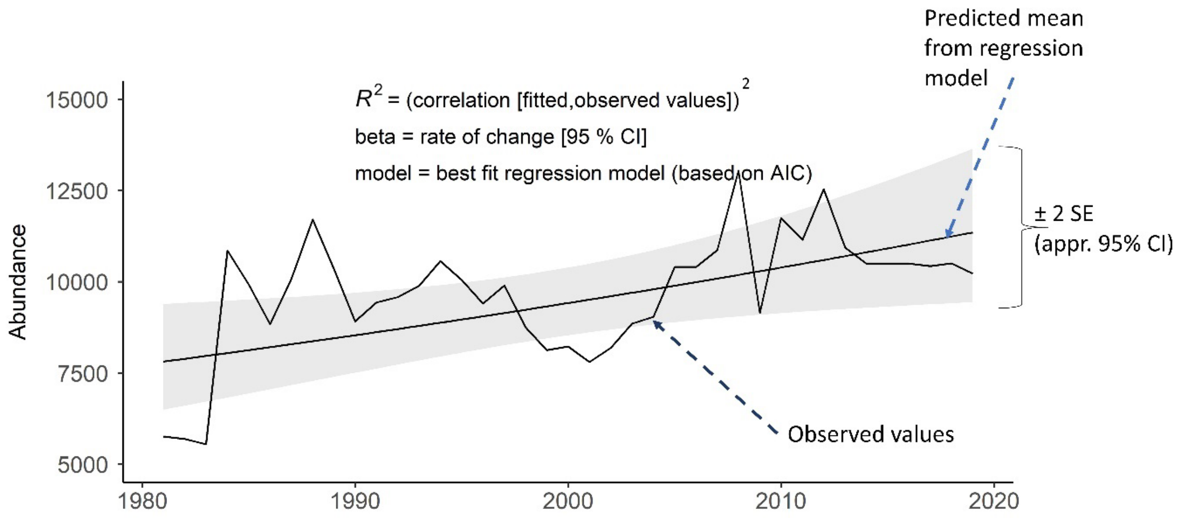

Figure A2. *Generic example of how rates of change are described and estimated for the time-series for biotic indicators. The rate of change, beta, is given with 95 % confidence intervals (CI). R^2 is the percentage of variance of the observed time-series explained by the fitted model. The structure of the best model is specified (e.g. AR2 for indicators with cyclic behaviour).*

A small adjustment to the general framework above was done for data on ungulate metabolic biomass which are decadal estimates on a municipality level. The models were constructed as Linear Mixed Effects Models to account for the differences among municipalities. The best fitting model was chosen based on AIC. The possible models included in the model selection were: 1) linear effects of time with a random intercept for each municipality, 2) linear effects of time and both random intercept and slope for each municipality, 3) quadratic effects of time and random intercept for each municipality, and 4) quadratic effects of time and both random intercept and slope for each municipality. R^2 was calculated as both the conditional and marginal coefficient of determination for Generalized mixed-effects models (Barton 2020), and the 95% confidence intervals of the regression coefficients were estimated using the function confint() in Base R. The model predictions shown in figures are predictions excluding random effects.

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1.3 Weighting of gridded data according to the ecosystem delineation

Raster-based data sources (gridded climate and hydrological data, remote sensing data) were summarized by means of area-weighted summary statistics (weighted mean, standard deviations and quantiles) using the library bigvis in R. The weighting was based on the proportional occurrence of each ecosystem class (forest, alpine, wetland, open lowland; see ecosystem delineation in Chapter 3 of the report) within each pixel in the gridded data source. The proportions were calculated on the native resolution of the gridded data (1 x 1 km for climate and hydrological data, 250 x 250 m for MODIS data).

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2 Indicators for *Primary productivity*

2.1 Maximum greenness [F10, A10, W10, S10]

Ecosystem characteristic: Primary productivity

2.1.1 Supplementary metadata

Not relevant.

2.1.2 Supplementary methods

Maximum greenness is calculated based on MODIS EVI 16–day composites (product MOD13Q1). We have used data from all 16–day periods throughout the growing season (day 65–day 289) for the years 2000–2019. Pixels that can be assumed not to contain vegetated ground (EVI < 0.1) were removed. Each pixel was then fitted to a double logistic function (Beck et al. 2006, Tveraa et al. 2013). For each pixel, maximum greenness in a given year is expressed as the highest EVI value estimated from this function throughout the growing season. Changes in maximum greenness over time are estimated for each pixel based on a simple linear model with maximum greenness as response and year as predictor.

2.1.3 Plots of indicator values

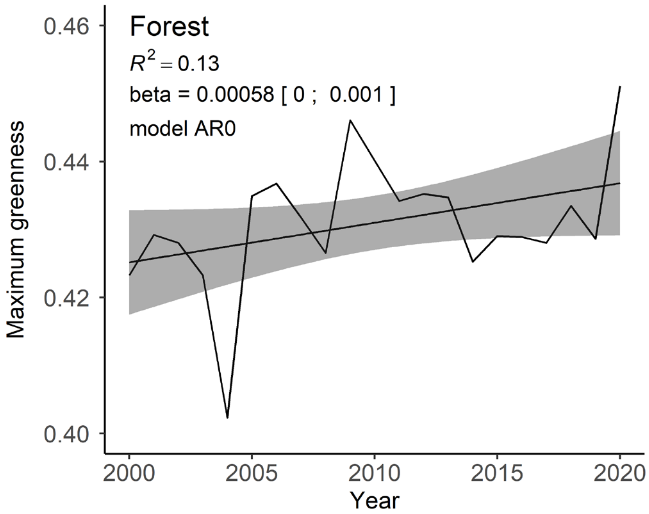

Figure A2.1.1 *Maximum greenness (EVI) for forest ecosystems in Trøndelag. The figure shows maximum greenness (EVI) averaged over all pixels. Each pixel is weighted according to the proportion of each pixel occupied by forest according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

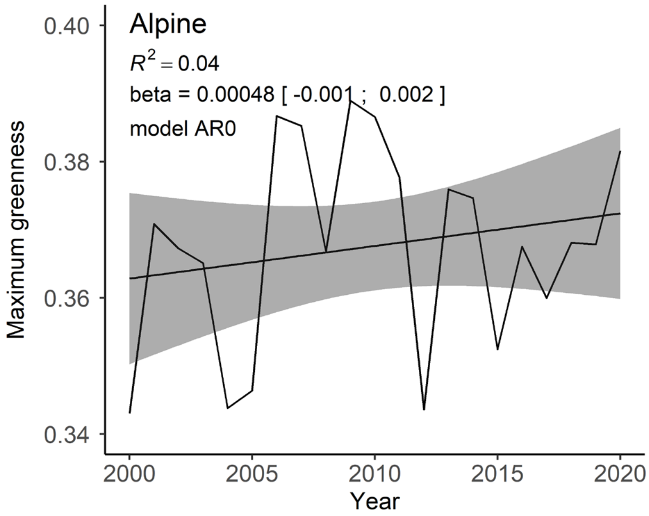

Figure A2.1.2 *Maximum greenness (EVI) for alpine ecosystems in Trøndelag. The figure shows maximum greenness (EVI) averaged over all pixels. Each pixel is weighted according to the proportion occupied by alpine according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

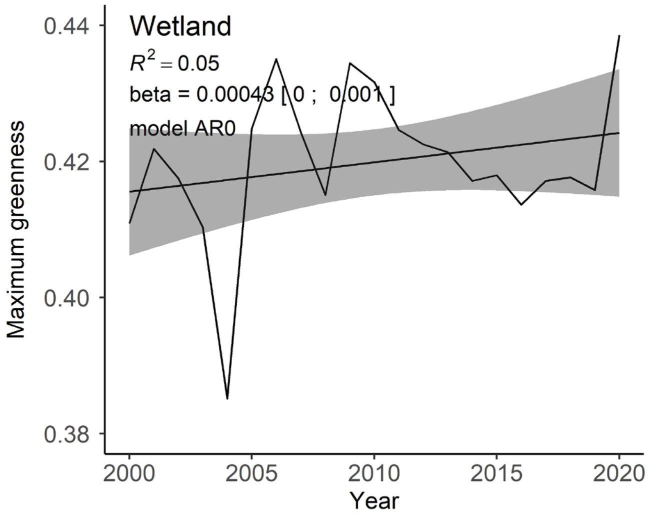

Figure A2.1.3 *Maximum greenness (EVI) for wetland ecosystems in Trøndelag. The figure shows maximum greenness (EVI) averaged over all pixels. Each pixel is weighted according to the proportion occupied by wetland according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

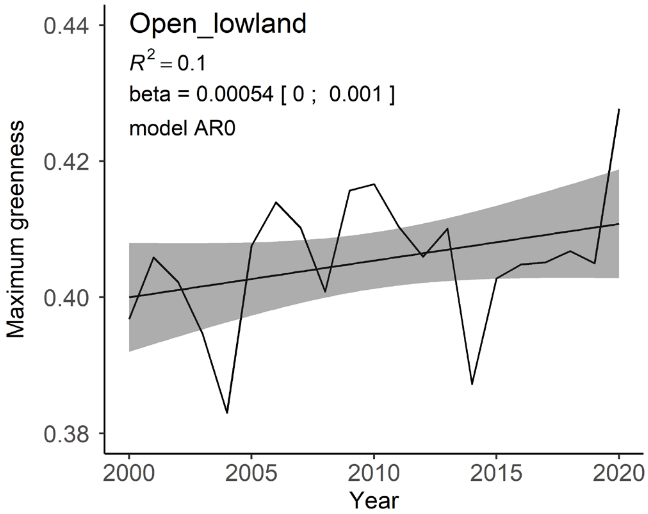

Figure A2.1.4 *Maximum greenness (EVI) for open lowland ecosystems in Trøndelag. The figure shows maximum greenness (EVI) averaged over all pixels. Each pixel is weighted according to the proportion occupied by open lowland according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

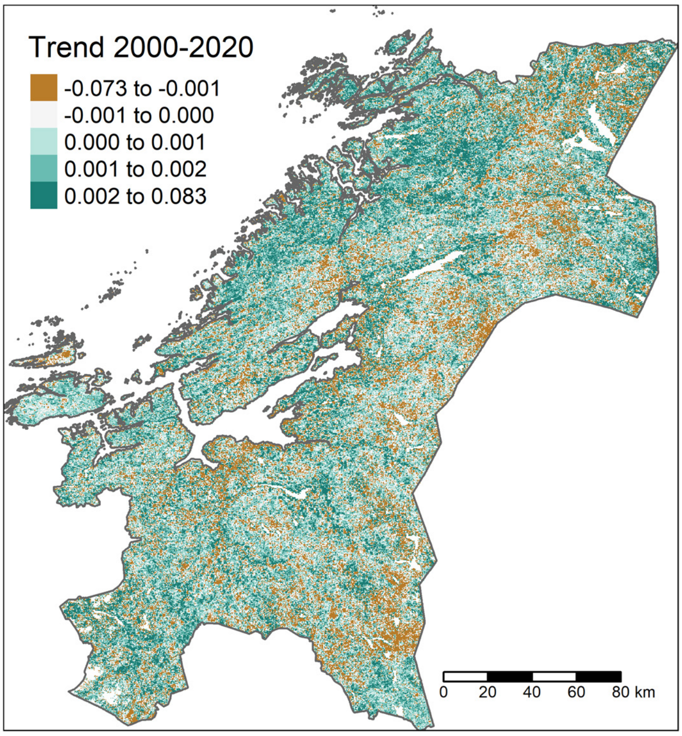

Figure A2.1.5 *The spatial distribution of the rates of change in maximum greenness over the years 2000-2020 from a linear model.*

2.1.4 Background data and supplementary analysis

Not relevant.

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2.1.5 Recommendations for future development of the indicator

The indicator describes the linear trend in maximum greenness. This is a simplified model that may be inappropriate, especially when changes in productivity are due to threshold effects, such as insect outbreaks, drought, or fire. Future improvements of this indicator should include an evaluation of the validity of a linear approximation. Further, it will be appropriate to supplement the underlying data currently being used (MODIS) with new Sentinel based products on vegetation productivity and phenology such as the HR-VPP (High Resolution Vegetation Phenology and Productivity — Copernicus Land Monitoring Service).

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2.2 Onset of spring [F11, A11, W11, S11]

Ecosystem characteristic: Primary productivity

2.2.1 Supplementary metadata

Not relevant.

2.2.2 Supplementary methods

The onset of spring (e.g. the beginning of the growing season) is calculated based on the MODIS EVI 16–day composites (product MOD13Q1). We have used data from all 16–day periods throughout the growing season (day 65–day 289) for the years 2000–2019. Pixels that can be assumed not to contain vegetated ground (Enhanced Vegetation Index (EVI) < 0.1) were removed. Each pixel was then fitted to a double logistic function (Beck et al. 2006, Tveraa et al. 2013). For each pixel, the onset of spring in a given year is expressed as the day (in days after 1 January) when EVI reaches 50 % of maximum EVI (denoted “spring inflection point” in the double logistic function). Changes in the onset of spring over time are estimated for each pixel based on a simple linear model with the onset of spring as response and year as a predictor (i.e. negative trend= earlier onset of spring).

2.2.3 Plots of indicator values

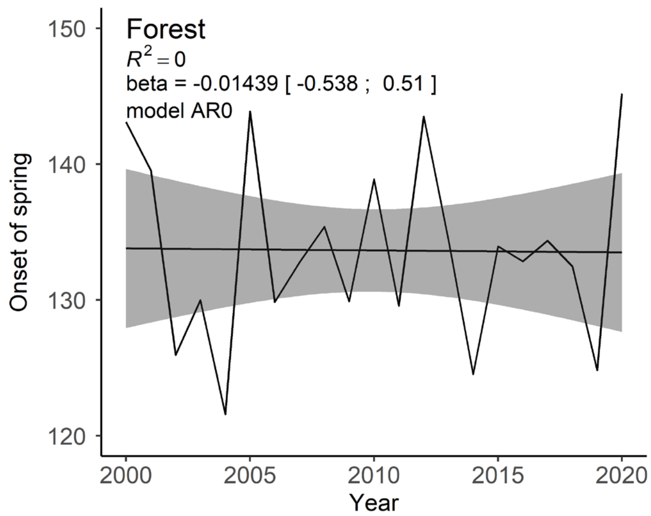

Figure A2.2.1 *Onset of spring for forest ecosystems in Trøndelag. The figure shows the onset of spring (day of year) averaged over all pixels. Each pixel is weighted according to the proportion of the pixel occupied by forest according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

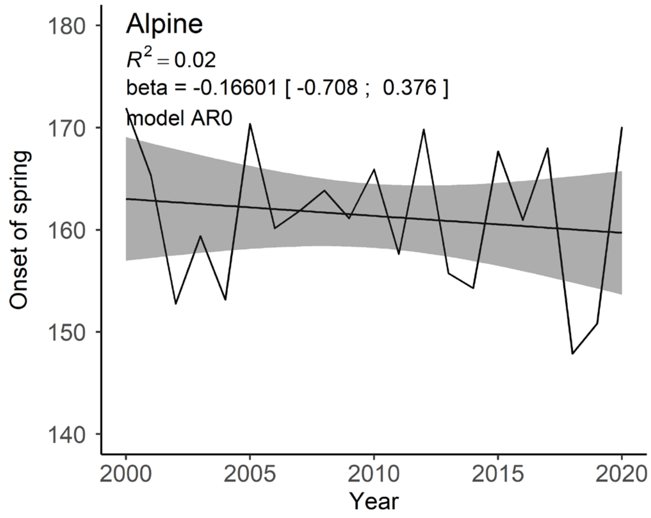

Figure A2.2.2 *Onset of spring for alpine ecosystems in Trøndelag. The figure shows the onset of spring (day of year) averaged over all pixels. Each pixel is weighted according to the proportion of the pixel occupied by forest according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

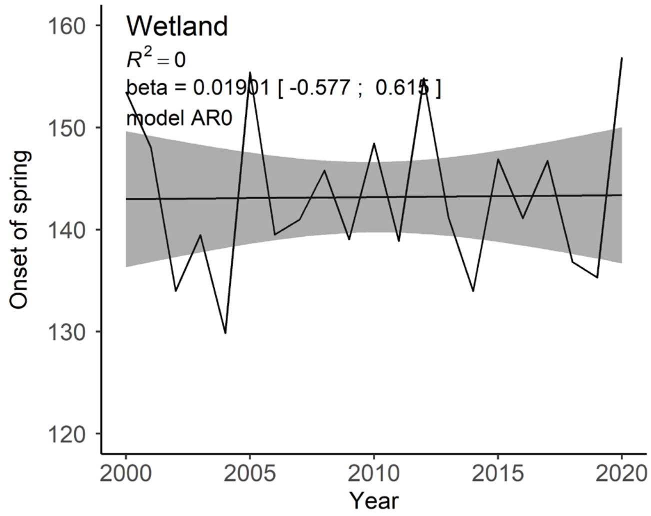

Figure A2.2.3. *Onset of spring for wetland ecosystems in Trøndelag. The figure shows the onset of spring (DOY) averaged over all pixels. Each pixel is weighted according to the proportion of the pixel occupied by forest according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

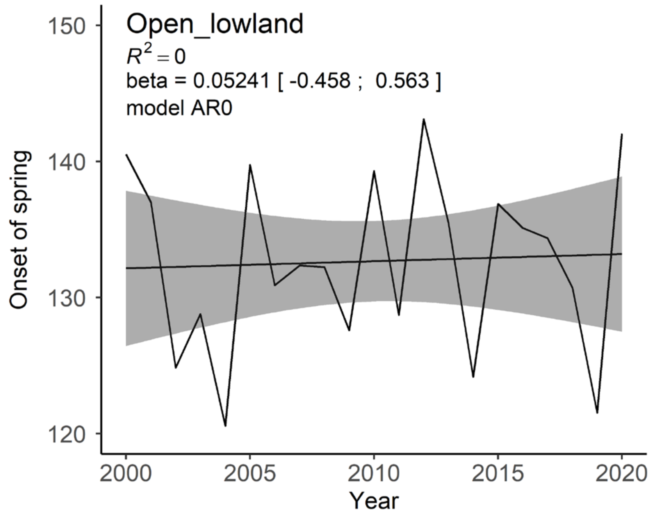

Figure A2.3.4 *Onset of spring for open lowland ecosystems in Trøndelag. The figure shows the onset of spring (DOY) averaged over all pixels. Each pixel is weighted according to the proportion of the pixel occupied by forest according to the ecosystem delineation map. Rates of change are shown with ±2SE (shaded areas).*

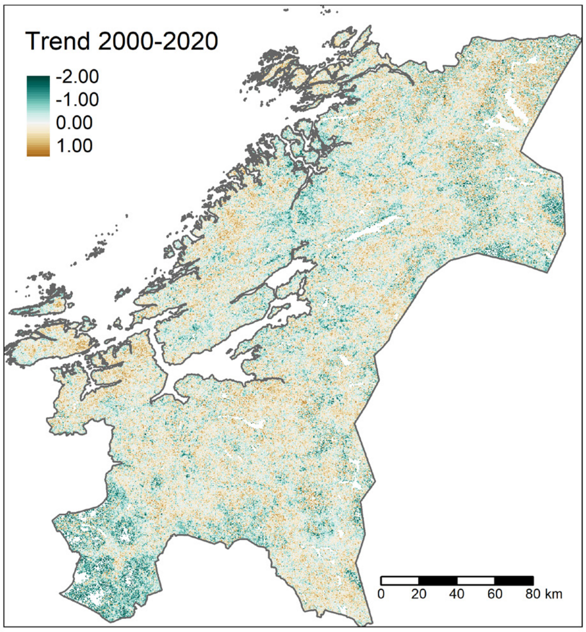

Figure A2.2.5 *The spatial distribution of the rates of change in onset of spring (days/yr) over the years 2000-2020 from a linear model.*

2.2.4 Background data and supplementary analysis

Not relevant.

2.2.5 Recommendations for future development of the indicator

The indicator describes the linear trend in the timing of the onset of spring with a negative trend indicating earlier onset of spring. This is a simplified model that may be inappropriate. Future improvements of this indicator should include an evaluation of the validity of a linear approximation. Further, it will be appropriate to supplement the data currently being used (MODIS) with new Sentinel based products on vegetation productivity and phenology such as the HR-VPP (High Resolution Vegetation Phenology and Productivity — Copernicus Land Monitoring Service).

2.3 Tree volume [F22]

Ecosystem characteristic: Primary productivity

2.3.1 Supplementary metadata

Not relevant.

2.3.2 Supplementary methods

The indicator is based on data from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data on tree volume (‘*vmprha* = volume med bark per ha’) are available for the 5 latest rotations (1994-1998, 2000-2004, 2005-2009, 2010-2014 and 2015-2019).

Estimates are presented separately for three different forest types according to the NFI classification (Spruce: NFI *best_tresl* = 1-3, Pine: NFI *best_tres* = 4-6, Deciduous: NFI *best_tres* = 7-9) and we include harvest class (HC) 4 and 5 for productive forest, as well as all unproductive forest as separate categories.

2.3.3 Plots of indicator values

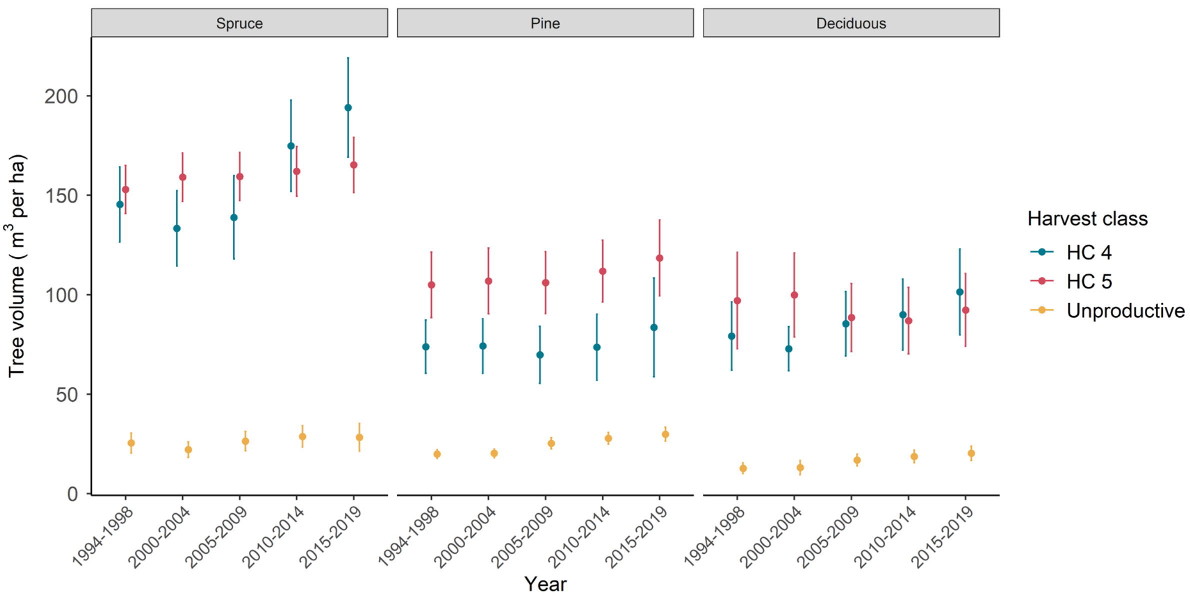

Figure A2.3.1. *Volume of trees (m³ per ha) per forest type (spruce, pine and deciduous) and harvest class. The estimates are given as mean ±2SE across all surveyed plots in Trøndelag. Sample sizes (the number of plots) vary somewhat between rotations. Range per forest type are; Spruce: 672-870 plots, Pine: 448-591 plots, Deciduous: 312-452 plots.*

2.3.4 Background data and supplementary analysis

Not relevant.

2.3.5 Recommendations for future development of the indicator

The indicator for tree volume shows clear trends for the higher harvest classes for productive forest. Less so for the unproductive forest. To get a better estimate of ecosystem significance of changes in tree volume, it should be explored, in collaboration with NIBIO, whether the data series could be supplemented by data prior to the 1994-1998 rotation.

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3 Indicators for *Biomass distribution among trophic levels*

3.1 ROS species versus moose [F18]

Ecosystem characteristic: Biomass distribution among trophic levels

3.1.1 Supplementary metadata

Not relevant.

3.1.2 Supplementary methods

Data on browsing pressure (percentage of shoots browsed) on ROS species from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data from the 10^{th} to 12^{th} rotations, 2010-2020 are included here). A reference line at 20% browsing is added, at which rowan regeneration is hindered (Speed et al. 2013).

3.1.3 Plots of indicator values

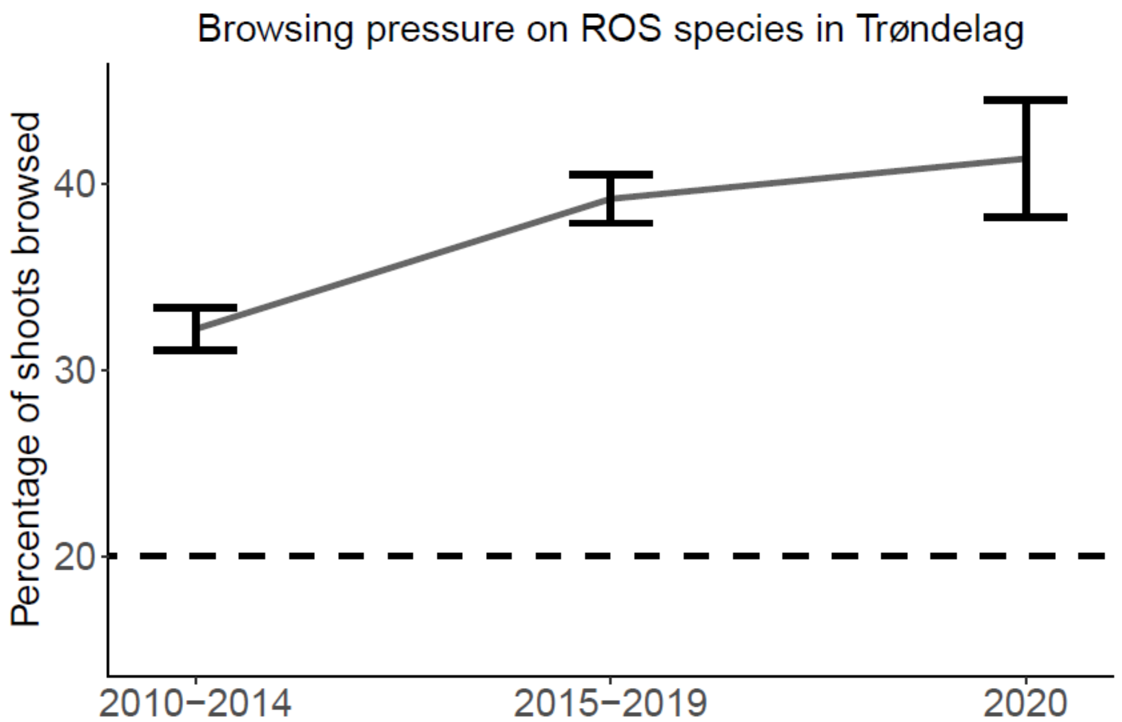

Figure A3.1.1. *Browsing pressure on ROS (rowan, aspen, goat willow) in Trøndelag between 2010 and 2014. The figure shows mean browsing pressure ± standard error across Trøndelag.*

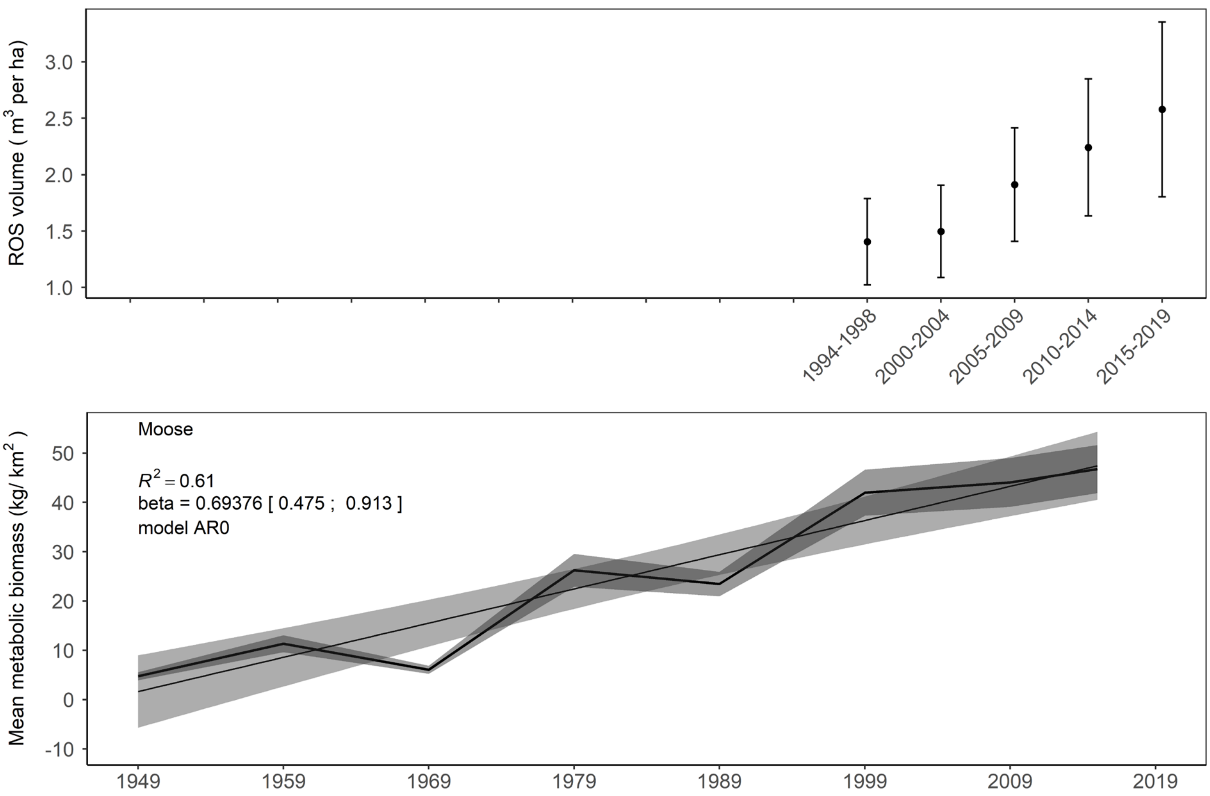

Figure A3.1.2. *Top: ROS species (*rowan, aspen, goat willow) *volume (m^3 per ha). The estimates are given as mean ±2SE across all surveyed plots in Trøndelag. Bottom: Metabolic biomass of moose in forest municipalities. Rate of change is shown with ±2SE (shaded area).*

3.1.4 Background data and supplementary analysis

Not relevant.

3.1.5 Recommendations for future development of the indicator

The dataset used for the moose part of this indicator is currently available at a decadal level. The estimates are made across municipalities that are characterized as forest. Therefore, parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate. Approaches to correct for this should be investigated. The temporal overlap between the moose and the ROS datasets was poor due to each being collected at different time windows. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered. Alternatively, the use of browsing pressure on ROS species, and thresholds of ROS species responses to browsing could be further developed.

3.2 Bilberry versus deer and moose [F24]

Ecosystem characteristic: Biomass distribution among trophic levels

3.2.1 Supplementary metadata

Not relevant.

3.2.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019). The mean metabolic biomass of red deer and moose was calculated across all municipalities.

3.2.3 Plots of indicator values

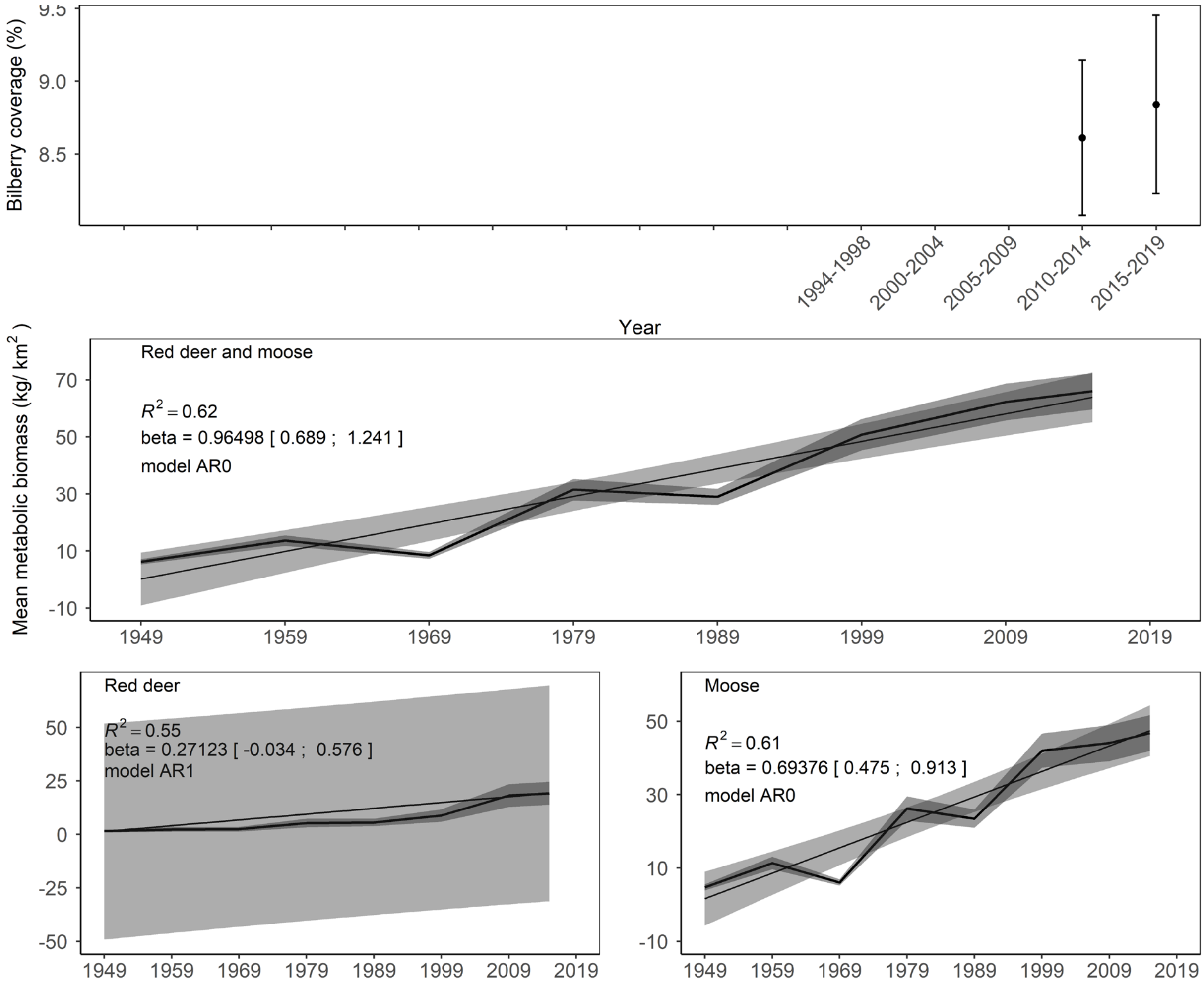

Figure A3.2.1. *Percent bilberry coverage vs. mean metabolic biomass of red deer and moose across municipalities. Rate of change for models are shown with ±2SE, mean of observed values are shown ±SE (shaded areas).*

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3.2.4 Background data and supplementary analysis

Not relevant.

3.2.5 Recommendations for future development of the indicator

The ungulate estimates are made across municipalities that are characterized as forest. Therefore, parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate. Approaches to correct for this should be investigated. The temporal overlap between the moose and the bilberry datasets was poor due to each being collected at different time windows. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered. This indicator is likely to be more valuable as the bilberry data-series grows.

3.3 Ungulates versus carnivorous vertebrates [F25, A24]

Ecosystem characteristic: Biomass distribution among trophic levels

3.3.1 Supplementary metadata

Not relevant

3.3.2 Supplementary methods

For forest ecosystems, the metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019). The mean metabolic biomasses of the ungulates were calculated across all forest municipalities. For the indicator in alpine ecosystems, counts of wild reindeer were used (sum across of all herds and subpopulations in Snøhetta, Forollhogna and Knutshø each year). The count is performed as a total count during summer, prior to harvest. The abundance of semi-domestic reindeer is reported annually to the Norwegian Agricultural Agency (Landbruksdirektoratet) by each reindeer herding family (siida) and is reported at the reindeer district scale per 31st March. The abundance is an estimate based on a count of each herd with no correction for detectability.

3.3.3 Plots of indicator values

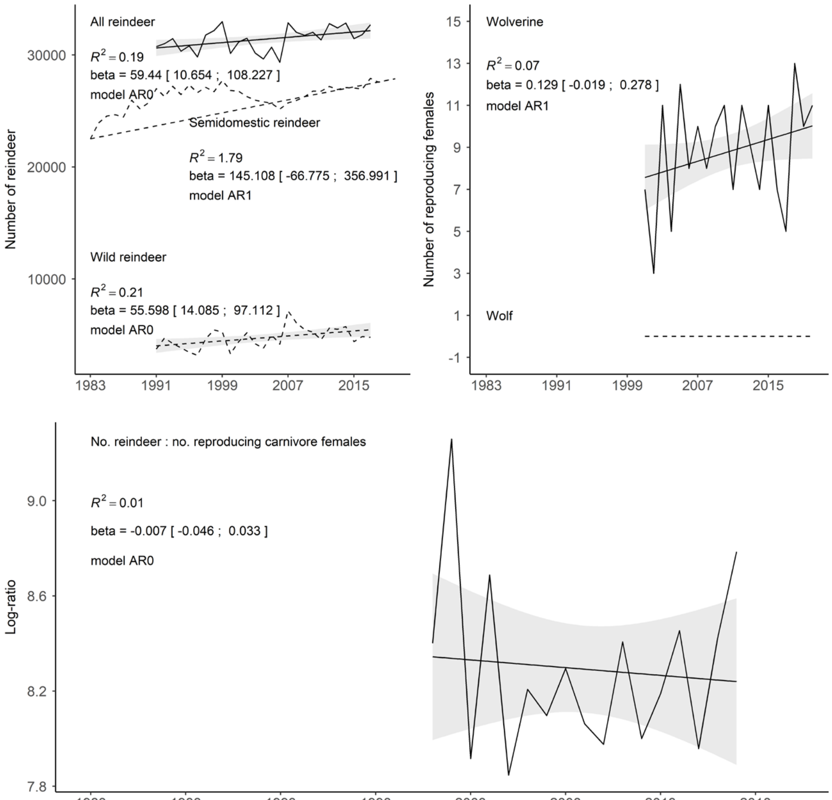

Figure A3.3.1. *The ratio between reindeer and large carnivores in Trøndelag. Total number of reindeer across Trøndelag (top left, solid line), number of reproducing female wolverines and wolf (absent; top right), and log ratio between the two trophic levels (bottom). Rate of change for models are shown with ±2SE. Dashed lines in the upper left plot indicate respectively wild- and semidomestic reindeer. Standard errors are not shown for the semidomestic reindeer.*

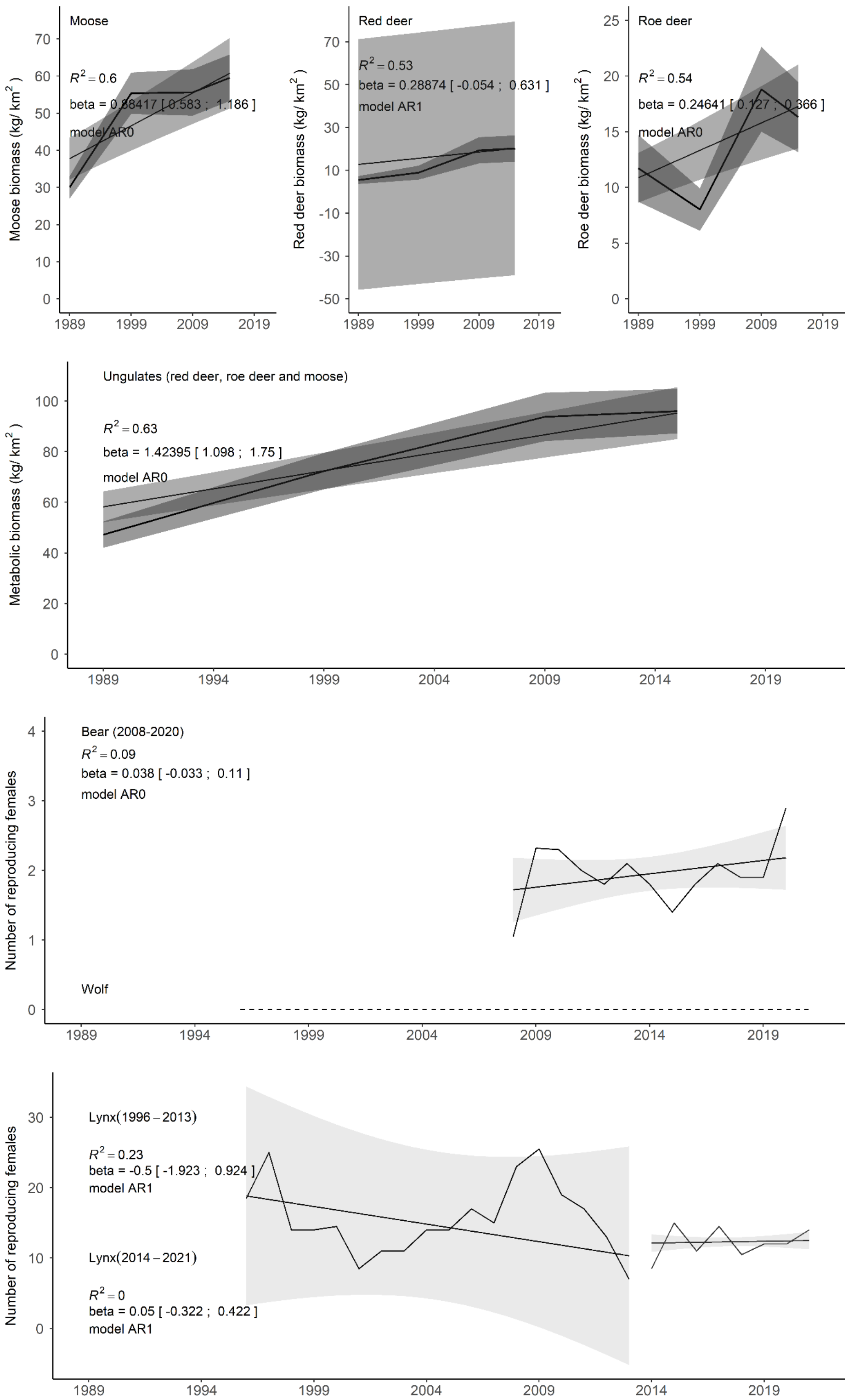

Figure A3.3.2. *Forest ungulate vs. carnivore abundance across all municipalities. Metabolic biomass of forest ungulates (kg/km^2) and number of reproducing female bears, wolves and lynx (as methodology changed in 2014 for the latter, the trends are shown separately). Rate of change for models are shown with ±2SE, mean of observed values are shown ±SE (shaded areas).*

3.3.4 Background data and supplementary analysis

Not relevant.

3.3.5 Recommendations for future development of the indicator

The main limitation of the datasets used for this indicator are the length of the temporal overlap between ungulates and carnivores. With continued monitoring of both sets of populations, this indicator will become more useful. The ungulate estimates are made across municipalities that are characterized as forest. Therefore, parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate. Approaches to correct for this should be investigated. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered.

4 Indicators for *Functional groups within trophic levels*

4.1 Plant growth forms: deciduous proportion [F27]

Ecosystem characteristic: Functional groups within trophic levels

4.1.1 Supplementary metadata

Not relevant

4.1.2 Supplementary methods

The indicator is based on data from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data on tree volume (‘*vmprha* = volume under bark per ha’ and *vmprhal*=‘volume deciduous under bark per ha’) are available for the 5 latest rotations (1994-1998, 2000-2004, 2005-2009, 2010-2014 and 2015-2019). Estimates are presented separately for three different forest types according to the NFI classification (Spruce: NFI *best_tresl* = 1-3, Pine: NFI *best_tres* = 4-6, Deciduous: NFI *best_tres* = 7-9). We include harvest class (HC) 2-5 for productive forest, as well as all unproductive forest as separate categories.

4.1.3 Plots of indicator values

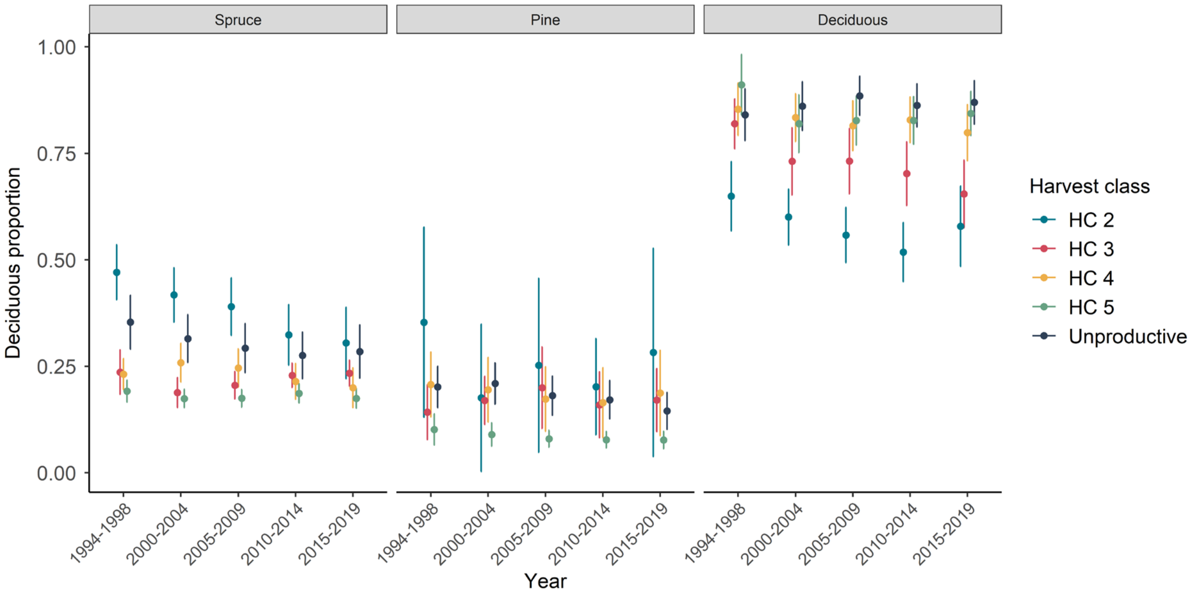

Figure A4.1.1*. The deciduous proportion of the total tree volume (m³ per ha) per forest type (spruce, pine and deciduous). Sample sizes (the number of plots) vary somewhat between rotations. Range per forest type are; Spruce: 574-704 plots, Pine: 220-268 plots, Deciduous: 273-413 plots.*

4.1.4 Background data and supplementary analysis

Tending of young stands aims at giving future trees better growth conditions. This practice includes mechanically removing deciduous trees in spruce and pine stands. In addition, pesticides are sometimes used for removal of weeds and young deciduous trees. However, only c. 1% of the total tending of young stands are done with pesticides (Tomter & Dalen 2018). Therefore, the variables “subsidized chemical treatment targeted at weeds and young deciduous species” (Figure A4.1.2) and “subsidized tending targeted at removing young deciduous species” (Figure A4.1.3) indicate the loss of deciduous trees due to forest management.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

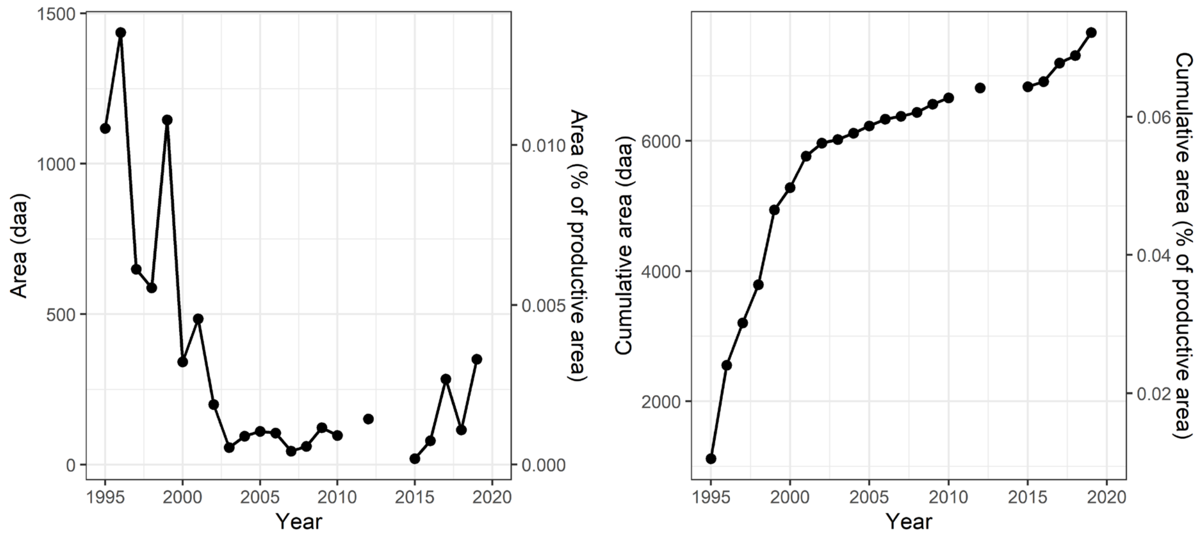

Figure A4.1.2 *The area of forest subject to subsidized chemical treatment targeted at weeds and young deciduous species ("kjemisk rydding og ugresskontroll"). Areas are given both as annual and cumulative areas in daa (1 dd= 0.001 km2) and in % of the total area of productive forest (2020 estimate).*

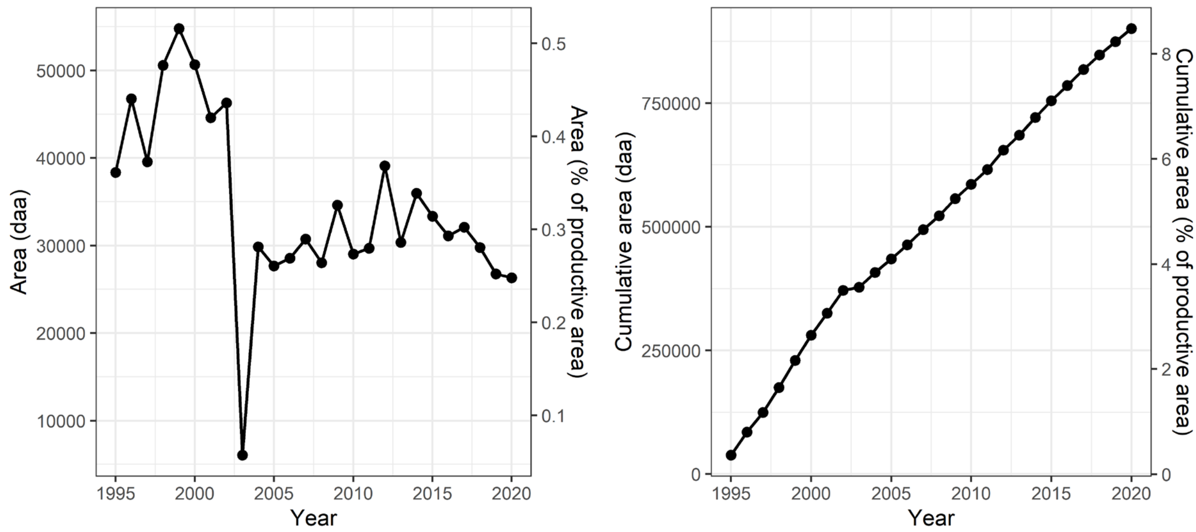

Figure A4.1.3 *The area of forest subject to subsidized tending targeted at removing young deciduous species ("ungskogpleie"). Areas are given both as annual and cumulative areas in daa (1 dd= 0.001 km2) and in % of the total area of productive forest (2020 estimate).*

4.1.5 Recommendations for future development of the indicator

Because chemical removal of weeds and young deciduous trees are commonly done in harvest class I and mechanical removal of competing trees are done in harvest class II it would be good to relate these data to the area of these harvest classes. If the area of harvest class II is low but chemical removal of deciduous trees in these stands are high, the indicator would wrongly indicate a decreasing trend.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

4.2 Herbivorous vertebrates: browsers versus grazers [F19]

Ecosystem characteristic: Functional groups within trophic levels

4.2.1 Supplementary metadata

4.2.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019).

The municipalities were classified as either “Forest”, “Alpine”, “Wetland” or “Open lowland" according to land-cover. If either of the four categories covered ≥50% of the area, the municipality was classified as such; the threshold for “Wetland” being ≥22.5% due to the rarity of this land-cover type. In the case of no land-cover type occupying ≥50%, the dominant land-cover type was assigned, unless “Wetland” covered ≥20%.

The proportion of browsers and grazers within municipalities were based on the proportion of graze and browse in the diets of the ungulates given by Austrheim et al. (2011). The indicator was calculated for all “Forest” municipalities.

4.2.3 Plots of indicator values

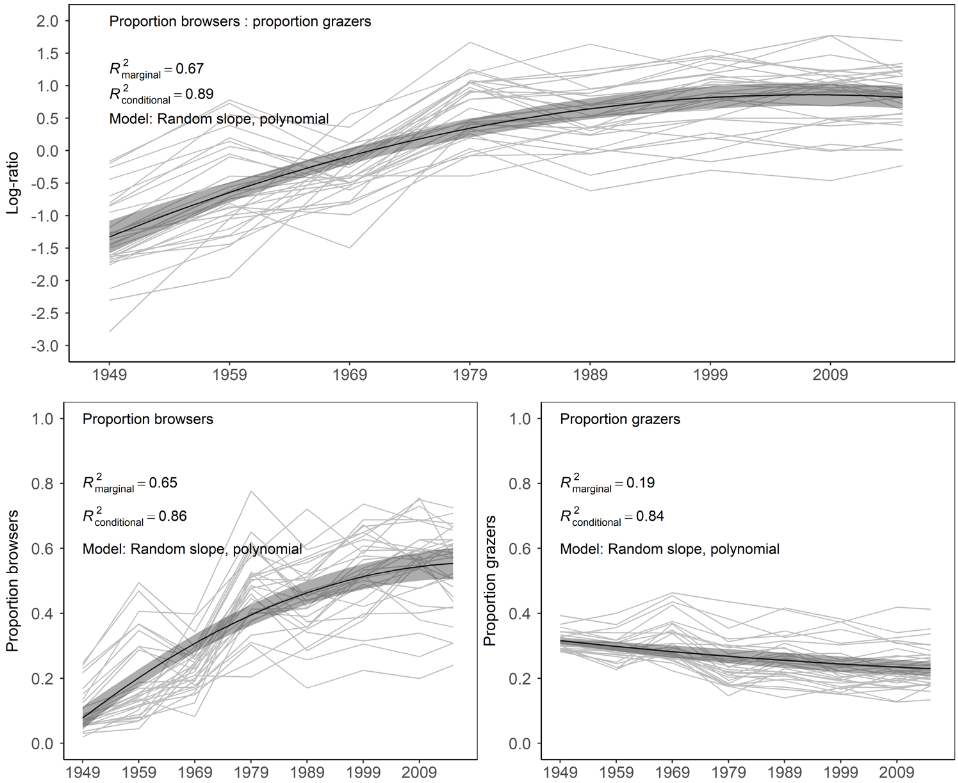

Figure A4.2.1. *Relative biomass of browsers vs. grazers in forest municipalities. The figure shows the log-ratio of proportion of browsers and proportion of grazers within the ungulate community in each municipality. Rate of change is shown with ±2SE (shaded area). Gray lines indicate individual municipalities.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

4.2.4 Background data and supplementary analysis

Not relevant.

4.2.5 Recommendations for future development of the indicator

This indicator is considered adequately formulated.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

4.3 Herbivorous vertebrates: reindeer versus moose/deer [A22]

Ecosystem characteristic: Functional groups within trophic levels

4.3.1 Supplementary metadata

Not relevant.

4.3.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019). The municipalities were classified as either “Forest”, “Alpine”, “Wetland” or “Open lowland" according to land-cover. If either of the four categories covered ≥50% of the area, the municipality was classified as such; the threshold for “Wetland” being ≥22.5% due to the rarity of this land-cover type. In the case of no land-cover type occupying ≥50%, the dominant land-cover type was assigned, unless “Wetland” covered ≥20%. The indicator was calculated for all “Alpine” municipalities.

4.3.3 Plots of indicator values

Figure A4.3.1 *Log ratio between reindeer and moose/deer. The figure shows the log ratio between the total biomass of reindeer (both semi-domestic and wild) and the total biomass of moose and red deer combined. Rate of change is shown with ±2SE (shaded area). Gray lines indicate observed trends for individual municipalities. The model was fitted with log(y+1). The scaling of x could not be standardised due to convergence failures.*

4.3.4 Background data and supplementary analysis

Not relevant.

4.3.5 Recommendations for future development of the indicator

The dataset used for this indicator is currently available at a decadal level. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered. The estimates are made across municipalities that are characterized as alpine. Therefore, parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate. Approaches to deal with this should be investigated.

4.4 Carnivorous vertebrates: Arctic versus red fox [A21]

Ecosystem characteristic: Functional groups within trophic levels

4.4.1 Supplementary metadata

Not relevant.

4.4.2 Supplementary methods

The proportion of days where a given fox species is recorded by wildlife cameras is calculated as the number of observation days when at least one fox is captured in an image / total number of observation days. An observation day is defined as one camera having taken pictures for one day (excluding days with bad visibility or malfunctioning of the camera). The data set contains data from 3 of the 5 alpine areas included in the national monitoring program for Arctic foxes. The areas are subject to different types of management interventions to support the endangered Arctic fox. The three areas where camera data are available are Børgefjell (no management interventions), and Blåfjellet/Hestkjølen/Skjækerfjellet, and Kjølifjellet/Sylane (both subject to supplementary feeding of arctic foxes). The proportion of days when foxes are recorded is calculated separately for each area. Log ratio between Arctic fox and red fox is calculated as log (proportion of days with image of Arctic fox / proportion of days with image of red fox). To handle zero values in the Arctic fox data set, a constant (0.001) is added to each year in the Arctic fox time-series. Rates of change in all data sets are calculated with AR models as described in the general methods and are shown ±2SE. The most suitable model based on AIC is indicated on the figures.

4.4.3 Plots of indicator values

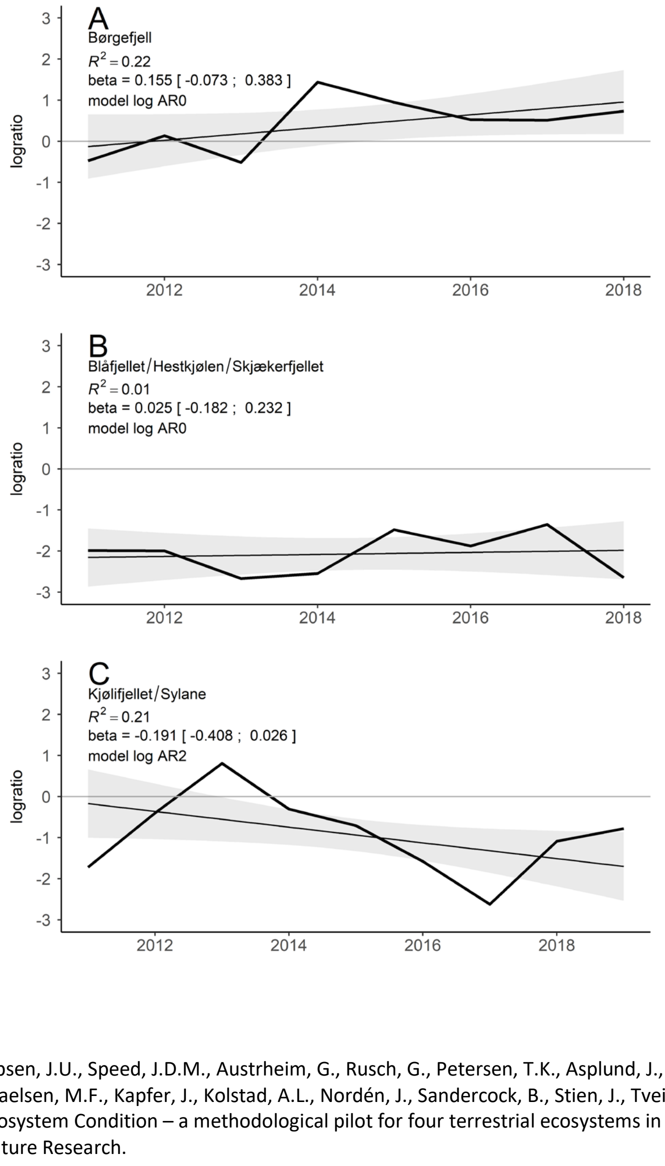

***Figure A4.4.1** Log ratio between Arctic fox and red fox recorded across all camera traps per alpine area A) Børgefjell (no management interventions), and B) Blåfjellet/Hestkjølen/Skjækerfjellet, and C) Kjølifjellet/Sylane (both subject to supplementary feeding of arctic foxes). Rates of change are shown ± 2SE (shaded areas).*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

4.4.4 Background data and supplementary analysis

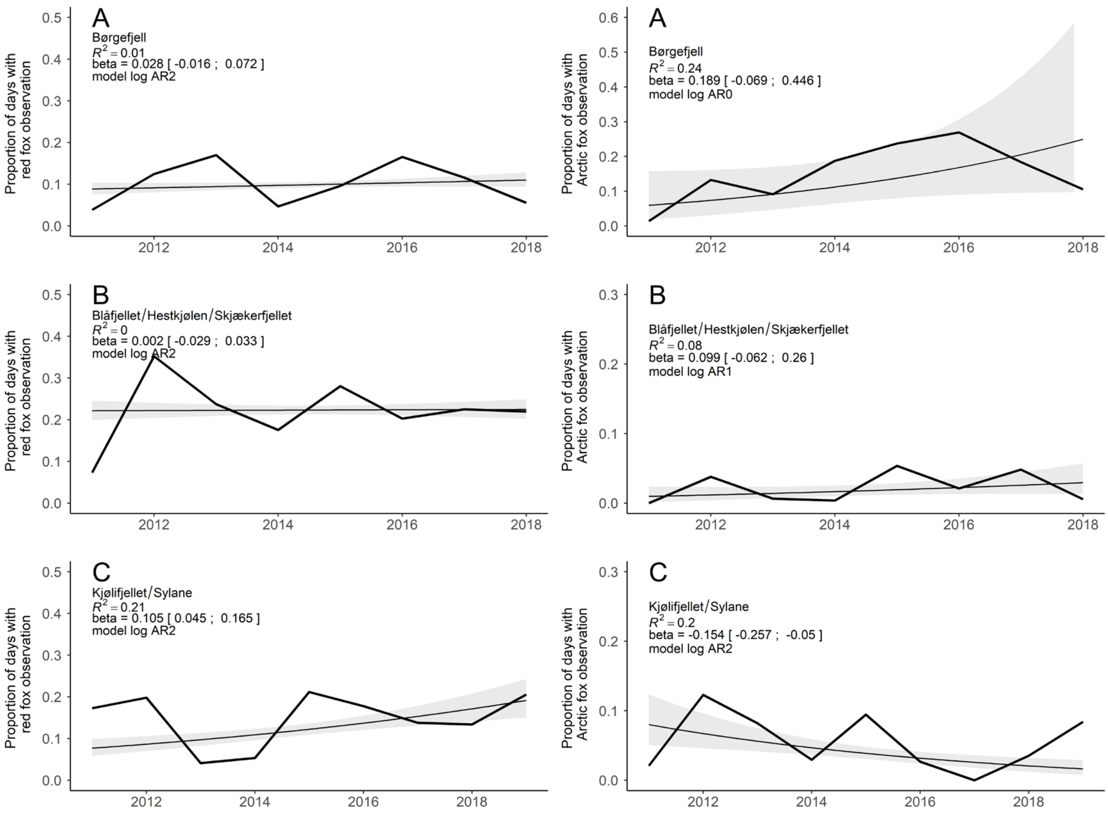

Figure A4.4.2 *The proportion of days each fox species is captured on camera traps for red fox (left) and Arctic fox (right).*

4.4.5 Recommendations for future development of the indicator

The camera-based monitoring on which this indicator is based, was initiated to evaluate effects of arctic fox conservation actions. It is currently discontinued due to absence of funding. Camera traps placed on arctic fox den sites and feeding stations could possibly be used to cover this indicator in the future. Independent of which data source is chosen, the geographical representativity of the trap network should evaluated relative to the region being assessed (e.g. here Trøndelag), to ensure coverage of relevant bioclimatic gradients (sub - high alpine). Moreover, current knowledge is poor concerning whether and to what degree the camera-based index for Arctic fox is affected by the supplementary feeding done in conjunction with the release of Arctic fox. There is also a risk that estimates of arctic foxes can be low biased due to avoidance behaviour (Hamel et al. 2013a, Tannerfeldt et al. 2002). The indicator can be sensitive to abundance of alternative prey and must be interpreted carefully in terms of densities per se (Gomo et al. 2020, 2021). This should be evaluated. In the short term, it is recommended that the relationship between Arctic fox and red fox is refined by use of a statistical model that takes into account the varying discoverability of the species, to analyze presence of the two species based on camera trap data.

5 Indicators for *Functionally important species and biophysical structures*

5.1 Bark beetle abundance [F14]

Ecosystem characteristic: Functionally important species and biophysical structures

5.1.1 Supplementary metadata

Not relevant.

5.1.2 Supplementary methods

Not relevant.

5.1.3 Plots of indicator values

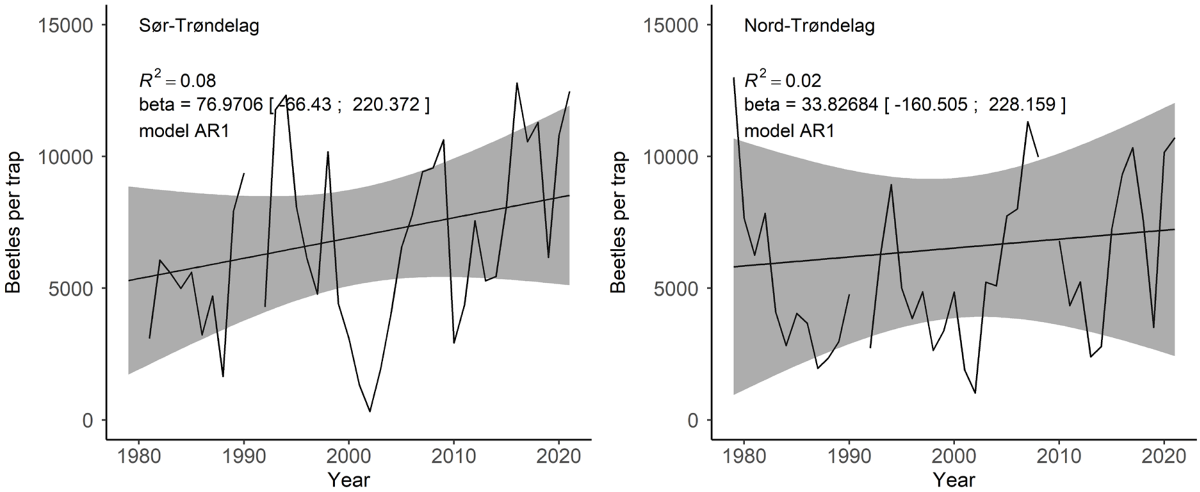

Figure A5.1.1. The average number of beetles per trap within each region (Nord-Trøndelag and Sør-Trøndelag). Rates of change are shown ± 2SE (shaded areas).

5.1.4 Background data and supplementary analysis

Not relevant.

5.1.5 Recommendations for future development of the indicator

From 2021, the Norwegian bark beetle monitoring program (NIBIO 2021) includes model estimates also for the predicted dates for completion of a 2nd generation based on a temperature driven population model. The model estimates (Lange et al. 2009, Økland et al. 2021) show that during the 1961-1990 climatic reference, bark beetle populations in Norway would mostly complete one generation per year (univoltinism). Ongoing climate change improve the conditions for completing a second generation (e.g., bivoltinism), and the proportion of localities which complete a 2nd generation is increasing also in Norway (Økland et al. 2021). Model estimates for Norway predicts that, with continued climate change, bivoltinism will become the new norm particularly in the southern parts of the country. We would recommend that the indicator on bark beetles, is supplemented with prediction from this model, on the % completion of the 2nd generation per year and population. The predicted time series should be extended as far back in time as possible.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.2 Wild ungulate density [F16, A17, S14]

Ecosystem characteristic: Functionally important species and biophysical structures

5.2.1 Supplementary metadata

Not relevant.

5.2.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019).

The municipalities were classified as either “Forest”, “Alpine”, “Wetland” or “Open lowland" according to land-cover. If either of the four categories covered ≥50% of the area, the municipality was classified as such; the threshold for “Wetland” being ≥22.5% due to the rarity of this land-cover type. In the case of no land-cover type occupying ≥50%, the dominant land-cover type was assigned, unless “Wetland” covered ≥20%. The indicators were calculated for all “Forest”, “Alpine” and “Open lowland” municipalities, respectively.

5.2.3 Plots of indicator values

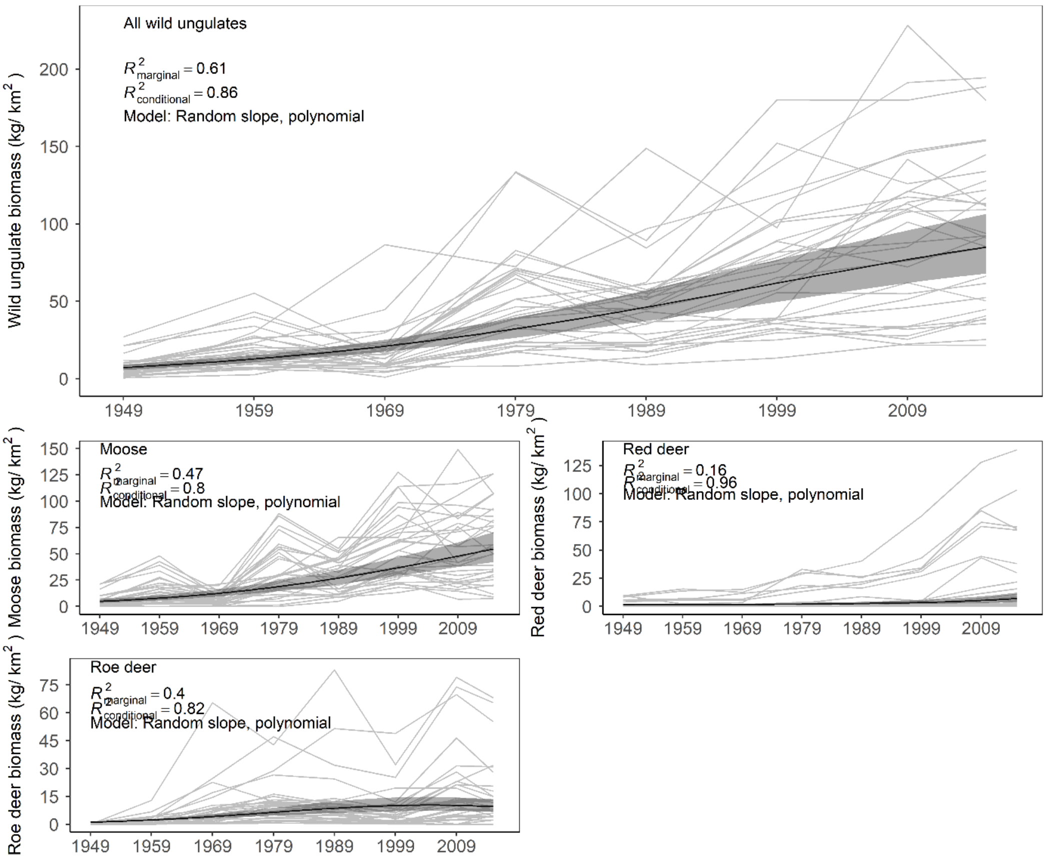

Figure A5.2.1. *Metabolic biomass of wild ungulates in forest municipalities. The figure shows the metabolic biomass of all wild ungulates, and the included species (moose, red deer and roe deer) separately. Rate of change is shown with ±2SE (shaded area). Gray lines indicate individual municipalities. The models were fitted to log(y+1).*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

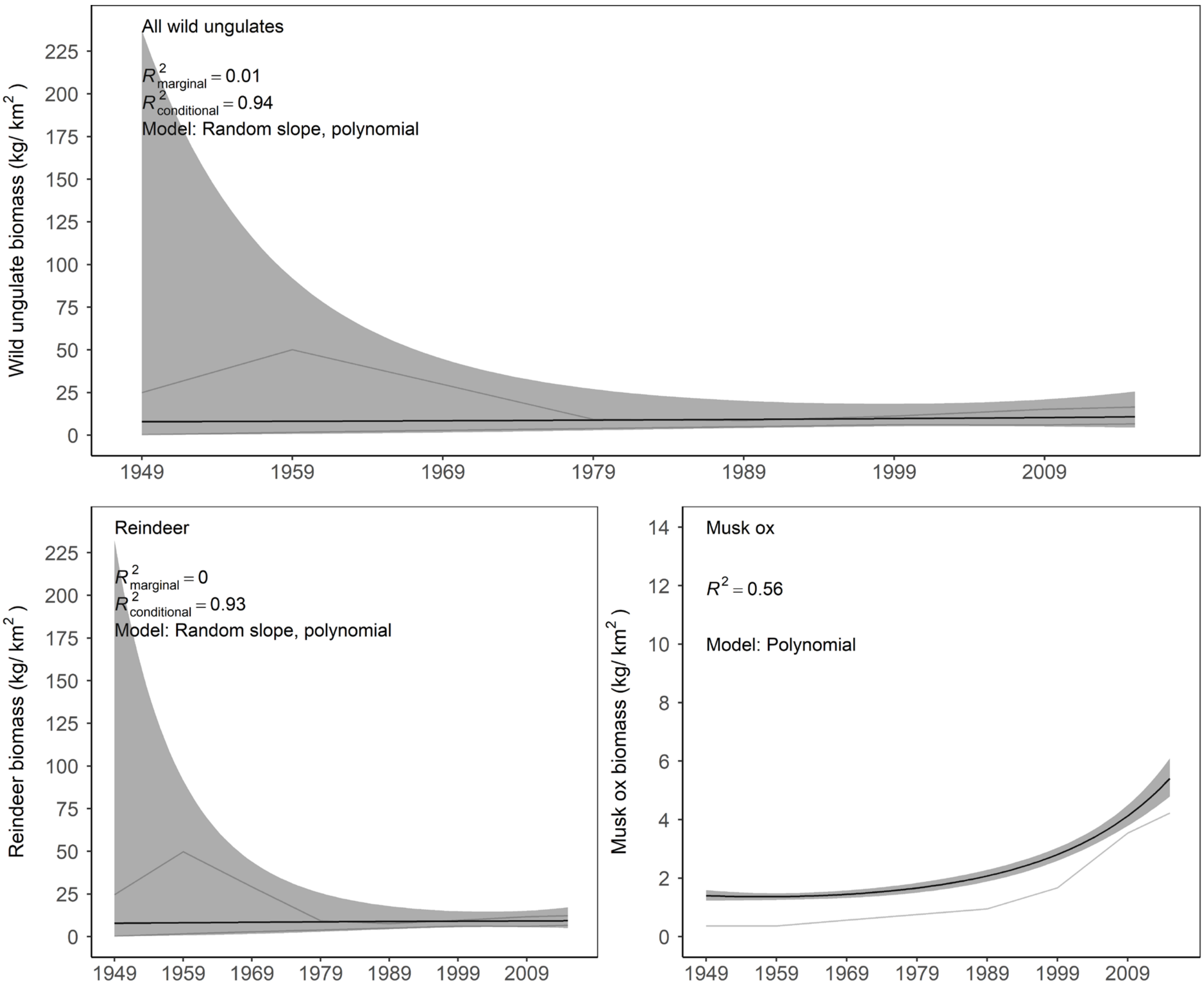

Figure A5.2.2. *Metabolic biomass of wild ungulates in alpine municipalities. The figure shows the metabolic biomass of all wild ungulates, and the included species (wild reindeer and musk ox) separately. Rate of change is shown with ±2SE (shaded area). The models for all ungulates and reindeer were fitted with random effects, the model for musk ox was not (only the Oppdal site has musk ox data). The models were fitted to log(y+1).*

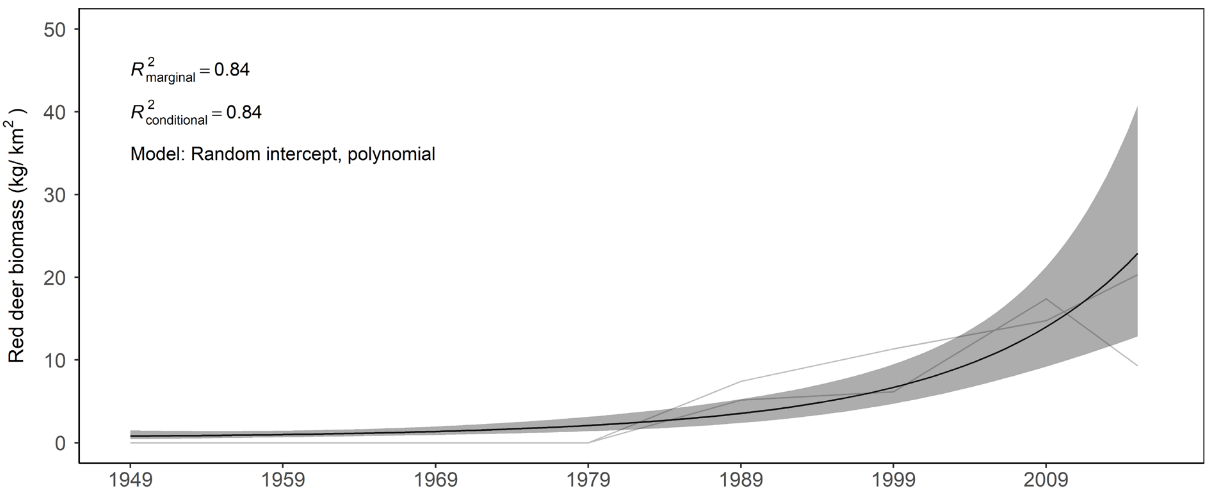

Figure A5.2.3. *Metabolic biomass of red deer for open lowland municipalities. The figure shows the metabolic biomass of red deer. Rate of change is shown with ±2SE (shaded area). Gray lines indicate observed trends for individual municipalities. The models were fitted to log(y+1). Only two of the four "Open lowland" municipalities have values for red deer and were included in the models.*

5.2.4 Background data and supplementary analysis

Not relevant.

5.2.5 Recommendations for future development of the indicator

The dataset used for this indicator is currently available at a decadal level. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered. The ungulate estimates are made across municipalities that are characterized as alpine Therefore parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate, and approaches to correct for this should be considered.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.3 Semi-domestic reindeer density [A13]

5.3.1 Supplementary metadata

Not relevant.

5.3.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019).

The municipalities were classified as either “Forest”, “Alpine”, “Wetland” or “Open lowland" according to land-cover. If either of the four categories covered ≥50% of the area, the municipality was classified as such; the threshold for “Wetland” being ≥22.5% due to the rarity of this land-cover type. In the case of no land-cover type occupying ≥50%, the dominant land-cover type was assigned, unless “Wetland” covered ≥20%.

The indicator was calculated for all “Alpine” municipalities.

5.3.3 Plots of indicator values

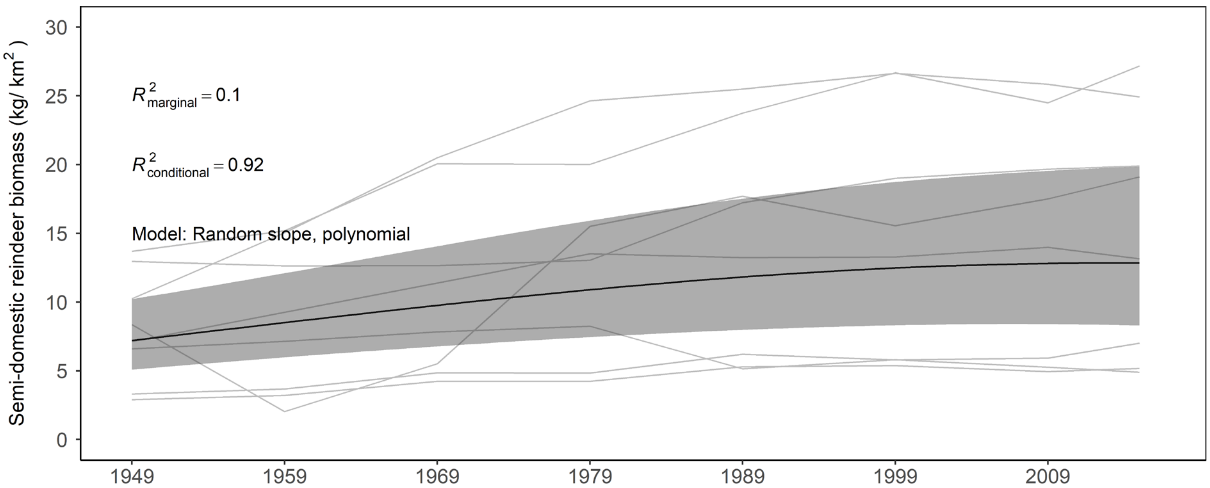

Figure A5.3.1. Metabolic biomass of semi-domestic reindeer in alpine municipalities. The figure shows the metabolic biomass of semi-domestic reindeer. Rate of change is shown with ±2SE (shaded area). Gray lines indicated observed trends for individual municipalities.

5.3.4 Background data and supplementary analysis

Not relevant.

5.3.5 Recommendations for future development of the indicator

The estimates are made across municipalities that are characterized as alpine. Therefore parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate. Approaches to correct for this should be investigated. The dataset used for this indicator is currently available at a decadal level. It is feasible to calculate the ungulate metabolic biomass densities at higher temporal resolutions (e.g. annually) and this should be considered.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.4 Domestic ungulate density [F17, A16, S13]

Ecosystem characteristic: Functionally important species and biophysical structures

5.4.1 Supplementary metadata

Not relevant.

5.4.2 Supplementary methods

The metabolic biomass of wild and (semi-)domestic ungulates for municipalities in Trøndelag were obtained from Speed et al. (2019). The data was given for each 10th year from 1949 to 2009 and from 2015 in addition. The data were originally compiled through agricultural statistics for livestock, reindeer herding data, and hunting statistics for the wild species. Numbers of wild ungulates were estimated through a simple population model. Numbers were converted to metabolic biomass using allometric scaling, and the values for livestock were standardized for time spent in unenclosed land (Speed et al. 2019).

The municipalities were classified as either “Forest”, “Alpine”, “Wetland” or “Open lowland" according to land-cover. If either of the four categories covered ≥50% of the area, the municipality was classified as such; the threshold for “Wetland” being ≥22.5% due to the rarity of this land-cover type. In the case of no land-cover type occupying ≥50%, the dominant land-cover type was assigned, unless “Wetland” covered ≥20%. The indicators were calculated for all “Forest”, “Alpine” and “Open lowland” municipalities, respectively.

5.4.3 Plots of indicator values

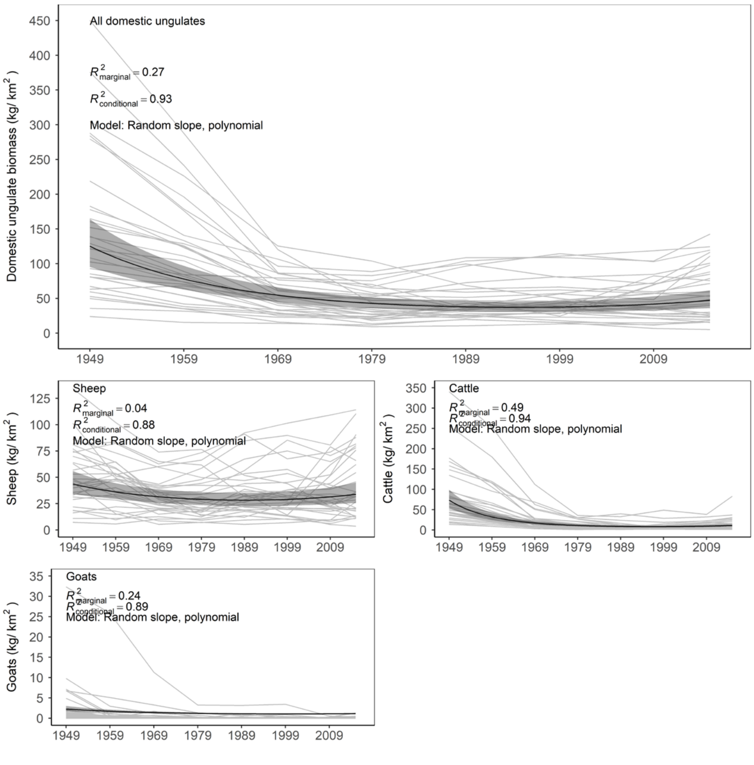

Figure A5.4.1. *Metabolic biomass of domestic ungulates in forest municipalities. The figure shows the metabolic biomass of all domestic ungulates, and the included species (Semi-domestic reindeer, sheep, cattle, goat and horse) separately. Horse could not be modelled separately and is thus not shown. Horse is however included in the total metabolic biomass. Rate of change is shown with ±2SE (shaded area). Gray lines indicate individual municipalities.*

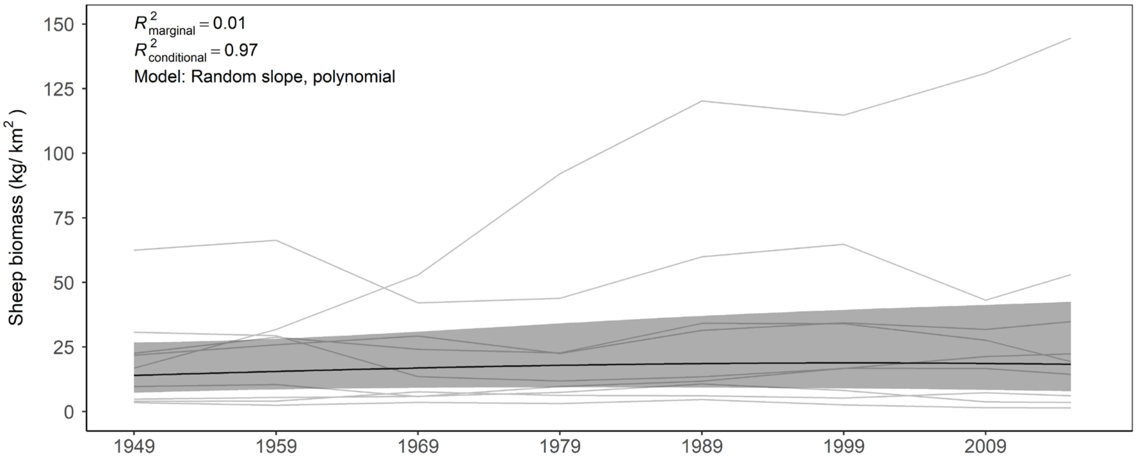

Figure A5.4.2. *Metabolic biomass of sheep for alpine municipalities. The figure shows the metabolic biomass of sheep. Rate of change is shown with ±2SE (shaded area). Gray lines indicate observed trends for individual municipalities. The models were fitted to log(y+1).*

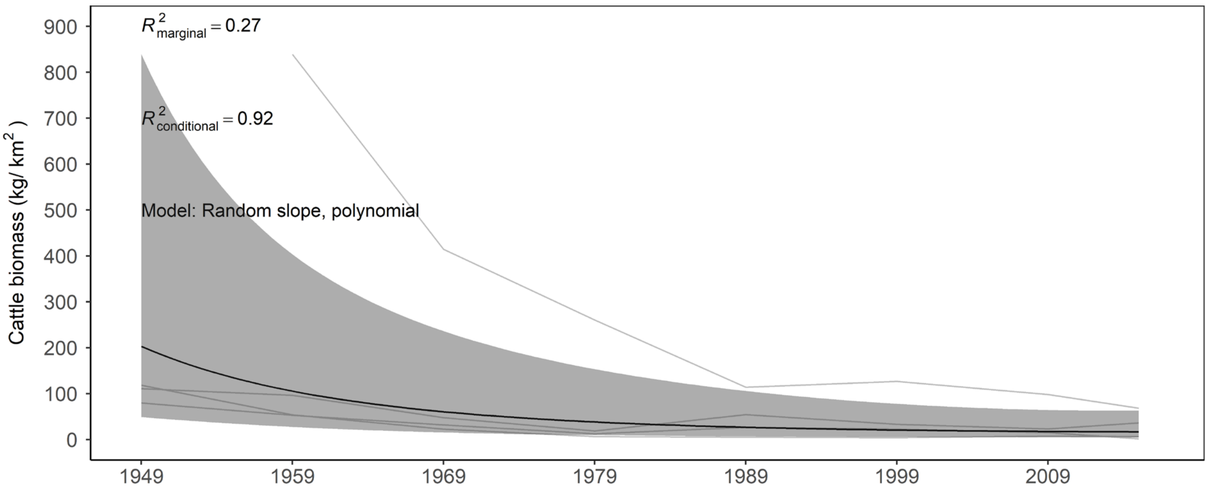

Figure A5.4.3. *Metabolic biomass of cattle for open lowland municipalities. The figure shows the metabolic biomass of cattle. Rate of change is shown with ±2SE (shaded area). Gray lines indicate observed trends for individual municipalities. For visualization purposes, the 1949-value for Ørland municipality (1494.16 kg/km^2) has been excluded from the plot. The models were fitted to log(y+1).*

5.4.4 Background data and supplementary analysis

Not relevant.

5.4.5 Recommendations for future development of the indicator

The dataset used for this indicator is currently available at a decadal level. The estimates are made across municipalities that are characterized as open-lowland. Therefore, parts of the population (within the target ecosystem in municipalities that are characterized as other ecosystems) may be missing from this estimate.

5.5 Dead wood volume [F21]

Ecosystem characteristic: Functionally important species and biophysical structures

5.5.1 Supplementary metadata

Not relevant.

5.5.2 Supplementary methods

The indicator is based on data from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data on deadwood volume (‘*DODVED_10CM_VMPRHA: Volume (m3/ha) of dead wood > 10 cm in diameter’ and ‘DODVED_30CM_VMPRHA: Volume of coarse dead wood > 30 cm in diameter ‘)* are available for three rotations (1994-1998, 2010-2014 and 2015-2019). There was a change in recording methods between the first and later rotations, but evaluations suggest that this has not impacted the results of the surveys significantly (Storaunet and Rolstad 2015, Svensson et al 2021). Estimates are presented separately for three different forest types according to the NFI classification (Spruce: NFI *best_tresl* = 1-3, Pine: NFI *best_tres* = 4-6, Deciduous: NFI *best_tres* = 7-9).

5.5.3 Plots of indicator values

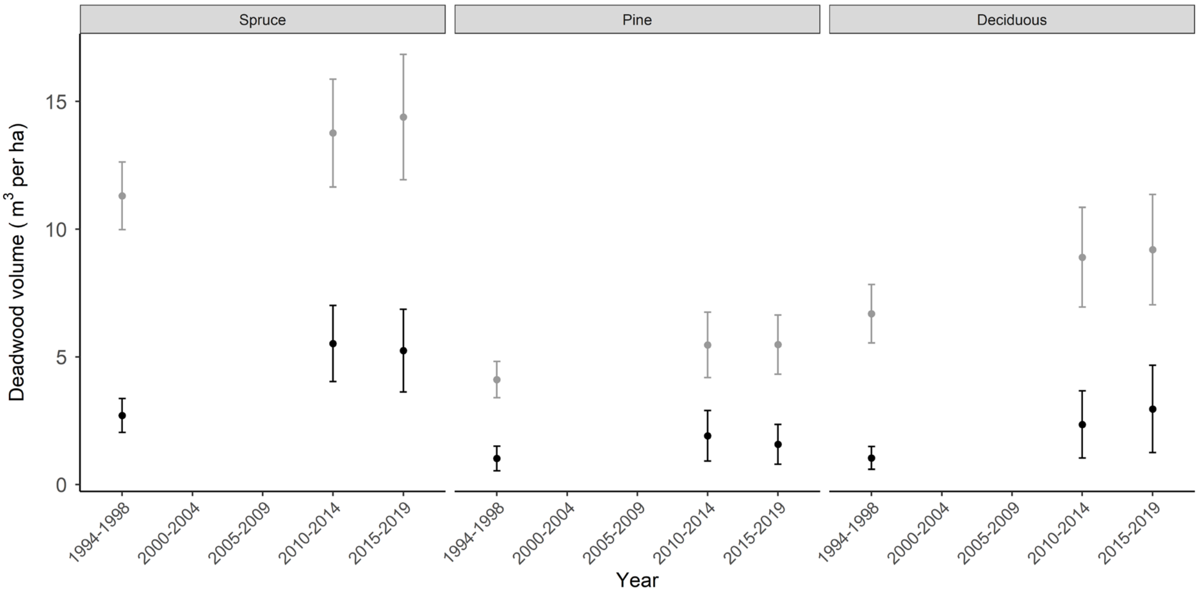

Figure A5.5.1 *Deadwood volume (m³ per ha) per forest type (spruce, pine and deciduous) divided into total volume of deadwood (> 10 cm, grey symbols) and volume coarse deadwood (> 30 cm, black symbols). The estimates are given as mean ±2SE across all surveyed plots in Trøndelag. Sample sizes (the number of plots) vary somewhat between rotations. Range per forest type are Spruce: 672-870 plots, Pine: 448-580 plots, Deciduous: 312-442 plots.*

5.5.4 Background data and supplementary analysis

Not relevant.

5.5.5 Recommendations for future development of the indicator

This indicator is considered appropriately formulated.

5.6 ROS volume [F28]

Ecosystem characteristic: Functionally important species and biophysical structures

5.6.1 Supplementary metadata

Not relevant.

5.6.2 Supplementary methods

The indicator is based on data from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data on ROS species (rowan, aspen, goat willow) volume (‘*ROS_10CM_VMPRHA* = volum pr ha av ROS (rogn, osp, selje) >10cm’) are available for the 5 latest rotations (1994-1998, 2000-2004, 2005-2009, 2010-2014 and 2015-2019). Estimates are presented separately for three different forest types according to the NFI classification (Spruce: NFI *best_tresl* = 1-3, Pine: NFI *best_tres* = 4-6, Deciduous: NFI *best_tres* = 7-9).

5.6.3 Plots of indicator values

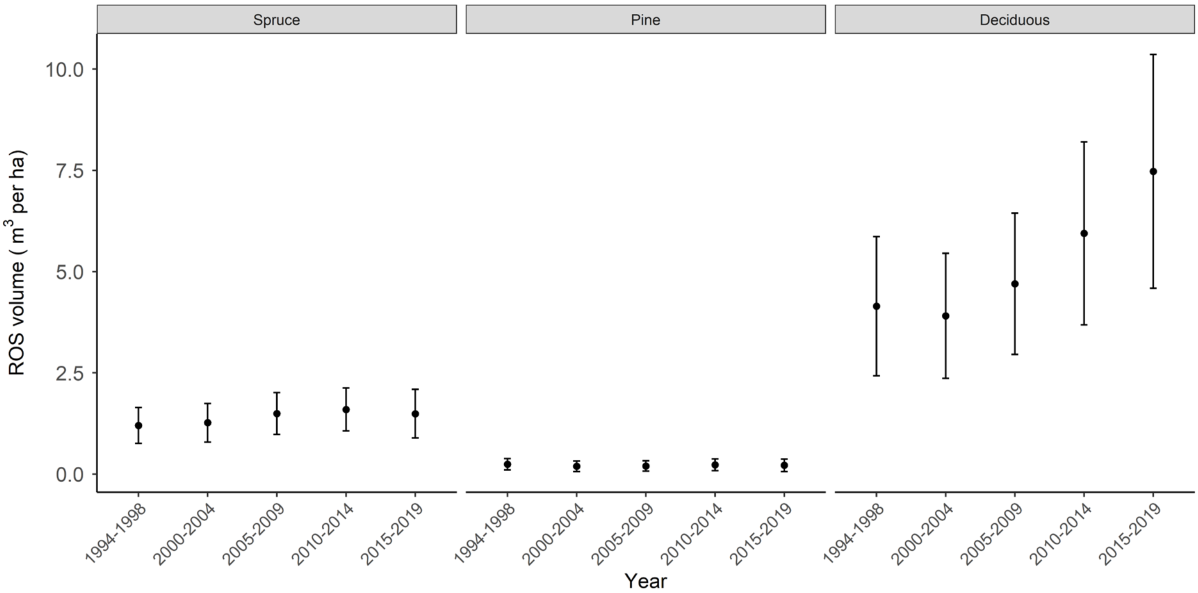

Figure A5.6.1 *ROS species (*rowan, aspen, goat willow) *volume (m^3 per ha) per forest type (spruce, pine and deciduous). The estimates are given as mean ±2SE across all surveyed plots in Trøndelag. Sample sizes (the number of plots) vary somewhat between rotations. Range per forest type are Spruce: 672-870 plots, Pine: 448-591 plots, Deciduous: 312-422 plots.*

5.6.4 Background data and supplementary analysis

Not relevant.

5.6.5 Recommendations for future development of the indicator

This indicator is considered appropriately formulated.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.7 Bilberry coverage [F20]

Ecosystem characteristic: Functionally important species and biophysical structures

5.7.1 Supplementary metadata

Not relevant.

5.7.2 Supplementary methods

The indicator is based on data from the National Forest Inventory (NFI), which consist of surveys of 250 m² plots in a 5-year rotation. Data on bilberry coverage (‘*BLAABAER_GJSN = % coverage of bilberry as average over 4, 0.25m² squares*’) are only available for the two latest rotations (2010-2014 and 2015-2019), which is not sufficient to evaluate changes bilberry coverage between rotation periods. Estimates are presented separately for three different forest types according to the NFI classification (Spruce: NFI *best_tresl* = 1-3, Pine: NFI *best_tres* = 4-6, Deciduous: NFI *best_tres* = 7-9).

5.7.3 Plots of indicator values

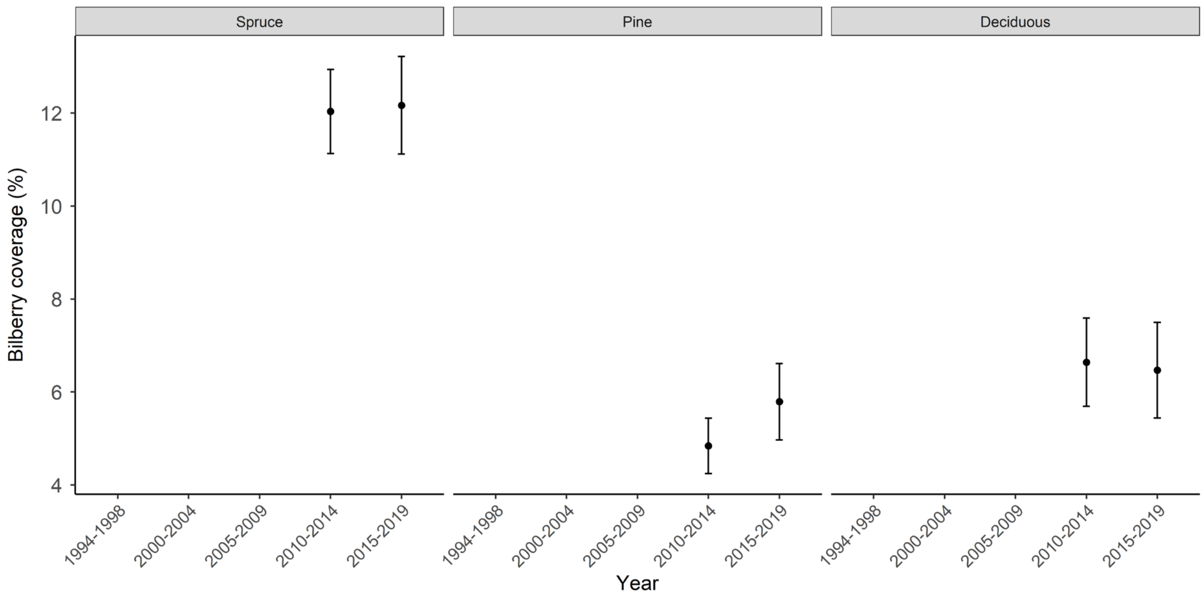

Figure A5.7.1. *Bilberry coverage (%) per forest type (spruce, pine and deciduous). The estimates are given as mean ±2SE across all surveyed plots in Trøndelag. Sample sizes (the number of plots) vary somewhat between rotations. Range per forest type are; Spruce: 669-846 plots, Pine: 447-537 plots, Deciduous: 363-442 plots.*

5.7.4 Background data and supplementary analysis

Not relevant.

5.7.5 Recommendations for future development of the indicator

This indicator is considered appropriately formulated.

5.8 Large predator abundance [F23, A15]

Ecosystem characteristic: Functionally important species and biophysical structures

5.8.1 Supplementary metadata

Not relevant.

5.8.2 Supplementary methods

Top predator abundance is represented by the abundance of the large predator species expected to be present in intact forest and alpine ecosystems. Several of these species utilize both ecosystems. The data (annual number of reproducing females) are on a county level and do not permit a separation in space. We therefore chose to base the indicators on the species which most closely typify forest and alpine ecosystems respectively. For forest ecosystems these are lynx, brown bear and wolf. For alpine ecosystems these are wolverine. The data on golden eagle do not permit inclusion of this species at present. There are no resident wolves in Trøndelag.

5.8.3 Plots of indicator values

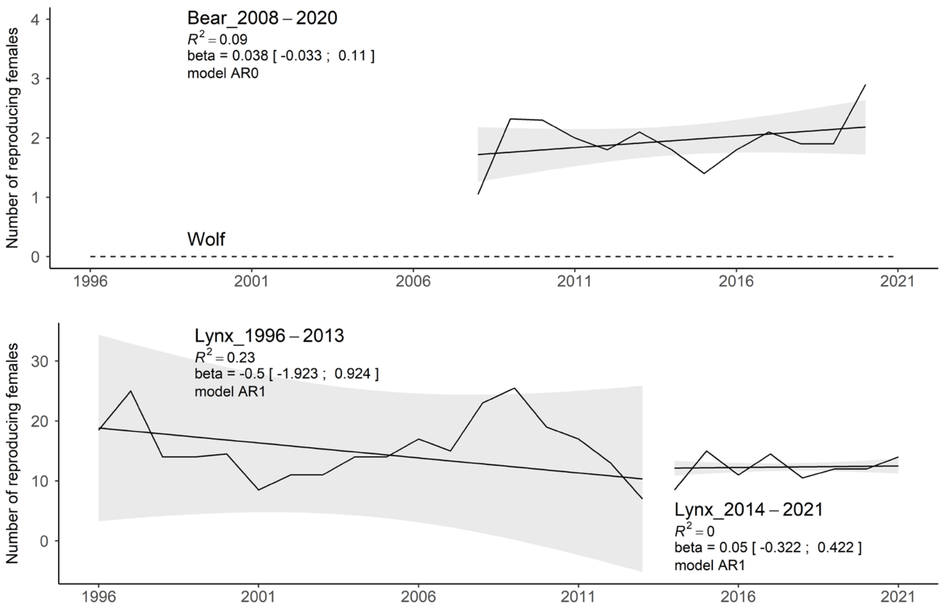

Figure A5.8.1 *The abundance of large predators which typify forest ecosystems (brown bear, wolf and lynx). Rates of change are shown ± 2SE.*

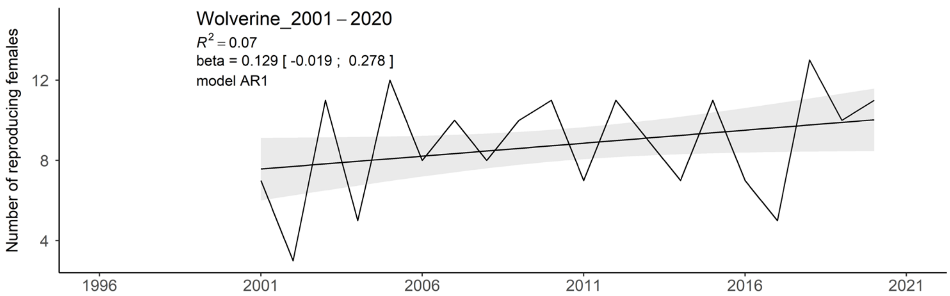

Figure A5.8.2 *The abundance of large predators which typify alpine ecosystems (wolverine). Rates of change are shown ± 2SE.*

5.8.4 Background data and supplementary analysis

Not relevant.

5.8.5 Recommendations for future development of the indicator

Available data for golden eagle is the number of occupied territories during a five-year period from the extensive national monitoring program for the golden eagle (Rovdata.no). Coverage is non-systematic and is therefore open to sampling bias (Mattisson et al. 2020), fails to capture the temporal scale of population dynamics as reproduction occurs annually, and is too short (two data periods) to allow estimation of change in this long-lived species. A minimal requirement for estimation of occupied territories from future data is that the sampling design is statistically robust, taking into account incomplete surveying. It should also be investigated whether the number of territories is sufficient to produce robust annual estimates based on a suitable sampling design, thereby capturing changes in this metric at the scale of the population dynamics for golden eagle.

5.9 Red fox camera index [A14]

Ecosystem characteristic: Functionally important species and biophysical structures

5.9.1 Supplementary metadata

Not relevant.

5.9.2 Supplementary methods

The proportion of days where red fox is recorded by wildlife cameras is calculated as the number of observation days when at least one fox is captured in an image / total number of observation days. An observation day is defined as one camera having taken pictures for one day (excluding days with bad visibility or malfunctioning of the camera). The data set contains data from 3 of the 5 alpine areas included in the national monitoring program for Arctic foxes. The areas are subject to different types of management interventions to support the endangered Arctic fox. The three areas where camera data are available are Børgefjell (no management interventions), and Blåfjellet/Hestkjølen/Skjækerfjellet, and Kjølifjellet/Sylane (both subject to supplementary feeding of arctic foxes). The proportion of days when foxes are recorded is calculated separately for each area. Rates of change in all data sets are calculated with AR models as described in the general methods and are shown ±2SE. The most suitable model based on AIC is indicated on the figures.

5.9.3 Plots of indicator values

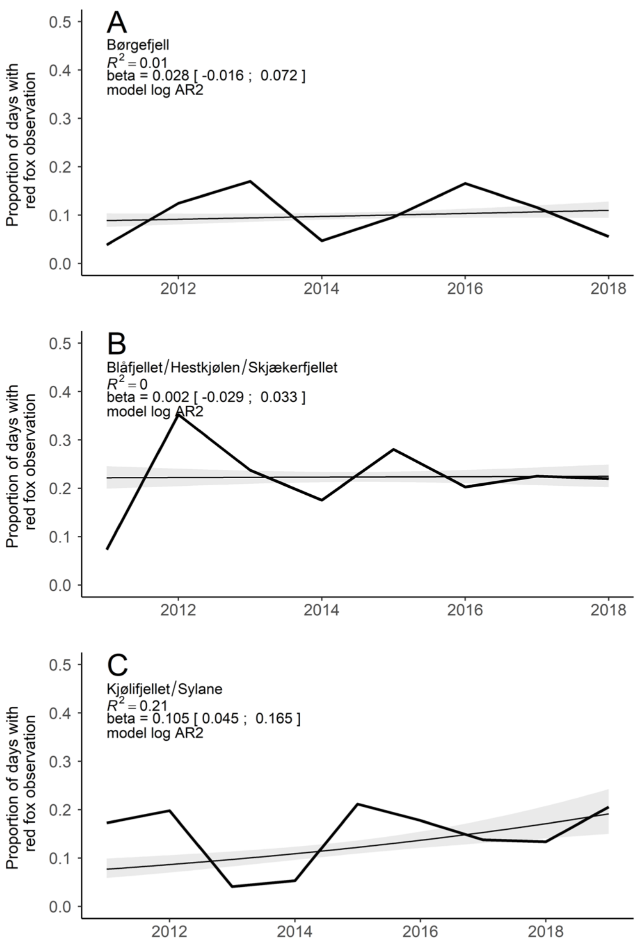

Figure A5.9.1 *The proportion of days where red fox is recorded across all camera traps per alpine area A) Børgefjell (no management interventions), and B) Blåfjellet/Hestkjølen/Skjækerfjellet, and C) Kjølifjellet/Sylane (both subject to supplementary feeding of arctic foxes). Rates of change are shown ± 2SE (shaded areas).*

5.9.4 Background data and supplementary analysis

Not relevant.

5.9.5 Recommendations for future development of the indicator

The camera-based monitoring on which this indicator is based, was initiated to evaluate effects of arctic fox conservation actions. It is currently discontinued due to absence of funding. Camera traps placed on arctic fox den sites and feeding stations could possibly be used to cover this indicator in the future. Independent of which data source is chosen, the geographical representativity of the trap network should evaluated relative to the region being assessed (e.g. here Trøndelag), to ensure coverage of relevant bioclimatic gradients (sub- - high alpine). The indicator can be sensitive to abundance of alternative prey and must be interpreted carefully in terms of densities per se (Gomo et al. 2020, 2021). There are indications that red foxes avoid camera sites with baits in areas where hunting on the species are intensive (Rød-Eriksen et al. 2020). This should be evaluated. In the short term, it is recommended that the indicator is refined by use of a statistical model that takes into account the varying discoverability of the red fox.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.10 Bumblebee abundance and species richness [S17]

Ecosystem characteristic: Functionally important species and biophysical structures

5.10.1 Supplementary metadata

Not relevant.

5.10.2 Supplementary methods

The data set used is from the Norwegian Monitoring Program for Bumblebees and Butterflies and the sampling approach is described in Öberg et al. 2011, see also Åström et al. 2021. In Trøndelag, the data series covers from 2010 to date, but the first 2 years were used for testing, so the analysis in this report starts in 2012. In Trøndelag, a total of 18 LUCAS-grids (area representative grid network with 18 km distance between grids) are visited, representing two kinds of open habitats along a coast-inland gradient (grassland and open forest (forest glade)). The 18 “monitoring plots” (1.5*1.5 km grid cells) have been selected using a stratified random sampling but considering accessibility as a pre-selection criterion. Each grid cell is surveyed along linear elements, using a protocol for netting inventories, with 20 transects (50 m each), covering ca 180 transects in each habitat type in Trøndelag (Åström et al. 2021). The habitats in the plots have been documented using air-photos and each transect is allocated to either grassland or open forest. Insects and environmental parameters are recorded through the inventories, three times during the growing season (spring, summer and late-summer) to include the phenology of different species. The inventories are conducted by volunteers, following a course given each year prior to the inventory season on species identification, inventory techniques and the protocol. The volunteers can select the location of the transects, while following the protocol guideline.

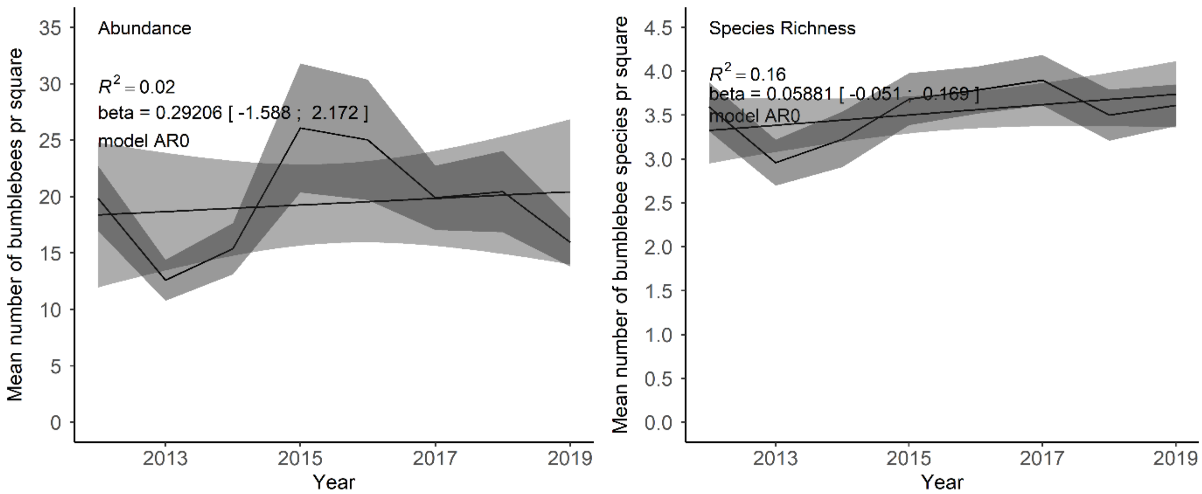

Figure A5.10.1. *Bumblebee abundance and species richness. The figure shows mean abundance and species richness of bumblebees within 1.5×1.5 km squares in Trøndelag, surveyed along 50m transects. Rates of change are shown ± 2SE.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

5.10.3 Background data and supplementary analysis

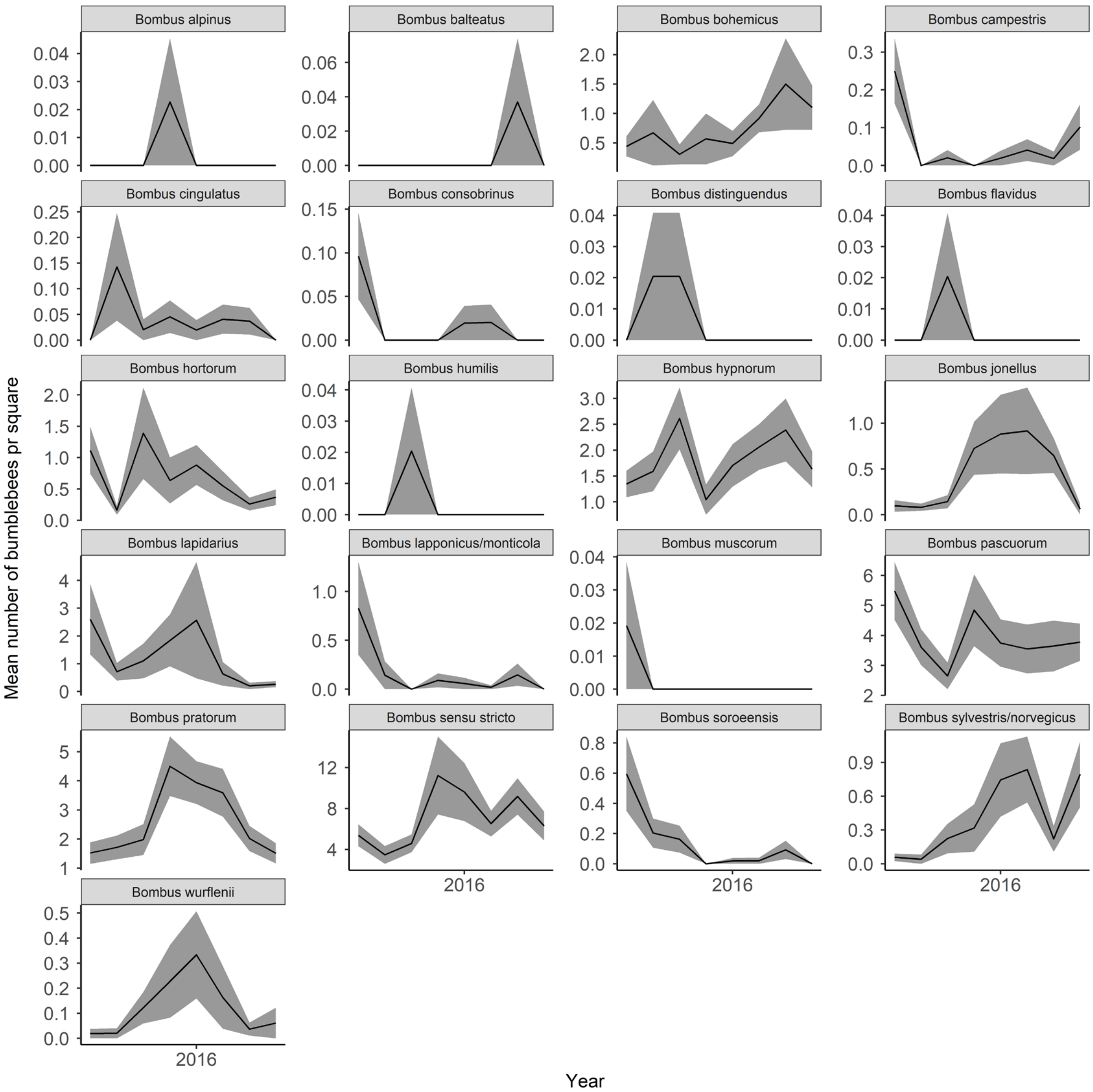

Figure A5.10.2. *Annual abundance of individual species. The figure shows mean abundance of individual bumblebee species within 1.5×1.5 km squares in Trøndelag, surveyed along 20×50m transects. Rates of change are shown ± 2SE.*

5.10.4 Recommendations for future development of the indicator

This is the most comprehensive time series available to assess the condition of semi-natural open habitats (grassland), and open forest habitats (forest glades). The analyses in the latest report (Åström et al. 2021) indicates that some trends only become evident when flower covered is included in the analyses, and flower cover also helps show that there are other unknown factors that drive the trends in both butterflies and bumblebees in the region. If the monitoring program would be expanded to more regions (upland areas, and areas in Northern Norway) and other habitat types it may be possible to identify the significance of these factors for species diversity and populations of different species of bumblebees. Two novel avenues for improving the robustness of the assessments of ecological condition of semi-natural, open lowland habitats could be possible by complementing bumblebee monitoring with: i) a further development of the newly established insect monitoring program (Åström et al. 2019) and ii) ongoing NINA research project (Landbruksdirektoratet, NFR – Arealer under press) that aim at developing area-coverage techniques to monitor habitat quality for pollinators.

5.11 Lemming abundance [A18]

Ecosystem characteristic: Functionally important species and biophysical structures

5.11.1 Supplementary metadata

Not relevant.

5.11.2 Supplementary methods

The abundance of lemmings is given as the average number of lemmings per 100 trap nights, subdivided according to locality (Børgefjell central, alpine habitat, Børgefjell TOV and Åmotsdalen TOV, subalpine birch forest). Rates of change in all data sets are calculated with AR2 models as described in the general methods and are shown ±2SE.

5.11.3 Plots of indicator values

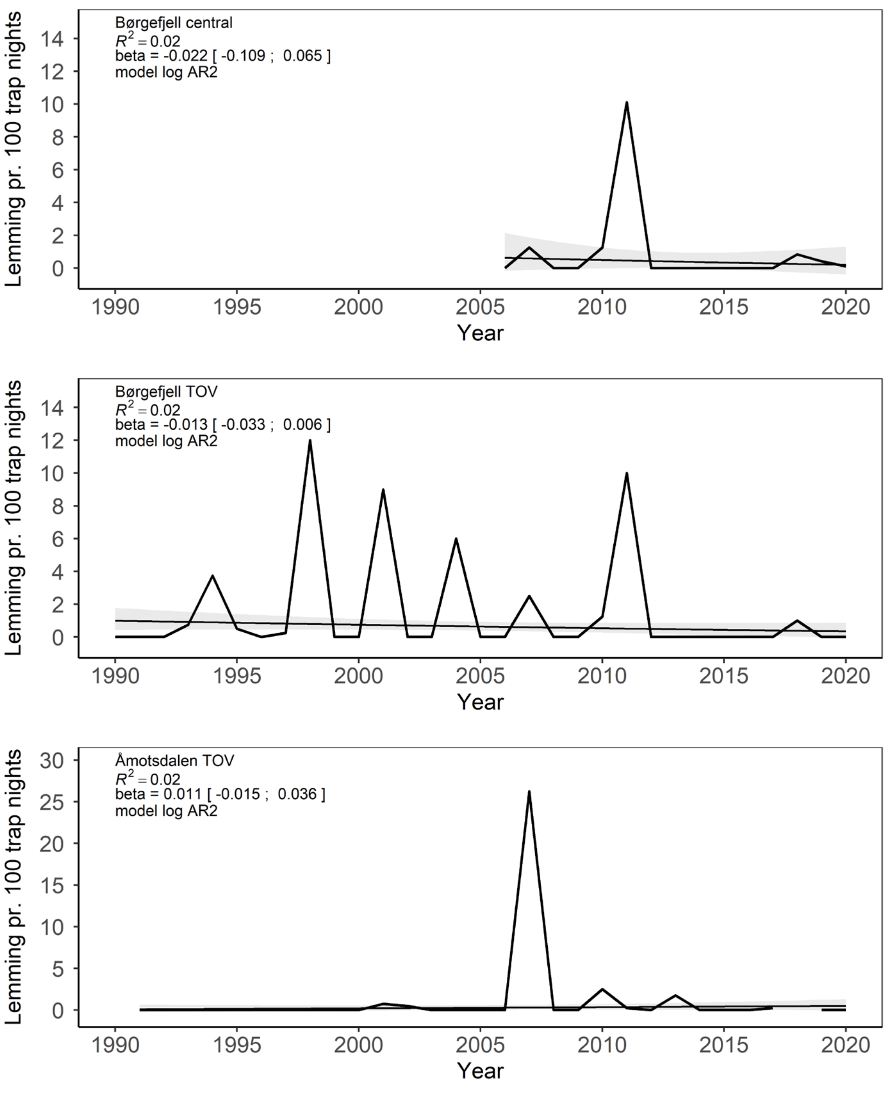

Figure A5.13.1. *Lemming per 100 trap nights. Rates of change are shown with ±2SE (shaded areas).*

5.11.4 Background data and supplementary analysisNot relevant.

Not relevant.

5.11.5 Recommendations for future development of the indicator

The surveys should be extended to a regionally representative design. The spatial cover in Børgefjell TOV and Åmotsdalen TOV is limited to a few line-transects placed in a narrow elevation gradient, while Børgefjell Central is more widely scattered to cover a larger part of Børgefjell National Park. Following new technological development in COAT (Soininen et al. 2015) a camera-based monitoring design has been implemented in the TOV areas 2021, which will eventually replace snap trapping. Camera monitoring gives much greater representation over time (continuous year-round rather than two annual captures). This method could be deployed at a wider spatial scale covering important ecological gradients within Trøndelag.

Small mammal camera traps also provide additional data about the small rodent specialist predators stoat and least weasel, thus opening new possibilities to monitor crucially important trophic interactions. However, owing to the higher costs of camera traps versus snap traps, camera monitoring must be carried out at fewer capture localities than the current regional monitoring. Thus, it is important to assess both how the spatial representativity of the indicator is affected by a shift to camera-based monitoring, and the relationship between time-series based on the two methods.

6 Indicators for *Landscape ecological patterns*

6.1 Areas free of major infrastructure [F12, A12, W12]

Ecosystem characteristic: Landscape ecological patterns

6.1.1 Supplementary metadata

Not relevant.

6.1.2 Supplementary methods

Not relevant.

6.1.3 Plots of indicator values

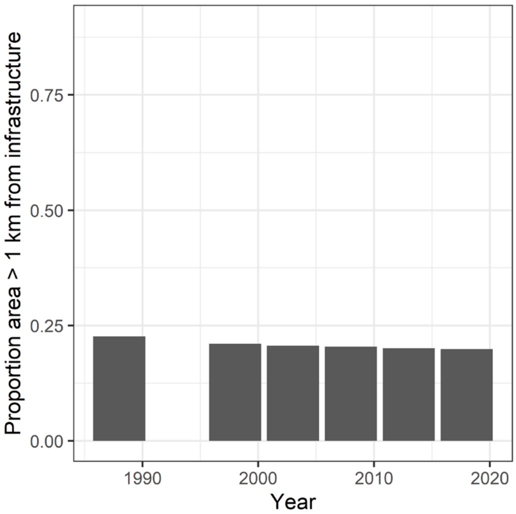

Figure A6.1.1 *The proportion of forest area located > 1 km from major technical installations for each available status year.*

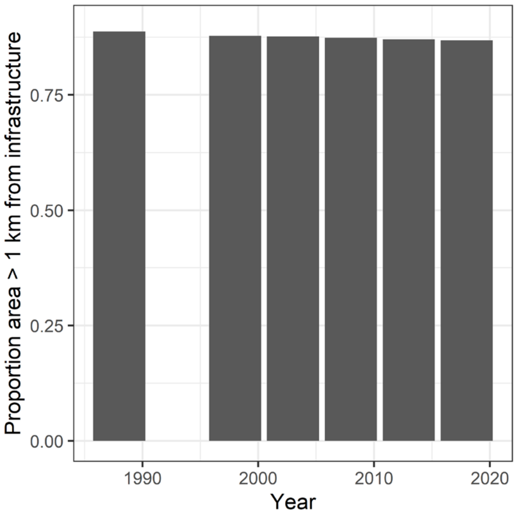

Figure A6.1.2 *The proportion of alpine area located > 1 km from major technical installations for each available status year.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

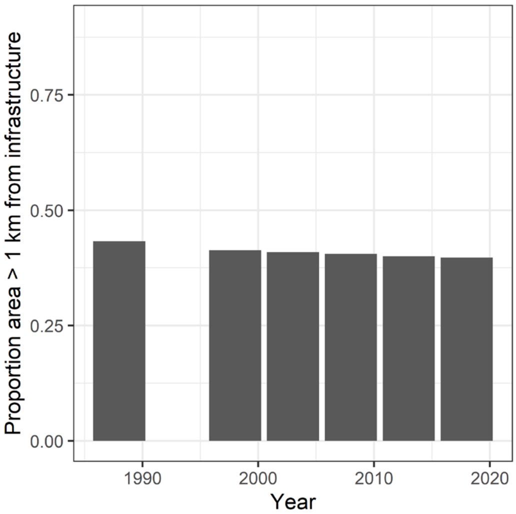

Figure A6.1.3 *The proportion of wetland area located > 1 km from major technical installations for each available status year.*

6.1.4 Background data and supplementary analysis

Not relevant.

6.1.5 Recommendations for future development of the indicator

The indicator quantifies the extent of areas > 1 km away from major infrastructure such as roads, major power lines, railroads, and reservoirs for hydroelectric power. The indicator does not capture small technical installations such as cottages, minor power lines, or isolated masts without associated infrastructure. Neither does it include activities such as drainage/trenching in natural habitats. However, in assessments of ecosystem condition, minor perturbations can be highly relevant. This requires ongoing consideration of the possibility of supplementing this indicator by including the presence of minor technical installations.

Another challenge with the available data for infrastructure is the rather delayed update, and the potential lack of inclusion (e.g. illegal or not reported to the authorities). Here, remote sensing technology can provide up-to-date maps different type of human activities, also those that are not included in standard digital map data.

New methods under rapid development, such as eco-acoustics, can be used to assess the level of human activities, in cases where changes cannot be detected visually, through soundscapes (Farina & Gage 2017, Tzu-Hao et al. 2020). They can both provide higher spatial resolution data on human activities, be scalable and provide valuable information of human pressures on nature (Rosten & Fossøy 2020) other than disturbance caused by physical barriers.

Theoretical and empirical studies provide strong evidence that rather simple measures of the landscape or habitat can be strong predictors of factors such as population viability, species richness, species turnover rates and dynamics of species communities (McGill et al. 2015). Measures such as number of patches, patch size, patch shape (indicating the degree of edge effects) and connectivity of patches are straightforward to calculate given appropriate data. These measures also capture ecosystem change due to land use changes very well. Unfortunately, the base map of the four ecosystems, with a rather coarse raster resolution, did not allow us to calculate these measures appropriately. This is particularly true for patch shape (e.g. the ratio of perimeter to area).

7 Indicators for *Biological diversity*

7.1 Forest/Alpine/Wetland/Farmland bird communities [F15, A23, W16, S16]

Ecosystem characteristic: Biological diversity

7.1.1 Supplementary metadata

Bird communities indicators are based on the monitoring program *Extensive monitoring of breeding birds* (TOV-E; Kålås et al. 2021, Lislevand et al. 2021). Supplementary data from the *3Q monitoring of breeding birds* (3Q; Pedersen 2020) are also shown. TOV-E targets all ecosystems, while 3Q targets cultural and agricultural land specifically, and 3Q data hence support the indicator for farmland birds in open lowland ecosystems. Both monitoring programs use monitoring sites which are randomly drawn from a systematic grid covering the entire country, but there are differences in the sampling protocol used by the two programs. TOV-E adhere to an annual monitoring protocol, while 3Q perform the monitoring in an approximately Three-year rotation. The methodology used in both programs is point transect sampling done by trained observers. For Trøndelag, TOV-E consists of 70 monitoring sites covering the years 2006-2020, while 3Q consists of 19 monitoring sites covering 6 rotations over the years 2001-2017.

7.1.2 Supplementary methods

The indicator values are composite (i.e. multi-species) indices calculated based on TOV-E over a subset of species which typify forest, alpine, wetland and open lowland ecosystems respectively (Husby & Kålås 2011). In addition, we show single species indices for each species separately. For open lowland ecosystem, we summarize the data based on 3Q for the same 8 species selected from TOV-E (Table 7.1.1), but do not calculate species level or composite indices. TOV-E indices are calculated based on standard methodology used in both national (Kålås et al. 2021) and international (Gregory et al. 2005, Lehikoinen et al. 2019) bird monitoring schemes, using TRIM (TRends and Indices for Monitoring data; Pannekoek & van Strien 2001) models implemented in the R library rtrim (Bogaart et al 2020). Confidence intervals around composite indices are calculated using Monte Carlo simulation following Soldaat et al. (2017). Model formulation is identical to the one used in TOV-E which is a time effect model (TRIM model type 2) correcting for serial correlation and overdispersion (Kålås et al. 2021). TRIM models give population indices relative to a base year which is routinely set as the first time unit in the data series. Due to low sample sizes in the first years of the TOV-E data series, we used the mean counts over the years 2006-08 to represent the base year (2008). Although we have used all data available for Trøndelag County, sample sizes (in term of the number of counts, and the number of sites at which the species has been observed) for many species are much lower that what is required in order to produce reliable e.g. (representative and precise) trend estimates. We therefore present composite indices for subsets of species with different sample sizes, in order to illustrate the effect that the inclusion of species with insufficient sample sizes exert on the overall composite index.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

***Table A7.1.1**. A list of species included in the biodiversity indicators for bird communities. Sample sizes are given as the number of total counts of the species [number of total sites at which the species has been observed].*

Ecosystem	Species	Sample size TOV-E	Sample size 3Q
Forest	Black Woodpecker (*Dryocopus martius*) [Svartspett]	88 [25]	
Forest	Blackbird (*Turdus merula*) [Svarttrost]	1440 [49]	
Forest	Blackcap (*Sylvia atricapilla*) [Munk]	400 [25]	
Forest	Bullfinch (*Pyrrhula pyrrhula*) [Dompap]	213 [36]	
Forest	Chaffinch (*Fringilla coelebs*) [Bokfink]	4728 [56]	
Forest	Chiffchaff (*Phylloscopus collybita*) [Gransanger]	4309 [47]	
Forest	Coal Tit (*Periparus ater*) [Svartmeis]	210 [31]	
Forest	Crested Tit (*Lophophanes cristatus*) [Toppmeis]	62 [22]	
Forest	Dunnock (*Prunella modularis*) [Jernspurv]	922 [54]	
Forest	Garden Warbler (*Sylvia borin*) [Hagesanger]	70 [16]	
Forest	Goldcrest (*Regulus regulus*) [Fuglekonge]	503 [46]	
Forest	Great Spotted Woodpecker (*Dendrocopos major*) [Flaggspett]	135 [29]	
Forest	Icterine Warbler (*Hippolais icterina*) [Gulsanger]	122 [22]	
Forest	Jay (*Garrulus glandarius*) [Nøtteskrike]	57 [24]	
Forest	Mistle Thrush (*Turdus viscivorus*) [Duetrost]	36 [11]	
Forest	Redstart (*Phoenicurus phoenicurus*) [Rødstjert]	2121 [49]	
Forest	Redwing (*Turdus iliacus*) [Rødvingetrost]	5373 [66]	
Forest	Robin (*Erithacus rubecula*) [Rødstrupe]	2569 [52]	
Forest	Song Thrush (*Turdus philomelos*) [Måltrost]	2436 [61]	
Forest	Spotted Flycatcher (*Muscicapa striata*) [Gråfluesnapper]	134 [30]	
Forest	Tree Pipit (*Anthus trivialis*) [Trepiplerke]	2041 [56]	
Forest	Treecreeper (*Certhia familiaris*) [Trekryper]	62 [19]	
Forest	Willow Tit (*Poecile montanus*) [Granmeis]	714 [51]	
Forest	Willow Warbler (*Phylloscopus trochilus*) [Løvsanger]	12126 [69]	
Forest	Wren (*Troglodytes troglodytes*) [Gjerdesmett]	660 [43]	
Alpine	Bluethroat (*Luscinia svecica*) [Blåstrupe]	278 [28]	
Alpine	Golden Plover (*Pluvialis apricaria*) [Heilo]	2731 [47]	
Alpine	Lapland Bunting (*Calcarius lapponicus*) [Lappspurv]	51 [6]	
Alpine	Long-tailed Skua (*Stercorarius longicaudus*) [Fjelljo]	29 [8]	
Alpine	Ring Ouzel (*Turdus torquatus*) [Ringtrost]	417 [39]	
Alpine	Rock ptarmigan (*Lagopus muta*) [Fjellrype]	236 [20]	
Alpine	Rough-legged Buzzard (*Buteo lagopus*) [Fjellvåk]	96 [38]	
Alpine	Wheatear (*Oenanthe oenanthe*) [Steinskvett]	692 [36]	
Alpine	Willow Grouse (*Lagopus lagopus*) [Lirype]	529 [49]	
Wetland	Common Sandpiper (*Actitis hypoleucos*) [Strandsnipe]	454 [48]	
Wetland	Crane (*Grus grus*) [Trane]	255 [45]	
Wetland	Dipper (*Cinclus cinclus*) [Fossekall]	35 [13]	
Wetland	Greenshank (*Tringa nebularia*) [Gluttsnipe]	714 [52]	
Wetland	Redshank (*Tringa totanus*) [Rødstilk]	1354 [67]	
Wetland	Reed Bunting (*Emberiza schoeniclus*) [Sivspurv]	468 [44]	

Wetland	Snipe (*Gallinago gallinago*) [Enkeltbekkasin]	691 [57]	
Wetland	Whimbrel (*Numenius phaeopus*) [Småspove]	726 [44]	
Wetland	Wood Sandpiper (*Tringa glareola*) [Grønnstilk]	195 [28]	
Open lowland	Curlew (*Numenius arquata*) [Storspove]	265 [17]	166 [19]
Open lowland	Lapwing (*Vanellus vanellus*) [Vipe]	64 [12]	47 [11]
Open lowland	Sky Lark (*Alauda arvensis*) [Sanglerke]	335 [5]	76 [10]
Open lowland	Starling (*Sturnus vulgaris*) [Stær]	556 [20]	270 [18]
Open lowland	Swallow (*Hirundo rustica*) [Låvesvale]	228 [18]	91 [17]
Open lowland	Whinchat (*Saxicola rubetra*) [Buskskvett]	142 [18]	108 [17]
Open lowland	White Wagtail (*Motacilla alba*) [Linerle]	249 [25]	84 [16]
Open lowland	Yellowhammer (*Emberiza citrinella*) [Gulspurv]	577 [20]	634 [19]

7.1.3 Plots of indicator values

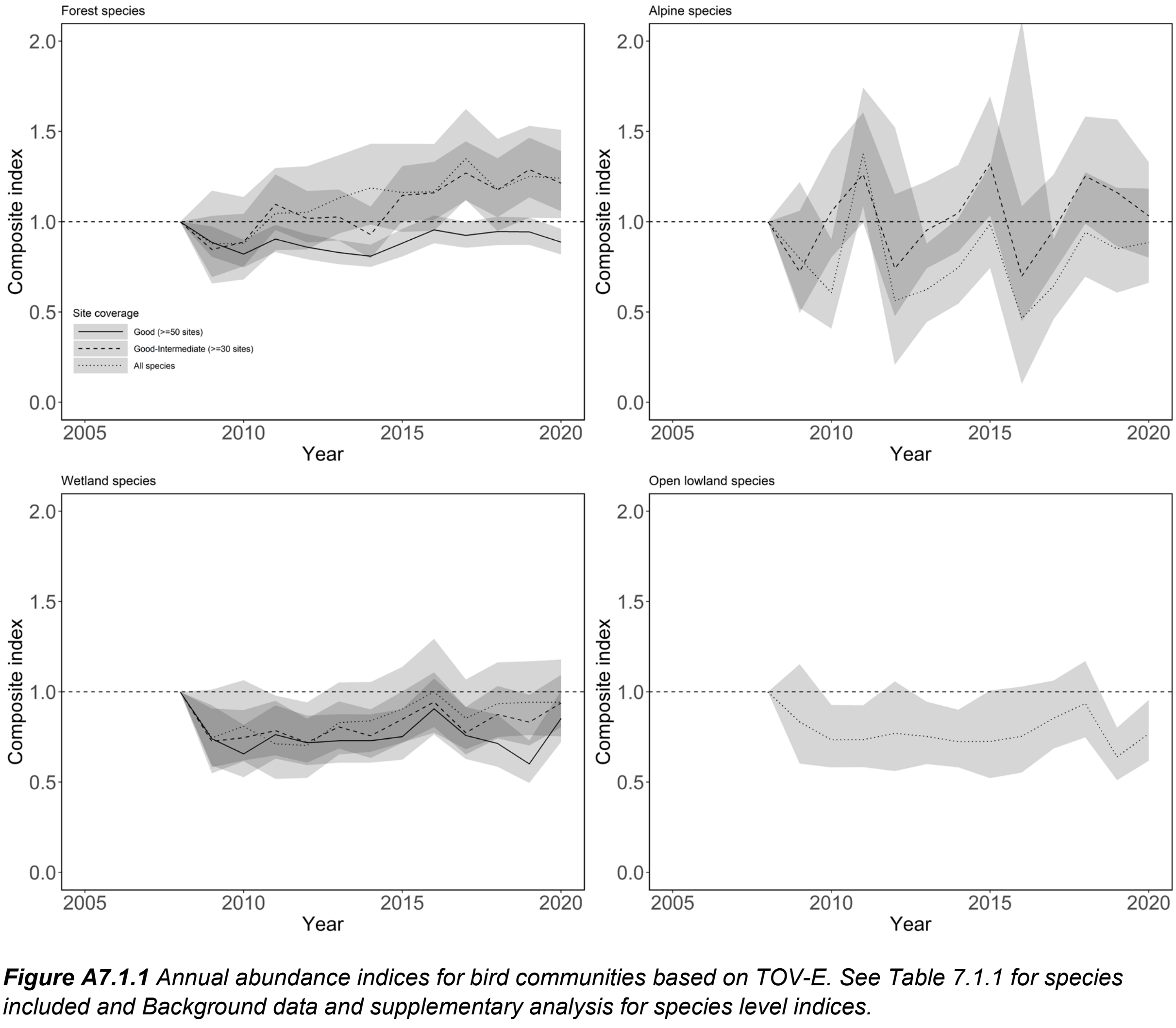

Figure A7.1.1 *Annual abundance indices for bird communities based on TOV-E. See Table 7.1.1 for species included and Background data and supplementary analysis for species level indices.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

7.1.4 Background data and supplementary analysis

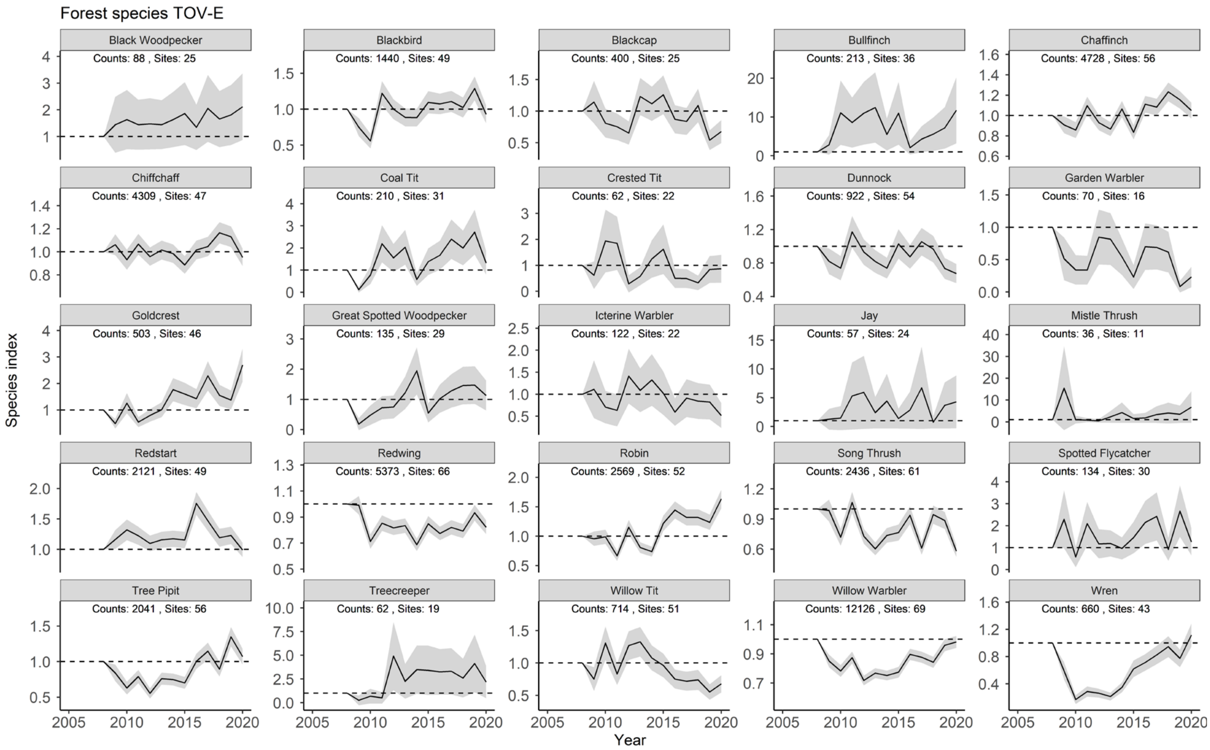

***Figure A.7.1.2**. Annual abundance indices from TOV-E for the individual bird species included in the forest bird community index.*

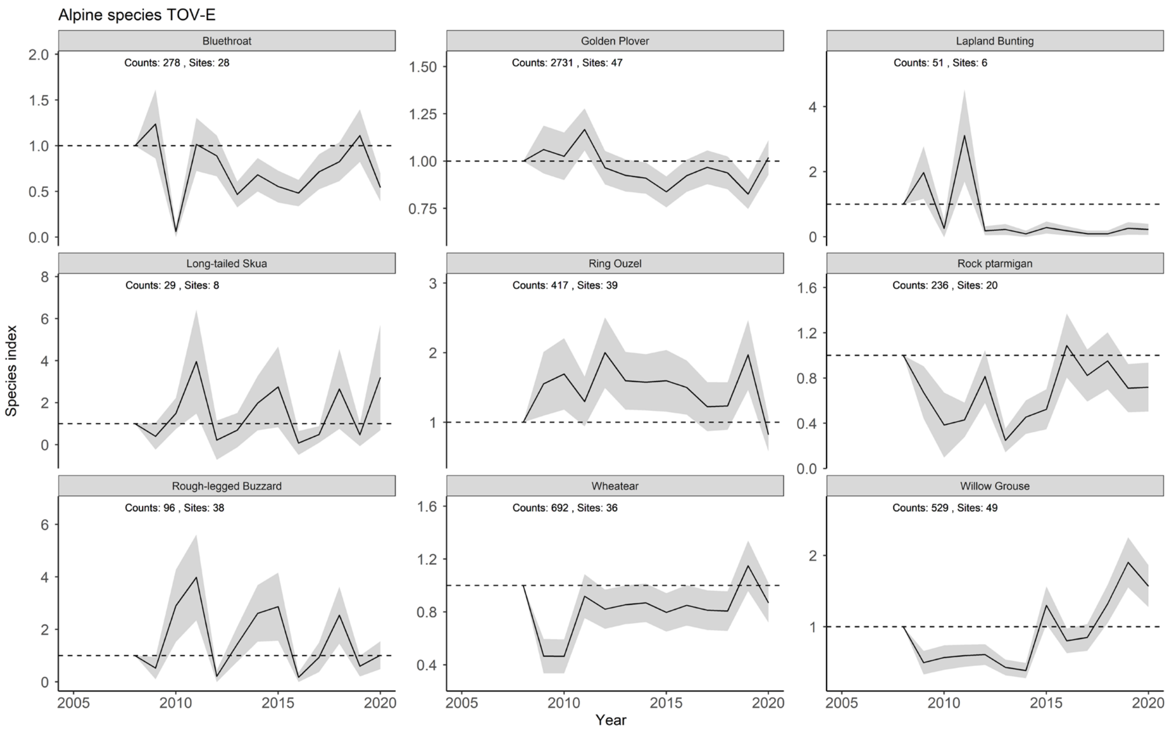

***Figure A.7.1.3**. Annual abundance indices from TOV-E for the individual bird species included in the alpine bird community index.*

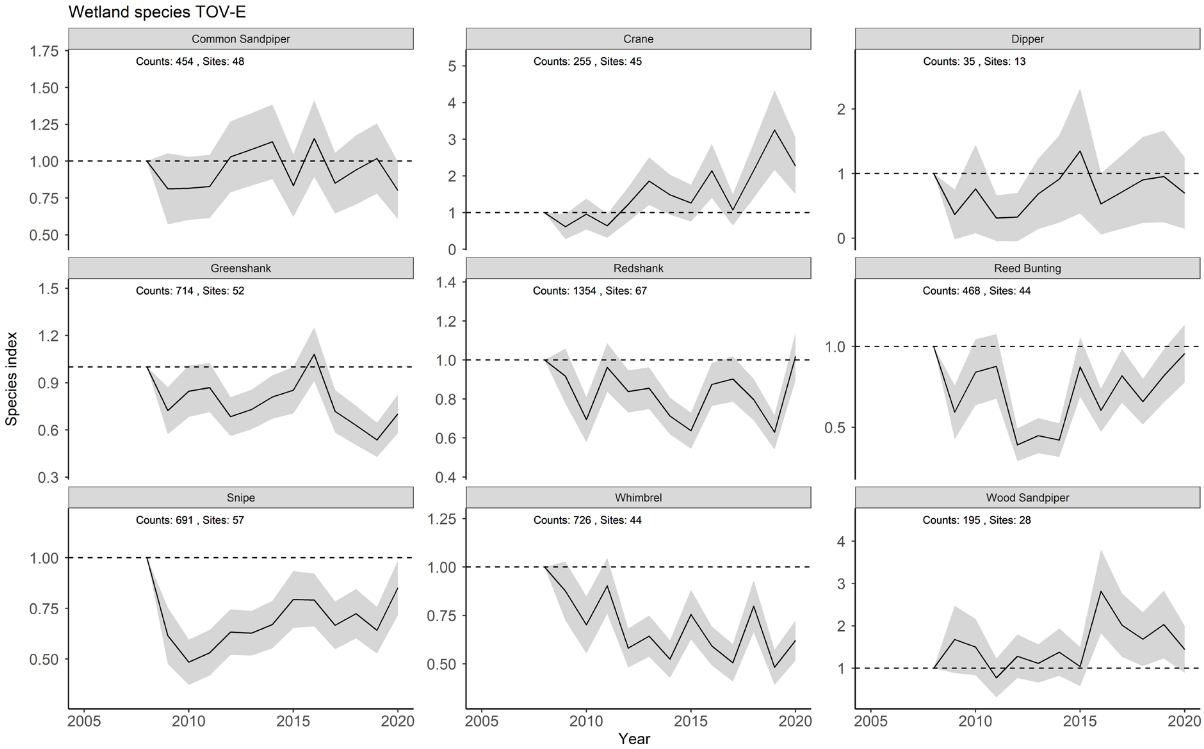

***Figure A.7.1.4**. Annual abundance indices from TOV-E for the individual bird species included in the wetland bird community index.*

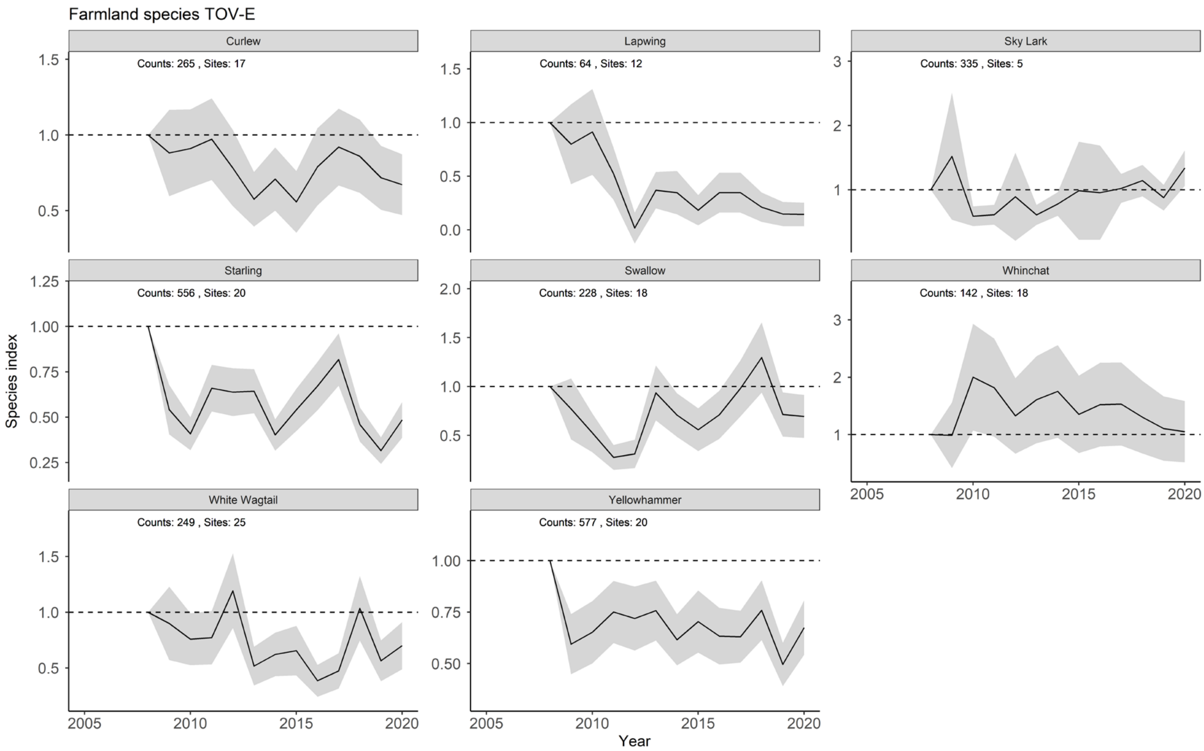

***Figure A.7.1.5**. Annual abundance indices from TOV-E for the individual bird species included in the farmland bird community index for the open lowland ecosystem.*

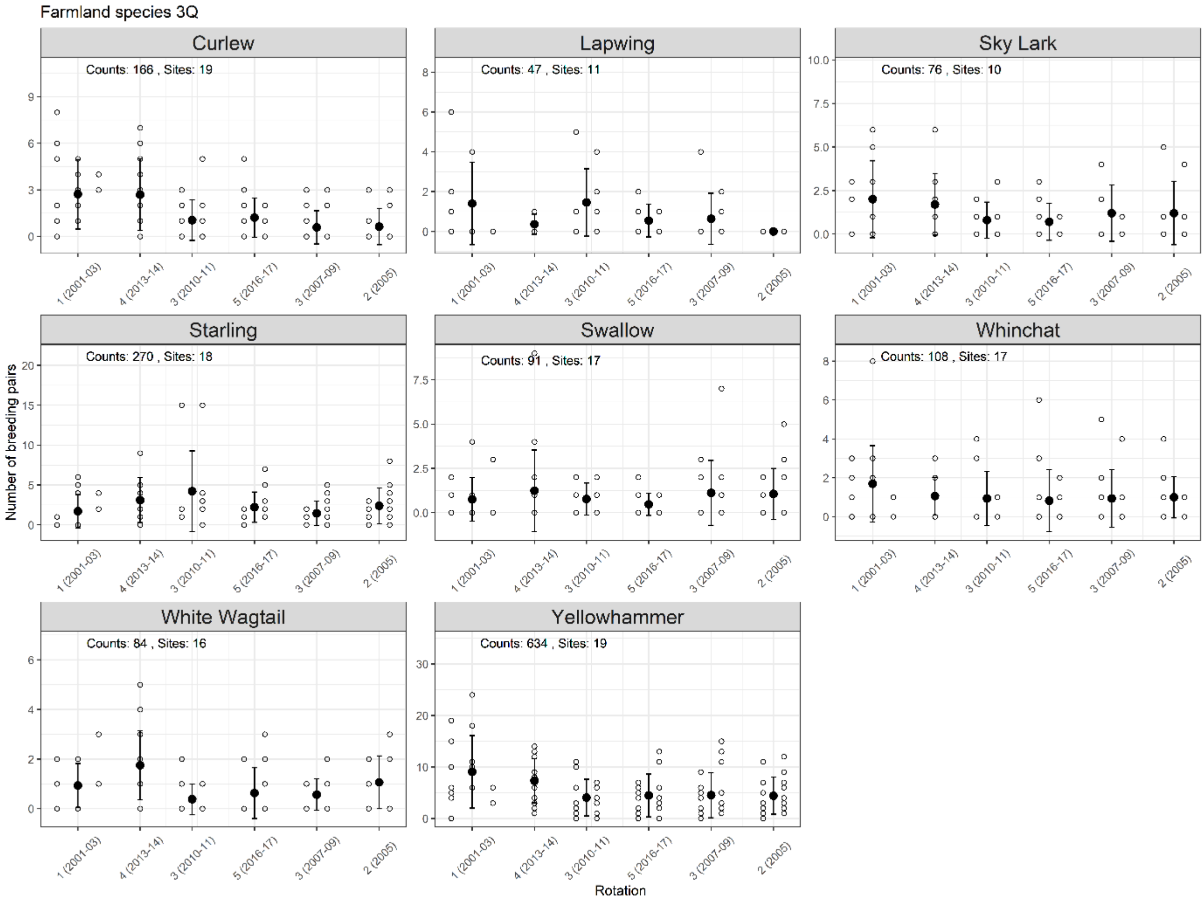

Figure A7.1.2 *Abundances from 3Q for the individual bird species included in the farmland bird community index. Open symbols show the counts per species in individual years for each of the visited sites. Black symbols show the mean ± SD per rotation.*

7.1.5 Recommendations for future development of the indicator

The most important avenue for improvement of this indicator is to remedy the fact that many species in TOV-E have inadequate sample sizes for reliable trend estimates on a county level. TOV-E is a monitoring program where the goal primarily is to deliver trend estimates for common species on a national level (Kålås & Husby 2002). A rule of thumb is that sample sizes in the order of 50 potential sites (i.e. sites where the species could potentially be observed) are required in order to achieve this (Kålås et al. 2014). The total number of sites at which a given species has been observed over an ~10 year period, give a rough approximation of the number of potential sites in the material. Currently TOV-E contain 70 sites in total in Trøndelag. Of the 51 species included here, 11 (21%) have been observed in > 50 sites over the 13 years included here (2008-2020), while 17 (33%) of species have been observed at between 30-49 sites.

7.2 Butterfly abundance and diversity [S15]

Ecosystem characteristic: Biological diversity

7.2.1 Supplementary metadata

Not relevant.

7.2.2 Supplementary methods

The sampling procedure on which this data set is based is the same used for recording observations of bumble-bee densities and richness and are described in Chapter 5.10.2.

7.2.3 Plots of indicator values

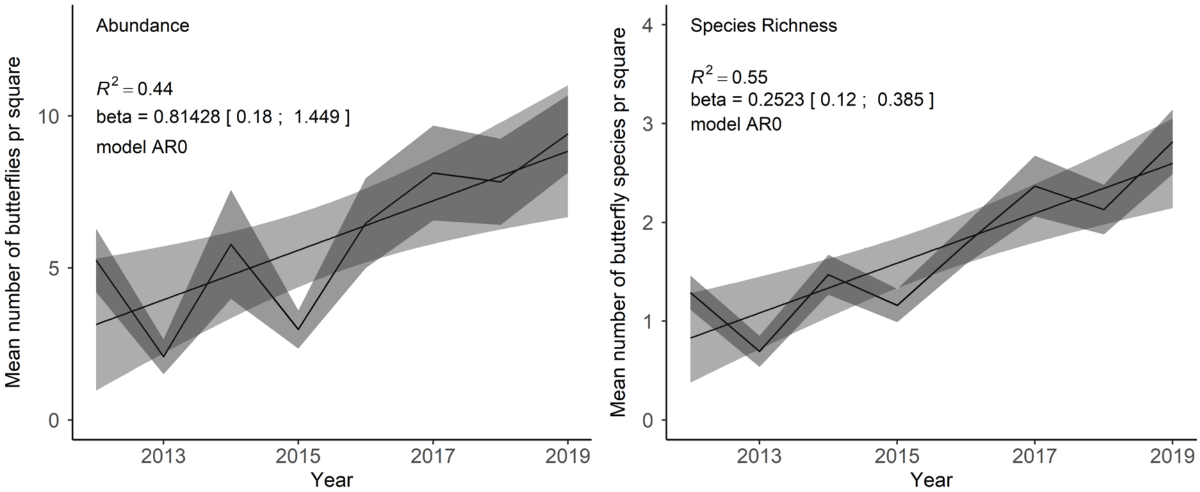

Figure A7.2.1. *Butterfly abundance and species richness. The figure shows mean abundance and species richness of butterflies within 1.5×1.5 km squares in Trøndelag, surveyed along 50m transects. Rates of change are shown ± 2SE.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

7.2.4 Background data and supplementary analysis

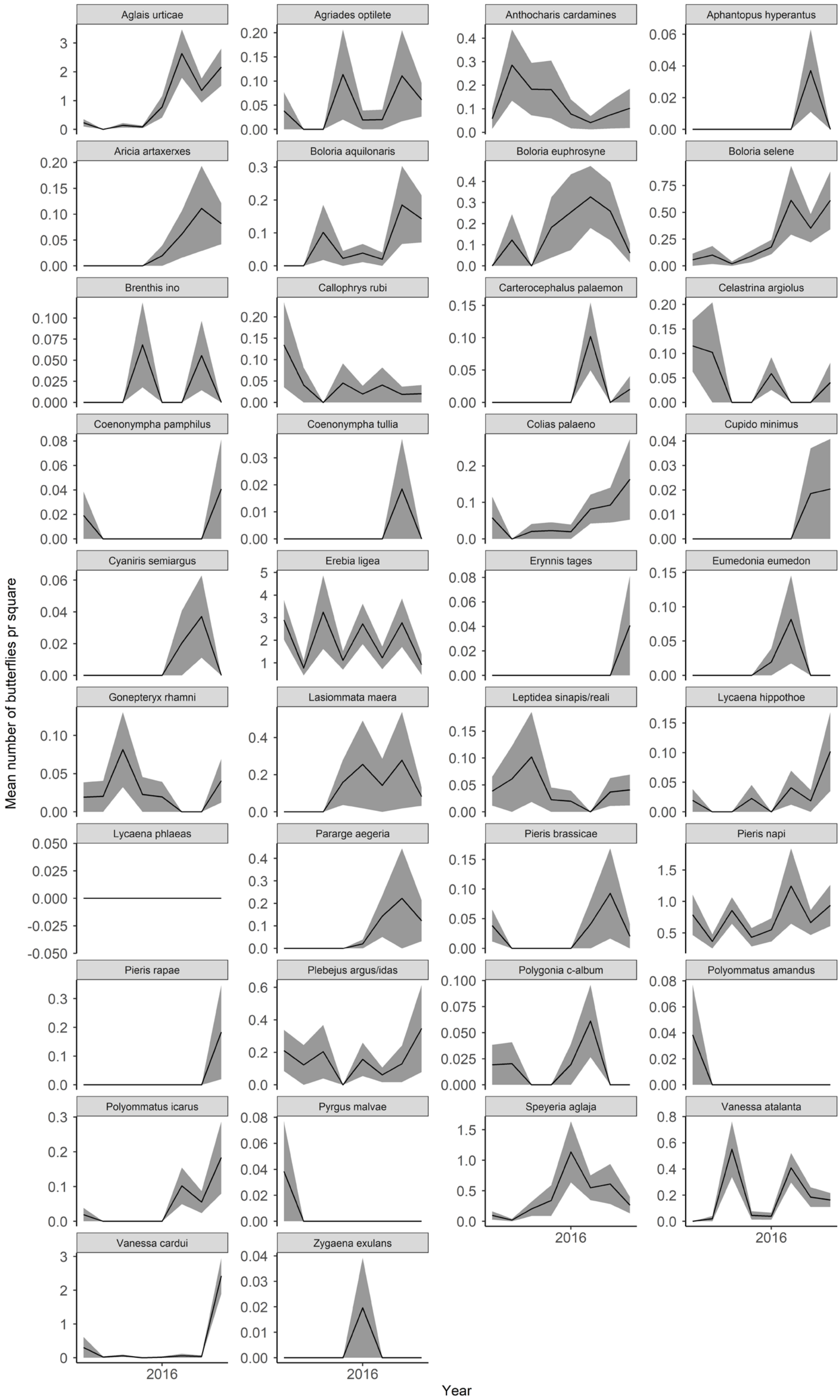

Figure A7.2.2. *Annual abundance of individual species. The figure shows mean abundance of individual butterfly species within 1.5×1.5 km squares in Trøndelag, surveyed along 50m transects. Rates of change are shown ± 2SE.*

7.2.5 Recommendations for future development of the indicator

These indicators are based on the same monitoring program explained in section 5.10.4 for bumblebee species, and the recommendations for future development are in line with those proposed there. This refers mainly with expanding the geographical coverage and representation of the monitoring program to align it with the national insect monitoring (Åström et al. 2019).

7.3 Arctic fox abundance [A19]

Ecosystem characteristic: Biological diversity

7.3.1 Supplementary metadata

Not relevant.

7.3.2 Supplementary methods

The Arctic fox national monitoring program was established in 2003, as part of the species first action plan. Former monitoring initiatives was then gathered to one nationally coordinated program, run by NINA since then. The monitoring program is built up on a combination of systematic controls of known den sites and non-invasive collection of scats for genetic analyses (Hemphill et al. 2020, Eide et al. 2020). Field personnel conduct regular annual visits to active and historic den sites throughout the species distribution in Norway, covering all 16 sub-population from south to north. Statens naturoppsyn (SNO) coordinate the field work, while NINA is responsible for developing the protocol, harmonization between regions and the yearly report. During den visits, observers score den occupancy according to a standardized protocol based on indirect evidence of different tracks/signs, as well as direct observations of adult foxes and their pups; if the den was in use (no, little, or much activity), which species was present (arctic fox, red fox, or wolverine), and an assessment of breeding status (none, presumed occupied, or photographic evidence that a breeding pair produced pups), as well as noting minimum number of pups observed. Starting in 2008, observers have systematically collected fox fecal samples at den sites or near supplemental feeding stations during the winter months of January to May. DNA is extracted from the samples and unique individuals are identified. The methods have developed from 10 microsatellite markers to SNP-genotyping with 96 genetic markers. Based on sampling/resampling of DNA we constructed bimonthly encounter histories for individual foxes and used closed population models to estimate number of foxes separately for each sub-population and region each year.

In this report: Rates of change in all data sets are calculated with AR models as described in the general methods and are shown ±2SE. The most suitable model based on AIC is indicated on each individual diagram.

7.3.3 Plots of indicator values

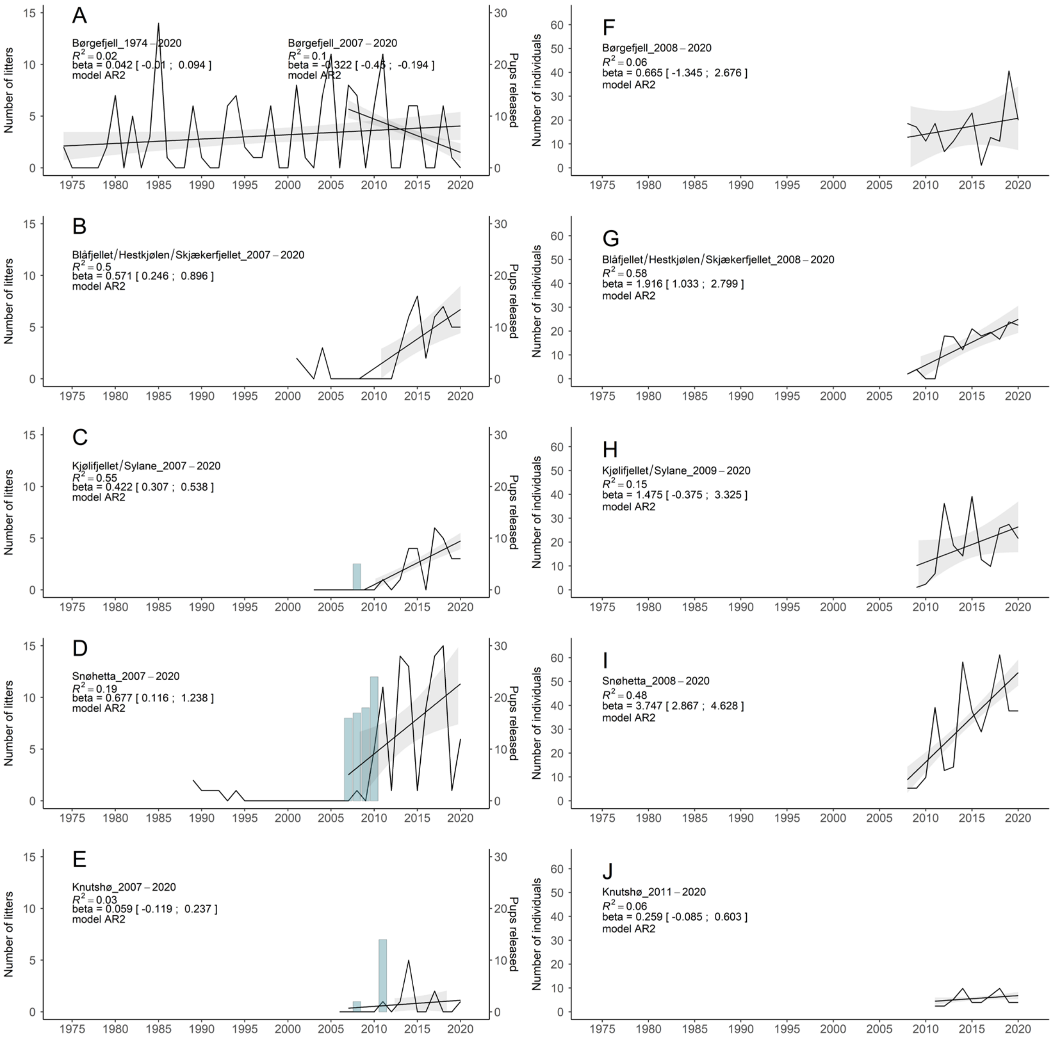

Figure A7.3.1 *Number of Arctic fox dens with litters for each alpine area (A-E, full lines), the number of cubs released (C-E, blue bars) and the estimated number of Arctic fox individuals from a population model (F-J). The areas are subject to different management interventions; Børgefjell (Control, no management, A and F), Blåfjellet/Hestkjølen/Skjækerfjellet and Kjølifjellet/Sylane (Supplementary feeding, a single release, B-C and G-H), Snøhetta and Knutshø (Supplementary feeding and captive breeding and release, D-E and I-J). A-E: The fluctuating lines show the total number of litters per area and the solid regression line the estimated rate of rate ±2SE (shaded area) in the number of litters across the years 2007-2020. 2007 represent the beginning of the first management interventions and prior to this the populations were functionally extinct except for Børgefjell (A).*

7.3.4 Background data and supplementary analysis

Not relevant.

7.3.5 Recommendations for future development of the indicator

This indicator is considered appropriately formulated.

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

7.4 Arctic fox litter size [A20]

Ecosystem characteristic: Biological diversity

7.4.1 Supplementary metadata

Not relevant.

7.4.2 Supplementary methods

Monitored as part of the national monitoring program, see description in 7.3.2.

7.4.3 Plots of indicator values

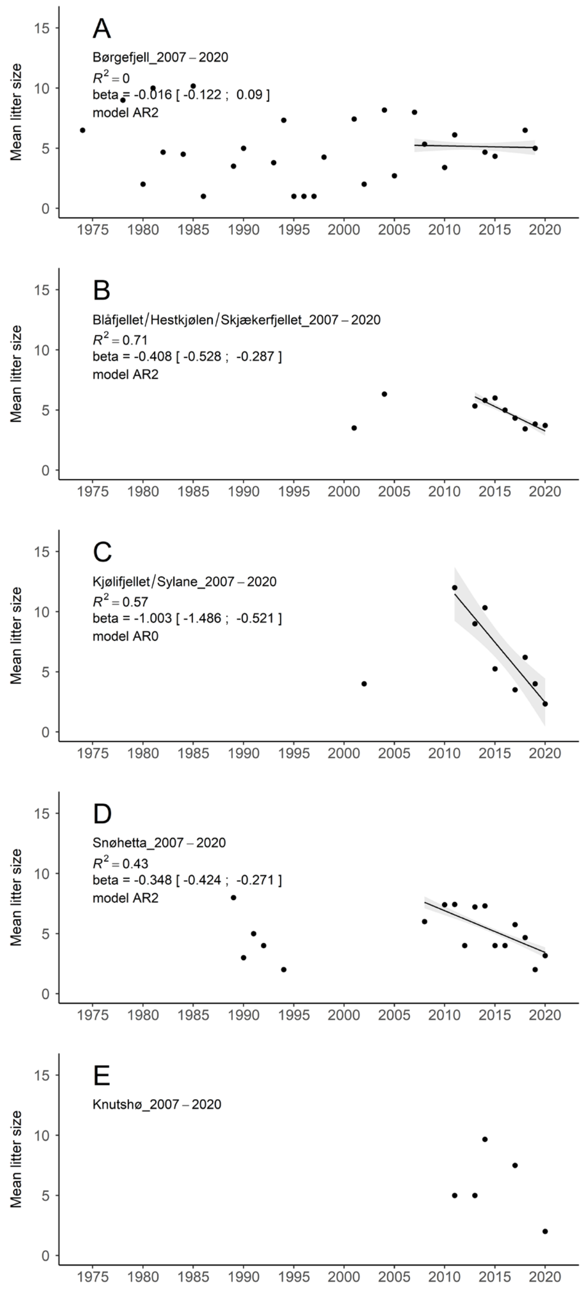

Figure A7.4.1 *Minimum estimates of Arctic fox litter size for each alpine area. The areas are subject to different management interventions; Børgefjell (Control, no management, A), Blåfjellet/Hestkjølen/Skjækerfjellet and Kjølifjellet/Sylane (Supplementary feeding, a single release, B-C), Snøhetta and Knutshø (Supplementary feeding and captive breeding and release, D-E). The dots show the mean number of cubs per litter across all known litters in a given year. The solid line indicates the estimated rate of rate ±2SE (shaded area) in average litter size across the years 2007-2020. 2007 represent the beginning of the first management interventions (see indicator Arctic fox abundance), and prior to this the populations were functionally extinct except for Børgefjell (A).*

7.4.4 Background data and supplementary analysis

Not relevant.

7.4.5 Recommendations for future development of the indicator

This indicator is appropriately formulated. However, following the protocol describing the monitoring program, litter size is not part of mandatory registrations at den controls, meaning that all estimates must be considered as minimum estimates. To increase the value of the monitoring program we suggest that more precise estimates of litter size are included in the protocol, in particular given the clear decrease in minimum litter size observed. Non-invasive techniques based on camera traps at breeding dens are available and implemented in several monitoring regions in Norway.

8 Indicators for *Abiotic factors*

8.1 Annual mean temperature [F01, A01, W01, S01]

Ecosystem characteristic: Abiotic factors

8.1.1 Supplementary metadata

Not relevant.

8.1.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.1.3 Plots of indicator values

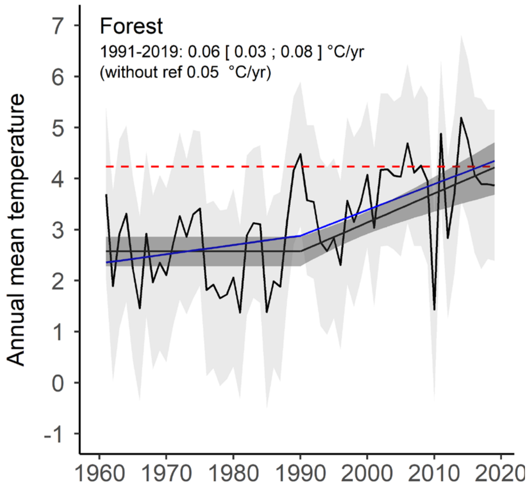

***Figure A8.1.1**. Annual mean temperature (±1SD) for forest during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

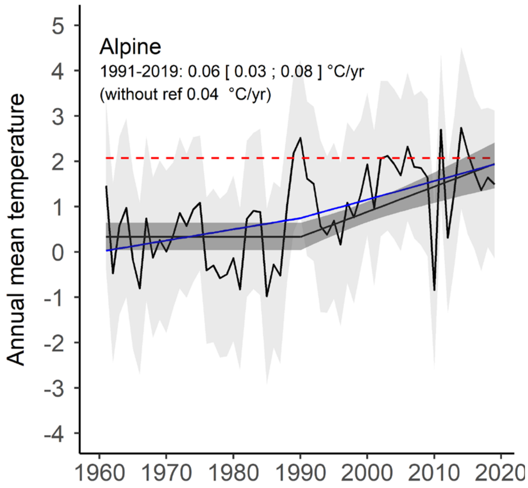

Figure A8.1.2. *Annual mean temperature (±1SD) for alpine during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

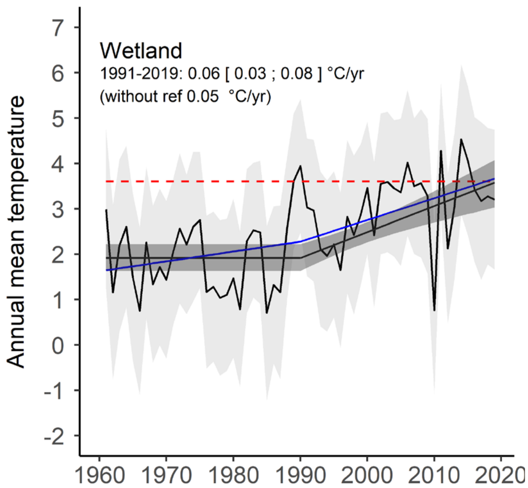

Figure A8.1.3. *Annual mean temperature (±1SD) for wetland during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

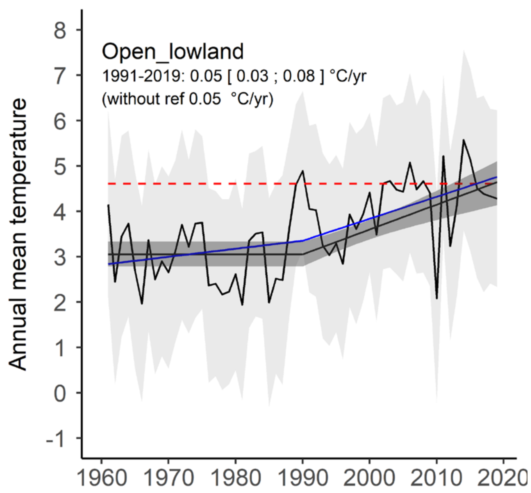

Figure A8.1.4. *Annual mean temperature (±1SD) for open lowland during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

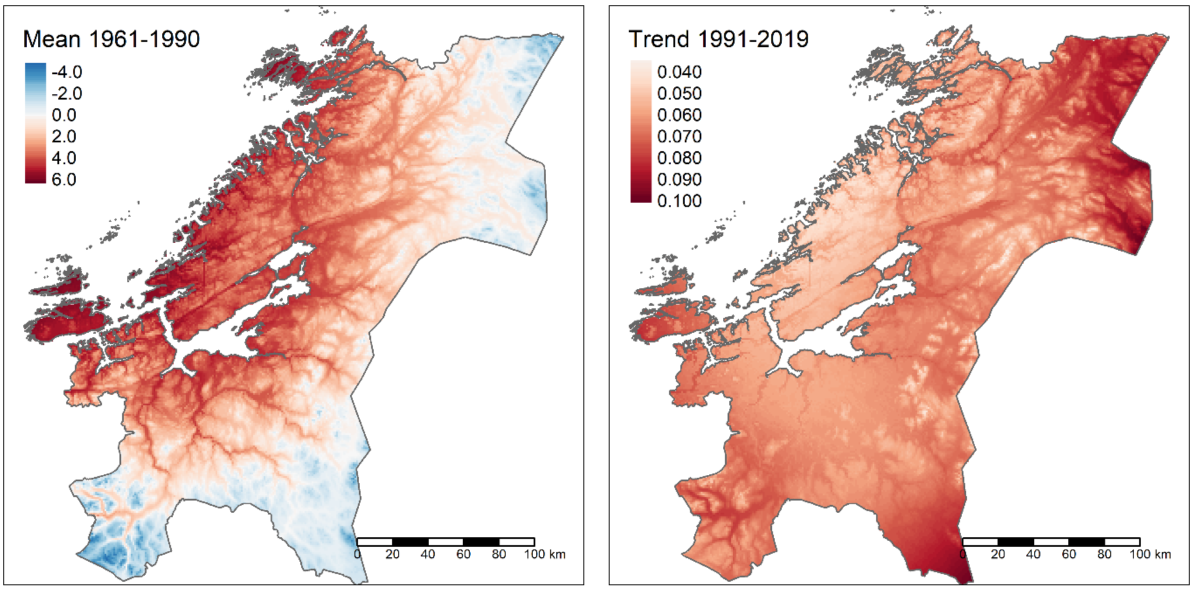

Figure A8.1.5 *The spatial distribution of the annual mean temperature for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (°C/yr) from a linear model during the subsequent years (1991–2019; right).*

8.1.4 Background data and supplementary analysis

Not relevant.

8.1.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.2 January mean temperature [F02, A02, W02, S02]

Ecosystem characteristic: Abiotic factors

8.2.1 Supplementary metadata

Not relevant.

8.2.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.2.3 Plots of indicator values

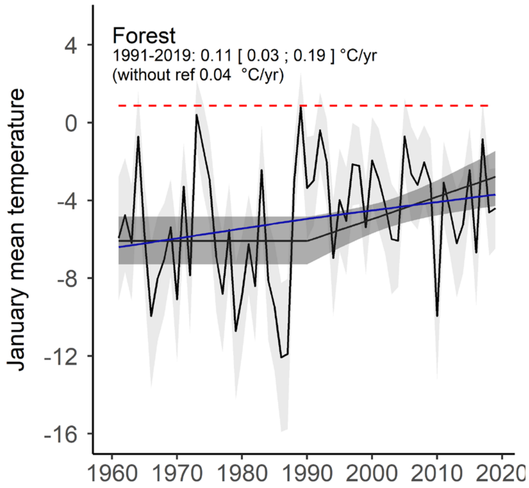

Figure A8.2.1. *Annual January temperature (±1SD) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The ed dashed line indicates the 2SD of the variation observed during the climatic reference period.*

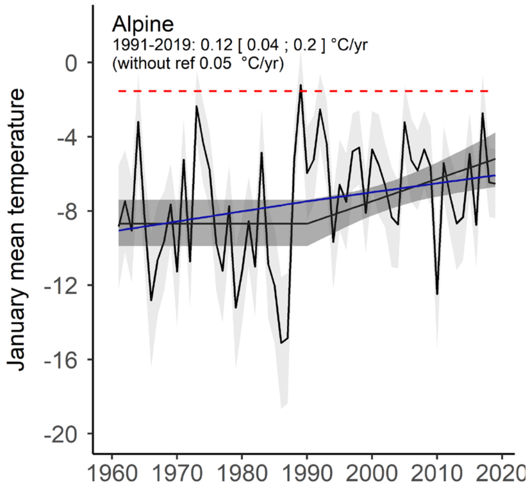

Figure A8.2.2. *Annual January temperature (±1SD) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.

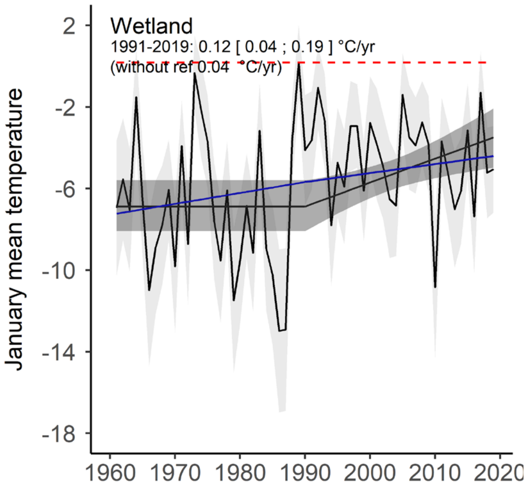

Figure A8.2.3. *Annual January temperature (±1SD) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

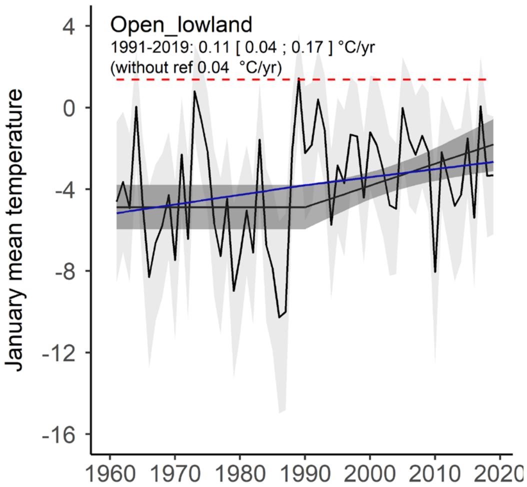

Figure A8.2.4. *Annual January temperature (±1SD) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

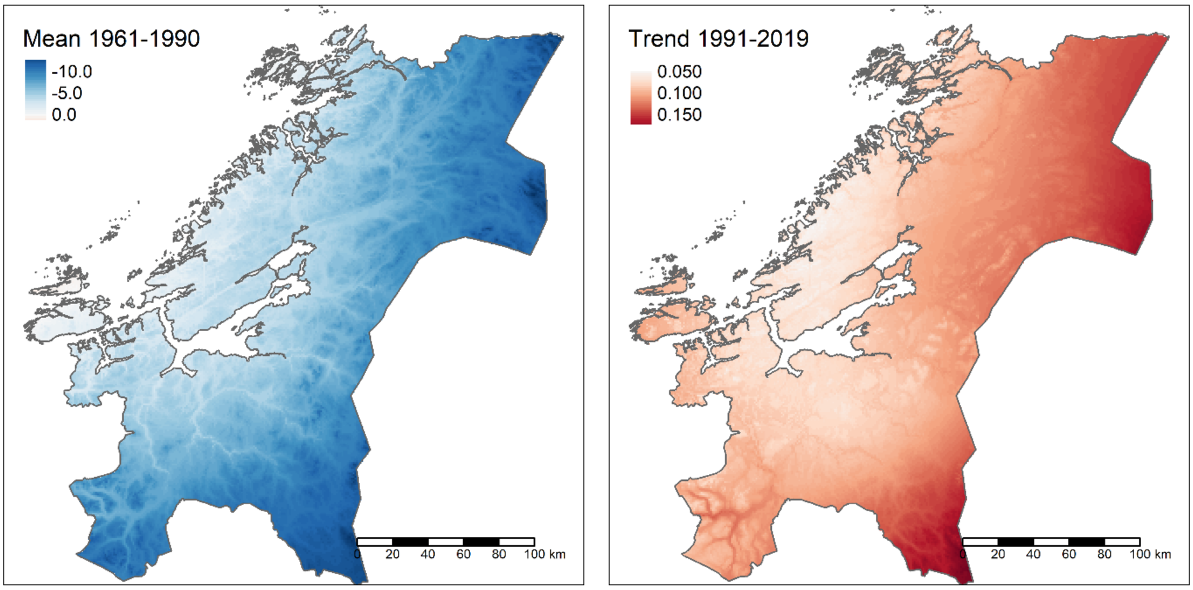

Figure A8.2.5 *The spatial distribution of the January mean temperature for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (°C/yr) from a linear model during the subsequent years (1991–2019; right).*

8.2.4 Background data and supplementary analysis

Not relevant.

8.2.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty must the weather station coverage in mountain regions continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.3 July mean temperature [F03, A03, W03, S03]

Ecosystem characteristic: Abiotic factors

8.3.1 Supplementary metadata

Not relevant.

8.3.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.3.3 Plots of indicator values

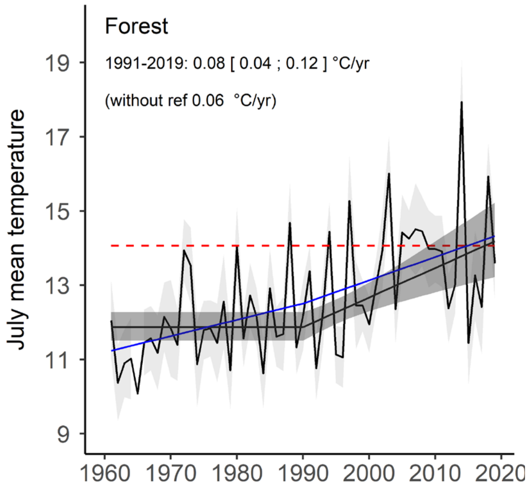

Figure A8.3.1. *Annual July temperature (±1SD) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

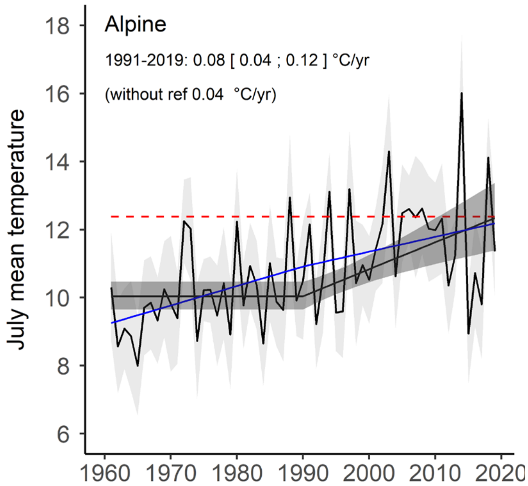

Figure A8.3.2. *Annual July temperature (±1SD) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is* *assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

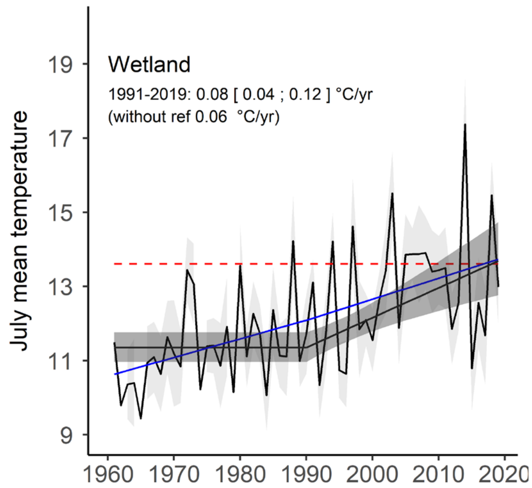

Figure A8.3.3. *Annual July temperature (±1SD) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

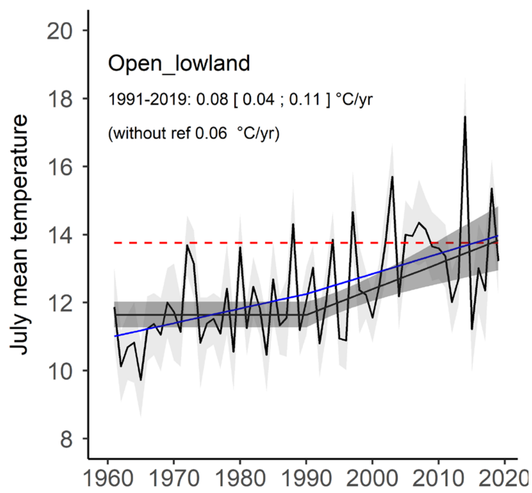

Figure A8.3.4. *Annual July temperature (±1SD) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. Red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

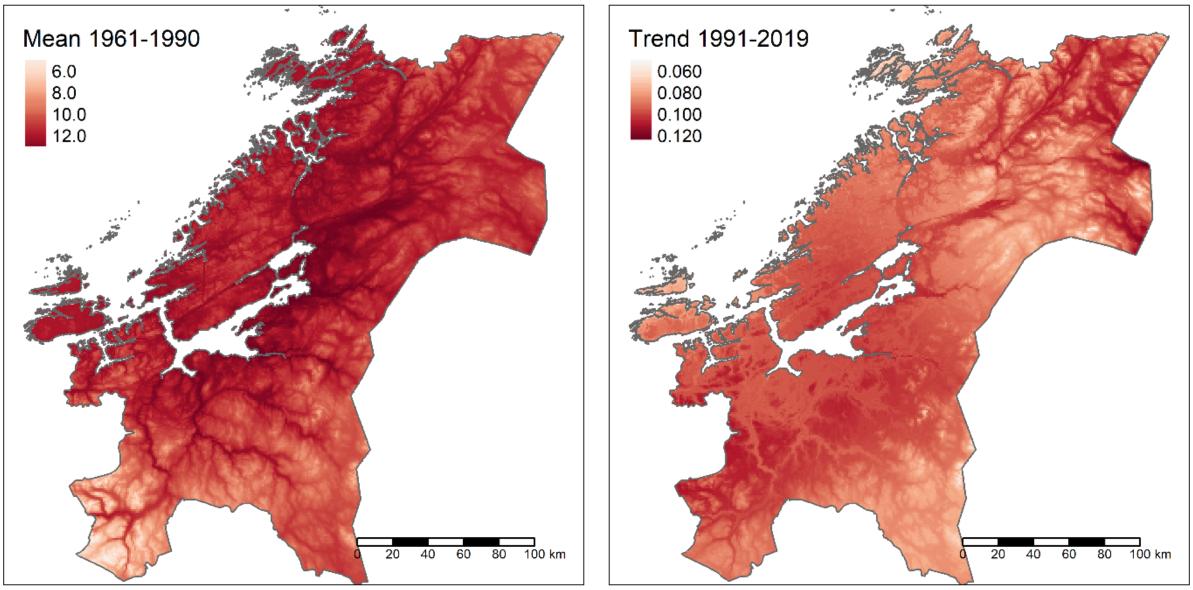

Figure A8.3.5 *The spatial distribution of the July mean temperature for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (°C/yr) from a linear model during the subsequent years (1991–2019; right).*

8.3.4 Background data and supplementary analysis

Not relevant.

8.3.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty must the weather station coverage in mountain regions continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.4 Winter days above zero [F04, A04, W04, S04]

Ecosystem characteristic: Abiotic factors

8.4.1 Supplementary metadata

Not relevant.

8.4.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.4.3 Plots of indicator values

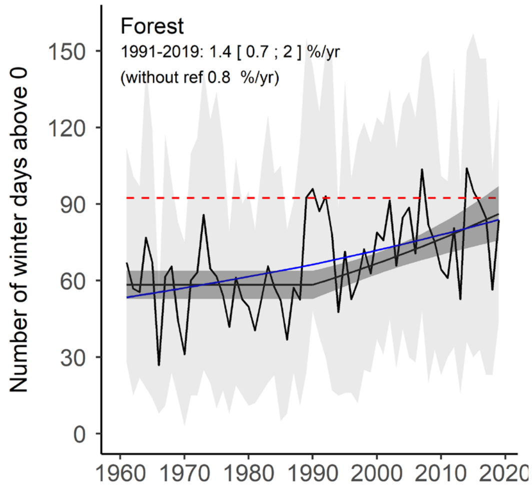

Figure A8.4.1. *The number of winter days above 0°C (±1SD) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

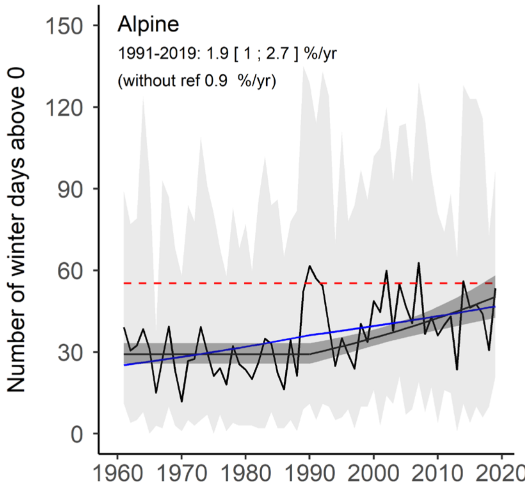

Figure A8.4.2. *The number of winter days above 0°C (±1SD) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.

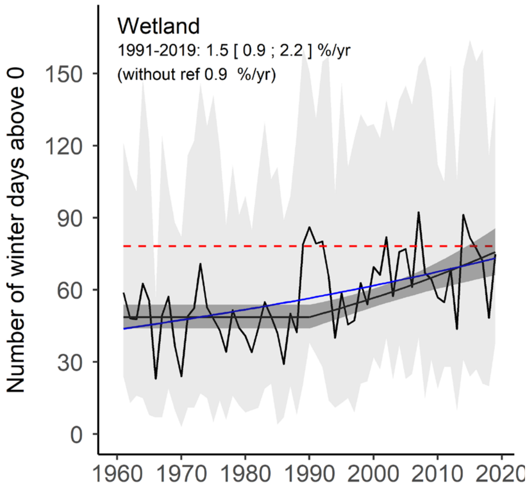

Figure A8.4.3. *The number of winter days above 0°C (±1SD) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

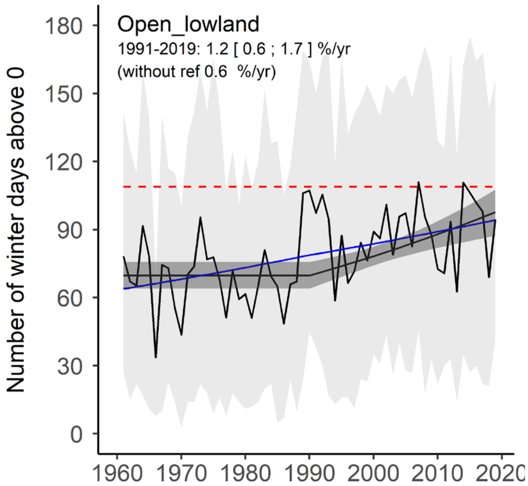

Figure A8.4.4. *The number of winter days above 0°C (±1SD) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

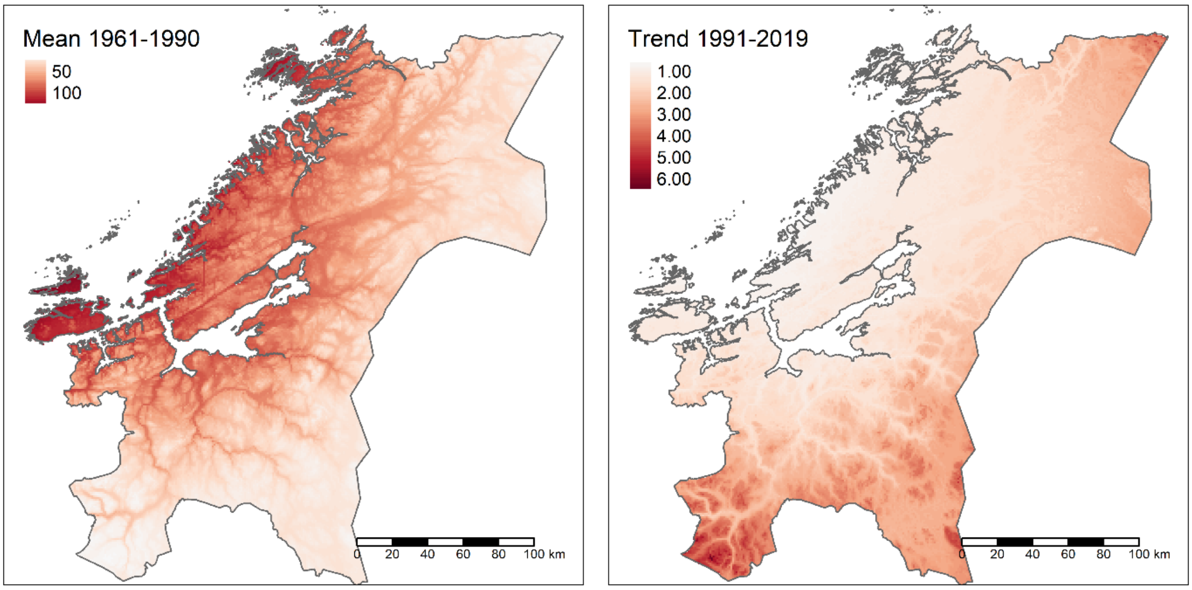

Figure A8.4.5 *The spatial distribution of the number of winter days above 0°C for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (%/yr) from a generalized linear model during the subsequent years (1991–2019; right).*

8.4.4 Background data and supplementary analysis

Not relevant.

8.4.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

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8.5 Degree days [F05, A05, W05, S05]

Ecosystem characteristic: Abiotic factors

8.5.1 Supplementary metadata

Not relevant.

8.5.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.5.3 Plots of indicator values

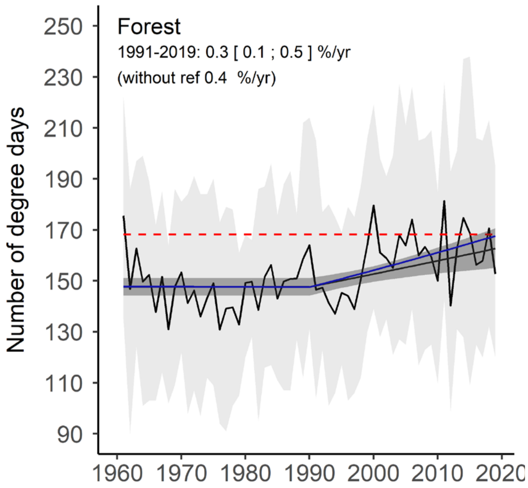


Figure A8.5.1. *The number of degree days (days with daily mean temperature > 5°C) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

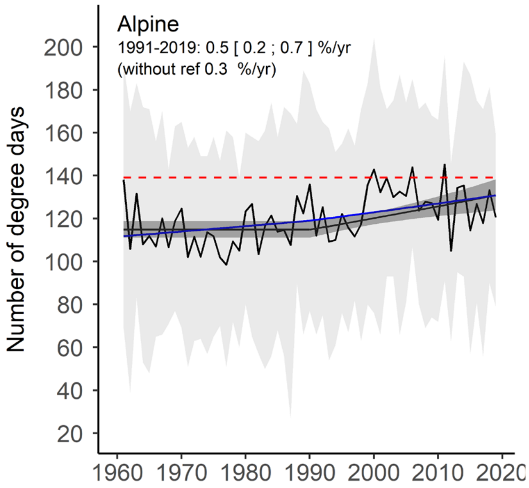


Figure A8.5.2. *The number of degree days (days with daily mean temperature > 5°C) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

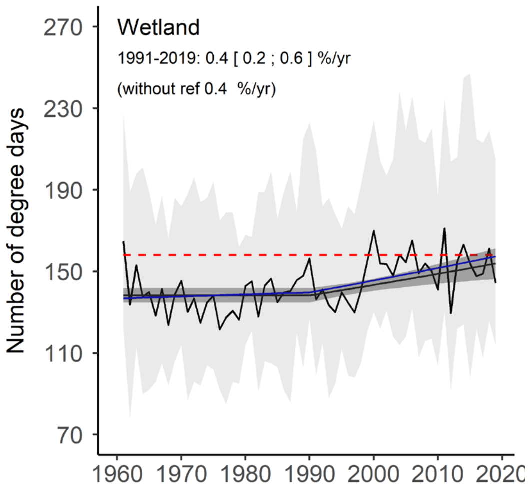


Figure A8.5.3. *The number of degree days (days with daily mean temperature > 5°C) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

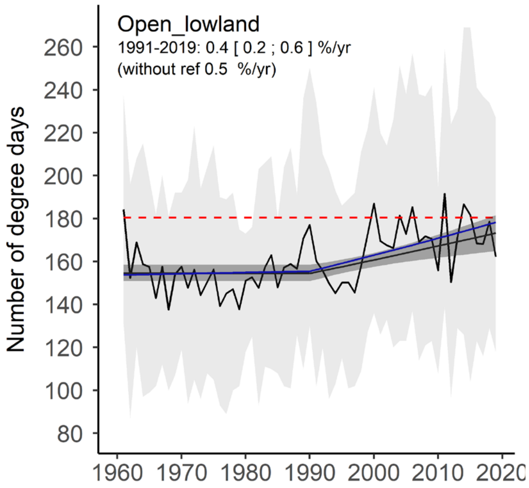


Figure A8.5.4. *The number of degree days (days with daily mean temperature > 5°C) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

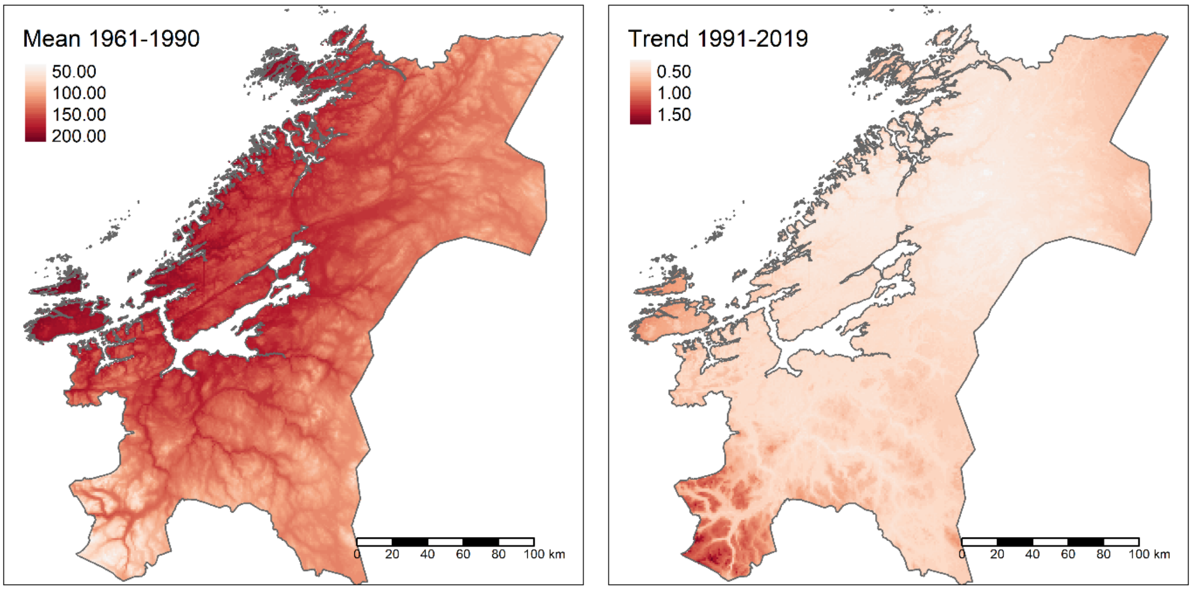


Figure A8.5.5 *The spatial distribution of degree days (days with daily mean temperature > 5°C) for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (%/yr) from a generalized linear model during the subsequent years (1991–2019; right).*

8.5.4 Background data and supplementary analysis

Not relevant.

8.5.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.6 Growing degree days [F06, A06, W06, S06]

Ecosystem characteristic: Abiotic factors

8.6.1 Supplementary metadata

8.6.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.6.3 Plots of indicator values

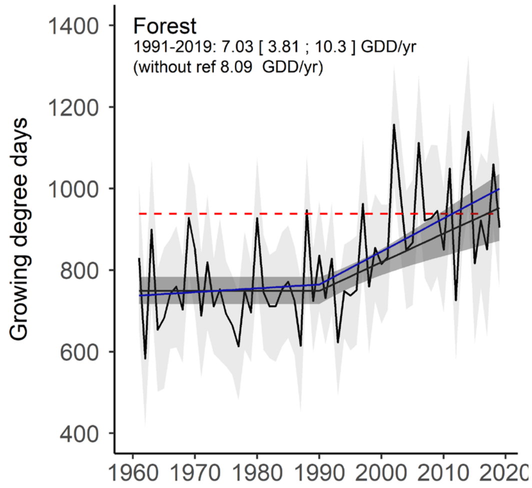
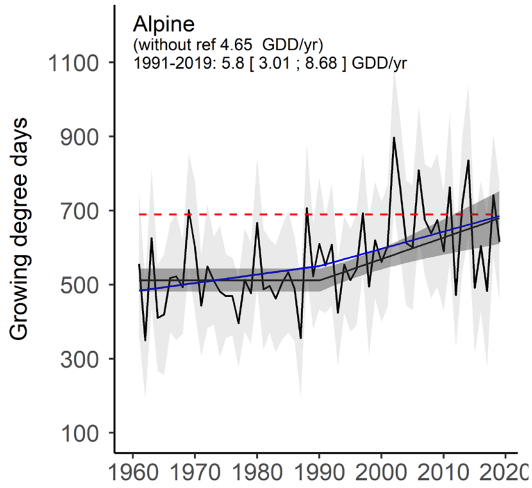


Figure A8.6.1. *Growing degree days (sum of daily mean temperatures > 5°C, May-Oct) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*



Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

Figure A8.6.2. *Growing degree days (sum of daily mean temperatures > 5°C, May-Oct) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

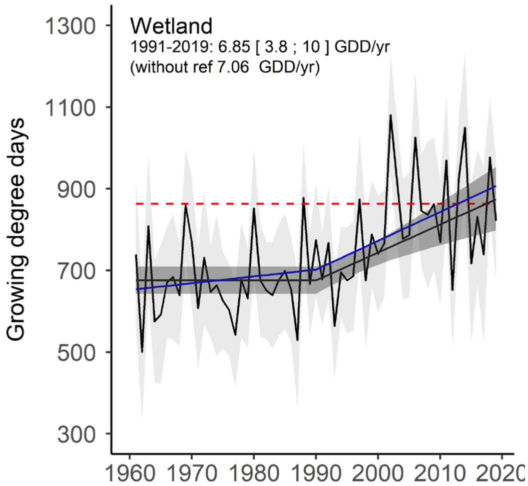


Figure A8.6.3. *Growing degree days (sum of daily mean temperatures > 5°C, May-Oct) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

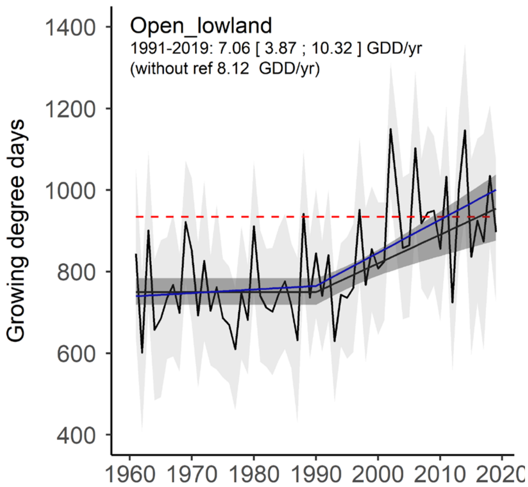


Figure A8.6.4. *Growing degree days (sum of daily mean temperatures > 5°C, May-Oct) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is NOT assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the*

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period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.

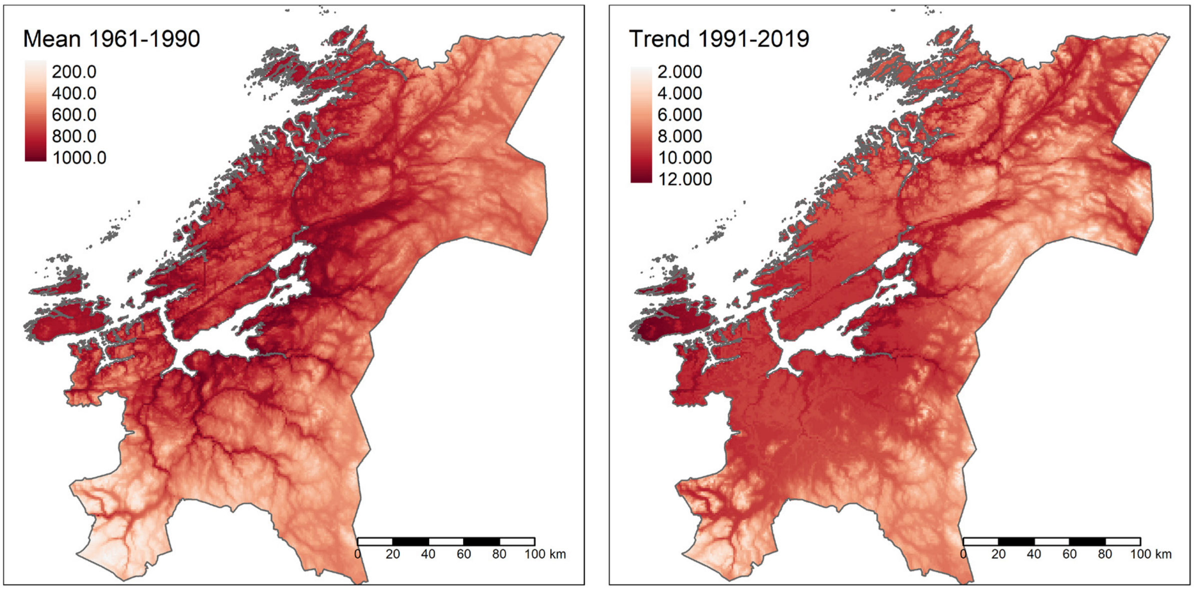

***Figure A8.6.5** The spatial distribution of growing degree days (sum of daily mean temperatures > 5°C, May-Oct) for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (°C/yr) from a linear model during the subsequent years (1991–2019; right).*

8.6.4 Background data and supplementary analysis

Not relevant.

8.6.5 Recommendations for future development of the indicator

This indicator is based on gridded temperature data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.7 Annual precipitation [F07, A07, W07, S07]

Ecosystem characteristic: Abiotic factors

8.7.1 Supplementary metadata

8.7.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.7.3 Plots of indicator values

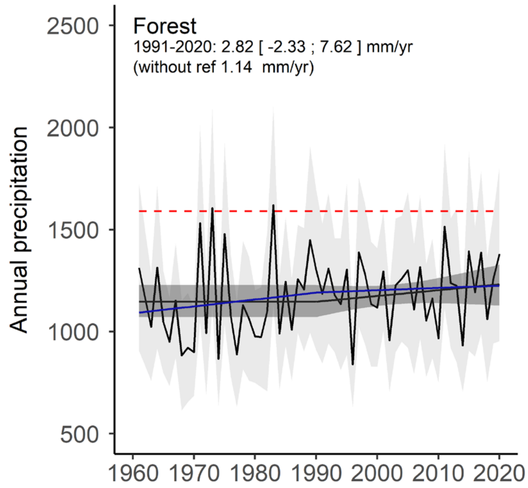

Figure A8.7.1. *Annual precipitation in mm (±1SD) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

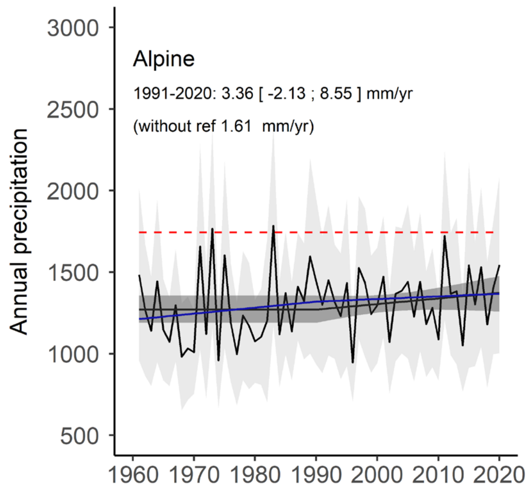

Figure A8.7.2. *Annual precipitation in mm (±1SD) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic*

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reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

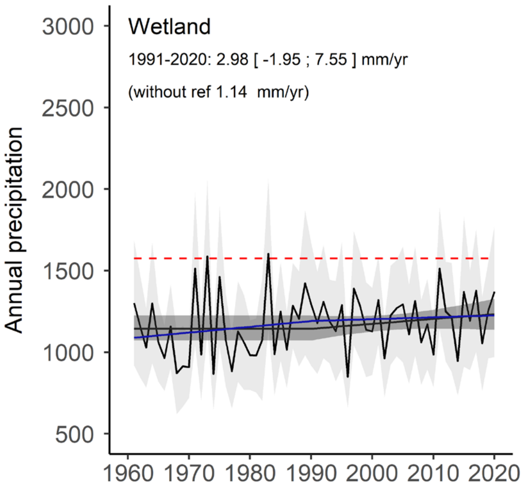


***Figure A8.7.3.** Annual precipitation in mm (±1SD) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

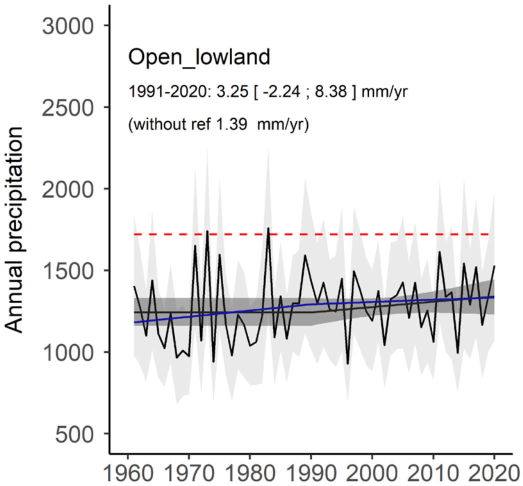


***Figure A8.7.4.** Annual precipitation in mm (±1SD) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

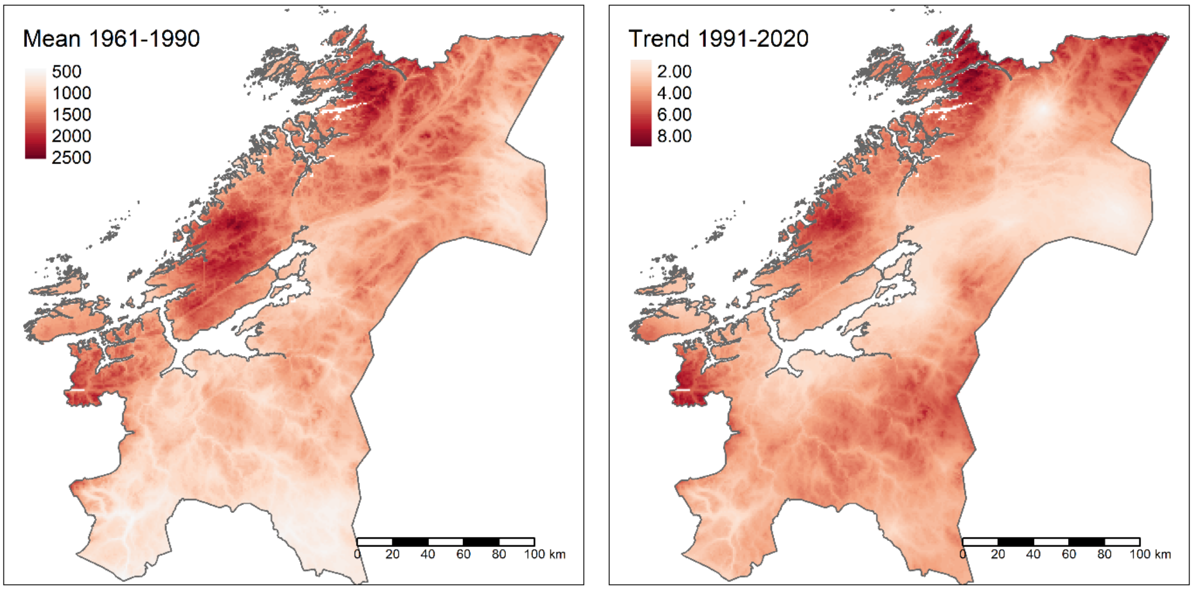


Figure A8.7.5 *The spatial distribution of the total annual precipitation for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (mm/yr) from a linear model during the subsequent years (1991–2019; right).*

8.7.4 Background data and supplementary analysis

Not relevant.

8.7.5 Recommendations for future development of the indicator

This indicator is based on gridded precipitation data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.8 Growing season precipitation [F08, A08, W08, S08]

Ecosystem characteristic: Abiotic factors

8.8.1 Supplementary metadata

8.8.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.8.3 Plots of indicator values

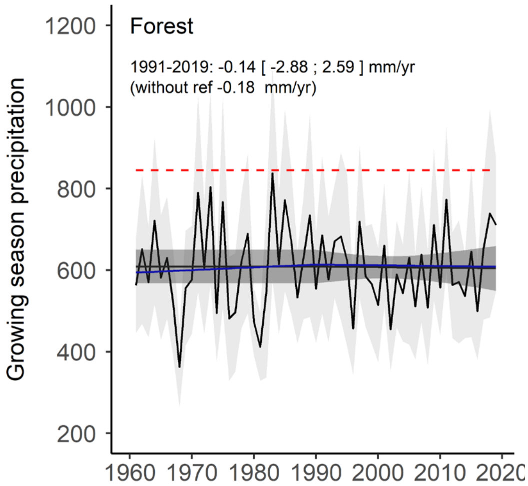
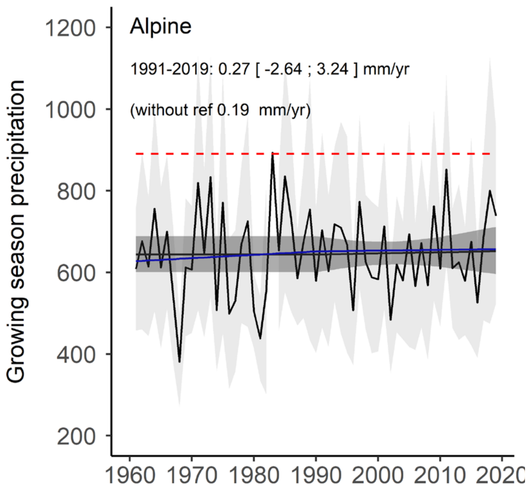


Figure A8.8.1. *Precipitation in mm (±1SD) during the growing season (May-Oct) for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*



Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

Figure A8.8.2. *Precipitation in mm (±1SD) during the growing season (May-Oct) for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

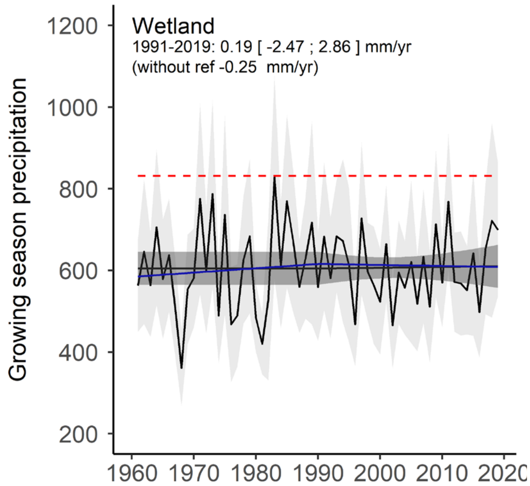


Figure A8.8.3. *Precipitation in mm (±1SD) during the growing season (May-Oct) for wetland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

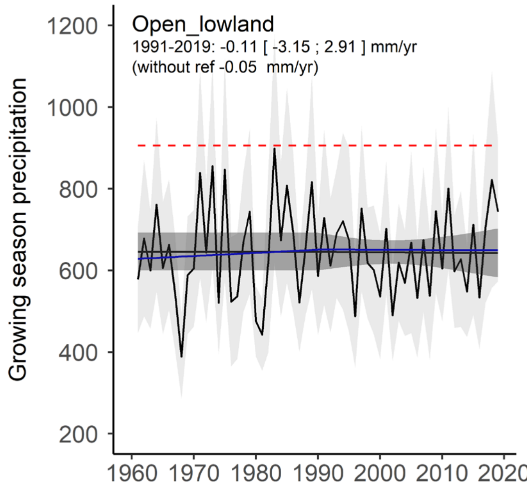


Figure A8.8.4. *Precipitation in mm (±1SD) during the growing season (May-Oct) for open lowland ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

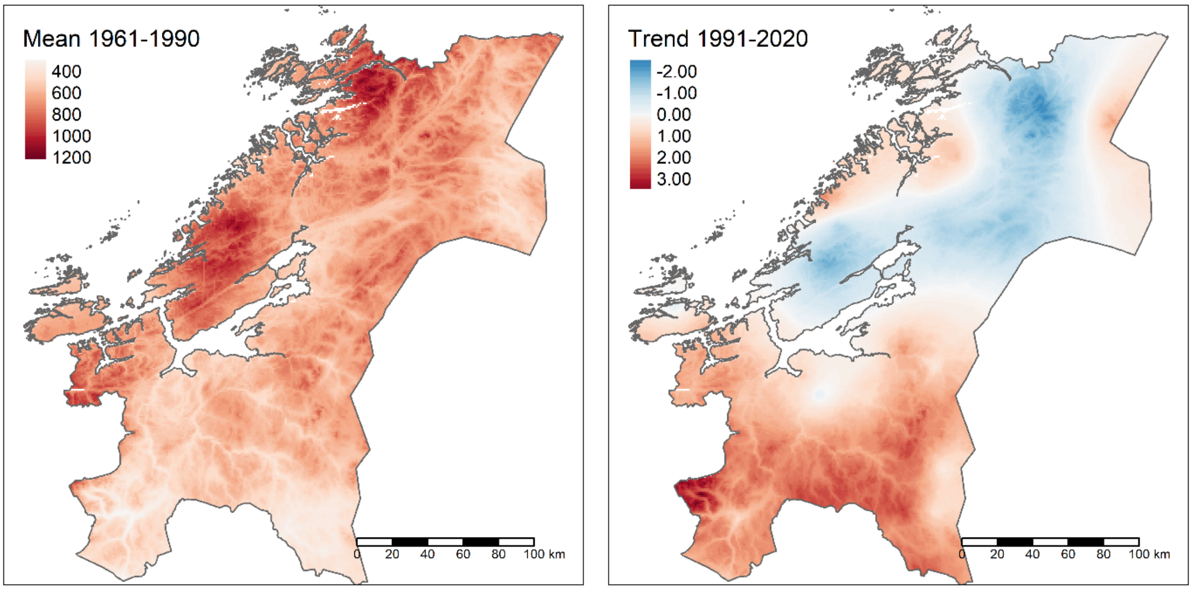


Figure A8.8.5 *The spatial distribution of the total precipitation during the growing season (May-Oct) for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (mm/yr) from a linear model during the subsequent years (1991–2019; right).*

8.8.4 Background data and supplementary analysis

Not relevant.

8.8.5 Recommendations for future development of the indicator

This indicator is based on gridded precipitation data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

8.9 Snow cover duration [F09, A09, W09, S09]

Ecosystem characteristic: Abiotic factors

8.9.1 Supplementary metadata

Not relevant.

8.9.2 Supplementary methods

Rates of change for all gridded climate data are calculated with linear models as described in the general methods.

8.9.3 Plots of indicator values

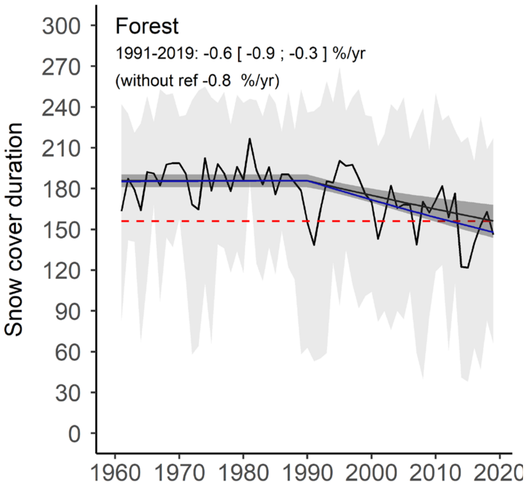
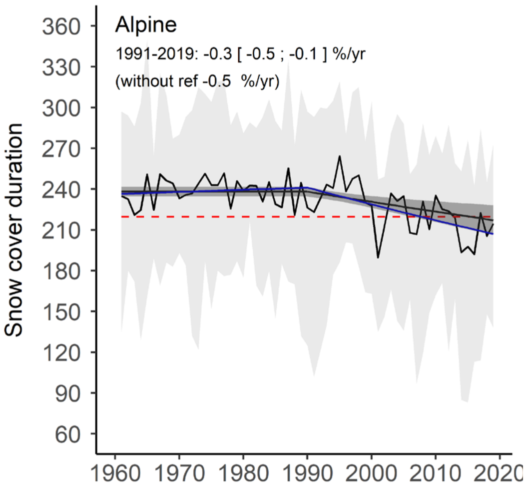


Figure A8.9.1. *Snow cover duration (days) per year for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*



Jepsen, J.U., Speed, J.D.M., Austrheim, G., Rusch, G., Petersen, T.K., Asplund, J., Bjerke, J.W., Bjune, A.E., Eide, N.E., Herfindal, I., Ims, R.A., Israelsen, M.F., Kapfer, J., Kolstad, A.L., Nordén, J., Sandercock, B., Stien, J., Tveito, O.E., Yoccoz, N.G. 2022. Panel-based Assessment of Ecosystem Condition – a methodological pilot for four terrestrial ecosystems in Trøndelag. NINA Report 2094. Norwegian Institute for Nature Research.

Figure A8.9.2. *Snow cover duration (days) per year for alpine ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

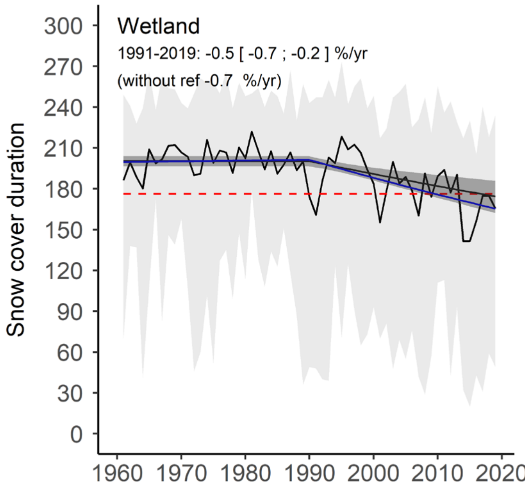


Figure A8.9.3. *Snow cover duration (days) per year for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

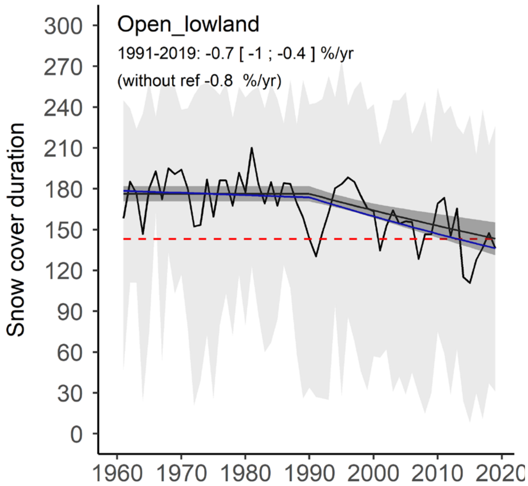


Figure A8.9.4. *Snow cover duration (days) per year for forest ecosystems in Trøndelag during and after the climatic reference period (1961–1990). The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

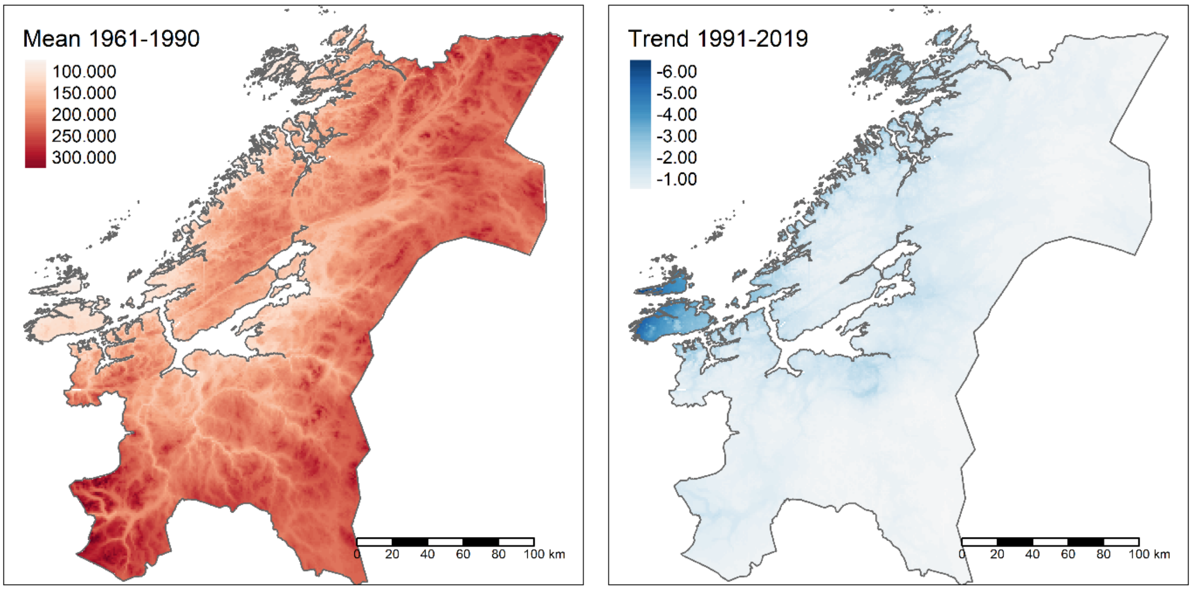


Figure A8.9.5 *The spatial distribution of the snow cover duration (days) for Trøndelag during the climatic reference period (1961–1990; left), and the rates of change (%/yr) from a generalized linear model during the subsequent years (1991–2019; right).*

8.9.4 Background data and supplementary analysis

Not relevant.

8.9.5 Recommendations for future development of the indicator

This indicator is based on gridded climate data, and although these data are extensive in time and space, they are not observations, but model-based estimates based on data from weather stations. The quality is thus dependent on the spatial density and representativity of the weather stations. Weather station coverage is lower in inland and alpine areas than in lowland and coastal areas, which implies greater uncertainty in the model calculations. In order to reduce the uncertainty, the weather station coverage in mountain regions must continue to increase. Ongoing weather and climate model developments will also lead to more precise estimates.

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8.10 Soil water content during growing season [W14]

Ecosystem characteristic: Abiotic factors

8.10.1 Supplementary metadata

Not relevant.

8.10.2 Supplementary methods

Rates of change for all gridded hydrological data are calculated with linear models as described in the general methods.

8.10.3 Plots of indicator values

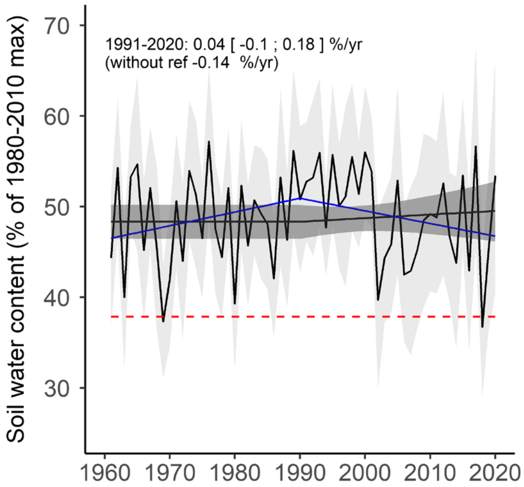

Figure A8.10.1. *The mean soil water content (±SD) during and after the climatic reference period (1961–1990) for wetland ecosystems in Trøndelag. The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

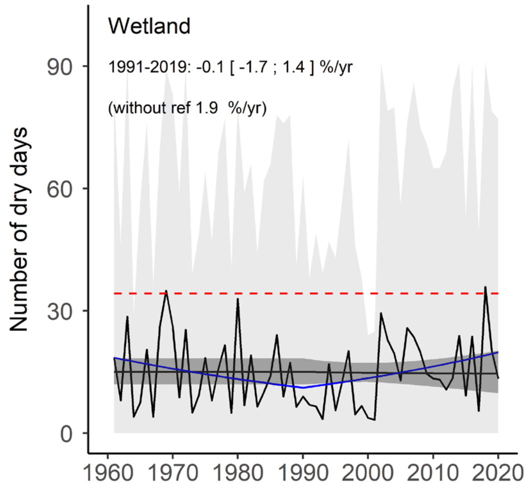

Figure A8.10.2 *The mean number of days during summer (June-August) where the average soil water content is below 40% (e.g. 'dry days') during and after the climatic reference period (1961–1990) for wetland ecosystems in Trøndelag.The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

8.10.4 Background data and supplementary analysis

Not relevant.

8.10.5 Recommendations for future development of the indicator

The indicator is based on a gridded water balance model applying gridded weather data as input. The parameterisation of soil and land use characteristics is very general, and does represent local conditions in detail. Although these data are extensive in time and space, they are purely modelled estimates not based on direct observations of the phenomena. Observations of the phenomena are few. Increased monitoring and more detailed data of soil and land-use characteristics are needed to develop models providing more precise and robust estimates.

8.11 Ground water condition during growing season [W15]

Ecosystem characteristic: Abiotic factors

8.11.1 Supplementary metadata

8.11.2 Supplementary methods

Rates of change for all gridded hydrological data are calculated with linear models as described in the general methods.

8.11.3 Plots of indicator values

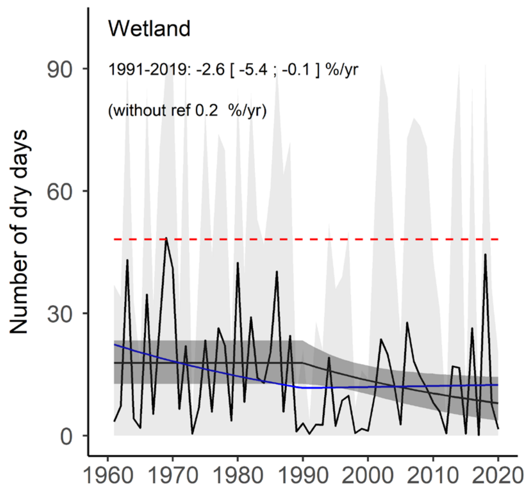

Figure A8.11.1. *The mean number of days during the summer (June-August) in which the ground water condition is either 'low' or 'very low' (e.g. 'dry days') during and after the climatic reference period (1961–1990) for wetland ecosystems in Trøndelag. The black regression line shows the rate of change (±2SE) if the indicator value is assumed constant during the climatic reference period (1961–1990). The blue regression line shows, as an illustration, the rate of change if the indicator value is NOT assumed to be constant during the climatic reference period, but equal to the predicted regression line for the period 1961–1990. The red dashed line indicates the 2SD of the variation observed during the climatic reference period.*

8.11.4 Background data and supplementary analysis

Not relevant.

8.11.5 Recommendations for future development of the indicator

The indicator is based on a gridded water balance model applying gridded weather data as input. The parameterisation of soil and land use characteristics is very general, and does represent local conditions in detail. Although these data are extensive in time and space, they are purely modelled estimates not based on direct observations of the phenomena. Observations of the phenomena are few. Increased monitoring and more detailed data of soil and land-use characteristics are needed to develop models providing more precise and robust estimates.

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8.12 Trenching [F13, W13]

Ecosystem characteristic: Abiotic factors

8.12.1 Supplementary metadata

Land conversion of wetlands into agricultural land implies draining with trenching and other practices that lower the water table of wetlands. Data on land conversion into agricultural land are reported to Statistics Norway, by the municipalities (KOSTRA Statistics), but data on newly trenched/converted peatland for agricultural purposes are not readily available on a yearly basis, and are reported in an indirect way, i.e. the statistics are based on municipal reports on applications to authorize land-use change. However, there are often lags of years in the update of land-use maps. Timely and spatially explicit information on the magnitude of trenching activities on wetlands is therefore very limited. Area statistics can give an indication of the level of impact of conversion of land for agricultural purpose (NIBIO 2017). Other statistics, such as the proportion of agricultural land on organic soils, provide an indication of the magnitude of peatland conversion into agriculture, but these data do not enable an estimation of when land conversion took place, nor the proportion of wetlands with natural hydrological regime that has been affected.

In the case of trenching in forestry, it includes drainage of both swamp forest and peatland. Hence, in the case of forest, the change is not reported as land-use change, but as a forestry practice. New trenching in peatland and swamp forest was banned in Norway in 2006, but it can be conducted in previously trenched forest areas, after logging (PEFC Norge 2015), and in other ecosystems than peatland and swamp forest. The data shown below have been retrieved from Statistics Norway's data base and comprise the period from 1968 to 2020 for Trøndelag (Sør-Trøndelag and Nord-Trøndelag). The statistics are reported yearly and provides information on measures covered by the 'Skogsfond' or which have received subsidies (Statistics Norway 2021). The data source is Landbruksdirektoratets database for 'Skogfond'. No data have been reported after 2007. The data consist of the area drained with trenches in this period, but trenching in previously drained forest or peatland area is not reported to the national statistics. It is not possible to distinguish from this data if trenching has been conducted on peatland, swamp forest or other forest type. The areas of original peatland and swamp forest are poorly estimated, which hinders the estimation of the proportion of the nature type that has been affected by trenching.

8.12.2 Supplementary methods

Not relevant.

8.12.3 Plots of indicator values

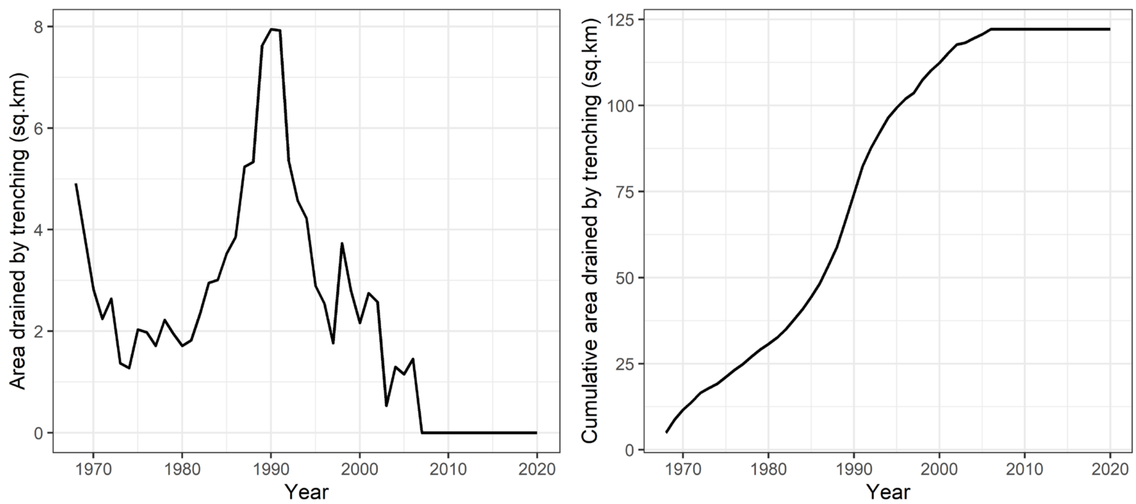

Figure A8.12.1 *The amount of forest area subject to subsidized trenching per year (left) and the cumulative total area (right).*

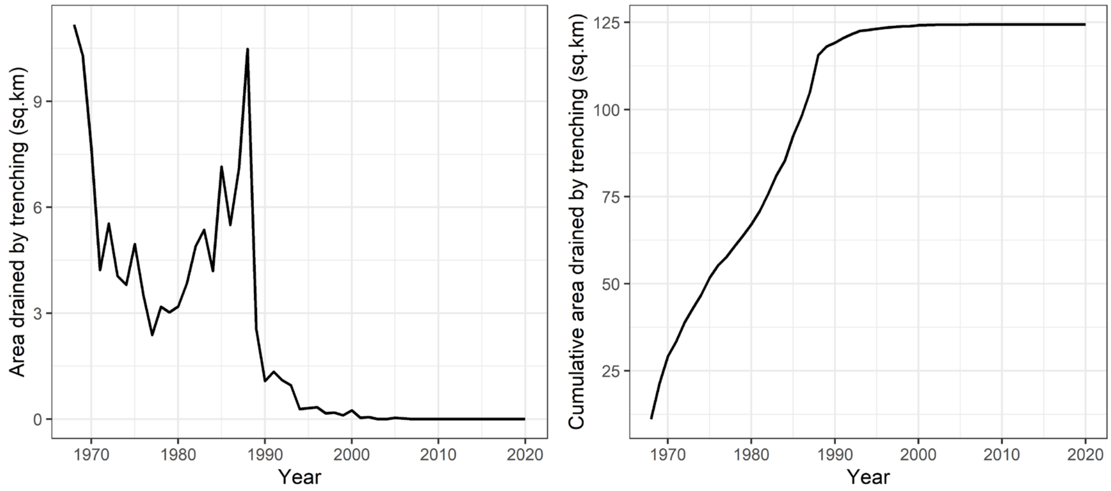

Figure A8.12.2 *The amount of wetland area subject to subsidized trenching for forestry per year (left) and the cumulative total area (right). The displayed numbers reflect the sum of all affected areas, the original (Norwegian) subcategories being "Næringsrik tilsigsmyr", "Svakt tilsigspreget myr" and "Rein nedbørsmyr".*

8.12.4 Background data and supplementary analysis

Not relevant.

8.12.5 Recommendations for future development of the indicator

The indicator of trenching for forestry, the cumulative amount of area drained, provides a proxy of the peatland and swamp forest area that has been drained (average water table maintained at 40-60 cm). The main limitations of this indicator are: (i) poor map information of non-trenched swamp forest, which limits the estimates of the proportion of this ecosystem type that is affected by drainage. (ii) poor maps information of trenched forest on peatland. More informative indicators of area coverage could be developed combining remote-sensing and ground data.

In the case of trenching and other practices to enhance soil aeration for agricultural purposes, data availability is very limited due to: (i) limited map information on peatland types, area and distribution. (ii) limited geographical data basis for regular monitoring of conversion into agricultural land from peatland.

Current data on peatland drainage and conversion into agricultural land provide very limited information about the condition of peatland ecosystems. They are based on limited/inaccurate geographical information of peatland area. Since the ban on peatland conversion for agricultural purposes has been lifted, there is an urgent need for reliable cartography of peatland distribution and a regularly updated monitoring system of land-use conversion. Techniques based on remote-sensing data provide excellent opportunities for further development of more fit-for-purpose and updatable data (Venter et al. 2021).