Use of Standard Photography as a Reliable Method for Monitoring Climate Change

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Introduction

Phenological studies have become increasingly useful to studies of environmental change over recent decades. However the traditional techniques in collating data can be labour intensive, expensive, and limited in focus.
We propose a simple, cost effective repeat photography method, which requires non specialist researchers that is applicable to research in traditional phenology, localised and landscape climatic events, land cover and land use change.

Methods

• Manually taken weekly photographs (1977-present) were collated by the Abisko Scientific Research Station (ANS) in Lappland, Sweden. Photographs collated since 1999 were taken by either Kodak DC260 (1999-2003) or Canon Powershot G5 (2004-Present) and stored as digital media. Prior to 1999 images were taken on a Canon Datematic 40mm (1:2.8) and stored as 24x35mm Kodak projector slides, then digitised prior to analysis using an Agfa Snapscan e50 scanner (1200x2400dpi, 42-bit).

• Three photo-series (TABLE 1) were selected for analysis based on their completeness and differing viewpoints. From each series a number of identifiable events were chosen for study, and a key (TABLE 2) of clearly identifiable phenophases was then created for each event.

• Compiled digital images were grouped by series and year. To avoid pre-judgement of expected phenophase by the recorder these were then analysed and scored in a random order within each group.

Series:	01 (Mast)	02 (Njulla)	03 (Torneträsk)
Start of data	2001	1979	1978
Frequency	Weekly (Monday)	Weekly (Monday)	Weekly (Monday)
Altitudinal range	390m	390-1169m	347-1200m
Image Direction		West	North-West
Photography type	Manual	Manual	Manual
Overview of picture	Relatively close up image of shrub species and mountain birch saplings	View from research station to Njulla / Slattatjakka. Encompasses birch forest and climatic tree line	From research station over Torneträsk toward Vadvetjakka National Park. Encompassing birch forest/scrub.
Number of events analysed	Two	Two	Four
Identifiable species	*Betula pubescens* ssp. *czerepanovii*	*Betula pubescens* ssp. *czerepanovii*	*Betula pubescens* ssp. *czerepanovii*
Other useable data	Snow cover (local)	Snow cover (montane)	Lake ice; snow cover (local & montane)

Table 1. Metadata of image series used in analyses of phenophases

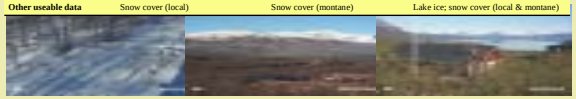


Table 2. Phenophases assigned to events extractable from images. Image series number (1-3) is shown in brackets. Due to varying distances between photo series it was not possible to assign the same categories to snow cover in each case.

Phenophase	Mountain Birch (01, 02, 03)	Lake Ice Cover (03)	Montane Snow Cover (02)	Montane Snow Cover (03)	ANS Snow Cover (03)	ANS Snow Cover (01)
1	All branches bare of leaves	Lake completely frozen over	Full cover, high slopes to ANS	Full cover (down to lake shore)	Full thick ground cover	Fresh build of heavy snow (can be seen on plants and mast)
2	Sporadic leaf and low density foliage	Broken ice / some stretches of water	Variable cover on slopes, patchy at ANS	Tops only fully covered	Full but thin cover (lower plants, rocks showing through)	Permanent (winter) full cover
3	Full leaf growth	No ice	Thin cover (ground visible in places). Upper and middle slopes only. ANS clear	Snow cover thin throughout	Snow cover is patchy with substantial bare ground visible	Slight melt in full cover (small troughs around plant stems visible)
4	Yellow/brown appearing		Thin / patchy cover on upper slopes only.	Remnant (circled slope is clear) or no snow cover	Light dusting of fresh snow (generally continuous)	Thinning (lower plants visible through snow)
5	All trees yellow/brown		Fresh blanket cover on upper slopes		No snow visible	Snow cover is patchy with substantial bare ground visible
6	Thinning of leaves		Remnant patches (circled band becomes fragmented) or no snow cover			Light dusting of fresh snow (generally continuous)
7						No snow visible

Data generation & quality

From the 2121 useable photographs, 6254 date/event data points were generated for analysis.

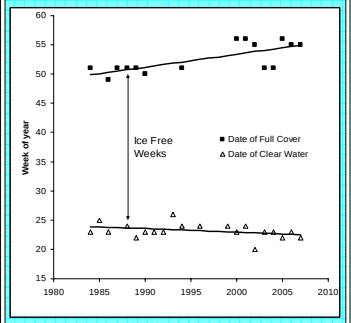
Photo-Series	Total Expected	Actual Total (% missing)	Quality impaired due to weather (% of actual)	Quality impaired due to light (% of actual)
Njulla	1497	988 (34)	49 (5)	35 (3.5)
Torneträsk	1497	1006 (32.8)	176 (17.5)	37 (3.7)
Mast	366	127 (34.7)	0	0
Totals	**3360**	**2121 (36.9)**	**225 (10.6)**	**72 (3.4)**

Table 3. Image series quality issues, from the 3 ANS photo-series.

Photographic data reliability

No significant differences were found to exist between manual and photographic recordings for Ice freeze (p= 0.276) or melt (p= 0.340), and first week of permanent local snowfall (p= 0.692). However a significant difference (p= 0.013) did exist between recording method for spring snow melt.

Lake Ice

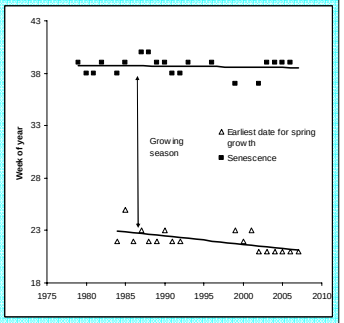


Winter freeze-up and spring melt of Torneträsk (Torneträsk photo-series), 1984-2007.

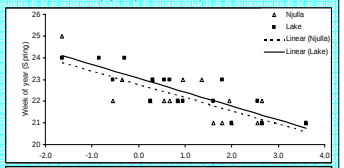
• Weeks of complete Tornetrask ice cover has reduced from 21.8 weeks (Av, 1985-89) to 17.4 weeks in recent years (Av, 2003-07).

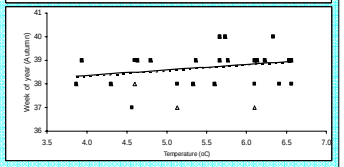
• Ice cover currently forms 3.2 weeks later than 1985-89 average.

Birch Phenology



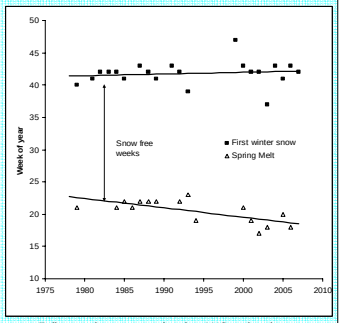
Growing season by first appearance and senescence (Njulla photo-series), 1979-2007.



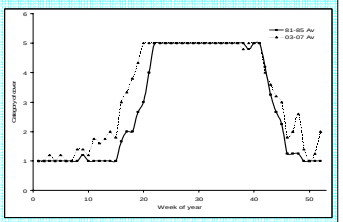


Relationship of temperature (Av, 2 months prior to event) and the first date of A) Spring birch growth (1984-2007) and B) Autumn senescence (1979-2007), in Njulla & Tornetrask (lake) photographs.

Snow



Full ground snow cover local to ANS and spring melt (Njulla photo-series), 1979-2007



Local ANS snow cover, 5 year averages 1981-85 & 2003-07. Categories as follows; 1= Full, 2= Full but thin, 3= Patchy, 4= Light dusting, 5= No snow

• Evidence for earlier spring snow melt in 2003-07 average, compared to 1985-89.

• Winter snow appears thinner and marginally more variable in later years.

Conclusions

• Weekly photographic records can provide an accurate representation of phenological events, when compared to manual recording methods.
• Studies of lake ice melt, snow melt and leaf expansion all show a trend towards earlier annual occurrence.
• Birch spring phenology shows a strong link to preceding monthly temperatures, occurring significantly earlier (p= 0.006; 1.84 weeks) in 2007 than 1984.
• Local snow melt occurs 2 weeks earlier (Av, 2003-07) compared to 1981-85 average.