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Flight of Trichoptera (caddisflies) north of the Arctic Circle: seven years light-trapping in alpine Scandinavian birch forest

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ABSTRACT

Light traps might not perform well under the bright summer nights at high latitudes. Trichoptera were caught in light-traps at Abisko, northern Sweden, 1970–1976. Among the 45 species collected, the family Limnephilidae was the most species-rich. *Apatania stigmatella* (Zetterstedt, 1840) made up 92% of the 65,400 specimens collected, and mostly in traps in open, dry birch forest. The species composition among these traps was surprisingly similar and differed greatly from these in dense birch forest, near small water bodies and near bogs. Most species started to fly at the end of July or later. The temporal pattern of *Apatania stigmatella* and *Limnephilus borealis* (Zetterstedt, 1840) was similar over these years, and the median day (when 50% of the catch was reached) being 11 and eight days, respectively. In traps with a fluorescent lamp, the temporal pattern for *Apatania stigmatella* was 5–13 days later than in a trap with a strong mercury vapor lamp. Sex ratios varied among species, but most species were male-dominated. The unique light conditions at high latitudes did not preclude the use of light traps, but they appeared to bias catches towards species with a late flight period, and catches were sensitive to the light source used.

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Midnight sun; flight phenology; light; Sweden; dispersal

Introduction

For long-term monitoring of insect populations, different types of traps are useful because they may capture different numbers of a given species, different sexes, or even different life stages (Muirhead-Thompson 1991). Light traps are often preferred because they are generally efficient for capturing nocturnal species (Douwes and Stenram 1972). There are numerous potential biases involved in insect trapping with lights with collection efficiency being affected by, for example, trap type, light source and placement (e.g., Muirhead-Thompson 1991, Nabli, Bailey, and Necibi 1999, Urbanič 2002, Ramamurthy et al. 2010, Larsson, Göthberg, and Milberg 2020). It

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is likely that the efficiency of light traps varies with ambient light conditions (e.g., Nowinszky, Kiss, and Puskas 2014), and trap efficiency would be expected to decrease at northern latitudes where the sun can shine even during most of the night during summer (i.e., midnight sun).

In 1970, Per Douwes, Lund University, started a light trap programme with a mercury vapour lamp north of the Arctic Circle at Abisko, northern Sweden, to evaluate the usefulness of light trapping under the extended daylight conditions that prevail there. Later, Karl Müller set up more light traps with a different light source (fluorescent tube). Here, we evaluate the Trichoptera material from these two trapping efforts to investigate the following topics:

1. Species composition in relation to larval habitats and terrestrial vegetation types representing habitats with different physical structure.
2. Flight phenology of the species.
3. Interannual variation in flight phenology.
4. Sex ratio.

We also tested the hypothesis that low intensity lamps work poorly early in the Trichoptera flight season at high latitudes because the nights are too bright making the lamps less visible to the caddisflies.

Material and methods

Study area and traps

Abisko National Park (established in 1909) and the Abisko Scientific Research Station (ASRS, in operation since 1913) have attracted a great deal of natural history attention from both amateurs and professional scientists due to their accessibility by railway (since 1903).

The current study is based on historical data collected 1970–76. Sampling was carried out using facilities provided by ASRS, and most traps were located within a few hundred metres (Figure 1, Table 1).

The data used consisted of two independent data sets:

a. One light trap (mercury vapor) operated 1970–76 close to ASRS (with only one minor modification between years). Sampling was initiated by Per Douwes, Lund University (Douwes, Göthberg, Mendl, and Müller 1972; Douwes 1975) to monitor insect populations (Douwes and Stenram 1972). The trap had a powerful mercury vapour lamp (Osram HQI 400 W) and a fan forced insects through a funnel into a collection container. In 1971–75 this container was changed every two hours (cf. Müller and Ulfstrand 1970). The trap was protected by a plexiglass roof. The trap was emptied once a week (every five days in 1970).
b. Several light traps (fluorescent tubes) 1975–76 operated by Karl Müller, later professor at the Department of Ecological Zoology, Umeå University. Eleven and eight light traps were operated during 1975 and 1976, respectively. One trap was at the same location in both years. They were placed

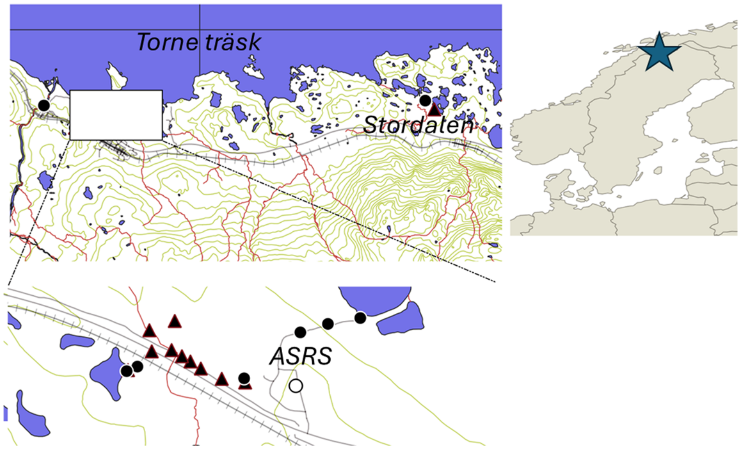

Figure 1. Study area: star indicates the location of Abisko within Scandinavia, the other maps show location of light traps at Abisko. Open circle Douwes' trap 1970–76; Triangles Müller's traps in 1975; Closed circles Müller's traps in 1976. ASRS (Abisko Scientific Research Station). Roads and a railroad are indicated.

in different environments close to ASRS or further away, e.g., one trap at Abiskojokk, in Abisko National Park, 1.5 km to the west and two traps 10 km to the east at the mires of Stordalen (ASRS field hut and at the meteorological station at Stordalen). Thus, the data sets contain both temporal (A) and spatial (B) information. Müller's traps were white-painted inventory traps (Rickleå type; cf. Olsson 1971) with a 15 W fluorescent tube (Standard Electric F 15 T 8 BLD) supplemented with a roof and a small fan. The trap at Stordalen in 1975, however, was similar to Douwes' trap. The traps were usually emptied once a week, but trap 75–10 had a two-week trapping period (September 15–29).

Information concerning traps and trap locations (Figure 1, Table 1) was compiled from Douwes et al. (1972), Douwes (1975), and Malicky (1978), supplemented with information from Nils-Åke Andersson, Kävlinge, Arne Müller, Umeå and a field visit in 2022 (PM).

Some traps were set near open water in 1975–76, including the large lake Torne träsk, a small brook (unofficially named Njakajokk by Müller), a small lake (Nissejaure), and a large pool in the mires of Stordalen. The other traps were set some distance from water, many in dry, open mountain birch forest (*Betula pubescens* ssp. *czerepanovii*) that dominates the vegetation at Abisko, while others were set in denser birch forest mixed with a *Salix* shrub layer.

A total of 26 trapping seasons were sampled using two types of light traps, over seven years, and in six habitat types. Some of the data have previously been presented in publications with limited circulation (Douwes et al. 1972; Douwes 1975; Malicky 1978).

The area around ASRS has changed since the 1970s. For example, a road (E10) was built just north of and close to the railway (Figure 1) and a new building was constructed just south of the station and just north of the site of Douwes' trap.

Table 1. Information of insect traps at Abisko 1970–76.

Trap ID	Type of trap	Location	Habitat
Douwes' trap			
70D-76D	Strong lamp (Osram HQI 400 W)	Close to ASRS	Dry, sparse *Betula*
Müller's traps			
Year 1975			
75-St	Strong lamp: Osram HQI 400 W; strong fan	Stordalen; just E of the field laboratorium	Pond at mire
75-1	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	ASRS W of the workshop	Dry, sparse *Betula*
75-2	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	North of the railroad	Dry, sparse *Betula*
75-3	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	North of the railroad	Moist, dense *Betula*
75-4	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	North of the railroad	Moist, dense *Betula*
75-5	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	North of the railroad	Moist, dense *Betula*
75-6	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Close to brook Njakajokk	Moist, dense *Betula*
75-7	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Close to brook Njakajokk	Dry, sparse *Betula*
75-8	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Above brook Njakajokk between the railroad and a local road	*Salix* shrubs, dense, brook
75-9	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Above Njakajokk between the railroad and the local road	*Salix* shrubs, dense, brook
75-10	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Shore of lake Nissejaure close to its outlet	*Salix* shrubs, dense, lake
Year 1976			
76-1	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	76-1 is the same trap as 75-1	Dry, sparse *Betula*
76-2	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Along small road from ASRS to lake Torne träsk, near ASRS	Dry, sparse *Betula*
76-3	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Along small road from ASRS to lake Torne träsk, midway	Dry, sparse *Betula*
76-4	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Along small road from ASRS to lake Torne träsk, near the shore	Dry, sparse *Betula*
76-5	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Near the shore of lake Nissejaure close to its outlet	*Salix* shrubs, dense, lake
76-6	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	At the shore of lake Nissejaure, close to its outlet; close to 75-10	*Salix* shrubs, dense, lake
76-7	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	On a hillock at the edge of the canyon of river Abiskojokk	Dry, sparse *Betula*, river
76-8	white 'Rickleå' light traps (Standard Electric F 15 T 8 BLD)	Stordalen, at the meteorological station; 365 m NW of 75-St	Mire

ASRS: Abisko Scientific Research Station.

Identification

Trichoptera caught in Douwes' trap were identified by Bo W. Svensson, Lund, and one of authors (AG) for the years 1970 and 1971–76, respectively. Trichoptera caught in Müller's traps in 1975–76 were identified by Hans Malicky, Lunz am See, Austria. The nomenclature follows Gullefors (2015), except for the genus *Apatania* Kolenati, 1848, which is now placed in the family Apataniidae. Species' classifications regarding life style were compiled from Salokannel and Mattila (2018) and Gullefors (2015).

Analyses

Species composition data from traps were subjected to Principal Component Analysis (PCA) using the CANOCO 5.0 software (Ter Braak and Šmilauer 2018).

To illustrate the flight phenology of the 17 most abundant species (≥30 individuals caught in total) we compared combined data from all traps and years in cumulative plots. The onset and termination of flight are elusive traits because they occur when populations are at their lowest (Van Strien, Plantenga, Soldaat, Van Swaay, and Wallis DeVries 2008; Belitz, Larsen, Ries, and Guralnick 2020). Consequently, they are highly sensitive to sampling effort, making comparisons between species difficult. This problem is partially solved by applying an arbitrary cut-off, and we have chosen to define the flight period of a species as dates between 10 and 90% of the catch, following some recent examples (Larsen, Belitz, Guralnick, and Ries 2022; Milberg, Franzén, Karpaty Wickbom, Svelander, and Johansson 2024).

For the two most abundant species (*Apatania stigmatella* (Zetterstedt, 1840) and *Limnephilus borealis* (Zetterstedt, 1840)) it was possible to carry out three separate analyses of phenological patterns.

1. Interannual variation in phenology using data from Douwes' stationary trap 1970–76 (both species).
2. Degree of synchrony between nearby traps in similar environments for 1975 and 1976 (*Apatania stigmatella* only).
3. Possible influence of lamp type (strong mercury vapour vs. weaker fluorescent lamps) between nearby traps (*Apatania stigmatella* only).

Generalised linear models (GLM, normal distribution with log link) were used to analyse (i) the number of *Limnephilus borealis*, (ii) of *Apatania stigmatella* and (iii) the proportion of males over time.

Results

Species composition

In total, 65,425 caddisfly specimens belonging to nine families and 45 species were caught: 38,935 in Douwes' trap (1970–76) and 26,490 in Müller's traps (1975–76) (Table 2). All data, are available in a data repository (see below for link).

The traps caught between five (Abiskojokk) and 24 (Stordalen) species, with most records between nine and 18 species. In total, Douwes' trap, which was placed at a single site, attracted 28 species over seven years, while Müller's traps, that were in different habitats, attracted 42 species over two years (Table 2).

The family Limnephilidae was the dominant family, while other species-rich families were conspicuously not collected, e.g., Hydropsychidae, Leptoceridae, and Hydroptilidae.

Apatania stigmatella completely dominated the number of individuals collected accounting for 92.7% of the total catch (Table 2, Figure 2). Other abundant species (>500 individuals) were *Limnephilus borealis* (Table 2, Figure 3a), *Limnephilus coenosus* Curtis, 1834, and *Halesus digitatus* (Schrank, 1781) (Table 2). A further

Table 2. Mean number of Trichoptera caught in light traps in different habitats at Abisko, northern Sweden in 1970–76, and their sex ratio.

	Abbreviated name	Family	Life style	Douwes dry birch (7 years)	Müller Dry birch ($N=7$)	Müller Moist birch ($N=5$)	Müller Brook ($N=2$)	Müller Lake ($N=3$)	Müller Mire ($N=2$)	Grand total	Males (%)
Apatania stigmatella (Zetterstedt, 1840)	Apa st	Apataniidae	Eurytope	5429.9	2699.6	404.2	88.0	473.0	69.0	60660	82
Limnephilus borealis (Zetterstedt, 1840)	Lim bo	Limnephilidae	Lentic	94.1	6.6	16.8	8.0	79.0	217.5	1477	84
Limnephilus coenosus (Curtis, 1834)	Lim co	Limnephilidae	Mire	5.7	11.9	75.6	51.5	9.3	54.0	740	94
Halesus digitatus (Schrank, 1781)	Hal di	Limnephilidae	Lotic	5.0	2.9	60.0	93.5	25.0	15.5	648	75
Anabolia concentrica (Zetterstedt, 1840)	Ana co	Limnephilidae	Lotic			10.2	162.0	10.3		406	97
Plectrocnemia conspersa (Curtis, 1834)	Ple co	Polycentropodidae	Lotic			5.2	140.5	2.3		314	93
Limnephilus externus (Hagen, 1861)	Lim ex	Limnephilidae	Mire	4.7	1.4	11.0	9.0	40.7	3.0	244	76
Chaetopteryx sahlbergi (McLachlan, 1876)	Cha sa	Limnephilidae	Lotic		3.4	7.6	54.5	0.7	0.5	174	74
Asynarchus lapponicus (Zetterstedt, 1840)	Asy la	Limnephilidae	Lentic	3.1	5.7	10.2	5.0	4.0	10.0	155	95
Apatania wallengreni (McLachlan, 1871)	Apa wa	Apataniidae	Eurytope	2.4	16.0					129	75
Apatania zonella (Zetterstedt, 1840)	Apa zo	Apataniidae	Spring	1.7	7.7					66	2
Limnephilus sericeus (Say, 1824)	Lim se	Limnephilidae	Lentic	5.3	2.1	0.4	0.5	0.3	1.5	59	78
Chilostigma sieboldi (McLachlan, 1876)	Chi si	Limnephilidae	Mire		0.6	0.6		4.7	11.5	44	43
Arctopora trimaculata (Zetterstedt, 1840)	Arc tr	Limnephilidae	Mire	0.1	0.1			0.3	18.0	39	55
Limnephilus pantodapus (McLachlan, 1875)	Lim pa	Limnephilidae	Lentic					6.3	8.5	36	56
Rhyacophila nubila (Zetterstedt, 1840)	Rhy nu	Rhyacophilidae	Lotic	1.4	2.3		0.5	2.0	0.5	34	79
Rhadicoleptus alpestris (Kolenati, 1848)	Rha al	Limnephilidae	Mire	1.9	0.3	1.6	0.5	1.0	1.5	30	100
Limnephilus rhombicus (Linnaeus, 1758)	Lim rh	Limnephilidae	Lentic	0.7	0.1	0.4		0.3	4.5	18	83
Limnephilus stigma (Curtis, 1834)	Lim st	Limnephilidae	Lentic	1.7					1.5	15	93
Micrasema gelidum (McLachlan, 1876)	Mic ge	Brachycentridae	Lotic			0.2	7.0			15	67
Limnephilus sparsus (Curtis, 1834)	Lim sp	Limnephilidae	Ephemeral	0.1	1.6	0.2				13	86
Agrypnia obsoleta (Hagen, 1864)	Agr ob	Phyganeidae	Lentic					0.3	6.0	13	15
Grammotaulius signatipennis (McLachlan, 1876)	Gra si	Limnephilidae	Lentic	0.4					5.0	13	92
Limnephilus dispar (McLachlan, 1875)	Lim di	Limnephilidae	Mire			0.2	0.5	2.7	1.0	12	50
Limnephilus fenestratus (Zetterstedt, 1840)	Lim fen	Limnephilidae	Mire	0.9	0.1	0.4			1.0	11	82
Asynarchus contumax (McLachlan, 1880)	Asy co	Limnephilidae	Ephemeral	1.0	0.3	0.2				10	100
Molannodes tinctus (Zetterstedt, 1840)	Mol ti	Molannidae	Lentic					2.0		6	
Micropterna sequax (McLachlan, 1875)	Mic se	Limnephilidae	Lotic	0.3		0.4	0.5			5	
Potamophylax nigricornis (Pictet, 1834)	Pot ni	Limnephilidae	Spring	0.1	0.1		1.0	0.3		5	
Lenarchus productus (Morton, 1896)	Len pr	Limnephilidae	Lentic		0.4		0.5			4	
Oligotricha lapponica (Hagen, 1864)	Oli la	Phyganeidae	Mire	0.1		0.2			1.0	4	
Limnephilus nigriceps (Zetterstedt, 1840)	Lim ni	Limnephilidae	Lentic						1.5	3	
Limnephilus femoralis (Kirby, 1837)	Lim fel	Limnephilidae	Mire	0.1					1.0	3	
Brachypsyche sibirica (Martynov, 1924)	Bra si	Limnephilidae	Spring	0.1					0.5	2	
Glossosoma intermedium (Klapálek, 1892)	Glo in	Glossosomatidae	Lotic			0.2	0.5			2	

(*Continued*)

Table 2. Continued.

	Abbreviated name	Family	Life style	Douwes dry birch (7 years)	Müller Dry birch ($N = 7$)	Müller Moist birch ($N = 5$)	Müller Brook ($N = 2$)	Müller Lake ($N = 3$)	Müller Mire ($N = 2$)	Grand total	Males (%)
Halesus radiatus (Curtis, 1834)	Hal ra	Limnephilidae	Eurytope	0.1		0.2				2	
Limnephilus griseus (Linnaeus, 1758)	Lim gr	Limnephilidae	Mire	0.3						2	
Limnephilus picturatus (McLachlan, 1875)	Lim pi	Limnephilidae	Mire	0.3						2	
Phryganea bipunctata (Retzius, 1783)	Phr bi	Phyganeidae	Lentic					0.3	0.5	2	
Potamophylax cingulatus (Stephens, 1837)	Pot ci	Limnephilidae	Lotic			0.2			0.5	2	
Potamophylax latipennis (Curtis, 1834)	Pot la	Limnephilidae	Eurytope	0.1	0.1					2	
Beraea pullata (Curtis, 1834)	Ber pu	Beraeidae	Spring					0.3		1	
Holocentropus insignis (Martynov, 1924)	Hol in	Polycentropodidae	Mire				0.5			1	
Limnephilus femoratus (Zetterstedt, 1840)	Lim fet	Limnephilidae	Lentic						0.5	1	
Limnephilus subnitidus (McLachlan, 1875)	Lim su	Limnephilidae	Lentic	0.1						1	
Total				5562	2763	606.2	624.0	665.3	435.5	65425	

Species are listed according to total catches. Average number per trap/year. Abbreviated names used in Figure 4.

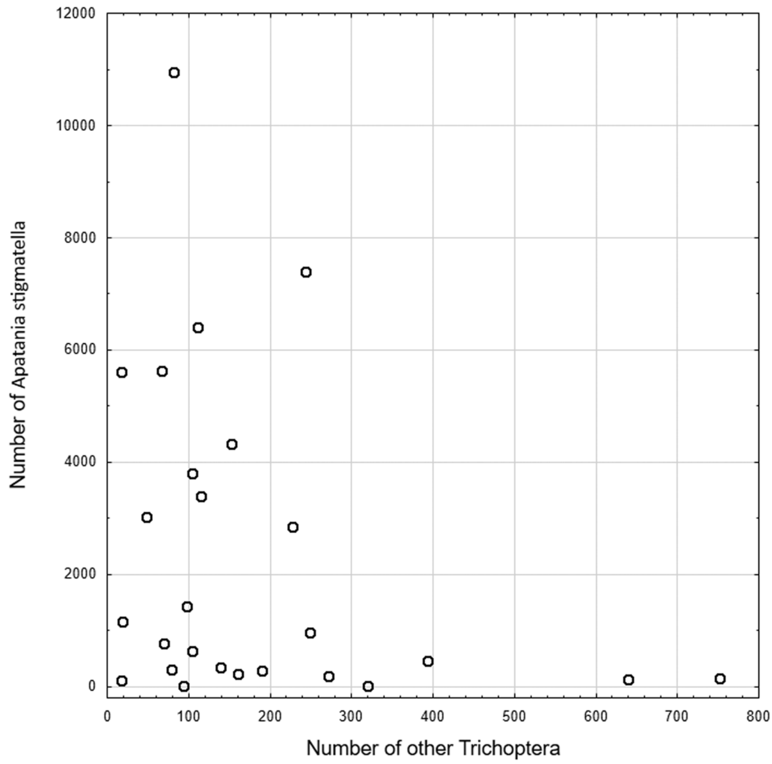

Figure 2. Number of *Apatania stigmatella* (Zetterstedt, 1840) caught in light traps at Abisko 1970–76, as a function of the number of specimens of all other species.

six species contributed >100 individuals each (Table 2), while 19 species were represented by <10 individuals each.

Apatania stigmatella, *Asynarchus lapponicus* (Zetterstedt, 1840), *Limnephilus borealis*, *Halesus digitatus*, *Limnephilus coenosus,* and *Limnephilus externus* Hagen, 1861 were the most widespread species in these collections, being found in most samples (Table 2). Among them, *Asynarchus lapponicus* had a low but surprisingly uniform occurrence in the traps.

With the exception of *Limnephilus subnitidus* McLachlan, 1875, all species have been previously recorded from the Torne Lappmark region according to the latest compilation of Swedish Trichoptera (Gullefors 2015).

Community structure

The PCA revealed a gradient from dry to moist trap sites (Figure 4a). It is noteworthy that all catches in the open, dry birch forest were very similar in composition. The seven catches from Douwes' trap constituted together with catches from 75-1, 76-1 and 76-7 one subgroup, three traps along the track from Torne träsk to ASRS (76-2, 76-3, 76-4) formed one subgroup, while traps 75-2 and 75-7 formed a group close to the traps in moist birch forest and also to those close to a small lake. The trap beside the bog at the mires at Stordalen was very different from all other traps.

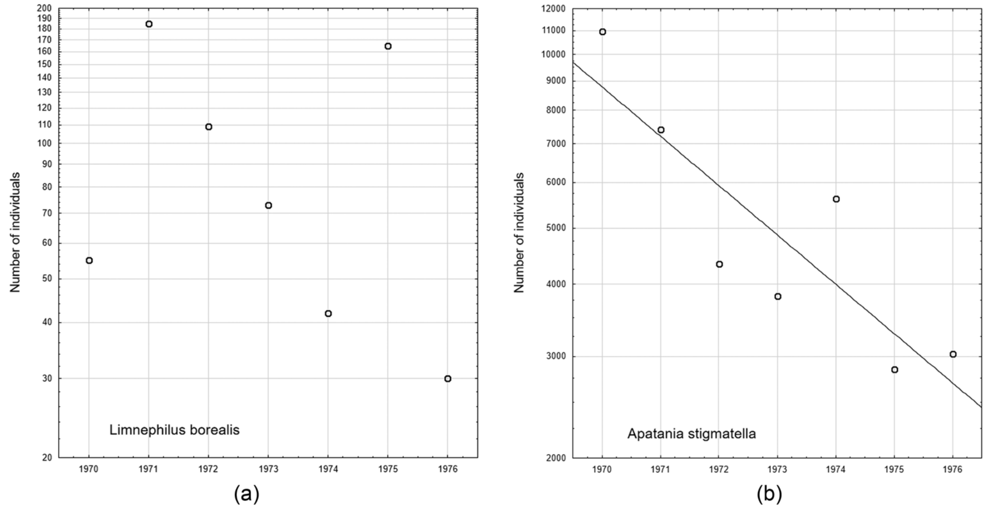

Figure 3. Annual catches of a) *Limnephilus borealis* (Zetterstedt, 1840) and b) *Apatania stigmatella* (Zetterstedt, 1840) in a stationary light trap at Abisko [$y = 1.663E172 * \exp(-0.197 * x)$].

The most striking feature of the catches in open, dry birch forest was the dominance of *Apatania stigmatella* (>90% of all individuals in each trap) combined with few specimens of other species (Figure 2, Table 2). Traps in dense birch forest or *Salix* shrub, or near to a small lake and a brook caught few *Apatania stigmatella* but many specimens of other species (Table 2).

Habitat preferences

Some functional groups of species fitted expectations surprisingly well with most lentic and bog species concentrated in one direction and lotic species in the other (Figure 4b).

Most lotic species were caught in traps at the Njakajokk brook (traps 75-8, 75-9) and its nearby moist birch forest. *Anabolia concentrica* (Zetterstedt, 1840), *Plectrocnemia conspersa* (Curtis, 1834), *Chaetopteryx sahlbergi* McLachlan, 1876, and *Halesus digitatus* were particularly abundant (Table 2, Figure 4b).

Lentic species were caught in traps near the small lake Nissejaure bordered by mires to the east (traps 75-10, 76-5, 76-6), e.g., *Limnephilus externus* and *Limnephilus pantodapus* McLachlan, 1875 (Table 2, Figure 4b).

The catch next to a large bog pool at Stordalen (75-St) differed greatly from all other catches (Table 2, Figure 4a), mainly by the presence of a considerable number of species typical of this habitat, e.g., *Limnephilus borealis, Limnephilus coenosus, Chilostigma sieboldi* McLachlan, 1876, *Arctopora trimaculata* (Zetterstedt, 1840), and *Agrypnia obsoleta* (Hagen, 1864) (Table 2, Figure 4b).

Many species classified as 'lentic', or 'mire', occurred in similar habitats and also in more or less ephemeral, small waters in the forest. Thus, e.g., *Limnephilus borealis, Limnephilus coenosus, Limnephilus externus, Asynarchus lapponicus* and *Rhadicoleptus alpestris* (Kolenati, 1848) were frequent in traps in moist habitats as well.

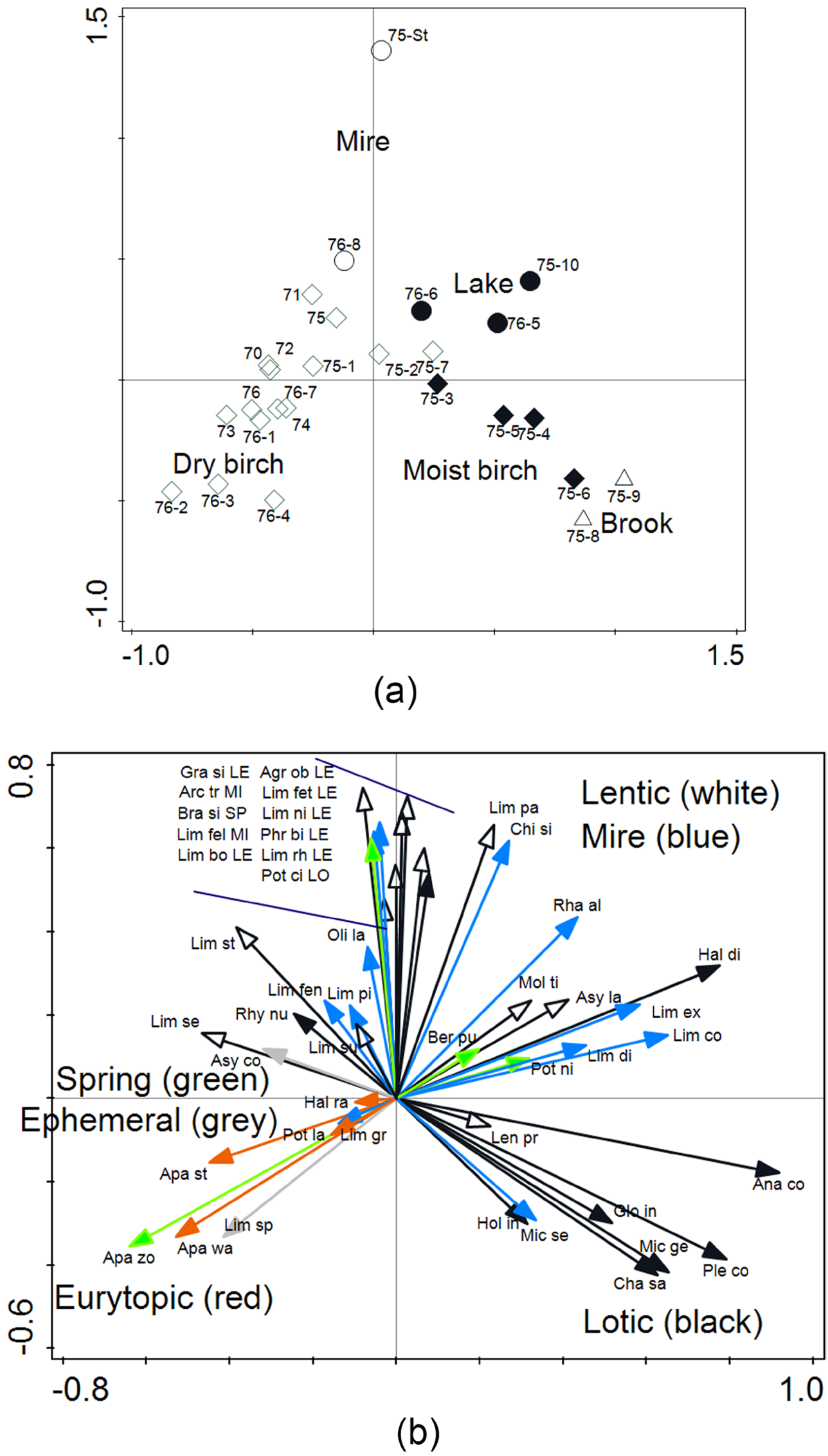

Figure 4. PCA of Trichoptera catches at Abisko. Eigenvalues of PC1 and PC2 were 0.271 and 0.156, respectively. Symbols group samples by vegetation type. a) Traps and b) Species illustrated by arrows of different colours according to life-style: lentic (white), mire (blue), spring (green), ephemeral (grey), eurytopic (red) and lotic (black). Abbreviated species names are given in Table 2.

Apatania zonella (Zetterstedt, 1840) and *Apatania wallengreni* (McLachlan, 1871) were caught only in the traps along the road down to Torne träsk and in Douwes′ trap. The catch at the top of the deep gorge of the river Abiskojokk (76-7) was similar to that in open dry birch forest (Figure 4a), but with the addition of the lotic habitat obligate *Rhyacophila nubila* (Zetterstedt, 1840), which was abundant there.

Flight phenology

Species differences

The flight periods for the 17 most abundant species in the combined data from all traps and years are shown in Figures 5a–d. Only *Apatania wallengreni*, *Apatania zonella*, and *Limnephilus pantodapus* were caught in June and peaked in July (Figure 5b, c). Also, the rarer *Limnephilus dispar* McLachlan, 1875, *Potamophylax nigricornis* (Pictet, 1834), *Arctopora trimaculata*, and *Micrasema gelidum* McLachlan, 1876 were caught early in the season only (data not shown). Most species appeared in the traps in late July and early August, peaking in mid-August to early September (Figure 5a, b, c). Late-flying species were *Chaetopteryx sahlbergi*, and *Chilostigma sieboldi,* of which the latter was also caught in low numbers in early June after overwintering (Figure 5a).

The length of the flight periods – defined here as the number of days between 10 and 90% of the catch – varied from two weeks to almost six weeks between species (Table 3, then excluding *Chilostigma sieboldi,* which flies from autumn to spring).

Interannual variation

Two species collected in Douwes' trap were sufficiently abundant to analyse changes in annual catches. *Limnephilus borealis* was highly variable between years (mean = 94.1; SD = 61.0; Figure 3a) with no significant change ($p = 0.58$). In contrast, *Apatania stigmatella* (mean = 5430; SD = 2907) clearly decreased (Figure 3b; $p < 0.0001$) and parallel to this observation, the proportion of males also increased (Figure 3c; $p = 0.033$).

The date for 50% of the catch each year (median date) differed by 11 days for *Apatania stigmatella* (from day number 230 to 241; Figure 5d) and eight days for *Limnephilus borealis* (227–235; Figure 5f).

Despite the phenology of *Apatania stigmatella* was similar between years when expressed as percentage of annual catch, the total number of individuals was high in 1971 and 1974 and especially in 1970 (Figure 5e), and many more individuals were caught early these years (Figure 5e).

Synchrony among traps and lamp type

In the same year, nearby traps (75-1, 75-2) showed very similar flight phenology for *Apatania stigmatella*, with a difference in median catch of 5 days (Figure 5g).

Fluorescent light traps caught fewer individuals early in the summer compared to the strong mercury vapor light lamp (Figure 5g): differences in median days were 8 and 13 days, respectively in 1975 (75D vs. 75-1, 75-2), and 5 days in 1976 (76D vs. 76-1).

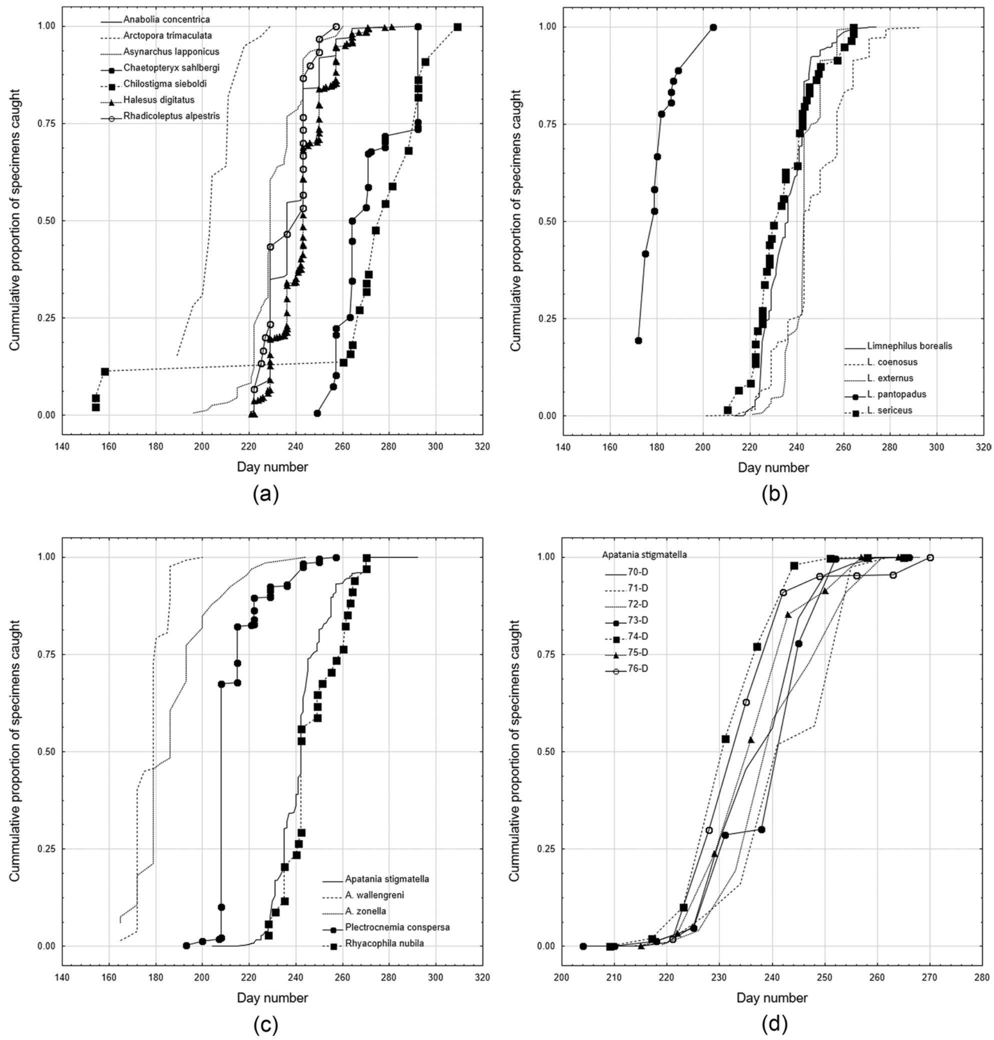

Figure 5. Temporal pattern of Trichoptera catches in light traps at Abisko 1970–76 expressed as cumulative frequency. (a–c) 17 Species with totally >25 individuals in all traps. (d) Temporal pattern of catches of *Apatania stigmatella* (Zetterstedt, 1840) in a light trap at Abisko 1970–76 expressed as cumulative proportion of total annual catches. (e) Temporal pattern of cumulative catches of *Apatania stigmatella* in a light trap at Abisko 1970–76. (f) Temporal pattern of catches of *Limnephilus borealis* (Zetterstedt, 1840) in a light trap at Abisko 1970–76. (g) Temporal patterns of catches of *Apatania stigmatella* in three traps in similar environments in 1975 and 1976. Traps 75-D and 76-D had a strong mercury vapour lamp and the other two had a fluorescent tube.

Sex ratio

Overall, 82.5% of the specimens caught were males, with considerable variation between species (Figure 6). For example, only 3.0% of *Apatania zonella* were males, compared to >95% of *Anabolia concentrica* and *Asynarchus lapponicus* (Figure 6). In *Chilostigma sieboldi, Arctopora trimaculata* and *Limnephilus pantodapus* the sex ratio was relatively even, but most species were represented by >70% males (Figure 6). Sex ratios may be density dependent, as the proportion of males in *Apatania stigmatella* increased with decreasing abundance (data not shown).

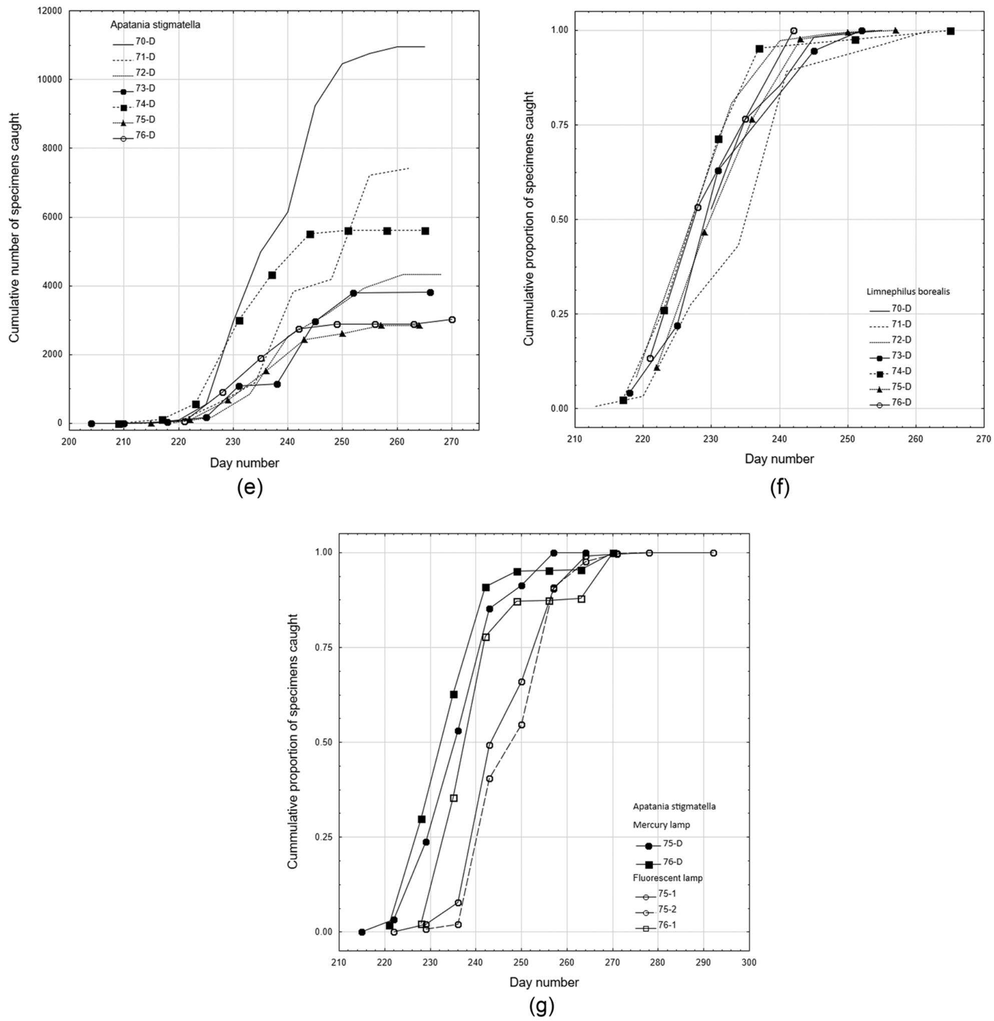

Figure 5. Continued.

Discussion

Species composition

Although sampling was conducted over a small geographic area, the differences between traps were marked. The pattern is easily interpreted as mainly a gradient from dry/open birch forest to moist/dense birch forest with a *Salix* shrub layer. We believe that this gradient is primarily one of openness and visibility, with light attracting over longer distances in the open environments.

The species composition in traps near water habitats (except near Torne träsk) or in dense birch forest with shrubs differed from traps in open birch forest (Figure 4a), mainly due to much lower dominance of *Apatania stigmatella*. Traps in dense vegetation do not attract animals from far away, and traps near water catches mainly species living in that water. Thus, the large catches of *Apatania stigmatella* in traps in open birch forest most likely came from other waters than Nissejaure, Njakajokk and Stordalen. Instead, the likely habitat of the larvae is the huge lake Torne träsk

Table 3. Length of flight period (number of days) of the most abundant species of Trichoptera caught in light traps at Abisko, northern Sweden 1970–76.

	10–90%	Abundance
Apatania wallengreni	14	129
Limnephilus externus	15	244
Limnephilus borealis	21	1477
Anabolia concentrica	21	406
Plectrocnemia conspersa	21	314
Asynarchus lapponicus	21	155
Rhadicoleptus alpestris	21	30
Arctopora trimaculata	22	39
Apatania stigmatella	26	60660
Halesus digitatus	28	648
Rhyacophila nubila	29	34
Limnephilus pantodapus	32	36
Limnephilus coenosus	35	740
Chaetopteryx sahlbergi	35	174
Limnephilus sericeus	35	59
Apatania zonella	40	66
Chilostigma sieboldi *		44

*indicates flight period autumn - spring
Flight period defined as number of days from 10 to 90% of the total catch. Data from all traps combined.

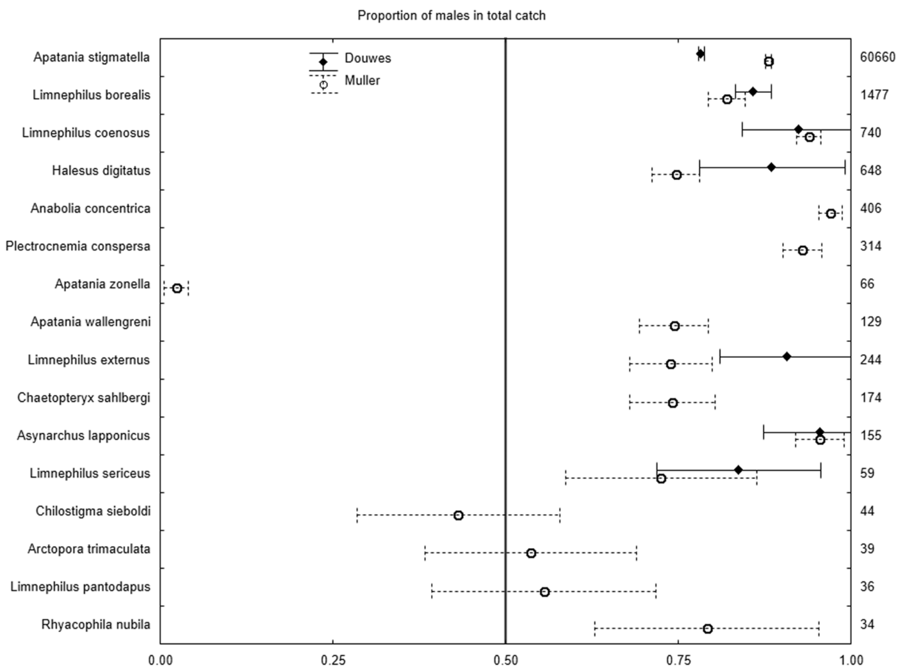

Figure 6. Sex ratio of Trichoptera species (>30 specimens in total) in two types of light traps at Abisko in 1970–76. Douwes' trap had a powerful mercury lamp, while Müller's traps had fluorescent tubes. Bars show 95% confidence intervals.

(331 km²), which may produce immense numbers of individuals each year (cf. Forsslund 1931). Also, the large number of specimens caught over several years rules out the possibility that they originate from small larval habitats.

The Trichoptera fauna of the Abisko area was described by Forsslund (1931) on the basis of previously published data and a visit from 6 to 25 July 1930, i.e., before *Apatania stigmatella* was flying. He noted 'The most striking feature of the shore of Torne träsk is the immense abundance of *Apatelia zonella*. At the beginning and middle of July 1930 there was hardly a leaf on trees and bushes without one or more specimens' (our translation). Forsslund also assumed that *Apatania wallengreni* should have been very common there earlier in the summer. At that time, *Apatania stigmatella* was thought to occur mainly in high mountain streams. That *Apatania zonella* and *Apatania wallengreni* were only caught close to Torne träsk confirmed Forsslund′s observations and assumption. Thus, larvae of all three *Apatania* species live in the lake.

The families Limnephilidae and Apataniidae strongly dominated the catches with 99% of the specimens and 35 out of a total of 45 species. Ulfstrand (1970) also found Limnephilids to be dominant in light trap catches at the river Vindelälven (68%, 41 of 60 species), while other studies in northern Sweden (e. g., Göthberg 1970, 1974 and unpublished, Olsson 1971, Söderström unpublished, Carlsson 1979; Gullefors and Sjöberg 1987) reported lower numbers of Limnephilids, 30–62% and comparatively more species of non-Limnephilids. Forsslund (1931), who did not use light traps, reported many non-Limnephilids from the Abisko area, which were caught in sweep nets.

Many species of Limnephilidae and Apataniidae disperse from their hatching areas more frequently and for longer distances than species of other families (e.g., Göthberg 1973; Sarremejane et al. 2020; Arce, Hörren, Schletterer, and Kail 2021). As a result, they will be caught in traps far away from their larval habitats, such as *Apatania stigmatella* at Abisko. Therefore, with many traps placed away from the source habitats, it was not surprising that Limnephilidae and Apataniidae were generally well represented in the data, compared with other families. Thus, >50% of all 64 species of Limnephilidae and Apataniidae known from the province Torne lappmark was caught, but only 13% of the other families (79) (cf. Gullefors 2015).

Flight phenology

That flight phenology should differ between species was expected, even at this northern site with a short insect activity season. It is perhaps more surprising that the great majority of Limnephilidae and Apataniidae flew so late – late August to early September – with only very few early species (n.b. the late start of sampling in Douwes' trap in 1970–72 (1 or 15 July) – which reduces the total number caught in June). Other studies using light traps in northern Sweden also recorded few individuals and species of Limnephilidae and Apataniidae in June (Göthberg 1970, 1974; Ulfstrand 1970; Olsson 1971; Carlsson 1979; Gullefors and Sjöberg 1987). Thus, most Limnephilidae and Apataniidae are active late in the summer, while many non-Limnephilids fly earlier in the season, and this difference was pronounced at Abisko. This prevalence of late flight in many Limnephilidae and Apataniidae depends on larval development from autumn into the early part of the season (e.g., Solem and Johansson 1991), as they are shredders and highly dependent on leaves and other plant material reaching the water in the autumn (Bohman and Herrmann 2006).

In addition to this phylogenetic difference in flight, there may be a bias in catches due to the increasing effectiveness of light traps as the influence of the midnight sun diminish and nights become longer and darker. Thus, late flying Limnephilidae and Apataniidae will be over-represented. In southern Sweden Svensson (1972) documented that catches in light traps peaked later than in Malaise traps (suggesting an increasing attraction to light with longer and darker nights).

The fact that early flying species were caught despite midnight sun conditions suggests that meaningful light trapping can be carried out over a full season. However, the extent of any midnight sun bias remains unresolved, and would require parallel sampling using different methods. A more cost-effective approach may be to focus on the latter part of the season, when light trapping is more efficient.

Although numbers varied between years, a striking feature of the data was the temporal consistency of trap catches (Douwes' stationary trap over seven years; Figure 5d, f). This consistency bodes well for any monitoring effort, assuming that trap locations are permanent.

Further, it is interesting to compare phenology in different traps and at different trap sites. First, there were consistent patterns of flight phenology between traps sites in a single year (Figure 5g). Second, not unsurprisingly, there was some variation in flight phenology between years. Third, a stronger light source resulted in larger catches, which could imply an earlier flight pattern compared to a weaker lamp (Figure 5g). This further suggests that low-intensity lights work poorly in the early part of the season at this high latitude, which is consistent with the hypothesis that the extended daylight reduced catches. In conclusion, the trap type dependence shows the importance of lamp type, an effect that is likely to be exacerbated at high latitudes.

Interannual variation in numbers

From a monitoring point of view, it is important to know the extent of interannual variation as this is the background against which any changes will be inferred. Data on two species from Douwes' trap showed very large interannual variation (Figure 3a, b) and would therefore require many replicate traps if conventional statistics were used for evaluation. The decline of the super-abundant *Apatania stigmatella* between 1970 and 1976 is striking. Whether this reflects a general decline of the species or is part of a long-term cycle (e.g., Solbreck 1995) is important from a monitoring perspective. It remains to be investigated.

Catches in light traps reflect the abundance of a species as well as its activity, which is sensitive to weather conditions (e.g., cooler periods may reduce flying time and intensity, or overcast and warm nights may increase light trap catches). However, neither weather data (Abisko, SMHI nr: 188790; www.smhi.se) nor data on timing of ice break-up on Torne träsk, could explain this large variation in catches between years (data not shown). However, the size of interannual variation suggests that using raw numbers to assess change will require long time series, or a large number of replicate traps.

Interannual variation in flight phenology

More promising for monitoring was the consistency of the phenology between years, knowledge useful for designing a programme that covers only a part of the season (e.g., when most species are at peak flight).

If using the sum of the whole season, data would be more robust to interannual changes in flight phenology and short-term weather events. On the downside, such data are costly to collect and identify compared to one or more short sampling periods per year.

Sex ratio

Sex ratios in light trap catches of insects are often highly uneven, and seems not to reflect the population they sample. Many factors can be involved in this unbalance, e. g., different flight behaviour between sexes, including swarming and egg laying, trap position in relation to larval habitat, light source or a real skewness in sex ratio in the population. Thus, just a few species in our material had a sex ratio close to 0.5. Many *Apatania* species (not *Apatania stigmatella* and *Apatania wallengreni*) are known to be more or less parthenogenetic. *Apatania zonella* have very few males, while *Apatania muliebris* (McLachlan, 1866), and *Apatania hispida* (Forsslund, 1930), found in window traps north of Torne träsk (unpublished data), are thought to be completely parthenogenetic (Salokannel and Mattila 2018).

Methodological considerations

In the long term, maintaining permanent and unaltered trap sites is a challenge, as shown here by road and house building activity, and possibly, in the case of light traps, the addition of lights around buildings, roads and tracks. Of the trap sites used in 1970–76, Douwes' trap site is now affected by a new building (obscuring visibility and possibly providing competing light), two of Müller's sites were lost due to a road construction, and two other sites may have been affected by altered hydrology as a result of the new road. In addition, street lights have been installed in the vicinity of the ASRS. So even in this remote and sparsely populated area, which is mainly used for research, changes have occurred that would affect trapping, and thus obscure our ability to conclude population changes over time.

Monitoring with light traps

It is not surprising that the type of light source affects captures (e.g., Szanyi, Nagy, Varga, Potish, and Szanyi 2022), but it remains unclear to what extent this depends on the wavelengths of light emitted, or intensity of the light, which determines how far insects can be attracted.

Douwes' and Müller′s traps provided large catches of Trichoptera that could be analysed in various ways. Douwes' original aim was to catch Lepidoptera, but as this proved unsuccessful (low catches), trapping was abandoned. Thus, light trap monitoring may not work for one group of insects but may work well on another, depending on the environmental conditions at the sampling site and the biological characteristics of the group. It is hoped that our results will help with designing/improving monitoring of this ecologically important group of insects.

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Data availability statement

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