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Tortricid pests (Lepidoptera: Tortricidae) in apple orchards of South-Eastern Norway surveyed by pheromone-baited traps

Branislav Endel
Ecology

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Norwegian University of Life Sciences, Ås

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Branislav Endel

Abstract

The trend of minimizing pesticide usage in agriculture leads scientists to think about alternatives of how pest numbers can be reduced. The tortricid moths (Lepidoptera: Tortricidae) is a group of insects responsible for great damage in fruit orchards. Efficient models for predicting damage by these moths have so far mainly been developed for the most serious world-wide apple pest, the codling moth *Cydia pomonella*. Such forecasting models are not well-established for other tortricids and recent data on their status in Norwegian conditions are scare. The overall aim of this study was to provide such data on the flight activity of tortricids attacking apple trees, and thus contribute to the improvement of pest management in Norwegian orchards. The monitoring was undertaken in the Viken and Telemark regions, both in South-Eastern Norway, during 2018 and 2019. In each region, three orchards were selected. Six target species were surveyed by using pheromone-baited traps and some additional collecting of their immature stages. The presence of four out of the six target tortricids, *C. pomonella, Pammene rhediella, Archips podana* and *Hedya nubiferana*, was confirmed in high numbers. One species, *Adoxophyes orana*, was very rare in all the orchards and another, *Pandemis heparana* appeared to be rare, probably due to a poorly functioning pheromone attractant.

Differences in flight activity between the two years, one abnormally hot (2018) and the other slightly warmer than an average year (2019) were prominent. It was found that minimum temperature better explained the flight activity of 2 of the target species (spring and early summer ones), but in the case of *A. podana* (late summer species) the maximum temperature seemed to be a more important limiting factor. The majority (67%) of lepidopteran individuals caught by the pheromone traps belonged to the six target species. Regarding the remainder, 15% represented other pests and 18% were of species not considered as pests. Two pheromone lures, the ones employed for *C. pomonella* and *P. rhediella*, appeared to be reciprocal (attracting both target species). The lure for *H.nubiferna* trapped a greater amount of the non-target pest tortricid *Grapholita funebrana* than of the target. The lure for *P. heparana* surprisingly appeared to be more specific for the non-target pest tortricid *Ptycholoma lecheana*. Such a high proportion of non-target species caught in the target traps suggested that this issue needs to be taken into account. Their identification may be complicated for persons with little entomological experience.

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Abbreviations

IPM – Integrated Pest Management

NHM UiO – Natural History Museum, University of Oslo

NLR – Norwegian Agricultural Advisory Service (Norsk Landbruksrådgiving)

SID – Simpson's index of diversity

LMT – Agricultural Meteorological Service (Landbruks Meteorologisk Tjeneste)

Acronyms of the lures:

CYPO – the codling moth *Cydia pomonella* (Linnaeus, 1758)

PARH – the fruitlet mining tortrix *Pammene rhediella* (Clerck, 1759)

HENU – the marbled orchard tortrix *Hedya nubiferana* (Haworth, 1811), syn. *H. dimidioalba*

ARPO – the large fruit-tree tortrix *Archips podana* (Scopoli, 1763)

ADOR – the summer fruit tortrix *Adoxophyes orana* (Fischer V. Röslerstamm, 1834)

PAHE – the dark fruit-tree tortrix *Pandemis heparana* (Denis & Schiffermüller, 1775)

1 Introduction

Damage to crops caused by pests is a worldwide problem. Global losses of yields due to animal pests and pathogens reach 16-18% (Oerke, 2006), from which insects alone are responsible for approximately 11% losses (Dhaliwal et al., 2015). In order to mitigate this negative effect, pesticides have been used in a huge amount, especially in the late-1940s to mid-1960s (Pimentel, 2009). It was found later that not all these pesticide treatments were necessary (Edland, 1997). Current research in agriculture is trying to avoid unnecessary spraying. This is going to help farmers to minimize the economic costs incurred from using pesticides. In addition, reducing pesticides mitigates negative side-effects on the environment and human health (Perkins, 1982).

Integrated pest management (IPM) is a world-wide accepted plant protection strategy developed during the 1950s (Pimentel, 2009). Nowadays, it is mandatory in EU countries (Lefebvre et al., 2017). The main effort is to reduce the overuse of pesticides. For the implementation of IPM, knowledge of pest species ecology and phenology is a substantial issue. If monitoring reveals the presence of pests and proves their numbers to exceed an economic threshold (the density of pests under which control measures are more profitable than no action), further steps should be initiated for suppressing their damage (Edland, 1983; Stern et al., 1959). The use of softer control measures such as biological agents (entomopathogens, predators and parasitoids) (Lacey & Unruh, 2005), or mating disruption, e.g. (Angeli et al., 2007; Porcel et al., 2015) are preferred in IPM. If chemical treatment against pests seems to be the only suitable solution, the right timing of its application is crucial. Suitable time for pesticide application differs from country to country, may vary within smaller geographical region (Edland, 1997), and also depends on the pesticides' persistence (half-life). The optimal timing for pesticide treatments set up in the past may have also changed through time within the same region due to shifts in species’ phenology.

In organic orchards, all approaches that prevent pest outbreak must comply with strict organic production standards. Many of the fertilizers, insecticides, herbicides, and fungicides are prohibited there (Coleman, 2012). The pest outbreaks are trying to be suppressed, for instance, by planting disease-resistant varieties of crops, incorporation hedgerows and flowers around orchards that may harbor beneficial insects (natural enemies). The last phases, same as in case of IPM, include biological agents (bacteria, viruses), or approved insecticides (Wyss et al., 2005).

Climate change affects population dynamics, population size, phenology and geographical ranges of multiple insect species (Altermatt, 2010). In general, an earlier onset of the flight period of insects has been described from a variety of regions. Higher temperatures may prolong the flight period of adult insects, triggering the production of additional generations. This leads to a change in the phenology of immature stages. The damage by larvae is usually greater than damage caused by adults (this damage varying among insect orders). Thus, the time when the host plants are most susceptible to pests' attacks has changed too. Increasing temperature variability in Europe (Schär et al., 2004) is also an important factor that should be taken into account. All such changes in the climate make it difficult to estimate the right timing for pesticide application without using more complex mathematical models.

Simulation models predict the risk of damage from a given pest species based on meteorological data and forecasts. These models seem to be more precise and very convenient compared to laborious monitoring of pests in the field each season. For example, several models for predicting the codling moth *Cydia pomonella* (Lepidoptera: Tortricidae), a key pest on apple trees *Malus domestica* worldwide, have been developed and are commonly used. However, there are more than 20 other species of tortricids feeding on various fruit trees in Norway (Edland, 1987). The damage potential of these species is in most cases less but not negligible. For example, a strong attack of *P. rhediella* was described in 1970 from Ås (South-Eastern Norway), where over 40% of all apples were damaged (Edland, 1987). No predicting models for these tortricids have been used in Norway till now.

Based on their way of life, the larvae of fruit tortricids can be divided into three groups of species feeding: 1) on the leaves and buds (leafrollers), these species can also do great damage to fruitlets – *Archips podana, Hedya nubiferana, Pandemis heparana, Adoxophyes orana* and other species, 2) inside the fruits – *Cydia pomonella, Pammene rhediella* and *Grapholita funebrana*, and 3) on the bark of older trees, mining in the outer layer of bark – *Enarmonia formosana* – (Baker, 1983).

Information about tortricids developing on apple trees in Norway, is found in the reports of Torgeir Edland, e.g. (Edland, 1978; 1994; 1997). The MSc thesis of his student Bente Stensland (1993), provides an overview of eight pest tortricids: *C. pomonella, P. rhediella, E. formosana, P. heparana, A. podana, Archips rosana, Ptycholoma lecheana* and *Spilonota ocellana*, monitored with pheromone traps in the apple orchards in Ås and Svelvik in 1990-1991. The PhD work of May-Guri Sæthre was primarily focused on the adaptation of *C. pomonella* to Norwegian conditions (Saethre & Edland, 2001; Saethre & Hofsvang, 2005), etc. A large study on fruit leaf tortricids in Sweden was published by Sylvén (1958), this information can only partially be applied for regions in Norway, since this study concerns a neighboring country. An inventory of tortricids in Swedish apple orchards was more recently carried out, mainly by Patrick Sjöberg (Sjöberg, 2009; Sjöberg et al., 2015).

Initially, the main plan of this MSc thesis was to perform a monitoring of six tortricid pests, whose larvae develop on apple trees. The species were selected by The Norwegian Institute of Bioeconomy Research (NIBIO), to be included in the project Åmeåtak (2017-19) of which my study is a part. I will refer to these species as "target species" (described in the methods chapter). Since during the study, quite a number of other pest species of tortricids, and also other Lepidoptera families, were confirmed, I decided to include some of them. All innocuous species of Lepidoptera (i.e. not considered as pests) were identified too, but they are not discussed in detail (see Appendix 1-3).

Objectives

The overall objective of this MSc thesis is to provide further information about pest tortricids which can lead to improved IPM in Norwegian apple orchards, including forecasting models for the target species in the future.

Sub objectives:

1) Monitor the abundance and flight period of six target tortricids and some non-target moths.

2) Investigate the relationship between adult abundance and the presence of larvae.

3) Investigate the dependence of target species on three external factors: temperature, growing system and trap placement in the orchards.

4) Study specificity of the pheromone lures employed for the six target tortricids.

2 Material and methods

2.1 Study area

The study took place in the two regions Viken and Telemark (southeastern Norway). In both regions three orchards had been selected for the project (Table 1, Figure 1). In each of these orchards three plots (rows of trees) were established, each plot having pheromone traps for the six target species of tortricids deployed in a random order. A minimum distance of 40 meters between two pheromone lures serving for the same species was kept. Within the plot, the pheromone traps were placed 10 meters apart in order not to bias their functionality.

Table 1 List and position of the study sites and plots

Region	**Orchard**	**Management**	**GPS coordinates**		
			Plot 1	**Plot 2**	**Plot 3**
Viken	V1	organic	59°24'19.6"N 10°39'44.3"E	59°24'20.0"N 10°39'46.3"E	59°24'20.5"N 10°39'48.7"E
	V2	integrated (IPM)	59°48'06.5"N 10°14'48.7"E	59°48'06.7"N 10°14'47.9"E	59°48'05.4"N 10°14'37.2"E
	V3	integrated (IPM)	59°48'33.9"N 10°14'39.6"E	59°48'33.5"N 10°14'35.2"E	59°48'31.6"N 10°14'36.6"E
Telemark	T1	organic	59°22'41.6"N 9°13'10.0"E	59°22'41.5"N 9°13'07.6"E	59°22'40.1"N 9°13'05.9"E
	T2	organic	59°23'18.9"N 9°13'43.2"E	59°23'21.4"N 9°13'42.8"E	59°23'21.1"N 9°13'45.4"E
	T3	integrated (IPM)	59°22'50.9"N 9°12'52.0"E	59°22'49.9"N 9°12'50.0"E	59°22'48.8"N 9°12'48.5"E

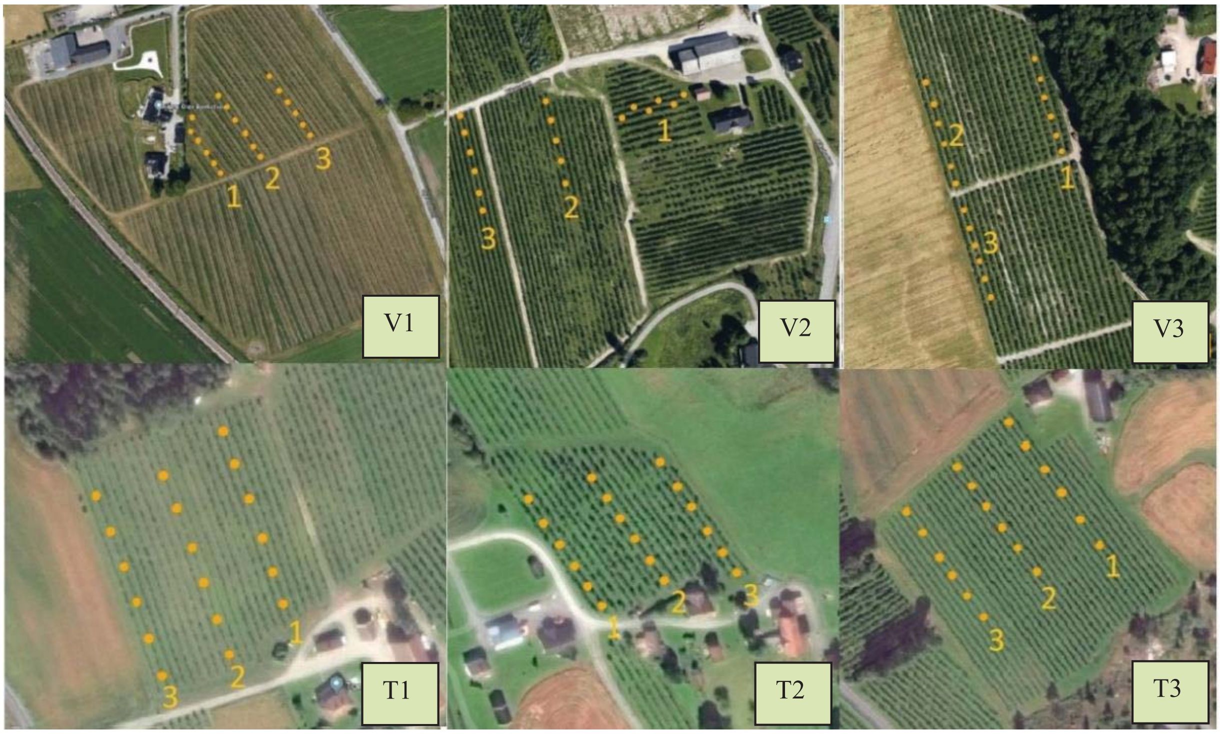

Figure 1 Maps of the study sites. The upper three orchards are from Viken and the three orchards below are from Telemark. Each dot indicates the position of one trap. The plots are shown as numbers 1-3, where 1 and 3 are regarded in later stages of this thesis as "edge" and 2 as "middle". Maps are from www.google.com/maps.

2.2 The six target species

Cydia pomonella (Linnaeus, 1758), codling moth, is according to Alford (2007) classified as a very important world-wide pest. The larvae feed mainly on apple *Malus,* and occasionally on pear *Pyrus.* No other host plants of the larvae known from Norway. Imagines of the species have been recorded in Norway between 18th May and 21nd September (all data based on collections from Naturhistorisk museum Oslo – NHM UiO).

Pammene rhediella (Clerck, 1759), fruitlet mining tortrix, is according to Alford (2007) classified as an occasional pest on apple *Malus*, and not that often on plum *Prunus.* Other shrubs and trees in continental Europe are attacked, while *Crataegus* is considered as a natural host plant (Edland, 1987). In Norway the larvae have been reared from: apple *Malus* and pear *Pyrus.* Imagines of the species have been recorded in Norway between 3rd May and 20th June (all data based on collections from NHM UiO).

Hedya nubiferana (Haworth, 1811), marbled orchard tortrix, is according to Alford (2007) classified as a minor fruit pest occasionally reaching high abundances in unsprayed orchards. The larvae feed on different trees and shrubs such as: apple *Malus*, pear *Pyrus*, cherry *Cerasus* and plum *Prunus*. In Norway the larvae have been reared from: *Malus, Pyrus, Prunus avium* and also the other wild shrubs: *Sorbus aucuparia, Crataegus* and *Cotoneaster*. Imagines of the species have been recorded in Norway between 27th May and 27th August (all data based on collections from NHM UiO).

Archips podana (Scopoli, 1763), large fruit-tree tortrix, is according to Alford (2007) classified as a more abundant tortricids associated with apple orchards. The larvae feed on many different trees and shrubs such as: apple *Malus*, pear *Pyrus*, cherry *Cerasus*, plum *Prunus*, currant *Ribes*, blackberry, raspberry *Rubus* and hop *Humulus.* In Norway the larvae have been reared from: *Malus*, *Pyrus, Rubus idaeus* and also the other wild shrubs and trees: *Populus tremula, Vaccinium, Rhamnus, Fagus, Sorbus aucuparia* and *Spiraea.* Imagines of the species have been recorded in Norway between 31th May and 16th August (all collections from NHM UiO).

Adoxophyes orana (Fischer von Röslerstamm, 1834), summer fruit tortrix, is according to Alford (2007) classified as species spreading in continental Europe where it is an important pest. The larvae feed on trees such as: apple *Malus*, pear *Pyrus,* occasionally on cherry *Cerasus* and plum *Prunus.* In Norway the larvae have been reared from: *Malus* and also the other wild shrubs and trees: *Sorbus, Rhamnus frangula.* Imagines of the species have been recorded in Norway between 11th June and 2nd September (all data based on collections from NHM UiO).

Pandemis heparana (Denis & Schiffermüller, 1775), dark fruit-tree tortrix, is according to Alford (2007) classified as an unimportant pest. The larvae feed on different trees and shrubs such as: apple *Malus*, pear *Pyrus*, plum *Prunus*, currant *Ribes* and raspberry *Rubus*, as well as occasionally feed on flowers and therefore causing damage (Alford, 2007). In Norway the larvae have been reared from: *Malus, Pyrus, Prunus padus, P. spinosa, Ribes nigrum* and also the other wild shrubs and trees such as: *Fagus sylvatica, Sorbus aucuparia* and *Cotoneaster*. Imagines of the species have been recorded in Norway between 13th May and 22nd September (all data based on collections from NHM UiO).

In addition, some other pest tortricids commonly found in the traps, were analyzed: *Enarmonia formosana* (Scopoli, 1763), cherry-bark moth, *Grapholita funebrana* Treitschke, 1835, plum fruit moth and *Ptycholoma lecheana* (Linnaeus, 1758), brindled tortrix.

2.3 Sampling in the orchards

Transparent plastic delta traps (21 cm x 10 cm x 8.5 cm) (Pherobank®, Wageningen, The Netherlands) with species-specific pheromone lures were used for monitoring the target species. Each delta trap consisted of a lure with pheromones hung 2-3 centimeters above the sticky surface (sticky insert) (Figure 2). Every lure was used for a period of 18 weeks but the sticky plates were changed every week (Table 2). The study was made in cooperation with advisors from Norwegian Agricultural Advisory Service (NLR). The orchards were regularly visited every ≈14 days in 2018 and every ≈7 days in 2019 in order to change the sticky inserts. The work in 2018 was done by NLR, without my personal involvement in the monitoring, whereas, all the inserts from 2019 were checked in the lab by myself. Both target and non-target lepidopterans were identified to species.

Figure 2 Design of delta trap baited with pheromone lure and sticky insert used in the study.

Table 2 List of the 2019 field visits with week numbers and dates (dates in bold were visited by the author, all the others by employees of NLR).

Orchard		**Week**																	
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
V1	**Date**	**2.5.**	9.5.	**17.5.**	23.5.	**30.5.**	**5.6.**	**12.6.**	20.6.	**26.6.**	4.7.	**11.7.**	18.7.	**24.7.**	1.8.	**6.8.**	15.8.	**23.8.**	29.8.
V2				**16.5.**			**6.6.**	**13.6.**		**27.6.**				**25.7.**					
V3																			
T1		3.5.	**7.5.**			31.5.			21.6.	**28.6.**	**5.7.**		19.7		3.8.			21.8.	**29.8.**
T2																			
T3																			

I also undertook a monitoring of the larval stages of tortricids in the three orchards in Telemark region (Table 1). Two orchards were organic (T1, T2) and one additional integrated orchard was used as control site (T3). The orchards were monitored three times: May 7th, May 16th and June 7th. During the first visit, a beating tray was tested, however, this method seemed to be not very effective. During the second visit, 10 random trees in each orchard were marked with a cord and checked. For the third visit, I chose an average-sized tree in close vicinity to each of those trees examined by the previous visit (in total 20 trees examined per orchard). The same rules were used for every orchard in Telemark. Subsequently, I spent approximately 20 minutes checking each tree, performing a detailed visual control of the whole tree up to a height of approximately 220 centimeters. I only collected tortricid larvae. During the field work and handling of samples, the larvae were temporarily stored in plastic bags and kept in a big cooling bag with ice packs.

Monitoring of skin damage and presence of larvae inside apples (Lepidoptera including *P. rhediella* and *C. pomonella*) were done twice. The first collection, July 1st, took place before the thinning (removal of damaged fruitlets by farmers) and the second, August 15th, shortly before harvesting. During both visits, 30 apples from 10 random trees were collected from each of the three orchards in Telemark region. The collecting the fruitlets and apples was done by Jop Westplate (Norsk landbruksrådgiving). A leaflet of Rein (1996) was used for identification of damage on the apples (Appendix 4).

2.4 Identification and laboratory work

All target species in the adult stage were easy to identify in the field, only on some occasions, if the specimens were too worn, or damaged from glue used in the delta traps, dissection in the laboratory was performed. The non-target species, both from target family Tortricidae and other lepidopteran families, were identified in the lab. The larvae collected from the field were reared in the lab (see below) and identified when the adult moths emerged. Difficult to distinguish species were dissected and genitalia were compared with literature by using a stereomicroscope and a compound microscope following standard techniques (Robinson, 1976). A few individuals of each of the following tortricids were dissected: *Adoxophyes orana, Archips rosana, Cydia nigricana, Eucosma cana, Cnephasia stephensiana, Pammene argyrana, Endothenia quadrimaculana, Aleimma loeflingiana, Epiblema cirsiana* and identified based on keys (Razowski, 2002; Razowski, 2003). From other families: *Bryotropha senectella,* *Anthophila fabriciana, Amphipoea fucosa, Cucullia chamomillae, Hoplodrina octogenaria, Mompha subbistrigella* and *Metzneria lapella* were dissected and identified based on an internet source: (www.mothdissection.co.uk, 2019).

The rearing of the larvae collected in the field took place in small plastic boxes with perforated lids kept at room temperature. Larvae from each tree were placed into separate box. The apple leaves larvae were feeding on were changed regularly, every third-fourth day, in order to provide fresh forage for the larvae. Pupae were moisturized regularly. The larvae collected on May 16th were put in a refrigerator in order to slow down their development during my absence from NIBIO (May 21st – 30th) without changing their forage supply regime.

2.5 Meteorological data

The temperature data were retrieved from the meteorological stations listed in Agricultural Meteorological Service (LMT). The closest meteorological station to the studied orchards were selected. The temperatures were measured 2 meters above the ground.

Subsequently, for every period between two field visits (Table 2), the mean value was calculated from the daily values of: maximal, mean and minimal temperatures in the period.

Table 3 List of the orchards and the meteorological station positioned nearest to each of them. Distance from the nearest meteorological station indicates the precision of the data.

Orchard	Name of the nearest meteorological station	Distance from the meteorological station (m)
V1	Rygge	5,260
V2	Lier	1,370
V3	Lier	2,260
T1	Gvarv	640
T2	Gvarv	1,200
T3	Gvarv	290

2.6 Statistical analysis

All analyses were conducted in the software R version 3.5.2 R (Core Team 2014) and the publication of Crawley (2012) served as a guideline. Some statistical analyses are performed on the four target tortricids trapped in a higher number, and some non-target tortricids which appeared to be numerous.

The flight activity of different species was processed by simple linear plots of weekly catches in pheromone traps. For diversity evaluation of adults and immature stages, the following formula, the Simpson's Diversity Index was used,

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

where n = the total number of individuals of a particular species and N = the total number of individuals of all species.

The effect of orchards's production system (IPM vs organic, Tab. 1) and of trap placement (edge vs middle, Fig. 1) on adult abundance was tested. Firstly the data were tested for normality by using Shapiro–Wilk test. Due to the non-normally distributed data, the Wilcoxon rank sum test (W) with continuity correction had to be used. Subsequently, the data were displayed by Box-whisker plots. The significance level used for tests was 0.05.

To analyze the effect of weekly averaged minimum, mean and maximum temperature on adult's flight pattern of the most common tortricids, a GLM model was chosen. After transforming weekly based data from 2019 (Figure 3) to every other week trap inspection (Figure 10), as it had been done in 2018, the variation in data was considerably reduced. Therefore the 2018 data were not included in the analysis. The residual deviance and degrees of freedom were compared in order to check data overdispersion. The p values <0.05 in the output of the analysis are marked in bold.

3 Results

3.1 Abundance and flight period

3.1.1 General overview of trap catches

During 2019 a total of 3,956 individuals of moths belonging to 54 species and 13 families were captured in the traps. In this chapter, those species regarded as pests are described in detail (82.1% of the total number of moths). The flight periods of some of the reminders are included in Appendix 3. Due to the high proportion of non-target species in the catch, the following subchapters are divided into separate categories: the target tortricids, other pest tortricids, and other lepidopteran pests.

3.1.2 Target tortricids

The presence of all six target species was documented by pheromone trap monitoring in 2018 and 2019 (Table 4). Two of them appeared to be rare – *A. orana* was present but very rare in both regions and *P. heparana* was found only in the Viken region. Because of the low abundance of these two species, most of the statistical analyses provided in later stages of this thesis do not include them. The remaining four target species were significantly more abundant.

The abundance of two species, *C. pomonella* and *A. podana*, followed more or less the same pattern in both regions Viken and Telemark, whereas *P. rhediella* was markedly more abundant in Telemark and *H. nubiferana* in Viken. The total abundance of the four numerous species all together reached a slightly higher number in 2019 – 2,423 individuals, against 2018 – 2,208 individuals (difference equivalent to 8.9% decline). The annual deviations in abundance were approximately the same for each species in both regions (species either increased in both regions, or decreased in both regions).

Three of the four numerous species showed a difference in their phenology among the regions (Figure 3). The emergence of *A. podana* occured one week earlier in Telemark. The first individuals of two species, *P. rhediella* and *H. nubiferana,* appeared in both regions at the same time, but with higher initial numbers in Telemark. The swarming time (peak activity) of *H. nubiferana* and *A. podana* was reached one week earlier in Telemark. Two other species followed the same trend between the two regions for most of their flight period (more about shifts between the regions during the two years 2018-19 can be found in chapter 3.3.2).

Table 4. Average abundances of target species per trap with standard deviation. Data from the Viken and Telemark regions for 2018 and 2019. The target species captured by non-target traps are not included. The species are sorted based on the total catch from the two years. The species with numbers in parentheses were possibly not identified correctly.

Target species	**Abundance in Viken**		**Abundance in Telemark**	
	2018	**2019**	**2018**	**2019**
Pammene rhediella	37.2 ±22.9	32.7 ±33.5	75.2 ±70.8	40.8 ±37.8
Hedya nubiferana	43.7 ±19.3	51.1 ±48.1	15.8 ±9.6	25.0 ±17.4
Cydia pomonella	11.2 ±8.5	43.6 ±32.2	20.1 ±13.5 *	41.8 ±20.7
Archips podana	22.1 ±9.2	17.7 ±20.8	20.0 ±6.2	16.7 ±15.9
Adoxophyes orana	(0.7 ±0.8)	0.2 ±0.4	(0.2 ±0.6)	0.1 ±0.3
Pandemis heparana	(8 ±5.3)	0.1 ±0.3	(6.6 ±4.8)	0

* The flight pattern of *C. pomonella* suggests this species had a second generation only in Telemark, in 2018. Abundances of the first generation in 2018 were almost identical in both regions.

Flight period in 2019

P. rhediella was recorded for the first time in week 18 (April 26th – May 2nd), the time when pheromone trapping was started in 2019. Because of late traps deployment of the traps, it is not known when the first imago emerged. The flight period of the species showed, compared to the other species, a sharp rise and fall in a relatively short period. In week 20 (May 8th – 16th) the flight period reached a maximum of 20.2 moths/trap in Viken and 18.0 moths/trap in Telemark.

C. pomonella emerged in week 21 (May 16th – 23th) in Viken, and in week 22 (May 23th – 31th) in Telemark. In week 25 (June 13th – May 20th) the flight period reached a maximum of 8.2 moths/trap in Viken and 12.9 moths/trap in Telemark. After 2 – 3 weeks with no catch (weeks 32-34), 3 individuals appeared in the last week of trapping – week 35 (August 23th – 29th).

H. nubiferana emerged in week 23 (June 31st May – 6th) in both regions. Later, the swarming time in Telemark was reached between weeks 24 (June 6th – 13th) and 25 (June 13th – 21st), both weeks with 7.1 moths/trap. The peak of flight activity in Viken was delayed until week 27 (June 26th – July 4th) with 11.2 moths/trap.

A. podana emerged in week 25 (June 13th – 21st) in Telemark and in week 26 (20th – 27st June) in Viken. In week 26 (June 21st – 28th) the flight period reached the maximum of 4.8 moths/trap in Telemark, and subsequently dropped down preliminary. The peak of flight activity in Viken was delayed until week 28 (July 4st – July 11th) with 5.4 moths/trap.

A. orana – two individuals observed between week 26 and 28 (June 20st – July 11th) in Viken and one individual in week 28 (July 5st –11th) in Telemark.

P. heparana – only one individual observed in week 28 (July 4st – 11th) in Viken.

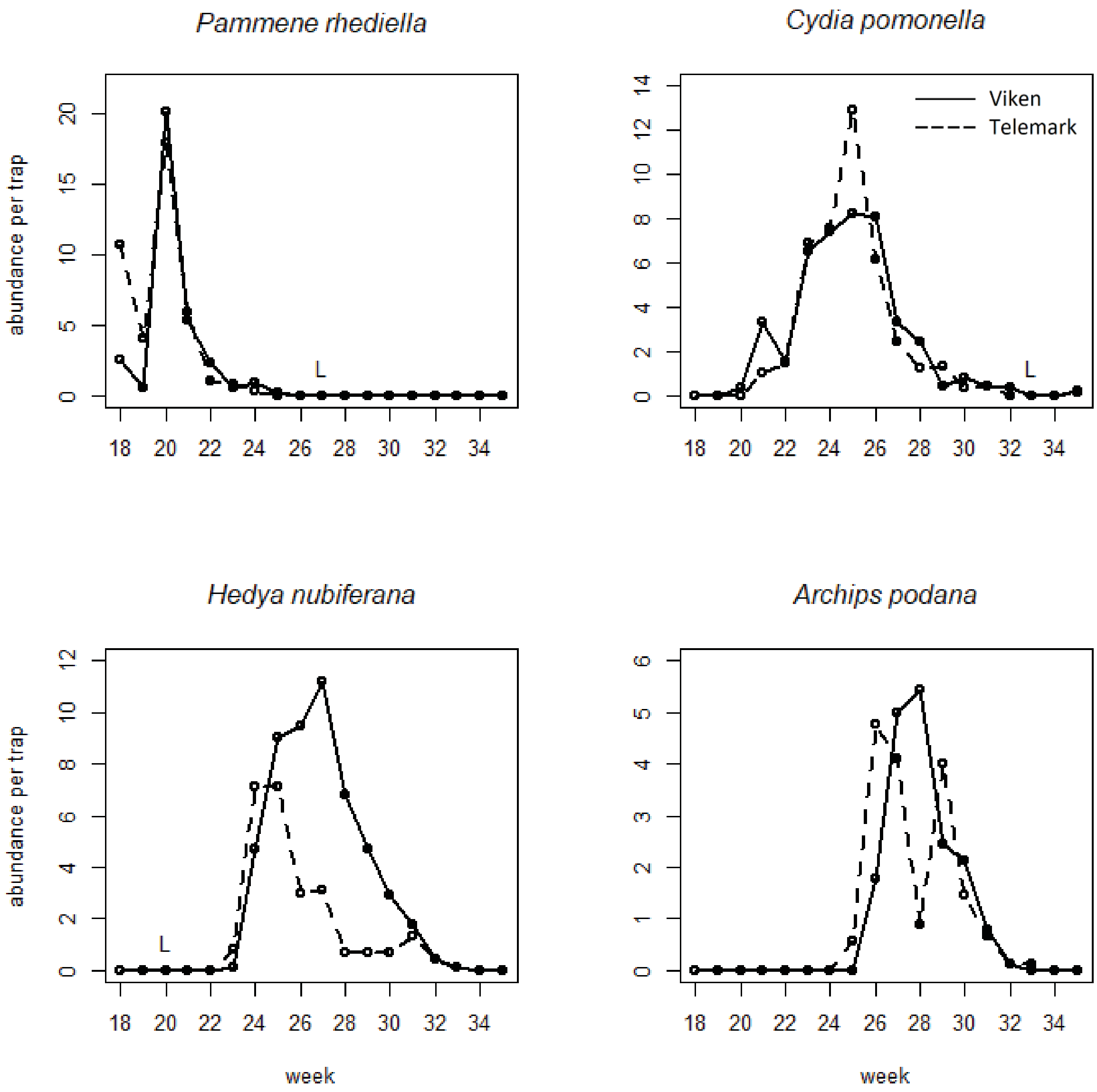

Figure 3 The flight activity of the four most numerous target species in the two regions in 2019 (average numbers of males per target trap used, n=9). Only male catches from target traps included. Symbol L indicates the week in which the larval stages were observed in Telemark. Note the different y-axis scale. The other two target species are not displayed due to the low numbers.

3.1.3 Other pest tortricids

Besides the target tortricids, some non-target tortricid pests were commonly attracted to the pheromone lures. Therefore, data used in the following graphs provide only a rough outline of their real abundance. The three most abundant species are shown in Figure 4.

E. formosana was observed for the first time in week 23 (May 31st – June 6th) and then reached its flight maximum in week 25 (June 13st – 20th). Occasional findings were possible too after the last recorded individuals in week 34 (August 15st – 23th) when the monitoring had finished.

G. funebrana was observed for the first time in week 21 (May 16st – 23th). Two well-defined peaks of its flight activity were observed. The total maximum of flight activity was reached in week 23 (May 30st – June 6th) and the second, not very pronounced peak, around weeks 33 to 34 (August 6st – 23th). Its flight activity apparently continued after August 29th, when the study had finished.

P. lecheana was observed for the first time in week 23 (May 30st – June 6th). A week after - week 24 (June 6th – 13th) the flight time reached its maximum. The last individuals were found in week 27 (June 27th – July 4th). The flight followed the same pattern in Viken and Telemark.

Table 5 Total numbers of other tortricid pests for each region. The male catch from all traps from three orchards for each species used (n=54). The flight period is combined for the two regions.

Species	**Abundance**		**Weeks**
	Viken	**Telemark**	
Acleris holmiana (Linnaeus, 1758)	0	1	30
Archips crataegana (Hübner, 1799)	13	1	27-28
Archips rosana (Linnaeus, 1758)	2	0	28, 31
Syndemis musculana (Hübner, 1799)	4	6	18-20
Spilonota ocellana (Denis & Schiffermüller, 1775)	1	0	29
Cydia nigricana (Fabricius, 1794)	9	12	24-28
Pammene argyrana (Hübner, 1799)	3	1	20-25
Total number	**32**	**21**	

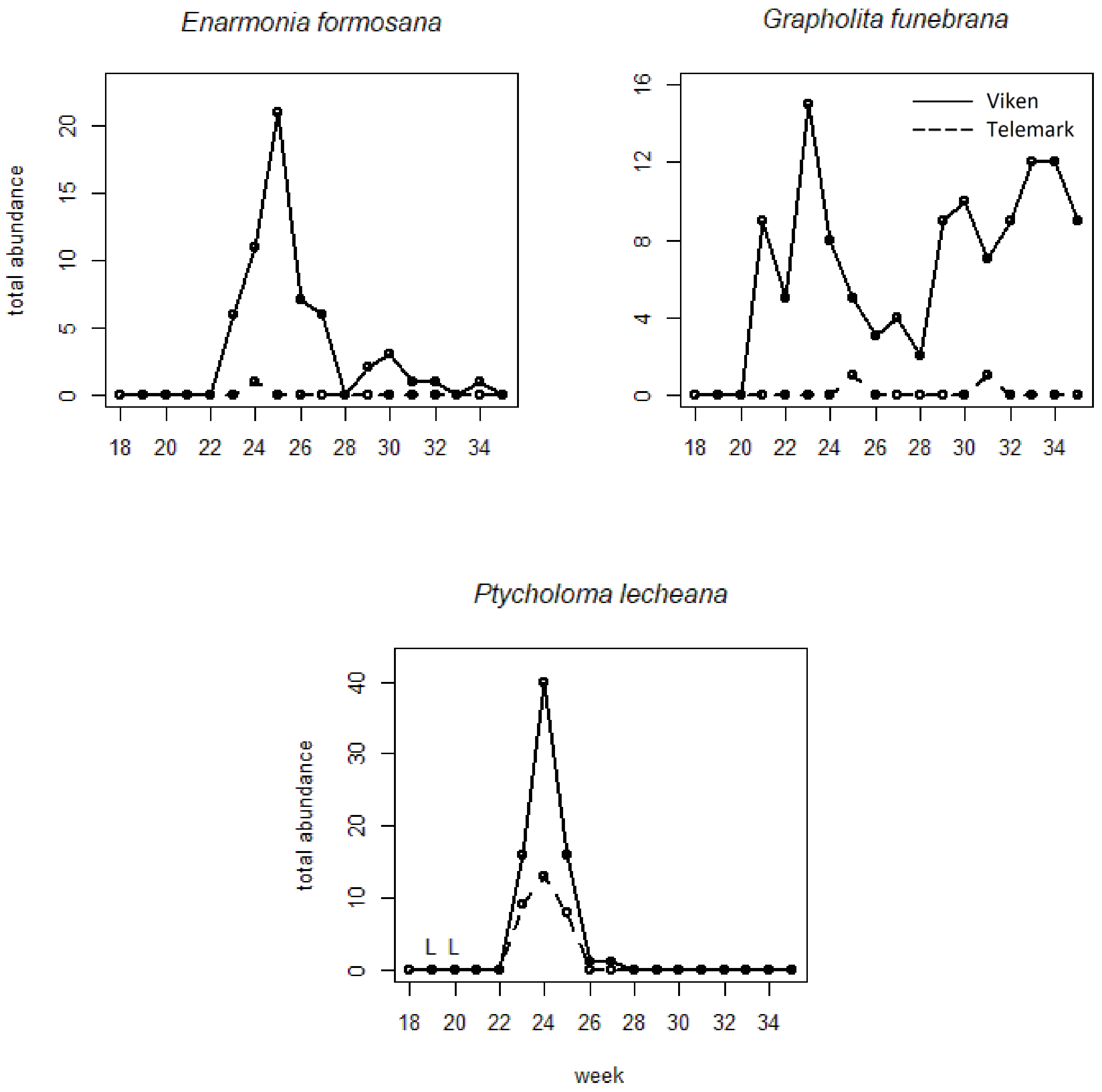

Figure 4 The total catches of the three most numerous non-target pest tortricids found in traps of target species (male catch from all traps for the six target species used, n=54). Symbol L indicates the weeks in which the larval stages were observed in Telemark. Note the different y-axis scale. Not all the species described above are displayed due to their low numbers.

3.1.4 Other lepidopteran pests

Ten additional lepidopteran pests, not belonging to the Tortricidae family, were caught in the traps (Table 6). All included species in this category are defined as pests by Alford (2007). Their total number is equal to 14.9% of all lepidopteran individuals found in 2019. The species belonging to the following families are sorted in a descending order with numbers of the species in parenthesis: Noctuidae (3), Gracillariidae (2), Gelechiidae (2), Yponomeutidae (1), Plutellidae (1) and Lyonetiidae (1). The two most numerous species are shown in Figure 5.

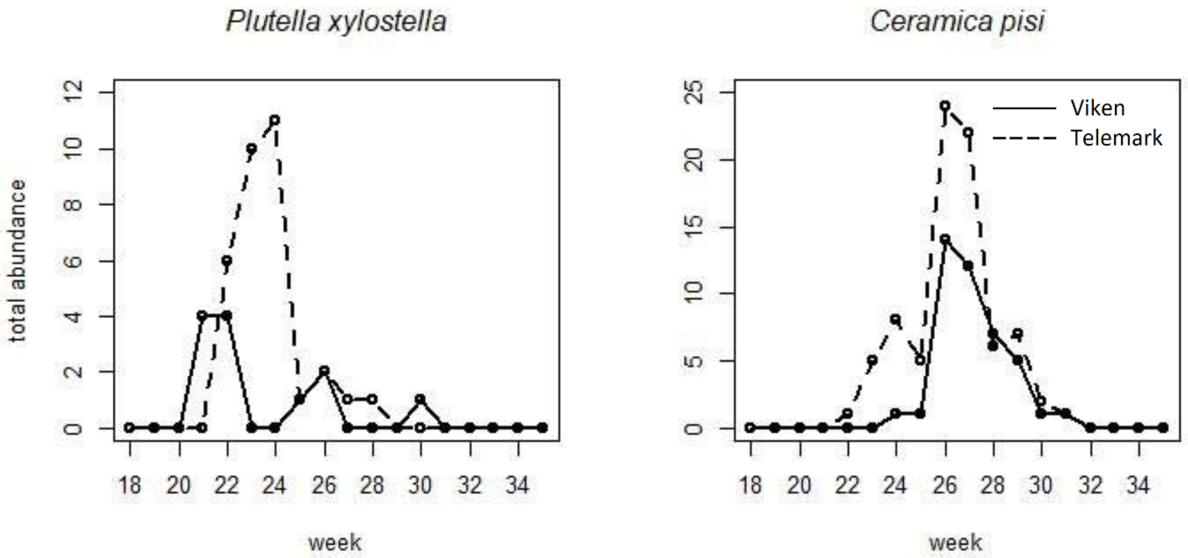

Figure 5 The flight activity of the two most numerous lepidopteran pests. Total male catch from traps for all six target species (n=54). Note the different y-axis scale.

Table 6 Total numbers of other lepidopteran pests for each region. The male catch from all traps from three orchards for each species used (n=54). The flight period is combined for the two regions.

Species	**Abundance**		**Weeks**
	Viken	**Telemark**	
Callisto denticulella (Thunberg, 1794)	1	6	22-24
Phyllonorycter blancardella (Fabricius, 1781)	13	3	31-35
Euhyponomeutoides albithoracellus Gaj, 1954	8	4	31-35
Lyonetia clerkella (Linnaeus, 1758)	17	3	28-35
Recurvaria leucatella (Clerck, 1759)	1	1	28-31
Gelechia rhombella (Denis & Schiffermüller, 1775)	1	0	29
Noctua fimbriata (Schreber, 1759)	20	3	33-35
Autographa gamma (Linnaeus, 1758)	0	6	24-27
Total number	**115**	**134**	

3.1.5 Catches of moths not considered as pests

In addition to the species described in the previous chapters, a variety of innocuous lepidopteran species (not considered pests on any crop) were caught by the target pheromone traps. In 2019, I identified 46 such species, which is equal to 78% of all lepidopteran species found in the traps in Telemark and Viken. The total abundance of all innocuous species is 639, which is equal to 17.9% of all lepidopteran individuals found in 2019. Most of the species from this category (19), belong to the family Tortricidae, the remaining families represented by one or more individuals are sorted in descending order: Noctuidae (8 species), Gracillariidae (5 species), Gelechiidae (4 species), all other families, Crambidae, Geometridae, Chimabachidae, Choreutidae, Momphidae, Pyralidae and Ypsolophidae, were represented by one species each.

The most common accompanying species from this category were: *Eucosma cana* (Haworth, 1811) – 182 individuals, *Euspilapteryx auroguttella* (Stephens, 1835) – 137, *Bryotropha senectella* (Zeller, 1839) – 97, *Amphipoea fucosa* (Freyer, 1830) – 63, *Cucullia chamomillae* (Denis & Schiffermüller, 1775) – 48, *Celypha striana* (Denis & Schiffermüller, 1775) – 24 and *Grapholita compositella* (Fabricius, 1775) – 23.

3.2 Relationship between larval and adult occurrence

Data from visual control of tortricid larvae and pheromone traps monitoring were combined here in order to reveal to what extent the species composition and abundances of these two methods of monitoring match. The monitoring of larvae was restricted to the Telemark region. The total abundance of larvae obtained by visual monitoring was approximately 27 times lower than the total abundance of imagines attracted by the traps. No larvae were found in control IPM orchard T3 (Table 7).

From the target species, *C. pomonella*, *P. rhediella* and *H. nubiferana,* were recorded both as larvae and adults. *P. heparana* was found only in the larval stage, and *A. podana* and *A. orana* vice versa were only caught by pheromone traps (Table 7).

Four of the non-target pest tortricids attracted by the target pheromone lures were also found as larvae, *P. lecheana, A. rosana, A. holmiana* and *S. ocellana,* (imago of the last species, however, trapped only in Viken). Three species, *P. cerasana, A. variegana* and *R. naevana* were confirmed only by larvae monitoring and two other species, *S. musculana* and *A. crataegana,* vice versa only by pheromone traps. The same applies for *E. formosana, G. funebrana, C. nigricana* and *P. argyrana* whose larvae are, however, not leafrollers and thus could not have been spotted by my methods of larvae monitoring.

Although eight species in total were reared from larvae in both organic orchards (T1, T2), the species composition and abundances differed to some extent. The most remarkable is the case of *R. naevana*, whose larvae occurred in a relatively high number in field T2, but was absent in T1.

Simpson's index of diversity (SID), tended to have lower values (i. e. lower biodiversity) for larvae collection than pheromone trapping in both orchards where the larvae were found. Data also indicate that both *C. pomonella* and other Lepidopteran damage on apple fruits increased with increasing SID (based on damage data from NLR). The value of SID for pheromone catches is lowest in the IPM orchard. The main target tortricid *C. pomonella* is present in IPM orchard T3 only as an adult.

Table 7 Total abundances of adults and larvae of Tortricidae pests from all three orchards in Telemark. Lepidopteran damage monitored shortly before apples thinning and data for *C. pomonella* before apple harvesting are attached in the last two rows (data from Jop Westplate, NLR, n = 300). All other numbers derived from the author's data.

Telemark		**T1 (organic)**		**T2 (organic)**		**T3 (IPM)**	
Species	Category	Adult	Larvae	Adult	Larvae	Adult	Larvae
A. orana	target	0	0	1	0	0	0
P. heparana	target	0	2 [c]	0	1 [b]	0	0
A. podana	target	37	0	73	0	40	0
H. nubiferana	target	77	4 [b]	147	0	19	0
C. pomonella	target	189	34 [e]	175	33 [e]	156	0
P. rhediella	target	256	1 [d]	140	3 [d]	10	0
P. lecheana	non-target	11	1 [b]	14	1 [a]	5	0
S. ocellana	non-target	0	1 [b]	0	0	0	0
A.variegana	non-target	0	1 [c]	0	0	0	0
A.holmiana	non-target	1	2 [c]	0	2 [c]	0	0
R. naevana	non-target	0	0	0	10 [c]	0	0
A. rosana	non-target	0	0	0	2 [c]	0	0
P. cerasana	non-target	0	0	0	1 [b]	0	0
C. nigricana	non-target	0	0	8	0	4	0
E. formosana	non-target	2	0	0	0	0	0
G. funebrana	non-target	0	0	0	0	2	0
S. musculana	non-target	2	0	4	0	0	0
P. argyrana	non-target	0	0	1	0	0	0
A. crataegana	non-target	0	0	1	0	0	0
Total number of species		**8**	**8**	**11**	**8**	**7**	**0**
Total abundance		**574**	**44**	**565**	**53**	**234**	**0**
Simpson's index of diversity		**0.671**	**0.399**	**0.759**	**0.581**	**0.528**	**-**
***C. pomonella* damage (%) [e]**		**-**	**20.3**	**-**	**34.3**	**-**	**0**
Other lepidopteran damage (%) [d]		**-**	**26.7**	**-**	**39**	**-**	**12.3**

Collecting dates for a-e: a – 7.5., b – 16.5., c – 7.6., d – 1.7., e – 15.8.

3.3 Factors affecting catch extent

3.3.1 Production system and trap placement

In terms of the total abundance of the four most common species, there was a significant difference between the two **production systems** (W=378.5, P=0.023, n=67). The differences were even more pronounced on the species level. Two of the species tended to be significantly more abundant in organic orchards, *H. nubiferana* (W=6, P=0.005) and *P. rhediella* (W=6.5, P=0.005), whereas no significant difference was shown by *A. podana* (W=47, P=0.13) and *C. pomonella* (W=44, P=0.48) (Figure 6). On the contrary, the last two species were more abundant in the IPM orchard in Viken (not shown in graph).

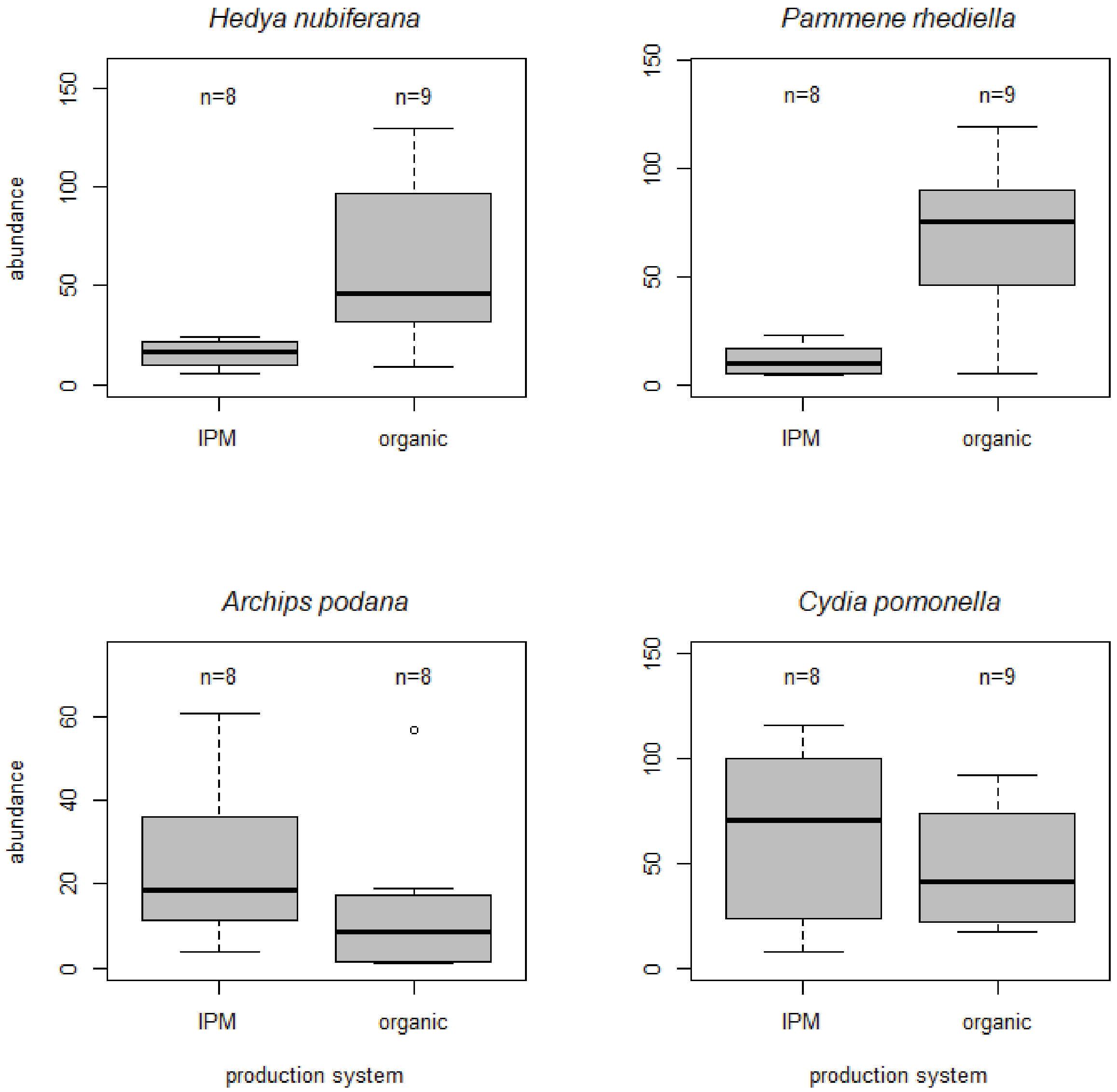

Figure 6 Box-whisker plots of the total abundance of four numerous target species based on production system.

Total abundance of the four species analyzed above was also significantly affected by **trap placement** only in IPM orchards (W=175, P=0.035) and not in organic orchards (W=127, P=0.72). There is a lack of data for evaluating the effect of trap placement at the species level.

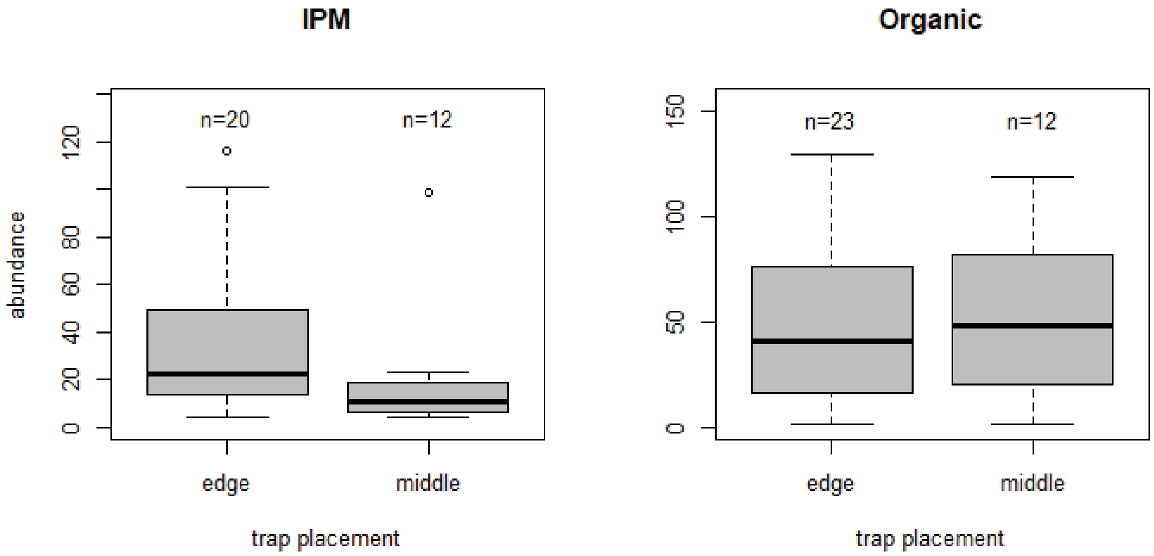

Figure 7 Box-whisker plots of the total abundance of four numerous target species based on traps placement.

3.3.2 Temperature

Differences between the years

The average annual air temperature for both regions included was 0.35 °C higher in 2018 compared to 2019 (Figure 8). Mainly late spring and summer (May 3th – July 27th) were markedly warmer in 2018, whereas late winter and the first half of spring (February 12th – April 16th) were markedly warmer in 2019. The difference between the years raise up to +2.6 °C for 2018 by restricting only on the period of traps servicing (April 26th – August 30th, resp. weeks 18 – 35) (Figure 6b, 7).

Differences between the regions

The average annual air temperature for both years 2018 and 2019 was 0.57 °C higher in Viken than Telemark. The average temperature in the period when the traps were in service was, for both regions, nearly the same in 2018 (0.01 °C higher temperature in Telemark), but 0.4 °C higher in Viken the next year - 2019.

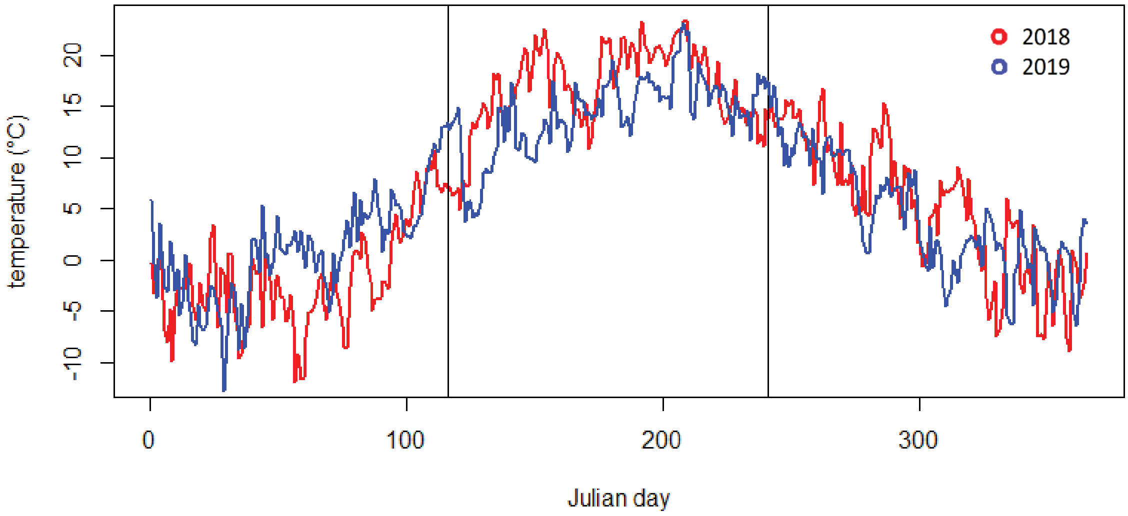

Figure 8 The daily mean temperatures in 2018 and 2019. Each line represents the averaged values from the respective meteorological stations located in the two regions (see methods). The time during which the pheromone traps were serviced is shown by vertical lines. The differences between the regions were negligible and thus the average values are used.

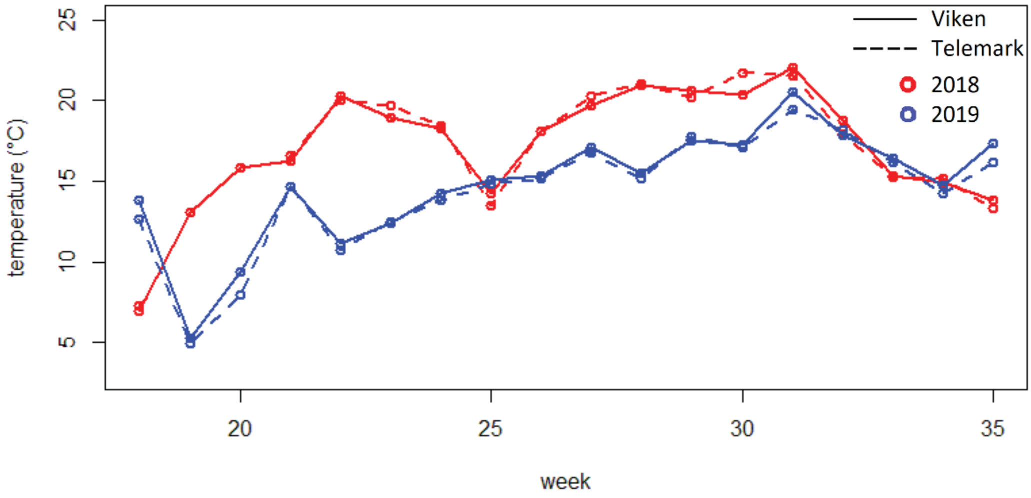

Figure 9 The weakly mean temperatures for Viken and Telemark in 2018 and 2019. The temperatures were recorded during the weeks 18-35, when the traps were serviced. No available data in LMT for weeks 18 and 19 in 2018 from the meteorological station Gvarv in Telemark.

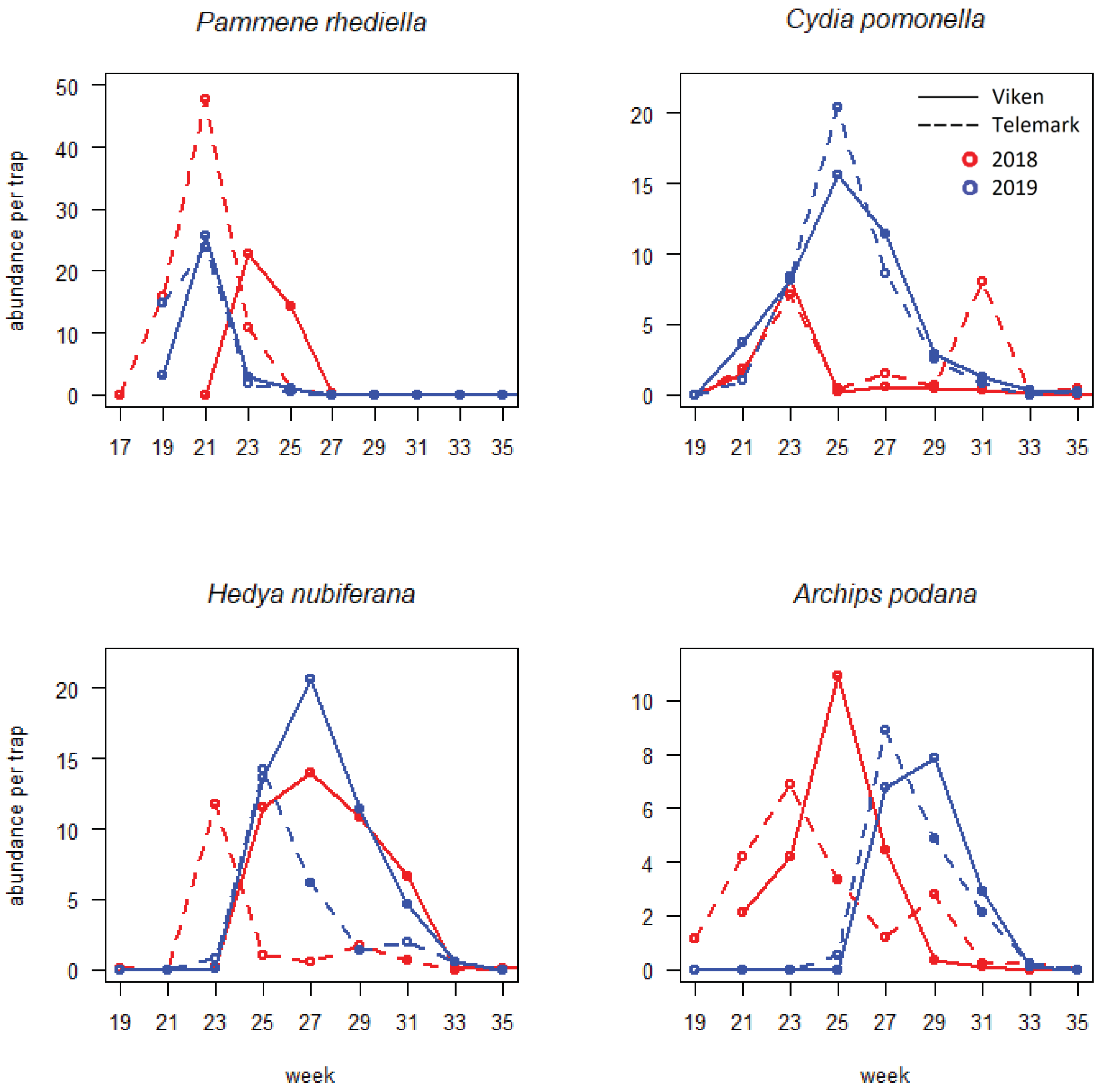

Figure 10 Flight activity of *P. rhediella, C. pomonella, H. nubiferana* and *A. podana* in 2018 and 2019 from Viken and Telemark. The graphs are arranged according to timing - from early spring to summer species. Pheromone traps in 2018 were inspected every other week and the weekly base data from 2019 are collectively compared in the same format. The average numbers per trap are provided, n=9 for each line.

Differences in activity of moths between the years

The peak activity of *P. rhediella* was recorded earlier in 2019 in Viken, but no such shifts were found in Telemark (no early data from 2019 were available to evaluate emergence). The emergence time of *C. pomonella* followed nearly the same trend in both years, however, in 2018 two generations appeared in Telemark. The most markable shifts in the flight activity are recorded for *A. podana*, as well as for *H. nubiferana* (only in Telemark). For both species in 2018 their flight period began somewhat earlier.

Differences in activity of moths between the regions

The flight activity for most of the species was delayed in Viken compared to Telemark (Figure 10). Most pronounced is the later onset for *P. rhediella, H. nubiferana* and *A. podana* in both years. The pattern of the first generation of *C. pomonella* in 2018 pretty much coincides in both regions, however, the additional second generation was present only in Telemark. No significant differences are seen for 2019.

Figure 11 shows the temperature ranges of the most numerous tortricid species. The sequence of temperature ranges coincides with the sequence for the onset of the species (i.e. the spring species' flight activity was concentrated at lower temperature ranges). The variation decreases from spring to summer (except for *P. lecheana*).

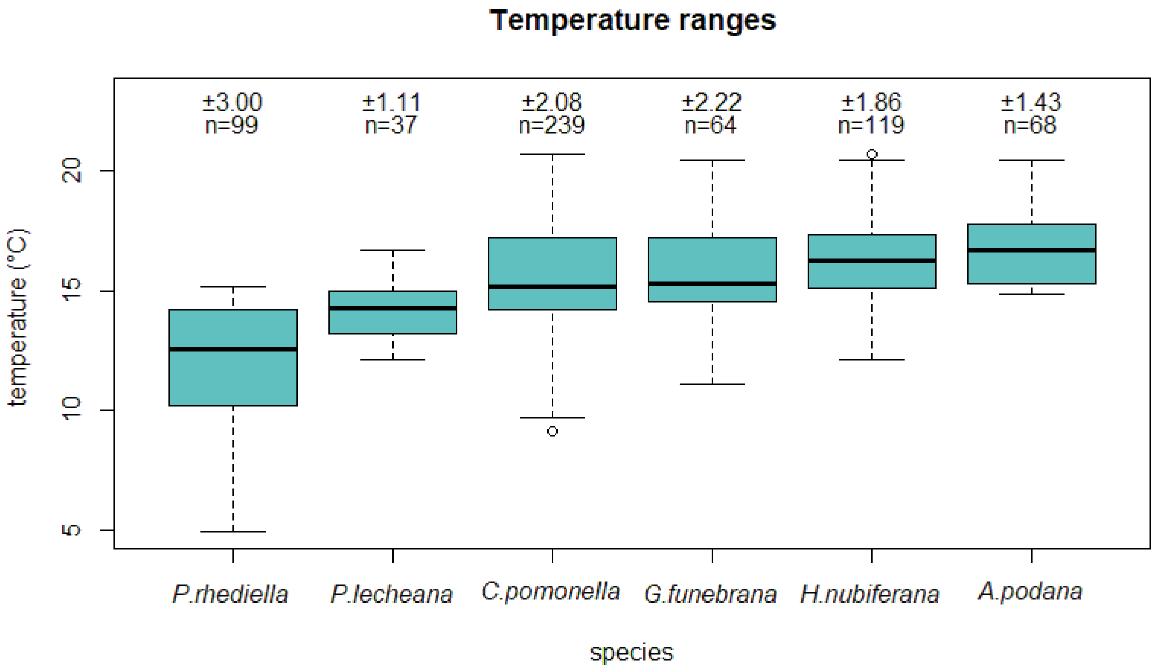

Figure 11 Presence of the most numerous tortricids collected by the pheromone traps related to temperature. Data from all six orchards and traps from 2019 are included. One weekly mean temperature was assigned to each sighting of the species when the traps were in operation, but the abundances in respective weeks are not considered. The species are sorted from left to right, based on the first emergence of imagines.

As can be seen in Table 8, most of the species have the tendency to be more influenced by minimum temperature. This applies mainly for *G. funebrana* and *H. nubiferana.* In contrary, *A. podana* seems to be limited more by the maximum temperature. No differences are pronounced in the case of *P. rhediella* and *C. pomonella*.

Table 8 Output of the GLM analysis – weekly minimal, mean and maximal temperatures related to the abundances of the most numerous tortricids caught in both target and non-target traps. The first row for each species covers the whole flight period, the second one the period leading up to the peak of their activity. Bold indicates significance at P < 0.05, n shows total number of observations.

Temperature	**Min**			**Mean**			**Max**		
Species	**Std. Error**	**t value**	**p-value**	**Std. Error**	**t value**	**p-value**	**Std. Error**	**t value**	**p-value**
G. funebrana n=41	0.061	2.511	**0.012 ***	0.060	2.047	**0.041 ***	0.051	1.922	0.055 .
	0.067	2.177	**0.030 ***	0.065	1.807	0.072 .	0.056	1.739	0.088 .
H. nubiferana n=24	0.057	2.740	**0.006 ****	0.056	1.883	0.060 .	0.047	0.994	0.32
	0.130	4.969	**1.11e-06 *****	0.107	4.023	**7.22e-05 *****	0.083	2.563	**0.011 ***
A. podana n=33	0.073	2.390	**0.017 ***	0.069	4.156	**3.76e-05 *****	0.055	5.266	**2.01e-07 *****
	0.173	1.945	0.053 .	0.158	5.716	**2.26e-08 *****	0.099	7.539	**3.71e-13 *****
P. rhediella n=46	0.028	-12.03	**<2e-16 *****	0.030	-11.83	**<2e-16 *****	0.031	-10.91	**<2e-16 *****
	0.071	0.061	0.95	0.069	-0.040	0.97	0.060	-0.449	0.66
C. pomonella n=141	0.033	-0.379	0.70	0.031	-1.282	0.20	0.028	-1.687	0.092 .
	0.064	4.173	**4.11e-05 *****	0.072	3.844	**0.0002 *****	0.066	3.662	**0.0003 *****

3.4 Specificity of pheromone lures

The proportion of target individuals found in the traps varied considerably among the six species. Only one pheromone lure, ARPO (acronym of the target species), was very specific for its target species, *A. podana*. All the other lures, in addition to the target species, also attracted other tortricids (Table 9) and different families of Lepidoptera. Two lures, CYPO and PAHR, appeared to be very conspecific: adults of *C. pomonella* and *P. rhediella* were often found in the trap with lure developed for other species of this couple. Two other lures, ADOR and PAHE, trapped their target species only in a small amount. Moreover, the lure PAHE was very specific - attracting a non-target species *P. lecheana* instead. Other conspicuous non-target tortricids were: *G. funebrana*, attracted only by HENU, and *E. formosana*, which was caught predominantly by PARH. Two target lures also specifically attracted the following two abundant but innocuous tortricids: *Eucosma cana* – HENU, *Celypha striana* – PARE. A few individual specimens of many other tortricid species were also observed. The recognition of similar tortricids and possible mistakes in their identification are attached in the appendix.

Specificity of pheromone lures employed for the four most numerous target species ranged between 71 and 88%, whereas for the other two, *P. heparana* and *A. orana*, the probability of being trapped decreased to 0.3 and 1.0%, respectively (Table 9).

Table 9 Total numbers of pest tortricids from all six orchards captured by pheromone lures. Only the most numerous species are included. The increase in specificity is indicated by a light green to dark green color for each lure separately. Maximum values of specificity are shown for each lure in dark green. The sequence of lure acronyms (horizontally) is the same as the sequence of the species (vertically). The total catch of all lepidopteran individuals and the percentage proportion of the target species are included in the last three lines.

Species	Lure (acronyms used in Pherobank catalogue)					
	CYPO	PARH	HENU	ARPO	ADOR	PAHE
C. pomonella	813	151	6	1	12	7
P. rhediella	56	670	1	0	0	0
H. nubiferana	0	2	748	1	0	0
A. podana	0	0	0	318	0	1
A. orana	0	0	0	0	3	0
P. heparana	0	0	0	0	0	1
P. lecheana	0	0	0	0	0	113
G. funebrana	0	0	121	0	0	0
E. formosana	7	41	7	1	1	3
Total catch of Lepidoptera	924	927	1,053	367	301	384
Target species proportion (%)	88.0	72.3	71.0	86.6	1.0	0.3

4 Discussion

4.1 Flight activity of target tortricids

The flight patterns indicate that all four more common target species experienced one generation in 2019 (Figure 3,4). The abnormally warm summer of 2018 probably triggered a second generation of *C. pomonella* (Figure 10). It happened only in the Telemark fruit district once during the whole period (2017-2019) of the project Åmeåtak (Jaastad, 2020). This phenomenon used to be rather rare for that species in Norway, for instance Edland and Berle (1994) reported a second generation in Lier (Viken region) in 1976. Other species are very likely monovoltine in Norway. In southern latitudes *P. rhediella* seems to be univoltine (Razowski, 2003), while Central Europe is a transition zone for the second generation of *P. heparana, H. nubiferana* (Stara & Kocourek, 2001), as well as *A. podana* and *A. orana* usually being bivoltine there (Kocourek & Stara, 2005; Stara & Kocourek, 2005).

Variation in abundance between the two years seemed to be great for *P. rhediella* in Telemark - the abundance in 2019 reaching only half the number of the 2018 abundance at its peak (the whole abundance cannot be assessed due to missing data from early spring 2019). In contrast, *C. pomonella* experienced significant growth of abundance in 2019, on average 172% for both regions, which may be the result of 2018 being a very favorable year for development of the immature stages.

Collections from museums offer a rich source of data about phenology across insect groups. The most comprehensive data on the four numerous species, gathered from various regions of Norway in the last four decades, are registered in the catalogue of the Naturhistorisk museum in Oslo (NHM UiO). Temporal climate anomalies from year-to-year (Pak et al., 2019), varied topography and a large latitudinal range (Tauber et al., 1986) cause variability in phenology. Therefore, data from the NHM UiO make a broad base line that can be compared with flight dates obtained in my own fieldwork.

Most of the target species occurred within the same time period as the NHM UIO data. However, activity of two species began earlier in spring 2019 than previously recorded in Norway. The first individuals of *C. pomonella* were observed at least two days earlier, and *P. rhediella* at least one day earlier. Furthermore, the first *P. rhediella* individuals probably emerged even earlier as a high number of moths were observed during the first control of the traps.

Stensland (1993) studied the abundance and flight activity of three of the target species included in my study (*P. rhediella, C. pomonella* and *A. podana*). Her investigation took place in 1990 and 1991 in four apple orchards near Svelvik and two near Ås. Both locations lie in the Viken region. This makes the data partially comparable with ours from this region.

The hatching and swarming of *A. podana* were recorded on average 6.5 and 4.5 days earlier by Stensland than in my study. Its larval development in 2019 might have been delayed due to lower temperatures in the first twenty days of May. Stensland's study also showed fluctuations in the abundance of *A. podana* with two well-developed peaks during its flight activity.

The opposite trend is displayed for the hatching and swarming of *C. pomonella* which was recorded on average 16.5 and 20.5 days later by Stensland. Her monitoring was restricted to 1991, whereas no monitoring was carried out in the warmer year of 1990 (historic temperatures from Svelvik available on www.yr.no). The species might have started hatching earlier in 2019 as usual because of the high April temperatures.

It is difficult to compare the start of the *P. rhediella* flight period between mine and Stenslands's study as the traps were probably deployed too late in 1990 and 1991 (in May). As soon as the traps were put into operation, specimens were immediately caught. Even though the emergence cannot be compared, the swarming time appeared approximately 10 – 15 days earlier in 2019. The total catch was markedly lower in 1990 and 1991, compared to my data.

Comparing the flight activity with Stensland's study does not reveal clear trend in shifts in the flight activity of the moths. This may be due to the short period of tortricid trapping restricted to 1 or maximum 2 years and the low number of orchards included in the analysis.

4.2 Flight activity of other Lepidoptera

It is important to note that the phenology and abundance of non-target species recorded in the traps of target species do not necessarily reflect their actual abundance in the locality where they were recorded. For this reason, their abundance cannot be compared with the target species. However, for such abundant species like *E. formosana, G. funebrana* and *P. lecheana* with similar phenology to the target species, it is likely that their true emergence and swarming period is well reflected by the trap phenology.

Information on flight activity of other tortricid pests based on pheromone traps catches is limited in Norway. Strandtun (2017) studied the flight activity of *G. funebrana* in selected orchards in Viken. The most representative graph drawn is based on data from Ås. The first individuals appeared there in week 21 (May 23th) and the species numbers reached their lowest around week 30, a week later no more specimens being caught. However, my data from Viken show a prominent increase of abundance after week 28 (Figure 4), it presumably establishing a second generation that year.

E. formosana imagines appeared in the study of Stensland (1993) at the same time as in my data, or somewhat earlier. The earliest individuals were recorded in week 22 (May 25th). However, my observations of this species lasted one year less. Stensland's one year-based data on *P. lecheana* from Svelvik significantly differ from my data on this species. Even though the emergence is reported from week 23 (June 4th), which matches with my data, a majority of the individuals were recorded in weeks 28-32. During this time in 2019, the species reached, after a sharp fall, a zero catch. A significantly longer length of the flight period was, however, observed by the author in the traps from the Sogn region (Western Norway) during weeks 25-35 (the exact data are not available here).

Another tortricid *P. argyrana* seemingly not common in Viken nor Telemark (Table 5) appeared to be very numerous in Sogn, where it was spotted in the hundreds. It is not impossible that this species, not yet considered as an important pest, may cause more damage on apple fruits if it reaches such a high abundance.

In addition to tortricids described above, species from other families were present too. Adult moths of *P.xylostella* (Plutellidae) migrate to Norway on warm winds from eastern and southeastern countries (Russia, the Baltic, Turkey). In 2019, Annette F. Schjøll (pers. comm.) announced the first observation of individuals in Lier (Viken region) between May 17th and 18th. My recordings match that observation. This information indicates that the same methods used for monitoring of target species might be also applicable for monitoring of some other, very numerous, non-target species of Lepidoptera.

The majority of the non-target lepidopteran pests are associated with apples. However, *G.funebrana*, whose larval development is linked to plums *Prunus*, *Cydia nigricana*, a species developing on peas *Pisum sativum,* and *C.pisi* a pest on cabbage *Brassica* (Reiprich, 2001) are exceptions. These plants might have been presented in surrounding gardens.

4.3 Relationship between larval and adult occurrence

Differences in species composition and timing of imagines and larvae

The abundance of most species in the larval stage did not reflect the abundance of imagines caught by the pheromone traps. This might be due to a low number of trees examined for larval presence, the sampling method used, or that only two sample examinations were performed during the season. On the other hand, the pheromones attract individuals from a wider area, and might not reflect the actual presence of larvae in the specific field.

Despite relatively high numbers of *A. podana* imagines in the traps, no larvae were found at the time when monitoring took place. It is surprising, due to the fact that the rearing experiments of Sylvén (1958) produced this species in similar high numbers compared to other common species included in his study. The other tortricids were also obtained in my fieldwork. His collections took place during two periods similar to mine: fairly early in the spring and early in the summer (without the exact dates being known). However, the method of larvae collection is not mentioned in the paper. Those *A. podana* larvae collected in this study could have also been affected by cooling all the larvae from the first collection which resulted in a higher mortality (see methods, p. 11). The species *A. orana* was either not present as an imago, or appeared to be very rare in traps from several study sites. Due to this, the larvae could not be expected. *P. heparana* is the only case of a target species where the visual monitoring of larvae proved a higher number of individuals. Thus, it is very likely that the low catches was affected by the low effectivity of pheromones used.

The species composition of tortricid leafrollers gained from the beating tray method carried out by Edland (1994) in May – June in Svelvik (Viken) showed more similarities with my results. The author found 10 different leafrollers of tortricids (compared to 9 in my fieldwork). Most remarkable is no finding of *Acleris rhombana*, which belonged to the dominant species in Edland's study. Four other not so numerous species were also missing. On the other hand, three species collected by myself, *P. lecheana, A. holmiana* and *A. variegana* (Table 7), are not mentioned in Edland's study.

Differences in species composition of larvae between the sites

The species composition and abundances varied between the fields. A fairly high number of *R. naevana* larvae were recorded in orchard T2, but absent in T1, even if it is only a short distance between these fields, both are organic and microclimate conditions are similar. I assume the difference might have been caused by the generally patchy distribution of this species. Itamies and Kyrki (1987), discovered a strong fluctuation in abundance among years and variations among sites of close distance for this species in their study carried out in Finland. Different proportions of apple varieties, mainly, the absence of the Aroma apple variety in orchard T1 could also explain this variation. This variety was present in approximately 50% of the T2 area. In any case, *R. naevana* is, based on the experiments of Edland (1994), not considered as an important pest in terms of damage to fruitlets. The low catch of other species does not provide enough evidence for detailed evaluation.

Diversity index

The higher diversity (Simpson's index of diversity) and higher numbers of species from the pheromone catches could have been caused by the longer sampling period and their ability to attract a broad spectrum of lepidoptera species. In contrast, larval collection included only tortricids developing on apple trees. Additionally, the short time of field collection excluded some of the other species that could have been taken by the pheromone traps. However, the field T2 appeared to be more diverse both in larvae and adults' diversity.

Remark on larvae monitoring

Regarding the methods considered in this study, the beating tray is commonly used for monitoring insects that fall, rather than fly from the host plants, for instance lepidopteran larvae (Southwood & Henderson, 2009). Nevertheless, I found a few obstacles while testing this method in the field. Even though the signs of tortricid larvae presence were often very obvious even by a quick look at the trees, the amount of collected larvae in the beating tray did not coincide with the expected numbers. I assume the relatively small size, and the way most of the tortricid larvae develop in sheltered leaves prevented them from falling into the beating tray. Most of the specimens collected by testing the beating tray method belonged to genus *Opheroptera* (family Geometridae), which is more robust than the tortricids and, moreover, the larvae did not always hide in leaf rolls. Beating tray monitoring was also challenging during the blossoming period of the apple trees due to a huge amount of flower petals falling in the beating tray thus making it even more difficult to see small larvae on the tray. Because of these factors, I decided to perform a more time consuming detailed visual control of the whole trees, which allowed me to collect larvae from the part of the branches that were developing without the stress on them caused by beating them. This, indeed, enhanced the chance of larvae being successfully reared to adult stages and correctly identified afterwards. Identification of immature stages would have been very problematic otherwise, without having enough experience about their morphology. On the other hand, the visual control had to be performed on a lower number of trees (10 in each orchard), because of time limitations, which might have resulted in a partially biased numbers of species with a patchy distribution. Suckling et al. (1996), tested the effectiveness of both the beating tray and the suction sampler (a tool where insects are drawn into a collection jar by airstream). The number of species collected from apple foliage was significantly higher when they used the suction sampler, even though, sorting out the insects required more time afterwards. As both methods capture sufficient number of insects to estimate diversity, and time constraints are in place, the beating tray method should be sufficient.

4.4 Factors affecting adults' abundance

4.4.1 Production system

The results proved that *P. rhediella* and *H. nubiferana* tend to be more abundant in organic orchards, whereas in the case of *A. podana* and *C. pomonella,* the differences in abundance based on production system are not significant. This sighting is supported by Sjöberg et al. (2015) who provided responses of seven tortricid pests after the ban of azinphosmethyl (a broad spectrum insecticide previously used in European apple orchards). The study reported that the density of *H. nubiferana* increased very significantly in the years following the ban, whereas *A. podana* and *C. pomonella* abundances increased only slightly. It indicates, therefore, that *H. nubiferana* might be highly sensitive to the use of chemical treatments. However, the lack of reported damage by of *C. pomonella* in the IPM orchard (T3; Table 7), is not in agreement with the idea of higher sensitivity for this species.

Another reason for the lower numbers of *P. rhediella* and *H. nubiferana* in the IPM orchards could be their smaller wingspan – 10-12 and 15-21 mm, respectively, compared to the larger *A. podana* and *C. pomonella*, with wingspans of 18-22 and 14-22 mm, respectively (Razowski, 2002; Razowski, 2003). Moths with longer forewing length tend to be better at flying over longer distances (Shirai, 1993) and have a more elaborate antennae capable of detecting female pheromones from longer distances (Symonds et al., 2012). Thus, larger bodied moths could have been more easily attracted from more suitable habitats further away.

In addition, it should be mentioned that my results were, to a certain extent, affected by the different proportion of organic to IPM orchards in each of the two regions, as well as the distance between the orchards within one region. Thus, some species might have shown different abundances only due to the differences in their distribution range and not due to orchard management. For example, the two species discussed above, *A. podana* and *C. pomonella,* were slightly more abundant in Viken (Table 4), the region with more IPM than organic orchards. At the same time, the species were significantly less abundant in one distant organic orchard V1 compared to other IPM in that region (the orchard was more than 50 km away from the other two IPM). This gave us an unexpected result with higher abundances in IPM orchards (Figure 6). On the contrary, *H. nubiferana* abundance was much higher in Viken (Table 4). The differences between the two production systems would have differed probably even more for this tortricid, if an equal amount of IPM and organic production systems had been chosen for each region. All these reasons may have created the false signals in the analyses that are difficult to assess without standardization and increasing the number of orchards considered for such an investigation.

4.4.2 Trap placement

There appeared to be no statistically significant effect caused by the position of pheromone trap placement in the organic orchards. Results revealed that the numbers of tortricid individuals were quite evenly spread over the whole area and thus the total numbers from these orchards could be considered as representative.

In contrast, the higher number of individuals caught in the traps placed at the edges of IPM orchards compared to the middle was very likely influenced by their greater immigration from the adjoining areas. Some of these areas were either unsprayed orchards, or semi-natural habitats also harboring a variety of orchard pests. In contrast with this finding, Jeanneret and Charmillot (1995) found no massive immigration of tortricids from the surrounding habitats. Their result might have been caused by selection of Malaise traps for recording moths, which work in a different way than pheromone traps.

Because of the described reason, the total numbers of pest tortricids in the IPM orchards were evidently artificially increased. In order to solve this problem, the traps on the edges need to be placed further towards the middle of study plots, or if that is not possible due to the spatial limitations of the fields, the economical threshold for spraying should be based on the higher density of tortricid pests caught by pheromone traps.

4.4.3 Temperature

Even though the average temperature within the period of trap service (weeks 18-35) was higher in 2018, compared to 2019, the flight period for some species did not differ considerably between these years. A key factor influencing insects phenology is considered to be the spring temperature, which can shorten or prolong immature development and thus lead to shifts in adult emergence (Stefanescu et al., 2003). This also seems to be the case for the studied species, *P. rhediella,* which experienced an earlier onset in 2019, supposedly because of abnormally warm temperatures in April of that year. The hatching experiment by Edland (1987) suggests a strong relationship between April temperatures and the spring emergence of *P. rhediella*. The imagines hatching time was delayed by approximately 2 weeks in a year with colder April temperatures, while the temperatures during the flight period in May were almost the same for both years. In addition, the flight period, based on Edland's two-year observations seems to coincide with the blossoming period of apples.

The emergence of *C. pomonella*, began approximately in the same period in both years. Initial higher temperatures in the early spring of 2019 dropped in week 19 (Figure 9), while the temperatures in the colder beginning of spring 2018 increased during the same period. This might have later diminished the differences in onset of *C. pomonella* as this species emerged at approximately the same time in both years. Later, very warm weather (weeks 19-31) in 2018 also enabled this species to establish a second generation in late summer (only in Telemark). Pak et al. (2019) studied, according to long-term obtained data over 36 years, the period of the year when temperature best explains the spring emergence of the tortricid pests. The authors found out that mainly March, and to a lesser extent, April temperatures, positively influenced *C. pomonella* emergence. However, a lack of precise data from a number of years does not allow to perform such analysis.

The most significant between years shifts are displayed for the remaining two species whose flight period mostly took place during and after the heat wave of summer 2018. *H. nubiferana* hatched slightly earlier in the warmer 2018 compared to 2019, and an even higher difference in flight onset between the years was observed for *A. podana*. These species normally appear later in the season compared to the other two target species discussed above.

Despite slightly warmer mean temperature in Telemark, most of the examined species there experienced an earlier onset, but also a longer lasting flight period in late summer compared to Viken. The flight activity of later summer species with enough samples, such as *Eucosma cana*, or *Bryotropha senectella* can be seen in Appendix 3. It is very difficult to assess whether this remarkable phenomenon is not caused by other factors than the microclimate differences between the regions (for instance the more southern exposure of orchards in Telemark as described by Rein (1994)).

Based on the temperature and adult flight data during the period of trap service 2019, it seemed like every short-lasting period of lower temperatures caused a temporary fall in adult abundance. Some decreases in abundance were very abrupt, mainly week 19 for *P. rhediella*, and also week 22 for *C. pomonella*, as well as week 28 for both *E. formosana* and *G. funebrana* (Figure 3, 4). On the other hand, not every descent in abundance was due to changes in temperature. This applies for *A. podana* in week 28 (Figure 3). A very abrupt decrease in abundance of this species was observed in Telemark only (Figure 3). The reason for this is unknown.

There is an indication that the flight period of some species have the tendency to be more affected by minimum temperature, mainly *H. nubiferana* and partially *G. funebrana*, whereas abundance of *A. podana* and partially *C. pomonella* conversely were more related to the maximum temperature (Table 8). I assume the differences in flight period may explain why the species respond to temperature in a different way. While the flight of *H. nubiferana* takes place during the spring in typically moderate temperatures when a fall in temperature may slow down their activity more rapidly; in the case of summer species such as *A. podana* a temporary drop in temperature is less likely to be so much as it is in the spring. The flight activity of *P. rhediella* was restricted just to a short period of time, the same as some data from early spring were missing. That may explain why no dependence on temperature factors is evident in the results. For achieving a better result, the frequency for trap checks should be intensified for species with such a short flight period.

Abnormal temperatures and precipitations during the summer may also affect the damage (Edland, 1994). The great damage by tortricids larvae on apples in 1992 was attributed to high temperatures and droughts in June and not enough precipitations up to mid-August. This led to stress on apple trees, and thus the tortricids which usually develop on leaves caused damage to fruitlets and fruits instead. In the following year 1993, the numbers of leaf rollers larvae collected by the beating tray method increased significantly but fruitlet damage was compared to the previous year much lower. The larvae could feed on leaves and did not damage the fruitlets any more. This hypothesis cannot be proved or rejected since the damage extent to apple fruits from 2018 and 2019 from the study plots is comparable.

It is also important to mention, that effectiveness of pheromone lures might be changed by weather parameters. Prasannakumar et al. (2011) assumes that a higher temperature might cause higher evaporation of the pheromone compounds and hence, lower catches of moths in pheromone traps. This may also be the case for my data.

4.5 Specificity of pheromone lures

Synthetic pheromone lures contain a mixture of chemical compounds of which some of these might be effective for several species (Jakubíková et al., 2016). The effectiveness of lures may be, moreover, altered by low density of the species at study plots. The fairly low density of the species *A. orana* in the traps could be probably explained by its scarcity in the surveyed orchards.

In contrary, the second species with a low catch in the pheromone traps was *P. heparana*. Only one individual was caught in spite of several larvae being found by us and also by Edland (1994) (beating tray experiments). This shows that the pheromone traps probably do not exactly reflect the abundance of this species. Instead of this, more robust species from the family Noctuidae, were very frequently trapped by PAHE (and also ADOR, see Appendix 2). Thus, the sticky surface of the inserts often became covered by them. To some extent it could have lowered the trap efficiency. However, the total loss of its function is not very likely. The lure designed for this species was tested in the Czech republic by Jakubíková et al. (2016). Even though the lure used in the paper is produced by a different manufacturer, no specimens of the target species were captured. Interestingly, the authors found this lure highly selective for *Euspilapteryx auroguttella* (Gracillariidae) and *Noctua fimbriata* (Noctuidae), which matches exactly with my observations from the six orchards (Appendix 2). In addition, my own records matched Stensland (1993), who reported a high number of *Ceramica pisi* (Noctuidae) in the traps baited for PAHE. Surprisingly, the flight period of *P. heparana* drawn in her results proves the higher effectiveness of the lure. Lures from the same manufacturer Pherobank® were recently used by Sjöberg et al. (2015) with a relatively high number of the target species.

The reciprocal attractivity of pheromones for *Cydia spp.* and *Pammene spp.* is described by Hrdý et al. (1997) in (Hrudová, 2003). This corresponds with the findings from this study, however, the exact species of these two genera recorded by the two traps differed.

4.5.1 Identification of species recorded by pheromone traps

Species studied in this thesis occur in apple orchards or in places where their cultivated host-plant is present (Alford, 2007; Reiprich, 2001). Since many other non-target species of Lepidoptera were also attracted and captured by pheromone traps developed for the target species, and many of them belong to innocuous species, awareness about the problems connected with incorrect identification is necessary. For example, the larvae of very abundant tortricid present in my study *Celypha striana* develop on dandelion *Taraxacum officinale,* which does not cause any damage to agricultural crops (Reiprich, 2001). Due to its drab colors and pattern of the wings, there is a higher chance of misidentification.

As explained for one species, it is likely that the similar appearance of species could have led to mistakes in identification in several cases before 2019. A discrepancy in the abundance of *Pandemis heparana* (PAHE lure) between the years 2018 and 2019 might be explained by misidentification (Table 4). The species was very likely mixed up with another pest tortricid, *P. lecheana*, which reached almost identical total abundance in 2019 of 74 individuals in Viken and 59 in Telemark, as individuals falsely identified as "*P. heparana*" in 2018. The flight period of the moths from 2018 also coincided with the flight period of real *P. lecheana* in 2019. This reciprocal activity was also described by Stensland (1993).

The date when only one imago of *P. heparana* in 2019 was confirmed in the pheromone trap, was delayed by 4 weeks compared to *P. lecheana*. The larvae of *P. lecheana* were collected before and during the flowering of apple trees, whereas the larvae of *P. heparana* were collected during and after the flowering of apple trees, more than 2 weeks later respectively (both examples based on sightings from 2019). The shifts in phenology may have an impact on the difference in damage potential of these two species (Edland, 1997).

The results show that there is a need for description and guidelines for identification of species that might occur in traps designed for other species. If, for instance, all tortricids in traps with *H. nubiferana* pheromones were counted as *H. nubiferana*, the total number would have increased to 348 (see Table 9 and Appendix 2). I provide a brief guideline about what similar species need to be taken into account while identifying the target ones (Appendix 1).

5 Conclusions

The results of this thesis provide basic knowledge about phenology of concerned pest moths and also give an insight into factors affecting obtained data. I assume, the timing of insect flight activity in general may be, in the future, more often affected by increasing temperature variability making difficult to predict damage and adjust the measures for suppressing their attacks. The four aims of the study may be concluded as follows:

1. The records from the pheromone traps showed that the target species commonly caught in both apple districts Viken and Telemark have largely the same population densities. However, the differences in abundance seem to be great for some non-target tortricids, namely *Enarmonia formosana* and *Grapholita funebrana*. Other pest moths summed up in the tables give a very rough estimate about their presence in the two regions.

2. The species composition of tortricids in the pheromone traps and the larvae collection was somewhat similar, but most of the species were found only by one of the methods. It is mainly due to the species-specific use of pheromone traps and also frequent presence of non-target species whose larvae development occur on different part of the trees, or respectively on other plants which were not examined. For an increase of sample size, the beating tray method conducted in late spring could be considered as the most efficient method for monitoring of leafroller tortricids damage. However, this would not apply to the majority of early emerging species.

3. Even though the number of orchards with the same production system was not standardized for the two regions, the abundance of *H. nubiferana* and *P. rhediella* seemed to be truly affected by different production systems. However, higher immigration of species to the edge traps in IPM orchards from the areas further away could have led to a partially skewed picture concerning pest densities. The earlier flight period of most of the species in the slightly colder Telemark region was surprising. In general, the species responded according to temperature deviations in 2018, 2019. Minimum temperatures significantly affected the phenology patterns for most species.

4. It was found that some pheromones sold as species-specific attracted a huge amount of lepidopteran species from different families. Data may thus be easily distorted by misidentification of similar non-target tortricids. The right choice of pheromone lures with highly selective components is therefore important for obtaining reliable results.

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APPENDIX 1 Watch out for non-targets

The information given here serves as a guide to tortricid recognition captured by pheromone traps, based on my experiences with the 2019 ‘Åmeåtak’ data from Telemark and Viken. The total abundances of species from all six orchards attracted by the respective lures are stated in parenthesis behind the scientific names. Apart from the species discussed here, some other very abundant, but markedly different species from other lepidopteran families were caught too. For instance, the webpage http://lepiforum.de/ could be used for searching photos of the species mentioned in this appendix.

- PAHE lure (target species *Pandemis heparana*): the vast majority of all moths captured by the lure belong to the species *Ptycholoma lecheana* (113). The wingspan of the target species ranges from 16-21 mm, whereas *P. lecheana* reaches 16-20 mm (Razowski, 2002). This similar size, therefore, may cause mistakes in identification, especially when the specimens are so worn. Their flight period also overlaps and so it is not possible to distinguish them based on phenology. All other species that were attracted to this lure were so either very sporadically, or they differed markedly in appearance.
- ARPO lure (target species *Archips podana*): only a few occasional non-target species were captured by this lure. The most frequent accompanying species was *Syndemis musculana* (10). Although the wingspan of the target species reaches from 18-22 mm, which is nearly the same as *S. musculana* at 17-22 mm (Razowski, 2002), the first target species moths emerged five weeks after the last observation of *S.musculana*. This difference in phenology is a good way of distinguishing these species, although the coloration of the wings is different too. Other species were caught only very sporadically, of which *Endothenia quadrimaculana* (1) is the most similar in appearance. Worn specimens of *Aleimma loeflingiana* (4) were captured only by ARPO. These specimens may be identified wrongly as another target species – *A. orana*.
- CYPO lure (target species *Cydia pomonella*): the most frequent accompanying species was *Pammene rhediella* (56). The first individuals of the target species emerged at a time when the flight period of *P. rhediella* was decreasing. In that period, both species were very often caught by the same trap. The different size of the two species enables recognition. While the wingspan of *P. rhediella* is only 10-12 mm, the target species reaches 14-22 mm (Razowski, 2003). Numerous

Pammene populana (41) with a wingspan of 10-15 mm emerged during the last few weeks of the target species' activity. *Grapholita compositella* (23) occurs during the peak activity of the target species, but differs considerably in wingspan – 10-13 mm, wing pattern and colors. The other species were quite sporadic and very different in appearance. An albino form of the target species was also spotted in the trap.

- PARH lure (target species *Pammene rhediella*): the most frequent accompanying species was *Cydia pomonella* (151). Its difference from the target species is described above. The second most abundant species was *Enarmonia formosana* (41) with a different wing pattern, size and phenology. Its wing span is 12-19 mm (Razowski, 2003), whereas the target species reaches 10-12 mm. *E. formosana* emerged during the last few weeks of the target species' activity. *P.populana* (28) described above matches in size, however, the 5 week gap in the flight activity between this late summer species and the target species is easily noticeable. *Celypha striana* (21) begins its flight activity observably later than the activity of the target species lasts and also differs in wingspan – 17-22 mm (Razowski, 2003). The other species were quite sporadic and very different in appearance.
- ADOR lure (target species *Adoxophyes orana*): the most frequent accompanying species was *Cydia pomonella* (12), which is very different in wings coloration, although the wing span of the target species 15-19 mm (Razowski, 2002) overlaps with *C. pomonella* – 14-22 mm (Razowski, 2003). The other species were very sporadic and different in appearance.
- HENU lure (target species *Hedya nubiferana*): the most frequent accompanying species was *Eucosma cana* (182) with rather different wings coloration but a similar wing span – 16-23 mm (Razowski, 2003), compared to the target species – 15-21 mm (Razowski, 2003). The phenology of these two species overlaps. *Grapholita funebrana* (121), a species markedly different in wing color and size, reaches only 12-15 mm (Razowski, 2003). Its flight period also coincided with the target species. The other species were quite sporadic or very different in appearance.

APPENDIX 2

The non-target species of Lepidoptera captured by the six pheromone lures (continuation of the Table 9). The full names of the lure acronyms are listed in “Abbreviations”. The species are ordered alphabeticaly separately for each family.

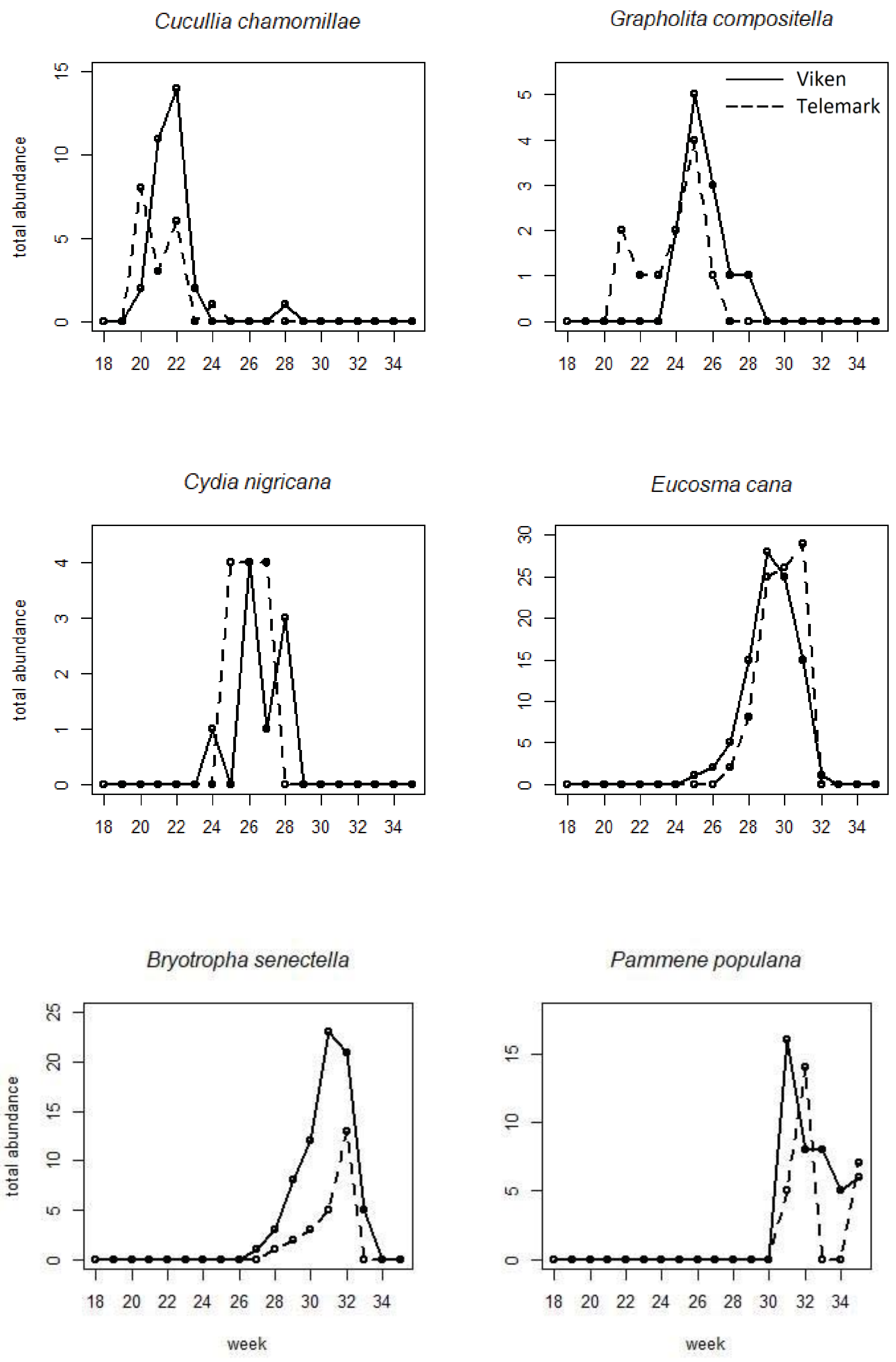
Species	**Family**	**CYPO**	**PARH**	**HENU**	**ARPO**	**ADOR**	**PAHE**
Anania funebris (Ström, 1768)	Crambidae					1	
Acompsia cinerella (Clerck, 1759)	Gelechiidae				9		
Bryotropha senectella (Zeller, 1839)	Gelechiidae					77	20
Metzneria lappella (Linnaeus, 1758)	Gelechiidae						1
Recurvaria leucatella (Clerck, 1759)	Gelechiidae			1		1	
Callisto denticulella (Thunberg, 1794)	Gracillariidae	2	2	1	1		1
Euspilapteryx auroguttella (Stephens, 1835)	Gracillariidae					1	136
Phyllonorycter blancardella (Fabricius, 1781)	Gracillariidae	2	2	6	4	2	
Diurnea fagella (Denis & Schiffermüller, 1775)	Chimabachidae				1		1
Anthophila fabriciana (Linnaeus, 1767)	Choreutidae		1				
Lyonetia clerkella (Linnaeus, 1758)	Lyonetiidae	2	1	5	6	3	3
Mompha subbistrigella (Haworth, 1828)	Momphidae		1	1	3		
Amphipoea fucosa (Freyer, 1830)	Noctuidae				2	60	1
Autographa gamma (Linnaeus, 1758)	Noctuidae		5				1
Anarta myrtilli (Linnaeus, 1761)	Noctuidae					2	
Colocasia coryli (Linnaeus, 1758)	Noctuidae				2		
Cucullia chamomillae (Denis & Sch., 1775)	Noctuidae					41	7
Ceramica pisi (Linnaeus, 1758)	Noctuidae	1				86	36
Hoplodrina octogenaria (Goeze, 1781)	Noctuidae		3				
Noctua fimbriata (Schreber, 1759)	Noctuidae						23
Noctua janthe (Borkhausen, 1792)	Noctuidae					1	
Plutella xylostella (Linnaeus, 1758)	Plutellidae	15	11	3	7	3	5
Myelois circumvoluta (Fourcroy, 1785)	Pyralidae					5	
Archips crataegana (Hübner, 1799)	Tortricidae						14
Acleris holmiana (Linnaeus, 1758)	Tortricidae	1					
Aleimma loeflingiana (Linnaeus, 1758)	Tortricidae				4		
Archips rosana (Linnaeus, 1758)	Tortricidae						2
Celypha striana (Denis & Schiffermüller, 1775)	Tortricidae		21				
Cnephasia stephensiana (Doubleday, 1849)	Tortricidae			4			
Cydia nigricana (Fabricius, 1794)	Tortricidae			21			
Dichrorampha petiverella (Linnaeus, 1758)	Tortricidae				2		
Eucosma campoliliana (Denis & Sch., 1775)	Tortricidae	4	5				
Eucosma cana (Haworth, 1811)	Tortricidae			182			
Epiblema cirsiana (Zeller, 1843)	Tortricidae			1			
Eulia ministrana (Linnaeus, 1758)	Tortricidae						3
Endothenia quadrimaculana (Haworth, 1811)	Tortricidae				1	1	
Grapholita compositella (Fabricius, 1775)	Tortricidae	23					
Hedya dimidiana (Clerck, 1759)	Tortricidae	1		1			

Pammene argyrana (Hübner, 1799)	Tortricidae			4			
Phtheochroa sodaliana (Haworth, 1811)	Tortricidae				3		
Pammene populana (Fabricius, 1787)	Tortricidae	41	28				
Syndemis musculana (Hübner, 1799)	Tortricidae				10		
Spilonota ocellana (Denis & Sch., 1775)	Tortricidae						1
Euhyponomeutoides albithoracellus Gaj, 1954	Yponomeutidae						12
Ypsolopha asperella (Linnaeus, 1761)	Ypsolophidae			1			
Unidentified species		1	1	1			1
Lepidopteran species in total *		**14**	**16**	**19**	**18**	**18**	**23**
Lepidopteran families in total		**5**	**7**	**7**	**8**	**8**	**8**

* including the species in Table 9

APPENDIX 3

The total catches of selected Lepidoptera found in traps of target species (n=54). Note the different y-axis scale.



APPENDIX 4

Figure 3-8 Adults of the target tortricids. 3. *Pammene rhediella*, Telemark, Norway, photo: Erling Fløistad, 4. *Hedya nubiferana*, Viken, Norway, 5. *Cydia pomonella*, Spiš, Slovakia, 6. *Archips podana*, Spiš, Slovakia, 7. *Pandemis heparana*, Spiš, Slovakia, 8. *Adoxophyes orana*, Telemark, Norway, all photos author

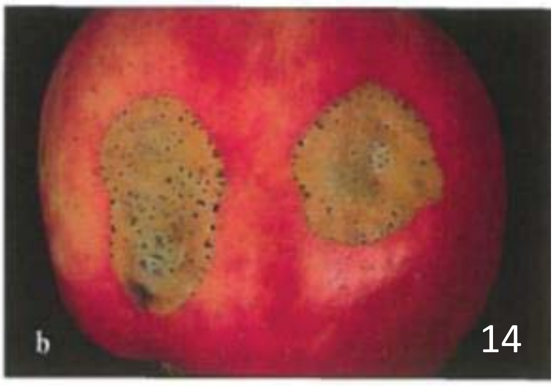


Figure 9-16 Larvae sympthoms of the target tortricids. 9, 10. *Pammene rhediella*; 11, 12. *Cydia pomonella*; 13-16. other Lepidoptera (Noctuidae, Tortricidae, Geometridae). The photos used from publication of Rein (1996).

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway