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# Precision sensor technology that supports area specific monitoring of target insect pests in oil seed rape and digitalization of registration

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# 1. Introduction

Cabbage stem flea beetles *(Psylliodes chrysocephala*) and pollen beetles (*Meligethes aeneus*) are two major pests in oilseed rape (OSR), with cabbage stem flea beetles being the dominant flying pest in Autumn and pollen beetles in Spring. Over the last year, two main trials were conducted to demonstrate the use of the FaunaPhotonics sensor to detect these two pests. The trials aimed to measure the in-field flight activity of the target pests over the course of the season in order to provide information to the farmer on immigration, emergence, and population build-up, supporting them to make more informed decisions to effectively manage timing of pesticide use. Due to seasonal differences in insect species presence and activity, the trial in Autumn 2019 focused specifically on the cabbage stem flea beetle and the trial in Spring 2020 focused on pollen beetles. The studies were performed in partnership with VKST Landbrugsrådgivning (www.vkst.dk, who performed parallel ground-truth sampling (yellow water traps), and the Danish Technological Institute (www.teknologisk.dk), which provided statistical verification of our methods in relation to conventional approaches. This report focuses on the core results from sensor data and water traps collected by FaunaPhotonics during these trials.

The Faunaphotonics sensor, called the Volito, is an optical monitoring system derived from entomological lidar systems. The instrument is a small and portable system based on dual-wavelength infrared LEDs which is capable of unsupervised and automated long term insect monitoring. It records the backscattered signal from any object entering its measurement volume, automatically extracts insect events and transmits these together with environmental metadata over cellular connection. The basic principles are explained in Figure 1 below. A more elaborate discussion of the sensor technology can be found in [1].

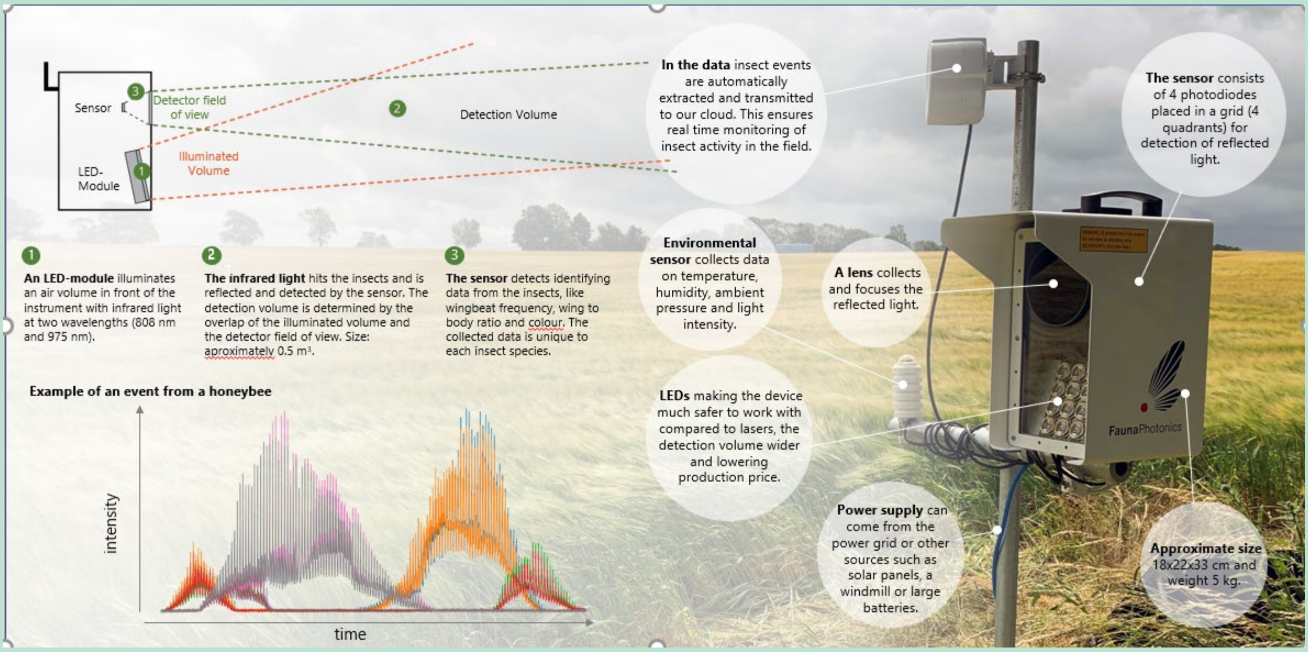



**FIGURE 1**. A schematic view with explanatory text on the FaunaPhotonics sensor, the Volito

This is the sensor that was used for the pollen beetle experiments in the Spring of 2020, whereas a laser-based prototype was used for the cabbage stem flea beetle experiments in the Autumn of 2019. In order to avoid confusion, we shall in the following refer to both as the

"FaunaPhotonics sensors", however, when a distinction is needed, we shall refer to them as the Volito (Spring 2020) or the prototype sensor (Autumn 2019), respectively, understanding that there are these minor differences between the two types of sensor described above, that does not directly affect the quality of the experimental results, we discuss.

In contrast to traditional insect sampling methods, e.g. water trapping and sweep netting, the FaunaPhotonics sensor offers the possibility to monitor and identify insects continuously without major human labor input and the hope is also to be able to demonstrate that the sensor can detect insect pest in-field flight activity before the insects can be detected via the traditional sampling methods, thus providing an early warning system (to be discussed in the following).

In order the recognize specific insects, the sensor is trained on known insect species in a cage, and based on these "labelled data" (to be discussed further in section 6), machine learning algorithms are applied to make classifiers that enable the sensor to identify specific insects in the field continuously and in real time.

# 2. Autumn campaign 2019

## 2.1 Campaign goals

1. To validate the feasibility of performing real-time insect-specific observations of the cabbage stem flea beetle in a field setting using the FaunaPhotonics sensor.
2. To assess the degree of correlation between sensor data and conventional data sampling approaches.
3. To perform an initial study of the spatial coverage we can expect from the sensor for cabbage stem flea beetles.
4. To determine the feasibility of establishing spraying thresholds.
5. To develop a use case for cabbage stem flea beetle detection and identification in OSR.

## 2.2 Summary of the main results

Using previous findings on characteristic behaviors of cabbage stem flea beetles, notably circadian rhythm and wingbeat frequency, insect events were divided into ‘cabbage stem flea beetles’ and ‘other insects’ as a simplified machine learning algorithm. For a more elaborate discussion of these insect characteristics and the way, they can be used to differentiate species, see [2].

Using this measure, the immigration of cabbage stem flea beetles into the test field was independently identified by two FaunaPhotonics prototype sensors a number of days before the same immigration was identified in the conventional traps. It is important to note that this immigration phase was able to be detected despite the generally low numbers of beetles in relation to common standard thresholds for spraying based on shot hole damage on plants.

More study is required to determine a sensor-based spraying threshold, as the abundance of cabbage stem flea beetles did not pass the conventional threshold at any point during this study. The sensor also faced challenges in power supply and reliability, reducing the uptime. Findings from these prototype sensors from the Autumn/Winter 2019 have provided the groundwork for the new more stable sensor system (the Volito) with a chance for better uptime. From the study, an important use case has been determined which would use the sensors as an early detection system to detect a flying immigration of cabbage stem flea beetle into the field.

# 3. Spring campaign 2020

## 3.1 Campaign goals

1. To validate the feasibility of monitoring changes in the measured activity of.
    a. Pollen Beetles (Main success criteria)
    b. Seed Weevils
    c. Pod Midges
2. To evaluate spatial representation of sensor measurements.
3. To evaluate differences in sensor-to-sensor performance.

## 3.2 Summary of main results

Pollen beetle events in the sensor were identified using a machine-learning based classifier, trained using labelled data (see section 6) collected for pollen beetles in a laboratory setting (i.e. in a cage), as explained in the Introduction. Using this classifier, six FaunaPhotonics 'Volito' sensors, distributed in a grid format interspersed with conventional traps (see Section 4), showed good potential at being able to independently pick up the temporal variations in pollen beetle activity over the Spring 2020 season. In addition to this, the relative standard deviation for the pollen beetle count between the six sensors were equal to or smaller than for the six compared water traps in the same main plot grid, indicating that the sensor-to-sensor agreement for pollen beetles is equal to or better than the trap-to-trap agreement in this case.

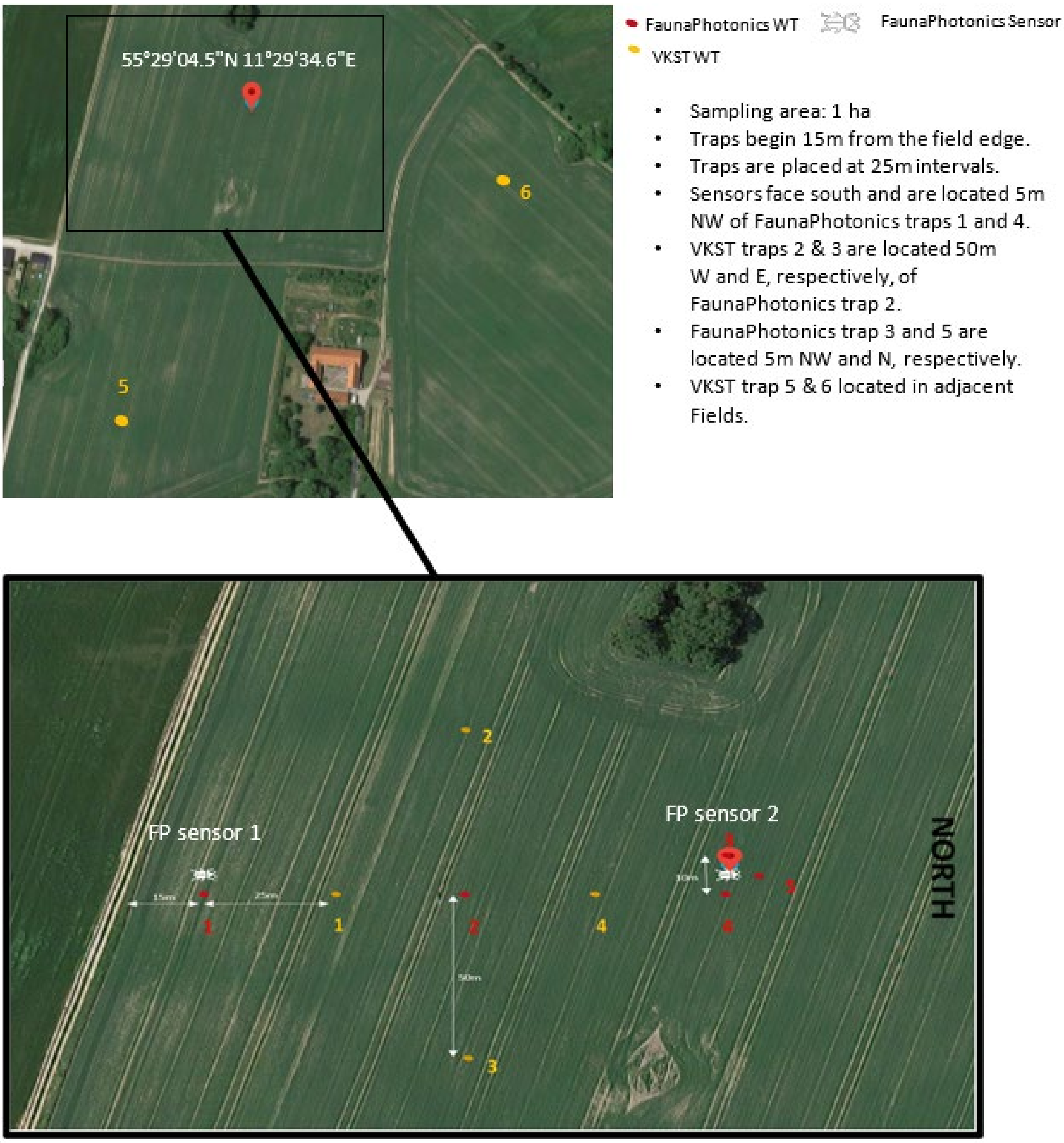
When traps in adjacent fields were included in the analysis, the water traps showed no indication that the difference in pollen beetle count between traps increased with the distance between the traps in the range of 45-700 m. This indicates that spatially intensive sampling may not be required in order to obtain a usable representation of relative pollen beetle activity in an area.

It was not possible, following the same method as with the pollen beetles, to track the temporal variation in activity of the two other targets, seed weevils and pod midges, due to difficulties in obtaining sufficient volumes of labelled data. These difficulties consisted primarily of issues in parallel cage development, sensor development, delays and restrictions posed by the outbreak of COVID-19, and limited numbers of available sensors. However, great improvements were made on data quality, sensor reliability for uptime and more automatic detection of high event noise times, such as rain, compared to the sensor data collected with the prototype during the 2019 Autumn campaign.

# 4. Experimental setups

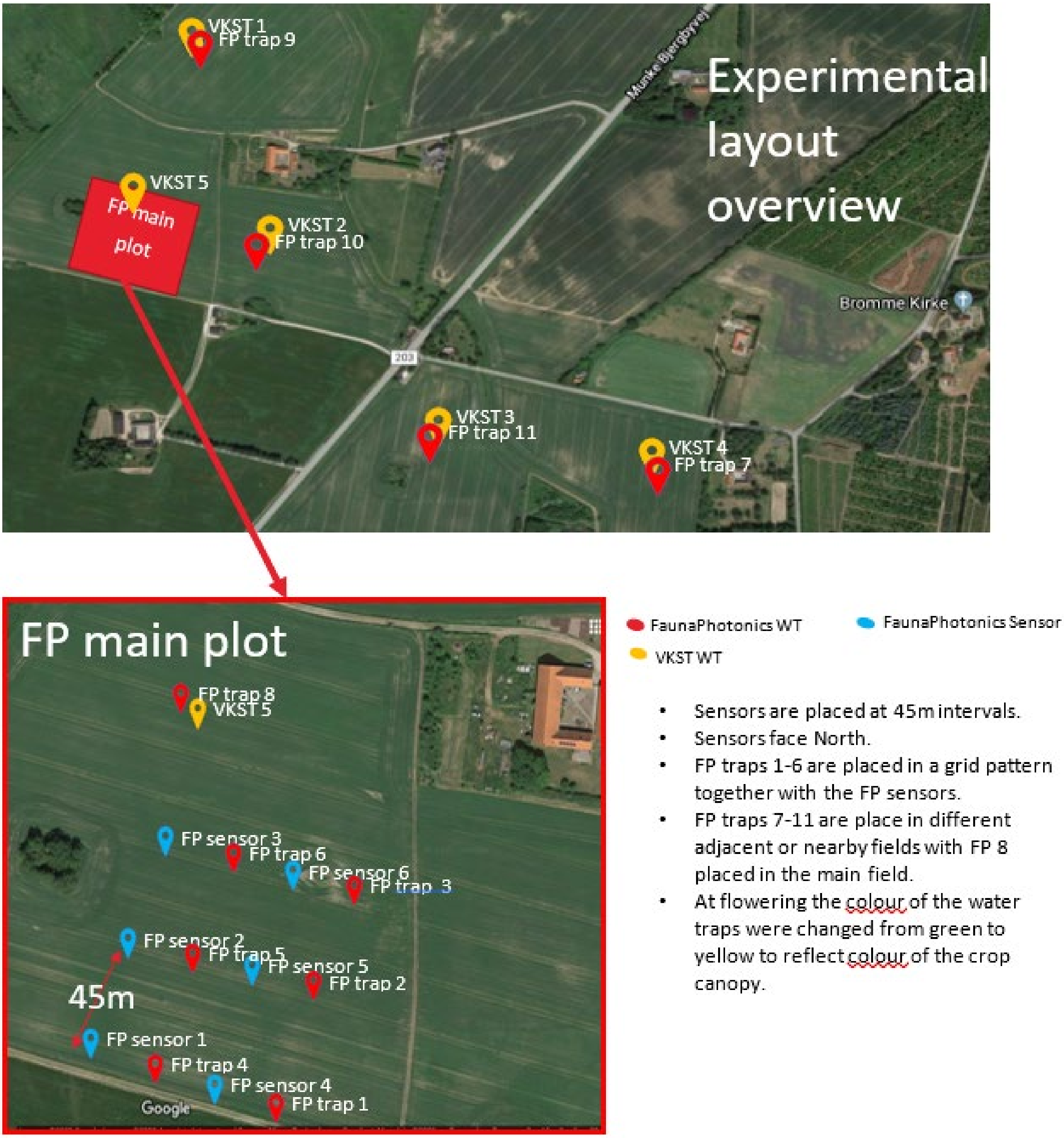
## 4.1 Autumn 2019

Below, we have displayed the distribution of the FaunaPhotonics sensors as well as the FaunaPhotonics water traps (WT) and the water traps from VKST Landbrugsrådgivning. The location is an organic OSR field in Sorø, Denmark



## 4.2 Spring 2020

Below, we have displayed the distribution of the FaunaPhotonics sensors as well as the FaunaPhotonics water traps (WT) and the water traps from VKST Landbrugsrådgivning. The location is the same organic OSR field in Sorø, Denmark



# 5. Ground truthing insect distribution

Ground truthing data is collected predominantly using conventional methods such as water traps. This is a resource intensive process, but it is necessary to be able to verify results from our sensors, learn about within-field and between-ffield representativeness of measurements and learn about the insect background species which are required to build a representative labelled data collection.

## 5.1 Autumn 2019

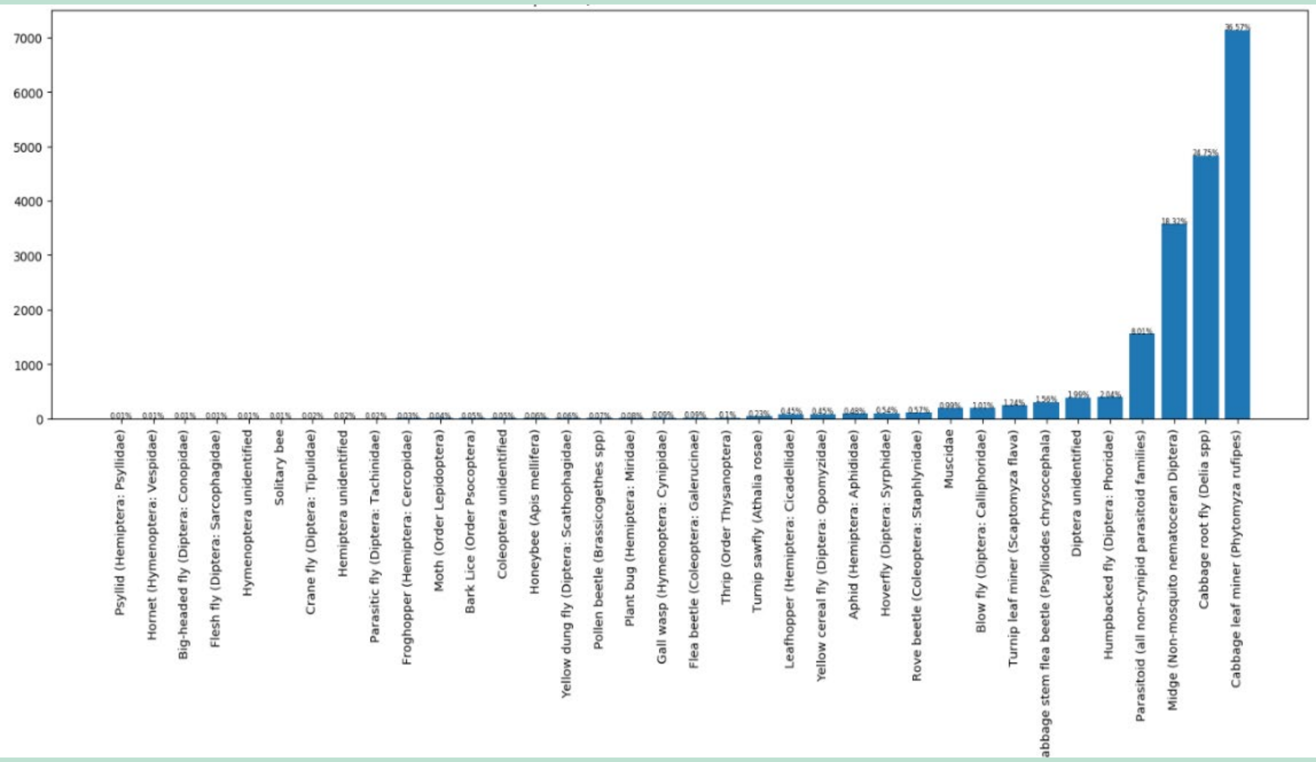



**FIGURE 2** Total FaunaPhotonics water trap count by taxon over the full 2019 Autumn campaign.

The relative abundance of the target cabbage stem flea beetle is very small throughout the season ranking as the seventh most abundant species and corresponding to only 1.5% of the total counts in the water traps, as seen in Figure 2. This relative scarcity is also reflected in the shot hole damage as sampled weekly by VKST Landbrugsrådgivning, which reached no more than 6% at any point, well under the standard spraying thresholds of 25%. A very low abundance of cabbage stem flea beetles in the test field provides significant challenges in terms of sensor verification, as there is a limited contrast in insect activity across the measurement period. However, a majority of the most abundant species are expected to display significantly higher wingbeat frequencies compared to the cabbage stem flea beetle.

This has also been confirmed by the labelled data recorded for most abundant species in laboratory settings (cages). A key missing species in the labelled data collection is the cabbage leaf miner, the most abundant species in the traps, however this species is expected to have a high wingbeat frequency, in line with other small flies, and it is therefore unlikely to disturb the measurements of the lower wingbeat-frequency cabbage stem flea beetle.

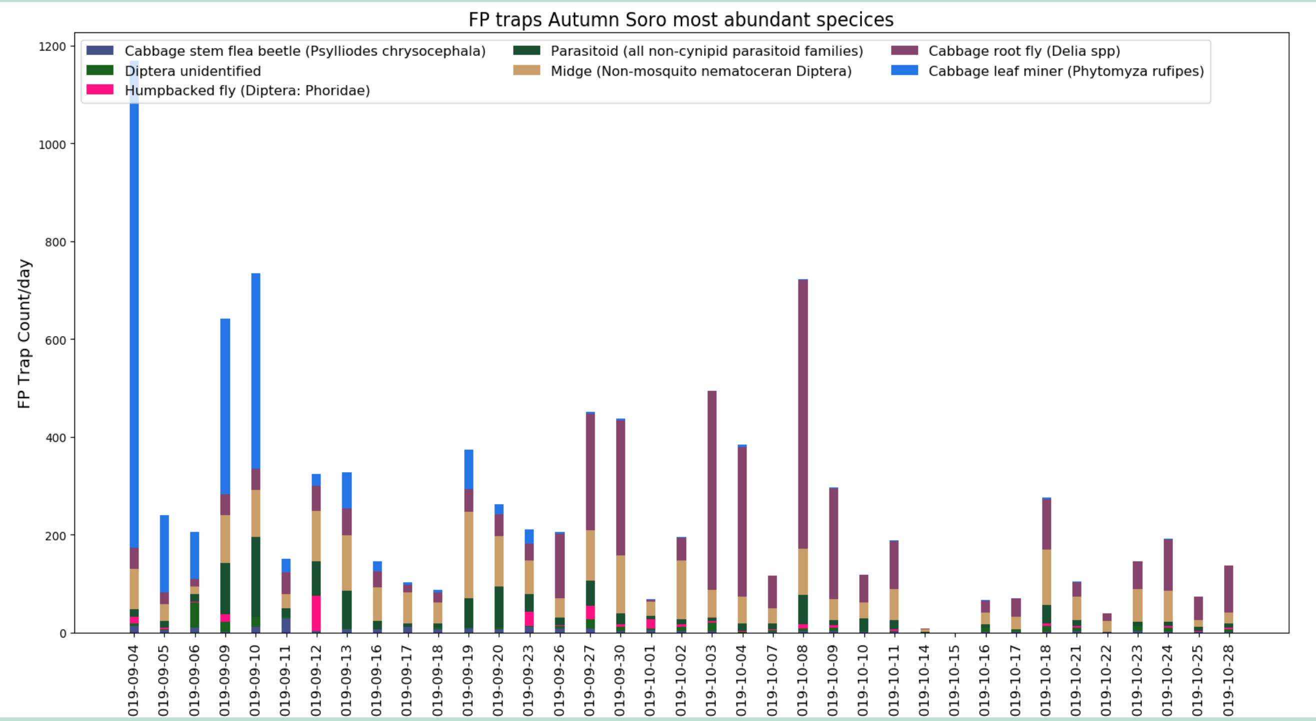



**FIGURE 3** Most abundant taxa in the FaunaPhotonics (FP) water traps as displayed by stacked counts per day on the sample day over the Autumn 2019 season.

Figure 3 shows how the abundance of different taxa caught in the FaunaPhotonics water traps changes over the season. Even on the day, where the cabbage stem flea beetle is most abundant (2019-09-11), it is still significantly in the minority compared to the most dominating species. The most noticeable change over the season in general is how the population changes from being dominated by cabbage leaf miners in the beginning of the season to being dominated by cabbage root flies towards the later parts. This shows how the most abundant species varies over the season which is important to consider when analyzing the results.

During the Spring 2020 season, pollen beetles represented almost 23% of the total water trap counts and were the most abundant species overall in the field during the full season as seen in Figure 4. However, it is important to note that the relative abundance of species changes significantly over the season, as seen in Figure 4. The early part of the season has a high abundance of midges and rove beetles. This is followed by the mid-season which is dominated primarily by our main target, the pollen beetle. In the later parts of the season, the field is mostly dominated by various fly species, but it is also important to note the increase of and peak of seed weevils.

## 5.2 Spring 2020

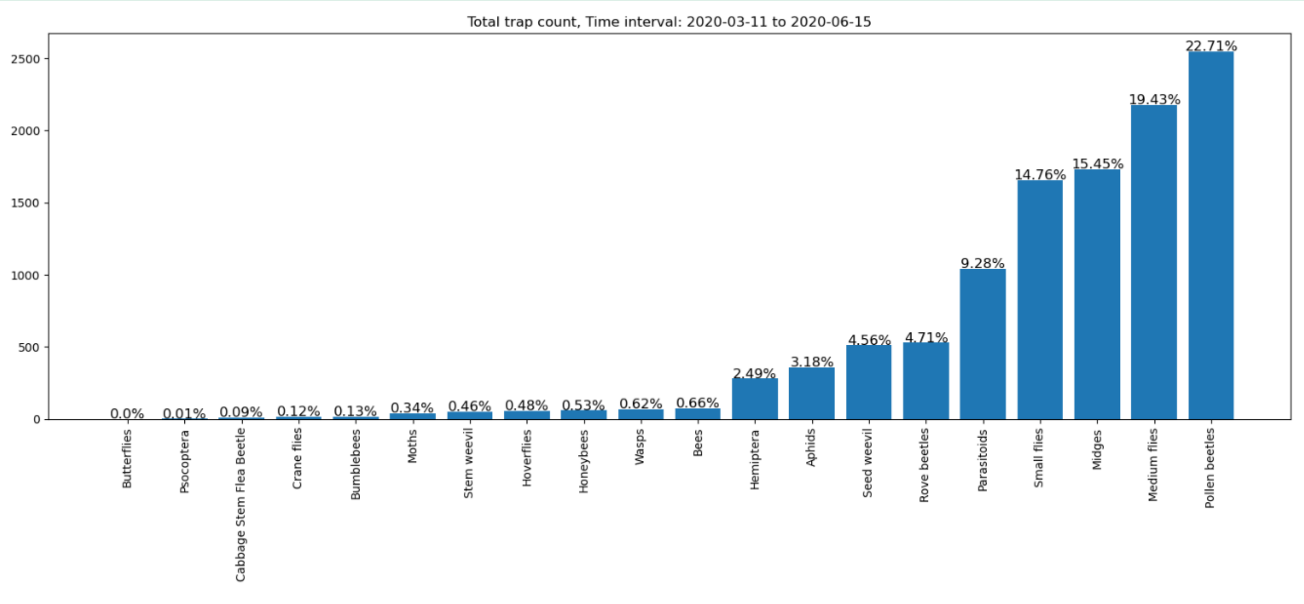



**FIGURE 4** Total FaunaPhotonics (FP) water trap (FP1-FP6) count by taxon for the most abundant species over the full 2020 Spring campaign.

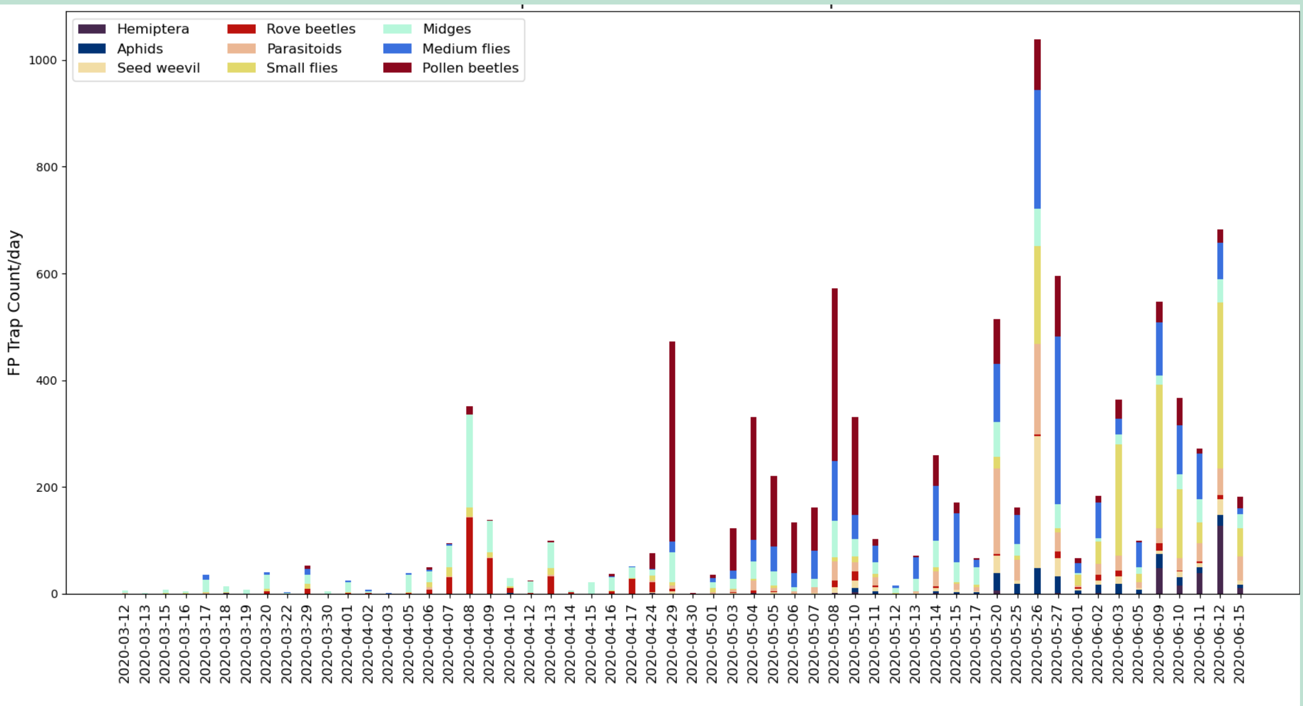



**FIGURE 5** Most abundant taxa in the FP1-FP6 water traps as displayed by stacked counts per day on the sample day over the Spring 2020 season.

# 6. Labelled data collected

Classification of target insects in the field is based on lab-based characterization of both the target, and the 'background', non-target insects. All these characteristics are inherently contained in the event signal displayed in Figure 1. Insect characteristica, such as wing beat frequency (the frequency of the spikes in the event), relative body-size (the size of bulk signals), body-to-wing ration (the intensity of the bulk signal vs. The intensity of the spikes) can readily be evaluated. However, after training on the insect events, and creating the insect classifiers, the machine learning algorithms will have identified many other insect characteristics, that may not have any apparent physical meaning for the human observer.

We need to know the characteristics of the target insect when recorded with our sensors, as described above, but it is equally important to know the characteristics of the other most abundant species in the field that we want to separate our target insects from. This characterization is achieved by collecting captive and separate populations of insects into a controlled environment and observing them using the sensor. The data collected during these sessions is referred to as 'labelled data'.

## 6.1 Autumn 2019

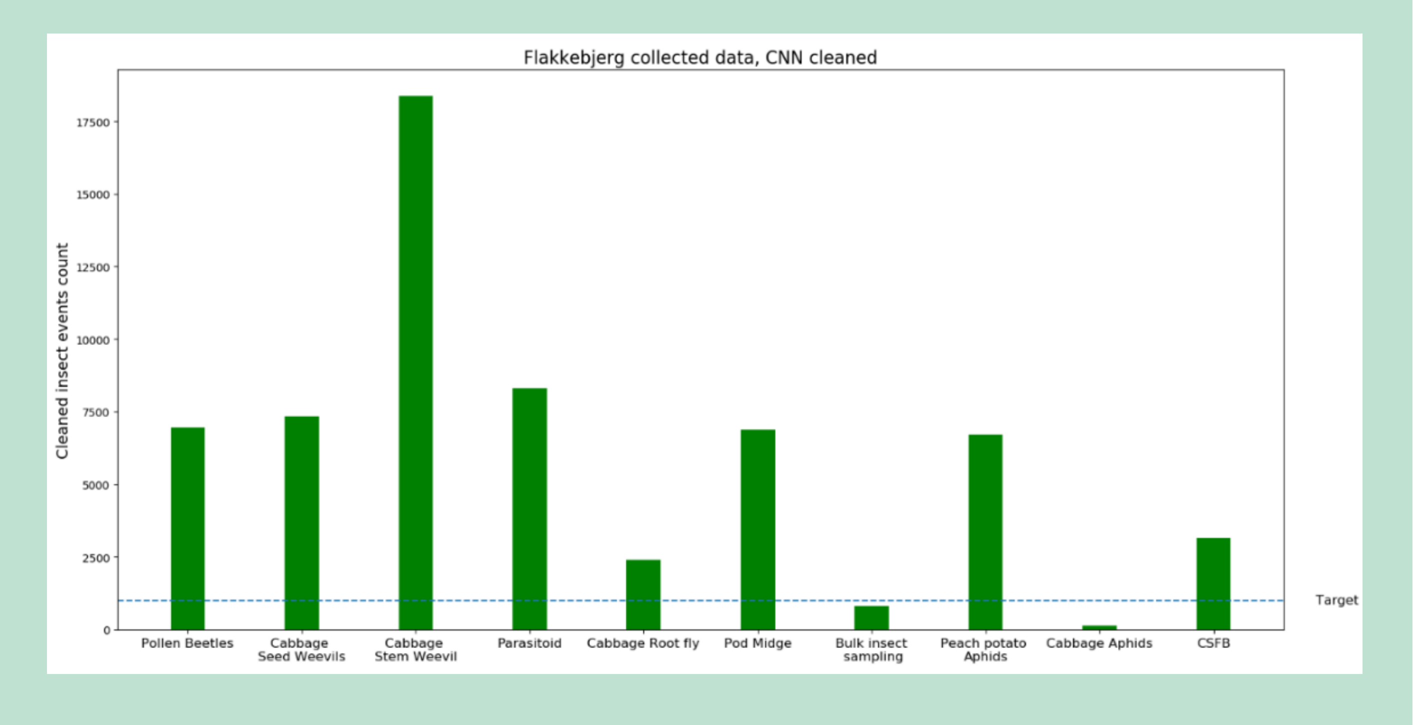



**FIGURE 6.** Number of events collected as labelled data for the prototype sensor in the Spring and Autumn of 2019.

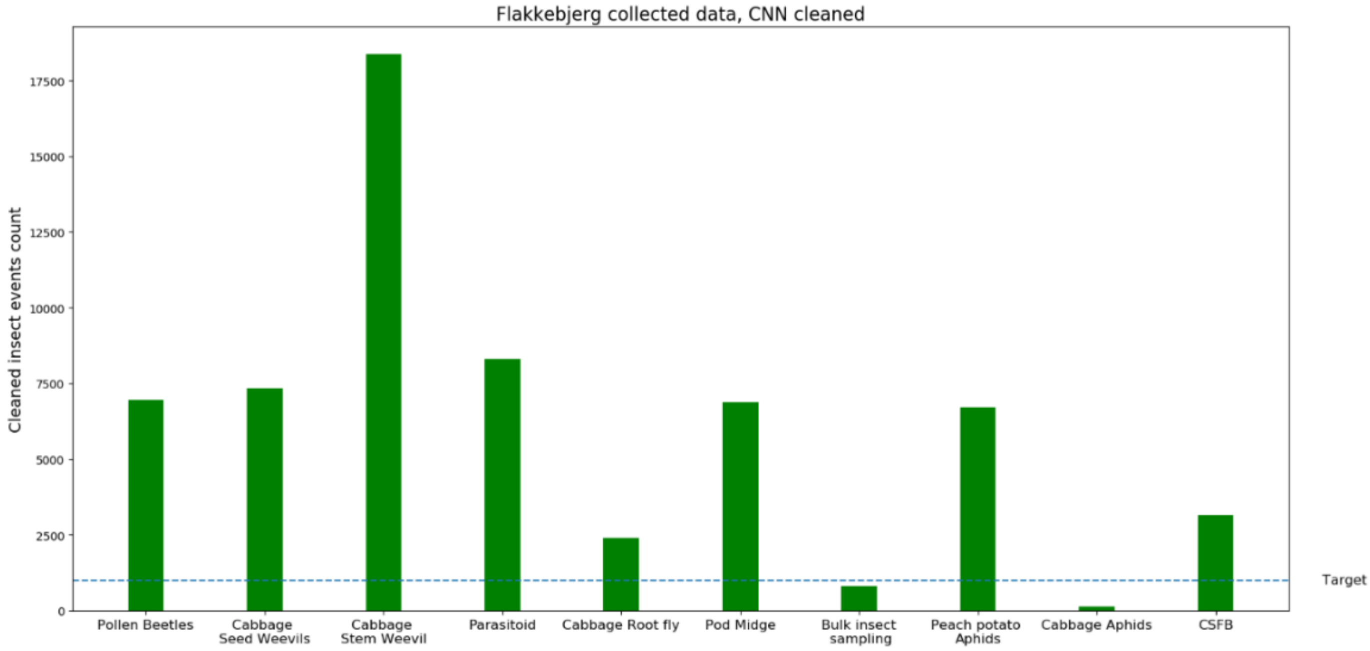



Figure  shows the labelled data that was recorded with the prototype sensor system in 2019. On that occasion, the target number of collected events was reached for many of the species, including the pod midge, following a breakthrough in rearing methodology after previous difficulties. Hardware issues during labelled data collection did affect some data, primarily that for the cabbage seed weevil, where part of the data was missing in one channel. These data are nonetheless included in the total recorded event count, as valuable insights can still be gleaned using the remaining channel, however the use of these data for machine classification is comparatively limited.

## 6.2 Spring 2020

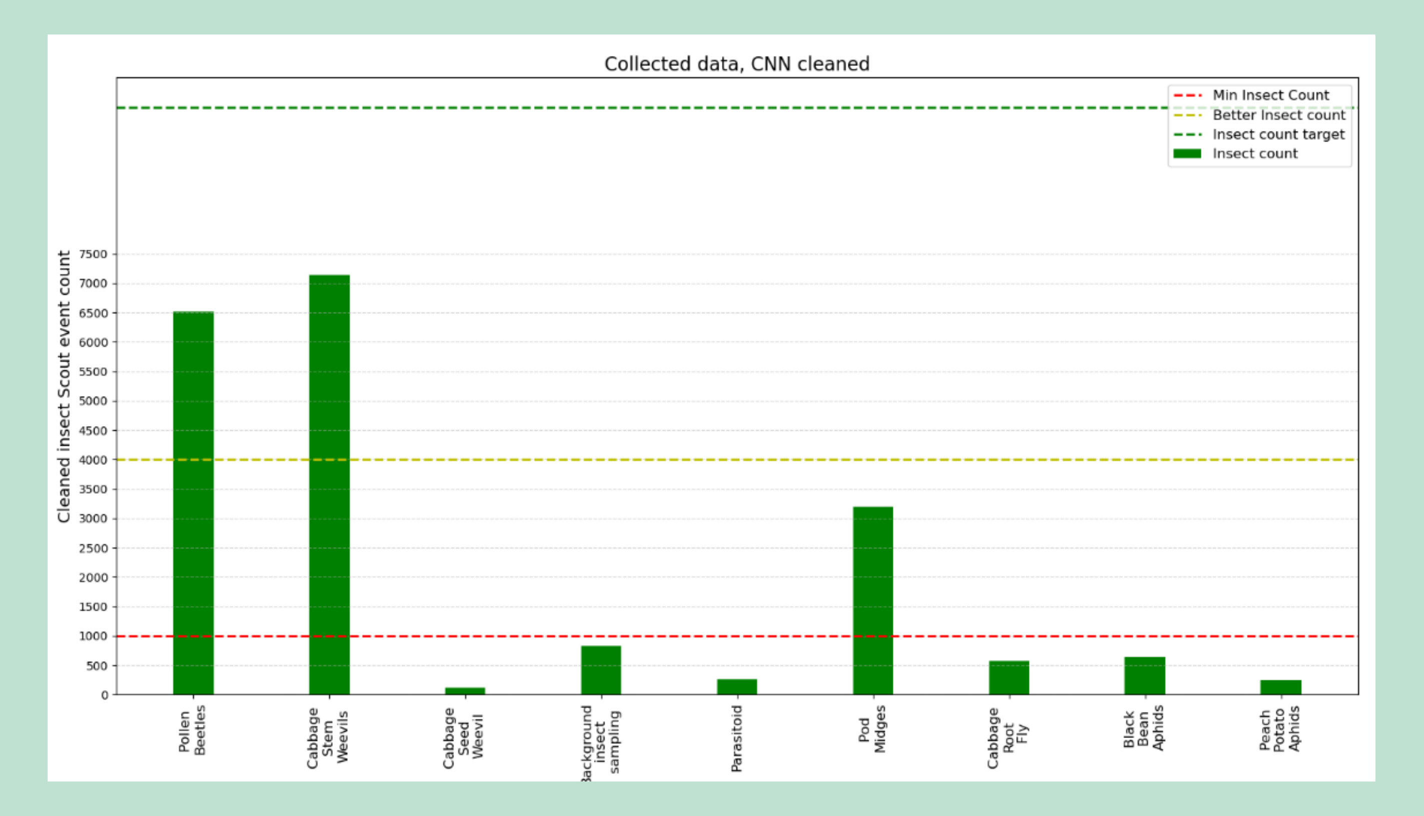



**FIGURE 7** Volito sensor labelled data recorded Spring 2020**.**

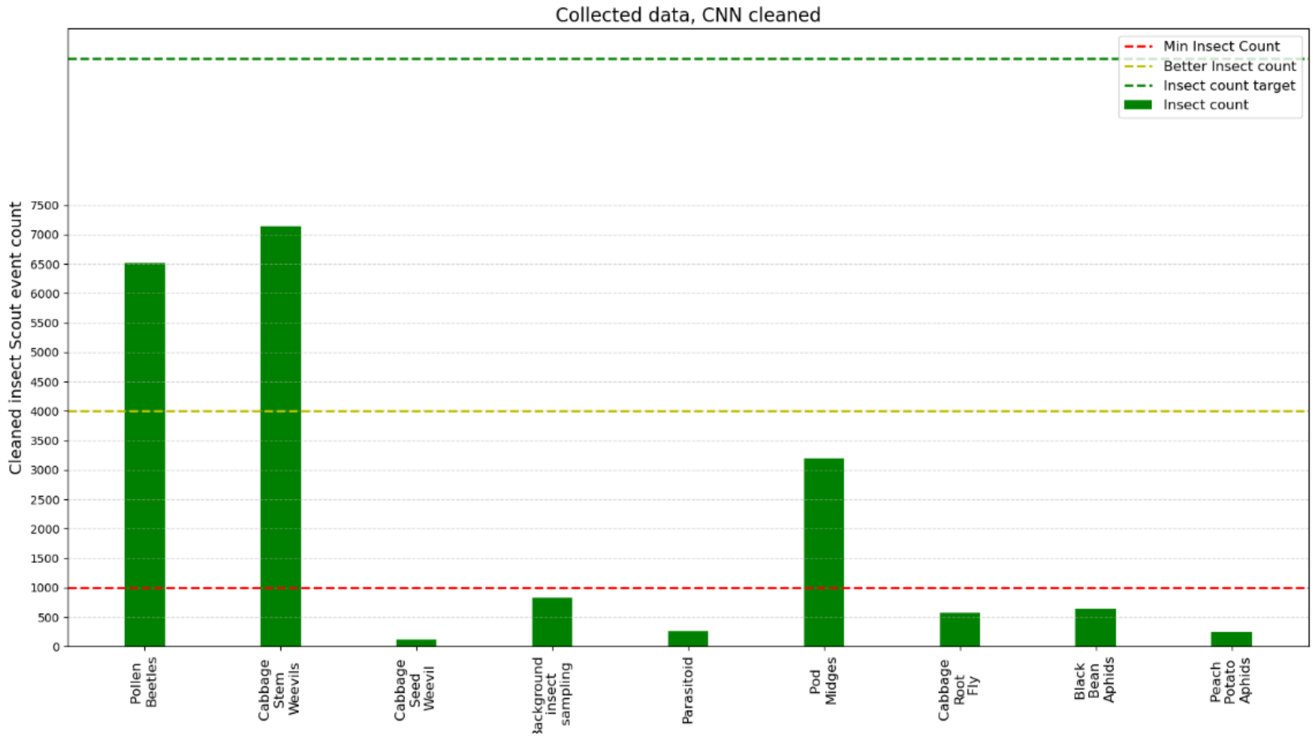



Figure  shows the labelled data collected with the ‘Volito’ sensor during Spring 2020. The target value for insect events was set to a higher value than previous years to allow for a greater environmental variation in the data. The introduction of the new ‘Volito’ sensor posed significant, unforeseen challenges in labelled data collection. The transition to an LED based light source increases the divergence of the light output, which increases the sampling volume but creates a need for the development of a more specialized cage in order to handle artefacts caused by reflections inside the cage. Challenges in the development of such a cage were due to the contradicting needs of a larger, darker volume to reduce data artefacts, and a smaller, lighter volume to achieve high numbers of insect flight events.

Additional challenges were faced regarding the limited number of available sensor systems, in part due to supply chain disturbances caused by the COVID-19 pandemic. To compound these challenges, technical issues with some of the early sensors caused some significant downtime, resulting in unfortunately missing the opportunity to collect and record cabbage seed weevil during its period of activity. These challenges have at the time of writing now been resolved with the finalization of the labelled data cage design and a greater sensor availability.

Unfortunately, the above stated difficulties resulted in lower insect counts for many of the important insects, as seen in 7. Especially note that the mixed fly groups that were very abundant in the field (Figure 4) were either not recorded or not recorded in high enough abundance.

# 7. Cabbage stem flea beetle (Psylliodes chrysocephala)

The main objective of the 2019 Autumn campaign was to validate feasibility of doing insect-specific observations of cabbage stem flea beetles in the field and do a preliminary study on the feasibility of correlating sensor data to traditional ground truthing. Applying previous findings on characteristic behaviors of cabbage stem flea beetles, notably circadian rhythm and wingbeat frequency, insect events were divided into 'cabbage stem flea beetles' and 'other insects' as a simplified machine learning algorithm. For a more elaborate discussion of these insect characteristics and the way, they can be used to differentiate species, see [2]. Using this measure, the immigration of cabbage stem flea beetles into the test field was independently identified by two FaunaPhotonics prototype sensors a number of days before the same immigration was identified in the conventional water traps, as seen in Figure 8 and in Figure 9.

Unfortunately, a significant amount of downtime of the prototype sensors made it difficult to draw any conclusions on how well the system was able to pick up the influx of the cabbage stem flea beetle. However, results indicate a potential key use case for the sensors in serving as an early warning system to detect a flying migration of cabbage stem flea beetles into the field. Initial observations from studies in 2020 indicate that we *are* able to pick up an influx of the cabbage stem flea beetle with our sensors before they start being observed in the field, possibly further validating the results from 2019.

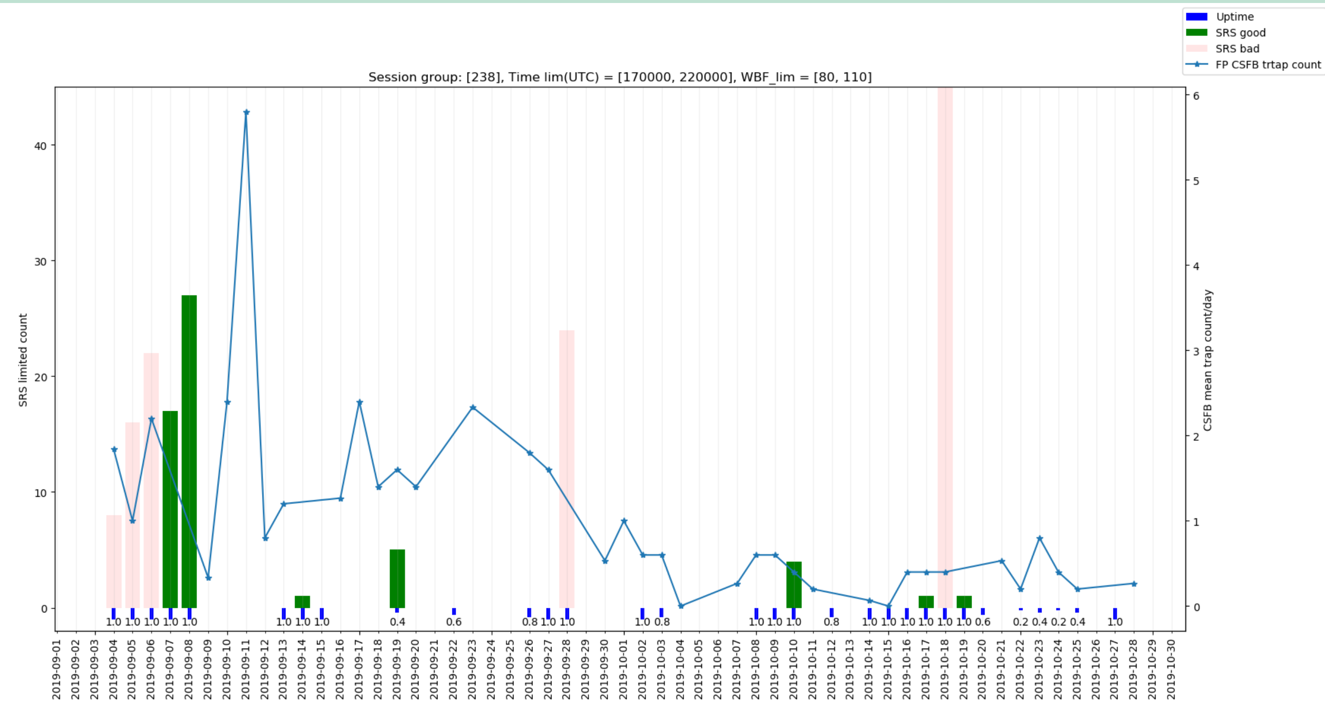



**FIGURE 8** A comparison between the cabbage stem flea beetle count per day as classified by the simple wing beat frequency and time restricted classifier for the first FaunaPhotonics prototype sensor (denoted SRS in the Figure legend), compared with the mean cabbage stem flea beetle count per day in the FaunaPhotonics water traps.

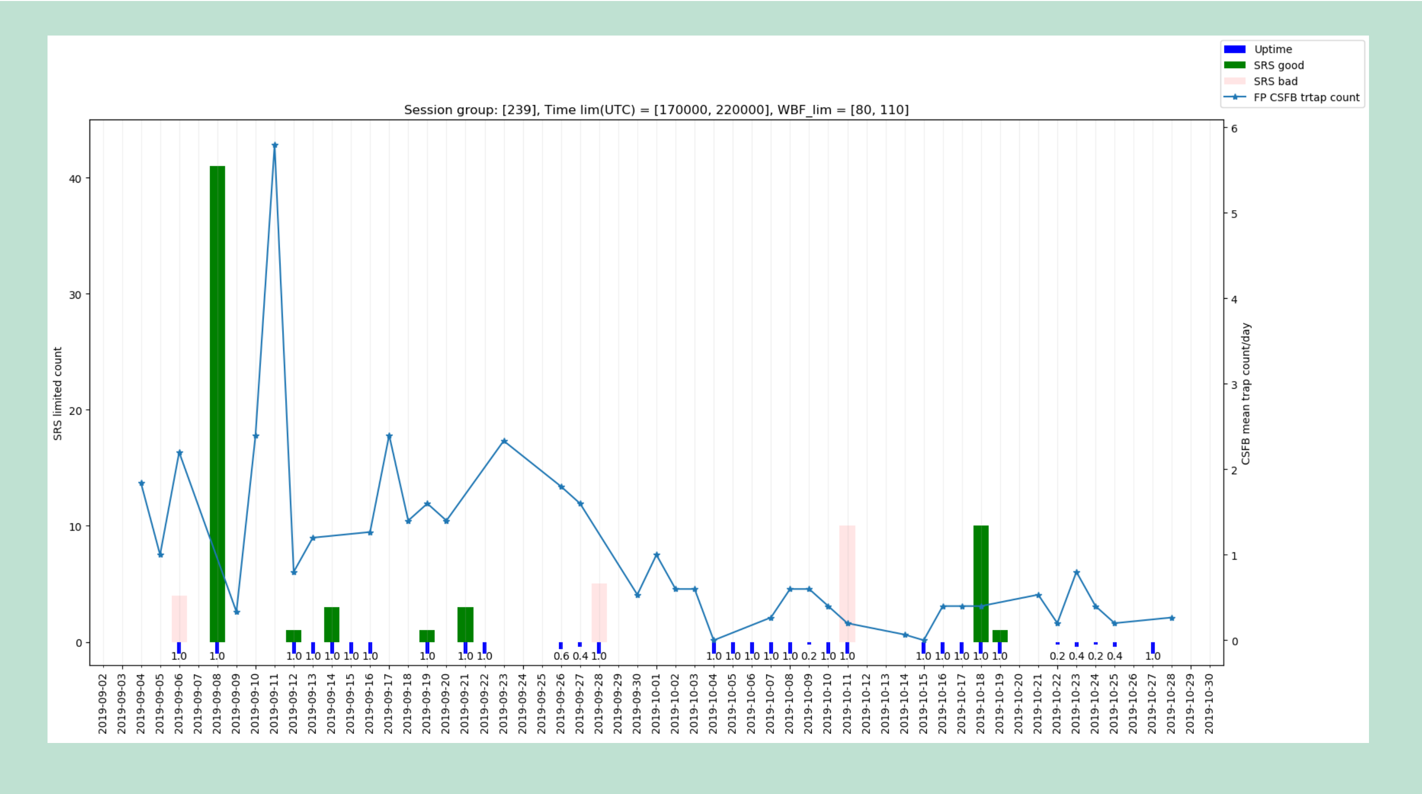
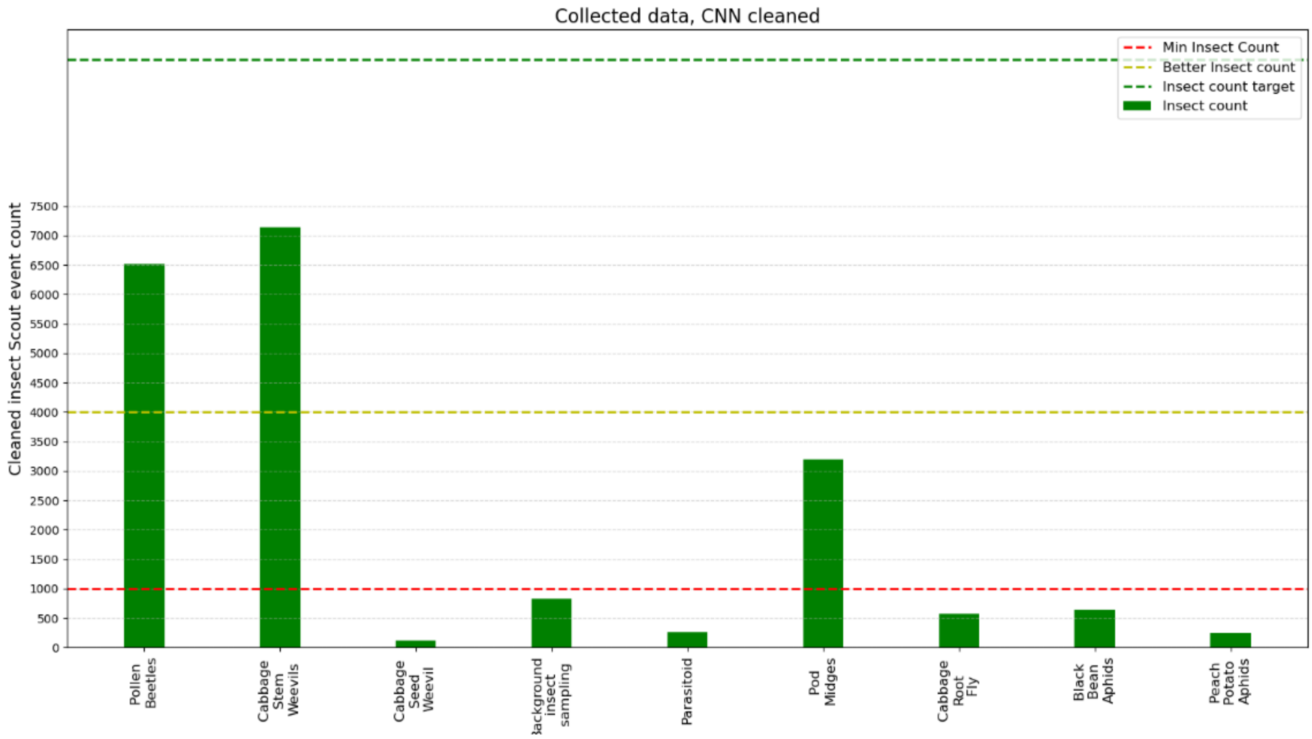



**FIGURE 9** A comparison between the cabbage stem flea beetle count per day as classified by the simple wing beat frequency and time restricted classifier for the second FaunaPhotonics prototype sensor (denoted SRS in the Figure legend), compared with the mean cabbage stem flea beetle count per day in the FaunaPhotonics water traps.

# 8. Pollen beetle (Meligethes aeneus)

The main objective of the 2020 Spring campaign was to validate the feasibility of monitoring the temporal change in pollen beetle activity. To be able to do this, a convolutional neural network (CNN) classifier was trained to identify pollen beetles based on labelled data collected in 2020, Figure 7. The resulting network performs well on the test set, with an accuracy of 95% in distinguishing labelled pollen beetle data from labelled data for all other collected species. Despite a limited training data set, pollen beetle detection represents an achievable goal with pollen beetles being the most abundant insect (Figure 4 and Figure 5) and their wing beat frequencies expected not to overlap too significantly with most other top abundant species (
Figure ).




## 8.1 Temporal changes in the abundance of pollen beetles over the spring 2020 season

Figure 10 and Figure 11 show the temporal variation of pollen beetle counts over the Spring 2020 season (yellow means rainy days, green means non-rainy days) as a comparison between the mean pollen beetle count in the water traps FP1-FP6 and the FaunaPhotonics 'Volito' sensors 1-6 placed in a grid in the FaunaPhotonics main plot (see Section 4).

As the actual pollen beetles counts for the traps and the sensors are of different magnitude, we can use something called the relative standard deviation, defined as,

$$\sigma^r = 100 \cdot \frac{\sigma}{|\mu|}$$

where μ is the mean value, and σ is the standard deviation, to compare the variation between the water traps and the variation between sensors. To get a value that represent the overall variation over the season, a variation metric is created that calculates the mean of the relative standard deviation for all days, defined as,

$$Variation\ metric = \frac{\sum_i^n \sigma_i^r}{n}$$ , where i is a date and n the total number of days.

This is done for the water traps and sensors respectively to get comparable numbers. This results in,

- Variation metric sensors = **53**
- Variation metric traps = **101**

Thus, according to this metric the variation between the traps is higher than the variation between sensors. This indicates that the sensor-to-sensor agreement for pollen beetles is equal or better compared to the trap-to-trap agreement.

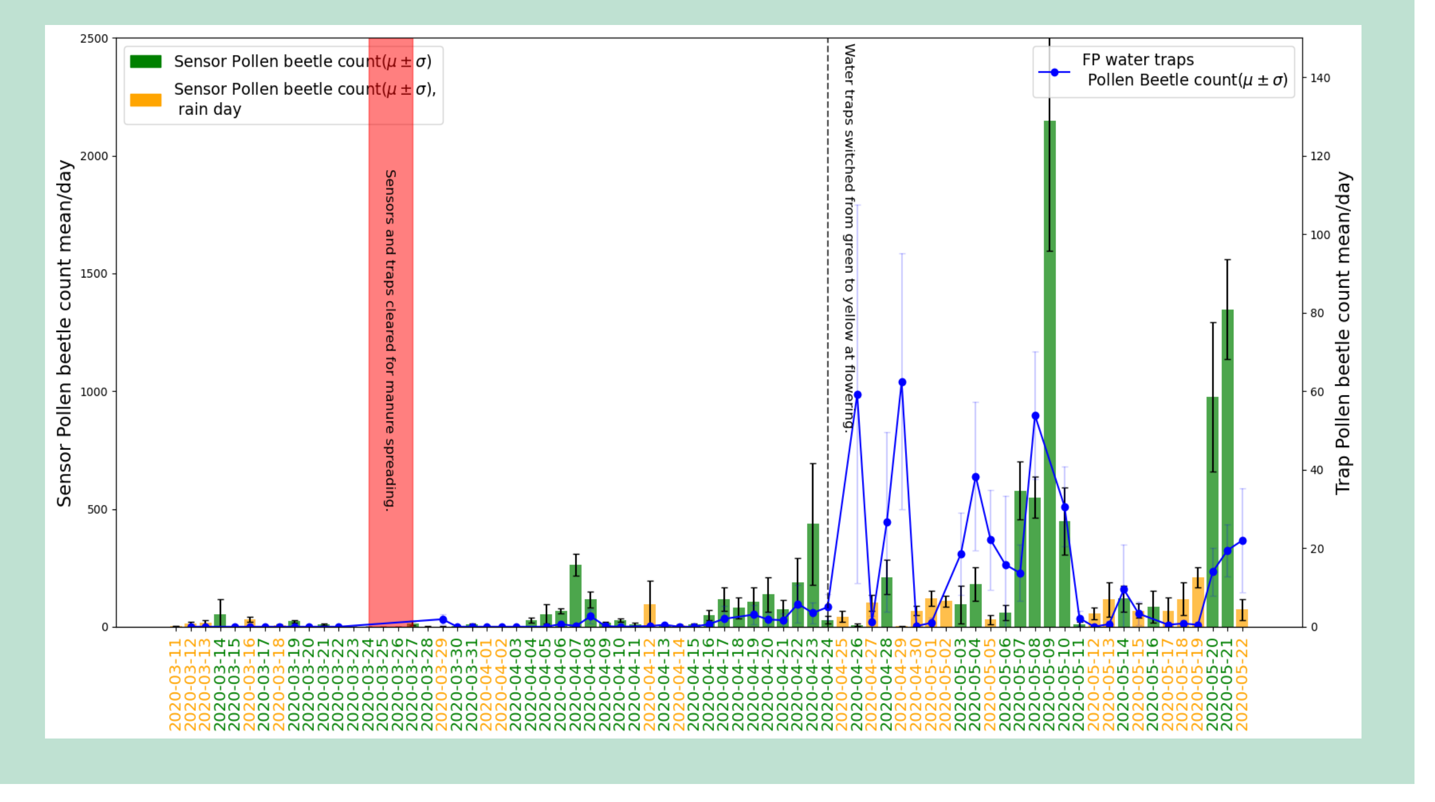



**FIGURE 10** Mean pollen beetle count per day from six FaunaPhotonics Volito sensors based on a trained pollen beetle classifier, compared with the mean pollen beetle count per day for six adjacent FaunaPhotonics water traps.

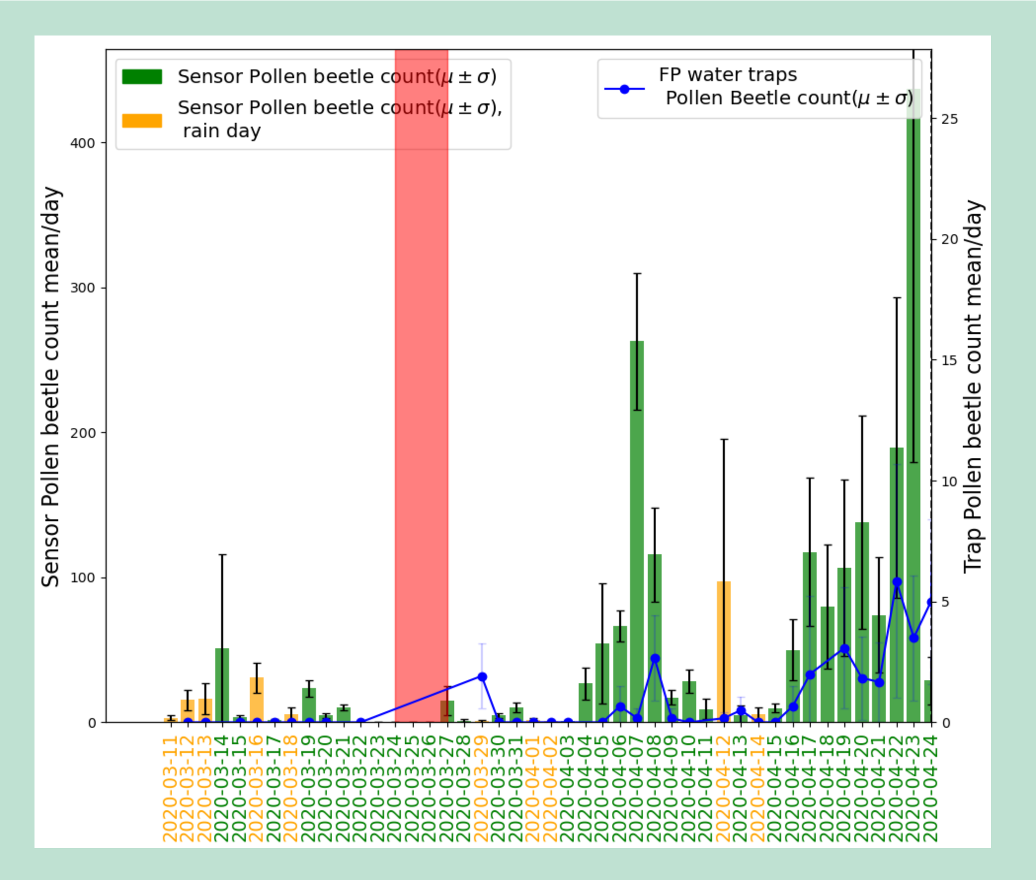



**FIGURE 11** Mean pollen beetle count per day from six FaunaPhotonics Volito sensors based on a trained pollen beetle classifier, compared with the mean Pollen beetle count per day for six adjacent FP water traps for the early part of the season before water traps color changed (zooming in on the first part of Figure 9).

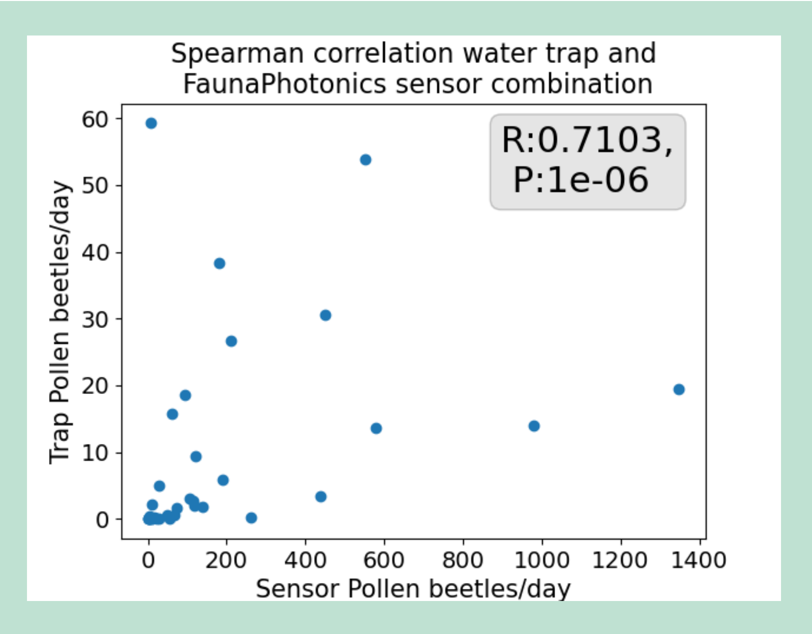



**FIGURE 12** Spearman correlation between daily water trap pollen beetle counts and FaunaPhotonics Volito sensor pollen beetle counts per day over the full season

Over the season there are a few important events to note.

1) Around March 24, 2020, the farmer drove over the field to spread manure. During this period, water traps and sensors were removed, and no data was collected.
2) All days marked as yellow are days with any rain as reported by DMI in the Sorø area (and consequently days marked as green are non-rainy days). A very important observation is that the pollen beetle count in the traps is low or zero on all days with rain, indicating very low levels of activity. As the FaunaPhotonics Volito sensor is unable to make accurate insect count readings on rainy days due to the high increase of noise events caused by the rain, these periods are therefore disregarded. However, as activity appears to be very low during these periods this is not expected to significantly change results.
3) On April 24, 2020, the water traps F1-F6 were switched from green to yellow traps. This was done to keep the trap color as neutral to the crop canopy as possible when the crop began to flower. This seems to have caused an initial upsurge in pollen beetle counts in the water traps which were not reflected in the sensors and may also change the relationship between water traps and sensors, potentially affecting the correlation seen in Figure 12. The upsurge in pollen beetle incidence when the traps were changed could be caused by a sudden change to yellow attracting more pollen beetles. However, after approx. 1-2 weeks the yellow water traps and the sensor counts appears to have settled back into better agreement. Still, care should be taken when comparing these counts with the early season with green water traps. Generally speaking, and aside from this changeover period, the water traps and sensors visually do follow a similar trend most of the season.
4) The sensors seem to be more sensitive to pollen beetles than the water traps, as shown above. An example of this can be seen in the beginning of April, 2020, where the sensors start registering an increase in pollen beetle activity before the numbers begin to rise in the water traps. Throughout the season, the sensors yield more than 10x the pollen beetle count for the same sampling interval as compared to water traps. This early response, combined with the advantages of a near real-time automated system in contrast to the resource-intensive collection of water traps, highlight the opportunity

for the sensors as an early/instant warning system for pollen beetles, compared to water traps which must be manually collected.

5) All sensors in the field independently report the same temporal activity variation of the pollen beetle. Additionally, the variation between sensors is smaller than the variation between water traps, indicating a potential for higher reliability with a smaller number of sensors.
6) The uptime in the Spring 2020 field season, using the Volito sensors, was significantly better and more stable than during the Autumn 2019 campaign, using the prototype sen which can be seen by making the following comparison.

**Autumn 2019**

a. 2 prototype sensors
b. Full time = 1296 x 2 = 2592 hours
c. On time = 628.8 + 633.6 = 1262.4 hours -> **48.7%**
d. On time without rain = 465.6 + 537.6 = 994.2 hours -> 38.4% (If sensor down full day it might also have rained but it is unknown)

**Spring 2020**

e. 6 Volito sensors
f. 1 sensor failed 2 days before the end of the season, and one died a few weeks before but was not replaced/fixed due to lack of sensors.
g. Full time = 1752 x 6 = 10512 hours
h. On time= 1752 x 4 + 1728+ 1296 = 9962 hours -> **94.8%**
i. On time without noise/rain (rain part of day all day counts as rain) = 1176 x 5 + 912 = 6792 hours -->64.6%

In terms of showing that the Volito sensors were working much better than the prototype sensors, the functional uptime shows this the best as it is not dependent on weather.

| Year | Functional uptime [%] | Clean data uptime [%] |
|---|---|---|
| 2019 | 48.7 | 38.4 |
| 2020 | 94.8 | 64.6 |

Functional uptime = Time recording and sending data / Experiment time period
Clean data uptime = Time with clean useful data / Experiment time period

These conclusions can also be backed by comparing Figure 10 and Figure 11 with Figure 8 and Figure 9.

## 8.2 Spatial representativeness of pollen beetles

Once it is shown that one sensor can detect the target, it is of interest to know how well this measurement represents the rest of the same field, as well as adjacent fields, in order to determine how many sensors it would require to monitor a pollen beetles in a given area. The grid-based experimental set-up used in the Spring 2020 campaign, shown in Section 4, allows exploration of this question. Figure 13 plots the difference in pollen beetle counts between each set of two water traps against the straight-line distance between them.

To get an idea of the pollen beetle counts representativeness for longer distances in adjacent fields the traps FP7-FP11 can be compared. Figure 13 shows a comparison of the difference in Pollen beetle count between each trap-to-trap combination per sample point for the main plot traps FP1-FP6 and FP7-FP11 respectively. It shows the mean and standard deviation of the difference in pollen beetle counts for each trap to trap comparison against the distance between each pair of compared traps. To be able to compare the local traps and the traps in the adjacent fields it is the later part of the season that is shown ensuring comparability with all traps being yellow.

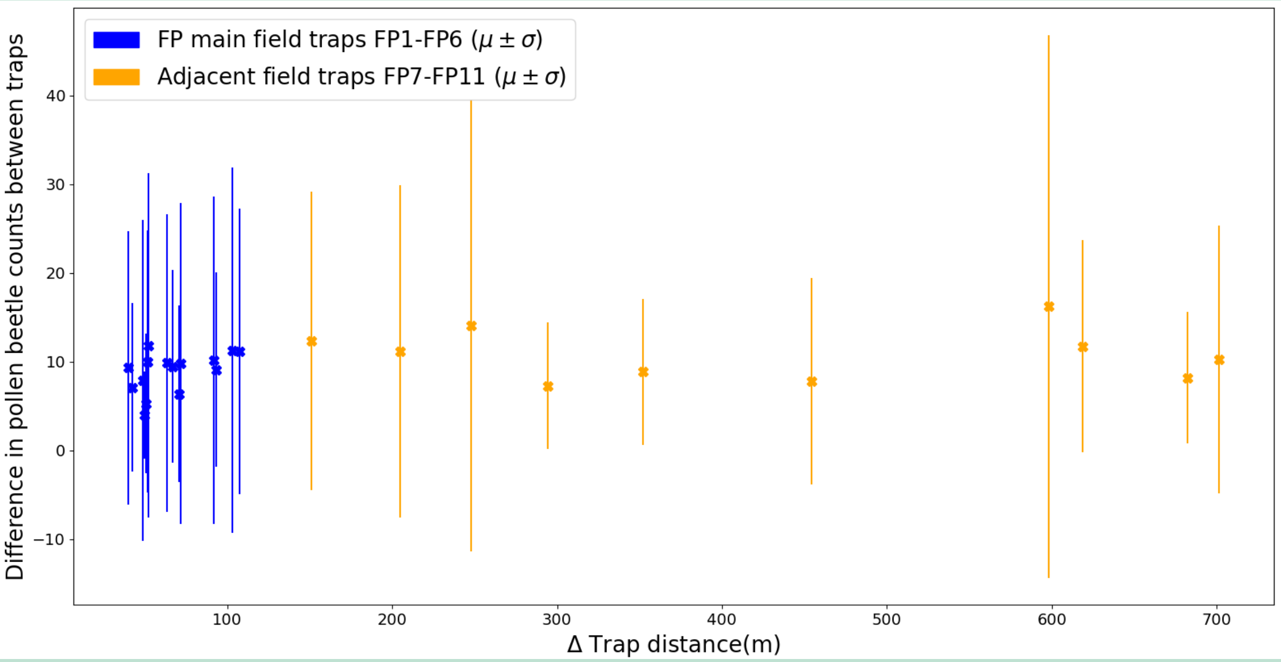



**FIGURE 13** shows delta pollen beetle count difference vs trap distance for main plot FP1-FP6 together and FP7-FP11 together after 2020-04-24. Groupings to ensure same sampling frequency and date to ensure same color of traps.

The hypothesis under investigation is that – given a non-uniform pollen beetle population in an area – the greater the distance between water traps, the greater the difference in insect counts. However, the results in Figure 13 appear to reject this hypothesis. There is no clear trend corresponding to larger differences in counts of pollen beetles with a larger trap-to-trap distance.

Fitting a line, assuming a linear relationship between the count difference and the distance to all the underlying values creating the plot in figure 13, results in the line described by,

y = **0.00423**x + 8.625

Assuming that such a linear model is valid, it means that the pollen beetle count difference along this line change by 4.2 over a distance between the water traps of 1000m. This is not a big difference within the scope of the data in relation to the fact that the standard deviation at each distance clearly is higher than this at all distances included! This means that the variation at each distance is higher than count difference at all the distances within the distance limits of the data according to the linear model.

Considering that the relative standard variation was equal or lower for the sensors compared to the traps in the main plot, it could be expected that we would get a similar result as in Figure 13 for the sensors. However, confirmation of this subsequent hypothesis would require sensors stations further out in adjacent fields, a step outside of the scope of the experiment at this time. If confirmed, this finding would indicate that relatively few sensors are required to report on pollen beetle activity variation in a large area.

# 9. Other target species

In addition to the pollen beetle, two other target species are mentioned in the campaign goals, the cabbage seed weevil (Ceutorhynchus obstrictus) and the pod midge (Dasineura Brassicae). These were unfortunately not successfully detected in the field for the following reasons.

Study of the Cabbage Seed Weevil was critically obstructed by unsuccessful collection of labelled data, mainly due to an early failure of the new sensors. Labelled data collection for the Pod Midge was on the other hand very successful, however attempts to build a meaningful classifier for the pod midge were fatally undermined by the exclusion of a key similar abundant background species – the leaf miner fly – from labelled data collection, as well as very low recorded incidence of pod midges in the field.

# 10. Summary and Conclusion

It has been two insightful campaigns. Over the course of the campaigns, big steps have been taken in sensor development with regards to stability, data quality and uptime of the sensors. This enabled multiple sensors to independently detect pollen beetles and cabbage stem flea beetle in each campaign.

In the first campaign, Autumn 2019, two prototype sensors were able to independently pick up an early cabbage stem flea beetle peak days before it showed up in the water traps, despite low numbers of the pest in the field. This gives a good foundation for a use case for the sensors as an early detection system detecting the flying influx of the cabbage steam flea beetles. Initial results from 2020 Autumn trials (not discussed in this report) also indicate a possibility of detecting the influx of the cabbage stem flea beetle and hopefully end up confirming this as a viable use case. In addition, the 'Volito' sensor is designed with the possibility to also detect cabbage stem flea beetle jumps even though it requires further development before this would be possible.

In the Spring 2020 campaign, six new 'Volito' sensors showed good signs of being able to independently detect temporal trends over the season for the main target, pollen beetles. The between sensor agreement and the agreement with traps looked promising even if some changes in the setup over the season makes the full season comparison a bit trickier. Based on trap data a large spatial representativeness for the daily temporal development of pollen beetles could be expected. An interesting next step for coming seasons would be to test this fully by placing sensors in multiple adjacent fields.

The main bottleneck in both campaigns was the challenge of getting the required labelled data to be able to create machine learning based classifiers. In the Autumn 2019 campaign, the aim would be to improve the wing beat frequency-and time-based cabbage steam flea beetle classifier. For the Spring 2020 campaign, the aim would be to better be able to detect lower abundance target species, such as cabbage seed weevils and pod midges.

A combination of missed abundant species, COVID-19 restrictions (which severely limited access to the insect labelling facility at AU, Flakkebjerg), limited availability of Volito sensors, and parallel cage-and sensor development made it difficult to reach the required insect counts for some important species. However, coming out of the campaigns now with a cage specially designed for the 'Volito' sensor and with many more sensors available, there is a significantly improved chance of being able to get the required labelled data going forward.

# 11. References

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**Precision sensor technology that supports area specific monitoring of target insect pests in oil seed rape and digitalization of registration**

Cabbage stem flea beetles (Psylliodes chrysocephala) and pollen beetles (Meligethes aeneus) are two major pests in oilseed rape. In 2019 and 2020, two trials were conducted to demonstrate the use of the FaunaPhotonics Volito sensor to detect these two pests.
In the first campaign, Autumn 2019, two prototype sensors were able to independently pick up an early cabbage stem flea beetle peak days before it showed up in the water traps, despite low numbers of the pest in the field.
In the Spring 2020 campaign, six Volito sensors showed good signs of being able to independently detect temporal trends over the season for pollen beetles.
This gives a good foundation for a use case for the Volito sensors as an early detection system detecting the flying influx of pollen beetles and cabbage steam flea beetles in oilseed rape.

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