Forest Research

Review of the FTN Year One Rollout 2022

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The Research Agency of the
Forestry Commission

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1 Executive summary

The Future Surveillance Plan (FSP) is a Great Britain-wide, broad-spectrum strategy to monitor quarantine and priority forest pests included in the Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020. The FSP outlines several survey techniques which target species on the EU-survey list. These include drone, visual and aerial surveys, but some species on the list cannot be monitored using these techniques. The Forest Trapping Network (FTN) was formed as a key part of the FSP and fills this gap by targeting quarantine and priority species which the other survey methods cannot detect. The goals of the FTN are (1) Form a key FSP survey strategy which targets pests that other survey methods cannot detect, including species of non-European Scolytinae and several other non-native Scolytids, several species of non-native *Pissodes* (Molytinae), *Monochamus* spp. and *Xylotrechus* spp. (Cerambycidae), and *Arrhenodes minutus* (Brentidae); (2) Consolidate current trapping programmes into a single network to ease logistical issues (aiming to replace some existing trapping programmes long-term); (3) Improve current trapping methods for quarantine pests; (4) Ensure a cohesive approach across the three countries involved (England, Scotland and Wales).

The FTN is a rolling programme which will survey 100 forests for EU-survey list pests over five years. In each forest, plots of oak, pine, spruce, fir and mature mixed broadleaf are chosen to target different pest species. The FTN is currently in the first year of the Beta-phase (2022 - 2025), with the first full 5-year reporting period commencing in 2025 and finishing in 2030. The Alpha-phase of the project ran from 2020-2022, testing different lure and forest-type combinations.

The FTN in 2022 deployed 38 traps across 10 sites in SE England. We trapped 10,247 individuals from 48 species or genera of interest to tree health, including a very good sampling coverage of Scolytinae (bark beetles), of which we trapped 34 species across all sites. This included one quarantine species, *Ips typographus*, at one site in SE England, and economically important species, such as *Xylosandrus germanus* and *Tomicus piniperda*. It revealed generally interesting information about the flight patterns and habitat preferences of common species and about species abundances and diversity across different forest types.

Questions addressed in this report:

Q1 – Did the FTN 2022 meet its four overarching goals?

Mostly – It trapped one quarantine pest on the EU survey list that would likely not have been detected otherwise. It also consolidated *Ips typographus* monitoring into the broader network, although more could be done to consolidate trapping programmes for other quarantine species. It improved on existing monitoring programmes for quarantine pests by using novel, broad-spectrum lure combinations that have been shown in previous pilot studies to be more effective at attracting quarantine and other pest species (e.g. *Ips typographus*) than existing monitoring techniques. It also surveyed a far wider range of forest types than other programmes and targeted a wider range of quarantine pests in doing so. Relationships between the three countries in terms of delivering the FTN were developed and strengthened, and have led to a significant amount of input from all three parties in delivering the FTN 2023.

Q2 – Was the FTN 2022 effective in surveying for quarantine pests?

Yes - whilst we only trapped one quarantine list species, we are confident that it effectively targeted quarantine pests on the EU-survey list. This is evidenced by trapping 18 positive control species, which are analogous to species on the quarantine list, showing that had quarantine species been present the FTN would very likely have detected them.

Q3 – Do any changes need to be planned for 2023 and into the future?

Yes – The FTN 2022 had a narrow geographic scope, and we plan to widen the area covered in GB by designating 10 sites in England across the North West, South West and the East Midlands, four sites in Wales and ten in Scotland. We propose more training for staff who are responsible for choosing appropriate forest types, due to one trap being situated in a woodland with suboptimal tree species composition which biased the data. We also plan to identify natural predators of tree pests in order to give a more holistic view of the health of our forests. Due to the large amount of wasted bycatch invertebrates in the FTN 2022, we plan to keep and store certain understudied groups so that the data can be used in future studies.

2 Introduction

2.1 Background

The Forest Trapping Network is one of the monitoring strategies outlined in the Future Surveillance Plan (FSP). The FSP was designed to provide high-level surveillance strategies for multi-annual surveys of all priority, quarantine and provisional quarantine forestry pests, as described in the Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 (Appendix A). There are several insect pests identified in the new legislation that cannot be detected by other methods in the FSP (e.g. visual surveys via the National Forest Inventory, aerial and drone surveys), nor are they likely to be sampled through existing networks (e.g. billet and Port, Pier, Processor trapping for quarantine *Ips* spp., or the Wider Environment survey for *Ips typographus*). The FTN was developed to address this deficit in existing trapping techniques.

The overarching goals of the FTN are:

(1) Form a key FSP survey strategy which targets pests that other survey methods cannot detect

(2) Consolidate current trapping programmes into a single network to ease logistical issues (aiming to replace some existing trapping programmes long-term)

(3) Improve current trapping methods for quarantine pests

(4) Ensure a cohesive approach across the three countries

The Forest Trapping Network (FTN) is the result of two years of pilot studies in 2020 and 2021 (Blake *et al*., 2021) which compared and refined trapping methods to better detect invasive non-native bark-boring insects. These pilots revealed several issues with the traditional trapping method for quarantine species (billet trapping), including samples arriving in poor condition making them unidentifiable; the quarantine species *Ips typographus* being missed in samples despite being present in nearby pheromone traps; and poor sampling leading to false negatives when non-quarantine species indistinguishable from quarantine species in the field (e.g. *Ips sexdentatus*) weren't sampled despite being present in billet piles. The pilot program tested three types of experimental lures in cross-vane traps as attractants for quarantine species and other species of interest to plant health. The pilots revealed that billet traps caught considerably fewer quarantine species compared with traps containing the experimental lures, and also showed that different lures were effective at trapping different species. The results of these pilots therefore highlighted a need for a broader, more adaptable trapping method for quarantine species and other species of interest to tree health.

The FTN has been developed as a broad-spectrum, rolling programme which aims to survey 100 forest plots across England, Scotland and Wales over a five-year reporting period, with 20 plots set up each year. Forests will be selected across the three countries, with each contributing at least three of the five tree-species surveys (mixed broadleaf, oak, pine, spruce & fir). Oak (*Quercus*), pine (*Pinus*), spruce (*Picea*) and fir (both *Abies* and *Pseudotsuga*) all have a number of target species associated with them, while the mixed broadleaf species (alder, chestnut, beech, cherry, birch and hornbeam) have only one or two associated pests and therefore need less intensive surveillance. Each forest will be surveyed once in the five-year period, with the goal of having at least 40 sites per tree species over the five years, and 20 sites for each target species within Mixed Broadleaf. Each woodland type will have a trap with the appropriate lures installed.

The alpha-phase of the FTN was rolled out in 2022. The second- and third-year rollout (beta phase) of the FTN will be used to refine the experimental methods that will ultimately become standardised for the first full 5-year reporting period, commencing in 2025.

The questions addressed in this report are:

Q1 – Did the FTN 2022 meet its four overarching goals?

Q2 – Was the FTN 2022 effective in surveying for quarantine pests?

Q3 – Do any changes need to be planned for 2023 and into the future?

2.2 Experimental approach

2.2.1 Site selection

Ten forest sites were chosen across South England in which to set up the FTN in the year one rollout (Fig. 1). These sites were all chosen due to their proximity to traps monitored as part of the *Ips typographus* Wider Environment monitoring programme, the aim being that a single surveyor could manage traps from both programmes at the same time, reducing travel costs. Forester Web was used to determine appropriate locations for up to five cross-vane traps within each site (Fig 2). The locations met the following criteria at a minimum: within a >1 ha sub-compartment dominated by either oak, pine, spruce, fir, or mixed broadleaf (alder, chestnut, beech, cherry, birch or hornbeam), where the planting date for the target tree species was earlier than 1982 (40 years ago).

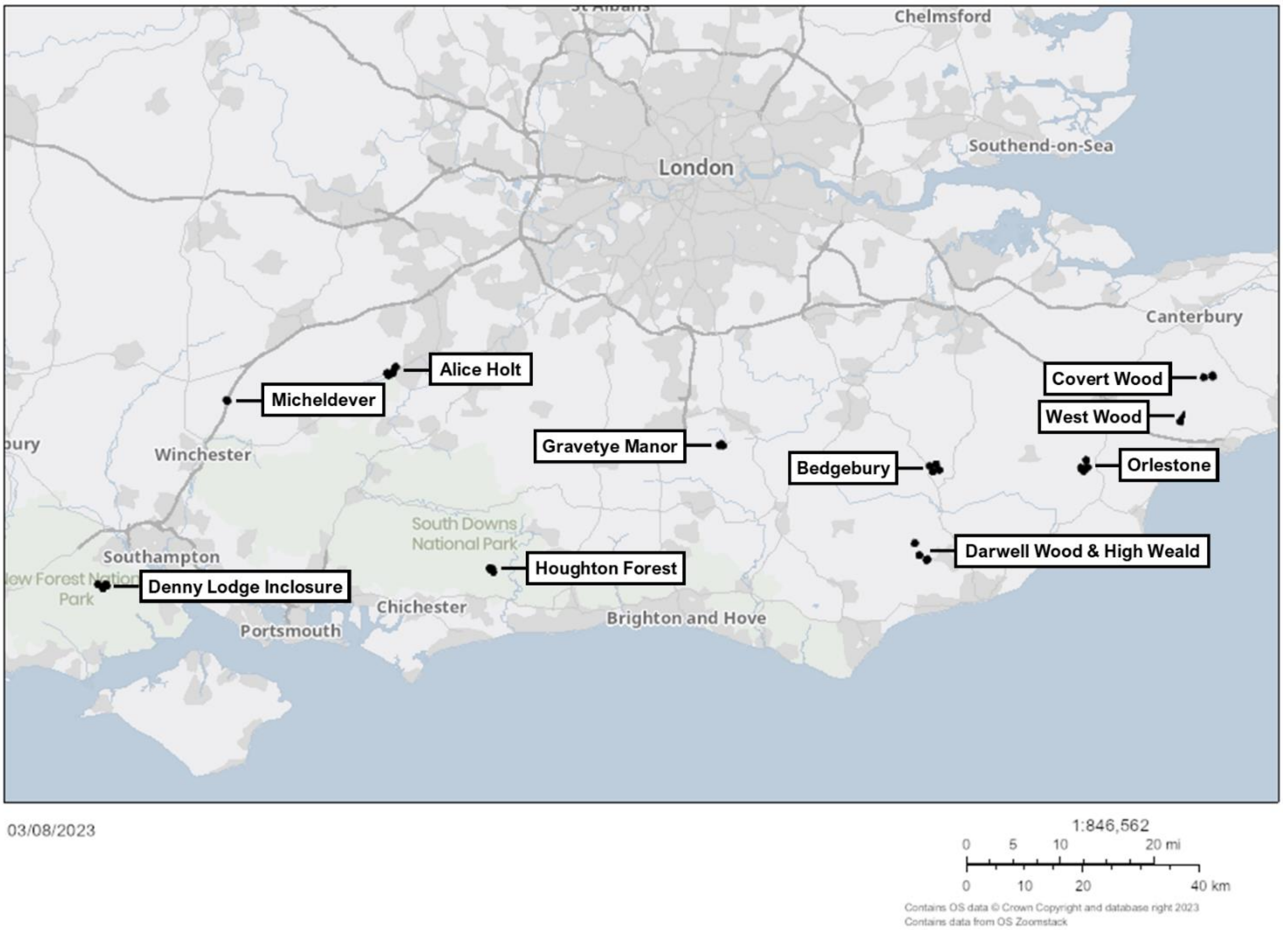

Fig. 1. Map of FTN traps set up across sites (labelled) in South-East England.

The lures used in the traps were ethanol, α-pinene and the *Ips typographus* pheromone (Fig 2). Ethanol and α-pinene are general lures for beetles that are attracted to damaged or dying trees, with ethanol generally associated with broadleaved species, and α-pinene with conifers. The *Ips typographus* pheromone is a species-specific pheromone lure for *I. typographus*, which can also attract other species of *Ips*. Within each woodland type, a cross vane trap was set up with appropriate lures: ethanol only (oak and other broadleaf); α-pinene + ethanol (fir and pine); α-pinene + ethanol + *Ips typographus* pheromone (spruce).

2.2.2 Cross-vane trap set up

All cross-vane traps were set up with 30-50% propylene glycol as a preservative in the base. Trapping started in March and continued until the end of August or early September. Traps were set up on 6ft stakes, or hung between trees, with samples collected fortnightly and sent to Alice Holt for processing.

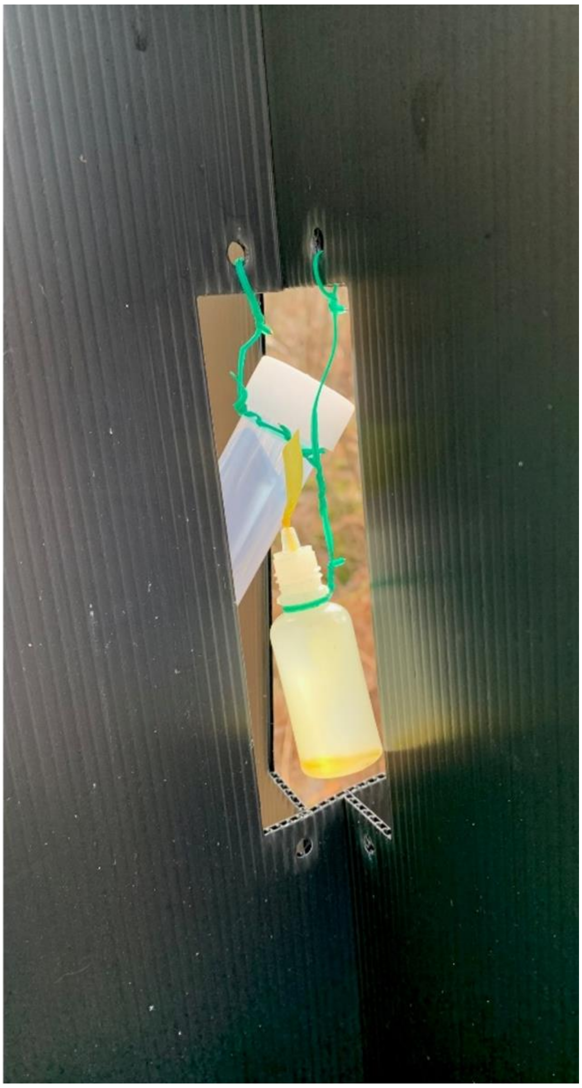

Fig. 2. Set up of a typical cross-vane trap (left). Ethanol and alpha-pinene lures in place in a cross-vane trap (right).

2.2.3 Sample processing and identifications

2.2.3.1 Target species/groups

Our broad-spectrum trapping method inevitably caught large numbers of non-quarantine insects. Although not the primary target of the FTN, the information on the abundances, native ranges, and seasonal dynamics of other insect groups of interest to tree health (such as bark beetles and longhorn beetles) is important. Therefore, specimens within specific families or subfamilies were identified to species (where possible) at Forest Research:

a) **Scolytinae** – bark beetles. All identified to species level. Last survey of this group was between 2013-2017 (D. J. Inward, 2020), which collected three species new to the UK. Particular attention should be paid to species of major plant heath significance such as *Ips*, *Tomicus* and the ambrosia beetles. All non-European Scolytinae are included on the EU-survey list (Appendix A).

b) **Cerambycidae** – longhorn beetles. All identified to species level. Many species are woodborers, particularly attacking trees that are already stressed, e.g. by climatic stressors or bark beetle infestation. Several species of Cerambycidae are included in the EU-survey list (Appendix A).

c) **Molytinae** – wood-boring weevils: *Pissodes* and *Hylobius*. Identified to species level. Eight species of *Pissodes* are on the EU-survey list (Appendix A) yet few previous surveys have targeted this genus.

d) **Ptinidae –** "spider beetles". This family is extremely diverse but includes a range of woodboring species – some of which are well-known pests, such the furniture beetle (*Anobium punctatum*) and the death-watch beetle (*Xestobium rufovillosum*).

e) **Cossoninae** – wood boring weevils similar to Molytinae. There are 16 species present in the UK but only *Euophryum confine*, which attacks decaying wood (adults) and dry wood (larvae) or various deciduous and coniferous trees, is particularly common. *Euophryum confine* is native to New Zealand but has become widespread throughout Europe and North America during the last century.

f) **Siricidae** – wood wasps. Identified to genus or species where possible. This group is very poorly known but often collected in traps, new species occasionally intercepted in the past. This is an important group which are pests in warmer climates, and therefore surveying for wood wasps will be crucial for monitoring a potential climate-facilitated spread.

g) ***Arrenodes minutus*** – the oak timberworm. This is a species of weevil in the Brentidae family (i.e. not falling into the above groups) that is on the EU-survey list.

2.2.3.2 Positive controls

Some species within the groups above can be considered "positive controls", which indicate that the FTN is functioning correctly in attracting target species:

- **Ambrosia beetles** (certain species of Scolytinae and Platypodinae), e.g. species in the Xyleborini tribe such as *Anisandrus dispar*, *Xylosandrus germanus*, *Xyleborinus saxesenii* and *Xyleborus* spp. – there is one specific species of ambrosia beetle on the EU-survey list, *Euwallacea fornicates*, and many other non-European ambrosia beetles would fall onto the list too (Appendix A). We expect these species to be strongly attracted to the ethanol and alpha-pinene lures, as previous studies and pilot trials have shown (e.g. Blake *et al.* 2020, Inward 2020). Hence, trapping these suggests that the lures are attracting the right kinds of species.

- ***Ips typographus*** – we know *Ips typographus* is present at some of the sites which are in the Ips demarcated area in South-East England. This species is therefore a positive control as it is one of the target species of the FTN (Appendix A).

- ***Tomicus piniperda*** –a native species which is not on the EU-survey list, but which can be highly damaging to pine trees. Again, this species is attracted to the lures used (Blake *et al*., 2021) so trapping it would be a positive sign that the FTN is functioning correctly.

- ***Pissodes pini*** – this species is closely related to the eight species of *Pissodes* that are on the EU-survey list (Appendix A).

- ***Hylobius* spp.** – this genus is closely related to *Pissodes*.

- ***Polygraphus poligraphus*** –a rare species associated with Norway spruce, which is within the same genus as one of the EU-survey list species (*Polygraphus proximus*; Appendix A).

- **Woodboring Cerambycidae**, e.g. *Arhopalus rusticus*, *Rhagium mordax*, *Clytus arietus*, *Rhagium bifasciatum*, and *Rupelta maculata* – trapping these species would be a good indicator that the FTN is targeting woodboring Cerambycids effectively, several species of which are on the EU-survey list (Appendix A).

Bark beetles were identified using Grüne (1979) & Duff (2016). Longhorn beetles were identified to species using Duff (2016), whilst other species and genera were identified using Duff (Duff, 2020), Mike's Insect Keys (2023) and experience.

2.2.4 Data analysis

Because abundance data were zero-inflated and overdispersed, negative binomial generalised linear models (glmmTMB) were used to explore the variation in abundances of abundant groups and species between forest types (n = 5) and sites (n = 14), using the glmmTMB package in R (Magnusson *et al*., 2017). The responses of each common species were analysed separately to avoid overfitting the models, and because we were interested in the single-term effects of habitat and site, for each species two separate models were run to test the effects of each predictor. For each model, each data point represented abundance from one trap on one sampling date. To account for abundances varying as the year progressed due to seasonal effects, week number of the trapping season (i.e. the first week in which we collected samples was week 1) was included as a random effect. As each trap was sampled multiple times (repeated measures), trap number was also included as a random effect. Goodness-of-fit tests were carried out on each model using the DHARMa package (Hartig & Hartig, 2017). The Anova function from the lme4 package was run on each model to determine the overall significance (Type II Wald test) of each predictor (habitat and forest).

Rarefaction curves were created using the iNext package in R (Chao *et al*., 2014; Hsieh *et al*., 2016).

One trap set up in spruce at the Orlestone site collected large numbers of broadleaf-associated species, particularly *Xyleborinus saxesenii* – on one date this trap collected the highest number of *X. saxesenii* of any trap throughout the sampling season. The trap was set up in a sub-compartment of which the spruce component only comprised 3%, where the remaining 97% of trees were all broadleaf species. For this reason, this trap was excluded from analyses to avoid outlier bias.

3 Results

Across the 10 sites and including all forest types, 10,247 individuals were collected in 313 samples, encompassing 48 different species or genera of interest to tree health (Fig. 3; Appendix B). 2988 specimens were trapped in mixed broadleaf forests across the trapping season, 2672 in pine forests, 2620 in oak forests, 1317 in fir forests, and only 650 in spruce forests (Appendix B).

In terms of detecting EU-survey pests (the primary goal of the FTN), *Ips typographus* was the only quarantine species trapped. Thirteen individuals were collected between late July and early September from a trap in a spruce woodland at one site, but surveys revealed that this was not related to a localised outbreak of the species. There were no species new to the UK, however, the pilot programme to the FTN (Experimental Lures) which was conducted in 2020 yielded the first record of a nationally rare sawfly species, *Xeris pallicoxae*, in Northamptonshire.

The most abundant species in the samples were ambrosia beetles: *Xylosandrus germanus, Xyleborinus saxesenii, Anisandrus dispar, Trypodendron domesticum, Gnathotrichus materiarius*; and also the Hylastini: *Hylurgops palliatus, Hylastes attenuatus, Hylastes angustatus*, and *Tomicus piniperda* (Fig. 3). Data from ambrosia beetles and other target groups are presented in sections 3.3-3.7. Data from the Hylastini are presented in Appendix C.

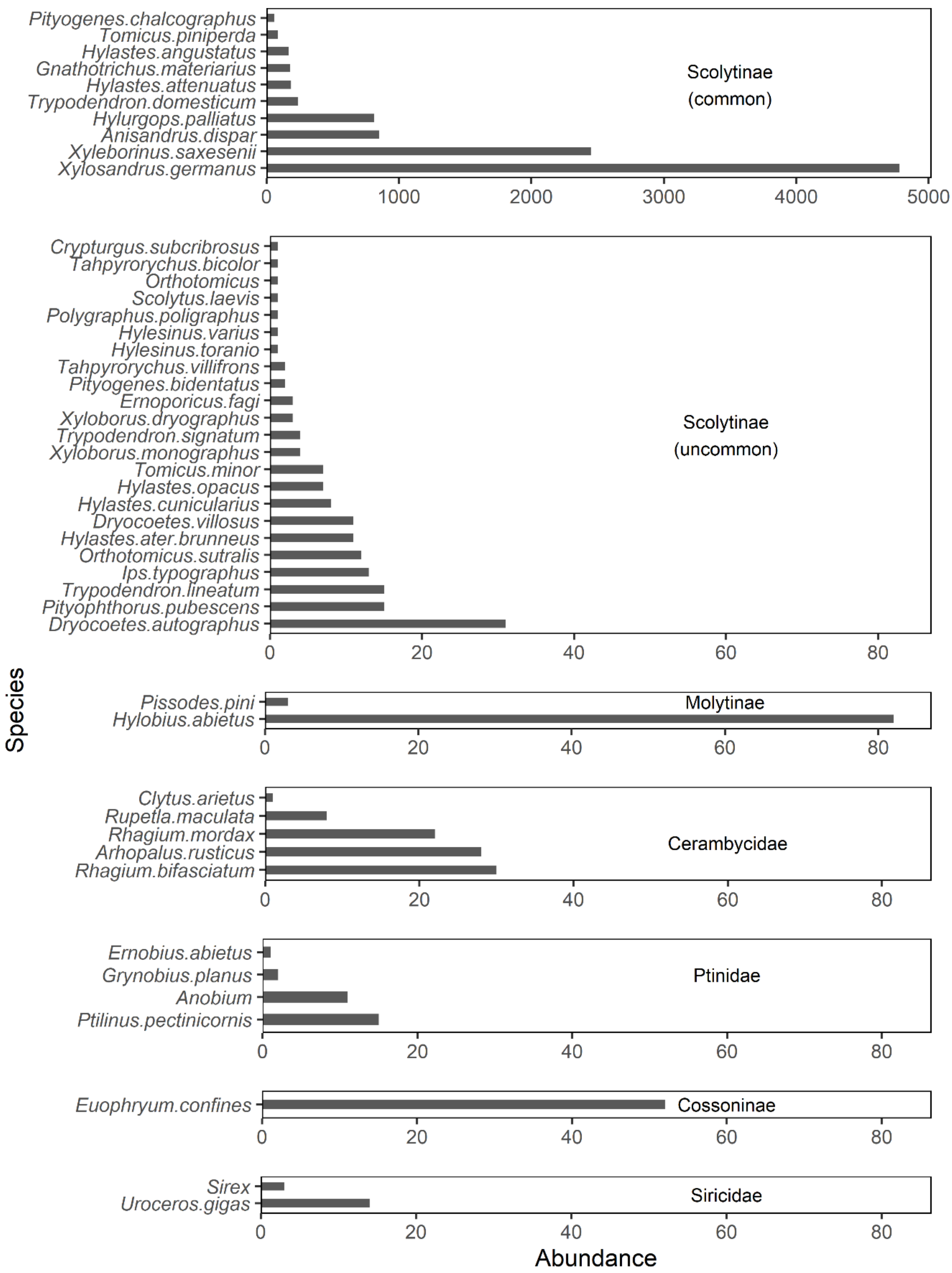

Fig. 3. Total species abundances of target groups across all sites and forest types. Note that the x-axis of the top graph (common Scolytinae) is on a different scale. Species with one individual are not displayed.

3.1 Positive controls

We trapped 18 species that we deemed to be positive controls (species which are closely related to species on the EU-survey list in terms of genetics and behaviour). Trapping these species demonstrates the effectiveness of the FTN, and indicates that the FTN would likely trap species on the EU-survey list if present at the sites. These were: ambrosia beetles (*Xylosandrus germanus, Xyleborinus saxesenii, Anisandrus dispar, Xyleborous dryographus, Xyleborous monographus, Trypodendron domesticum, Trypodendron lineatum, Trypodendron signatum*), *Ips typographus*, *T. piniperda*, *Hylobius abietus*, *Pityopthorus pubescens*, *Polygraphus poligraphus*, *Arhopalus rusticus*, *Rhagium mordax*, *Clytus arietus*, *Rhagium bifasciatum*, and *Rupelta maculata* (Appendix B).

3.2 Scolytinae

In total, we collected 9975 individuals comprising 34 species of Scolytinae. In general, Scolytinae richness was slightly higher in coniferous forests than broadleaf forests, although the differences were not large (Table 1, Fig. 4). A good level of sampling effort was achieved in sampling this group – the level of species richness we measured is near to the plateau of extrapolated total species richness for all forest types except mixed broadleaf (Fig. 4). This suggests that the FTN detected the majority of bark beetle species (which are attracted by our lures) that are present at our sites. For context, Inward (2020) detected 39 established bark beetle species in the UK over a three-year period from 87 sites across the whole of England. The relatively large difference between the species richness we measured and the estimated species richness (the extrapolated part of the rarefaction curve; Fig. 4) in mixed broadleaf forests suggests that more species in the target groups went undiscovered in this forest type, although again the wide confidence intervals mean that this should be interpreted with caution. Spruce forests had the lowest average per-sample abundances of Scolytinae, with very little difference amongst other forest types (Fig. 5). Two sites, Denny Lodge Inclosure and Orlestone, had much higher average per-sample abundances than other sites (Fig. 5).

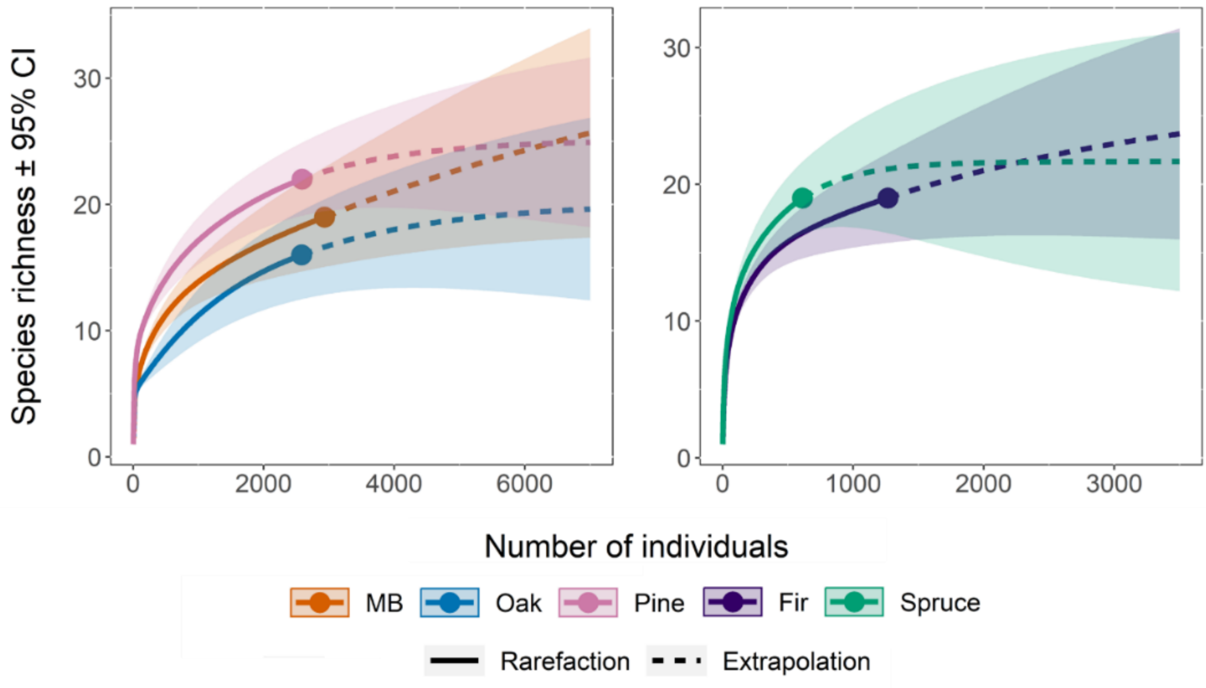

Fig. 4. Rarefaction curve and extrapolated estimation of total species richness for Scolytinae species sampled across all sites, forest types and dates. The circular points on each line indicate the total richness of species trapped in this study.

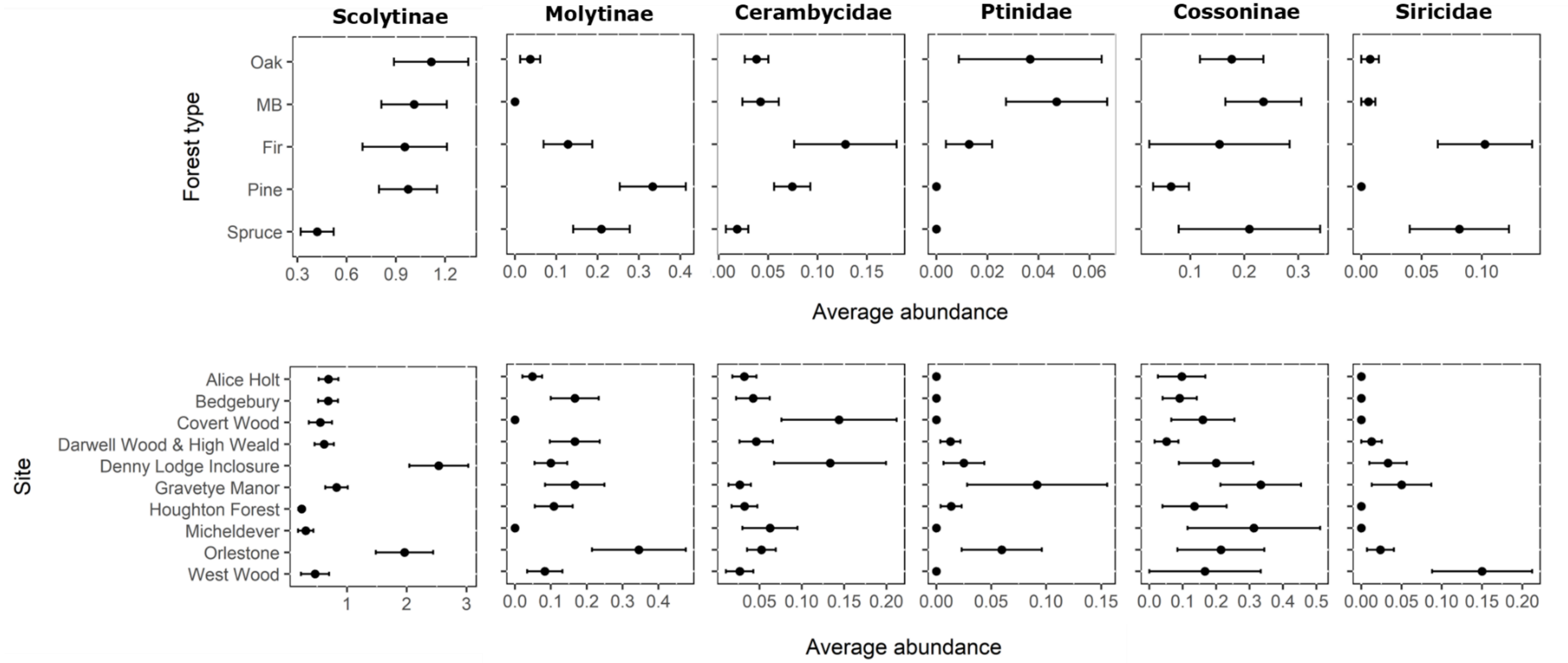

Fig. 5. Top row, left to right: average abundance (per sample) of Scolytinae, Molytinae, Cerambycidae, Ptinidae, Cossoninae and Siricidae in the five forest types (all sites combined). Bottom row, left to right: average abundance (per sample) of Scolytinae, Molytinae, Cerambycidae, Ptinidae, Cossoninae and Siricidae in the different sites (all forest types combined). Bars indicate standard error of the mean.

3.3 *Ips* spp.

One species of *Ips* was trapped in the FTN 2022: *Ips typographus* (n = 13; Fig. 3; Appendix B), which was trapped in one trap (set up in a spruce woodland in Kent with an *I. typographus* lure) four times between the 27th July and 7th September. This corresponded to an influx of *I. typographus* in the South-East in late July/early August. The site was surveyed and found to be free of *I. typographus*. This compares with the 2021 pilot in which *I. typographus* was caught at three sites between 10th June and 16th September, but the vast majority (n = 591) of these were from one site (Blake *et al*., 2021); and the 2020 pilot in which eleven individuals were caught across two sites between 17th April and 12th August.

3.4 *Tomicus* spp.

We trapped both species of *Tomicus* that are native to the UK: *Tomicus piniperda* (n = 86) and *Tomicus minor* (n = 7; Fig. 3; Appendix B). *Tomicus piniperda* is a positive control species as it is a major pest of pine. *T. piniperda* was the ninth most common species we trapped – this species attack primarily pine, but can be found on fir, and accordingly, the average abundance of *T. piniperda* was significantly higher abundances in pine forests than most the other forest types ($p < 0.01$; Fig. 6), and was significantly higher in fir than the two broadleaf forest types ($p < 0.0010$). In terms of relative abundance it constituted 2.4% of individuals trapped in pine forests, 1.2% of individuals trapped in fir, and less than 1% of individuals trapped in the other forest types (Fig. 7). Average abundances of *T. piniperda* did not vary significantly between sites ($p > 0.05$; Fig. 6). *T. piniperda* abundances were highest in May, decreasing until mid-June when no more individuals were caught (Fig. 6). *Tomicus minor* was relatively uncommon and was largely associated with fir (Appendix B).

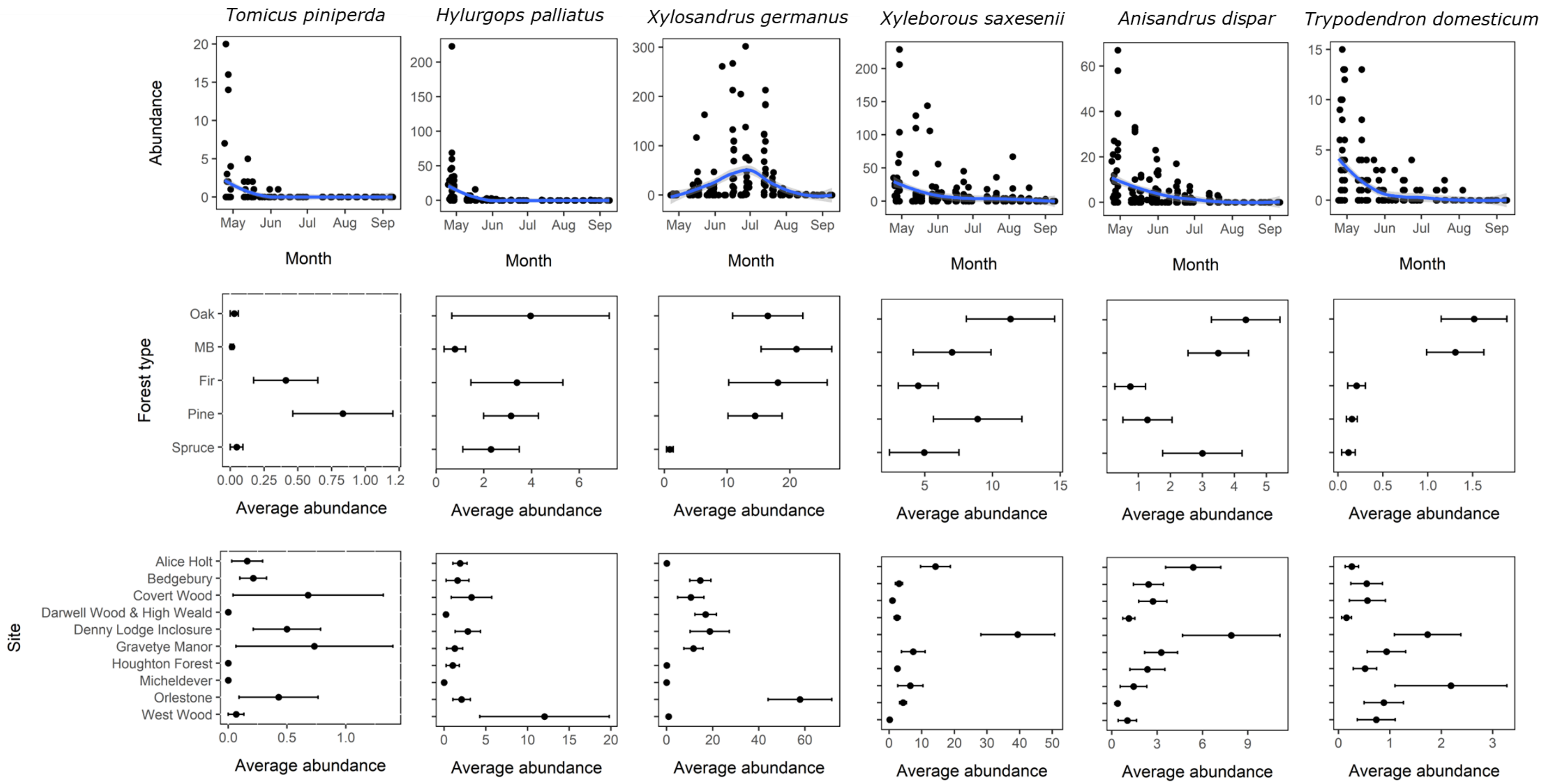

Fig. 6. Top row: points represent raw abundances of each species (each column of graphs corresponds to the species labels at the top) collected in traps throughout the trapping season. Each point represents raw abundance in a single trap on a single collection date. Middle row: points represent average abundances per sample of each species in different forest types (all sites combined). Bottom row: points represent average abundances per sample of each species per site (all forest types combined). Bars represent standard error of the mean

3.5 *Polygraphus poligraphus*

We trapped one individual of this rare species in a spruce forest. This species is a positive control for the closely related and spruce-associated *Polygraphus proximus* on the EU-survey list. Trapping this species, despite its rarity, is very promising, and suggests we would detect *P. proximus* if present.

3.6 Ambrosia beetles

Ambrosia beetle species are positive controls as they are of major significance to tree health and have analogues on the EU-survey list – the fact that they were trapped by the FTN is a very good indicator of the effectiveness of the network. Data for five species trapped by the FTN 2022 are presented here.

3.6.1 *Xylosandrus germanus*

Xylosandrus germanus (n = 4781) was the most common species trapped (Fig. 3; Appendix B). It attacks various broad-leaved trees. Accordingly, average abundances of *Xylosandrus germanus* were significantly higher in mixed broadleaf and oak forests than all coniferous forests except pine ($p < 0.03$), with which there was no significant difference. It was a dominant species in all forest types except spruce (n = 38; Fig. 6), comprising 60% of individuals trapped in mixed broadleaf forests (n = 1789), 54% in fir forests (n = 706), 43% in pine forests (n = 1120) and 42% in oak forests (n = 1128; Fig. 7). Average abundance of *X. germanus* also responded strongly to site effects - abundances were very low or zero at several sites (Alice Holt, Houghton Forest, Micheldever, and West Wood), which all differed significantly from the six sites where abundances were higher ($p < 0.001$; Fig. 6). Orlestone had a considerably higher average abundance than the other sites, which was significantly higher than all other sites ($p < 0.05$ for all comparisons) except Denny Lodge

Inclosure for which there was no significant difference (Fig. 6). Abundances of *Xylosandrus germanus* peaked in early July (Fig. 6).

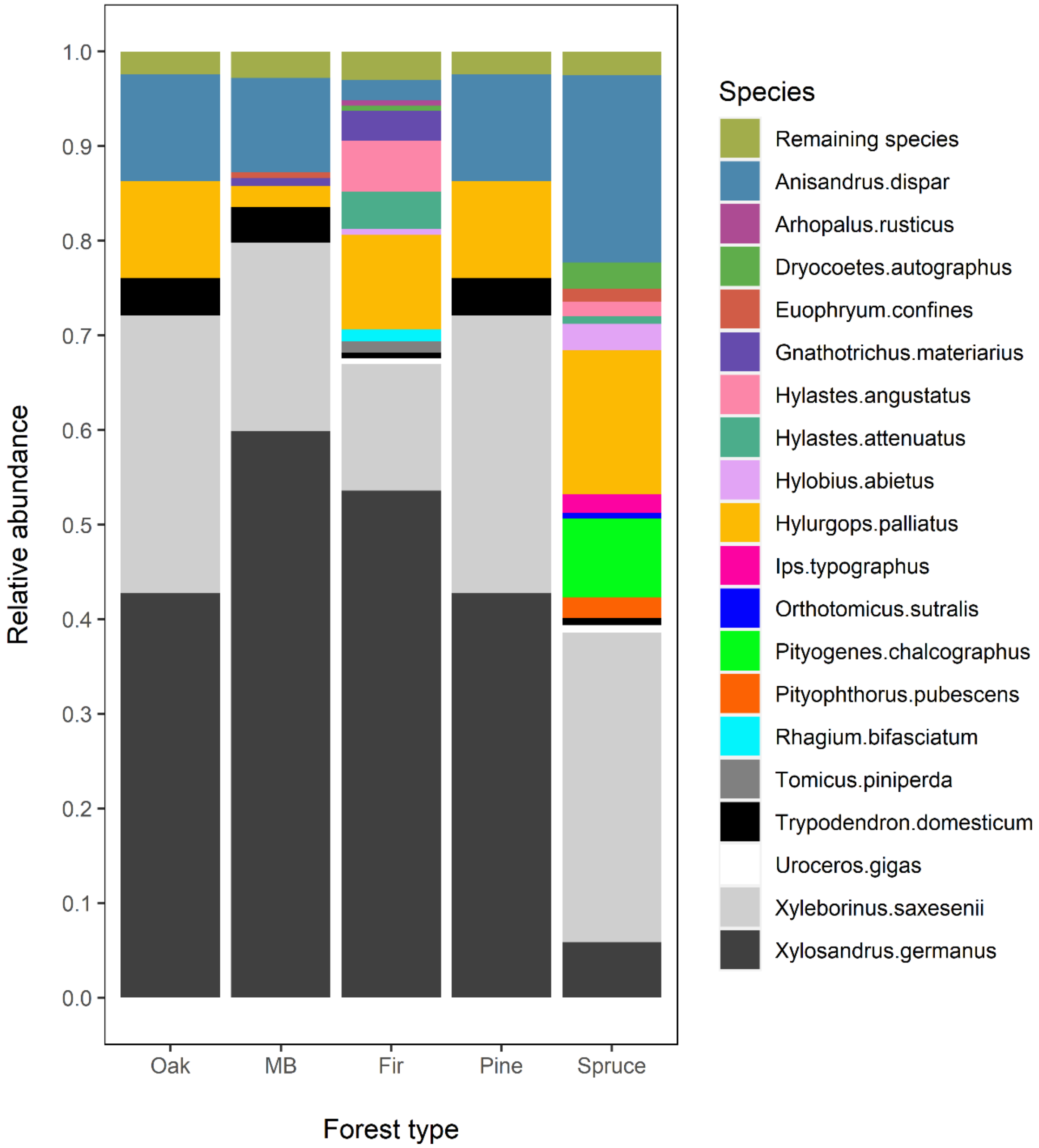

Fig. 7. Relative abundances (expressed as a proportion on the y-axis) of the most abundant species in each forest type. The species listed comprise approximately 95% of all individuals captured in each habitat.

3.6.2 *Xyleborinus saxesenii*

In general, all habitats were characterised by the dominance of *Xyleborinus saxesenii* (n = 2449), which was the second most abundant species in the traps (Fig. 3; Appendix B). This is also a species generally associated with broadleaved trees, however, average abundances of *Xyleborinus saxesenii* were not significantly affected by forest type ($p > 0.05$; Fig. 6). This species dominated most forest types, comprising 33% of individuals trapped in spruce woodlands (n = 213), 29% in pine (n = 770), 26% in oak (n = 694), 20% in mixed broadleaf (n = 596) and 13% in fir (n = 176; Fig. 7). *Xyleborinus saxesenii* abundances were highest in May and decreased steadily until the end of the trapping season (Fig. 6). On the other hand, site had a large effect on the average abundances of this species – Denny Lodge Inclosure had a much greater average per-sample abundance of *X. saxesenii* in samples than all other sites ($p < 0.05$ compared with Alice Holt; $p < 0.01$ compared with Gravetye Manor; $p < 0.001$ compared with all other sites; Fig. 6).

3.6.3 *Anisandrus dispar*

Anisandrus dispar was the third most abundant species we trapped (n = 851; Fig. 3; Appendix B). *A. dispar* is usually found on mainly broadleaved and more rarely coniferous trees. Accordingly, average abundance varied significantly between forest types, with the two broadleaf forest types (particularly oak forests) yielding higher average abundances than fir and pine forests ($p < 0.01$; Fig. 6). However, we found no significant difference between average abundance in mixed broadleaf/oak and spruce ($p > 0.05$) despite the fact far fewer individuals were trapped in spruce forests (Fig. 6; Appendix B) – this is likely due to the large variation in counts of *A. dispar* in spruce traps (Fig. 6). There was also a site effect, where average abundance was higher at the Denny Lodge Inclosure and Alice Holt when compared with most other sites ($p < 0.05$; Fig. 6). The highest relative abundance was in spruce forests (20%), followed by oak (11%), and then mixed broadleaf forests (10%), and made up only

3.7% and 2.2% of individuals trapped in pine and fir (Fig. 7). *A. dispar* abundances were highest in May, then decreased steadily until late July, after which no further individuals were trapped (Fig. 6).

3.6.4 *Trypodendron domesticum*

This was the fifth most abundant species in our samples (n = 239; Fig. 3; Appendix B). This is an ambrosia beetle associated with broadleaf trees, and accordingly, mixed broadleaf and oak woodlands had significantly higher average abundances when compared with the three coniferous forest types ($p < 0.001$). Relative abundances were also highest in oak forests (3.9%), followed by mixed broadleaf (3.7%), being less than 1% in the remaining forest types (Fig. 7).

3.6.5 *Gnathotrichus materiarius*

Gnathotrichus materiarius, a relatively new species to Britain, was the seventh most common species trapped (n = 178, Fig. 3; Appendix B). The highest total abundance was in pine (n = 108), whilst 42 and 25 were trapped in fir and mixed broadleaf forests respectively, 3 in oak and none in spruce (Appendix B). Accordingly, it comprised 4% of individuals trapped in pine forests, and 3.2% of those trapped in fir (Fig. 7), and made up fewer than 1% of individuals trapped in mixed broadleaf forests. This species was trapped in reasonably large numbers at one site, Denny Lodge Inclosure (Fig. 6). This species was trapped in all forest types at this site except for spruce, and all individuals were trapped in early summer (May and June; Fig. 6). The only other site to yield this species was Alice Holt (n = 2). This species was trapped too sporadically to conduct statistical analyses.

3.7 Woodboring Cerambycidae

We trapped 89 individuals belonging to Cerambycidae, which spanned 5 woodboring species which were positive controls (*Arhopalus rusticus,* n = 28; *Clytus arietus*, n =

1; *Rutpela maculata*, n = 8; *Rhagium bifasciatum*, n = 30; *Rhagium mordax*, n = 22; Fig. 3; Appendix B). *Arhopalus rusticus* was trapped mainly in pine forests, *Clytus arietus* was only ever trapped in pine, *Rhagium bifasciatum* was mainly associated with fir, *Rhagium mordax* was mainly associated with oak and mixed broadleaf woodland, and *Rupelta maculata* was trapped in low numbers across all forest types except spruce (Appendix B). Sample sizes were too small and zero-inflated to conduct statistical analyses on the separate species, but average abundances of Cerambycidae in general appear to be higher in fir than the other forest types, and possibly slightly higher in pine compared with oak and spruce (Fig. 5). Two sites, Covert Wood and Denny Lodge Inclosure, had higher average per-sample abundances of Cerambycidae than other sites, although this inference should be treated with caution as there was a large standard error around the mean for both sites (Fig. 5).

3.8 Molytinae

We trapped 85 individuals belonging to the Molytinae subfamily, and which were on the positive controls list (*Hylobius abietus*, n = 82 & *Pissodes pini*, n = 3; Fig. 3; Appendix B) as analogues of *Pissodes*. Trapping these species and particularly the rarer *Pissodes pini* is an excellent indicator that the FTN functioned effectively as intended. Again, the data were too zero-inflated to carry out statistical tests, but the highest average per-sample abundances of Molytinae generally were in pine forests, followed by spruce, then fir, with very low catches in broadleaf forest types (Fig. 6). Orlestone had the highest average per-sample abundances of Molytinae, although again the standard error bars are wide so this should be considered with caution.

3.9 Ptinidae

Of the Ptinidae, the FTN trapped: *Ptilinus pectinicornis* (n = 15), *Grynobius planus* (n = 2), *Ernobius abeitus* (n = 1), and *Anobium* spp. (n = 11; Fig. 3; Appendix B). Again there was not enough data to perform statistical analyses, but it is notable that the higher per-trap average abundances of Ptinids occurred in oak and mixed-broadleaf forests, and two sites showed higher average per-trap abundances than the others (Fig. 5).

3.10 Cossoninae

We trapped one species belonging to Cossoninae, *Euophryum confine* (n = 52; Fig. 3; Appendix B). This was expected as this is by far the most common species in this subfamily. Again, the nature of the data did not allow for statistical analyses, but it should be noted that this species was fairly evenly distributed amongst sites and habitats, although average per-sample abundance was lowest in pine forests (Fig. 5)

3.11 Siricidae

We trapped two Siricidae taxa: *Urocerus gigas* (n = 14) and Sirex spp. (n = 3; Fig. 3; Appendix B). We again could not conduct statistical analyses, but it is notable that average per-sample abundances of Siricidae were considerably higher in fir and spruce woodlands compared with the other three forest types, and this family was never trapped in pine forests (Fig. 3). At one site, West Wood, average per-sample abundance of Siricids in general was much higher than the other sites (Fig. 5).

3.12 Bycatch

There was also a lot of bycatch, i.e. individuals from non-target groups. These were not counted or identified as our focus was on the target groups, and we did not have sufficient staff time. Consequently there is potentially a lot of information yet to be gained from these samples, particularly with regards to natural predators of tree pests with implications for biocontrol. Natural enemies of tree pests include parasitic wasps (e.g. Ichneumonoidea, Chalcidoidea), and predatory beetles (e.g.

Staphylinidae, *Thanasimus formicarius*, *Rhizophagus* spp.). We also trapped other invertebrate groups as bycatch that are generally understudied, such as Araneae (spiders), Isopoda (woodlice), Opiliones (harvestmen).

3.13 Seasonal trends in capture rates

The total number of species captured across all sites and forest types gradually increased until late July: between late July and the end of the trapping season, only two new species were trapped. *Ips typographus* was trapped for the first time in late July (Fig. 5), and only one new species was trapped in August – a species of wood wasp (*Sirex*; Fig. 5). No new species were trapped in the first week of September (the final week of the trapping season).

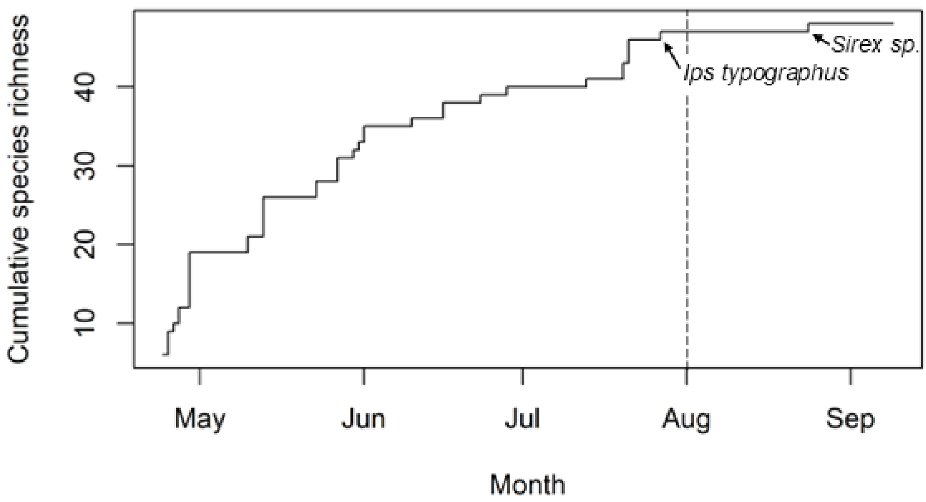

Fig. 8. Cumulative species richness across all sites and forest types over the sampling season (late April to early September 2022). A dashed line indicates the beginning of August, a month which typically produces very few new species in cross vane traps.

3.14 Sampling coverage

Species rarefaction curves can be used to assess whether our sampling was sufficient to detect all the target species that are attracted by the lures used (sampling coverage), because when more individuals are sampled, more species will be found until all have been detected. These curves indicate whether the FTN 2022 trapped enough individuals to capture all the species from the target groups that are attracted by the lures used (Fig. 6).

Sampling coverage differed between forest types (Fig. 6). For fir and spruce forests, the extrapolated curves are at a near-plateau and do not increase much above the species richness that we measured – this suggests that the FTN trapped nearly all the species from target groups that are attracted by the lures. On the other hand, for mixed broadleaf, oak and pine forests, the extrapolated curves continue to increase above the species richness that we measured, suggesting that some species that may be attracted by the lures went undiscovered. Specifically, for mixed broadleaf, oak and pine forest types, the estimated total richness of target groups (Fig. 9) was 5-10 species higher than the species richness we measured (Table 1), meaning that increasing the sample size could potentially capture ~5-10 additional species in each forest type. However, to reach a near-plateau in species accumulation the sample size would need to be at least three times greater than was collected in the FTN 2022 (Fig. 6), which would increase budgetary and time demands in terms of sample processing.

Note that the reasonably wide confidence intervals around the extrapolations mean this result should be interpreted with caution.

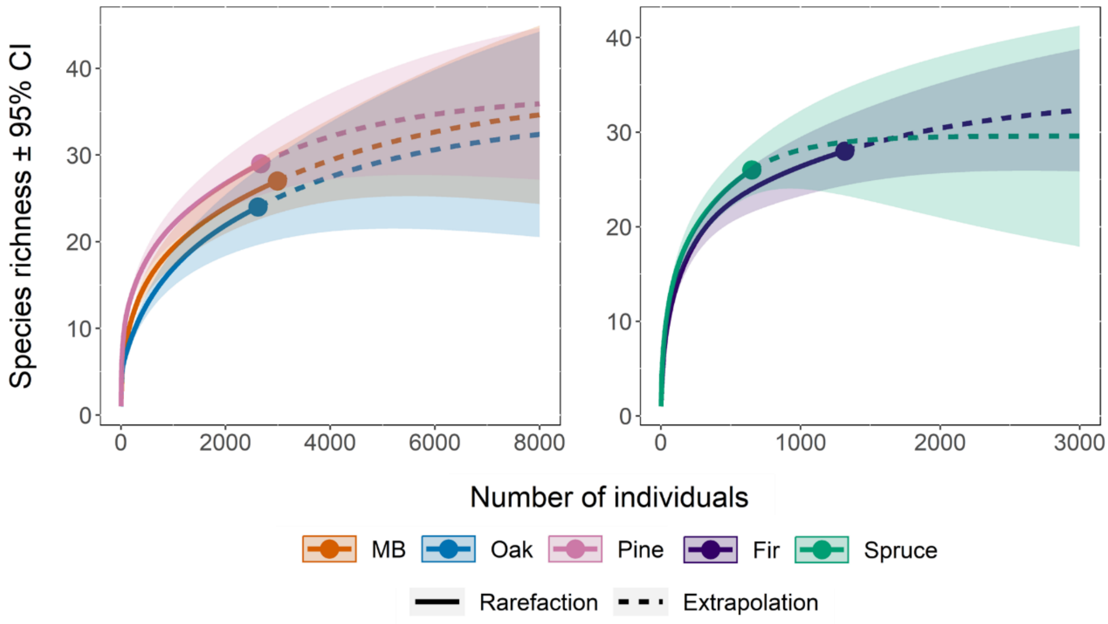

Fig. 9. Rarefaction curves and extrapolated estimations of total species richness for communities (of target groups) sampled in the five different forest types across all sites and dates. If the extrapolated richness increases with the number of individuals sampled beyond total richness, it indicates sampling coverage could be improved (i.e. we did not detect all the species that are attracted to the lures). The circular points on each line indicate the total richness of species trapped in each forest type (also see Table 1).

3.15 Pest diversity in different forest types

We looked at species richness and Simpson diversity across all sites. Simpson diversity takes species richness AND relative abundances (evenness) of species into account – where higher values (expressed as a proportion) indicate a higher probability that two individuals drawn from the same community will be different species. A lack of replication and a large degree of variation in diversity between sites and throughout the year meant that it was necessary to combine all samples (from all collection dates) from each forest type within sites for the diversity analysis (n =

37). This also led to a lack of significant differences in Simpson diversity amongst forest types – however, general trends are discussed here.

Species richness across forest types was remarkably similar (Table 1). The coniferous forests in general trended towards higher richness compared with broadleaf and oak forests, but Simpson diversity did not show the same trend (Table 1). Pine forests had the highest species richness, followed by fir, mixed broadleaf, spruce, and oak forests.

We found the highest overall Simpson diversity (of the groups targeted by this study) in spruce forests (Table 1). This is likely due to a high degree of species evenness, where no one species was particularly dominant (Fig. 7). The next highest Simpson diversity was found in oak forests, followed by pine, fir and mixed broadleaf forests (Table 1).

The lowest Simpson diversity was found in mixed broadleaf forests, which scored middle-range for species richness (Table 1). This low diversity is likely due to the very high relative abundances of two species (*Xyleborinus saxesenii*, but particularly *Xylosandrus germanus*), which dominated the samples, comprising 60% and 20%, respectively (Fig. 7), of all individuals trapped in mixed broadleaf forests. Very high abundances of *X. germanus* in mixed broadleaf traps lead to this forest type yielding the highest number of individuals in total (Appendix B). These two species also dominated in most the other forest types (Fig. 7; Appendix B).

Fir forests scored relatively high for richness and relatively low for Simpson diversity (Table 1). This low Simpson diversity is again likely due to a high relative abundance of the three most dominant species (*Xylosandrus germanus*, *Xyleborinus saxesenii*, *Hylurgops palliatus*), which comprised 77% of all individuals (54%, 13% and 10% respectively; Fig. 7).

Oak forests, interestingly, had the lowest richness but the second highest Simpson diversity (Table 1). This is likely to be because, despite the fact that two species

(*Xylosandrus germanus*, 42% and *Xyleborinus saxesenii*, 26%) were relatively dominant, the relative abundances of the remaining species were reasonably even (Fig. 7; but note that most remaining species were rare and were pooled within "remaining species" in this figure).

Pine forests had higher species richness than most other forest types and relatively high Simpson diversity (Table 1; Fig. 7, but again note that most species pooled within "remaining species" in this figure). This trend may be because 95% of individuals belonged to only five species, and the relative abundances of these five were comparatively even (Fig. 7). Again, the two relatively most abundant species were *Xylosandrus germanus* and *Xyleborinus saxesenii* which comprised 43% and 29% of species trapped in pine forests (Fig. 7).

Table 1. Species richness of the target groups in different forest types, and total species richness and Simpson diversity (evenness) indices in the different forest types.

	Oak	MB	Fir	Pine	Spruce
Cerambycidae	3	3	2	3	3
Ptinidae	2	2	3	1	2
Scolytinae	16	19	18	21	21
Molytinae	1	0	2	2	1
Cossoninae	1	1	1	1	1
Siricidae	1	1	1	0	2
Total richness	**24**	**27**	**28**	**29**	**26**
Simpson diversity	**0.74**	**0.59**	**0.68**	**0.71**	**0.82**

Note: Simpson diversity is expressed here as the reciprocal, so higher values indicate higher diversity. To calculate Simpson's diversity for the specific woodland types, samples from all collection dates from each woodland type were combined within sites.

4 Discussion

Achievements of the FTN 2022:

- Surveyed five forest types at 10 sites across SE England.
- Detected one EU-survey list species, *Ips typographus*, at one site.
- Trapped 18 positive control species, indicating that the network is functioning as intended.
- Trapped 10,247 individuals comprising and 48 species/genera tree pests and natural predators, many of which were of interest to plant health or economically important – despite covering just SE England.
- Achieved very good sampling coverage of target groups.
- Generated a large amount of data that could be used to inform on forest health, and on tree pest population dynamics and biodiversity across SE England.
- Surveyed a wide range of broadleaf woodland for pests, which is a forest type that previous trapping programmes neglected.
- Revealed novel information about the diversity of tree pests in spruce, fir, pine, oak and mixed broadleaf forests in SE England.
- Formed a novel and one-of-its-kind large-scale, long-term monitoring program targeting tree pests in England.

4.1 Did the FTN 2022 meet its overarching goals?

(1) Form a key FSP survey strategy which targets pests that other survey methods cannot detect

We consider that the FTN 2022 was successful in meeting this goal, particularly because we trapped one quarantine species (*Ips typographus*) which may not have been detected without the FTN. We also trapped many positive controls, meaning that the analogous species on the EU-survey list would likely have been detected if present.

(2) Consolidate current trapping programmes into a single network to ease logistical issues (potentially replacing existing trapping programmes long-term)

The FTN 2022 met this goal in that it could replace the PZ Billet Trapping program for *Ips typographus*, having successfully surveyed for this species, and it consolidates *Ips typographus* surveying with surveying for other quarantine pests. The FTN 2022 covered a broad range of forest types and could be adapted to target other quarantine pests. More could be done in terms of consolidating existing trapping programmes in future – for example, including *Monochamus* lures to consolidate the *Monochamus* trapping program; canopy trapping to capture canopy-dwelling pests such as the emerald ash borer and bronze birch borer.

(3) Improve current trapping methods for quarantine pests

The FTN 2022 has improved on existing trapping programmes such as the PZ Billet Trapping program, and the Wider Environment Network, which only target a narrow range of species, by using a range of lures and surveying a much wider range of forest types than have been surveyed previously. The fact that we achieved a good level of sampling effort in trapping for Scolytinae (by far the most abundant group; Fig. 7) suggests that the methods of the FTN are highly effective for monitoring this major group. This is a promising result as it suggests that if non-European Scolytinae on the quarantine list (Appendix A) are present at a site monitored by the FTN, they are likely to be detected. We trapped the other target groups in lower numbers but the fact we trapped many positive controls suggests that we would trap other quarantine species within these target groups if present.

(4) Ensure a cohesive approach across the three countries

The FTN 2022 was deployed in England, but not Scotland or Wales. This was because the FTN was in the early stages and we wanted to trial the network in England before rolling it out to the other countries. Relationships between Forest Research, Scottish Forestry, and Natural Resources Wales were developed over the course of 2022, which led to the planning of ten sites in Scotland and four sites in Wales for FTN 2023.

4.2 Was the FTN 2022 effective in surveying for quarantine pests?

The FTN trapped 18 positive control species from several insect families, indicating that it worked effectively in attracting a broad-range of target species. One quarantine species (*I. typographus*) that we know to be present SE England and expected to detect, was trapped at one site (subsequently surveyed and found to be clear of *Ips*). We are confident that novel, broad-spectrum methods employed by the FTN are highly suitable for meeting its targets and those of the Future Surveillance Plan.

4.3 Implications of the FTN 2022 findings for forest health

4.3.1 Value of surveying different forest types

The FTN 2022 is unique amongst tree pest monitoring programmes in that it surveyed five different forest types: spruce-dominant, pine-dominant, fir dominant, oak-dominant, and other mixed broadleaf-dominant. Other monitoring programmes such as the Wider Environment Network place traps only in spruce forests as the target species is *Ips typographus*. The FTN consolidates this kind of trapping with a much broader-spectrum program – providing a vital opportunity to detect quarantine species which are associated with other tree species. Many species on the EU-survey list use trees other than spruce, such as several *Pissodes* and *Monochamus* species which attack mainly pine, *Pissodes fasciatus* which attacks fir, *Euwallacea fornicatus* which is associated with mixed broadleaf species, or *Arrhenodes minutus*, *Neocerambyx raddei*, *Xylotrechus* spp. and two *Pseudopityopthorus* species which attack a range of broadleaf trees.

Furthermore, biodiversity data from the FTN could give an indication of the health of forest ecosystems over time. For example, tracking species evenness, richness, and the relative abundances of species within forest types year-on-year will allow us to monitor shifts in tree pest communities, and predict knock-on effects on forest ecosystem functioning. Tracking the population trends of the non-native species will be particularly important – for example, monitoring the invasive *Xylosandrus germanus* (Fig. 7) in different forest types will be important for evaluating its potential effects on forest ecosystems.

4.3.2 Quarantine species monitoring

Our results show that the FTN is effective in monitoring quarantine species, as we trapped 13 individuals of the EU-survey list species *Ips typographus* at a site that was within the demarcated area, where we might expect *I. typographus* to be. The FTN will therefore be vital for monitoring the distribution and abundances of this species in future, and will enhance the overall monitoring of *I. typographus* in the UK, in addition to the specific *Ips* monitoring network (Wider Environment).

4.3.3 Monitoring species of economic importance

Aside from monitoring quarantine pests, the FTN was effective in monitoring populations of bark beetles that are of economic importance or interest to plant health, such as *Ips*, *Tomicus*, *Pityogenes*, *Polygraphus*, *Sirex* woodwasps, *Trypodendron*, *Xylosandrus* and other ambrosia beetles.

The samples were dominated by ambrosia beetles (*Xyleborinus saxesenii*, *Xylosandrus germanus*, and *Anisandrus dispar*) which can be economically significant, particularly invasive species. *Xylosandrus germanus* dominated most forest types except spruce. This species was first detected as an established invasive species in the UK in 2012 in North Hampshire (D. J. Inward, 2020). *Xylosandrus germanus* is highly polyphagous, typically as a secondary agent upon stressed, unhealthy or recently dead hosts, although it has been known to attack healthy trees (Graf & Manser, 2000; Riba-Flinch *et al*., 2022). To date it has caused limited mortality in its established range but has been involved in damaging attacks on deciduous trees, often in association with other ambrosia beetles. It has also been recorded as causing damage to recently felled logs of oak, beech and spruce in Europe, reducing the quality of the timber (Galko *et al*., 2018). It is thought that the recent rapid spread of *X. germanus* is being facilitated by global warming and increasing frequency of timber trade. In 2015 the economic, environmental and social impact of this species was assessed as small to medium (D. Inward, 2015) – although the very large numbers of *X. germanus* in the FTN samples this year could mean that re-assessment is necessary. The FTN 2022 has proven its capabilities in monitoring this species going forwards.

We also collected 178 individuals of the ambrosia beetle *Gnathotrichus materiarius*. Species was detected as an established invasive species in the UK for the first time in 2013 (Inward 2020). *G. materirarius* has been little-studied but is known to be associated with Scots Pine, Corsican Pine and Norway Spruce in the UK (Inward 2020). It usually attacks dead and dying trees, and de-barked timber (Bussler & Immler, 2007). However, a number of ambrosia beetle species that normally only attack weakened host trees have been changing their habits to attack healthy trees (Kühnholz *et al*., 2001). The FTN 2022 has shown that this network will be effective in monitoring year-on-year increases of *G. materiarius* in future.

Tomicus piniperda is not invasive, but can be economically important as it is the major pest of plantation or nursery pine trees (particularly Scots) in the UK, but will also attack spruce, larch and firs. *T. piniperda* prefers to attack weakened trees, or fallen or cut logs, but it can attack standing trees resulting in dead and dying shoots, especially when beetle populations are allowed to build up. It can also be a vector of blue-stain fungi (Solheim *et al*., 2001) which stain timber. *T. destruens* is another a highly economically damaging pest of pine in Southern Europe – it is not present yet in the UK but its range is expanding under current global warming (Horn *et al*., 2012). This could be a species to watch, particularly because its similarity to *T. piniperda* has meant populations in Europe going undiscovered for long periods.

4.3.4 Generation of information on species distributions, population dynamics and biodiversity

The vast amount of data collected by the FTN 2022 highlights the utility of this network as a general tree pest monitoring program. As we intend to include more sites and traps in 2023, and cover a wider area within GB, this benefit will only increase. The data can be used to monitor native species distributions and facilitate early detection of outbreaks, which will be important as we know that bark beetle populations dynamics and ranges are changing in Europe due to climate change and increased transport of timber (Hlásny *et al*., 2021; Marini *et al*., 2012; Økland *et al*., 2019). In addition, the data can be used to track pest population dynamics with changing seasons or weather conditions. Since many bark beetles are sensitive to climate, only flying at certain points in the year and when certain temperatures and weather conditions are reached, our data will help in improving our understanding of pest life histories, and could help in improving our predictions for how the impacts of tree pests might change in future. The FTN data can also be used to monitor the biodiversity of tree pest communities in forests dominated by certain tree species, which may provide us with an overall impression of the health of different forest types within the UK.

4.4 Planned changes for FTN 2023

4.4.1 Sites in Scotland and Wales, and better coverage of England

The FTN 2022 only had sites in South East England because sites from the Wider Environment network were utilised to reduce staff time and costs, as they were already being serviced by FC Plant Health Operational Support Officers. The geographical scope was therefore very narrow. We plan to include sites in other areas of England in 2023 (South West, East Midlands, North West) in order to cover a much greater area of the country. We will roll out the FTN in Scotland and Wales in 2023 in order to achieve our goal of the FTN forming a cohesive GB-wide survey. We have selected 10 sites in England, 10 sites in Scotland and four in Wales for the FTN in 2023, which will almost double the number of sites compared with in 2022.

4.4.2 Improved training for staff with regards to site selection

One minor issue that arose was the suboptimal selection of the location of one of the traps at Orlestone wood. The trap had been placed in what was meant to be a spruce woodland, but the trap yielded very high numbers of broadleaf tree pests, particularly *Xyleborinus saxesenii*. On inspecting the sub-compartment within which the trap was placed on Forester, the composition of this section of woodland transpired to be only 3% Norway Spruce, with the majority of tree species being broadleaved. This trap had to be removed from the data analysis as the extremely high abundances of the broadleaved associated *X. saxesenii* biased the results. Such issues should be reduced in future years as from 2023 onwards there will be 2 dedicated, full-time entomologists for the FTN, based at FR. As part of these roles, they will manage the operation of the FTN, take responsibility for appropriate site selection, and provide specialist knowledge, training, and support to trap operators across all three countries.

4.4.3 Trapping earlier in the season

Due to logistical constraints, trapping began in late April in 2022. We plan to start trapping in late March in 2023 (with the first collection in mid-April), as this is when some species of health interest begin to emerge (e.g. *Tomicus piniperda*, *Trypodendron domesticum*), as well as the highly abundant *Hylurgops palliatus*, and some important predators of tree pests (*Rhizophagus* and *Thanasimus*). Trapping earlier in this way will provide better insights into the timings of beetle emergences, and the data could be used to inform phenological studies.

4.4.4 Recording bycatch

The FTN 2022 trapped a lot of bycatch which due to budgetary constraints we were unable to look at, but could contain a lot of potentially interesting information. This information, such as abundance and distribution of natural predators of tree pests, and associations between particular predator and pest species, could be valuable for gathering knowledge on potential biocontrol agents. For example, there were parasitic wasps in the bycatch – it is known that *Ips typographus* is susceptible to parasitism by some Pteromalid wasps in Europe (Georgiev & Stojanova, 2006); elm bark beetles (*Scolytus* spp., vectors of Dutch elm disease) are parasitised by species of Braconid wasp (Manojlović *et al*., 2000); and certain woodwasps are known to be parasitised by some parasitoid wasp species in North America (Coyle & Gandhi, 2012). There were also Staphylinidae (rove beetles), *Thanasimus formicarius* and *Rhizophagus* spp. in the bycatch, some species of which predate bark beetles – for example, *Rhizophagus grandis* is already being used by FR to control *Dendroctinus micans* in the Pest-Free Area. Ants were also present, which would be a very novel group to investigate as potential biocontrol agents, as four native ant species were very recently found to reduce population sizes of an invasive Scolytid (*Xylosandrus compactus*) in Europe (Giannetti *et al*., 2022).

In addition to predators of tree pests, bycatch contained several understudied taxa such as spiders, woodlice, harvestmen, and certain poorly-known beetle families such as Silvanidae and Salpingidae. The data on these groups in the FTN bycatch could potentially provide novel insights into species distributions, or shed light on poorly-known species. For this reason, we plan to keep certain groups of bycatch that may be of interest to research (non-target Coleoptera, Hymenoptera, Spiders, Hemiptera), and note the presence/absence of these in our data so they can be easily located and identified at a later date.

4.5 Potential areas of change for FTN in future years

4.5.1 Curtailment of trapping season

The length of the trapping season (April to early September) could be reconsidered for future years based on when the FTN stops finding new species for the year (e.g. if no new species are trapped in August, we can stop servicing traps at the end of July). Only one new species was trapped in August this year, and it was not a quarantine species (Fig. 5). This means it may be possible to reduce the trapping season of the FTN without the risk of missing any important species (e.g. ending in mid-August). This would decrease the budgets needed for trap servicing and decrease the number of samples by approximately two collections, which would decrease the budget needed for sample processing at Alice Holt and NRS in future years. We will monitor trapping rates in August over the next few years of the FTN to determine the optimal trapping season length for the first full rotation of the FTN in 2025.

4.5.2 Increased sample size

The FTN 2022 used one trap per forest type (e.g. spruce, fir) at each site. To increase coverage within a site, we could deploy multiple traps within each forest type. This has the benefit of greatly increasing the chances of detecting quarantine species if present, improving the statistical design of the programme, and potentially allowing for canopy invertebrates to be trapped. However, increasing the number of samples in this way would, at a minimum, double the number of samples yielded by the network, and consequently an additional member of staff, at least on a short-term basis, to help process the much larger number of samples would be needed.

4.5.3 Additional lures for quarantine pests and trapping in other strata

The only quarantine pest-specific lure we used in the FTN 2022 was the *Ips typographus* pheromone. To target other quarantine pests better, such as *Monochamus*, we might consider including these lures on our existing traps or adding new traps to the network that target this species specifically. We can consider canopy trapping in broadleaf forests to target invasive borers, such as the emerald ash and bronze birch borers, both of which are on the EU-survey list. This would greatly expand the scope of the FTN, but would also increase the staff time needed for trap servicing and for the increased number of samples that need processing. At current staffing levels we are not confident that we could incorporate both these new survey methods into the FTN, and would need to employ at least a short-term assistant to aid in sample processing.

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AW analysed the data and wrote the report. MB designed the study and reviewed the report. TK coordinated sample processing, identified samples and reviewed the report.

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Appendix A

List of pests on the Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 that the FTN is targeting, i.e. any pest which cannot be targeted by other survey methods in the FSP.

Group	Pest Species	Tree Species	Focus
Scolytidae	Scolytidae spp. (non-European)	Mixed Broadleaf	Primary
Brentidae	*Arrhenodes minutus*	Mixed Broadleaf	Primary
Scolytidae	*Pseudopityophthorus minutissimus*	Mixed Broadleaf	Primary
Scolytidae	*Pseudopityophthorus pruinosus*	Mixed Broadleaf	Primary
Scolytidae	*Euwallacea fornicatus*	Mixed Broadleaf	Primary
Cerambycidae	*Xylotrechus* spp.	Mixed Broadleaf	Primary
Cerambycidae	*Neocerambyx raddei*	Mixed Broadleaf	Secondary
Scolytidae	Scolytidae spp. (non-European)	Oak Dominant	Primary
Brentidae	*Arrhenodes minutus*	Oak Dominant	Primary
Scolytidae	*Pseudopityophthorus minutissimus*	Oak Dominant	Primary
Scolytidae	*Pseudopityophthorus pruinosus*	Oak Dominant	Primary
Molytinae	*Pissodes nitidus*	Pine Dominant	Primary
Molytinae	*Pissodes punctatus*	Pine Dominant	Primary
Molytinae	*Pissodes strobi*	Pine Dominant	Primary
Molytinae	*Pissodes zitacuarense*	Pine Dominant	Primary
Molytinae	*Pissodes cibriani*	Pine Dominant	Primary
Molytinae	*Pissodes nemorensis*	Pine Dominant	Primary
Molytinae	*Pissodes yunnanensis*	Pine Dominant	Primary
Scolytidae	*Polygraphus proximus*	Pine Dominant	Primary
Scolytidae	Scolytidae spp. (non-European)	Pine Dominant	Primary
Cerambycidae	*Monochamus* spp. (European and non-EU)	Pine Dominant	Secondary
Molytinae	*Pissodes strobi*	Spruce dominant	Primary
Molytinae	*Pissodes nemorensis*	Spruce dominant	Primary
Scolytidae	*Polygraphus proximus*	Spruce dominant	Primary
Scolytidae	Scolytidae spp. (non-European)	Spruce dominant	Primary
Molytinae	*Pissodes fasciatus*	Fir dominant	Primary
Scolytidae	*Polygraphus proximus*	Fir dominant	Primary
Scolytidae	Scolytidae spp. (non-European)	Fir dominant	Secondary

Appendix B

List of species trapped in the FTN 2022. Values in columns give the abundances of each species in different forest types.

Group	Species	Oak	MB	Fir	Pine	Spruce	**TOTAL**
Scolytidae	*Anisandrus dispar*	296	297	29	100	129	**851**
Ptinidae	*Anobium sp.*	10	1	0	0	0	**11**
Cerambycidae	*Arhopalus rusticus*	1	0	7	19	1	**28**
Cerambycidae	*Clytus arietus*	0	0	0	1	0	**1**
Scolytidae	*Crypturgus subcribrosus*	0	0	0	0	1	**1**
Scolytidae	*Dryocoetes autographus*	2	0	7	4	18	**31**
Scolytidae	*Dryocoetes villosus*	3	8	0	0	0	**11**
Ptinidae	*Ernobius abietus*	0	0	1	0	0	**1**
Scolytidae	*Ernoporicus fagi*	0	2	1	0	0	**3**
Cossoninae	*Euophryum confines*	12	20	6	5	9	**52**
Scolytidae	*Gnathotrichus materiarius*	3	25	42	108	0	**178**
Ptinidae	*Grynobius planus*	0	2	0	0	0	**2**
Scolytidae	*Hylastes angustatus*	4	9	71	73	10	**167**
Scolytidae	*Hylastes ater/brunneus*	0	0	1	8	2	**11**
Scolytidae	*Hylastes attenuatus*	1	4	52	124	5	**186**
Scolytidae	*Hylastes cunicularius*	0	0	6	2	0	**8**
Scolytidae	*Hylastes opacus*	0	0	1	5	1	**7**
Scolytidae	*Hylesinus toranio*	0	1	0	0	0	**1**
Scolytidae	*Hylesinus varius*	0	0	0	1	0	**1**
Scolytidae	*Hylobius abietus*	5	0	8	51	18	**82**
Scolytidae	*Hylurgops palliatus*	269	67	132	245	99	**812**
Scolytidae	*Ips typographus*	0	0	0	0	13	**13**
Scolytidae	*Orthotomicus* sp.	0	0	0	1	0	**1**
Scolytidae	*Orthotomicus sutralis*	0	0	6	2	4	**12**
Molytinae	*Pissodes pini*	0	0	2	1	0	**3**
Scolytidae	*Pityogenes bidentatus*	0	0	0	0	2	**2**
Scolytidae	*Pityogenes chalcographus*	2	4	0	1	54	**61**
Scolytidae	*Pitypthorous pubescens*	1	0	0	0	14	**15**
Scolytidae	*Polygraphus poligraphus*	0	0	0	0	1	**1**
Ptinidae	*Ptilinus pectinicornis*	0	14	1	0	0	**15**
Cerambycidae	*Rhagium bifasciatum*	1	3	16	8	2	**30**
Cerambycidae	*Rhagium mordax*	8	13	0	0	1	**22**
Cerambycidae	*Rupetla maculata*	3	2	2	1	0	**8**
Scolytidae	*Scolytus laevis*	1	0	0	0	0	**1**
Siricidae	*Sirex* sp.	1	0	0	0	2	**3**

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	Species	Oak	MB	Fir	Pine	Spruce	**TOTAL**
Scolytidae	*Tahpyrorychus bicolor*	0	1	0	0	0	**1**
Scolytidae	*Tahpyrorychus* sp.	0	1	2	7	0	**10**
Scolytidae	*Tahpyrorychus villifrons*	0	0	0	2	0	**2**
Scolytidae	*Tomicus minor*	0	0	6	1	0	**7**
Scolytidae	*Tomicus piniperda*	2	1	16	65	2	**86**
Scolytidae	*Trypodendron domesticum*	103	111	8	12	5	**239**
Scolytidae	*Trypodendron lineatum*	0	11	1	2	1	**15**
Scolytidae	*Trypodendron signatum*	1	3	0	0	0	**4**
Siricidae	*Uroceros gigas*	0	1	8	0	5	**14**
Scolytidae	*Xyleborinus saxesenii*	770	596	176	694	213	**2449**
Scolytidae	*Xyloborus dryographus*	1	1	0	1	0	**3**
Scolytidae	*Xyloborus monographus*	0	1	3	0	0	**4**
Scolytidae	*Xylosandrus germanus*	1120	1789	706	1128	38	**4781**
	TOTAL	**2620**	**2988**	**1317**	**2672**	**650**	**10247**

Appendix B

Data from the very abundant Hylastini tribe

The Hylastini in our samples comprise two genera, *Hylurgops* and *Hylastes*, and these were generally very abundant in most forest types but particularly fir and pine (Appendix B).

Hylurgops palliatus was the fourth most common species collected (n = 812; Fig. 3; Appendix B). This species is associated with conifers, particularly Norway spruce. Average abundances of this species did not vary significantly between the three coniferous forest types (Fig. 6). However, average per-sample abundances of this species were significantly higher in pine than oak ($p = 0.049$) and mixed broadleaf ($p = 0.01$; Fig. 6) forest types, although highest total abundance was found in oak (Appendix B), which was due to one particular trap at West Wood collecting an unusually large number of *H. palliatus* (223 individuals) on April 27th. This also led to West Wood having a significantly higher average abundance of *H. palliatus* than most other sites ($p < 0.01$; Fig. 6). The highest relative abundance of *H. palliatus* was found in spruce woodlands (15.2%), followed by oak and fir (10% each), pine (9.2%) and then mixed broadleaf forests (2.2%; Fig. 7). Abundances were highest in May, decreasing to zero from mid-June onwards.

Hylastes attenuatus was the sixth most abundant species in our samples, but as it usually attacks pine it was particularly abundant in pine forests (n = 187; Fig. 3; Appendix B), where average sample abundances were significantly higher than the two mixed broadleaf forests ($p < 0.001$) – although average abundances did not vary between the three coniferous forest types ($p > 0.05$). In contrast, in terms of relative abundance of *H. attenuatus*, the highest was found in pine (4.6%) followed by fir (4%), being less than 1% the remaining forest types (Fig. 7). The Denny Lodge Inclosure yielded significantly higher abundances of this species than most other sites ($p < 0.001$).

Hylastes angustatus was the eighth most common species trapped (n = 167; Fig. 3; Appendix B). It is usually associated with pine or spruce. However, the abundance of this species did not vary significantly between forest types ($p > 0.05$), nor varied strongly between sites, although was relatively most abundant in fir forests (5.3%), followed by pine (2.7%), and comprised less than 2% of individuals in the remaining forest types (Fig. 7).

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