A review of the status of the sawflies of Great Britain

Phase 1: Families other than the Tenthredinidae

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Summary

Data pertaining to the occurrence of sawflies (excluding the family Tenthredinidae) in Britain were collated and assessed against IUCN Red List criteria in order to categorise each species in terms of national threat status. Of 111 species under consideration, six were assessed as being Regionally Extinct, three Critically Endangered, three Endangered and six Vulnerable. In addition, the GB Rarity Status of the same species was assessed at the same time, with 24 species classed as Nationally Rare and 11 as Nationally Scarce. A full justification of the conclusions reached is provided, alongside discussion of the methodology used.

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1 Introduction

1.1 GB-level IUCN Red Lists for GB invertebrates

The UK government's 25 Year Environment Plan includes commitments to:

- take 'action to recover threatened … species of animals, plants and fungi'
- 'where possible to prevent human-induced extinction or loss of known threatened species'
- 'improve the overall status of declining species groups'

Moreover, the Plan notes that a relevant indicator for measuring its impact is one based on 'status and trends of wild species' and it is now agreed that a GB Red List Index will be one of indices used to track the effect of implementing the 25 Year Plan.

These commitments clearly require a sound understanding of the status of all species in GB, including an understanding of which species are threatened. The internationally recognised, objective approach to describing threat is by assigning each species to one of the International Union for the Conservation of Nature (IUCN) threat categories and collating these into a 'Red List'. Red Lists can be compiled at global or regional/national levels. Categorisation is a strictly defined process, in order to ensure traceability, comparability and repeatability. The current categories and criteria as well as guidelines for assigning species to the threat categories were set out in 2001 and are published by IUCN (2012a, 2012b, 2019).

Since 2012, an inter-agency working group of invertebrate specialists from the UK conservation bodies has undertaken a Species Status project with the aim of overseeing the production of a series of up-to-date status reviews, working to IUCN criteria as applied to national-level assessments. Webb & Brown (2016) described the work under this project that had, by that date, undertaken IUCN assessments of 3,769 British invertebrate species (about 10% of the total number of terrestrial and freshwater invertebrate species in Britain). Since then, further reviews have been published embracing approximately 3,500 more species, but there remain many significant gaps in coverage. Of the 'better-known groups' of British invertebrates, Webb & Brown (2016) noted that the most species-rich group that had never had a conservation status review undertaken (IUCN or otherwise) was the sawflies or 'Symphyta'.

Although sawflies were traditionally considered one of the two suborders of the Hymenoptera, they are now generally considered to comprise a paraphyletic grouping. For example, Peters *et al*. (2017) designates a clade of Eusymphyta comprising the majority of the sawflies, whilst including the endophagous groups (Xiphydriidae, Siricidae, Cephidae, Orussidae) within the larger Unicalcarida clade alongside all other Hymenoptera. Despite this, 'Symphyta' is still a useful and widely recognised term to refer to the group known as sawflies. British sawflies are divided into 12 families, with about 80% of species in the largest single family Tenthredinidae. A recent published British & Irish checklist of sawflies (Liston *et al.* 2014) lists 537 species, and a few more have been found subsequently, bringing the total now to over 550 with more likely to appear in the years to come. This species total is similar to that for the far-better studied aculeate Hymenoptera.

It appears that, to date, there has been virtually no conservation policy or action in the UK directed at sawflies, apart from a few mentions as interest features on some Sites of Special Scientific Interest in Scotland. Yet many sawflies are spectacular, rare, range-restricted and declining whilst others are of immense economic concern, notably those which are regarded as pests of trees and arable crops.

No sawflies are listed on the widely used and definitive JNCC spreadsheet of species conservation designations. A GB-level IUCN Red List for sawflies would likely alter our appreciation of this group and enable us to identify those for which we ought to have conservation concern, alongside other better-known insect groups.

The process of undertaking IUCN Red List assessments is well covered elsewhere (e.g. IUCN 2012a, 2012b, 2019). In short, available data are collated, summarised to produce standard metrics and compared against strictly defined criteria in order to determine which Red List category a species should have assigned to it. Issues that arose relating to assessing the available sawfly data within this framework are fully discussed below.

1.2 GB Rarity Status for invertebrates

It is important to recognise that threat and rarity are not the same thing. Whilst IUCN threat assessments are now the most important means of describing the conservation status of GB invertebrate (and all other) species, it remains useful to identify species with a restricted geographic distribution within Great Britain; species apparently occurring between 1-15 hectads of the national grid defined are as Nationally Rare whilst species occurring between 16-100 hectads are defined as Nationally Scarce. These measures are not IUCN categories, but they can be determined most readily during the data collation and analyses required for IUCN assessments and so most recent GB Red List reviews also identify those which are Nationally Rare and Nationally Scarce.

2 Methods

2.1 Data collation and management

2.1.1 Data sources

At the outset of work for this review there was no active recording scheme nor complete national dataset for sawflies. Hence, data pertaining to non-Tenthredinidae sawflies was sought from iRecord, the National Biodiversity Network (NBN) Atlas, all Local Environmental Records Centre, county sawfly recorders and key individual recorders, the latter being contacted directly and/or alerted to the project through social media and printed newsletters and journals. These were added to a compiled dataset collated about ten years previously by Guy Knight.

Museum collections would be a very valuable source of (mostly) older data. However, most museum collections remain uncatalogued and the time/resource to undertake such a task was not within the scope of the current review.

2.1.2 Data verification and deduplication

It was recognised from the outset that establishing the veracity of each individual sawfly record was never going to be possible. Many records are old and are provided 'as is', with no means of verification. Whilst many older records may still be supported by extant specimens in collections around Britain, it was not practical to visit all such collections to check every specimen. On the other hand, many recent records have been provided via online channels with accompanying photographs of sufficient quality as to be able to verify identification. In practice, a mixed approach had to be adopted.

Firstly, any descriptions of verification status that had been provided along with the record were considered carefully and for the most part followed. In particular, records from iRecord that had been assessed as 'not accepted' were not incorporated, whilst those that were 'plausible' or 'not reviewed' were considered on a species-by-species basis.

Secondly, a proportionate approach was taken to checking and deduplicating individual records, based on the volume of data per species. For example, it was impractical (and indeed unnecessary) to examine closely over 3,000 records of *Urocerus gigas*, but it was entirely feasible (and indeed important) to look over every individual record of those species with only a small number of records. In the end, 60 species were examined and deduplicated more carefully, which resulted in a reduction of 38% from 1,709 raw records to 1,057 deduplicated records. Were this ratio to remain the same for the more widespread species that would imply a total dataset of about 20,000 distinct records.

However, for the purposes of IUCN and GB rarity status assessments, deduplication of widespread species is not required, given that the key metrics rely on 'distinct' combinations of grid squares over time (i.e. five records from the same place in the same year will only 'count' as one). The same could be said for the rarer species also, but in those cases, the extra attention to detail was deemed important, given that assigning different categories can be strongly influenced by just a handful of records in some cases.

In terms of applying a level of verification assessment to individual records of the rarer species, a case-by-case assessment had to be made, based on a combination of location (compared to the range represented by other records), identification difficulty, changes in taxonomic opinion over time (which can be very significant), experience of the recorder and/or determiner, and so on. Such assessments will never be perfect, but were considered sufficient as to enable a robust assessment of status.

2.1.3 Data management

Particular attention was given to constructing a robust system of data management. This was because it was recognised that data would continue to be provided late into the process and it would not be possible to wait for all data to be provided before embarking on analyses and assessments. The steps required to generate the metrics necessary for undertaking the review are relatively complex and would be laborious to repeat in a manual way, hence as much of the process as possible was coded to enable rapid repetition when new data was received. Additionally, it was intended that in future, the same system could be used efficiently to generate the relevant statistics for other assessments, not least during review of the larger sawfly family Tenthredinidae.

The process was broadly as follows:

Individual datasets were mostly received as Excel files. No (or absolute minimal) manipulation of these files was undertaken, to avoid carrying out actions that might be missed in future should the dataset need re-loading. The datasets were saved as comma-separated text files.

The open source database system MySQL (version 8.0) was used to create a data management environment. Each dataset was loaded into the database, into an individual 'pre' table (e.g. pre_irecord, pre_norfolk, etc). Retaining each dataset as a separate table at this point enabled the wide variety of different data fields used for different systems to be retained easily for future use, without manual manipulation within Excel each time.

Initial data cleaning steps were undertaken for each dataset, to leave each with a consistent set of fields for date_from, date_to, date_type, year2use and gridref. All data cleaning steps were written as SQL statements to enable re-use in a consistent manner.

For each dataset, the scientific names used for the taxa were compared with a definitive checklist and used to continually build up a 'translation' table. This meant that taxon names could be retained in the 'pre' tables but that it was always then possible to map them onto their currently recognised taxonomic units.

For each dataset, a 'working' table was then created which included only the following fields: taxon, year, location_name, gridref, grid10km, grid2km, grid1km. The last three of these fields were constructed from the original grid reference where the resolution of the latter made it possible.

The 'working' tables for each dataset were then combined into a single 'working_combined' table. The source of each record was retained in the combined dataset. Two further fields were also created at this point. Firstly, for any grid references with only a 10-km resolution (e.g. TM29), a 'pseudotetrad' was created, representing the middle tetrad of the relevant 10-km square (e.g.

TM29M. Alternatively, the pseudotetrad field was populated with the actual tetrad for any grid references where this was possible (i.e. 2-km resolution or finer). The pseudotetrad approach was developed in order to enable certain important metrics to be generated for assessment against IUCN criteria (see below). Secondly, the grid references were compared against a lookup table to determine the best match in terms of country – i.e. England, Wales, Scotland, or where necessary, cross border England_Wales or England_Scotland.

Standard extracts were then produced for importing into QGIS for the determination of some area measurements, notably the calculation of Extent of Occurrence (EOO) over shorter time periods, requiring the construction of an 'alpha hull' concave polygon. For each combination of taxon and period (e.g. 'Abia aenea_06_20'), every associated pseudotetrad (see above) was extracted. A similar extraction was made for the purpose of deriving adjusted GB rarity status measures.

The use of QGIS (version 3.16.10) for the construction of the alpha-hulls and calculation of their areas, for all taxon/period combinations, involved a combination of standard geometry processing tools plus a bespoke plugin created by the Field Studies Council for the purposes of mapping biological records. More detailed notes on using QGIS for this purpose are provided in Appendix 1 in the hope they are useful to other workers.

The area measurements per taxon/period produced from QGIS were then imported back into a table in the MySQL database.

Finally, SQL code was used to extract all of the relevant metrics for the assessments of IUCN status and GB rarity status, forming the basis of the final data table. Importantly, because most of the above steps were retained as code, the entire process could be repeated easily, as and when additional (or updated) datasets arrived.

2.2 Undertaking the IUCN Red List Assessment

Regional assessments are carried out in a three-step process. First, assessors must determine which taxa and which regional populations to assess (step one). Next, the regional population for each taxon is evaluated according to the IUCN Red List Categories and Criteria (IUCN 2012), and a preliminary status category is assigned (step two). The effect of populations of the same taxon in neighbouring regions on the regional population is then considered, and the preliminary category is up- or down-listed if appropriate (step three). Thus, the final categorization reflects the extinction risk for the taxon within the region being evaluated, having considered potential interactions with populations outside that region.

2.2.1 Determining which taxa and which regional populations to assess

The first stage of the IUCN Red List GB assessment is to determine which taxa will be assessed at the level of Great Britain. This question has two main components. Firstly, it is necessary to decide on a taxonomic authority to follow, to determine species limits, list sequence and so on. Secondly, it is necessary to consider which species may need to be given the status Not Applicable (NA), meaning that whilst records of the species exist, there are good reasons not to allocate a further Red List status to them.

2.2.1.1 Taxonomic treatment

As is the case for many groups, sawfly taxonomy is in a state of flux and subject to ongoing revision and development. The most recent published British (and Irish) checklist is by Liston et al. (2014), as part of a series of papers covering all British and Irish Hymenoptera. It is several years out of date now, however. More recent updates have been obtained via the online world checklist ‘ecatsym’ (https://sdei.de/ecatsym/), hosted by the Senckenberg Deutsches Entomologisches Institut. This electronic catalogue (Taeger et al. 2018) was checked throughout this review in cases of taxonomic uncertainty.

It was decided to include in the review some of the species that had been omitted by Liston et al. (2014) for reasons of doubt over provenance, for the purpose of setting such doubts out clearly and clarifying their unacceptability.

Additionally, the sequence of families has been modified slightly to fit the phylogeny provided by Peters et al. (2017), which may better reflect the relationships between the different groups, in particular the monophyletic group of ‘true sawflies’ vs the internally-feeding Xiphydriidae, Siricidae, Cephidae and Orussidae, all of which appear to form a paraphyletic grading with regard to other Hymenoptera.

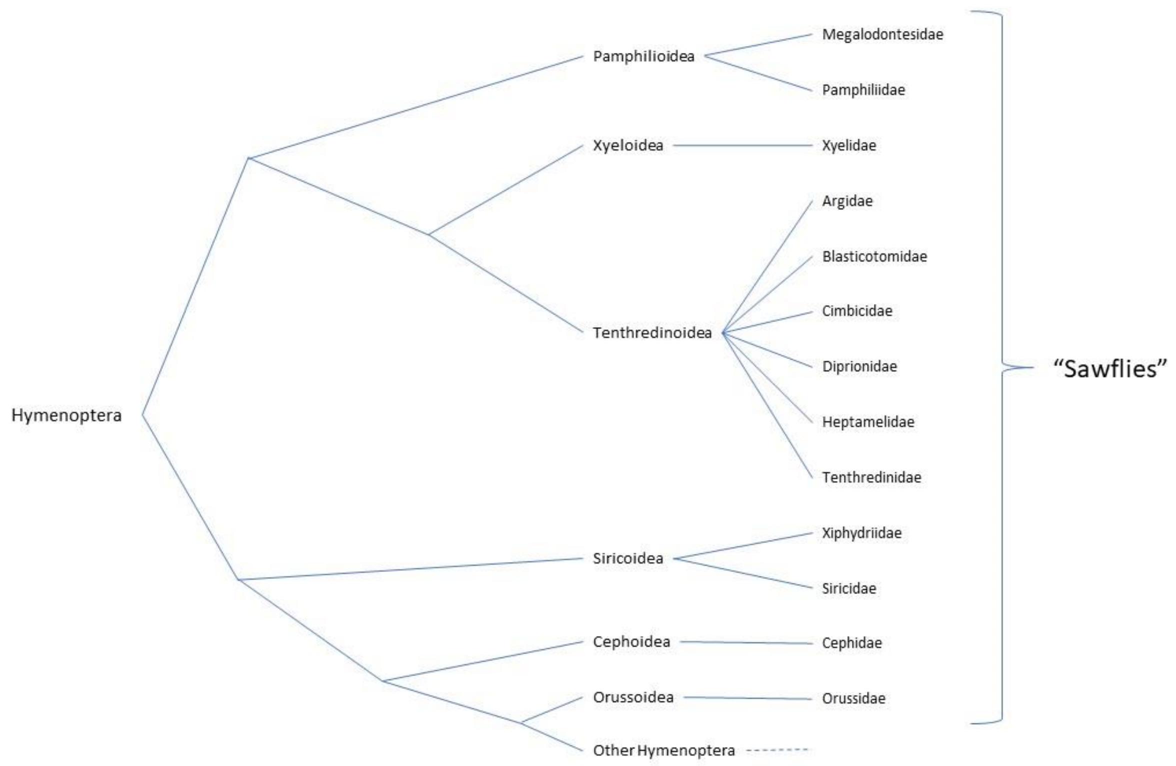


Figure 1: Evolutionary history of sawflies within the Hymenoptera according to Peters *et al.* (2017).

A number of species have been considered within the current review that were not listed in the Liston et al. (2014) checklist. For two species (*Megalodontes plagiocephalus, Cimbex americanus*) old records do exist and were considered as part of the review. For four species (*Pamphilius marginatus, Aproceros leucopoda, Janus compressus, Tremex fuscicornis*), the first records have only come to light since the publication of the checklist. Finally, two more species (*Xeris pallicoxae, Sirex atricornis*) are considered here in the light of new published work concerning the taxonomy of these genera.

Finally, it should be noted that the work for this review was finalised in early 2022. It is inevitable that further taxonomic understanding will continue to develop, and use of this review should take into account further changes in nomenclature and species limits.

2.2.1.2 Assessing whether Not Applicable (NA) is the correct status

Not Applicable (NA) is a status that can be used within regional Red List assessments (but not global ones) and is defined as a 'category for a taxon deemed to be ineligible for assessment at a regional level. A taxon may be NA because it is not a wild population or not within its natural range in the region, or because it is a vagrant to the region.' Moreover, 'a regional Red List categorization process should be applied only to wild populations inside their natural range and to populations resulting from benign introductions'. However, 'in contrast to other Red List Categories, it is not mandatory to use NA for all taxa to which it applies; but is recommended for taxa where its use is informative.' Therefore, there would appear to be a degree of leeway open regarding the use of NA in regional assessments, although it seems important that a clear rationale should be set out to justify the way in which the NA status has been deployed.

There are many species of sawflies in Britain for which the description 'not a wild population or not within its natural range in the region' could be argued as apt. However, the situation is far from clear-cut, with a wide range of graded scenarios. For example:

- Some species are considered native to the Caledonian pine forests but can be found on more recently established Scots Pines *Pinus sylvestris* elsewhere in Britain, which one could arguably say do not constitute their 'natural range in the region'. It is seldom clear whether the range expansion is due to natural dispersal (from Scotland and/or from continental Europe) or to human-mediated translocation. Differentiation into 'native' and 'non-native' ranges is sometimes possible (e.g. *Gilpinia frutetorum*) but often the two are less well-defined (e.g. *Urocerus gigas*).
- Some species (e.g. *Gilpinia virens*) have to date only been recorded around pines in southern Britain, albeit in wild-type settings. The foodplant is native but has not occurred naturally in that area for many centuries. Would one say that southern England was the 'natural range' of Scots Pine, and by extension of the sawfly? The means of arrival of the sawfly are unknown but it occurs throughout continental Europe.
- *Arge berberidis* is native to Europe, feeding on species of *Berberis* and *Mahonia*. It has colonised Britain where it is found almost exclusively in gardens and other domestic settings feeding on ornamental *Berberis* shrubs, although Common Barberry *B. vulgaris* is thought likely to be a native (albeit scarce) plant and the sawfly has been found on that also. The sawfly may feasibly have arrived by natural dispersal, and/or it may have been aided by human transportation.

- *Xyela curva* is native to continental Europe and has been recorded a few times in Britain in plantations of Corsican Pine *Pinus nigra*; the tree is not native to Britain although it forms a close ecological analogue to Scots Pine. Its means of dispersal are unknown.
- *Aproceros leucopoda* is an East Asian species that was presumably translocated by human means into southern Europe, from where it has spread to Britain to feed on native elms *Ulmus*. Its means of crossing the English Channel are unknown but it clearly disperses effectively.

No sawfly is known to have been deliberately introduced to Britain for any reason.

Given that the environment in Britain is so strongly human-modified (and has been for thousands of years), it seems unhelpful to adopt an overly purist approach to which species are truly wild or not. By analogy, House Sparrows *Passer domesticus* and Swifts *Apus apus* are often given significant attention from a conservation viewpoint, yet both are largely dependent on human-modified environments. Moreover, in most cases it is impossible to tell the mechanisms by which insects arrive into the UK.

Furthermore, the IUCN guidelines make clear that a threatened status does not imply that a species has any priority for conservation; it is simply an expression of the likelihood of extinction in the near future. If that is the case then it is not clear why it makes any difference whether a species is a long-established native or a more recent arrival, native or otherwise.

For these reasons, for the purposes of this review, the majority of species were considered to be suitable for assessment. Moreover, those species with a combination of an apparent native population in the Caledonian pine forests plus an apparent introduced population in southern Britain have had all parts of the population treated as of equal relevance for the purposes of threat review. In the end, species were only classified as NA for one of the following four reasons:

1) Species that have never been recorded 'at large' in the countryside but instead have been encountered solely in situations that strongly point to recent importation – this is clearly the case for a number of Nearctic species of Siricidae 'wood-wasps' for example.
2) Species that appear to be at a very early stage of colonisation. The Regional Guidelines say that a taxon 'should not be considered for regional assessment until the taxon has reproduced within the region for several years (typically for at least 10 consecutive years).' This currently appears to be the case for *Pamphilius marginatus* and *Janus compressus*, as well as for *Urocerus augur* in a wild-breeding sense (although there are some older records attributed to importation for the latter). These three cases have been assigned a status of NA for this reason. However, a strict 10-year limit does not seem appropriate for *Aproceros leucopoda*, which was first confirmed as present in 2017 (although it may have been present prior to this); this species has rapidly become abundant over most of the south-east of Britain and is clearly here to stay, and so it has been fully assessed.
3) Species with only records of questionable provenance. There are a number of species that have not been recorded since the 1800s, at which time there was known to have been a degree of dishonesty regarding the veracity of some specimens (given that allegedly rare specimens could fetch a high price). Whilst some of these taxa are deemed likely to have been present in a wild state back then, others are not. In making this assessment, the wider distributional range of each species has been taken into account, as well as the reported circumstance of capture and the opinions of earlier entomologists who are more likely to have been in possession of information regarding particular collectors.

4) The wood-wasp *Sirex atricornis* is a special case, in that it has been theorised to be (or have been) present in native Scottish pine forest, but this remains unproven to date; it has been retained in the review but given the status NA for this reason.

2.2.2 Evaluation of each taxon according to IUCN Red List Categories and Criteria

The process for evaluating data against criteria is well set out by the IUCN's documents and guidelines. However, the following notes discuss the particular issues encountered relating to the implementation of this process against the British sawfly dataset.

One general point to note was that most of the assessments were undertaken with records up to the end of the year 2020, to introduce a degree of consistency regarding differing speeds of accessibility to (and verification of) records from the year 2021. However, in a small number of cases, particularly significant records from 2021 were incorporated, where they would have a material effect on the status measures or commentary.

2.2.2.1 Assessing status under Criterion A

Criterion A relates to a reduction in population size. Population size reduction needs to be assessed over the longer of 10 years or three generations. Sawflies all have generation lengths of less than three years, and hence a 10 year period is the appropriate duration for the assessment of all species.

The Guidelines allow for predicted population change into the future to be used for assessments (subcriteria A3 and A4). However, data of sufficient quantity or quality do not exist for any British sawflies to make this a realistic proposition.

Subcriteria A1 and A2 differ based on whether 'the causes of the reduction are clearly reversible AND understood AND have ceased' (for A1) or whether at least one of those three provisos is incorrect (for A2). Again, the nature of the available data for sawflies at present means that A1 is not a realistic prospect. Hence, A2 is the only remaining subcriterion.

Population size reduction measures need to be based on at least one of,

(a) direct observation [except A3]

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

In effect, the only usable metrics that can be deployed for British sawflies relate to changes in distribution and range – i.e. in AOO and EOO, i.e. A2c. In reality we do not know the precise EOO or AOO in a given year, and instead have to try to derive an estimate of these measures by using data consolidated across longer time periods. The following approach was taken.

1) Records were combined across 1991-2005 and were all assigned to relate nominally to 1998; likewise, records were combined across 2006-2020 and were assigned nominally to 2013.
2) For each species and for each of the two time periods, the EOO was calculated via the construction of alpha-hull concave polygons. The polygons were constructed using the open-source desktop application QGIS using an alpha parameter value of 0.5 (assumed to be the QGIS equivalent of the value of 2 recommended by IUCN (2012); see Appendix 1 for further details). Note that alpha-hulls can fail to be constructable when looking at small datasets (i.e. if internal lines are removed such that fewer than three points remain), and hence EOO comparisons can only be undertaken if non-null areas remain for both time periods. In a small number of cases, the alpha parameter was relaxed to 1.0 to investigate plausible values for EOO in data-poor situations, although this was only then used to support a status of Near Threatened.
3) The AOO was also calculated for each species and time-period, by assigning every record to a 2 x 2 km square (using a nominal central 'pseudotetrad' for any records that were only defined to a 10 x 10 km resolution), and then summing the areas of the distinct squares.
4) For each species, and for each of EOO and AOO, the values assigned to the nominal years 1998 and 2013 were used to construct an exponential curve, from which the estimated change between the years 2010 and 2020 was calculated, following the approach discussed in section 4.5 of the Red List Guidelines (and underpinning the Criterion A tool downloadable from https://www.iucnredlist.org/resources/grid). In the absence of evidence to the contrary, exponential change (indicating a constant rate of change) was felt more likely to be a better fit than linear change (indicating a constant loss/gain of absolute numbers).
5) The calculated change measures were then compared against the threshold values for A2 of 30% (VU), 50% (EN) and 80% (CR). For 'near-misses', the potential for assigning the category NT was considered.

Note that IUCN guidelines state that only records of adults, not immatures, should be used for direct assessment of population size under Criterion A. However, records of sawfly larvae have also been retained for the purposes of calculating range measures (AOO, EOO) as their presence clearly indicates the recent presence of adults of the species. For many species of insects, including some sawflies, the vast majority of records will relate to the detection of larvae.

2.2.2.2 Assessing status under Criterion B

Criterion B relates broadly to an assessment of geographic range. Either EOO and/or AOO need to be below certain threshold values, AND at least two of three further conditions need to apply. However, one of these latter relates to demonstrating 'extreme fluctuations', which the sawfly dataset is not sufficiently detailed to enable. Therefore, to qualify under Criterion B, the range needs to be both

a) Severely fragmented OR with a low number of locations
b) Continuing decline observed, estimated, inferred or projected in any of i) EOO, ii) AOO, iii) area, extent and/or quality of habitats, iv) number of locations or subpopulations; v) number of mature individuals.

Severe fragmentation (within a) is defined as such: 'A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance.' There is insufficient knowledge available to say how big a habitat patch is required to support a viable population for any species, and hence the severe fragmentation is not usable within this review.

The remaining metrics were considered as follows:

Extent of Occurrence (EOO) was assessed by finding the area of a minimum convex polygon that contained the 'pseudotetrad' (see Criterion A) relating to every record of a species over the 30 year period 1991-2020. This value was calculable via in-built functions in MySQL, and was compared to the threshold values for VU (<20,000 km^2), EN (<5,000 km^2) and CR (<100 km^2). Near-misses were considered with regard to the potential for a NT status.

Area of Occupancy (AOO) was assessed by summing the area of all distinct 'pseudotetrads' (see Criterion A) relating to every record of a species over the 30 year period 1991-2020, and was compared to the threshold values for VU (<2,000 km^2), EN (<500 km^2) and CR (<10 km^2). Near-misses were considered with regard to the potential for a NT status.

'Number of locations' was assessed in the context of the IUCN definition of a 'location' relating to 'a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present'. For terrestrial insects, such an area would be quite small. For the purposes of this review, a location was defined as a 2 x 2 km square (tetrad), so making use of the same units as for the AOO calculations. In reality, a 'pseudotetrad' was used whereby a central tetrad of a hectad was used if the record was only defined to that 10 x 10 km level of precision.

Note that using pseudotetrads (which are 4 km^2) as the same measure for Locations and AOO calculation simply places a tighter constraint on the AOO requirement under criterion B2. That is, whilst AOO needs to be below 2,000 km^2 for a threatened status, there is also a need for there to be ten or fewer locations, which means that actually one needs an AOO of 40 km^2 or fewer. As it happens, because of the low level of recording of sawflies, almost all species currently have an AOO of below 2,000 km^2.

Finally, there is a need to assess whether there is "a continuing decline inferred in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals". Options (iii) and (v) are not calculable from the data available. Moreover, given that we are basing locations and AOO on the same pseudotetrad measure, (ii) and (iv) are entirely equivalent to each other.

For the purposes of the review, continuing decline was assessed over the 30 year period 1991 to 2020. This allowed for two overlapping assessments, looking at three 10-year block and two 15-year blocks, which it was intended would smooth over irregularities in a patchy dataset. For each of these five time-periods, EOO was calculated via the use of alpha hulls (where datasets were large enough to allow this), whilst AOO (and number of locations) was calculated from the distinct pseudotetrads. Continuing decline was assessed as occurring if:

2006-2020 < 1991-2005 – i.e. decline between two 15-year blocks

or

2011-2020 < 2001-2010 – i.e. decline between two most recent 10-year blocks

or

2001-2010 < 1991-2000 alongside 2011-2020 not >> 2001-2010 – i.e. decline from the 1990's to 2000's and not a clear bounce-back in 2010's.

In reality, the level of sawfly recording has increased greatly in the last decade (Figure 3, see Results) which in itself may be masking further real declines. For species to have seen a recent continuing decline is therefore especially noteworthy.

2.2.2.3 Assessing status under Criterion C

Criterion C requires a knowledge of the number of mature individuals in a population. This is not known for any British sawflies and hence Criterion C could not be used in the assessment.

2.2.2.4 Assessing status under Criterion D

Criterion D relates to very small or restricted populations. For a species to qualify under D1 a knowledge of the number of mature individuals is required, but we do not have this information for sawflies. However, qualification as Vulnerable under Criterion D2 is possible if there is a restricted area of occupancy (typically AOO < 20 km^2 or number of locations <=5), coupled with a 'plausible future threat that could drive the taxon to CR or EX in a very short time.'

For the current review, sawflies were identified as potentially qualifying for D2 if they had been recorded from five or fewer pseudotetrads between 1991 and 2020. For each of these, the question of a plausible future threat was considered. In practice, there were relatively few cases in which a plausible future threat could be suggested. However, in cases where a species had been reported from just one site since 1991 it was considered plausible that a threat could drive that species to Critically Endangered or Extinct in a short time.

2.2.2.5 Assessing status under Criterion E

Criterion E requires a quantitative analysis to be undertaken that indicates the probability of future extinction in the wild over a set time-period. No such analyses have been undertaken for British sawflies (and these are unlikely at present given the nature of the available dataset) and hence Criterion E could not be used in the assessment.

2.2.2.6 Assessing whether a Near Threatened (NT) status is appropriate

A taxon can be classed as Near Threatened (NT) when it has been evaluated against all possible criteria and does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future. The Guidelines note that NT is appropriate 'especially when there is a high degree of uncertainty', which certainly applies to many British sawflies.

A taxon may also qualify for NT if it is the focus of a continuing taxon-specific or habitat-specific conservation or management programme targeted towards the taxon in question, the cessation of which would result in the taxon qualifying for one of the threatened categories within a period of five years. However, this is not the case for any British sawflies to date.

The regional guidelines also note that NT could be appropriate if a Vulnerable species was deemed appropriate for 'downlisting' if it was felt that it could be 'rescued' by populations in neighbouring regions (i.e. mainland Europe). However, there is insufficient information available concerning either the status of sawflies in Europe, or their dispersal capabilities, with which to make such an assessment at present.

For taxa listed as Near Threatened on the IUCN Red List, assessors are asked to indicate which criteria were nearly met as part of the justification.

For the current review, all cases were carefully considered where metrics were close to threshold values (and in particular when some but not all subcriteria were met), noting particularly the upsurge in recording effort in recent years that may well mask actual declines.

2.2.2.7 Assessing whether a Data Deficient (DD) status is appropriate

Data Deficient is a status which can be allocated in cases where there is little available information (direct or indirect) with which to make an assessment. However, over-use of DD is discouraged, and even very limited data can be sufficient to draw conclusions regarding an IUCN Red List status.

If a taxon is known, but there is no direct or indirect information about its current status or possible threats, then it is obviously DD. The issue becomes more complex when there is very little information known about a taxon, but the available information indicates that the taxon may be threatened. The question then becomes how far is it acceptable to take inference and projection?

For the category of DD to be assigned, it must be demonstrable that data are inadequate to determine a threat category. If the data are so uncertain that both CR and LC are plausible categories, the taxon can be listed as DD. However, if plausible categories range from NT to threatened categories, DD is not the appropriate category.

Data Deficient species may be flagged with one or both of the following tags, although most DD species would not need either:

1. Unknown provenance. The taxon is known only from one or more specimens with no or extremely uncertain locality information, so that it is not possible to make any further inference about its status.

2. Taxonomic uncertainty explains lack of information. The paucity of data may be a consequence of taxonomic uncertainty. It is important to note that this tag should not be used for taxa that simply have uncertainty around their taxonomy, but rather that the taxonomic uncertainty impacts on the potential to assess records of that taxon.

2.2.2.8 Assessing whether a Regionally Extinct (RE) or Critically Endangered (Possibly Extinct) (CR(PE)) status is appropriate

The Regional Guidelines define RE as a ‘category for a taxon when there is no reasonable doubt that the last individual potentially capable of reproduction within the region has died.’ They further note that ‘it is not possible to set any general rules for a time period since the last observation before taxa are classified as RE. This will depend on how much effort has been devoted to searches for the taxon, which in turn will vary, both with organism and region. If the regional authority decides to adopt any time frames for RE assessments, these should be clearly specified.’

The term 'no reasonable doubt' is important for poorly recorded taxa like sawflies. Even apparently common and widespread species are relatively poorly recorded, compared to many other taxonomic groups. Moreover, little or (usually) no effort would appear to have been devoted to searches for most rare species. Therefore, it is difficult to say that there is not a reasonable level of doubt as to whether a species remains extant or not in Britain, even many years after being last recorded.

Having said this, there are some species with no recent records where one might reasonably expect detections to have been made. The general level of interest in sawfly recording has increased strongly in the last decade, and a number of species have been rediscovered through a combination of digital photography, social media and online biological recording applications. Therefore, a continuing absence by some species does give significant cause for concern, although this does need to be assessed on a species-by-species basis, based on distributional, habitat and behavioural factors, as well as distinctiveness from an identification point of view.

For this review, the approach that has been taken is that species that have not been recorded reliably since the beginning of 1991 have been considered as candidates for RE, with other factors then being taken into account.

Additionally, the tag of ‘Possibly Extinct’ has been developed by IUCN to identify those Critically Endangered species that are, on the balance of evidence, likely to be extinct, but for which there is a small chance that they may be extant. Therefore, the potential for using CR(PE) has also been considered for species that have not been recorded since 1991. There is a particular difficulty in deciding how best to provide criteria to back up an assessment of CR(PE), given that there are no recent data on which to assess Criterion A (i.e. a decline from zero to zero in the last ten years) and Criterion B (similar issue for assessing ‘continuing decline’ and there is a requirement for one location). Criterion D could apply (very small area and plausible future threat) but that is only able to lead to a status of VU, not CR.

The Guidelines (IUCN 2012, p82) do note ‘there are many species for which extinction is a possibility, but for which the declines or disappearances took place more than 10 years or three generations ago (whichever is longer), and for which the EOO and AOO are too large for listing as CR, and/or at least two subcriteria for CR B are not met. In such instances, the species should be listed as CR C2a(i), CR C2a(ii), and/or CR D, whichever seems more plausible. Such an assessment therefore implies an estimated population size of fewer than 250 mature individuals (for C2) or 50 mature individuals (for D). Even though it is impossible to know whether or not such an assumption is correct, it is a reasonable one for a species that could be Extinct.’ That is, although counts of individual insects might not be considered as a sensible metric, the Guidelines suggest this may be a way around the discrepancies in the criteria.

2.2.3 Consideration of the effect of populations in neighbouring regions

In step three of a regional IUCN Red List assessment, the existence and status of any conspecific populations outside the region that may affect the risk of extinction within the region should be investigated.

If the taxon is endemic to the region or the regional population is isolated, the Red List Category defined by the criteria should be adopted unaltered. However, none of the species covered during the current review are endemic or especially isolated.

If conspecific populations outside the region are judged to affect the regional extinction risk, the regional Red List Category should be changed to a more appropriate level that reflects the extinction risk. In most cases, this will mean downlisting the category obtained in step two, because populations within the region may experience a "rescue effect" from populations outside the region. In other words, immigration from outside the region will tend to decrease extinction risk within the region. Conversely, if the population within the region is a demographic sink that is unable to sustain itself without immigration from populations outside the region, and if the extra-regional source is expected to decrease, the extinction risk of the regional population may be underestimated by the criteria. In such exceptional cases, an uplisting of the category may be appropriate. If it is unknown whether or not extra-regional populations influence the extinction risk of the regional population, the category from step two should be kept unaltered.

There are no conservation reviews of sawflies in neighbouring European countries, nor is there sufficient information available concerning dispersal potential of sawflies. Therefore, it is hard to see on what basis one would alter a British assessment from this perspective. Therefore, none of the statuses have been altered as a result of Step 3.

2.3 Assessing GB rarity status

Threat, as described by the IUCN Red List process, is not the same thing as rarity. For example, a species may be common but threatened, or rare and stable. Whilst IUCN threat assessments are now the most important means of describing the conservation status of GB invertebrate species, it has also been found valuable to describe how restricted geographic distribution is within Great Britain. These measures are not IUCN categories, but they can be determined through essentially the same data analysis process required for IUCN and so most recent GB IUCN Red List reviews have produce these GB rarity status categorisations at the same time.

GB Rarity has traditionally been assessed by counting the number of hectads (10 x 10 km squares) from where a species has been recorded. Most recent invertebrate status reviews have used the following definition:

Nationally Rare (NR): species recorded from between 1-15 hectads of the Ordnance Survey national grid in Great Britain since 1991 and where there is reasonable confidence that exhaustive recording would not find them in more than 15 hectads. Broadly speaking, the Nationally Rare category is equivalent to the Red Data Book categories used by Hyman (revised Parsons) (1992, 1994), namely: Endangered (RDB1), Vulnerable (RDB2), Rare (RDB3), Insufficiently Known (RDBK), Indeterminate (RDBI) and Extinct.

Nationally Scarce (NS): species recorded from between 16-100 hectads of the Ordnance Survey national grid in Great Britain since 1991 and where there is reasonable confidence that exhaustive recording would not find them in more than 100 hectads. The Nationally Scarce category is directly equivalent to the combined 'Notable', Nationally Notable A (Na) and Nationally Notable B (Nb) categories used in the assessment of various taxonomic groups by Hyman (revised Parsons) (1992, 1994).

Missing, but implied from these definitions is that a species recorded in 15 or fewer hectads, but where there is reasonable confidence that exhaustive recording would find them in 16-100, would be defined as Nationally Scarce. Likewise, any species where there is reasonable confidence that exhaustive recording would find them in over 100 squares would be defined as having no GB rarity status.

The definitions imply a degree of subjectivity around what ***exhaustive recording*** could reasonably be expected to turn up. To some extent this makes sense, as this may vary from taxonomic group to group. For example, one group may be well-recorded and known to include many habitat specialists, and hence it would be relatively surprising to find them away from existing sites. Conversely, other groups may be poorly recorded but include many species that appear to be widely distributed in fairly 'common' habitats, and hence it would be reasonable to expect that exhaustive recording would uncover many more hectads. Sawflies fall clearly into the latter group.

For the purposes of this review, it was decided that it would be beneficial to develop an objective approach to estimating a likely number of expected hectads to assess against the GB rarity thresholds. A degree of trial and error was undertaken, making use of QGIS to examine different scenarios, before the following approach was settled upon.

1) Extract all hectads per species post-1990
2) To produce a broadly representative range map per species, use QGIS to produce an alpha-hull with threshold value 0.3. Note that for some species this will exclude some outlier records. For some species present in very few hectads then no alpha hull will be calculable and the unadjusted hectad count will simply need to be retained.
3) It is unlikely that all sites on the periphery of the range represent the absolute limit of the distribution, and so buffer the resulting shapes by 20 km.
4) Clip the resulting shape by the coastline.
5) Calculate the area of the clipped shape in km^2 and then divide by 100 to give an equivalent in hectads.
6) In recognition that species may not always be evenly distributed across the countryside, and to retain an element of precaution, take the mean of the actual recorded hectads and the calculated hectads, to give a final estimated value of hectads to compare against the GB Rarity thresholds.
7) Consider the results carefully in terms of any understanding of the habitat preferences and detectability of each species.
8) GB Rarity status is presented based on the estimated hectads, but clearly labelled so as to show the extent of any upgrading from the status that would have been achieved from simply relying on raw hectad counts.
9) For any species where the IUCN Red List category is Regionally Extinct, then a GB Rarity Status of 'Extinct' is given.
10) For any species where the IUCN Red List category is Not Applicable, for reasons of either a) lack of occurrence in the wild or b) doubt over provenance, then a GB Rarity status of 'n/a' is indicated. However, for localised recent colonists, the GB Rarity status is calculated as normal.

11) For any species where the IUCN Red List category is Data Deficient, then a GB Rarity status may still be calculable, but where not (particularly in cases of taxonomic uncertainty) then 'unclear' is indicated.
12) Finally, a similar approach to the concept of 'nativeness' has been used as for the IUCN Red List assessments (see 2.2.1.2).

3 Results

3.1 Datasets obtained

Publicly available datasets

The Biological Records Centre enabled access to data within iRecord, which was downloaded on 15/10/2021 and again on 04/02/2022, comprising over 25,000 records from across Britain.

Data from the NBN Atlas was downloaded on 26/10/2021 and again on 04/02/2022, comprising over 49,000 records from across Britain, although this included duplicates of the iRecord dataset.

Prior compilation exercise

Guy Knight kindly made available a dataset he had been compiling, mostly involving data up to 2012. This included data digitised by the Biological Records Centre as well as many contributions from individual recorders, some Local Environmental Records Centres and some museums. Following extensive reformatting work, this dataset comprised over 40,000 records from across Britain.

Local Environmental Records Centres and other county datasets

Requests for data were sent to all Local Environmental Records Centres (LERCs) in Britain. Data was provided by 32 LERCs, with data from eight LERCs not made available by the project deadline. For two of the missing counties, active local recorders had made direct submissions anyway (see below). In addition, for several counties (Norfolk, Lincolnshire, Yorkshire, Kent), active county recorders were in place who made their datasets available directly. The LERC/County datasets collectively totalled about 42,000 records, albeit involving significant levels of duplication with some of the national compiled datasets.

Individual recorders

Requests for data for the review were distributed through both social media (key Facebook discussion groups, plus Twitter) and print media channels, the latter being

- British Journal of Entomology and Natural History
- The Entomologist's Record
- Bulletin of the Dipterists Forum
- Newsletter of the Bees, Wasps and Ants Recording Society
- British Wildlife

In response, datasets totalling about 4,000 records were received from 15 individuals, including many of the most active British sawfly recorders of recent years. Other individuals confirmed that their records were available via iRecord.

Other sources

The Royal Horticultural Society made available 1,500 records originating from queries made to their entomologists over many years.

The Senckenberg Deutsches Entomologisches Institut undertakes an extensive programme of research into phylogenetic systematics of sawflies, and kindly made available about 900 British records it had compiled as a result of their researches.

The Herbert Art Gallery & Museum in Coventry has an extensive collection of sawflies, which had been catalogued by Adam Wright in 1985. The current curator Ali Wells kindly scanned a remaining hardcopy of the catalogue from which 500 records of non-Tenthredinidae were extracted for the purposes of this review.

3.2 Overall dataset metrics

In total, 162,849 records were made available, although these included many pertaining to Tenthredinidae also, which will comprise later phases. Reducing the dataset to the smaller families under consideration in the current phase of the review left 33,105 records.

This total included many duplicates. In particular, verified iRecord records are made available through the NBN Atlas; many county datasets have obtained data from other sources (like iRecord); and Guy Knight's prior compilation exercise also obtained many records that were submitted separately for the purposes of the current review.

Determining the number of overall number of duplicate records is not straightforward. For 65 of the 111 species under consideration, records were carefuly de-duplicated, but this was not possible in the time available for the more widespread species. Moreover, such a task is also not strictly necessary for most of the analyses required for a Red List (or GB Rarity) assessment, as most statistics are built upon counts of distinct grid squares, which does away with the duplicates automatically. However, for many rarer species, it was informative to consider all of the records in detail, and in those cases, a detailed de-deduplication exercise was undertaken (see Table 1). For the species concerned, de-duplication removed 37% of the records, and so if a similar pattern was seen for the more widespread species, we might expect that the overall dataset would be redcued to approximately 21,000 records following full de-duplication.

Figure 2 maps the records that were used, in terms of numbers of records and numbers of species. Records came from much of Britain, although were more sparse in the northern half of Britain.

Figure 3 illustrates the distribution of records through time. There has been a very significant upturn in recent years (albeit relative, as overall data volumes are still low). This is a pattern typical of the records of many taxonomic groups, as changes in information technology have made it easier to collate and share data.

Species	Records obtained	De-duplicated [or estimate]
Megalodontes cephalotes	5	5
Megalodontes plagiocephalus	1	1
Acantholyda erythrocephala	47	24
Acantholyda posticalis	74	32
Cephalcia lariciphila	194	[122]
Neurotoma mandibularis	17	6
Neurotoma saltuum	341	[214]
Pamphilius albopictus	5	3
Pamphilius balteatus	149	54
Pamphilius betulae	59	26
Pamphilius fumipennis	44	22
Pamphilius gyllenhali	88	[55]
Pamphilius histrio	48	20
Pamphilius hortorum	210	[132]
Pamphilius inanitus	135	[85]
Pamphilius latifrons	28	13
Pamphilius marginatus	2	1
Pamphilius pallipes	124	[78]
Pamphilius stramineipes	31	28
Pamphilius sylvarum	68	41
Pamphilius sylvaticus	421	[264]
Pamphilius vafer	96	[60]
Pamphilius varius	112	[70]
Xyela curva	9	3
Xyela julii	461	[289]
Xyela longula	19	7
Arge berberidis	5011	[3132]
Arge ciliaris	242	[152]
Arge cyanocrocea	2418	[1512]
Arge enodis	37	26
Arge expansa	22	40
Arge fuscipes	165	96
Arge gracilicornis	713	[446]
Arge melanochra	298	[187]
Arge metallica	11	7
Arge nigripes	426	[267]
Arge ochropus	582	[364]
Arge pagana	2346	[1467]
Arge rustica	50	31
Arge ustulata	1113	[696]
Aproceros leucopoda	957	[599]
Aprosthema fusicorne	5	9
Aprosthema melanurum	21	2
Aprosthema tardum	1	2
Sterictiphora angelicae	19	9
Sterictiphora geminata	134	[84]
Blasticotoma filiceti	54	30
Abia aenea	29	17
Abia candens	226	[142]
Abia fasciata	656	[410]
Abia lonicerae	234	[147]
Abia sericea	1118	[699]
Cimbex americanus	1	1
Cimbex connatus	298	[187]
Cimbex femoratus	1111	[695]
Cimbex luteus	141	[89]

Species	Records obtained	De-duplicated [or estimate]
Cimbex quadrimaculatus	4	1
Pseudoclavellaria amerinae	2	2
Trichiosoma laterale	19	16
Trichiosoma lucorum	400	289
Trichiosoma pusillum	3	2
Trichiosoma scalesii	29	[19]
Trichiosoma sorbi	94	[59]
Trichiosoma tibiale	138	88
Trichiosoma vitellina	46	32
Corynis crassicornis	1	1
Corynis obscura	4	1
Diprion pini	311	[195]
Diprion similis	93	[59]
Gilpinia frutetorum	42	29
Gilpinia hercyniae	80	44
Gilpinia pallida	41	32
Gilpinia virens	9	8
Microdiprion pallipes	24	15
Neodiprion sertifer	165	[104]
Monoctenus juniperi	40	31
Heptamelus dahlbomi	15	10
Heptamelus ochroleucus	108	81
Xiphydria camelus	318	[199]
Xiphydria longicollis	44	23
Xiphydria prolongata	186	[117]
Sirex areolatus	6	3
Sirex atricornis	0	0
Sirex juvencus	192	[120]
Sirex noctilio	171	[107]
Sirex torvus	109	66
Tremex columba	2	4
Tremex fuscicornis	1	1
Urocerus albicornis	4	4
Urocerus augur	19	6
Urocerus californicus	2	2
Urocerus fantoma	3	2
Urocerus flavicornis	1	1
Urocerus gigas	3022	[1889]
Xeris pallicoxae	4	6
Xeris spectrum	28	1
Calameuta filiformis	625	[391]
Calameuta pallipes	1076	[673]
Cephus nigrinus	229	[144]
Cephus pygmeus	1418	[887]
Cephus spinipes	1397	[874]
Trachelus tabidus	75	66
Trachelus troglodytus	15	11
Janus compressus	3	3
Janus cynosbati	93	[59]
Janus luteipes	35	25
Phylloecus faunus	1	1
Phylloecus linearis	223	[140]
Phylloecus niger	47	37
Phylloecus xanthostoma	196	[123]
Orussus abietinus	6	4

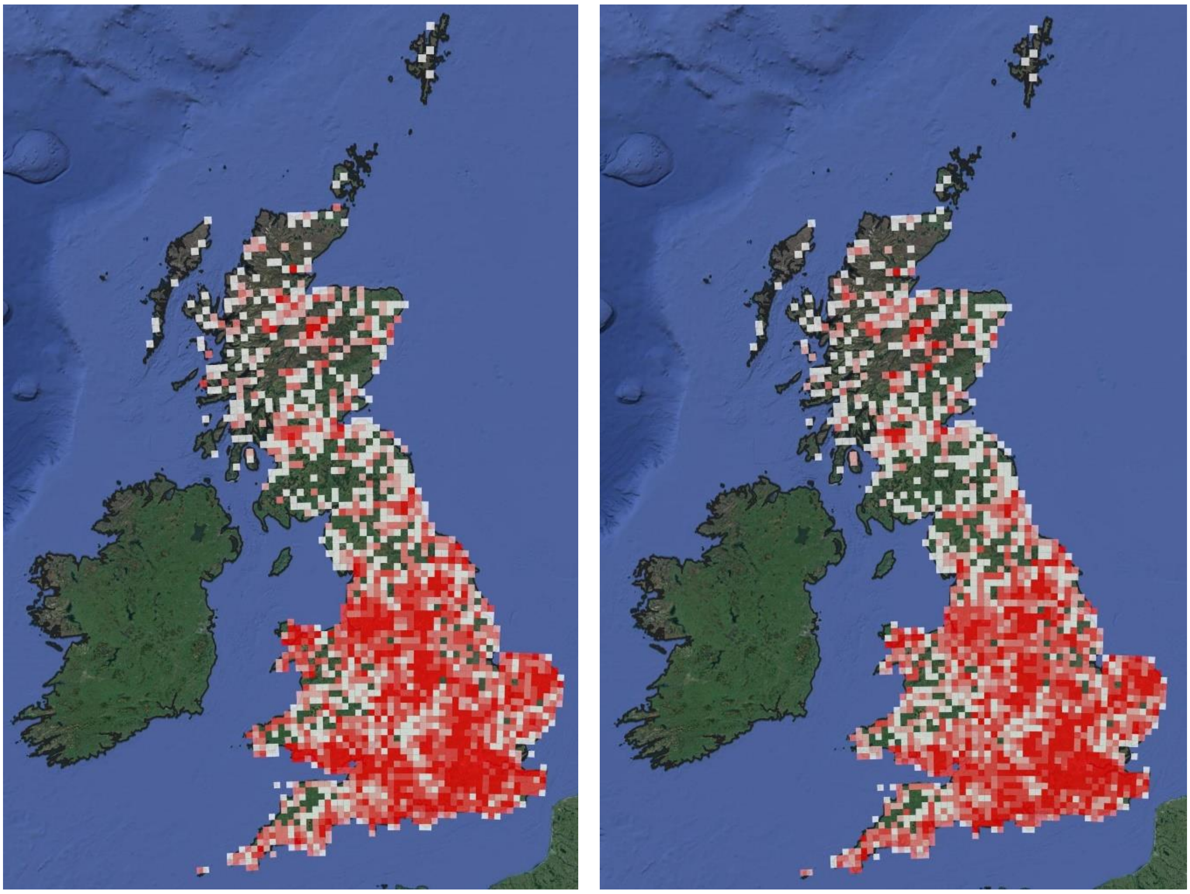
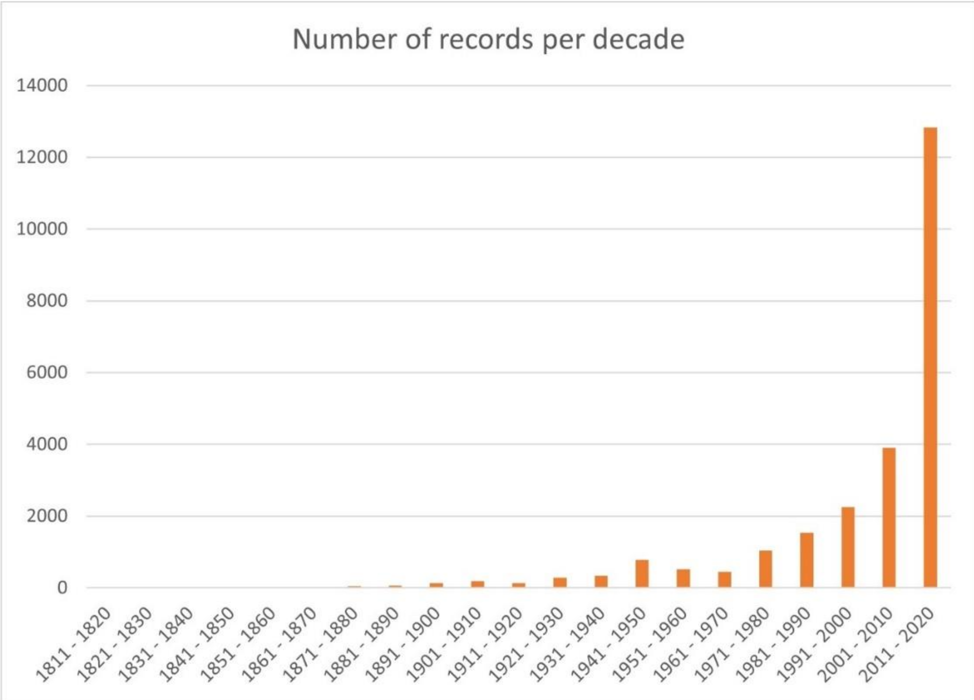


Figure 2: Number of records (left) and species (right) of non-Tenthredinidae sawflies per 10 km square



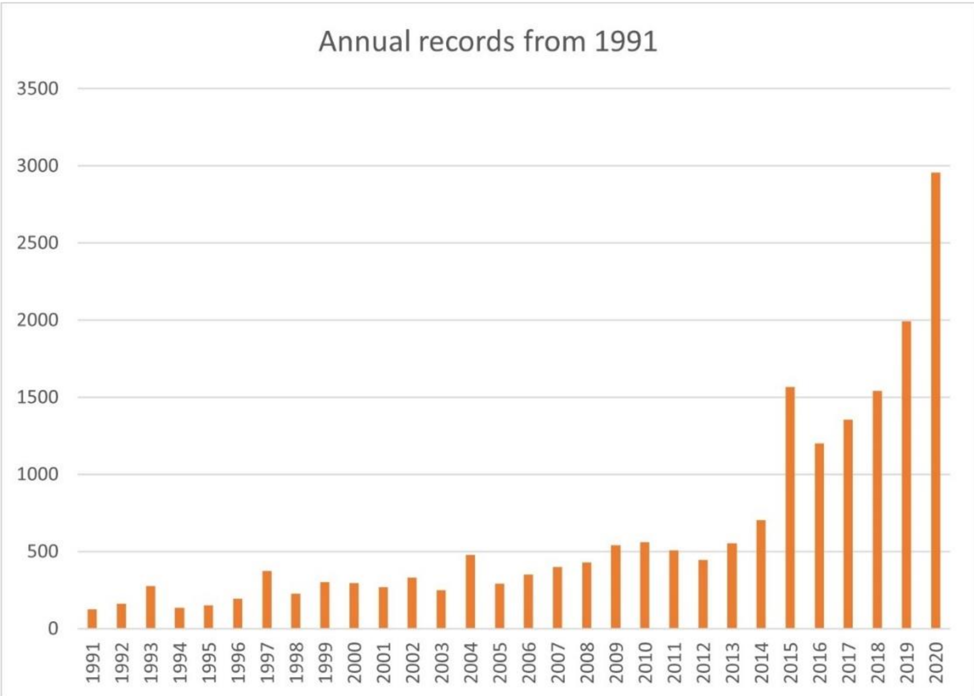


Figure 3: Numbers of records of non-Tenthredinidae sawflies per decade and year

3.3 IUCN Red List Status

The data table accompanying this report sets out the IUCN Red List Status for each species, along with the qualifying criteria, associated metrics and a commentary providing a rationale in support of the categorisation..

Table 2 summarises the number of species assigned each IUCN Red List Status following the assessment:

IUCN Red List Status	No. of species
Least Concern	51
Near Threatened	8
Vulnerable	6
Endangered	3
Critically Endangered	3
Regionally Extinct	6
Data Deficient	16
Not Applicable	18
Total	**111**

3.4. GB Rarity Status

The data table accompanying this report sets out the GB Rarity Status for each species, along with raw and estimated numbers of post-1990 hectads on which the statuses were based.

Table 3 summarises the number of species assigned each GB Rarity Status following the assessment:

GB Rarity Status (final)	No. of species
None	47
Not adjusted	[17]
Upgraded from NS	[26]
Upgraded from NR	[4]
Nationally Scarce	11
Not adjusted	[1]
Upgraded from NR	[10]
Nationally Rare	24
Extinct	6
Unclear	8
n/a	15
Total	**111**

4 Discussion

This first ever published review of the status of (some) British sawflies has revealed a group comprised of species experiencing widely differing fortunes. Of those species with sufficiently robust data to undertake a full assessment (i.e. not Data Deficient or Not Applicable), two-thirds were classed as being of Least Concern, including some readily detectable common species (within their individual ranges), such as *Arge pagana* (on garden roses), *Cephus pygmeus* (around wheat fields) and the recent colonist *Aproceros leucopoda* (on hedgerow elms). Many of the species assessed as being of Least Concern, however, are relatively unobtrusive insects about which there is still much to learn.

The other one-third of the fully-assessed species were deemed either threatened (Vulnerable, Endangered, Critically Endangered), Near Threatened or considered to be actually Regionally Extinct. The proportion of threatened species is comparatively high compared to most other groups of invertebrates, although more in line with the average level of threat across all taxonomic groups assessed to date (A. Brown pers. comm.); it should be noted, however, that direct comparisons are challenging due to different reviews having different evidence-bases to work from. The proportion of apparently extinct species is also comparatively high; this may be related to the group being relatively under-recorded and it is not implausible that some of these species may still be present at very low densities; targeted surveys could help reveal the true status of some of these species. Three of the six Regionally Extinct species were from the family Cephidae, with the most striking case being that of *Trachelus tabidus*, which Benson (1951) describes as 'common in the fens' and says the larvae are a 'well-known pest of wheat, barley, rye and various wild grasses', but despite this there have been no documented records since 1959. For an apparently common species to disappear from the British countryside, apparently unnoticed until now, says a lot about the relative lack of attention paid to sawflies (and many other less well-known insect groups) by naturalists and conservationists to date. Conversely, the relative lack of attention to sawflies does mean that it is plausible that some of these species assessed as Regionally Extinct could well be rediscovered with additional attention and effort. Considering the 12 species assessed as Vulnerable, Endangered and Critically Endangered, there is no obvious narrative linking them. Many are species with relatively few records overall, but a few (*Xyela julii, Pamphilius balteatus*) have more extensive datasets.

The 18 species for which the status Not Applicable was deemed appropriate was a relatively large proportion of the total (16%). In part this was because the opportunity was taken to document fully the evidence (or otherwise) relating to a number of more dubious species which were claimed to have occurred in the past and hence whose names remain in checklists or other references. Additionally, a good deal of thought was given to the issue of native *vs* non-native status in the current review. The associations of sawflies with their food-plants is often (although not always) well-understood, and whilst our knowledge of sawflies may sometimes be limited, there is a lot known about the occurrence of different plant species in Britain, which can then feed into consideration of the origins of the species that feed on them. However, we very often do not know the means of arrival of an invertebrate into Britain, although we may be able to make some guesses. As a result, it is perhaps worth questioning whether an overly purist approach to native *vs* non-native status is all that helpful. Moreover, even if a species has been clearly introduced (even if deliberately), it does not seem clear that this would affect an assessment of its risk of regional extinction; so long as ‘extinction’ is viewed dispassionately as a neutral descriptive term (i.e. the complete loss to zero remaining individuals). ‘Extinction’ does not have to be a value-loaded term, and we may not consider that it ‘matters’ greatly if a non-native species is regionally threatened with extinction (e.g. if the spruce-feeding *Gilpinia hercyniae* were to disappear entirely from British conifer plantations). The IUCN guidelines repeatedly make clear that IUCN categorisation is not the same as the setting of conservation priorities. However, any subsequent reintroduction of a Regionally Extinct species (were such ever contemplated) would clearly wish to give due regard to whether that species had initially been native or not.

A total of 16 species were assessed as being too Data Deficient to be able to categorise them otherwise. This is a relatively high proportion of the total, but every effort was made to find suitable metrics on which to make a defensible assessment. Whilst data deficiency might be expected with a relatively little-studied group of insects, in many cases the deficiency relates more to a lack of taxonomic clarity than to data volumes. When taxonomic viewpoints change over time this can make it difficult or impossible to interpret which modern taxon concept to assign an old record to. Within the sawfly families covered by this review, the genus *Trichiosoma* stands out as the most significant area of taxonomic uncertainty, with little to no consensus on where species limits should be defined. Otherwise, a few species were defined as Data Deficient based on extremely low numbers of records, which could be remedied through greater (ideally targeted) recording efforts in future.

The datasets obtained for the review displayed a number of biases. However, neither spatial nor temporal biases are unusual for invertebrate recording. Making use of Extent of Occurrence (EOO) as a measure of range, both absolute and relative, does to some extent deal with this issue. However, when datasets become very small, they can be prone to being strongly affected by individual records. Indeed, the calculation of EOO based on concave 'alpha' hulls is often impossible mathematically for small datasets. This could perhaps point to the potential for a recommendation over minimum numbers of records that need to exist before some of the assessments should take place; or else to consider the use of convex hulls as a fall-back solution where concave hulls cannot be constructed.

Temporal biases are also not unusual, and again the IUCN criteria do mitigate against them to some degree. However, recent increases in numbers of records have been (relatively) spectacular and one has to consider what effect this may have had on the assessments. It seems quite plausible that moderate-level declines could be masked by the increase in recording effort, particularly if such a decline were geographically fairly evenly spread, as that would affect Area of Occupancy (AOO) assessments (range contractions on the other hand would be picked up by EOO calculations). Hence it might be considered that the overall level of threat detected by this review process should be considered a minimum. One option might be to look into a metric to describe changes in records of a species as a proportion of total records.

Moreover, there is little opportunity for recognising historical decline. Whilst this may not be strictly necessary for assessing extinction risk, a consideration of older data can certainly bring important context and during this review, older records were found to be instructive in consideration of the Not Applicable category, the patterns of occurrence of recent taxonomic splits, and questions over when/whether a species should be considered to be Regionally Extinct. Having said that, the volume of (and biases in) older data are often such that their use for any standardised metric would be impractical. The sparsity of older records would be remedied somewhat, however, if museums were able to digitise the data behind their important collections.

Priorities for further work are suggested to be as follows:

- Undertake equivalent review of the family Tenthredinidae, albeit recognising that similar issues exist regarding low data volumes and taxonomic uncertainty for some groups (many Nematinae, *Empria,* etc.)
- Complete the de-duplication of the combined dataset and establish clear permissions with all data providers surrounding the onwards use of the data, with the aim of establishing a national Sawfly Recording Scheme.
- Encourage targeted fieldwork to clarify the status of some particularly data-poor species, with a particular focus on Caledonian pine-forest specialities.
- Encourage work to clarify the status of *Trichiosoma* and other difficult taxonomic issues.
- Encourage the production of electronic catalogues of museum collections of British sawflies.
- Encourage similar regional IUCN reviews in other parts of Europe, helping generate wider context to understand the international significance (if any) of populations of sawflies in Britain.

5 References

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Appendix 1: How to generate alpha hulls and associated area measurements in QGIS

Whilst the use of a ***convex*** hull is recommended for generating an Extent of Occurrence (EOO) across time, the IUCN Red List Guidelines (IUCN 2019, p50) make clear that ***concave*** hulls are more suitable as a method for comparing two or more temporal estimates of EOO for assessing reductions or continuing declines. This is essentially because if outliers are detected at one time and not another, this could result in erroneous inferences about reductions or increases.

Alpha hulls are a particular defined type of concave hull which depend upon a single parameter (alpha) that effectively defines the degree of concavity and the sensitivity to outliers. Their calculation is more complex than convex hulls. At present, convex hulls can be generated entirely within a MySQL database. However, at the time of writing, MySQL did not allow the generation of alpha hulls, and hence data was exported for analysis within the open-source QGIS application. The process to do so was somewhat complex to work out, but eventually proved efficient and effective. Hence it was felt that making a record of this process could be useful to other users in future.

The notes below refer to QGIS desktop version 3.16.10; clearly, other versions may introduce changes that necessitate departures from the following instructions.

Initial dataset

A file 'taxon_period_grids.csv' was created from the underlying database that had just two columns, as follows…

taxon_period	pseudotetrad
Abia aenea_06_20	TQ37Y
Abia aenea_06_20	TQ37T
Abia aenea_06_20	TQ18D

etc. The file was about 20,000 rows long.

For every combination of taxon and time period (e.g. 2006 to 2020) a list of 'pseudotetrads' was generated, these being equivalent to tetrads (2 km squares) except where a record only had a grid reference of 10 km resolution, in which cases the central tetrad (i.e. tetrad 'M') of that 10 km square was used. About 10% of the dataset (particularly older records) related to such 10 km resolution sites. Whilst using a pseudotetrad would seldom be justified in terms of fine-scale consideration of the record, it was deemed perfectly adequate for the calculation of range measures (both EOO and AOO) at a county-wide scale, particularly when set against the alternative of simply not using 10% of the dataset.

Importantly, this file should exclude taxon_period combinations that have fewer than three pseudotetrads; these cannot lead to a polygon and will cause problems later.

Creation of dot maps

Within QGIS, dot maps were created using the FSC plugin, which can be found via the plugin manager. The FSC plugin for QGIS version 3 is described at https://www.fscbiodiversity.uk/fsc-plugin-qgis-v3

Using this plugin, select the 'Biological Records Tool'.

On the 'data specification' tab

- specify the csv file as described above.
- Set the OS grid ref column to be the pseudotetrad field
- Set the taxon column to be the taxon_period field
- Set the output CRS to be British National Grid (EPSG 27700) in order to get areas in m^2
- Select 'Records as Points' on the Type of Map drop down (at the bottom in the middle)

On the 'taxa' tab

- Select 'check all'

On the 'options' tab

- Select 'Batch map mode' (drop-down at the top)

Then click the 'create map layer' button at the bottom left.

This creates a separate map layer for each combination of taxon and period. It takes less than a minute to run on my dataset of 20,000 rows (comprising all available subsets of data for 110 species and five different time periods).

Creation of the alpha hulls

From the Processing menu, select Toolbox, then Vector Geometry, then pick 'Concave hull (alpha shapes)'.

Select to run as batch process (button at bottom left).

Under Input point layer,

- Click the down arrow next to Autofill,
- 'Select from open layers'
- 'Select all'. Note that it can take a few minutes at this point before the layers appear in the window, be patient.

When there is a list of layers, then under Threshold,

- Change the value in the top row to 0.5
- Then Autofill arrow
- Fill down – all rows should change to same value

Likewise, under Allow holes, choose No, and then Autofill, Fill Down.

Under Concave Hull, you get to create the output files.

- On the top row, click the three dots, then select/create a directory to put the files into (if you end up doing all this multiple times, it's sensible to put them into different directories)
- Then for Autofill mode, pick Fill with parameter values
- For Parameter to use, leave it on Input point layer

Finally, don't tick to 'load the layers on completion' (bottom left) as that makes it slow and is unnecessary.

Then click Run. It takes a couple of minutes to run through them all.

Note that the process will fail for some combinations.

As mentioned earlier, there should be no taxon/period combinations with fewer than three pseudotetrads involved; if there are, you will get problems at this point. Furthermore though, a minority of other combinations will also fail to create alpha hulls, and the processing tool will create empty layers for these. This is due to the way an alpha hull is constructed by removing a variable number of existing internal lines (see IUCN 2019, p50), depending on the shape. For combinations with a small number of vertices, the removal of some of the lines could result in fewer than three vertices remaining, and hence it not being possible to create a polygon. This issue disappears rapidly once you have more than a handful of points per combination.

<u>Merge the alpha hulls into a single layer</u>

It is useful at this point to highlight all of the TEMP layers on the Layers list and Remove them all.

From the Processing menu, select Toolbox, then Vector General, then pick 'Merge vector layers'.

In this case, do not run as a batch process (i.e. don't click the button bottom left).

Input layers, click three dots, select Add Files, navigate to where you just created the files, and select all of those, then OK.

Do have the tick against 'Open File after running algorithm'.

Run. This takes less than 10 seconds, and you end up with a set of superimposed jagged shapes on your map in a single layer called 'Merged'.

<u>Calculate an area for each alpha hull</u>

You first need to remove a set of 'empty shapes'

- Right-click on the layer called Merged and Open Attribute Table.
- Toggle editing mode on (pencil icon, top left)
- Click on the header 'pseudotetrad' – this will sort the table to put those with null pseudotetrads at the top. (If you don't have any, then fine, toggle the pencil icon off again and close this table).
- Click on the '1' at the left of the top row to highlight this row. Scroll down until you find the last row with null pseudotetrads, hold Shift down and click the number at the left-hand side of the row. This should highlight all the null rows. Then click the red bin icon at the top (Delete selected features) to get rid of these rows. Click the pencil icon again to toggle editing off, agree to Save the changes, then close this window.

From the Processing menu, select Toolbox, then Vector Geometry, then pick 'Add geometry attributes'

Make sure 'Merged' is selected as the Input layer.

Do have the tick against 'Open output file after running algorithm'

Don't 'Run as batch process'

Click Run. This should work instantly.

<u>Pull the information out of QGIS ready to load back into your database</u>

You now have a new layer called 'Added geom info'

Right click on this, Open Attribute Table, click at the top left to highlight the whole table, Ctrl+C to copy.

Open a new blank spreadsheet and Paste Values.

Delete all columns except for layer and area

Change area by dividing by a million to get from m^2 to km^2

For the layer column, use Find/Replace to remove the prefix to leave you with something like 'Xyela julii_91_05'. Use standard Excel functions to split this into a period and taxon (e.g. you'll want something like

- =right(a2,5)
- =left(a2,len(a2)-6)

Add a field at the right-hand side called 'dummy' and give it a value of x for every row.

- This may not be necessary but it helped me deal with an issue that was encountered with importing a hidden paragraph mark back into the database.

So you should end up with a table with only the fields area, period, taxon, dummy in that order, e.g.

area	period	taxon	dummy
96846	91_05	Xyela julii	x
45822	06_20	Xyela julii	x
14870	11_20	Xyela julii	x
104670	91_00	Xyela julii	x
1258	91_00	Xiphydria prolongata	x
4590	91_05	Xiphydria prolongata	x

etc.

Save this as csv and then import back into your database to make use of where you need EOO measurements based on alpha hulls for given time periods.

<u>Finally</u>

It was found that one invariably needed to crash out of QGIS in the end as the processes didn't seem to want to stop - use Task Manager for this (Ctrl+Alt+Del).