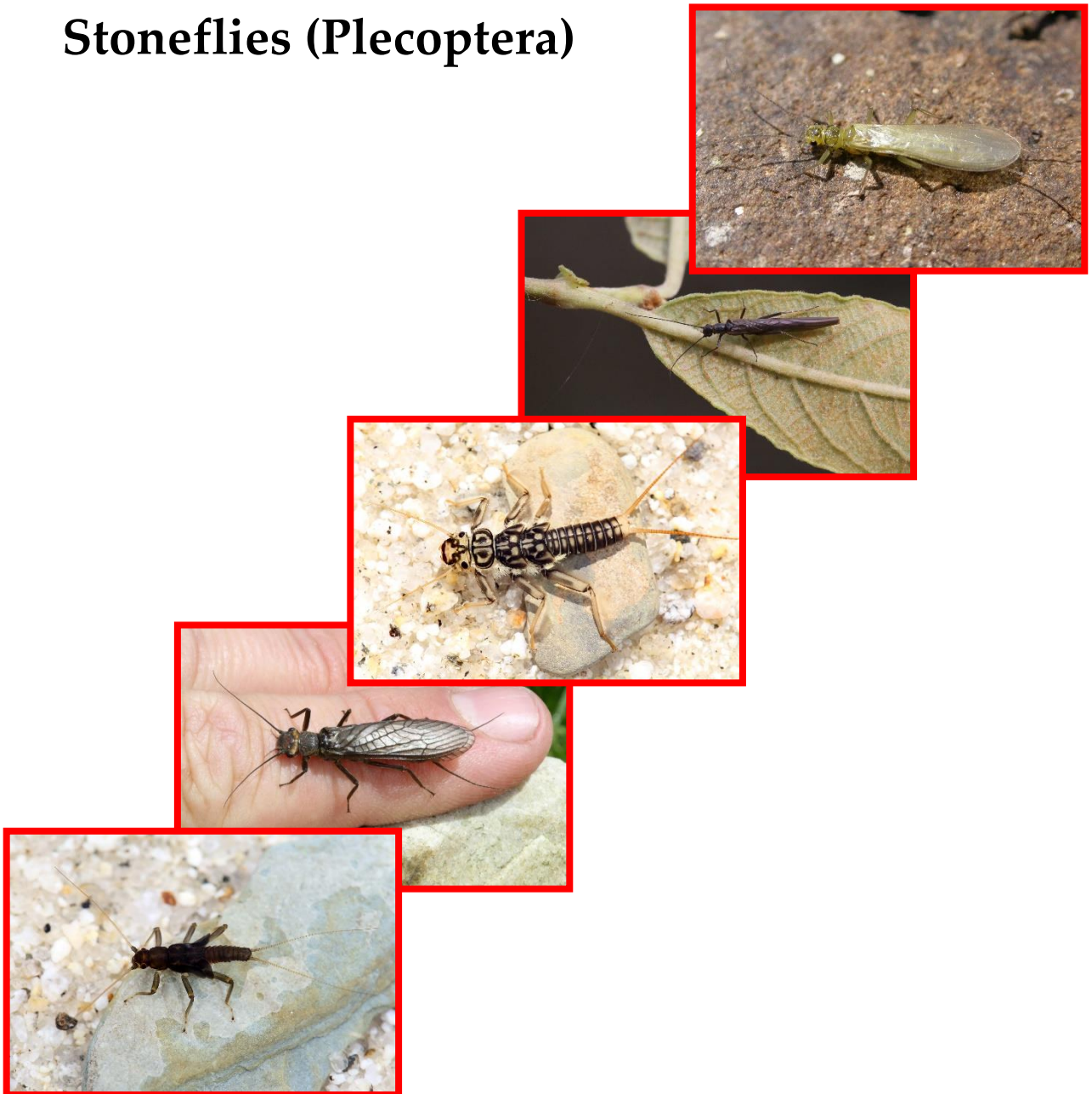


Ireland

Red List No. 13



Stoneflies (Plecoptera)



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Ireland Red List No. 13

Stoneflies (Plecoptera)

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Cover photos: From top: *Siphonoperla torrentium*, *Leuctra fusca*, *Perla bipunctata*, *Dinocras cephalotes* and *Nemoura cinerea*. All photos Jan-Robert Baars.

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CONTENTS

EXECUTIVE SUMMARY	i
ACKNOWLEDGEMENTS	ii
1 INTRODUCTION.....	3
1.1 Recording of stoneflies in Ireland	3
1.2 Legal protection.....	4
2 DEVELOPMENT OF THE RED LIST	5
2.1 Methodology used.....	5
2.2 Nomenclature and checklist	5
2.3 Data sources.....	5
2.4 Regionally determined settings	6
3 RED LIST OF IRISH STONEFLIES (PLECOPTERA)	8
3.1 Summary of evaluations.....	8
3.2 Species notes.....	9
<i>Amphinemura sulcicollis</i> (Stephens, 1836)	9
<i>Brachyptera risi</i> (Morton, 1896)	9
<i>Capnia atra</i> Morton, 1896.....	9
<i>Chloroperla tripunctata</i> (Scopoli, 1763)	9
<i>Dinocras cephalotes</i> (Curtis, 1827)	9
<i>Diura bicaudata</i> (Linnaeus, 1758).....	9
<i>Isoperla grammatica</i> (Poda, 1761)	10
<i>Leuctra fusca</i> (Linnaeus, 1758)	10
<i>Leuctra hippopus</i> Kempny, 1899.....	10
<i>Leuctra inermis</i> Kempny, 1899	10
<i>Leuctra nigra</i> (Olivier, 1811).....	10
<i>Nemoura avicularis</i> Morton, 1894.....	10
<i>Nemoura cinerea</i> (Retzius, 1783).....	10
<i>Nemurella pictetii</i> (Klapálek, 1900)	10
<i>Perla bipunctata</i> Pictet, 1833	11
<i>Perlodes mortoni</i> (Klapálek, 1906)	11
<i>Protonemura meyeri</i> (Pictet, 1841)	11
<i>Protonemura praecox</i> (Morton, 1894)	11
<i>Siphonoperla torrentium</i> (Pictet, 1841).....	11
<i>Zwickyia bifrons</i> (Newman, 1838).....	11
4 RECORDS, THREATS AND CONCLUSIONS.....	12
5 REFERENCES	14
APPENDIX 1.....	15
APPENDIX 2.....	16

EXECUTIVE SUMMARY

Based on just over 12,000 records for the island of Ireland, the 20 species of stonefly (Plecoptera) on the Irish check list were evaluated against the Red List criteria produced by the International Union for the Conservation of Nature (IUCN). This is the first time the threat status of the Irish Plecoptera has been assessed.

Two species are deemed under threat of extinction. *Protonemura praecox*, was assessed as Critically Endangered and *Capnia atra* as Vulnerable. A third species, *Perlodes mortoni*, was deemed Regionally Extinct in Ireland as it has not been recorded for over 100 years. The remaining 17 species were all evaluated as Least Concern. The records used in this assessment cover the period 1890 to 2018 and have largely been derived from collections of nymphs, although many adult records are included.

The threat status of two Red Listed species quite likely reflects increasing average temperatures associated with climate change. Other species confined to higher altitudes may become threatened in the near future as temperatures continue to rise. The threats that climate change, continuing organic pollution, habitat change and sedimentation pose to the Plecoptera in Ireland should not be underestimated, with most species highly susceptible to one or more of these pressures. Habitat destruction and hydromorphological change (e.g. flood protection schemes) are likely to have had a significant influence on the present distribution of the Irish stoneflies and the impact of these pose continuing and significant threats.

Lastly, the future recording of Plecoptera, and other aquatic insects, to species level must remain a priority. Reliable data are a pre-requisite for Red List assessments and atlases. However, it is of concern that fewer freshwater studies and surveys are producing species-level data. Unless this deficit is addressed, our ability to assess and understand trends in species distributions, and of Ireland's freshwater biodiversity, will be much diminished.

ACKNOWLEDGEMENTS

The authors wish to thank all those who have contributed stonefly records in Ireland. We also would like to thank Craig Macadam (Buglife, UK) who acted as external reviewer and freely shared his knowledge and experience of the group. Áine O Connor (NPWS) is also thanked for thoroughly proof reading and improving the layout of this Red List.

1 INTRODUCTION

The Plecoptera (from the Greek, "pleated wing"), commonly known as stoneflies, is an ancient order of insects originating at least 250 million years ago. The terms Plecoptera and stonefly are used interchangeably in this Red List. Globally there are approximately 3,500 recognised species of stonefly and approximately 570 known from Europe. There are verified records of 20 species from Ireland (Costello, 1988; Ashe *et al.*, 1998; O'Connor & Nelson, 2012; Feeley *et al.*, 2016).

Stoneflies are one of the hemimetabolous insect Orders, meaning they have no pupal stage, instead the adult emerges directly from the final nymphal skin. The nymphs of all Irish species of stonefly are aquatic and all of the growth and most of the development happens during this immature stage. Nymphal development lasts from a few months to over three years depending on the species and environmental conditions experienced. The adults of most species are winged and live out of the water, their life span averaging from a few days to months. Most adults feed on pollen grains and other material but some species do not feed at all during the adult stage and reproductive success is therefore largely determined by the conditions experienced by the aquatic nymphal stages.

The nymphs of all European Plecoptera species live in freshwater especially in cool, well-oxygenated waters. In Ireland, stoneflies form a large proportion of the invertebrate fauna in headwater streams, clean well-oxygenated upper and middle sections of rivers, and wave-washed lake shores. The aquatic nymphs are often particularly sensitive to elevated organic pollution and, owing to their high oxygen requirement, they are one of the first groups to disappear when organic pollution occurs in rivers and lakes. In contrast, many stoneflies are acid-tolerant, and diverse populations can dominate in naturally acidic streams draining peat and peaty soils, and in heavily conifer afforested upland streams. Many of our stonefly species can also survive high concentrations of heavy metal pollution with healthy, abundant and diverse populations often associated with waterbodies draining former mines.

The Irish species are not entirely restricted to these turbulent habitats. Some occur in seepages, springs and marshes amongst *Sphagnum* mosses or packed leaf litter and some can very occasionally be found in other waterways such as canals, large slow flowing rivers and ephemeral streams draining turloughs. Nymphs, depending on age and size, feed on biofilms, dead plant material or are predators and some go through a shift in their diet as they mature. Consequently, stoneflies are important species in nutrient flows and recycling in riverine systems. Under natural conditions, Plecoptera constitute a significant proportion of the biomass in streams and rivers and are an important part of the diet of fish in aquatic food-chains as well as terrestrial invertebrates (e.g. spiders) and vertebrates (e.g. bird and bat species) during adult flight periods.

1.1 Recording of stoneflies in Ireland

Amongst fishermen, stoneflies are well-known and have attracted common and local names. Examples include *Brachyptera risi* Morton which is known as the February Red and *Protonemura meyeri* (Pictet) which is the Early Brown or Winter Brown. Stoneflies of the family Leuctridae are commonly known as needle-flies, the two Irish species of Perlidae are known as Large Stonefly, while *Isoperla grammatica* (Poda) is known variously as a Yellow Sally or Old Joan. Despite the cultural significance of these aquatic insects to anglers (see Macadam & Stockan 2015 for more information), the local names they have been given are not completely aligned with the species recognised by taxonomists and more likely represent a taxonomic resolution higher than species (i.e. genus or even family level). The considerable knowledge of these aquatic insects held by anglers cannot therefore be transferred easily into distribution and ecological studies.

The Plecoptera is a group used extensively in biological river quality monitoring. While, historically, species-level data were not required for assessment methodologies, there have been recent efforts by the Environmental Protection Agency (EPA) in the Republic of Ireland to improve taxonomic resolution in both lake and river assessments. In addition, the EPA has been investigating the potential adoption of new ecological quality indices which has led to an increase in the availability of species level data.

As most of the Irish stoneflies live in running water the main method of sampling and recording is by kick sampling of river sediments and the retrieval of nymphs. Adults are predominantly found in spring and summer, except for *Leuctra fusca* (Linnaeus) which is present in late summer, autumn and sometimes early winter. Depending on the species, adults are usually found close to the breeding habitat amongst wet bankside stones, on marginal vegetation and trees, or on structures such as fence posts and bridges.

The major work on Irish stonefly distribution is the Atlas published in 2016 (Feeley *et al.*, 2016) and includes a comprehensive compilation of records from the island of Ireland. This built on some earlier works. Costello (1988) reviewed the Irish fauna (then 19 species) providing a general picture of the national range of each species. The presence of *Leuctra nigra* (Oliver) in Irish waters was confirmed by O'Connor & Costello (1997); many earlier reports of this species were tentative. Baars & Kelly-Quinn (2006) compiled distributional data and examined the biogeography of each species in relation to a selection of known physico-chemical parameters.

Lastly, the future recording of Plecoptera, and other aquatic insects, to species level must remain a priority. Reliable data are a pre-requisite for Red List assessments and atlases. However, it is of concern that fewer and fewer freshwater studies and surveys are producing species-level data. Unless this deficit is addressed, our ability to assess and understand trends in species distributions, and Ireland's river and lake biodiversity in general, will be much diminished. Future developments in DNA work and meta-barcoding technologies may aid the recording of stonefly species in Ireland but in the interim identification of species will still rely on expert validation of specimens. Training of recorders and verifiers is needed to address this skill shortage. Similarly, we need to address the knowledge gaps on the autecological requirements for most of our species, owing to the lack of Irish-specific research.

1.2 Legal protection

At the time of publication, no stonefly species are legally protected in Ireland or Northern Ireland.

2 DEVELOPMENT OF THE RED LIST

2.1 Methodology used

This Red List is part of the series of regional Red Lists for the island of Ireland being produced by the National Parks and Wildlife Service and the Northern Ireland Environment Agency in conjunction with the National Biodiversity Data Centre and the Northern Ireland biological records centre, CEDaR. The International Union for the Conservation of Nature (IUCN) provides guidelines for using the Red List categories at a regional level (IUCN, 2012). This guidance was used alongside the current IUCN categories and criteria (IUCN 2019; see Figure 1 and Appendix 1) in the production of this Red List.

Drafting of the Red List was commenced in September 2019 and the Red List assessment was finalised at a meeting of the authors in November 2019. The final draft of the Red List was circulated in December 2019.

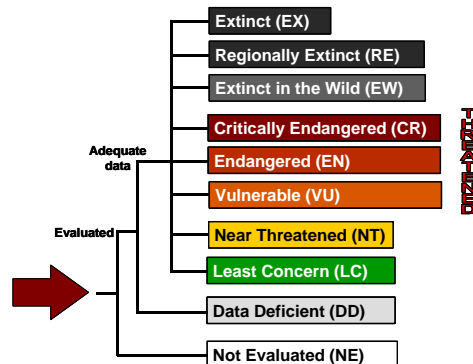


Figure 1 The Red List categories used for the purposes of this assessment. Further details and definitions for these categories and the criteria for achieving them are available in IUCN (2012, 2019) and Appendix 1.

2.2 Nomenclature and checklist

The most recent Irish checklist was produced by Feeley *et al.* (2016) and this updates earlier checklists in Costello (1988), Ashe *et al.* (1998) and O'Connor & Nelson (2012). There are 20 species of Plecoptera with validated records from Ireland, though the precise identity of one species is uncertain (see *Perlodes mortoni* below). Several other species have been included in publications but the records are not considered valid (see O'Connor & Nelson, 2012). The nomenclature in Feeley *et al.* (2016) is followed here with the exception of *Capnia bifrons* which is now placed in the genus *Zwicknia* (Murányi *et al.*, 2014). Species are listed alphabetically in the tables and species accounts. All 20 species of Irish Plecoptera were assessed for this Red List.

2.3 Data sources

The principal data source was the database created for the Stonefly Atlas (Feeley *et al.*, 2016). This included records up to 2012 and a summary of the source material used in the Atlas is provided in Feeley *et al.* (2016). The Atlas database has been maintained and updated with records collated and verified by HF. Approximately 2,000 additional records have been added. Species data from both Northern Ireland and the Republic of Ireland were included in line with the standard

practice for other all-Ireland regional Red Lists. The Irish Stonefly database is available online from the National Biodiversity Data Centre (NBDC) and an archive copy of the database used for this Red List assessment is held by National Parks and Wildlife Service.

2.4 Regionally determined settings

The timeframe for assessing change for this Red List was set as before 1 January 2000 and on and after 1 January 2000 to 31 December 2018. This split was considered the best in balancing even geographic and temporal coverage across the island. A split based on the median record in 2006 was examined and rejected as there are few species records from Northern Ireland in the database from 2006 onwards. There is therefore a bias in the database towards more recent records and as a result past change in distribution, particularly in lowland agricultural landscapes in central Ireland may not be apparent. Figure 2 shows the recording effort for Irish Plecoptera over time, Figure 3 shows the geographical coverage indicated by the occupied hectads in each time period and Table 1 provides summary statistics for the Irish database.

The IUCN guidelines (IUCN 2012) allow for uplisting or downlisting based on whether or not extra-regional populations influence the extinction risk of the regional population. This was not applicable to the Irish stoneflies as there is no evidence of immigration of species. Appendix 2 provides a summary of species of Irish stonefly (Plecoptera) that have some form of Red List status in other European countries.

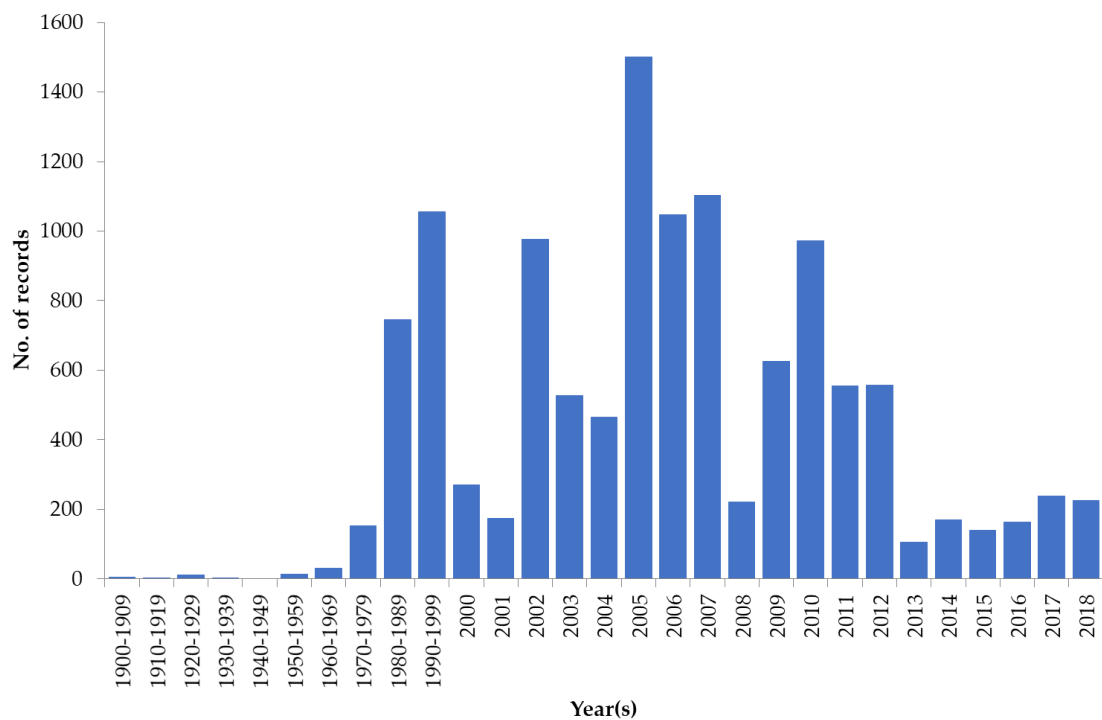


Figure 2 Number of Irish stonefly (Plecoptera) records for each decade from 1900 to 1999 and annually from 2000 to 2018.

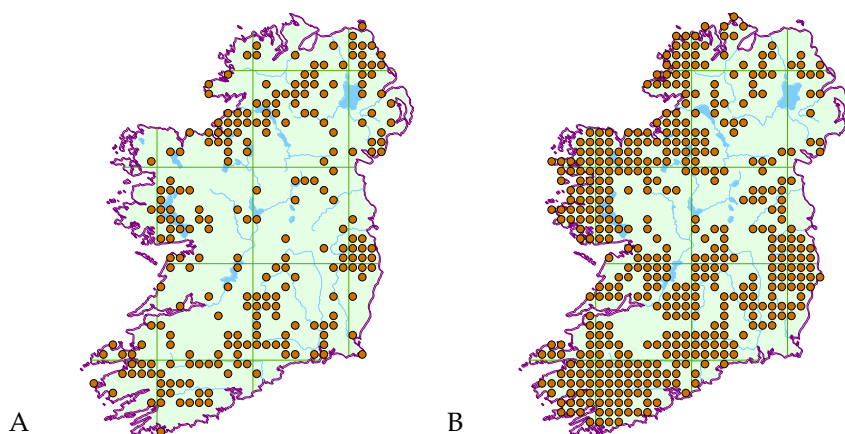


Figure 3 Coverage maps of records of Irish stoneflies (Plecoptera) showing, A, all the hectads with at least one validated record before 1 January 2000 (240) and, B, all the hectads with records on and after 1 January 2000 (463).

Table 1 Summary statistics of the Irish stonefly (Plecoptera) database showing the number of validated records and the number of occupied hectads in each of the two time periods used in this assessment.

Species	Validated records before 1/1/2000	Validated records on or after 1/1/2000	Hectads before 1/1/2000	Occupied hectads on or after 1/1/2000
<i>Amphinemura sulcicollis</i> (Stephens)	253	1,193	120	276
<i>Brachyptera risi</i> (Morton)	117	554	65	170
<i>Capnia atra</i> Morton	4	14	3	12
<i>Chloroperla tripunctata</i> (Scopoli)	70	279	41	99
<i>Dinocras cephalotes</i> (Curtis)	12	255	9	87
<i>Diura bicaudata</i> (Linnaeus)	34	213	14	50
<i>Isoperla grammatica</i> (Poda)	287	1,258	133	297
<i>Leuctra fusca</i> (Linnaeus)	77	303	51	154
<i>Leuctra hippopus</i> Kempny	188	719	84	207
<i>Leuctra inermis</i> Kempny	204	1,134	80	224
<i>Leuctra nigra</i> (Olivier)	5	128	5	64
<i>Nemoura avicularis</i> Morton	15	72	12	48
<i>Nemoura cinerea</i> (Retzius)	84	318	59	119
<i>Nemurella pictetii</i> (Klapálek)	40	135	31	60
<i>Perla bipunctata</i> Pictet	84	975	45	211
<i>Perlodes mortoni</i> (Klapálek)	2	0	2	0
<i>Protonemura meyeri</i> (Pictet)	205	1,061	91	248
<i>Protonemura praecox</i> (Morton)	10	0	7	0
<i>Siphonoperla torrentium</i> (Pictet)	299	1,378	127	270
<i>Zwicknia bifrons</i> (Newman)	29	48	21	34
All species	2,019	10,037	240	463

3 RED LIST OF IRISH STONEFLIES (PLECOPTERA)

3.1 Summary of evaluations

Two species were evaluated as under threat of extinction and these constitute the Irish Red List of stoneflies (Table 2). *Protonemura praecox* was assessed as Critically Endangered as there are very few reliable records and the last of these was in 1991. *Capnia atra* was assessed as Vulnerable. It is a northern and upland species in Ireland and is threatened by climate change especially in its few lowland sites in Ireland.

Table 2 Red List status of Irish stoneflies (Plecoptera)

Species	Assessment	Criteria
<i>Protonemura praecox</i> (Morton, 1894)	Critically Endangered	A2c
<i>Capnia atra</i> Morton, 1896	Vulnerable	B2 a b(iii)
<i>Perlodes mortoni</i> (Klapálek, 1906)	Regionally Extinct	
<i>Amphinemura sulcicollis</i> (Stephens, 1836)	Least Concern	
<i>Brachyptera risi</i> (Morton, 1896)	Least Concern	
<i>Chloroperla tripunctata</i> (Scopoli, 1763)	Least Concern	
<i>Dinocras cephalotes</i> (Curtis, 1827)	Least Concern	
<i>Diura bicaudata</i> (Linnaeus, 1758)	Least Concern	
<i>Isoperla grammatica</i> (Poda, 1761)	Least Concern	
<i>Leuctra fusca</i> (Linnaeus, 1758)	Least Concern	
<i>Leuctra hippopus</i> Kempny, 1899	Least Concern	
<i>Leuctra inermis</i> Kempny, 1899	Least Concern	
<i>Leuctra nigra</i> (Olivier, 1811)	Least Concern	
<i>Nemoura avicularis</i> Morton, 1894	Least Concern	
<i>Nemoura cinerea</i> (Retzius, 1783)	Least Concern	
<i>Nemurella pictetii</i> (Klapálek, 1900)	Least Concern	
<i>Perla bipunctata</i> Pictet, 1833	Least Concern	
<i>Protonemura meyeri</i> (Pictet, 1841)	Least Concern	
<i>Siphonoperla torrentium</i> (Pictet, 1841)	Least Concern	
<i>Zwicknia bifrons</i> (Newman, 1838)	Least Concern	

3.2 Species notes

This section gives brief notes on all the assessed species of Irish stonefly. Species are listed alphabetically following the nomenclature of Feeley *et al.* (2016). This should be consulted for distribution maps and detailed species accounts for the 19 extant species of Irish Plecoptera.

***Amphinemura sulcicollis* (Stephens, 1836) Least Concern**

Typically found at high densities amongst leaf-packs and particularly mosses in fast flowing reaches of stony streams and rivers and also lake shores. This widespread species has shown no significant change in status over the assessment period.

***Brachyptera risi* (Morton, 1896) Least Concern**

Common in many parts of the country especially in the east, southwest, northwest but seems to be more restricted in the western counties. Generally, this species can be found at high densities at high altitude, but it will also occur in low elevation sites. Adults emergence happens in late winter in February and early March, especially at low altitude, and this can result in it often being missed in nymphal surveys. There is no evidence of any change in range or abundance over the assessment period.

***Capnia atra* Morton, 1896 Vulnerable B2 a b(iii)**

This is one of the rarest species of stonefly in Ireland occurring in only a few lakes with coarse gravel and cobble shores along the western seaboard. It is known from several locations in Killarney National Park, Co. Kerry, and isolated locations in Counties Cork, Galway, Mayo, Sligo and Donegal. This species has a subarctic distribution and the Irish population is at the southern edge of its range suggesting it may be a glacial relict. The Irish population therefore is likely to be impacted by climate change.

***Chloroperla tripunctata* (Scopoli, 1763) Least Concern**

This has a relatively wide distribution range in Ireland, with the majority of records in the southern half of the island. It is found in stony rivers and streams and can be quite abundant where present. There is no evidence of change in status over the assessment period.

***Dinocras cephalotes* (Curtis, 1827) Least Concern**

This species is restricted to the western half of the island, there being no records from eastern counties apart from Co. Antrim. It is found in only a limited number of fast-flowing rivers with stable substrata and occurs in greater densities at higher elevations and rivers with generally, but not exclusively, more stable and narrow annual temperature ranges. There is no evidence of a decline and the species was assessed as Least Concern.

***Diura bicaudata* (Linnaeus, 1758) Least Concern**

A large stonefly species that occurs mainly in lotic habitats in high altitude (>200 m) upland areas, especially the Wicklow Mountains, where it can be found in very high densities, and with densities often increasing with increasing altitude. It also occurs occasionally in streams and rivers at high altitude or with stable low temperatures (e.g. groundwater springs) along the western seaboard and in both high and low altitude western lakes. Nymphs are found in stretches and shorelines with coarse gravel, cobbles and boulders, but can occur in very small (0.1 m wide) headwater seepages amongst vegetation. Whilst the species is considered localised, the assessment was Least Concern in the absence of any apparent decline.

***Isoperla grammatica* (Poda, 1761)**

Least Concern

This is a common and widespread species in Ireland, present in many types of rivers, although usually found at lower abundance above 200 m especially outside Co. Wicklow. There is no evidence of a decline and the species was assessed as Least Concern.

***Leuctra fusca* (Linnaeus, 1758)**

Least Concern

Common and widespread found in rivers and exposed lake shores during summer months. The species is tolerant of a wide range of water chemistry. Adults of this species differ being present in late summer, autumn and sometimes early winter. There is no evidence of any change in status over the assessment period and *L. fusca* was assessed as Least Concern.

***Leuctra hippopus* Kempny, 1899**

Least Concern

Common and widespread found in rivers and exposed lake shores. It is largely tolerant of acidic conditions and may form a large component of riffle communities in acid-sensitive streams and rivers but is common and abundant in most streams and rivers island-wide. There is no evidence of any change in status over the assessment period and the species was assessed as Least Concern.

***Leuctra inermis* Kempny, 1899**

Least Concern

This species has a widespread distribution in flowing waters and on wave-washed shores on stony substrata with detritus. This species is common and abundant in most streams and rivers, tolerating both basic and acidic conditions. There is no evidence of any change in status over the assessment period and the species is assessed as Least Concern.

***Leuctra nigra* (Olivier, 1811)**

Least Concern

Mainly restricted to the north and west of Ireland, this is a stream species often found in low altitude headwaters and low gradient peaty catchments. This species is restricted to sites with dense riparian cover in the south and east. However, there is no evidence of any change in status over the assessment period and the species was assessed as Least Concern.

***Nemoura avicularis* Morton, 1894**

Least Concern

This stonefly is recorded from lakes, rivers and streams and is generally scarce in Ireland typically found at low densities. The main distribution is across the central third of the island from Co. Dublin to Co. Mayo, and it is noticeably scarcer in both the northern and southern thirds. This species has likely been historically under recorded due to taxonomic similarities with *Nemoura cinerea*. There is no evidence of any change in status over the assessment period and the species was assessed as Least Concern.

***Nemoura cinerea* (Retzius, 1783)**

Least Concern

This species has a widespread distribution in muddy, sandy, gravel areas of still or very slow-running water such as ditches, ponds, lakes and streams, and even turloughs but is occasionally found in faster flowing stretches. It is rarely found in high densities. There is no evidence of any change in status over the assessment period and the species was assessed as Least Concern.

***Nemurella pictetii* (Klapálek, 1900)**

Least Concern

This species is found across the country in small streams and seepages usually at altitude but occasionally in streams and seepages at low elevation, especially when heavily shaded. It is widespread but local and can sometimes be found in high densities in Ireland. No detectable change in status is apparent, so the assessment was Least Concern.

Perla bipunctata* Pictet, 1833*Least Concern**

This large stonefly species occurs in large rivers across the southern half of Ireland and in western counties. It has not been recorded from much of Northern Ireland and north Leinster. There is no evidence of any decline in the Irish population, so the assessment was Least Concern.

Perlodes mortoni* (Klapálek, 1906)*Regionally Extinct**

King and Habert (1910) recorded *P. mortoni* from Co. Kerry (Deenagh River – no year) and Co. Louth (Castlebellingham and presumably the River Glyde – 1901). Attempts to re-find it have not been successful (Costello, 1988; Feeley *et al.*, 2016) and so as the records are over 100 years old, the species is assessed as Regionally Extinct. For many years *mortoni* Klapálek was synonymised with *microcephalus* Pictet, 1833 until Zwick (2011) recognised *mortoni* again as distinct and determined that it appears to be a species endemic to Britain and Ireland. Whilst Zwick (2011) confirmed the presence of *mortoni* in Britain, no Irish material is available to check whether the Irish records refer to the true *mortoni*. However, it is presumed that this would be the case. Observations in Scotland suggest this is a species of medium to large stony rivers, found at a variety of altitudes that overwinters as a nymph (Macadam pers. comm.).

Protonemura meyeri* (Pictet, 1841)*Least Concern**

This species is one of the most widespread stonefly species occurring throughout Ireland. It is abundant in streams and rivers on stable substrates and often forms a significant proportion of communities in acid-sensitive catchments. There is no evidence of any change in status over the assessment period.

Protonemura praecox* (Morton, 1894)*Critically Endangered A2 c**

Published records for this species based on nymphal records are available for counties Antrim, Cork, Dublin, Mayo and Wicklow. Two records, both from Co. Wicklow in 1890 and 1982, are supported by adult vouchers in the National Museum Ireland confirming its Irish status. The last published nymphal record is from Co. Wicklow in 1991. Recent attempts to re-find the species at reported sites have been unsuccessful. The species has always been rare in Ireland and the evidence for recent and ongoing decline justified a Critically Endangered assessment.

Siphonoperla torrentium* (Pictet, 1841)*Least Concern**

This is a widespread species and one of the most common stoneflies recorded in Ireland. Nymphs are often abundant in stony, shallow riffles in streams and rivers as well as stony lake shores, especially in soft oligotrophic waters. Adults are often common in grassy riparian areas throughout the summer months. This species was assessed as Least Concern in the absence of any evidence of a decline over the assessment period.

Zwicknia bifrons* (Newman, 1838)*Least Concern**

This species which was formerly classified in *Capnia* is now placed in *Zwicknia* following Murányi *et al.* (2014). Its main distribution is in northern and western areas, with isolated occurrences in the midlands and east. In Ireland it appears to prefer slightly nutrient rich or productive waters, with sand, gravel and cobble substrates and is rarely found in abundance. Although the species is likely under-recorded there is no evidence of significant decline and was assessed as Least Concern.

4 RECORDS, THREATS AND CONCLUSIONS

The Plecoptera, like most of our aquatic fauna, are species-poor compared to Britain and mainland Europe, due in large part to our glacial history and isolation from mainland Europe. Despite this, nymphs can constitute a high proportion of the macroinvertebrate fauna in many streams, rivers and stony lake shorelines, especially in mountainous areas and where conditions are acidic and/or oligotrophic. Adults, when present, tend to be hidden, especially during daylight hours and it often requires recorders to actively search riparian areas to find them. The adults can often travel significant distances from the riparian habitat making them difficult to find.

The records used in this assessment have been largely based on collections of nymphs. Nevertheless, many adult records are included and species such as *Protonemura praecox* and *Capnia atra* are generally, but not exclusively, reliably confirmed only from adult material. This may in part account for the deficiency in data for some species. Unfortunately, many potential data sources and surveys carried out in Ireland lack sufficient taxonomic resolution to species level, making the data unusable in this assessment. This has particularly affected records for *Leuctra fusca* and *Zwicknia bifrons* but is problematic for most multi-species genera of stonefly. A summary of source material (up to 2012) used in this red listing is available in Feeley *et al.* (2016). Additional records in the meantime have come predominantly from records held by the Environmental Protection Agency, the National Biodiversity Data Centre, and personal surveys and citizen science records verified by Hugh Feeley.

Interestingly, the two extant species considered vulnerable and critically endangered are both cold-water stenotherms (surviving within a narrow temperature range) possibly reflecting climate change and increasing average temperatures. Other species, most notably *Diura bicaudata* given its predominantly high altitude (>200 m) distributions, may become threatened in the very near future as temperatures continue to rise. Additionally, the reduction in the occurrence of many species post 2006 could reflect the fact stoneflies are sensitive to organic pollution and the on-going reductions in water quality nationwide (e.g. see EPA 2018, 2019). As algae and macrophytes begin to dominate the river bed in response to excess nutrients dissolved oxygen levels can be adversely depleted during the night, resulting in the loss of sensitive stonefly species. Similarly, reductions in bankside vegetation, especially broadleaf trees, and alterations to river banks and lake shorelines can lower the input of leaf litter, reducing food-availability for many stoneflies and potentially increase adjacent water temperatures due to the lack of shading. Furthermore, the removal of bankside vegetation can impact on the successful survival and breeding of adult stoneflies which use complex riparian areas to source food, provide shelter and locate mates by drumming (i.e. the repeated striking of the abdomen against substrates to produce a species-specific percussion signal – see Feeley *et al.*, 2016 for more details). Instream and shoreline alterations like dredging, flood works, bank protection, weed control, drainage and abstraction, and realignment of rivers can further reduce habitat diversity and increase fine silt mobilisation which in turn will reduce stonefly survival. The use of pesticides needs to be further considered as different types have been shown to have lethal and sub-lethal effects on macroinvertebrates, some communities only responding slowly and returning several years after the initial impact.

In conclusion, future recording and status assessments of stoneflies in Ireland requires species-level identification. Additional surveying should be targeted at adults, especially for species that are rare or difficult to determine accurately as nymphs. The timing of such surveys need to take into account when the species are typically present, and may require dedicated searches in early spring (February/March) as well as late summer (August/September). There remain some areas of Ireland where few or no records exist and these under-recorded areas should be a priority for survey. Future developments in DNA work and meta-barcoding will aid the recording of stonefly

species in Ireland but in the interim full taxonomic resolution of species should be encouraged, with records provided to the authors, the National Biodiversity Data Centre in Waterford, or CEDaR in Belfast. It is also essential that knowledge gaps on the autecological requirements and pollution sensitivity of Irish species be further addressed to inform conservation measures. The threat that climate change and continuing organic pollution poses to this insect order in Ireland should not be underestimated, with most species highly susceptible to both pressures. Finally, it is crucial that we identify and protect species-rich streams, rivers and lakes in catchments throughout the island to provide source areas for stoneflies and other pollution-sensitive species should impacted systems recover in the future.

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APPENDIX 1 Criteria used to evaluate whether a taxon belongs in a threatened category (IUCN 2019).

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
<p>A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.</p> <p>A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3].</p> <p>A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p>	<p>based on any of the following:</p>		<p>(a) direct observation [except A3]</p> <p>(b) an index of abundance appropriate to the taxon</p> <p>(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality</p> <p>(d) actual or potential levels of exploitation</p> <p>(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.</p>
B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km ²	< 5,000 km ²	< 20,000 km ²
B2. Area of occupancy (AOO)	< 10 km ²	< 500 km ²	< 2,000 km ²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected 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			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			
C. Small population size and decline			
	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(ii) % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	D1. < 1,000
D2. Only applies to the VU category Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	D2. typically: AOO < 20 km ² or number of locations ≤ 5
E. Quantitative Analysis			
	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the IUCN Red List Categories and Criteria and Guidelines for Using the IUCN Red List Categories and Criteria. Please refer to both documents for explanations of terms and concepts used here.

APPENDIX 2 Summary of species of Irish stonefly (Plecoptera) that have some form of Red List status in other European countries. CR = Critically Endangered; DD = Data Deficient; EN = Endangered; LC = Least Concern; NT = Near Threatened; RE = Regionally Extinct and VU = Vulnerable

Species	Ireland	GB	Switzerland	Croatia	Finland	Czech Rep.	Bulgaria
<i>Amphinemura sulcicollis</i>	LC	LC	LC	LC	LC	-	-
<i>Brachyptera risi</i>	LC	LC	-	-	LC	-	-
<i>Capnia atra</i>	VU	DD	-	-	LC	-	-
<i>Chloroperla tripunctata</i>	LC	LC	LC	VU	-	-	VU
<i>Dinocras cephalotes</i>	LC	LC	VU	-	NT	VU	VU
<i>Diura bicaudata</i>	LC	LC	-	-	LC	-	DD
<i>Isoperla grammatica</i>	LC	LC	LC	DD	LC	-	LC
<i>Leuctra fusca</i>	LC	LC	LC	LC	LC	-	LC
<i>Leuctra hippopus</i>	LC	LC	LC	LC	LC	-	LC
<i>Leuctra inermis</i>	LC	LC	LC	DD	-	-	LC
<i>Leuctra nigra</i>	LC	LC	LC	LC	LC	-	LC
<i>Nemoura avicularis</i>	LC	LC	EN	LC	LC	-	CR
<i>Nemoura cinerea</i>	LC	LC	LC	LC	LC	-	-
<i>Nemurella pictetii</i>	LC	LC	LC	LC	LC	-	-
<i>Perla bipunctata</i>	LC	LC	-	DD	-	-	-
<i>Perlodes mortoni</i>	RE	LC	-	-	-	-	-
<i>Protonemura meyeri</i>	LC	LC	VU	-	LC	VU	NT
<i>Protonemura praecox</i>	CR	LC	LC	LC	-	-	LC
<i>Siphonoperla torrentium</i>	LC	LC	LC	VU	-	-	-
<i>Zwickyia bifrons</i>	LC	LC	VU	LC	-	-	VU

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