First record of the four-lined silverfish, *Ctenolepisma lineata* (Fabricius, 1775) (Zygentoma, Lepismatidae), in Norway, with notes on other synanthropic lepismatids

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The four-lined silverfish, *Ctenolepisma lineata* (Fabricius, 1775), has been recorded in Norway for the first time. Two specimens were caught in sticky traps during pest control against the long-tailed silverfish *Ctenolepisma longicaudata* (Escherich, 1905). A brief account of the records is given together with a description of identification characteristics, biology, and its potential for pest status. The introduction of *Ctenolepisma lineata* and its pest potential are discussed in light of the establishment and dispersal of two other recently introduced silverfish species.

Key words: Zygentoma, Lepismatidae, *Ctenolepisma calva*, *Ctenolepisma lineata*, *Ctenolepisma longicaudata*, Indoor pest, Invasive pest, Silverfish, Synanthropic.

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Introduction

Bristletails (Zygentoma) is an ancient group of wingless insects with around 550 species worldwide (Robinson 2005, Elven & Aarvik 2018). The majority of these live outdoors. Some are synanthropic and occur as nuisance pests in private homes where they often are denoted simply as silverfish (Mallis *et al.* 2011). In terms of physical damage, their ability to feed on paper raises concern in libraries, archives, museums, and other collection-holding institutions (Querner 2015, Szpryngiel 2018). The common silverfish *Lepisma saccharina* (Linnaeus, 1758) and the firebrat *Thermobia domestica* (Packard, 1873) have been found in urban ecosystems in Europe for more than 100 years (Tillyard 1924, Sweetman 1938, 1939). Both require humid conditions, and the firebrat requires temperatures above 35 °C. These two species have also been recognized as synanthropic in Norway. The firebrat was first reported from Norway in 1964 (Lillehammer 1964), but it has not been reported since the 1970s (ENTBAS 2020). The common silverfish has been in Norway since the late 19th century and is widespread and omnipresent. During the last decade, *Ctenolepisma longicaudata* (Escherich, 1905) and *Ctenolepisma calva* (Ritter, 1910)

have been established in Norway (Mattsson 2014, 2018). The former has attracted substantial attention and is now considered a common indoor nuisance pest, whereas *C. calva* currently appears to have a more restricted distribution (Mattsson 2018, Aak *et al.* 2019, Aak *et al.* 2020a). A recent introduction of these two silverfish species is not limited to Norway. An increasing number of countries has reported the presence of long-tailed silverfish (Pape & Wahlstedt 2002, Lock 2007, Bujis 2009, Meineke & Menge 2014) with recent reports from Britain (Goddard *et al.* 2016), the Czech Republic (Kulma *et al.* 2018), and the Faroe Islands (Thomsen *et al.* 2019). Very little information is available on *C. calva*. It was initially described from Sri Lanka (Ritter 1910), and it is also known from Central America (Querner 2017). In Europe, it has, to our knowledge, only been reported from Germany, Austria and Norway (Querner 2017, Mattsson 2018).

Here, we describe the introduction of a third new silverfish species to Norway. This species is widely distributed in the world and a common synanthropic species. It has a partially overlapping ecology with *C. longicaudata*, and thus has the potential to be a nuisance pest in indoor environments.

FIGURE 1. A four-lined silverfish, *Ctenolepisma lineata* (Fabricius, 1775), stuck in a glue trap. Photo: Hans Petter Widerøe.

The species/material

In December 2019, the Norwegian Institute of Public Health (NIPH) - Department of Pest Control received two sticky traps containing the specimens. The traps had been collected from a food-producing facility in the northern part of Østfold (name of facility and position is archived at the NIPH to ensure anonymity) as part of a pest control program against the long-tailed silverfish (*C. longicaudata*). In addition to a few individuals of *C. longicaudata,* the two traps each caught one specimen of a silverfish distinctly different from all other silverfish species known from Norway (Figure 1). In March 2020, a live specimen was also collected from the same location. Closer inspection identified the new species to be the four-lined silverfish *Ctenolepisma lineata* (Fabricius, 1775). We suggest the Norwegian common name “stripekre” for this species.

The specimens had four yellowish-brown longitudinal stripes dorsally, contrasting an otherwise dark brown base color (Figure 1). This separates it from the more frequently observed *C. longicaudata*, *C. calva* and *L. saccharina*, all of which are unicoloured or mottled in appearance and never exhibit any distinctive pattern on the dorsal side (Aak *et al.* 2019). *T. domestica* has distinctive dorsal markings, but the markings are spotted and not striped in appearance (Pape & Wahlstedt 2002). The 3 + 3 bristle combs on urotergites II–VII and the subtriangular shape of urotergite X distinctly separate the specimens from *C. longicaudata*, which has 3 + 3 bristle combs on urotergites II–VI only and a trapezoidal urotergite X (Wygodzinsky 1991). The subtriangular shape of urotergite X also separates *C. lineata* from other synanthropic ctenolepismatids such as *Ctenolepisma targionii* (Grassi & Rovelli, 1889), *Ctenolepisma ciliata* (Dufour, 1831) (Molero-Baltanas *et al.* 2010) and *Ctenolepisma villosa* (Fabricius, 1775) (Wygodzinsky 1991). However, the superficially similar and

occasionally synanthropic *Ctenolepisma nicoletii* (Lucas, 1846) (Molero-Baltanas *et al.* 2012) has a subtriangular urotergite X and thus requires further characteristics for correct identification. Our specimens had a clearly truncated hind margin of the prosternum (Figure 2) and three pairs of styli (Figure 3). This separates the species from *C. nicoletii*, which has a rounded-elliptical to slightly truncated apex of the prosternum and only two pairs of styli (Molero-Baltanas *et al.* 2012).

FIGURE 2. Ventral view of *Ctenolepisma lineata* (Fabricius, 1775), highlighting the truncated apex of the prosternum. Photo: Morten Hage.

FIGURE 3. Adult *Ctenolepisma lineata* (Fabricius, 1775) with three pairs of styli. Photo: Morten Hage.

Discussion

C. lineata is native to the warmer regions of Central Europe and the North Mediterranean basin (Molero-Baltanas *et al.* 2012). Through trade and transportation, it has been introduced to other parts of the world, with records from North America and the Caribbean (Wygodzinsky 1972), Australia (Smith 2017), and several European countries (Molero-Baltanas *et al.* 2012, Fink 2016, Zimmermann 2016), including the northwestern parts (Notton 2018). It is a facultative synanthropic species, and in the urban environment, it appears to have a significant overlap in distribution with *C. longicaudata*. It is considered a nuisance pest only, but it should be noted that it has the ability to digest cellulose (Lasker & Giese 1956), and therefore it may cause damage in archives or museums. Observations of a wide infestation range inside buildings indicate that they can tolerate drier conditions than *L. saccharina* and *T. domestica* (Mallis *et al.* 2011). Attics may also be especially suitable, and from the United States, *C. lineata* is reported to show a preference for buildings with wooden roof tiles (Robinson 2005). Its natural biology and choice of habitat are poorly described, but they are typically observed in warm areas with access to stones, bark, fallen leaves and partially decomposed tree trunks (Robinson 2005, Molero-Baltanas *et al.* 2012).

Structure-invading silverfish are often treated in unison, with few distinctions in terms of control strategies (Gold & Jones 2000, Bennett *et al.* 2010, Mallis *et al.* 2011). Apart from infestations in museums and collection-holding institutions (Querner *et al.* 2013, Szpryngiel 2018), they have attracted limited attention as pests internationally.

They are often regarded as difficult to eradicate completely when first established indoors, but they are fortunately not considered a serious problem in private homes. Only in extreme cases involving large populations of the insect are pesticides used for control (Bennett *et al.* 2010, Mallis *et al.* 2011). Baits have recently been suggested as a safe and efficient strategy to eliminate or keep large indoor infestations at bay (Gutsmann 2019, Aak *et al.* 2020b).

Because silverfish often are treated as a group instead of as separate species, occasional infestations or the appearance of rare species may have gone unnoticed. In this respect, it is interesting that the discovery of *C. longicaudata* (Mattsson 2014) and its status as an emerging indoor nuisance pest in Norway (Aak *et al.* 2019) has prompted pest control technicians to be more conscious and aware when dealing with these creatures. This may have facilitated the discovery of *C. calva* (Mattsson 2018, Aak *et al.* 2020a) and now *C. lineata,* the third new species within 6 years.

The worldwide pool of synanthropic silverfish is poorly studied. The true number and distribution of anthropophilic silverfish species may therefore be subject to some uncertainty. Many species of silverfish have been reported as relevant for pest controllers in indoor environments worldwide (Wygodzinsky 1991, Robinson 2005, Bennett *et al.* 2010, Mallis *et al.* 2011). The most common are *Acrotelsa collaris* (Fabricius, 1793)*, T. domestica, C. longicaudata, C. lineata* and *L. saccharina* (Wygodzinsky 1991). The former is restricted to the tropics and requires high temperatures*,* whereas *T. domestica* is also found in areas with more temperate climate. Both are unlikely to establish themselves in Norway, but one should be aware of them potentially being able to settle in greenhouses and other high-temperature facilities, like bakeries. In addition, *C. targionii* is reported as synanthropic in Spain (Molero-Baltanas *et al.* 1997), Portugal (Mendes 2011), and Italy (Molero-Baltanas *et al.* 2000), but is also found free-living in areas around the eastern part of the Mediterranean basin (Mendes 2011). The species is also reported from the United States (Wygodzinsky 1972). The final potential candidate to appear in Norway is *C. villosa*, the oriental silverfish. It is a museum pest in Japan (Bell & Reichmuth 2002) and strikingly similar to *C. longicaudata*. The main distinguishing characteristic is the presence (*villosa*) or absence (*longicaudata*) of median bristle combs on the abdominal sternites (Wygodzinsky 1991). *C. ciliata* and *C. nicoletii* are also found indoors (Molero-Baltanas *et al.* 1997, Molero-Baltanas *et al.* 2012), but appear to have a weaker connection to the urban ecosystem and have not shown equal dispersal abilities. Their introductions may also occur, but are likely to be very sporadic and should not result in the same establishment as seen for *C. longicaudata* (Aak *et al.* 2020a).

Two of the new species detected in Norway (*C. longicaudata* and *C. lineata*) are cosmopolitan and thrive under our preferred indoor conditions. Considering the strong globalization of trade during the last 15–20 years (Hulme *et al.* 2008, Padayachee *et al.* 2017, Frøberg *et al.* 2020), it is not surprising that they have been introduced and detected. It is also likely that they will continue to be introduced in the years to come. *C. calva* appears to have been largely overlooked internationally but has been observed on several occasions in Norway in parallel with *C. longicaudata*. *C. lineata* was also found in parallel with *C. longicaudata*, and it appears that the rarer species often co-exists with the more common one in indoor habitats. During the preparation of this manuscript, we received information regarding another case with *C. lineata*. Again, the species had occurred in parallel with *C. longicaudata* and was found in sticky traps during pest control in an apartment in Agder county (Figure 4). Identification of insects solely based on photographs is uncertain, but from the distribution and pest status of synanthropic ctenolepismatids in Norway, we find it likely that this is another case involving *C. lineata*.

Increased temperatures due to climate change are not of significance for the synanthropic silverfish species of Norway, because they will not survive outdoors in our cold climate. They are mostly of tropical origin, and no extensive cold tolerance is known among the relevant species. The potential consequences of these alien species for Norwegian nature are therefore very

FIGURE 4. A silverfish, most likely *Ctenolepisma lineata* (Fabricius, 1775), from Agder county. Photo: anon.

limited. Climate change is nevertheless a factor in urban environments, and future scenarios are expected to affect Norwegian buildings through a heavier toll on moisture-related damage (Glaas *et al.* 2015). This is of relevance for the indoor silverfish fauna, because slightly higher humidity levels may be beneficial and increase survival for many of the species, and because heavy infestations are often seen in parallel with undiscovered moisture damage. Although most of the moisture-demanding species are fairly easy to control and therefore may be kept at bay (Bennett *et al.* 2010, Mallis *et al.* 2011, Aak *et al.* 2019), it is possible that a future with slightly warmer and more humid climate might bring an increase in the frequency of these indoor nuisance pests.

An increased awareness toward synanthropic silverfish, combined with a continuous risk of introduction through global trade, makes it possible that the discovery of new species may continue. The silverfish species that may arrive in Norway in the future are, however, very similar to each other and to *C. longicaudata*. Additional newcomers may therefore go unnoticed and, with an ongoing control program against the main culprit, *C. longicaudata,* they may even be eradicated before they are discovered. In conclusion, it is likely that we are close to a maximum number of synanthropic silverfish species capable of seizing permanent indoor establishment in Norway.

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