SPATIAL AND TEMPORAL DISTRIBUTION OF CADDISFLY LARVAE IN TWO LOWLAND STREAMS IN THE NETHERLANDS (TRICHOPTERA)

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Caddisflies are a species rich insect order. The adults are moth-like, but their wings bear hairs instead of scales. The larvae are aquatic and live in self-constructed cases, made of plant material, sand or debris. The species are used as indicators of water quality, but much is still not known about their biology and ecology. In this paper the preferred substrates and phenology of the larvae of 13 species are described, using the data of a survey of two lowland streams in the east of the Netherlands.

INTRODUCTION

Streams are heterogeneous environments, both spatially and temporally. The spatial distribution of aquatic invertebrates is in part determined by habitat conditions, such as substrate composition, oxygen availability and current velocity. Temporal variation in species abundance is to a large extent caused by seasonal changes in the physical and chemical environment (e.g. temperature, discharge and the availability of food resources).

So far, not much is known about the preferences of caddisfly larvae for substrates within the aquatic habitats or the periods of the year when larvae can be found. There is a need for more information on species distributions in general (Higler 2008b). Caddisflies (Trichoptera) are holometabolous insects (fig. 1-3) with an aquatic larval stage (fig. 4-6). The larvae secrete silk to construct a diverse array of portable cases, fixed shelters, filter nets and cocoons (Wiggins 2004). The cases are constructed from mineral grains and vegetation fragments and have different functions, such as to meet respiratory needs (Williams et al. 1987), providing protection from predators (Otto & Johansson 1995) and resisting flow induced dislodgement (Waringer 1993). As all species need a case in order to reach the pupal stadium (Mackay & Wiggins 1979), substrate composition is one of the major factors in caddisfly species distributions in streams, along with temperature, current velocity, food (size) and dissolved oxygen.

Temperature affects the development, and at temperate latitudes most caddisflies complete a single generation in the course of one year. Food resources probably affect the number of cohorts, and seasonal differences in growth periods may expose coexisting species to different food resources, whereas differences in flight period may result from seasonal growth periods or diapause (Mackay & Wiggins 1979, Wiggins 2004).

Figure 1. *Anabolia nervosa*, larva in case (Woudhuizermark, The Netherlands). Photo David Tempelman.
Figuur 1. *Anabolia nervosa*, larve in koker (Woudhuizermark). Photo David Tempelman.

Figure 2. *Anabolia nervosa*, adult in the field (Smalwater, The Netherlands). Photo David Tempelman.
Figuur 2. *Anabolia nervosa*, adult in het veld (Smalwater). Foto David Tempelman.

Figure 3. *Hydropsyche angustipennis*, larva (Anserbeek, The Netherlands). Photo David Tempelman.
Figuur 3. *Hydropsyche angustipennis*, larve (Anserbeek). Foto David Tempelman.

Figure 4. *Hydropsyche angustipennis,* adult resting on a leaf along a stream (Kleine Aa, Noord-Brabant, The Netherlands). Photo David Tempelman.
Figuur 4. *Hydropsyche angustipennis*, adult rustend op een blad langs een beek (Kleine Aa, Noord-Brabant). Foto David Tempelman.

Figure 5. *Limnephilus lunatus*, larva in case (sand pit, Hoogeveen, The Netherlands). Photo David Tempelman.
Figuur 5. *Limnephilus lunatus*, larve in koker (zandwinplas Hoogeveen). Foto David Tempelman.

Figure 6. *Limnephilus lunatus*, adult in the field (Berkheide, The Netherlands).
Photo Casper Zuyderduyn.
Figuur 6. *Limnephilus lunatus*, adult in het veld (Berkheide).
Foto Casper Zuyderduyn

In the Netherlands, most caddisfly species inhabit streams. Most information on larval distributions is based on routine sampling (often a single composite sample, once a year) by Water Boards (Higler 2005, 2008a). The results which are presented here are part of a study in which the spatial and temporal variation in invertebrate communities in two streams (Boven Slinge, Bekendelle and the Ramsbeek) were quantified at the scale of the mesohabitat, with intensive sampling (Franken & Klutman, in prep.). Mesohabitats are distinct patches of contrasting structure which describe the variability in a stream (Maddock 1999). Additionally, ecological, distributional and phenologic notes are included for each species. These are based on Higler (2008a), personal observations by the third author and waarneming.nl. The aim of this paper is to present new information on the ecology of a number of caddisfly species.

Figure 7. Location of the sampling sites.
Figuur 7. Locatie van de monsterpunten.

MATERIALS AND METHODS

The sampling site (fig. 7) at the Boven Slinge (51.942º, 6.694º) is situated in nature reserve Bekendelle, which is one of the few swamp forests in the Netherlands. The sampled section of this lowland stream meanders freely and is characterised by pulsed discharges as a result of the impermeable clay layers of the surrounding area. The highest peak discharge during this study was 6.17 m3/s (12-month average = 0.65 ± 0.93 (SD) m3/s (continued measurements, approximately 800 meters upstream). Sampled mesohabitats (described by the major substrate type) were sand, vegetation, fine particulate organic matter (FPOM, in the rest of this paper called fine detritus), banks, pool (deep with low current), riffle (shallow with fast current) and dead wood. The sampled section of the Ramsbeek (52.087º, 6.692º) has been restored in 2010. The stream has been placed back to its old course, the bed level was raised and small meanders were created. It is a half-open channel, with only trees at the west side, and high banks. Sampled mesohabitats were sand, vegetation and fine detritus. In-stream vegetation cover was high (30-40 %) at the Ramsbeek in summer, whereas at the Boven Slinge it was less than 5 %.

All mesohabitats were sampled monthly for 12 months from September 2012 until August 2013 in both streams, except for banks and vegetation in September 2012 at the Boven Slinge. Invertebrates were sampled by sweeping a D-frame hand-net (500 µm mesh, 30 × 20 cm). In every sample, the length from which a sample was taken was recorded. Due to the nature of the sampled habitat, which varies a lot over the stretches which where sampled, they should be considered semi-quantitative. Dead wood and aquatic vegetation, however, were hand-picked. For comparison among mesohabitats, they were expressed as a sweep sample. Samples were sorted at the same day and preserved in 80 % ethanol.

DESCRIPTION OF MESOHABITATS

Mesohabitat sand consisted of bare sand with some organic debris only. Dead wood was made up of woody litter like large branches and tree trunks which were collected from the stream bed. Fine detritus on sand, was mainly collected at the shallow edges. Riffle substrates consisted of coarse sand and fine gravel, along with coarse organic matter and twigs, whereas pool substrates consisted of sand covered by a layer of particulate organic matter. The aquatic vegetation of the Boven Slinge is dominated by *Sparganium emersum* and some *Agrostis stolonifera.* The Ramsbeek is dominated by *Callitriche obtusangula* and some *Lemna minor* and *Elodea nuttallii*.

Table 1. Caddisfly species caught and the number per stream.
Tabel 1. Gevangen kokerjuffersoorten met het aantal per beek.

Species	Boven Slinge	Ramsbeek
Anabolia nervosa	1335	79
Athripsodes aterrimus	-	10
Athripsodes cinereus	52	-
Beraeodes minutus	1	-
Cyrnus trimaculatus	36	-
Glyphotaelius pellucidus	97	-
Halesus radiatus	142	7
Hydropsyche angustipennis	637	19
Hydropsyche pellucidula	28	-
Hydroptila	1	3
Ironoquia dubia	11	15
Limnephilus extricatus	-	4
Limnephilus flavicornis	3	1
Limnephilus lunatus	82	182
Limnephilus rhombicus	85	2
Lype reducta	251	-
Molanna angustata	2	24
Mystacides azurea	12	-
Mystacides longicornis	7	1
Mystacides niger	20	43
Oecetis ochracea	-	1
Phryganea bipunctata	1	2
Phryganea grandis	-	1
Potamophylax rotundipennis	249	2
Tinodes waeneri	7	-

RESULTS

In total 22 caddisfly species were collected at the Boven Slinge and 18 at the Ramsbeek (table 1). The caddisfly larvae made up 11 % (Boven Slinge) and 4 % (Ramsbeek) of the number of individuals caught. Pie charts with the distribution over the mesohabitats were only generated for species of which more than 20 individuals were collected throughout the study, in a single stream. Temporal variation in species abundance is only shown when then number of individuals was > 50. Vegetation and banks might be underestimated as macroinvertebrates were not sampled in September 2012. However, most species had a low abundance in autumn or in these mesohabitats, except for *Potamophylax rotundipennis* in banks and *Hydropsyche angustipennis* in vegetation and *Limnephilus rhombicus* in both banks and vegetation.
For some species a distinction was made between early and later instars, as apparent differences in spatial distribution were observed.

Anabolia nervosa

In both streams (fig. 8, 9) larvae of *A. nervosa* Curtis, 1834 (fig.1, family Limnephilidae) were most abundant in fine detritus (46 and 73 %, respectively), and also in the pool at Boven Slinge (21 %, fig. 8). Cases were stronger (larger pieces of woody debris) in the riffle, when compared to those in fine detritus and the pool (pers. obs. Rob Franken), which is probably a result of the sorting effect of current on case-building material.
In both streams individuals peaked in March in fine detritus (fig. 25, 26) and increased in summer in the pool at the Boven Slinge, whereas at the Ramsbeek the number of individuals was only high in March.

The species is common in standing waters (mainly lakes) and streams (brooks and small rivers) in large parts of the Netherlands. Only lacking on the Wadden Islands and the brackish parts of the coastal areas, such as the province of Zeeland.
The habitats are permanent, non acidic, and generally rich in nutrients. The adults can readily be recognised by the roundish wings and typical wing pattern (fig. 2). They are found almost exclusively in September and October, with occasional records in November. They are easily encountered along streams, but rarely come to light.

Athripsodes cinereus

Larvae of *A. cinereus* Curtis, 1834 (family Leptoceridae) were most abundant in the riffle (34 %) and the pool (26 %) and were absent in fine detritus (fig. 10). Individuals in the pool were found in spring-early summer, whereas in the riffle also in winter (fig. 27). *Athripsodes cinereus* is common in the eastern and southeastern part of the Netherlands. In the western part it is rare, occurring near lakes. The adults can be easily identified by the dark brown wings and two distinct yellowish transverse markings. The antennae are about two times the length of the body and show a zebra-pattern. As in most leptocerids it is adult mainly in summer (May-September).
The species can be observed flying in groups just before sunset, in an up and down courtship display. It is attracted to at light; most individuals are found just after dusk.

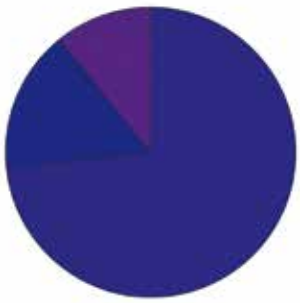
Cyrnus trimaculatus

Larvae of *C. trimaculatus* Curtis, 1834 (family Polycentropodidae) were predominantly (88 %) found on dead wood and for a small part in fine detritus. They were absent in the riffle and vegetation (fig. 11). *Cyrnus trimaculatus* is common in almost of the Netherlands, absent only in parts of the coastal region and the Wadden Islands.
The wing is dotted with numerous yellow patches on brown background. The species may be difficult to identify in the field, because the wing pattern is similar to *Ecnomus tenellus* (which is smaller) and *Polycentropus* species (which are larger). The adults are attracted to light and found mainly from May to September.

Glyphotaelius pellucidus

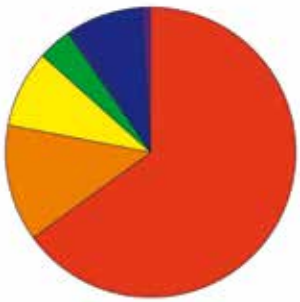
Larvae of *G. pellucidus* Retzius, 1783 (family Limnephilidae) were most abundant in fine detritus (46 %) and the pool (33 %) and absent in sand and vegetation (fig. 12). Individuals were found throughout the year and peaked in autumn-early winter in fine detritus and in November in pools (fig. 28). *Glyphotaelius pellucidus* is common in the Netherlands and is mainly found in forested areas. It is absent only from the Wadden Islands and some parts of the coastal region.
The adult has a very variable wing pattern but is easily recognised by the unique wingtip which is excised concavely. Adults can be found from April to November, with most records in May and in September. It is attracted to light but can be found also during the day. The larva needs leaves to construct the case. The well developed gills allow it to live in low oxygen conditions (Berlin & Thiele 2012). Egg sacs are encountered mainly

8. *Anabolia nervosa*, Boven Slinge.

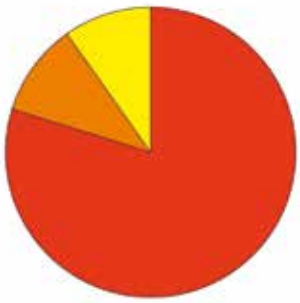


9. *Anabolia nervosa*, Ramsbeek.

13. *Halesus radiatus*, Boven Slinge.

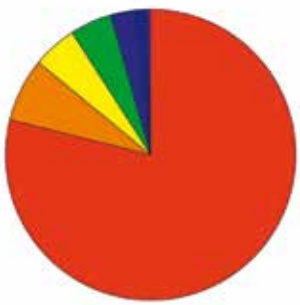


14. *Hydropsyche angustipennis*, Boven Slinge.

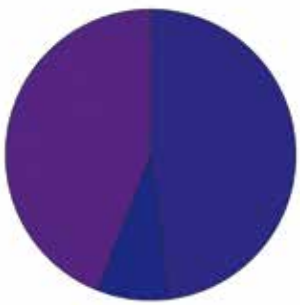


15. *Hydropsyche pellucidula*, Boven Slinge.

19. *Limnephilus rhombicus*, Boven Slinge.



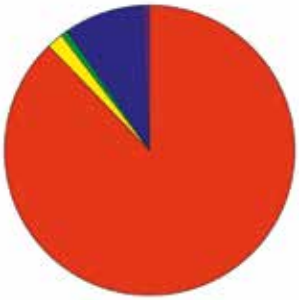
20. *Lype reducta*, Boven Slinge.



21. *Molanna angustata,* Boven Slinge.

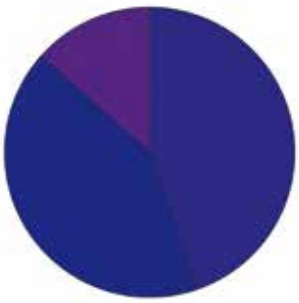
Figure 8-24. Spatial distribution of the larvae.
Figuur 8-24. Ruimtelijke verspreiding van de larven.

10. *Athripsodes cinereus*, Boven Slinge.

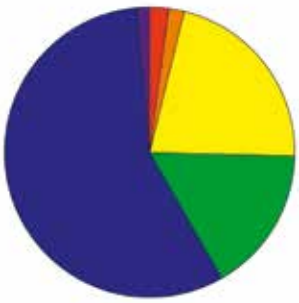


11. *Cyrnus trimaculatus*, Boven Slinge.

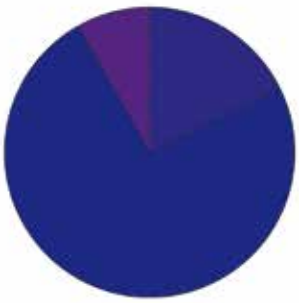
12. *Glyphotaelius pellucidus*, Boven Slinge.



16. Limnephilidae, Ramsbeek.

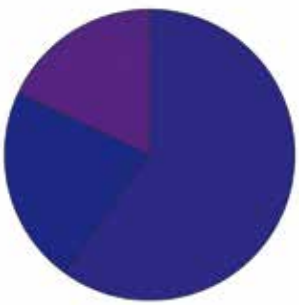


17. *Limnephilus lunatus*, Boven Slinge.



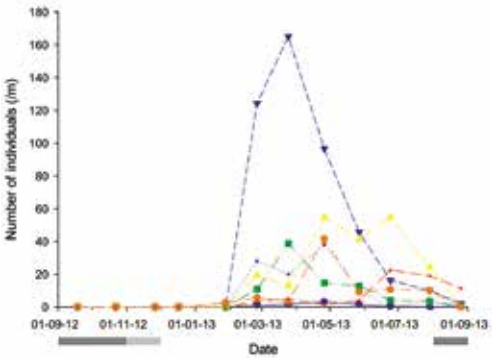
18. *Limnephilus lunatus*, Ramsbeek.

22. *Mystacides niger,* Boven Slinge.

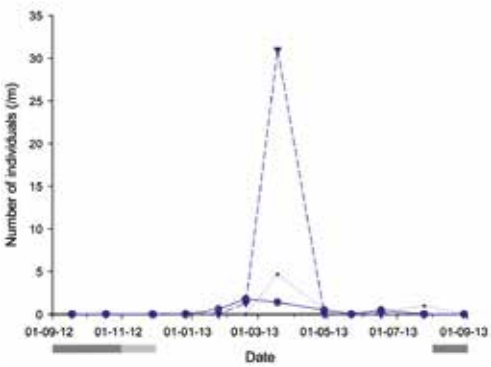


23. *Mystacides niger,* Ramsbeek.

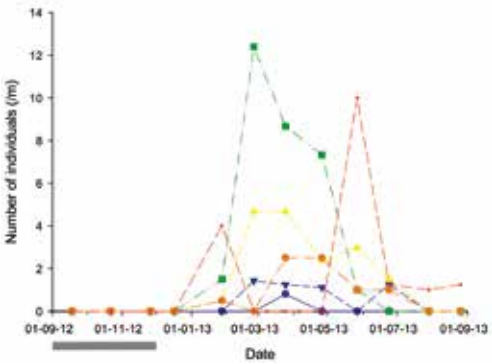
24. *Potamophylax rotundipennis,* Boven Slinge.



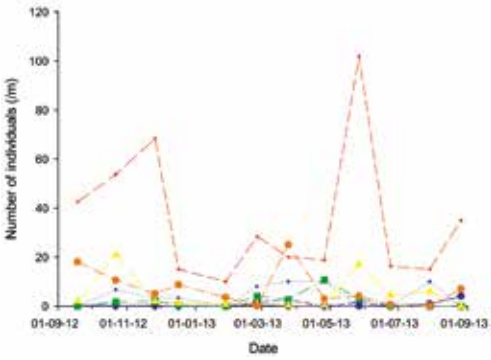
25. *Anabolia nervosa, Boven Slinge.*



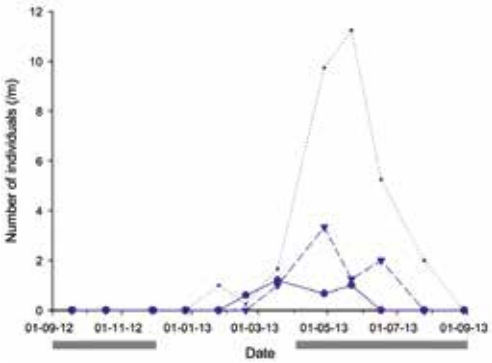
26. *Anabolia nervosa*, Ramsbeek.



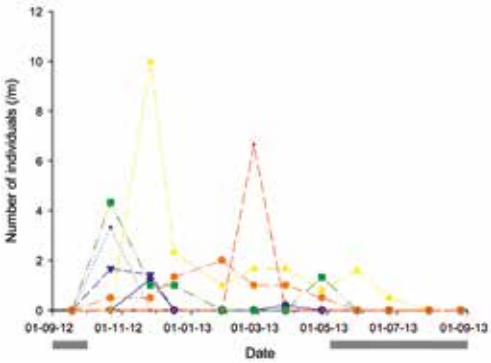
29. *Halesus radiatus,* Boven Slinge.



30. *Hydropsyche angustipennis,* Boven Slinge.

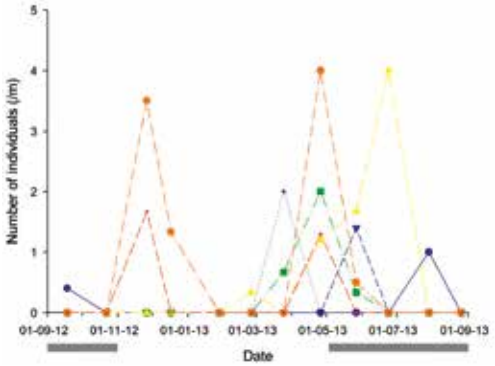


33. *Limnephilus lunatus*, Ramsbeek.

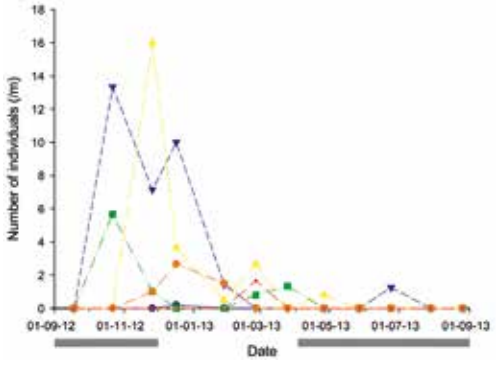


34. *Limnephilus rhombicus,* Boven Slinge.

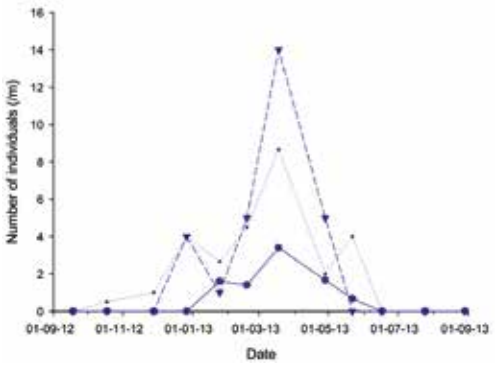
Figure 25-36. Temporal distribution of the larvae.
Figuur 25-36. Verspreiding van de larvae ove de tijd.



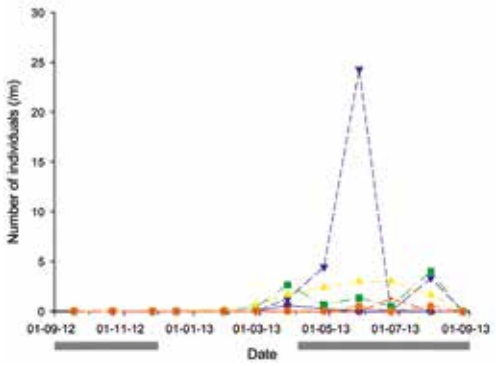
27. *Athripsodes cinereus*, Boven Slinge.



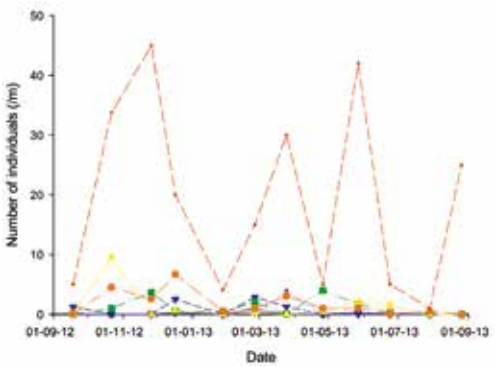
28. *Glyphotaelius pellucidus,* Boven Slinge.



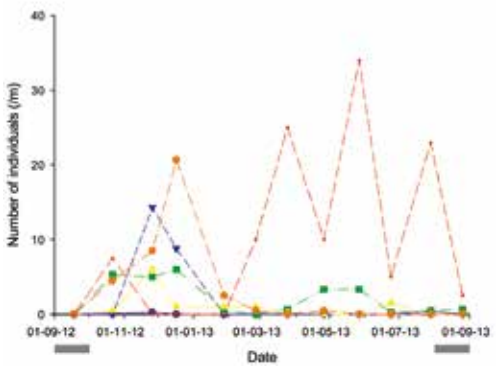
31. Limnephilidae, Ramsbeek.



32. *Limnephilus lunatus,* Boven Slinge.



35. *Lype reducta,* Boven Slinge.



36. *Potamophylax rotundipennis,* Boven Slinge.

in September and are usually deposited on leaves, typically 1 m above the water surface. The eggs develop into first stage larvae within this sac. They fall out of the case and drop into a pool below (Kampwerth 2010). With this strategy the species is able to survive the dry summer period when the pools dry up.

Halesus radiatus

Larvae of *H. radiatus* Curtis, 1834 (family Limnephilidae) were most abundant in banks (39 %) and also abundant in the pool (21 %) and dead wood (22 %, fig. 13). Larvae were found from December until August and peaked in February both in banks and the pool (fig. 29). A high number was also found on dead wood in May. *Halesus radiatus* is found mainly in the east and southeast of the Netherlands, with populations in the forest area Veluwe as well. The adult has a wing pattern typical for all three *Halesus* species known from the country. It is a typical autumn species, adults being found mainly in October. It is attracted to light.

Hydropsyche angustipennis

Larvae of *H. angustipennis* Curtis, 1834 (fig. 3, family Hydropsychidae) were most dominant on dead wood (65 %) and less in the riffle (13 %), vegetation (8 %) and pool (9 %, fig. 14). Individuals were collected throughout the year and peaked in November and May on dead wood (fig. 30). In addition, early instars, identified as *Hydropsyche* sp., were most abundant in vegetation and dead wood. These stages were found in summer and peaked in July. *Hydropsyche angustipennis* is very common in the east and southeastern part of the country. It has generally dark brown wings, with smaller and larger light spots (fig. 4). A summer species, attracted to light but it can be spotted during daytime as well. When numerous, dense clouds may be observed with animals flying frantically back and forth.

Hydropsyche pellucidula

Larvae of *H. pellucidula* Curtis, 1834 (family Hydropsychidae) were most abundant on dead wood (80 %), and less abundant in the riffle (10 %) and pool (10 %, fig. 15). *Hydropsyche pellucidula* is quite rare in the Netherlands. In contrast to *H. angustipennis* the wings are marked with many large yellowish spots. The adults fly mainly in summer and are attracted to light.

Limnephilidae

Limnephilids were abundant in fine detritus (45 %) and vegetation (42 %) at the Ramsbeek (fig. 16). Unidentified limnephilid larvae in the Ramsbeek were probably early instars of *L. lunatus*, as this species makes up 93 % of the limnephilid species in this stream. These early instars were less abundant in vegetation than later instars (*L. lunatus*, fig. 18), which is probably due to the fact that vegetation was less developed at the time early instars were present. This is evident from the number of larvae of *L. lunatus* after March (fig. 33) in comparison to limnephilids (fig. 31).

Limnephilus lunatus

Distribution patterns of *L. lunatus* Curtis, 1834 (fig. 5, family Limnephilidae) differed between both streams, as most larvae at the Boven Slinge (fig. 17) were abundant in fine detritus (57 %), and to a lesser degree in the pool (22 %) and banks (16 %) and it was absent in vegetation. However, at the Ramsbeek (fig. 18) *L. lunatus* was most abundant in vegetation (74 %). It was the most abundant caddisfly species in this stream. This confirms that species distribution is influenced by substrate availability (i.e, type of stream). At the Boven Slinge individuals were present from the end of winter onwards, and peaked in fine detritus in May (fig. 32). At the Ramsbeek larvae peaked in May in the vegetation

(fig. 33). *Limnephilus lunatus* is one of the commonest species of Trichoptera in the Netherlands, found all over the country, including coastal areas and Wadden Islands. It has a moon-shaped, hyaline wingtip ('lunatus'), with a black margin, making identification in the field very easy (fig. 6). The adults can be found from April to November. They are attracted to light, but can also be found during the day.

Limnephilus rhombicus

Larvae of *L. rhombicus* Linnaeus, 1758 (family Limnephilidae) were most abundant in the pool (40 %) and also in banks (16 %), riffle (14 %) and dead wood (14 %, fig. 19), Densities were highest in autumn-early winter, except on wood (February, fig. 34). *Limnephilus rhombicus* is found mainly in areas with sandy soils; it is absent from the Wadden Islands and parts of coastal areas. It is the largest *Limnephilus* species. The adults are easily recognised by the large, oblique white wing marking which is accompanied by black areas on both sides. It is found exclusively at night and is attracted to light. It is found from May to September. Larvae shred and scrape food particles and also take animal food (Graf et al. 2002).

Lype reducta

Larvae of *L. reducta* Hagen, 1868 (family Psychomyiidae) were predominantly found on dead wood (79 %) and were absent on sand (fig. 20). They were found throughout the year and peaked in November, March and May (fig. 35). *Lype reducta* is found in the east and southern part of the Netherlands. It is rather scarce and limited to streams. *Lype phaeopa,* the only other Dutch species of the genus, is more widespread and also found in lakes. The adult is a tiny, black caddisfly which is hard to identify in the field. It may be found during the day using a sweeping net.

Molanna angustata

Larvae of *M. angustata* Curtis, 1834 (family Molannidae) were mainly found in fine detritus (48 %) and sand (44 %, fig. 21). *Molanna angustata* is common in permanent, standing waters and streams. Larvae construct broad, flat cases from sand grains. It is common and very widespread in the Netherlands, but absent from the Wadden Islands and parts of coastal areas. The adults are yellowish-light brown in colour and are easily recognised by their long, slender wings with somewhat darkened veins. The antennae are stout and about the length of the body. Where abundant, the species may be found during daytime. However it is also attracted to light, the males more so than females. When sitting still, the species has its abdomen slightly raised.

Mystacides niger

Larvae of *Mystacides niger* Linnaeus, 1758 (family Leptoceridae) were most abundant in fine detritus (42 %) and dead wood (36 %) but absent in vegetation and riffle at the Boven Slinge (fig. 22). At the Ramsbeek larvae were most abundant in fine detritus (60 %, fig. 23). *Mystacides niger* is very common in the western part of the country, less so in the east. The adults can be recognised by the black wings and long antennae, which are up to three times body length. The adult can best be found during the day, when it may be seen swarming in large groups before sunset. It is found at light in small numbers only.

Potamophylax rotundipennis

The larvae of *Potamophylax rotundipennis* Brauer, 1857 (family Limnephilidae) were most abundant on dead wood (54 %), and also found in the riffle (17 %), banks (12 %) and fine detritus (11 %), and absent in sand and vegetation (fig. 24). From February until July the larvae were mainly found on dead wood (fig. 36), whereas in the riffle, fine

detritus and banks they were mainly found in autumn-early winter, after which the first high pulsed discharges occurred. In the Netherlands *Potamophylax rotundipennis* is mainly found along the eastern border, with populations in southeast Brabant and Veluwe. The adult flies in late summer, with most records from August and September. They are attracted to light.

DISCUSSION

In the lowland streams Boven Slinge and Ramsbeek, 22 and 18 species of caddis were found, respectively. As the different mesohabitats were studied in separate samples, it was possible to identify the preferred substrate of each species. The substrate preference was found to be widely different in the species studied. Most of the abundant species showed a preference for dead wood, followed by fine detritus. Dead wood was found to be the most important substrate for *Cyrnus trimaculatus*, *Hydropsyche angustipennis*, *H. pellucidula*, *Lype reducta* and *Potamophylax rotundipennis*. Submerged vegetation was an important substrate for *Limnephilus lunatus* in the half-open channel; fine detritus was the most important substrate for *Anabolia nervosa* and *Mystacides niger*, in both streams; banks were the most important substrate for *Halesus radiatus*. There were also remarkable phenological differences between the species. For instance, larvae of *H. radiatus* and *A. nervosa* were mainly found in spring and summer; *G. pellucidus* was found in autumn and winter; *L. lunatus* was mainly found in summer and *L. rhombicus* in winter and spring. *Hydropsyche angustipennis*, *L. reducta* and *P. rotundipennis* were found throughout the year. In addition, the summer of 2013 was warm and dry, which, might explain the observed differences in abundance of larvae in relation to known flight periods, see for instance *H. radiatus*.a

ACKNOWLEDGEMENTS

Funding for the study on temporal variation and invertebrate communities in streams was provided by the Rhine and IJssel Water Board. The authors are also grateful to Jet J.M. Altenburg and Maria J. Sanabria for giving important comments. Casper Zuyderduyn kindly provided a photo of *Limnephilus lunatus*.

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SAMENVATTING

Voorkomen in ruimte en tijd van kokerjufferlarven in twee Nederlandse laaglandbeken (Trichoptera)

Er is nog maar weinig bekend over het voorkomen in ruimte en tijd van kokerjufferlarven in de Nederlandse beeksystemen. De in dit artikel beschreven resultaten zijn onderdeel van een uitgebreid onderzoek naar temporale variatie in de levensgemeenschap van macroinvertebraten in twee beken in de Gelderse Achterhoek: de Boven Slinge in natuurreservaat Bekendelle en de Ramsbeek. In 2012 en 2013 werd een jaar lang elke maand gemonsterd, in respectievelijk zeven en drie mesohabitats in de Boven Slinge en Ramsbeek. Op basis van de resultaten wordt een ecologische beschrijving gegeven van 13 soorten kokerjuffers, met de nadruk op het voorkomen van de larven in de ruimte en tijd.

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