

DISTRIBUTION AND ECOLOGY OF *AULODRILUS JAPONICUS* IN THE NETHERLANDS (OLIGOCHAETA: TUBIFICIDAE)

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In 1997, the tubificid worm *Aulodrilus japonicus* was identified for the first time from the Netherlands. It was not recognised before because of close similarities with other species of the genus *Aulodrilus*, especially with *A. plurisetus*. A study was started to contribute to the knowledge on the distribution, microhabitat and life history in the Netherlands. *Aulodrilus japonicus* was observed at 38 of the 70 sites investigated, mostly as the dominant oligochaete. No microhabitat preference could be found. The population peaked in January and from July until September. Mature specimens only occurred in July and constituted only a small proportion of the whole population. *Aulodrilus japonicus* is a eurytopic species that we expect to be common all over the Netherlands and possibly in many other northwestern European countries.

INTRODUCTION

The last 25 years more attention was given to the group of Oligochaeta, which resulted in a number of new species for the Dutch fauna (Van Welzen 1977, Van Urk 1978, Verdonshot 1980a, Verdonshot 1980b, Mol et al. 1982, Janse & Monikkendam 1982, Verdonshot 1984, Verdonshot 2001, Van Haaren 2002). In this paper *Aulodrilus japonicus* Yamaguchi, 1953 is reported as new for the Netherlands. The identification of the Dutch specimens of *A. japonicus* was confirmed by A. Ohtaka. The species was described from Sapporo, northern Japan. Brinkhurst & Jamieson (1971) and Pinder & Brinkhurst (2000) considered *A. japonicus* a synonym of *A. plurisetus*, with the duplicated distal tooth in the dorsal bundles falling within the variation of *A. plurisetus*. Hrabě (1981) considered *A. japonicus* as a valid species based on the shape of the male gonoduct, the location of the male openings in segment x (in *A. plurisetus* situated in segment vii) and the higher number of chaetae per bundle. Finegenova & Arkhipova (1994) and Othaka & Nishimo (1995) confirmed the arguments of Hrabě. The distribution range of *A. japonicus* is limited. In his review on the distribution of freshwater oligochaetes in the western and eastern coastal

regions of the North Pacific Ocean Timm (1999) reported *A. japonicus* only from two Japanese Islands, Saharin and Kuriles. Outside Japan the species is only reported from Europe: Slovenia (Krno et al. 1996) and Norway (Sloreid & Halvorsen 2002). Until now *A. japonicus* is included only in the identification key of Hrabě (1981), which could be one of the reasons for the scarce amount of ecological information and distribution records in the literature. For the Netherlands it turned out that the distribution of *A. plurisetus* was quite restricted as most specimens refer to *A. japonicus*. The objective of this study was to improve the knowledge on *A. japonicus*, especially its external morphological features, distribution, habitat and ecological preferences in the Netherlands. The distribution and ecology was compared with that of *A. plurisetus*.

MATERIAL AND METHODS

In total, 70 sites were sampled in 1997. Either a standard pond net (mesh size 0.5 mm, width 30 cm) or a micro-macrofauna shovel (mesh size 0.5 mm, 10 cm width and 15 cm long) was used for taking samples. At each site all major habitat types were sampled in approximate proportion

to the frequency of occurrence. The oligochaetes were sorted alive, fixed in formalin (4%), and mounted in polyvinyl lactophenol prior to identification. The numbers of specimens per habitat type were expressed in abundance per square meter.

Thirteen environmental factors were measured at each of the sites. For all sites where *A. japonicus* and/or *A. pluriseta* occurred the minimum, average, and maximum as well as the standard deviation were calculated for each environmental factor.

The microhabitat preference of *A. japonicus* was studied in detail at 24 sites representing a variety of water types present in the Netherlands. In total, 78 microhabitat samples were collected.

The life history of *A. japonicus* was studied over one year (2002-2003) in the ‘Heelsumse beek’ a small, sandy lowland stream. For this study, two samples of each major habitat were taken every two months.

Water type	<i>A. japonicus</i>	<i>A. pluriseta</i>
natural streams	20	5
canalised streams	7	1
canals	5	
ditches	6	
total	38	6

Table 1. Number of records of *Aulodrilus japonicus* and *Aulodrilus pluriseta* per water type.

Tabel 1. Aantal vondsten van *Aulodrilus japonicus* en *Aulodrilus pluriseta* per watertype.

In total 12 immature and 8 mature specimens of *A. japonicus* were studied to describe the morphological features, especially the number of chaetae and hairs, and the length of the chaetae. The significance of morphological differences between immature and mature specimens was tested by using an analysis of variance.

Parameter	Minimum	Average	Maximum	Standard deviation	Number of observations
pH	6.4	6.9	7.1	0.3	7
conductivity (µS/cm)	283	540	760	176	8
dissolved oxygen (mg/l)	6.0	8.4	10.1	1.5	8
average depth (m)	0.06	0.15	0.29	0.08	8
average current velocity (m/s)	0.050	0.143	0.260	0.073	8
maximum current velocity (m/s)	0.136	0.266	0.530	0.140	8
chloride (mg/l)	35.0	48.8	67.4	12.1	6
ammonium (mgN/l)	0.10	0.43	1.00	0.38	6
nitrite (mgN/l)	0.020	0.052	0.085	0.025	6
nitrate (mgN/l)	1.10	2.82	4.75	1.325	6
ortho-phosphate (µgP/l)	7.00	49.17	140.00	52.553	6
total phosphate (µgP/l)	58.00	142.83	270.00	83.925	6
chlorophyl (µg/l)	5.00	10.96	23.83	8.75	4

Table 2. Physical and chemical characteristics of the habitat of *Aulodrilus pluriseta*.

Tabel 2. Fysische en chemische karakteristieken van de habitat van *Aulodrilus pluriseta*.

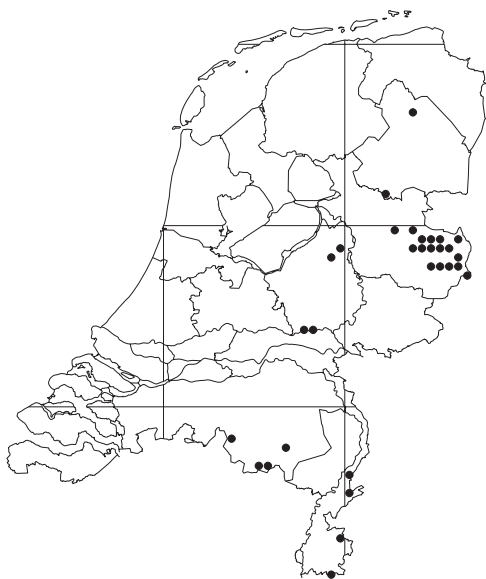


Figure 1. Records of *Aulodrilus japonicus* in the Netherlands.
 Figuur 1. Vindplaatsen van *Aulodrilus japonicus* in Nederland.



Figure 2. Records of *Aulodrilus plurisetia* in the Netherlands.
 Figuur 2. Vindplaatsen van *Aulodrilus plurisetia* in Nederland.

Parameter	Minimum	Average	Maximum deviation	Standard observations	Number of
pH	5.4	6.9	8.4	0.6	47
conductivity ($\mu\text{S}/\text{cm}$)	102	411	835	163	50
dissolved oxygen (mg/l)	3.9	8.6	14.0	1.9	50
average depth (m)	0.0	0.3	1.8	0.4	43
average current velocity (m/s)	0.009	0.155	0.525	0.117	43
maximum current velocity (m/s)	0.016	0.257	0.690	0.178	47
chloride (mg/l)	5.0	30.6	67.4	15.4	30
ammonium (mgN/l)	0.03	0.21	1.00	0.19	30
nitrite (mgN/l)	0.008	0.082	0.512	0.130	30
nitrate (mgN/l)	0.15	5.99	43.00	10.840	30
ortho-phosphate ($\mu\text{gP}/\text{l}$)	0.08	40.88	150.00	36.938	30
total phosphate ($\mu\text{gP}/\text{l}$)	0.04	113.53	270.00	74.539	30
chlorophyl ($\mu\text{g}/\text{l}$)	0.89	11.97	66.00	16.50	15

Table 3. Physical and chemical characteristics of the habitat of *Aulodrilus japonicus*.
 Tabel 3. Fysische en chemische karakteristieken van de habitat van *Aulodrilus japonicus*.

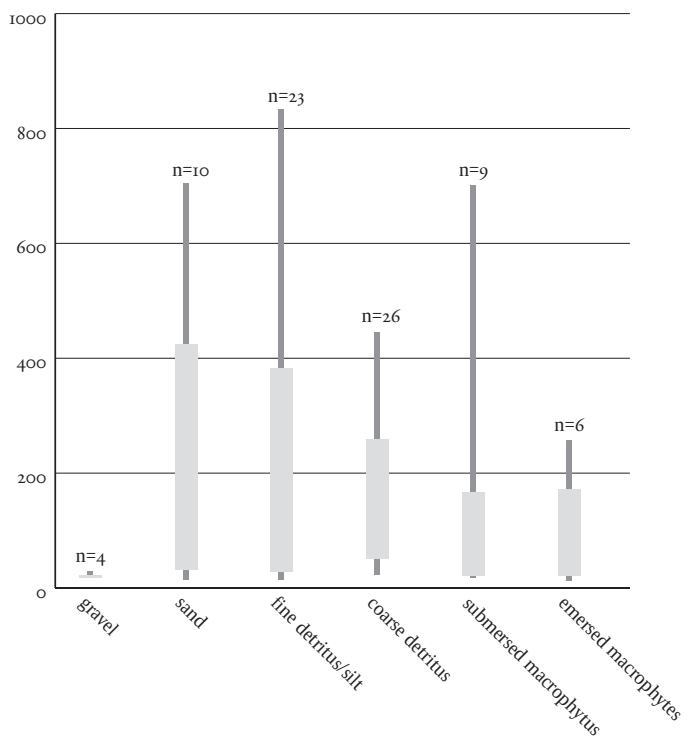


Figure 3. The habitat preference of *Aulodrilus japonicus*.
 Figuur 3. De habitatvoorkeur van *Aulodrilus japonicus*.

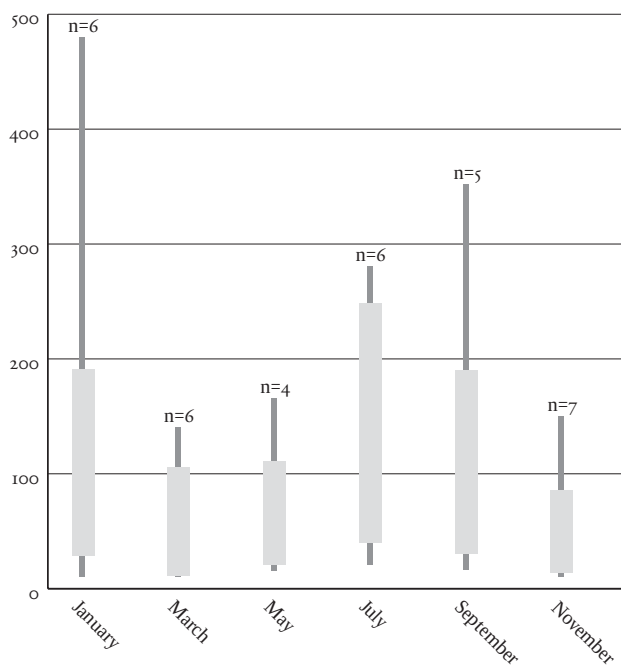


Figure 4. The abundance of *Aulodrilus japonicus* in the Heelsumse stream during the year.
 Figuur 4. De abundantie van *Aulodrilus japonicus* in de Heelsumse beek gedurende het jaar.

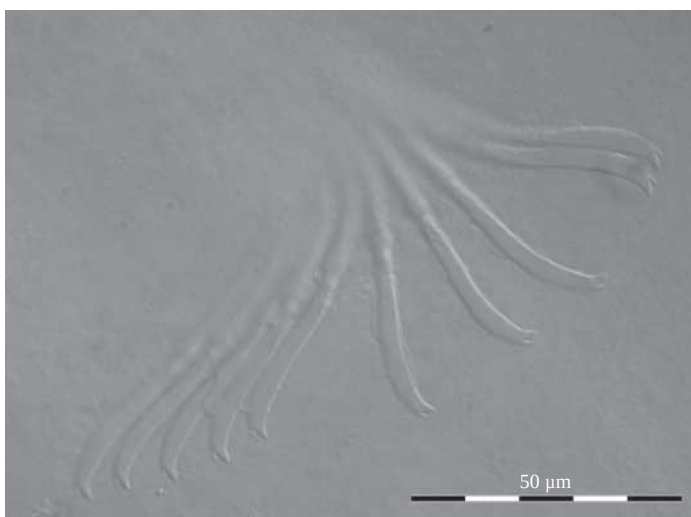


Figure 5. Anterior ventral bifid chaetae of *Aulodrilus japonicus*.
 Figuur 5. Anterieure ventrale chaetae van *Aulodrilus japonicus*.

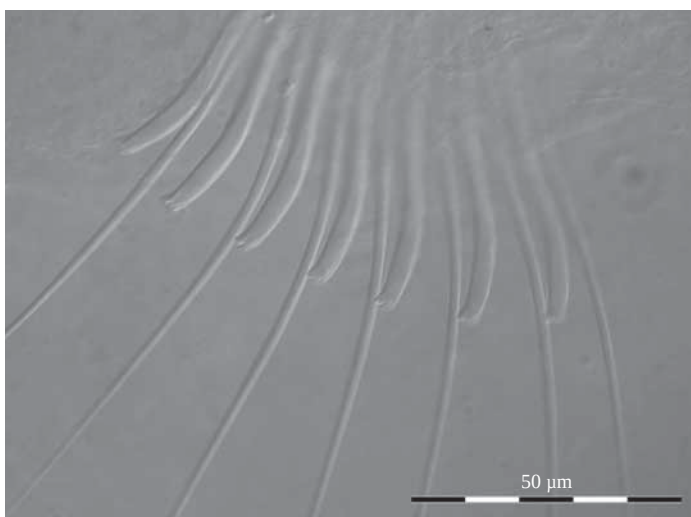


Figure 6. Anterior dorsal hairs and bifid chaetae of *Aulodrilus japonicus*.
 Figuur 6. Anterieure dorsale haarchaetae en dubbelpuntige chaetae van *Aulodrilus japonicus*.

RESULTS

Aulodrilus japonicus was first collected in 1997 in two lowland streams (Reusel and Rosep) situated in the south of the country. Shortly after these findings the species was collected at 38 sites in the eastern part of the Netherlands (fig. 1). It was mainly found in lowland streams, occasionally in canalised streams, canals and ditches (table 1). From these findings *A. japonicus* appears

to be eurytopic with a preference for lowland streams with a low current velocity. *Aulodrilus japonicus* reached the highest density of 3120 individuals per square meter in the Old Leutink stream.

The distribution of *A. plurisetus* was limited to six locations (fig. 2, table 1), always together with *A. japonicus*. *Aulodrilus plurisetus* also preferred

small to medium sized lowland streams with one exception, a canalised stream. The population density was always less than 20 individuals per square meter.

Aulodrilus japonicus did not show any habitat preference (fig. 3), but it clearly avoids gravel. *Aulodrilus pluriset*a occurred in sand, but also in fine detritus/silt and course detritus.

The population density of *A. japonicus* (fig. 4) was highest in January and from July to September. Maximum density was reached in January (780 individuals/m²). Mature specimens only occurred in July and represented a very small proportion of the total population (8 individuals or 3.25% of the total number).

In general, the ecological range of *A. pluriset*a (table 2) is similar to that of *A. japonicus* (table 3), except for nitrate which was somewhat lower for *A. pluriset*a. The data confirm the eurytopic character of both species.

The morphology of the genital organs of *A. japonicus* is described in detail by Hrabě (1981) and Finegenova & Arkhipova (1994). Less attention was paid to the external morphological features. The anterior dorsal bundles of *A. japonicus* have 6-12 bifid chaetae (length 94.1 ± 9.6 µm) and 6-9 short hair chaetae (±140 µm). The ventral bifid chaetae (length 94.3 ± 6.4 µm) are similar to those of *A. pluriset*a, anterior with 8-12 chaetae and posterior with 6-10. The ventral chaetae are all strongly sigmoid, with the upper teeth shorter and thinner than the lower, and frequently with some small teeth around the upper tooth (fig. 5). In *A. japonicus* the dorsal chaetae are modified, starting from about segment IV to VII. The upper teeth of these dorsal chaetae are modified with a row of small teeth semicircle around the lower teeth (fig. 6). Specimens with regenerated segments can have these characteristic dorsal chaetae already in segment II. The dorsal chaetae of *A. pluriset*a are not modified.

Chaetal measurements of 12 immature and 8 mature specimens of *A. japonicus* showed significant differences between the sizes and length of dorsal hairs and dorsal bifid chaetae of immature and mature specimens.

Furthermore, a significant difference of 1.2 chaetae ($p < 0.001$) was shown between the right and left number of dorsal bifid chaetae of *A. japonicus*.

KEY TO THE DUTCH SPECIES OF *AULODRILUS*

Based on Brinkhurst & Jamieson (1971), Brinkhurst (1971), Kathman & Brinkhurst (1998) and Finegenova & Arkhipova (1994).

- 1 Dorsal bundles with hairs 2
 - Dorsal bundles without hairs, up to 10 chaetae anteriorly, all bifid chaetae with the upper tooth shorter and thinner than the lower, those of the first bundles shorter and thicker and more strongly sigmoid than the rest. Chaetae of mid and posterior segments with lateral wings. Vasa deferentia long, atria long, cylindrical, eversible pseudopenes *Aulodrilus limnobius* Bretscher, 1899
 - 2 Anterior dorsal chaetae modified (look carefully at dorsal chaetae of segments II-XX) . . . 3
 - Anterior dorsal bundles with up to 8 short hair chaetae, and up to 10 bifid chaetae with 1 to several upper teeth which are thinner and shorter than the lower. Anterior ventral chaetae up to 16 chaetae per bundle, upper tooth shorter and thinner than the lower. Vasa deferentia fairly long, atria globular, large eversible pseudopenes *Aulodrilus pluriset*a (Piquet, 1906)
- Could be confused with *Branchiura sowerbyi* Beddard, 1982 when specimens lack posterior segments, both species could be separated by the pectinate chaetae of *B. sowerbyi* instead of the bifid chaetae from *A. pluriset*a.

	Immature specimens	Mature specimens	Standard error	p<0.001
number of specimens measured	12	8		
average number of dorsal hair chaetae	4.90	5.65	0.13	***
average number of dorsal bifid chaetae	8.05	9.40	0.20	***
length of dorsal bifid chaetae (µm)	88.05	94.09	0.67	***

Table 4. Chaetal measurements of immature and mature specimens of *Aulodrilus japonicus* (number of hair and dorsal bifid chaetae and length of chaetae). The difference between mature and immature specimens were tested by an ANOVA.

Tabel 4. Metingen van geslachtsrijpe en niet-geslachtsrijpe individuen van *Aulodrilus japonicus* (aantal haren, dorsale chaetae and lengte van chaetae). Het verschil tussen geslachtsrijpe en niet-geslachtsrijpe individuen is getoetst met ANOVA.

- 3 Dorsal anterior bundles with 4-5 or up to 12 simple pointed or bifid chaetae, the upper tooth shorter and thinner than the lower, and 2-5 hair chaetae often start in IV-VII, beyond VII bifid chaetae become oar-shaped. Anterior ventral bundles with 4-7 of 12 bifid chaetae with upper tooth shorter and thinner than the lower. Penial chaetae modified, two hollow spoon-shaped chaetae per bundle. Vasa deferentia short, atria bean-shaped, large eversible pseudopenes open via a median inversion of the body wall *Aulodrilus piqueti* Kowalevsky, 1914
- Anterior dorsal bundles with up to 12 chaetae, from about segment (II)-VI or VII with the distal teeth modified into numerous thin teeth semicircle around the lower teeth, dorsal bundles with 6-9 short hair chaetae. Anterior ventral bundles with 8-12 chaetae and posterior with 6-10 chaetae, strongly sigmoid with the distal tooth shorter and thinner than the proximal teeth. No modified genital chaetae. Vasa deferentia long, atria spindle-shaped, pseudopenes conical *Aulodrilus japonicus* Yamaguchi, 1953

DISCUSSION

Most representatives of the genus *Aulodrilus* have a world-wide distribution (Brinkhurst 1971, Kathman & Brinkhurst, 1998). Only *A. pluriset*a is not yet recorded from South America (Brinkhurst & Jamieson, 1971). Ohtaka & Nishino (1995) classified *A. japonicus* as a holarctic species. Despite their world-wide distribution little is known about the ecology (Milbrink 1973, pers. comm. A. Ohtaka). The confusion of *A. pluriset*a and *A. japonicus*, which probably have a similar distribution (Milbrink 1973) and ecology make the published information unreliable. Both species occur in several water types: rivers, streams, ditches, canals, lakes and pools. They prefer silty substrates in mesotrophic habitats and are moderately tolerant for organic enrichment (Brinkhurst & Wetzel 1984, Stimpson et al. 1982, Chekanovskaya 1962, 1981, Milbrink 1973). *Aulodrilus japonicus* is widespread over the Japanese islands, but mature worms were rarely collected (pers. comm. A. Ohtaka), probably because asexual reproduction is dominant as in other *Aulodrilus* species. Ohtaka (pers. comm.) reports that on the type locality, Sapporo (Japan), a small part of the population (less than 15%) matures in August, which corresponds to our data. This study showed that *A. pluriset*a is quite rare

in the Netherlands and that *A. japonicus* is dominant and widespread. *Aulodrilus japonicus* reaches the highest densities in January and July. In January no mature worms were found, so most probably this peak was due to non-generative reproduction. In summer also sexual reproduction probably plays a role. *Aulodrilus japonicus* is a eurytope species, common in lowland streams, which prefers coarse organic substrates and sandy substrates with a high content of fine organic material (Verdonschot 2001). Perhaps *A. pluriseta* is more restricted to natural streams. Both species seem to avoid gravel. In Japan specimens of *A. japonicus* were collected in silt or mud bottoms of lake littorals or gentle streams (pers. comm. A. Ohtaka), which corresponds to our data. We expect *A. japonicus* to be distributed throughout the whole of the Netherlands and probably the whole of the northwestern European lowland. The external morphology of *A. japonicus* has been poorly described. Finegenova & Arkhipova (1994) indicated a lower number of chaetae in the dorsal bundles (3-6 hairs and 4-8 chaetae). The descriptions of Hrabě (1981) (5-8 dorsal hairs and 5-10 dorsal chaetae) agree more to the Dutch specimens. Yamaguchi (1953) and Hrabě (1981: 147, fig. 5) included quite unclear drawings of the modified dorsal chaetae. In these drawings the dorsal teeth look duplicated instead of modified into a row of fine teeth semicircle around the lower teeth. Pinder & Brinkhurst (2000) also described the dorsal chaetae as lateral replicate teeth occurring on either side of the main tooth. The latter authors consider the replicate teeth as a form of pectination which has been shown to vary in other tubificids. All studied specimens of *A. japonicus* show the dorsal row of fine teeth semicircle around the proximal tooth. No intermediate forms between *A. japonicus* and *A. pluriseta* with modified or duplicated dorsal teeth were found. These findings confirm the description given by Finegenova & Arkhipova (1994: 8, fig. 6, 8). It must be noted that the modified dorsal chaetae can only be seen at a magnification of 1000 times.

ACKNOWLEDGEMENTS

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SAMENVATTING

Verspreiding en ecologie van de worm *Aulodrilus japonicus* in Nederland (Oligochaeta: Tubificidae)

De worm *Aulodrilus japonicus* Yamaguchi, 1953 is in 1997 voor het eerst in ons land herkend. Lange tijd is deze soort niet herkend vanwege de grote gelijkenis met de andere soorten in het genus, met name *A. pluriset*a. In dit artikel wordt een onderzoek naar de ecologie, verspreiding en levenscyclus in Nederland besproken. Daarnaast is de uitwendige morfologie onderzocht en is een determinatietabel voor de soorten van het genus *Aulodrilus* in Nederland opgesteld. *Aulodrilus japonicus* is op 38 van de 70 onderzochte locaties waargenomen, meestal als dominante oligochaet. De soort heeft geen duidelijke voorkeur voor een bepaald habitat. Populaties van *A. japonicus* vertonen een piek in aantallen in januari en van juli tot september. Geslachtsrijpe individuen zijn alleen in juli waargenomen en kwamen in zeer lage aantallen voor. *Aulodrilus japonicus* is een eurytope soort. We verwachten dat de soort algemeen in Nederland voorkomt en waarschijnlijk ook in grote delen van de rest van Noordwest-Europa.

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