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THE MAYFLY, *EPHORON VIRGO* (OLIVIER), BACK IN THE DUTCH PARTS OF THE RIVERS RHINE AND MEUSE.

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ABSTRACT

Due to severe water pollution, the mayfly *Ephoron virgo* (Olivier) disappeared from the Dutch parts of the rivers Rhine and Meuse in the first half of this century. In August 1991, however, larvae were found in the littoral zone of the Rhine near the Dutch-German border. Later, other stages were found along the Rhine branches and a small section of the Meuse. The occurrence in The Netherlands is the result of further expansion from the upstream regions of the Rhine.

INTRODUCTION

Morphological changes and water pollution in the rivers Rhine and Meuse resulted in the disappearance of habitats and, as a consequence, in the extinction of macroinvertebrate and fish species (KLINK, 1989; VAN DEN BRINK *et al.*, 1990). In the sixties of this century, water pollution of the Rhine reached maximum proportions, and the number of mayfly species had decreased from 21 around the turn of this century to two in that period. Only *Cloeon dipterum* (L.) and *Caenis luctuosa* (Burm.), living outside the summer bed, survived (KLINK, 1989; VAN DEN BRINK *et al.*, 1990). In the same period, measures were taken to reduce emissions of pollutants (VAN DER KLEI *et al.*, 1991). Effects of these measures on the macroinvertebrate community became visible in the next decades; the density and the number of species observed increased considerably (VAN URK, 1981; VAN URK and BIJ DE VAATE, 1990; VAN DEN BRINK *et al.*, 1990).

Water pollution in the Meuse is still a serious problem. Mayflies in the summer bed of both rivers were absent for some decades. The mayfly *Ephoron virgo* (Oliv.) is known to have occurred in massive numbers in the rivers Meuse and Rhine in The Netherlands until the first decades of this century (MOL, 1981). No observations of this species in the period after 1936 are known (MOL, 1985). Its extinction must have been the result of the severe water pollution in both rivers, which led to low oxygen contents in the river water, being unfavourable for most macroinvertebrate species. In the Dutch part of the Rhine oxygen concentration improved considerably in the last two decades (BIJ DE VAATE and OOSTERBROEK, 1992). Improvement of the water quality in upstream parts of the river in Germany led to the recolonization of *E. virgo* some years before (TITTIZER *et al.*, 1990).

METHODS

Larvae of *E. virgo* were collected in bottom samples, taken in the littoral zone with a hydraulic Van Veen grab (BIJ DE VAATE and OOSTERBROEK, 1992). After the discovery of the larvae, of which a part had already developed to the last instar (Mol, pers. comm.), other stages of the mayfly were used to study the recolonization pattern. The strategy was to look for exuviae of the subimagos and dead imagos in spider's webs at illuminated objects along or above the river.

RESULTS AND DISCUSSION

During a routine sampling in the littoral zone of the right bank in the Lower Rhine near Tolkamer, on 1991-August-13, larvae of the mayfly *E. virgo* were found in the bottom samples. Two days later, larvae were found at the same location and at a location in a similar habitat, about 7 km downstream (BIJ DE VAATE and OOSTERBROEK, 1991). A survey on different

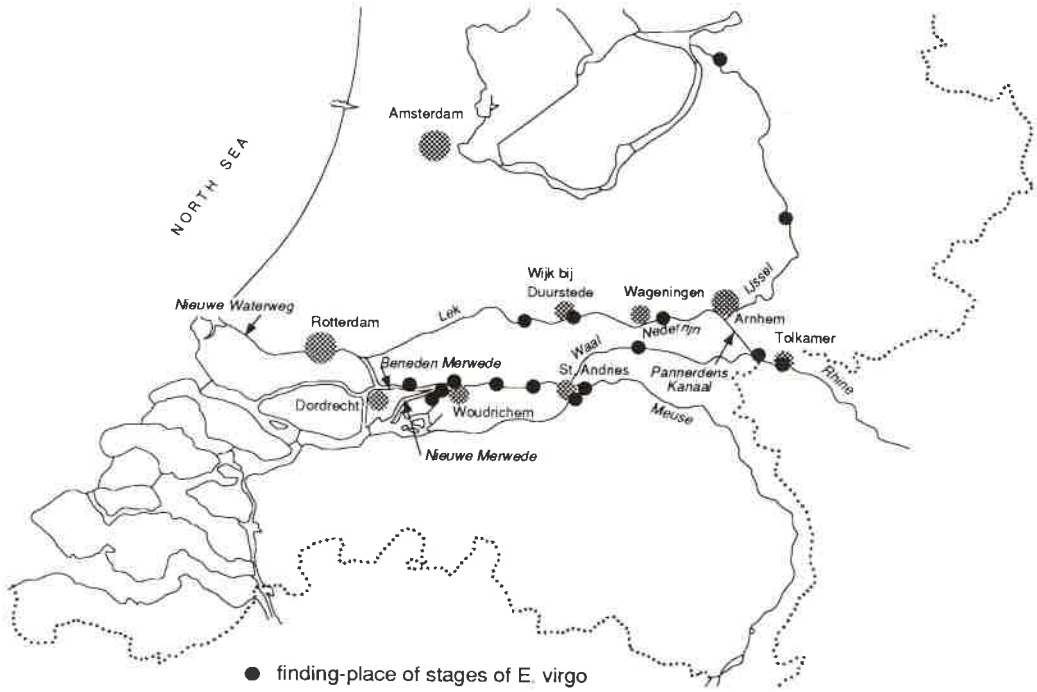

Fig. 1. Finding-places of different stages of *E. virgo* in the River Rhine, its branches, and in the River Meuse in The Netherlands in 1992.

locations in the Rhine branches and in the Meuse afterwards, led to the conclusion that *E. virgo* had already colonized the Rhine branches and a small part of the Meuse (Tables 1 and 2; Fig. 1). In general, the presence of the species was concluded from discoveries of both exuviae of subimagos and imagos in spider's webs. Exceptions were: (a) in the Waal, the location at kmr 906, at which exuviae of different stages were found in the material washed ashore; (b) a location in the Nieuwe Merwede at kmr 971; dead imagos were found on both river banks near the ferry ramps; (c) two locations at which swarms of imagos were observed, *viz.* in the Nederrijn/Lek near the harbour of Wageningen and in the Waal at kmr 953 near Woudrichem.

In the Nederrijn, at the location near the harbour of Wageningen, swarming of the imagos was observed on 1991-August-25 to 1991-August-29. Swarming started at 9.40 P.M. and ended at 10.20 P.M. Eggs were laid between 9.40 and 10.10 P.M.

The river bottom, from which the larvae were collected, mainly consisted of sand (Table 3). SCHÖNEMUND (1938) mentioned this substrate to be in general the habitat in which larvae of *E. virgo* live. However, according to SCHLEUTER *et al.* (1989), this is probably not the most favourite habitat for these animals. From their observations they concluded that a mixture of coarse (grain size >60 mm) and fine (grain size <60 mm) material is preferred, and that sandy bottoms are avoided.

The animals observed in the Meuse must originate from the Waal. At kmr 209 the Meuse is connected with the Waal by a canal of one km, provided with a lock. By tidal movements of the North Sea, noticeable up to the weir at kmr 201, upstream locations between kmr 201 and 209 can be reached by drifting stages. Colonization of the Meuse from upstream locations outside The Netherlands can be rejected as a possible explanation. The most recent observation known is from 1986 when two larval exuviae were found in a driftnet samle from a location near Hastière, near the Belgian-French border (FRANTZEN, 1991; KETELAARS, pers. comm.). In Belgium the Meuse is severly polluted by industrial and domestic waste water (RIWA, 1989; FRANTZEN, 1991) and forms an effective barrier for the downstream migration of species which are sensitive to the effects of pollution. In the Dutch part of the river, however, water quality improves. This is not only the result of the breakdown of organic matter, but also of the sedimentation of suspended materials, by which organic micropollutants and heavy metals are adsorbed (VAN VUUREN,

Table 1. List of first observations of different stages of *E. virgo* in the Lower Rhine and the Rhine branches.

[1]) the international accepted indication of river distance in km; [2]) no stages found.

River stretch	Kmr[1])	Date (1991)	Location	Number and status of specimens found
Lower Rhine	861	13 Aug.	right bank	14 larvae
	861-868	15 Aug.	right bank	12 larvae
	863	22 Aug.	right bank, permanent sampling station	exuviae of subimagos and imagos
IJssel	935.5	29 Aug.	left bank	2 ♂ imagos
	979.6	28 Aug.	bridge over the river	2)
	985,5	26 Aug.	bridge over the river	exuviae of subimagos and several hundreds of imagos
Nederrijn/Lek	900	25 Aug.	ferry	some tens imagos
	903	25 Aug.	near harbour of Wageningen	swarm of ca. 100 ♀ imagos
	927	31 Aug.	ferry	ca. 300 ♀ imagos and including many clumbs of eggs
	940	31 Aug.	ferry	1 ♀ imago
	953.5	27 Aug.	right bank, camping	2)
	961	27 Aug.	right bank, house	2)
Waal	886	2 Sept.	left bank, electric power plant	2)
	906	1 Sept.	right bank	over 100,000 exuviae of larvae and ca. 1,000 exuviae of subimagos
	915	2 Sept.	right bank, harbour of Tiel	2)
	937	2 Sept.	left bank	some imagos
	946	31 Aug.	ferry	ca. 150 ♀ and 1 ♂ imagos, some clumbs of eggs
	952	2 Sept.	right bank, permanent sampling station	some imagos
	953	31 Aug.	left bank	swarm of 10 ♀ and ca. 125 ♂ imagos, no eggs laid
Nieuwe Merwede	962,6	30 Aug.	left bank, harbour of Werkendam	dozens of imagos
	971	30 Aug.	right and left bank, near ferry	thousands of imagos

Table 2. List of first observations of different stages of *E. virgo* in the River Meuse.

[1]) and [2]) see Table 1.

Kmr[1])	Date (1991)	Location	Number and status of specimens found
201	28 Aug.	weir	2)
202	28 Aug.	ferry	8 imagos
210	1 Sept.	ferry	3 ♀ imagos
220	28 Aug.	bridge over the river	2)
228,8	2 Sept.	ferry	2)
230,5	28 Aug.	bridge over the Heusdens	2)
	1 Sept.	Kanaal	2)
236,6	2 Sept.	ferry	2)
241,6	2 Sept.	ferry	2)

1989). Sedimentation of silt in the river between the weirs is possible in the growing season when discharge of the river is relatively low (ANON., 1991). From the observations it can be concluded that at least after the last weir at kmr 201 water quality has improved sufficiently to allow larval development of *E. virgo* to imagos.

Tabel 3. Grain size composition, and standard deviation (S.D.; n=6) of the top layer of the Rhine bottom at the locations where larvae of *E. virgo* were found.

grain size	%	S.D.
0-2 µm	2,9	2,4
2-8 µm	1,0	1,1
8-25 µm	1,2	0,8
25-75 µm	2,2	2,0
75-210 µm	9,6	5,6
210-600 µm	54,8	16,7
0.6-2.0 mm	13,0	9,1
2-4 mm	6,1	5,1
4-9 mm	7,1	5,4
9-16 mm	2,0	2,8

Recolonization of the Dutch part of the Rhine by *E. virgo* is the result of a further extension of its range of distribution. In the upstream part of the Rhine, in the Federal Republic of Germany, recolonization started from a refugium in a tributary, probably the Main (BATHON, 1983). In 1986, the Rhine was colonized in downstream direction up to the town of Bonn, at kmr 652-658 (TITTIZER *et al.*, 1990), and in 1990, according to Schöll (pers. comm.), to the town of Düsseldorf at kmr 721-723. Finally, in 1991 the Rhine was further recolonized by *E. virgo* towards the freshwater tidal zone.

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