SPECIES ACCOUNT FOR *ANISUS VORTICULUS* (TROSCHEL, 1834) (GASTROPODA: PLANORBIDAE), A SPECIES LISTED IN ANNEXES II AND IV OF THE HABITATS DIRECTIVE

AURÉLIE TERRIER[1], EMMANUEL CASTELLA[1], GERHARD FALKNER[2] & IAN J. KILLEEN[3]

[1] Laboratoire d'Ecologie et de Biologie Aquatique et Centre en Sciences Naturelles de l'Environnement, University of Geneva, 18 chemin des Clochettes, CH-1206 Geneva, Switzerland.
[2] Raiffeisenstrasse 5, D-85457 Wörth-Hörlkofen, Germany.
[3] 53 Charleville Square, Rathfarnham, Dublin 14, Ireland.

Abstract *Information from more than hundred published sources, augmented by previously unpublished expert knowledge, is compiled to build up a species account for the Western Palaearctic planorbid gastropod* Anisus vorticulus *(Troschel, 1834), threatened at European level and recently listed in the EU Habitats Directive. The account summarizes the available data about the species, including identification, environmental requirements, life cycle, dispersal, food, geographic distribution and threats, together with recommendations for site management and survey procedures. The species occurs in both natural habitats (lake littoral, streams, river floodplains) and man-made habitats (drainage ditches, excavations). It is mostly associated with calcareous, moderately well vegetated habitats, especially with abundant floating plant coverage. The species has normally an annual life-cycle but the few available data suggest a high spatial and inter-annual variability in its phenology. To date, conservation measures for the species included vegetation removal and translocation. A dearth of quantitative and general information is obvious for almost all aspects of the biology and ecology of the species and prevents informed conservation recommendations being made.*

Key words Anisus vorticulus, *Planorbidae, Habitats Directive, ecological requirements, site management.*

INTRODUCTION

Since the 1st May 2004, the planorbid gastropod *Anisus vorticulus* (Figure 1) has been listed in the EU Habitats and Species Directive as a species of community interest, requiring special areas for conservation (Annex II) and strict protection (Annex IV). Conservation actions, surveillance, as well as research programmes will have to be undertaken by the member states in which the species occurs. However, the biology and ecology of the species remain relatively poorly known. This account brings together the widely dispersed information that is available, as an aid to conservation of the species and its habitats. It does not purport to be a definitive account, but only a statement of what is currently known. The present species account follows the format adopted by Cameron, Colville, Falkner *et al*. (2003) for four species of the genus *Vertigo*.

CLASS GASTROPODA
ORDER PULMONATA
SUB-ORDER BASOMMATOPHORA
FAMILY PLANORBIDAE

Contact author : Emmanuel.Castella@leba.unige.ch

Anisus (*Disculifer*) *vorticulus* (Troschel 1834)

Planorbis vorticulus Troschel 1834, *De Limnaeaceis*, p. 51.
Planorbis charteus Held 1837, *Isis* (Oken), 1837 (**4**): 305.
Planorbis acien Megerle von Mühlfeld A. & G. B. Villa 1841, *Disp. syst. Conchyliarum*, p. 34 [nom. nud.].
Planorbis acies Porro A. Schmidt 1851, *Verh. naturhist. Ver. preuss. Rheinl. Westph.*, **8**: 331 [nom. nud.].
Planorbis acies A. Schmidt 1856, *Z. ges. Naturwiss*., **8** (8/9): 154 [Beitr. Malak., p. 38].
Planorbis acies O. Goldfuss 1856, *Verh. naturhist. Ver. preuss. Rheinl. Westph*., **13**: 80.
Planorbis acies, — Kreglinger 1870, *Syst. Verz. Binnen-Moll*., pp. 287-288.
Planorbis vorticulus var. *bavaricus* Westerlund 1874, *Malak. Bl*., **22** (2): 106.
Planorbis (*Gyrorbis*) *vorticulus*, — Clessin 1877, *Excursions-Mollusken-Fauna,* Lief. 3, pp. 405-406.
Planorbis (*Diplodiscus*) *vorticulus* et *charteus*, — Westerlund 1897, *Acta Soc. Fauna Flora fenn*., **13** (7): 116-117.
Spiralina vorticulus, — Ehrmann 1933, *Tierw. Mitteleur.*, **2** (Lief. 1): 167-168.
Anisus (*Disculifer*) *vorticulus*, — C. Boettger 1944, *Tierw. Nord- u. Ostsee*, IX.b: 263.

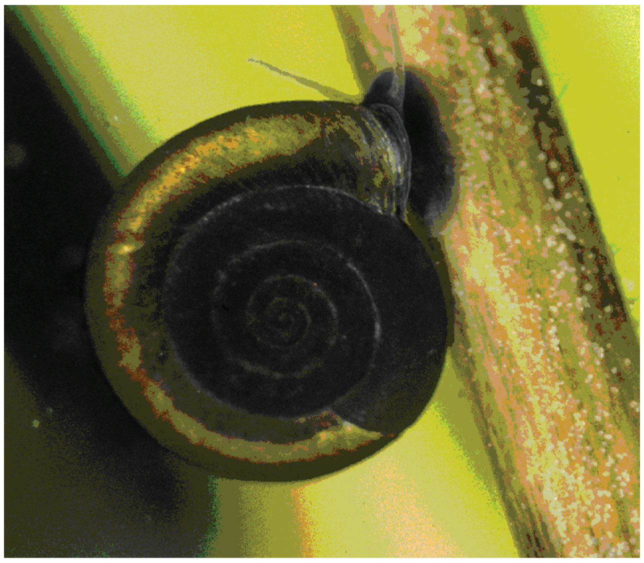

Figure 1 *Anisus vorticulus* (Troschel, 1934) from a ditch in the Vierlande marshes (former Elbe floodplain, upstream from Hamburg, Germany). The dark inner whorls are incrusted with iron manganate. The growth interruption marks the end of aestivation (specimen collected 25th August 1991, largest diameter of the shell: 5.3 mm, picture G. Falkner).

Identification

Descriptions and illustrations of the species are provided by Hudec (1967), Falkner (1990), Glöer (2002) and Glöer & Meier-Brook (2003). Both Glöer (2002) and Glöer & Meier-Brook (2003) provide an identification key that allows separation of the species from other Planorbidae. The reproductive apparatus is described and illustrated by Hudec (1964, reproduced in Glöer, 2002) and Grossu (1987). Piechocki (1979) and Beriozkina & Starobogatov (1988) show drawings of the egg capsule.

It is possible to confuse specimens of *Anisus vorticulus* with dwarf forms of *A. vortex* that occur in temporary water bodies (described as *Planorbis numulus* Held 1837). However, the transversal section of the whorls is more angular in young *A. vortex*, and *A. vortex* does not exhibit the periostracal "membrane" that often accentuates the carina in *A. vorticulus*.

Brief description of the species

This description is based upon Glöer (2002) and Germain (1931). The shell is pale, yellowish-brown and has longitudinal micro-ridges. The 5-6 convex whorls show a regular and slow growth (the penultimate whorl is only slightly smaller than the last). They are separated by a clear suture. The functional upper side (i.e. that of the crawling animal) is flat to slightly concave, whereas the lower is more distinctly, but not deeply, concave. The aperture is oval-elliptical with a depressed outer margin. The outer edge of the last whorl has a carina that can vary from rounded to very sharp. The carina often bears a thin expansion of the periostracum (forma *charteus*). In old specimens there is a tendency for this "membrane" to be visible only rarely. The shell is 0.5-0.8 mm high and 4-5 mm in diameter. Exceptionally, the diameter reaches 6-7 mm (Germain, 1931). The conchological variability, as potentially influenced by environmental factors (desiccation), is broadly discussed in Clessin (1876).

From observations derived from breeding *A. vorticulus* in an aquarium, Piechocki (1979) described the egg masses as oval capsules, 1.3 to 1.6 mm long and 1.2 to 1.4 mm wide surrounded by a suture. Each capsule contained 4 to 5, 0.5-0.6 mm long, ovoid eggs. He observed that, in some capsules, the eggs did not develop.

Habitats

The habitat characterization of the species lacks precision in many published sources. In such cases, only very broad categories are reported hereunder. From the available information two groups of *Anisus vorticulus* habitats can be identified.

Water bodies of natural origin

- The littoral of lakes (Schermer, 1930, 1932; Piechocki, 1979; Schmid, 1983; Müller & Meier-Brook, 2004).
- The banks of streams and slow rivers (Piechocki, 1979).
- Various types of water bodies in river floodplains (isolated pools, former channels and meanders) (Clessin, 1872; Geissert, 1960; Hässlein, 1966; Schmid, 1978, 1997; Piechocki, 1979; Yacine-Kassab, 1979; Castella, 1982, 1987; Henry *et al.*, 1994; Beran, 1997, 2000, 2002; Falkner *et al.*, 2002; Cucherat & Vanappelghem, 2003; Pellaud, 2004; Castella, Terrier, Pellard & Paillex, 2005). This habitat type is cited as the most typical for the species in several countries

such as France, Poland and the Czech Republic. In Germany about one half of the known occurrences are situated in river floodplains. The species has also been found as a Pleistocene fossil associated with alluvial deposits of the rivers Thames (Bridgland, Preece, Roe *et al*., 2001; Preece, 1999) and Avon (Maddy, Keen, Bridgland & Green, 1991).

- Small natural water bodies in fens (Piechocki, 1979).
- Coastal dune pools, as reported in the study of an 800-years old coastal paleo-environment in Holland (Kuijper, 2002).

Water bodies of anthropogenic origin

- Drainage ditches in humid grassland (Boycott, 1936; Piechocki, 1979; Killeen, 1992, 1999; Killeen & Willing, 1997; Willing & Killeen, 1998; Watson & Ormerod, 2004a, 2004b; Willing, 1999; Müller & Meier-Brook, 2004). These ditches are man-made linear water-bodies, the depth and discharge of which are often regulated by weirs and/or pumping stations (Watson & Ormerod, 2004b).
- Ditches and excavations in exploited peatland (Piechocki, 1979; Müller & Meier-Brook, 2004).
- Ponds created in sand pits (Beran, 1997; 2002).

MICROHABITATS AND ENVIRONMENTAL PARAMETERS

Anisus vorticulus occurs mostly in standing water (Ehrmann 1933, Frömming, 1956; Yacine-Kassab, 1979; Piechocki, 1979; Grossu, 1987; Glöer & Meier-Brook, 2003; Turner *et al*., 1998; Glöer, 2002), permanent (Yacine-Kassab, 1979; Turner *et al*, 1998; Cucherat & Vanappelghem 2003), clear (Ehrmann 1933, Frömming, 1956; Grossu, 1987; Yacine-Kassab, 1979; Beran, 1997; Glöer & Meier-Brook, 1998; Glöer 2002; Cucherat & Vanappelghem, 2003; Turner, Kuiper, Thew *et al*, 1998). The species is mentioned by some authors (e.g. Yacine-Kassab, 1979; Turner *et al*, 1998) as associated with oxygen-rich water, however, this statement contrasts with its known occurrence in well-vegetated water bodies where oxygen concentrations can fluctuate and reach very low levels. *A. vorticulus* can stand highly fluctuating water levels in floodplain water bodies, but does not seem to survive full desiccation (Colling & Schröder, in press). For Pleistocene ecological reconstruction, Sparks (1961) regarded *A. vorticulus* as member of a "ditch group" of species often found in ditches with "clean, slowly-moving water and abundant growth of aquatic plants". In contrast to *Anisus vortex*, the species does not occur in brackish (even slightly brackish) biotopes, as shown for coastal areas of the Baltic Sea (C. Boettger, 1944).

Beran (1997) indicates that *A. vorticulus* inhabits shallow, open water bodies with a sandy substrate. In a study carried out in a single abandoned meander of the Rhône floodplain in France ("la Morte de Glandieu") by Yacine-Kassab (1979), the species was found in water fluctuating in depth from 1-3 m. In this instance the substrate was clay with a high proportion of fine organic matter. Detailed depth distribution profiles were given by Schermer (1932) for a set of North-German lakes where the species was encountered to a depth between 4 and 5 metres.

The most detailed studies of the environmental condition of the species were carried out in ditches draining humid grasslands in England. There *Anisus vorticulus* declines where ditches become wider, deeper and with more extensive areas of open water (Watson & Ormerod, 2004a). According to Willing & Killeen (1998), ditch dimensions seem less important than presence of shallow water depth and open conditions that provide for rapid warming of the water. Temperature may be the most important factor in determining reproduction and growth. The severe winter conditions that can occur in the Central European sites where the species is found, suggest that *A. vorticulus* cannot be considered a true thermophile. Consistent quantitative data about the temperature range tolerated by the species and the effects of temperature on its physiology and reproduction are not available.

A. vorticulus is found more abundantly at the water surface than away from it (Watson & Ormerod, 2004b). Dissolved oxygen concentration decreases significantly with depth in a ditch, causing a corresponding decrease in the occurrence of this gastropod, which is particularly dependent upon gaseous exchange. *Anisus vorticulus,* being a pulmonate, can use atmospheric air for respiration. In consequence it often lives close to the surface to facilitate its respiratory requirements. At the same time its

Table 1 Average physico-chemical characteristics of the water in *Anisus vorticulus* sites in south-east England and France. Values in bracket are ranges, except when * indicates standard deviations. Superscript numbers refer to the corresponding source reference.

sites	Cut-off meander, (Rhône floodplain, France)	Floodplain channel, (Rhône floodplain, France)	Floodplain channels, (Rhône floodplain, France)	Drainage ditches, (Sussex, England)	Drainage ditches, (Suffolk and Norfolk, England)
sources	Yacine-Kassab (1979)	Henry *et al.* (1994)	Pellaud (2004)	Willing & Killeen (1998)[1], Watson & Ormerod (2004a[2] & b[3])	Willing & Killeen (1998)
Nb of water bodies with *A. vorticulus*	1	1	3	7[1], 13[2], 10[3]	25
Sampling years	1976-78	1992-94	2003	1997[1], 1999[2], 2000[3]	1997
pH	7.7 (7.5-7.9)	7.4 (7.1-7.9)	-	(6.5-7) [1]; 7.5 (0.6)* [2]; 7.2 (0.3)* [3]	(6.7-7.5)
Conductivity (µS cm^{-1})	436 (289-534)	361 (219-495)	529 (369-723)	344 (208-408) [1]; 493 (238)* [2]; 410 (140)* [3]	(707-1174)
Alkalinity (mg L^{-1})	292 (175-347)	220 (124-316)	-	142 (51)* [2]; 132 (40)* [3]	-
Calcium (mg L^{-1})	(64-112)	-	270 (184-378)	48 (18)* [2]; 44 (13)* [3]	-
Chloride (mg L^{-1})	(7.1-17.7)	-	-	59 (2)* [2]; 54 (35)* [3]	-
Ammonia (mg L^{-1})	0.38 (0.05-0.83)	0.21 (0.01-1.27)	0.26 (0-0.89)	0.18 (0.22)* [2]; 0.1 (0.1)* [3]	-
Nitrite (mg L^{-1})	0.02 (0-0.06)	0.04 (0-0.33)	-	0.03 (0.04)* [2]; 0.02 (0.03)* [3]	-
Nitrate (mg L^{-1})	0.5 (0.2-1.0)	2.5 (0-22.4)	1.3 (0-3.6)	1.06 (1.92)* [2]; 0.3 (0.2)* [3]	-
Phosphate (mg L^{-1})	-	0.20 (0.01-1.23)	0.05 (0.01-0.09)	0.42 (0.38)* [2]; 0.2 (0.2)* [3]	-

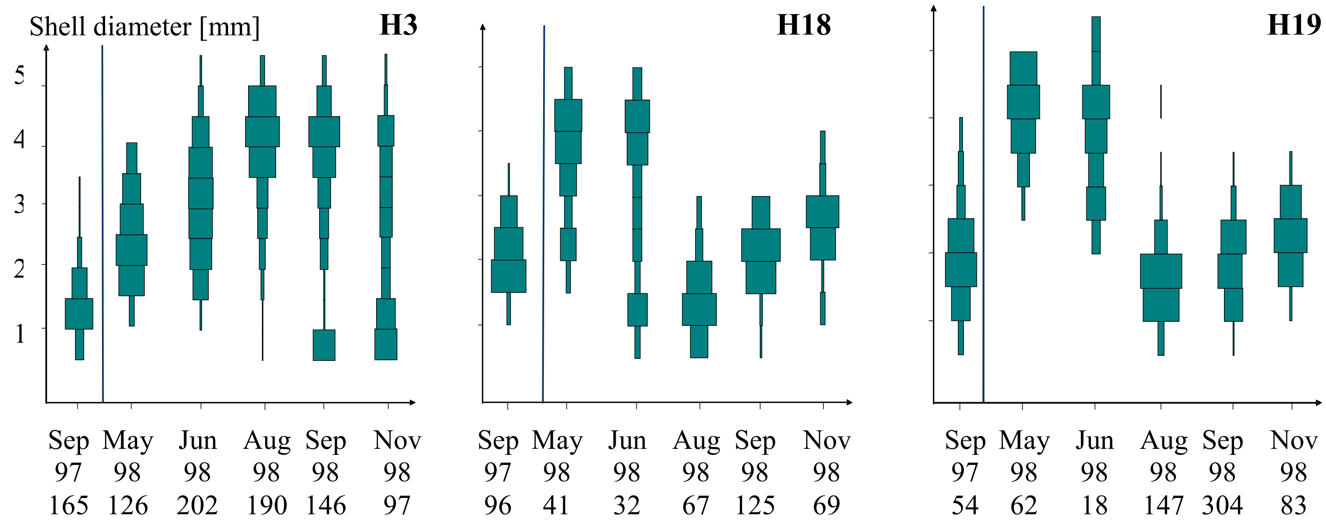

Figure 2 Size structure of *Anisus vorticulus* populations in threee ditches (H3, H18, H19) at Halvergate Marshes (East Anglia, England). The size of boxes is proportional to the percentual abundance of each size class at each date. The numbers below the dates are the number of individuals sampled. Adapted from Killeen (1999).

haemolymph is rich in haemoglobin, indicating a certain adaptation to cutaneous respiration whilst submerged, at least where gradients of dissolved oxygen are adequate to permit this (Watson & Ormerod, 2004b).

Anisus vorticulus lives in alkaline waters (Boycott, 1936; Yacine-Kassab, 1979 ; Killeen & Willing, 1997; Willing & Killeen, 1998; Willing, 1999; Watson & Ormerod, 2004a). The average calcium concentration in the English ditches with *A. vorticulus* was 48 mg/1 (Watson & Ormerod, 2004a). Their water hardness was moderate to high (Willing & Killeen, 1998), although pH, conductivity seems to have little influence on the presence of this species (Willing & Killeen, 1998). Table 1 summarizes some water quality parameters for the British ditches and some French Rhône floodplain sites where *A. vorticulus* occurs. This compilation of scattered data shows that the distribution of the species covers a relatively wide range of physico-chemical conditions. Willing & Killeen (1998) also reported that the fields adjacent to the ditches where the species occurred had received little or no agricultural fertilisers.

In ditches, *Anisus vorticulus* occupies habitats where plant succession is advanced (Drake, 1998; Killeen & Willing, 1998; Killeen, 1999; Watson & Ormerod, 2004a) and where there is a high diversity of plant species (Watson & Ormerod, 2004a; Killeen, 1992). This is also the case for all, but one, of the 11 floodplain water bodies known to have harboured the species between 1976 and 2004 in the French Rhône floodplain (Castella *et al.*, 2005).

According to Piechocki, (1979), Grossu (1987), Beran (1997, 2002) and Falkner (1990), *Anisus vorticulus* needs water bodies rich in floating and submerged vegetation. However, Watson & Ormerod (2004b) found the abundance of the species to increase with the abundance of floating plants, but to decrease with the abundance of submerged plants. Their data show that *A. vorticulus* occurs in less-well vegetated habitats than, for example, *Segmentina nitida*. *A. vorticulus* is not an early pioneer species, nor is it present in the latter stages of succession to terrestrial habitat (S. Ormerod, pers. com.). In North-German lakes, Schermer (1932) found the species in association with all types of habitats, including *Chara* or *Potamogeton* stands, as well as vegetation free areas.

Plant species occurring typically with *A. vorticulus* include *Chara* sp., *Berula erecta*, *Equisetum fluviatile*, *Glyceria maxima*, *Hydrocharis morsus-ranae*, *Juncus effusus*, *Elodea* spp., *Potamogeton acutifolius*, *P. natans*, *P. trichoides*, *Nymphaea alba*, *Myriophyllum spicatum*, *Lemna* spp. and *Ceratophyllum* spp. (Schermer, 1932; Frömming, 1956; Yacine-Kassab, 1979; Willing & Killeen, 1998, Cucherat & Vanappelghem, 2003; Castella *et al.* 2005). In the water-filled ditches and hollows resulting from peat exploitation, *Anisus vorticulus* can occur with *Carex* spp., *Sphagnum* spp., and *Marchantia* spp. (Piechocki, 1979).

According to Piechocki (1979), *Anisus vorticulus* is typically an epiphytic species, living among concentrations of filamentous algae, in patches of *Lemna* spp., or on leaves and stalks of *Sagittaria sagittifolia*, *Elodea canadensis*, *Ceratophyllum* spp., *Acorus calamus*, *Polygonum amphibium*, *Nuphar lutea* and *Nymphaea alba*.

Anisus vorticulus is reported to be associated with a wide range of mollusc species e.g. *Gyraulus riparius* and *Pisidium pseudosphaerium* (Piechocki, 1979; Willing & Killeen, 1998), *Valvata macrostoma* (Willing & Killeen, 1998; Cucherat & Vanappelghem, 2003), *Planorbis carinatus* (in gravel pits) (Beran, 1997), *Segmentina nitida* (observations by Willing & Killeen, 1998) and *Sphaerium nucleus* (in terrestrialised oxbow-lakes) (Falkner 2000). In the "ditch group" of Sparks (1961), *A. vorticulus* is associated with *Valvata cristata*, *Planorbis planorbis*, *Anisus vortex*, *Segmentina nitida*, *Acroloxus lacustris* and *Pisidium pulchellum*. In the Rhône floodplain in France (Pellaud, 2004), the species has been reported to coexist with the rapidly spreading, non-indigenous planorbid *Gyraulus parvus*. The scale dependence of such species associations must be kept in mind and the actual scale at which it is described is most of the time difficult to derive from published sources. An association at the scale of the whole water-body might not hold true at the individual patch scale. For example, in British ditches, *Anisus vorticulus* is associated with *Pisidium pseudosphaerium* at the patch scale (Watson & Ormerod, 2005), but not with *Segmentina nitida* (Watson & Ormerod, 2004a).

Life cycle and longevity

Anisus vorticulus is hermaphrodite, usually with an annual life cycle (Frömming, 1956; Piechocki, 1979; Willing & Killeen, 1998, Killeen 1999).

The most detailed studies of the life cycle of this species were carried out in England (Sussex, Norfolk and Suffolk) for drainage ditches in humid grasslands. A recent study (Killeen, 1999) showed that breeding occurred principally between June and mid-July, but its precise time could not be established. It was not a single event, but spread over a 6-8 week period. Furthermore, breeding in different ditches was not synchronized, as demonstrated in figure 2 that compares the size structure of *A. vorticulus* populations in three ditches covered by this study. For ditch H3, the main breeding took place sometimes in August/September, while for ditches H18 and H19, breeding began in June.

On 19th August 2004, several small specimens were taken from a rich population in a shallow, strongly terrestrialised, cut-off meander of the German Danube floodplain (near Isarmünd), densely covered with *Chara* spp. stands. On the 20th August, copulation was observed in the laboratory between specimens with diameter not larger than 2.5 and 2.65 mm and lasted more than two hours. After a first copulation in which one of the individuals acted as the male, a second occurred in which it acted as the female. Egg laying occurred during September. The full-grown animals reached a size of 3.6 and 3.8 mm before the end of the year (Falkner, unpublished).

Temperature may be one the most important factors in determining reproductive timing and growth rate. In British ditches, Killeen (1999) observed that the relatively rapid growth rate of adults in spring coincided with a period when the water in the ditches was also warming up rapidly. Following breeding, the juveniles grew at a slower rate, during a period where there was little increase in water temperature. From September to the end of November the ditches cooled down and *Anisus vorticulus* growth rate was observed to be slower. During winter, growth either stopped, followed by rapid restart in early spring, or it continued at a very slow rate. In figure 2, when the numbers of individuals recorded on May 1998 are compared with the numbers recorded on September 1997, it is difficult to determine whether during winter, growth stopped, followed by a rapid growth in early spring, or if it continued at a very slow rate.

The only information on life cycle in floodplain water bodies was reported by Yacine-Kassab (1979) in the French Upper-Rhône, and concerns one locality (la Morte de Glandieu), studied between December 1976 and March 1978 (Figure 3). Reproduction occurred in November and the snail was not found from mid-January to March and from July to mid-September (despite the fact that the abundance of other gastropods was high). Furthermore, the relative frequency of *A. vorticulus* was not the same in the two years of the study (December – February 1976-1977 vs. 1977-1978, Figure 3).

Figure 3 Total number of gastropods collected (top) and *Anisus vorticulus* relative frequency (bottom) in an abandoned meander of the Rhone floodplain (France) studied from December 1976 to February 1978. Modified from Yacine-Kassab (1979).

There is no information available on reproduction and life cycle in other habitats.

DISPERSAL AND COLONISATION

As for most gastropod species, details of the dispersal mechanisms of the species are poorly known. According to Willing & Killeen (1998), in drainage ditches in humid grassland, *A. vorticulus* can maintain populations in a managed site (i.e. where the vegetation is regularly cut) only if it is connected to an unmanaged one. In a study of recently cleared drainage ditches in East Sussex (England), Hingley (1979) showed that *A. vorticulus* belonged to the rarer species and was more frequent in the non-recently cleared channels (i.e. channels that were cleared more than two years before the study). It was a slower colonizer than *Bithynia tentaculata*, *B. leachii*, *Physa fontinalis*, *Planorbis planorbis* and *Radix labiata*. It is probable that, as in other gastropod species, flooding can play a role in the dispersal of *A. vorticulus*, either directly, or through the transport of plant fragments, to which the species is known to attach. This is certainly the case in active floodplains, where disconnected water bodies colonized by the species can be temporarily interconnected with each other, and with the main channel, during floods (Castella *et al*., 2005). Studies of dispersal of small aquatic organisms demonstrated that they may also be transported by other means, such as birds, either through adherence to the body surface or in the gut (Maguire, 1963; Malone, 1965; Proctor & Malone, 1965; Bilton, Freeland & Okamura, 2001). There is no reason to suppose such mechanisms would not operate for *Anisus vorticulus*, especially when young. However, transfer while in the gut is very probably lethal for species with no operculum, like *A. vorticulus*.

FOOD

The food and feeding habits of this species remain poorly known. It is given as feeding on periphytic algae (Aufwuchs), on dead tissues of terrestrial and aquatic macrophytes and on tissues of higher plants (Piechocki, 1979; Falkner *et al.*, 2001).

DISTRIBUTION

Anisus vorticulus is a Western Palaearctic species with its distribution centred on east and central Europe. Its populations tend to be widely separated and localised. It has been found in the following countries of Europe: Austria, Belarus, Belgium, Bulgaria, the Czech Republic, Denmark, France, Germany, Great Britain, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Rumania, Russia, Slovakia, Sweden, Switzerland and Ukraina (Ehrmann, 1933; Jaeckel jun., 1962; Adamowicz, 1939; Shadin, 1952; Girod, 1980; Grossu, 1987; Stadnichenko, 1990; Wells & Chatfield, 1992; Angelov 2000; Falkner *et al.*, 2001; Glöer, 2002; Pintér & Suara, 2004; Zettler *et al.*, Colling & Schröder, in press). A locality along the Danube in the former Yugoslavia is given by Frank *et al.* (1990), but it is not possible to locate this locality sufficiently precisely to determine if it is in present-day Croatia or Serbia. The known distribution extends in Scandinavia to the Skåne province in Sweden (Nilsson, 1957; Wells & Chatfield, 1992) and in Russia eastward to the Ob drainage system, where it has been found at Omsk and Tomsk (Johansen, 1934). It should be noted that the distribution map for *Anisus vorticulus* that was published by Meier-Brook (1983) was intended by the author only to give a rough idea of the part of the world where the species occurs for general zoogeographical comparisons. It was never intended to give precise records for individual countries that are covered or not by the hatching (Meier-Brook, pers. comm.). Therefore, inclusions of *A. vorticulus* in country checklists on the sole basis of this map (e. g. Dhora & Welter-Schultes, 1996), are not justified and are thus potentially misleading.

Threats and conservation status

Until 2004, *Anisus vorticulus* had no particular status at European level and was considered as widely distributed but in decline. It was nonetheless included on various national and regional red lists. In the United Kingdom it both appeared in the UK Red Data Book as vulnerable and became listed as a priority species under the national Biodiversity Convention Action Plan (BAP) (Bratton, 1991; Watson & Ormerod, 2004b). In various parts (Länder) of Germany it was listed as "extinct" (Körnig, 1998), "in danger of extinction" (Arbeitsgruppe Mollusken BW, in prep.; Jungbluth & Bürk, 1985; Herdam *et al.*, 1991; Knorre & Bössneck, 1993; Jueg *et al.*, 1994; Groh *et al.*, 1995; Jungbluth, 1996; Schniebs *et al.*, 1996; Dembinski *et al.*, 1997; Jungbluth & Knorre, 1998; Ant & Jungbluth, 1999; Falkner *et al.*, 2004) or "endangered" (Wiese, 1990; Herdam & Illig, 1992). It was listed as "strongly endangered" in Switzerland (Turner *et al.*, 1998), as "critically endangered" in Sweden (Gärdenfors, 2005) and the Czech Republic (Beran, 2002), as "in danger of extinction" in Austria (Frank & Reischütz, 1994) and as "near threatened" in Poland (Zajac, 2005). In the Netherlands, the species belongs to the "Red List candidates" (Gittenberger *et al.*, 1998). Since spring 2004 the species has been listed in Annexes II and IV of the European Habitats Directive.

The causes of the decline observed in *Anisus vorticulus* are not well understood. It has been attributed to loss of natural habitat (Falkner, 1991; Beran, 1997, 2002; Killeen & Willing, 1997; Willing & Killeen, 1998; Cucherat & Vanappelghem, 2003), pollution (Beran, 1997), eutrophication of water bodies caused by agricultural fertilisers (Killeen & Willing, 1997; Turner *et al*., 1998; Beran, 2002; Watson & Ormerod, 2004a; Colling & Schröder, in press), reduction in ground-water levels (Killeen & Willing, 1997; Willing & Killeen, 1998; Colling & Schröder, in press), inappropriate habitat management (Killeen & Willing, 1997; Willing & Killeen, 1998), drying out of wetlands (Turner *et al*, 1998; Cucherat & Vanappelghem, 2003) and modification of the physico-chemical character of water bodies (Killeen & Willing, 1997; Beran 1997).

Site management

Site management appropriate to *A. vorticulus* has been considered in Britain for the ditch habitat in humid grassland. The main focus of attention has been on treatment of vegetation (Willing & Killeen, 1998; Watson & Ormerod, 2004b). A form of ditch management is proposed that allows limited invasion by aquatic plants, that is to say vegetation cutting and sediment removal on a cycle of five years or longer. At the same time it is necessary to inhibit colonisation by shade-inducing plants like *Phragmites* (Willing & Killeen, 1998). This applies equally to plant cover at the air/water interface, to enable the species to reach the surface for purposes of respiration, especially in ditches where dissolved oxygen concentrations are low (Watson & Ormerod, 2004b). In a system of interconnected water bodies (cut-off channels, ditches), it is recommended that not all parts of the network are cleared at the same time, in order to maintain the possibility of recolonization. This also applies to more isolated linear structures, where only limited stretches should be cleared in an appropriate rotation.

In April 2005, a site surveyed by Willing & Killeen (1998), in north Suffolk, was revisited. In 1998 *A. vorticulus* was confined to 2 ditches in which it was rare. The ditches were managed to favour dragonflies, thus they were frequently and deeply cleared. Since 1998, the site management received less funding and management was reduced, such that the ditches became shallower and choked with vegetation. The results from 2005 showed that *A. vorticulus* was present in all 13 ditches sampled and in many it was abundant (Killeen, 2005).

It is necessary to recognise that vegetation management alone is insufficient to maintain or revive *A. vorticulus* populations where water quality is inappropriate for the species (whether due to natural processes or human influence) (Watson & Ormerod, 2004). Decrease in usage of agricultural fertilisers and other agricultural chemicals, as agricultural molluscicides, is thus of potential benefit to the species (Watson & Ormerod, 2004a).

In the Czech Republic, Beran (2002) also recommends removal of part of the vegetation biomass as an appropriate site management strategy. Furthermore, he indicates that the transfer of specimens into new suitable sites can be considered as a possible conservation measure, or as a way to sustain weak populations. Willing & Killeen (1998) also suggested introduction of *A. vorticulus* to seemingly suitable ditch stretches, in order to enhance the population sizes and to allow more flexibility in site management. Beran (2002) reports on two translocation trials attempted in the Czech Elbe floodplain, but for which the time since transfer was too short to draw any conclusion. According to this author, some basic recommendations should be applied in any re-introduction programme. For example, the transferred individuals should come from either (i) a population doomed to eradication, or from a non-threatened one, (ii) from the closest possible locality, (iii) from a site "typical" for the species. In addition, the introduction should be made into sites where appropriate conditions will be maintained in the future. The same author also suggests that man-made water bodies, such as small, densely vegetated sand- or gravel pits, established in the vicinity of the original natural sites, can be considered as appropriate for the relocation of the species. According to experiences by one of us (G. F.), *A. vorticulus* can be bred without problems in relatively small aquaria (about 0.5 to 1 litre, depth of water 4-5 cm). This allows production of large numbers of offspring from very few parents within 1 or 2 years. Thereby, the release of large numbers of individuals may considerably increase the success of re-introduction programmes, without affecting the populations of origin.

SURVEY AND SAMPLING PROCEDURES

No sampling procedures specific to *Anisus vorticulus* have been developed. Various generally applicable sampling methods have been employed in different studies.

To establish whether the species is present on a site a presence/absence study can be conducted. This would normally require a specialist who can recognise the species and find it where it occurs. However, one character of the species seems to be the inconsistency of its occurrence in time at a given site and the very low population densities it can exhibit. It is rare to proceed by direct observation in the field, more normally samples would be collected by passing a net through aquatic vegetation, preserving the samples in 70-80% alcohol and then extracting the molluscs from the samples in the laboratory. References to this type of study may be found in Colling (1992) and Økland (1990). They present methods for sampling aquatic gastropods that can as easily be used for *A. vorticulus* as for other species. Except when the species is present only, or largely, in the form of egg masses (a period that may vary between July and August, depending on localities), sampling can be carried out throughout the year. Deeper waters may be sampled by collection of debris (leaves, branches) from the site. The deepest waters may require use of a hand net mounted on a longer handle.

Modelling the distribution of *A. vorticulus* requires both survey data and accompanying information on the ecological preferences of the species. Sampling procedures are as mentioned above i.e. collection from the field and observation in the laboratory. References to these procedures are found in Willing & Killeen (1998). Quantitative sampling is required and habitat parameters are measured at the same time: aquatic vegetation, physico-chemical character of the water (temperature, pH, conductivity, dissolved oxygen, salinity), physical dimensions of the site. A critical task remaining to be undertaken is the investigation of the environmental relationships of *A. vorticulus* in active riverine floodplains, which seem to be among the original, and highly threatened, habitats of the species.

CONCLUSION

Although more than hundred sources were used to compile the present account, the autecology of *Anisus vorticulus* (like the vast majority of threatened European gastropods) is insufficiently well known to allow for authoritative statements to be made on how to manage the species and its habitat to maintain healthy populations. In the absence of fuller quantitative data from experiments or surveys for almost all aspects of the biology and ecology of the species, some components of the information presented above are difficult to generalize and reflect unmeasured observations. In order to develop informed conservation strategies, key information is needed about major topics, both fundamental – including the life cycle of the species, its population dynamics and survival across life stages, and applied, such as the effects of eutrophication and vegetation management, or the consequences of population isolation on its fitness and genetic diversity.

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