The Mollusca of the estuarine region of the rivers Rhine, Meuse and Scheldt in relation to the hydrography of the area. IV. The genus Sphaerium

by

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INTRODUCTION

This paper is the fourth of a series on the distribution and ecology of the Mollusca occurring in the Delta area in the south-western part of the Netherlands. An introduction to the aims of this study was given in the first paper, together with a description of the area investigated and its hydrography (Wolff, 1968). The sampling methods used in this investigation are described in that paper and also in one by Kuiper & Wolff (1970). During the period in which the samples for this investigation were collected, the hydrography of the Delta area did not differ from the situation described in the first paper (Wolff, op. cit.). The persons mentioned in the first paper assisted us once again in various ways, for which I should like to express my gratitude to them. I should also like to thank the Deltadienst of Rijkswaterstaat (Delta Service of the Department of Water Affairs) which provided us with important information on current velocities in the freshwater tidal area.

SYSTEMATIC PART

Sphaerium solidum (Normand, 1844) (fig. 1)

Van Benthem Jutting, 1943: 190-192; Adam, 1960: 358-359.

Distribution: *Sphaerium solidum* ranges from Central Europe to the Ural Mountains (U.S.S.R.). In the Netherlands it was once fairly common in the rivers Rhine and Meuse, but rather rare in other parts of the country. Its distribution in the Delta area is shown in fig. 1.

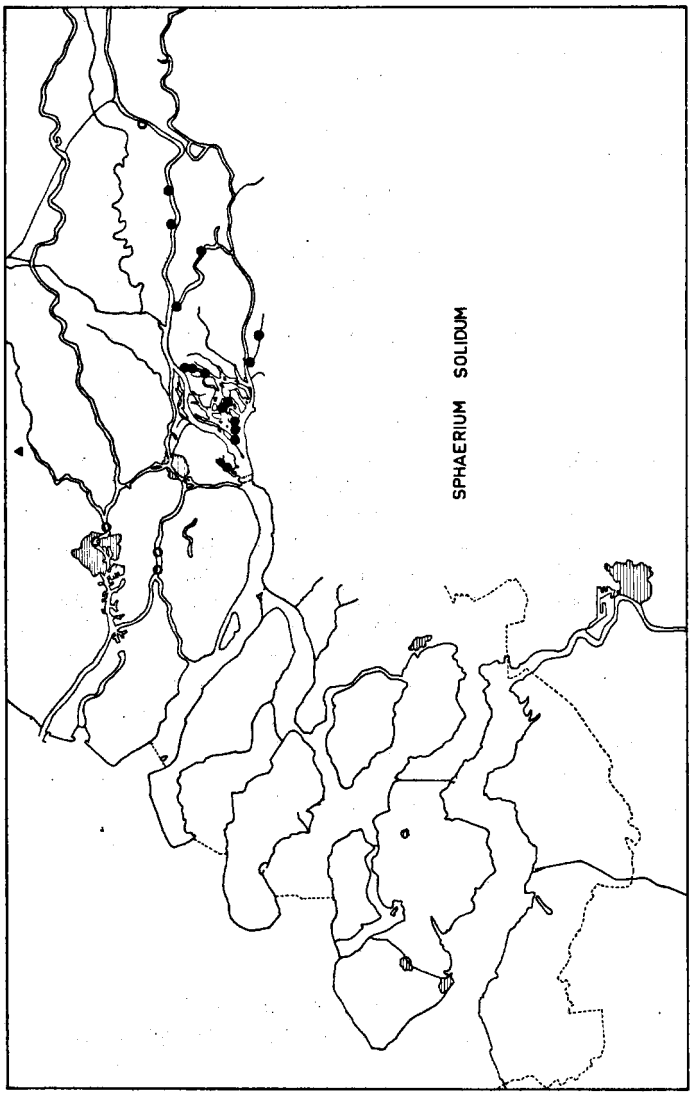

Fig. 1. Distribution of *Sphaerium solidum* in the Delta area. Triangles denote localities inside the dikes, i.e., non-tidal localities; dots and circles denote tidal localities outside the dikes. Closed symbols indicate localities where the species was found to live during this study, while open symbols indicate records of dead material.

Localities[1]: Province of Zuid-Holland: Gouwe near Gouda (RMNH); Nieuwe Maas near Rotterdam (†, RMNH); Oude Maas near Rhoon (†, RMNH) and near Heinenoord (†, ZMA); Zuid-Maartensgat, Dordtse Biesbosch (W). Province of Gelderland: Waal near Tiel (†, ZMA), near Zaltbommel (W), and near Hellouw (W); Afgedamde Maas near Aalst (W). Province of Noord-Brabant: Brabantse Biesbosch, Noordergat van de Vissen, Zuidergat van de Vissen, Gat van de Binnennieuwesteek, Buitenkooigat, Gat van Van Kampen, Steurgat (W); Bloemstrang near Woudrichem (RMNH); Oude Maasje near Keizersveer and near Waspikse Veer.

Ecology: *S. solidum* is predominantly a river species, but it is sometimes also found in former rivers and large lakes. In the Delta area we found it exclusively in the large rivers and the freshwater tidal area of the Biesbosch, except for one record from the former river Gouwe, a stagnant or slow-running inland water.

There is not the slightest indication that *S. solidum* is able to withstand elevated salinities, although Jaeckel (1962) remarks that the species is able to survive about 1.2‰Cl'.

S. solidum seems to tolerate polluted water fairly well. We found the species in the Waal, a branch of the polluted Rhine, as well as in the part of the Biesbosch under the influence of the Rhine. As might be expected, the species also occurs in some branches of the cleaner river Meuse. The statement of Thiel (1929) that *S. solidum* is extremely susceptible to pollution apparently does not hold.

In the freshwater tidal area of the Biesbosch the species lives, together with certain species of *Pisidium* (Kuiper & Wolff, loc. cit.), in low numbers in the intertidal zone. It has been found up to about mid-tide level, which means an immersion period of 5-7 hours during each tidal cycle. The numbers found in the intertidal zone usually remain low, at most 11 specimens per square metre.

Below mean low water level it was found down to a depth of 5 m. In this environment, densities up to 40-50 specimens per square metre are reached.

The occurrence of *S. solidum* in the intertidal zone of the freshwater tidal area is in striking contrast to the absence of unionids

1 Abbrevations: NMV = card index Mollusken-Comité, Nederlandse Malacologische Vereniging; NHMR = Natuurhistorisch Museum, Rotterdam; RMNH = Rijksmuseum van Natuurlijke Historie, Leiden; W = Delta-Instituut voor Hydrobiologisch Onderzoek (W.J. Wolff); ZMA = Zoölogisch Museum, Amsterdam.

there (Wolff, op. cit.). This is probably mainly due to the fact that *S. solidum*, unlike the various species of unionids, is able to burrow completely into the substratum.

The species lives on various grades of sediment. As compared to the other species of *Sphaerium*, it undoubtedly inhabits the coarsest sediments. Thiel (1924) also found that *S. solidum* lives preferably in the sandy types of sediment. We found it even in sands with a median diameter of about 500 μ, but also in muddy sands with median grain-sizes down to about 100 μ. Most observations of this species, however, were made in sands with median grain-sizes of about 250-300 μ.

From its occurrence in fairly coarse sediments, it follows that *S. solidum* is the *Sphaerium* most tolerant of high current velocities and the sand transport that attends such high velocities. It was found in the middle of various tidal channels in the freshwater tidal area, but we failed to discover it in the neighbouring river Amer, despite extensive sampling.

According to the Delta Service maximum current velocities in that part of the river are higher than elsewhere, up to about 0.9 m/sec. during normal river discharge and a normal tidal cycle. Their data are based on an electrical analogon of the Delta waters, the "Deltar", which is used to investigate the hydrography of the Delta area in connection with present and future hydrotechnical projects. *S. solidum* is probably absent from the sampled part of the river because of the high maximum current velocities, as a result of which the bottom of the river is extremely unstable and large quantities of coarse sand are continuously moving about. These moving sands probably prevent the occurrence in this part of the tidal river of *S. solidum* and other macro-fauna species.

I do not think that *S. solidum* will colonize the future Delta lakes straight away. It seems possible, however, that the species might establish itself there in some places.

Sphaerium rivicola (Leach, 1818) (fig. 2)

Van Benthem Jutting, 1943: 188-190; Adam, 1960: 357-358; Ellis, 1962: 31.

Distribution: *Sphaerium rivicola* ranges from western Europe to Russia. In the Netherlands it is rather rare, although fairly abundant in the Rhine and Meuse. Its distribution in the Delta area is shown in fig. 2.

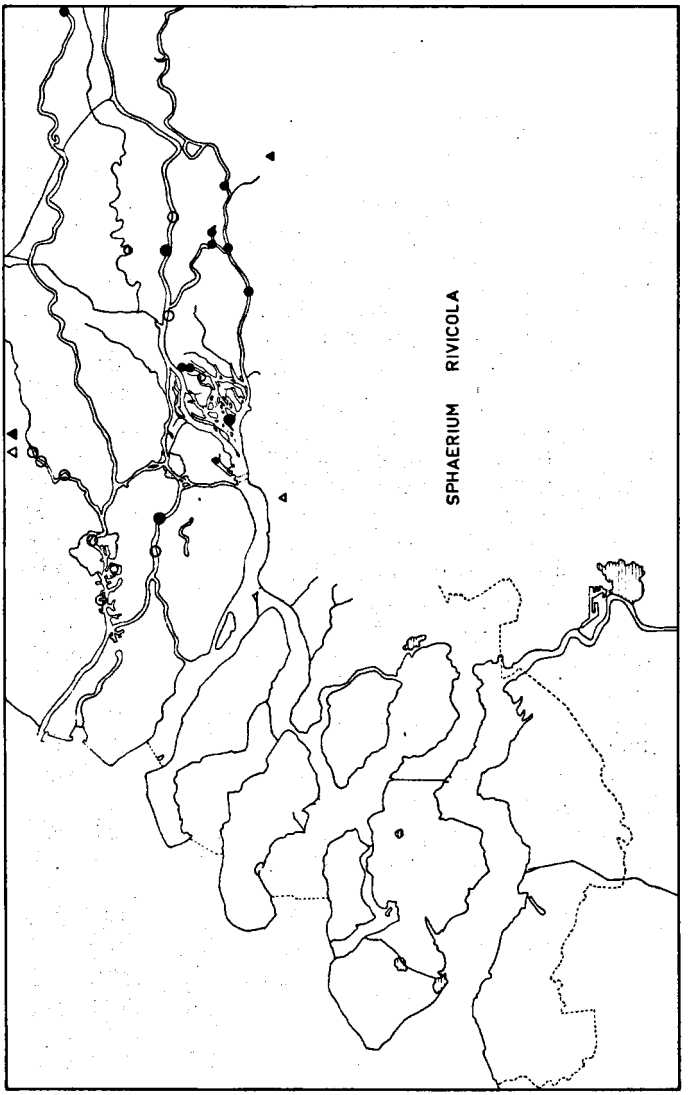

Fig. 2. Distribution of *Sphaerium rivicola* in the Delta area. Symbols as in fig. 1.

Localities: Province of Zuid-Holland: Reeuwijkse plassen (RMNH); Gouwe near Gouda; Hollandse IJssel near Gouderak, Moordrecht and Snellerak (†, ZMA); Nieuwe Maas near Rotterdam (†, RMNH); Waalhavens, Rotterdam (†, NHMR); Vlaardingerdijk (= Vijfsluizen?), Vlaardingen; Oude Maas near Heinenoord (NMV, †), and near Heerjansdam (W); Linge near Asperen (†, RMNH). Province of Gelderland: Rijn near Wageningen (W); Waal near Herwijnen (W) and near Zaltbommel (†, ZMA); Afgedamde Maas near Nederhemert (W, RMNH). Province of Noord-Brabant: Roodevaart near Klundert (†); Brabantse Biesbosch, Gat van de Binnennieuwesteek, Steurgat (W), Steenen Muur (†, W); Bloemstrang, Woudrichem (†, RMNH); Maas near Heusden (W) and near Hedel (RMNH); Bergse Maas near Drongelen (W); Zwarte Vaart near 's-Hertogenbosch (ZMA).

Ecology: *S. rivicola* was found in very few localities during our investigation. It has disappeared almost entirely from the Rhine, probably due to water pollution. Its resistence to pollution seems to be very low, as indicated by Thiel (1929) and Hässlein (1953). We found the species alive only in parts of the Biesbosch area that receive very small amounts of polluted Rhine water. According to e.g. Van Benthem Jutting (op. cit.) and Ellis (op. cit.) *S. rivicola* prefers river habitats. Owing to this preference, it is quite natural that it does not occur on the islands of the Delta area; this has already been indicated by Kuiper (1944).

Although we have only a few observations of this species, we nevertheless think that it prefers muddier sediments and lower current velocities than *S. solidum*. Our observations on this subject confirm the data of Thiel (1924).

It is difficult to predict how the species will behave as regards to the future Delta lakes. If it does colonize the lakes, it probably will do so very slowly.

Sphaerium corneum (Linnaeus, 1758) (fig. 3)

Van Benthem Jutting, 1943: 192-197; Adam, 1960: 356-357; Ellis, 1962: 31-32.

Distribution: *S. corneum* has a Holarctic distribution. In the Netherlands it is a common species. Its distribution in the Delta area is shown in fig. 3.

Localities: Province of Zuid-Holland: Monster, Poeldijk, Staelduin, 's-Gravenzande; Maassluis (RMNH); Zuidbuurt, Maasland (W);

Vlaardingse Vaart and Vlaardingerdijk (= Vijfsluizen?), Vlaardingen (RMNH); Kethel (NHMR); Nieuwe Maas near Krimpen aan de IJssel (W) and near Rotterdam (†); Nieuwerkerk aan de IJssel; Gouwe near Gouda (RMNH); Hollandse IJssel near Moordrecht and near Snellerak (ZMA); Ouderkerk aan de IJssel; Stolwijk (RMNH); Lek near Schoonhoven (W); Quackjeswater, Rockanje (RMNH); Brielle (W); Westerweg, Ouddorp (W); Waterleidingduinen, Goedereede (Butot, 1962; W); Spui near Oud-Beyerland; Poortugaal (W); Johannapolder, near the castle (RMNH) and in the Kooigat (W) near Rhoon; Oude Maas near Poortugaal, near Goidschalxoord (W), near Heinenoord (†, ZMA), near Heerjansdam, near Puttershoek, and near Zwijndrecht (W); Barendrecht; IJsselmonde (RMNH); Bolnes; Hendrik-Ido-Ambacht (W); Van-Brienenoord, Rotterdam (NHMR, RMNH); Bakenstijn and Kromme weg near Zwijndrecht (W); Oud-Beyerland; Westmaas; Puttershoek; Blaaksedijk near Maasdam; Mookhoek and Strijensas near Strijen (W); Dordrecht (†, RMNH); Dordtse Biesbosch near Prinsenheuvel; Nieuwe Merwede near Oosthaven and near Kop van 't Land (W); Giessen near Giessen-Oudekerk; Asperen (RMNH). Province of Utrecht: Fort Honswijk (W). Province of Gelderland: Rijn near Wageningen (RMNH); Geldermalsen (W); Linge near Hamsche Brug (ZMA); Waal near Hellouw, near Loevestein (W), and near Tiel (W, ZMA); Kil van Hurwenen; Maas near Andel (W) and near Nederhemert; Hedel; Wamel (RMNH). Province of Noord-Brabant: Zoom between Bergen op Zoom and Pindorp; Barend-Potmar-kreek near Steenbergen; Welberg, Steenbergen; Oud-Prinsenland-polder near Stampersgat; Rijpersweg, Oud-Gastel; Roodevaart, Klundert; Hollands Diep near Roodevaart and near Moerdijk; Amer near Lage Zwaluwe; Brabantse Biesbosch: Deneplaat, Groene Plaat benoorden 130, Keizersdijk, Binnenkooigat, Lange Plaat, Vijf-Ambachten-polder, De Dood (W), Lange Weer, Sluishoek (Heyligers, 1955), De Zalm, Ganzenest, Noord-Bevert, Steurgat, Prikpolder; Paulownapolder, Werkendam (W); near Werkendam (ZMA); between Hank and Nieuwendijk; Boven-Merwede near Sleeuwijk (W); Bloemstrang near Woudrichem (†); Wielstraat, Veen (RMNH); Afgedamde Maas near Rijswijk (†, ZMA); Bergse Maas near Drongelen; Oude Maasje near Capelle; Elshout near Heusden (W); Heusden (RMNH); 's-Gravenmoer (Van Benthem Jutting, 1943); Langstraat between Capelle and Waalwijk (W); Nieuwe Waal, Haarsteeg (ZMA); 's-Hertogenbosch; Orthense weg near 's-Hertogenbosch; between 't Wild, Alem, and Kruisstraat, Rosmalen (RMNH); Maas near Hedel; Hertogswetering, Lithoijen (RMNH). Province of Zeeland: Renesse near the lighthouse (ZMA)

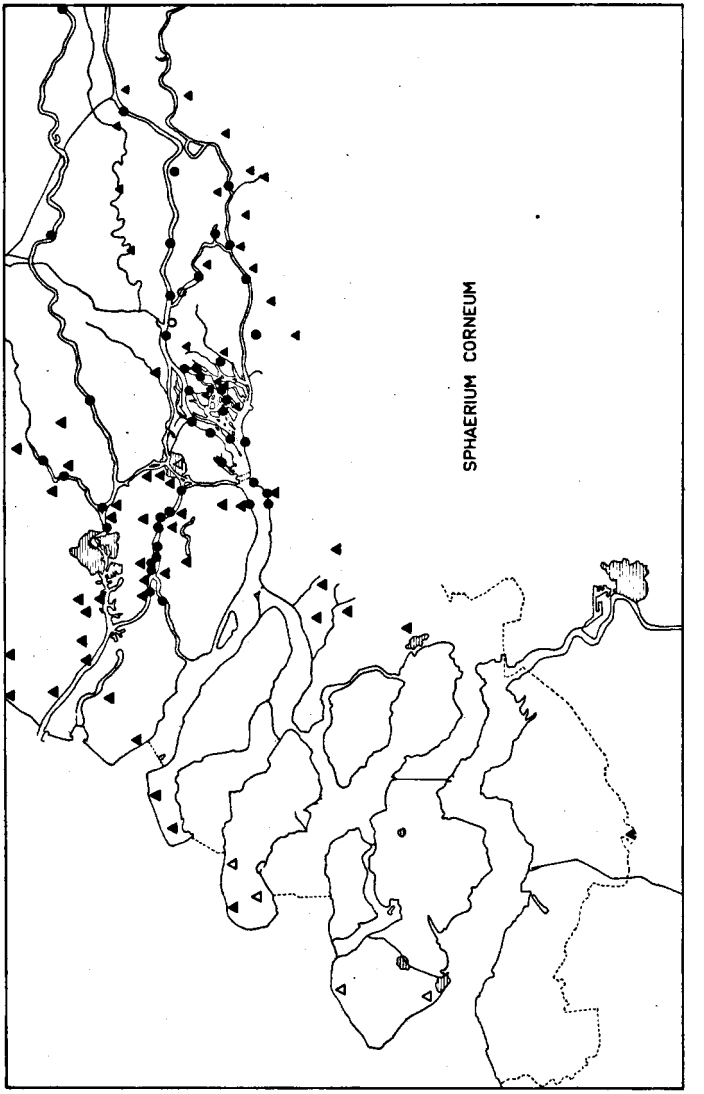

Fig. 3. Distribution of *Sphaerium corneum* in the Delta area. Symbols as in fig. 1.

and in the village (†, Kuiper, 1944); Haamstede (Butot, 1961); Zeeduin, Oostkapelle; Koudekerke, Walcheren (†, ZMA; probably the same locality as Koudekerke, Zuid-Beveland, mentioned by Kuiper, 1944); Overslag (W).

Ecology: *S. corneum* is the most common and ubiquitous representative of the genus in the Delta area. It is a very common species in most stagnant inland waters: canals, ponds, ditches, etc., as well as in the large rivers and, in small numbers, in the freshwater tidal area. Nevertheless, it does not occur in the large areas of the islands of the Delta area, except for the dune regions.

Jaeckel (1962) records a salinity of 1.67‰ Cl' as tolerated by this species, but the highest salinity at which we found *S. corneum* amounts to only about 0.3‰ Cl'. Koli (1961) indicates that in SW Finland *S. corneum* does not occur in brackish water. Therefore, its occurrence on the inlands of the Delta area seems to be prevented by the fairly high salinity of most inland waters (Wolff, 1968). Moreover, the large inundations with salt and brackish water in 1944/45 and in 1953 (Wolff, op. cit.) may have strongly influenced the distribution pattern of this species. However, this does not explain why *S. corneum* is absent from areas, for instance the central part of the island of Zuid-Beveland, that were not inundated and where salinity conditions would not prevent its occurrence. It must be assumed that its mode of dispersal is insufficient to colonize such isolated areas, but this seems remarkable, since it is generally stated that all the species of *Sphaerium* are easily distributed by waterfowl and water insects (Rees, 1965). In the areas where the species did occur, I found it, in accordance with the observations of Ökland (1964), only in shallow waters, down to a depth of 3 m. In the freshwater tidal area *S. corneum* is limited to small ditches and comparable sites in willow coppices, and in the softest part of the large mudflats. It does not live in the sandier parts and in the gully bottoms.

The substratum on which *S. corneum* lives is decidedly more muddy than that of *S. solidum*. This is also recorded by Thiel (1924). The median grain-size of the sediment in some of the localities where we found the species was always under 90μ. The species is often found between the roots of water-plants and sometimes even between the foliage of submersed species.

Compared to the other members of the genus, *S. corneum* has the highest tolerance for pollution. It occurs abundantly in ditches under the influence of the water of the polluted Rhine being the

only species of *Sphaerium* present here. Thiel (1930) also emphasizes its tolerance, and states that slight pollution is even favourable to *S. corneum*, because of the increased availability of food. Stronger pollution, however, leads to lethal shortages of oxygen and also may have a toxic effect. It may be emphasized that at present the water may (temporarily) be strongly toxic because of large quantities of chemical sewage drained into the rivers (Hässlein, 1954). In the polder area in the close vicinity of the Rhine and Meuse, *S. corneum* is abundant. Its occurrence in the dune area of the islands of the Delta area is most probably not of a relict nature as explained elsewhere (Wolff, 1968), and consequently dispersal by waterfowl and aquatic insects has to be assumed (Rees, 1965). It is remarkable, however, that this type of dispersal has not been effective in the isolated polder areas, as was shown before. I can offer no explanation for this phenomenon.

S. corneum will probably become a very abundant species in the future Delta lakes.

Sphaerium lacustre (O.F. Müller, 1774) (fig. 4)

Van Benthem Jutting, 1943: 197-199; Adam, 1960: 359-360; Ellis, 1962: 34-35.

Distribution: *Sphaerium lacustre* has a Palaearctic range and is fairly common in the Netherlands. Its distribution in the Delta area is shown in fig. 4.

Localities: Province of Zuid-Holland: Staelduin, 's-Gravenzande; Gouwe near Gouda (RMNH); Ouderkerk aan de IJssel; Rozenburg, Rozenburg; Brielse Meer near Brielle, near Zwartewaal and near Nieuwersluis; Groeneweg (W) and Heindijksloot (coll. A.W. Janssen), Oostvoorne; Strijpse polder (W) and Quackjeswater (Henrard, 1946), Rockanje; Kerkhoekseweg, Brielle; Vierpolders near Brielle; Hollemare, Zwartewaal; Polder Nieuwe Uitslag, Hekelingen; Velgerspolder, Zuidland; Welvliet near Geervliet; polder Heenvliet near Nieuwesluis; Spui near Oud-Beyerland (W); Rhoon (Van Benthem Jutting, 1943); Oude Koedood near Rhoon; Smitshoek, Barendrecht; willow coppices along the Oude Maas near Oud-Beyerland, and Goidschalxoord; De Klem near Strijen; canal between Strijen and Strijensas; Nieuw-Cromstrijenpolder, Groot-Cromstrijenpolder, and Torensteepolder near Numansdorp; willow coppices along the Hollands Diep near Strijensas (W). Province of Gelderland: in ditches near the Waal near Tiel and near Gameren (ZMA). Province of

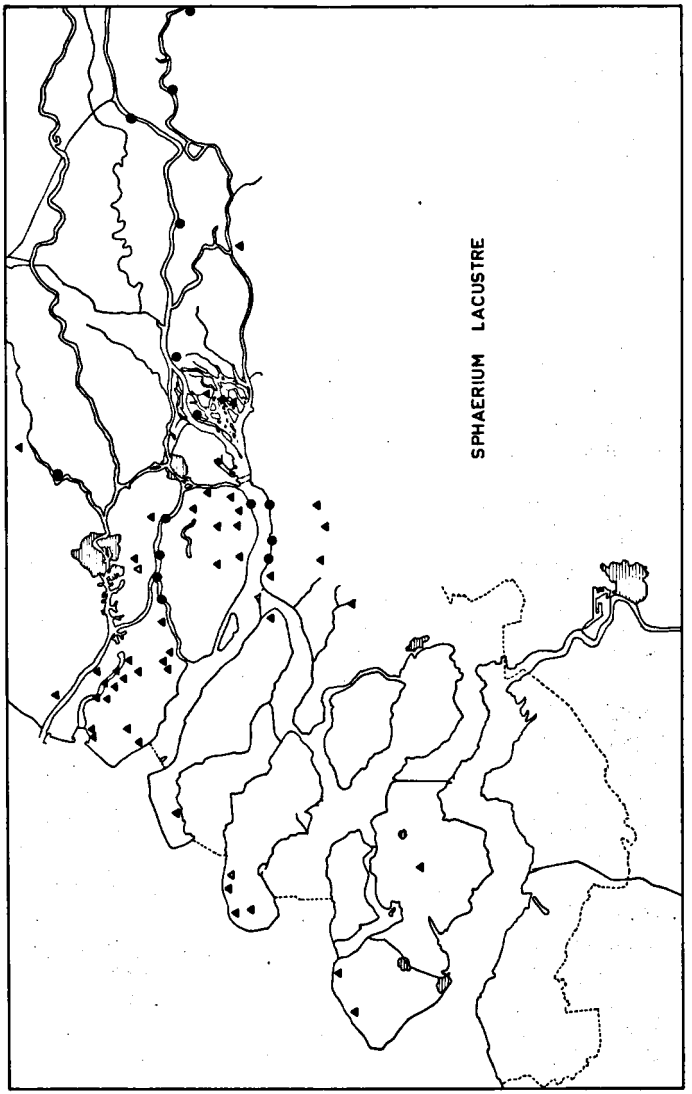

Fig. 4. Distribution of *Sphaerium lacustre* in the Delta area. Symbols as in fig. 1.

Noord-Brabant: Willemstad (NMV); in willow coppices along the Hollands Diep near Tonnekreek, near Noordschans, and near the Roode Vaart (W); Wouwse Beek, Steenbergen; Dinteloord; Standdaarbuiten; Stampersgat (NMV); Brabantse Biesbosch near the Spieringsluis in the Polder De Zalm, Noordplaat and Lange Plaat and near the Bakkersluis (W); Heusden; Littoijen (RMNH); Escharen near Grave (ZMA). Province of Zeeland: Road to Noordwelle (†, Kuiper, 1944; Butot, 1961), in the dunes (NMV) and near the lighthouse (ZMA), Renesse; dunes near Burgh (NMV); Oranjezon, near Vrouwenpolder (coll. B.J.J.R. Walrecht, leg. G.C. Groeneweg); Golflinks near Domburg; Heinkenszand (W).

Ecology: *S. lacustre* is predominantly a species of small, stagnant waters such as ditches, ponds and shallow pools. In such localities it is often the only species, though mostly quite abundant. The observations outside the dikes, i.e. in the tidal area, were all made in small ditches, in willow coppices and reed beds, where tidal currents are very weak and of only minor importance. Therefore, such localities are quite comparable to those inside the dikes.

On the islands of the Delta area *S. lacustre* is mainly found in the dune areas, but also in some localities in the polders that remained dry during the severe floods of 1944/45 and 1953. Its dispersal to such localities is probably effected through transport by waterfowl or aquatic insects (Rees, 1965) and facilitated by the occurrence of hermaphroditism and self-fertilization. These characteristics make the species well adapted to life in small, stagnant pools.

S. lacustre seems to be very susceptible to pollution (Thiel, 1924), but it nevertheless occurs in ditches along the polluted Rhine and its branches. In these ditches, however, biological self-purification of the water probably has an important effect.

Although such authors as Van Benthem Jutting (1959) and Jaeckel (1962) indicate that *S. lacustre* can tolerate a slightly elevated salinity, we found the species only in freshwater (below 0.3‰ Cl'), and Koli (1961) reports that in SW. Finland it does not occur in brackish water. In some localities in the Delta area, however, limited periods of higher salinity do occur, especially in the localities along the Hollands Diep. Maximum values to be endured are probably about 3-5‰ Cl', although we only registered values up to 1.44‰ Cl' in localities sampled during our field work. In the Brielse Meer salinities up to about 0.9‰ Cl' also occur temporarily.

As indicated by Thiel (1924) *S. lacustre* lives mainly on muddy bottoms. According to our observations, this substrate is often rich

in detritus. It is not very likely that *S. lacustre* will become important in the future Delta lakes. It may, however, become abundant in shallow places along the shores, and its dispersal in inland waters will also probably be facilitated by the freshening of those waters.

DISCUSSION

The present study has shown that the four species of *Sphaerium* occurring in the Delta area have different ecological requirements. *S. solidum* mainly lives in sandy sediments in parts of rivers having strong water movements. *S. rivicola* also lives in the rivers, but only where water movement is weak and the sediment is consequently muddy. *S. corneum* lives along the shores of rivers, in stagnant pools and ditches, and also in many stagnant inland waters. *S. lacustre*, lastly, is found only in shallow stagnant pools and ditches.

Thus, in the channels of the freshwater tidal area only *S. solidum* and *S. rivicola* are found under conditions comparable to the seaward reaches of the Delta estuaries in which tidal flats and channels predominate. In those seaward reaches, several filter-feeding lamellibranchs occur buried in the sediment. The most important of these is certainly *Cardium edule* L. This species is abundant on the tidal flats and also in the channels, but is never found at salinities under 10‰ Cl′. The brackish water species *Cardium lamarckii* Rve does not occur under tidal conditions in the Delta area.

On the other hand, *S. solidum* and *S. rivicola* do not live in salinities of over 0.3‰ Cl′, and the same holds for similar ecological types, such as *Pisidium amnicum* (Müll.), *P. casertanum* (Poli), *P. henslowanum* (Shepp.), *P. moitessierianum* Pal., *P. nitidum* Jenyns, *P. subtruncatum* Malm, and *P. supinum* Schmidt (Kuiper & Wolff, 1970).

Thus, in the parts of the estuaries where salinities vary between 0.3‰ and 10‰ Cl′ there are no bivalves having ecological requirements as regards their feeding and burrowing habits, such as *Cardium*, *Pisidium*, and *Sphaerium*. Similar conclusions have been reached for bivalves having ecological requirements such as *Mytilus* and *Dreissena* (Wolff, 1969) and also for those ecologically similar to *Anodonta*, *Unio*, and *Mya* (Wolff, 1968). The species *Macoma balthica* (L.) and *Mya arenaria* L. occur in the area with a salinity of between 5‰ and 10‰ Cl′. Hence, in the Dutch estuaries, there is

a zone between 1‰ and 5-10‰ Cl' in which there are no lamellibranchs.

The existence of such an area without bivalve species in an estuary is in accordance with the brackish water curve of Remane (1940), but the cause of the phenomenon is difficult to indicate. The wide fluctuations in salinity and the strong sedimentation of mud in this part of the estuary and its geological history may be important factors. A discussion of this question in planned for a future paper.

SUMMARY

The distribution and ecology of *Sphaerium solidum, S. rivicola, S. corneum,* and *S. lacustre* in the estuarine area of the Rhine, Meuse, and Scheldt are described. Attention is drawn to the fact that in these estuaries no lamellibranchs occur in water with salinities of between 1‰ and 5-10‰ Cl', which is in accordance with the well-known brackish water curve of Remane (1940).

SAMENVATTING

De verspreiding en oecologie van *Sphaerium solidum, S. rivicola, S. corneum* en *S. lacustre* in het Deltagebied worden beschreven. De eerste twee soorten komen uitsluitend in de rivieren voor, *S. solidum* op zandige bodems, *S. rivicola* op modderige bodems. *S. corneum* is in alle mogelijke wateren met weinig waterbeweging te vinden, behalve in het poldergebied van de Zeeuwse eilanden en Goeree-Overflakkee. *S. lacustre* bewoont vooral allerlei kleinere watertjes en heeft een nogal onregelmatige verspreiding. De aandacht wordt gevestigd op het feit dat er in de estuariën van het Deltagebied geen Lamellibranchia voorkomen in het gebied met zoutgehalten tussen 1‰ en 5-10‰ Cl'. Dit is in overeenstemming met de bekende brakwaterkromme van Remane (1940).

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