Discovery of male plants of *Najas marina* L. (Hydrocharitaceae) in Britain

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ABSTRACT

The dioecious, annual macrophyte *Najas marina* is represented in Britain only in the Norfolk Broads. Although it was discovered in 1883 (at Hickling Broad), only female plants had previously been recorded and all seed production was assumed to be apomictic. Following detailed study of the population biology of this species, the occurrence of male plants at Hickling and Upton Broads in the summer of 1998 is reported. Photographs of the inconspicuous male flowers and pollen are provided. Possible reasons for the plants remaining unreported for so long are discussed. The potential for sexual reproduction has implications for the conservation of this Red Data Book species in Britain.

Keywords: Annual, aquatic macrophyte, dioecy, Holly-leaved Naiad, rarity.

INTRODUCTION

Najas marina (Holly-leaved Naiad) is a dioecious annual which grows completely submerged in shallow lakes (1–3 m deep), rooting extensively into the bottom sediments. In Britain, *N. marina* is only found in the Norfolk Broads and there only in a handful of lakes, where it forms dense beds and can predominate over large areas. *N. marina* has a long history in the British flora, with fossil evidence for populations being far more widespread during the last climatic optimum than at present (Godwin 1975). In 1883, Arthur Bennett found *N. marina* for the first time as a living plant (Bennett 1884, 1909) and since then there has been a well reported increase in the number of sites at which it has been found (Barry & Jermy 1953) although there have rarely been more than seven sites in any one year.

Najas marina is listed as Vulnerable in the British Red Data Book and in the IUCN European Red Data Categories and is therefore specially protected under the Wildlife and Countryside Act 1981 (Wigginton 1999). Despite considerable interest in *N. marina*, arising from its rarity value in Britain and Europe, there has been little detailed knowledge of its autecology and life history. In particular, there have been no reports of male individuals of *N. marina* in Britain and, in the apparent absence of male flowers, there has been speculation that its prolific seed production is entirely apomictic (Stace 1997; Preston & Croft 1997). This paper reports that male plants do in fact occur in Britain and illustrates the features of male flowers.

THE IDENTIFICATION OF MALE PLANTS

The discovery of male plants of *Najas marina* was made while snorkel diving to collect plant material in Hickling Broad in East Norfolk (Nat. Grid ref: TG/418.209). Subsequently, plants bearing male flowers were found at Upton Broad, another well established site for this species. Hickling Broad is the largest of the Norfolk Broads and the site at which Bennett first recorded *N. marina* (Bennett 1884).

During 1998, Hickling and Upton Broads were visited at fortnightly intervals throughout the year in order to survey the populations of *N. marina*. In June and July, only plants bearing female flowers were observed; despite meticulous examination of a considerable quantity of plant material, male flowers could not be found. Plants apparently had only female flowers or no floral

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structures at all. However, in August 1998 male flowers were identified for the first time while diving. These flowers were evident for only a few weeks.

The dense beds, with near-continuous cover, and the branching growth form of *Najas marina* at Hickling and Upton Broads combine to create considerable difficulty in distinguishing individual plants. The bases of the stems often become covered in sediment and root at the covered nodes making the identification or extraction of individual plants impossible. Nevertheless it was clear that the ratio of female to male flower bearing stems in these beds was high, perhaps as high as 10:1, and that male stems occurred in distinct patches, suggesting that isolated, individual males were surrounded by females. With some care it was possible to collect entire stems of *N. marina*. Examination of these revealed that each stem bears either exclusively male flowers or exclusively female flowers. As an individual plant may comprise several stems arising from the initial node it is not possible to say categorically that all the stems of an individual plant were of the same sex. However, there is no evidence from work on these populations to query the traditional view that *N. marina* is dioecious.

FLORAL MORPHOLOGY

The flowers of *Najas marina* arise singly, or sometimes several together, on a fertile shoot with suppressed internodes within a sheath axil (Rendle 1899). The male flower is ellipsoid, c. 2–4 mm long and 1–2 mm wide at the widest point. It possesses a thin membranous spathe which forms a tight envelope about the flower and protrudes above it to form a narrow crown with characteristic spines (Fig. 1a). The four locules of the single anther are discernible within the perianth (Fig. 1b, 1c). The locules are densely packed with pollen grains, which are for the most part ellipsoid, but some are spherical (Fig. 1d). The morphology of these structures conforms well with the classical literature on the Najadaceae (Bailey 1885; Campbell 1897; Rendle 1899).

Initial field observations were of male flowers that appeared conspicuously pale in colour, apparently because the white pollen grains were visible through the anther wall and thin, membranous perianth. Subsequently, darker male flowers were found. The pale flowers were close to dehiscence, with mature pollen. In these flowers the pollen-filled anther was particularly visible, because elongation of the filament prior to dehiscence caused the anther to split the spathe from the apex downwards (Rendle 1899). Flowers were also found in which the anthers had clearly dehisced, leaving the anther filament and the vestiges of the four locules.

Male flowers are similar in size and shape to the maturing fruits of the female plant, and therefore they can be difficult to distinguish in the field. The phase during which the male flowers have a pale colour provides a reliable field diagnostic feature but this was evident only during August.

DISCUSSION

Given the small size and superficially similar appearance of male flowers to the developing fruits in *Najas marina*, it is perhaps not surprising that male plants of this dioecious species have gone unrecorded for so long in the British flora. The annual "window" during which the sexes are reasonably distinct appears to be narrow: outside this period, only very close scrutiny would reveal male flowers still within the spathe or the remains of dehisced anthers. In addition, the use of diving equipment and the unusually good water clarity in 1998 would have improved the chances of discrimination. Recently the macrophytes of the Norfolk Broads have been the subject of intensive study (Schutten *et al.* 1997; Kennison *et al.* 1998) without male plants of *N. marina* being reported; it is possible that the high ratio of female to male plants requires a sampling method more sensitive that the double-headed rake commonly used.

We cannot be sure, however, that male plants have always been present in the British population and therefore have simply been overlooked previously. An examination of *N. marina* herbarium material at **K** did not reveal male flowers that might have been overlooked by previous collectors. However the preservation in herbarium specimens of the minute flowers of *N. marina* is poor. There are alternative explanations. Sex expression in plants can be fickle and subject to strong environmental influences (Richards 1997). There may be an influence on *N. marina* that could make the expression of maleness a rare or uncommon event, or may have resulted in males in the British populations for the first time recently. The origins of the current British populations are not



FIGURE 1: (a) Photograph showing the male flower of *Najas marina* with spathe protruding above the anther to form characteristic spines, a second immature male flower can be seen to the left obscured by the leaf. (b) Photograph showing anther of *N. marina* with perianth wall removed but still visible, two locules of the anther can be seen through the anther wall. (c) Photograph showing the anther of *N. marina* with perianth and anther wall removed and one locule of the anther punctured spilling pollen. (d) Photograph of pollen grains of *N. marina* showing mostly elongate and some spherical grains.

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known: it may have gone unrecorded for many centuries before Bennett's discovery in 1883 or it may have been a relatively recent colonist from continental European populations, transported in the guts of migrating wildfowl (Agami & Waisel 1986). It is possible that there have been several or repeated colonization events, giving rise to plants of different gender by chance or under environmental control.

Najas marina in Britain is an obligate annual; therefore, even a temporary deficiency of males requires an alternative, apomictic mechanism for seed production. In 1998 fruit formation began well before the first male flowers were observed in the field, which suggests the possibility of facultative apomixis, with seed production early in the summer being apomictic and later seed production at least partially sexual (Asker & Jerling 1992).

At present it is impossible to say why male plants of *Najas marina* have not been recorded before. Perhaps the most parsimonious explanation is that male flowers simply went unnoticed until now. More significant is the fresh light shed on the nature of its breeding system, which is of fundamental importance in determining the genetic variability and survival potential of the British populations. The demonstrable occurrence of males gives a new perspective to our strategy for conserving this rare species.

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