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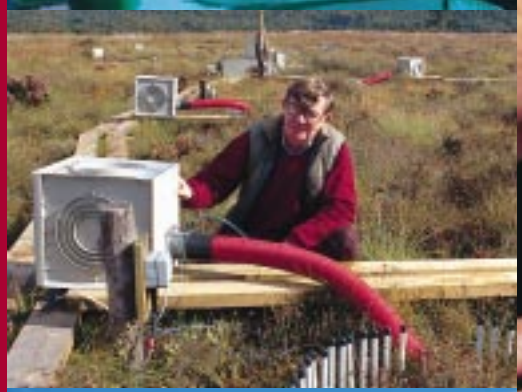

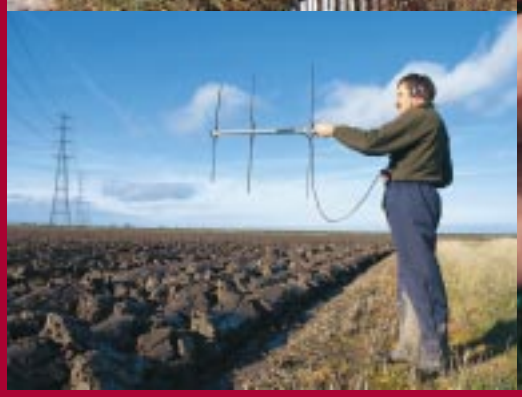

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A swallowtail population at Shapwick Heath? Preliminary study on the feasibility by comparing host plant properties in Norfolk and Somerset

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Summary

The purpose of this study was to investigate whether a thorough study into the possibilities of (re)-establishment of the Swallowtail butterfly in the Somerset Levels is useful, by comparing host plant properties in the Norfolk Broads and on Shapwick Heath National Nature Reserve (NNR)

In habitat in the Norfolk Broads, no positive relationship could be detected between the abundance of flowering Milk Parsley plants and the number of larvae encountered. However, the concealment factor was found to be significantly lower for plants bearing larvae in all three plots. Milk Parsley height was found to be significantly higher in two of the plots while the surrounding vegetation height was found to be significantly lower in one of the plots for plants on which larvae were recorded.

The abundance of flowering Milk Parsley plants is lower on Shapwick Heath NNR than in the Norfolk Broads. However, the habitat has only been created recently, the distribution and abundance of Milk Parsley probably hasn't reached its maximum potential in the area. Moreover, the management in the area does not encourage the recruitment and performance of Milk Parsley. The Milk Parsley plants encountered on Shapwick Heath were as large, if not larger than those encountered in the Norfolk Broads.

Part (38%) of the available flowering host plants occur in unfavourable conditions concerning concealment factor. The butterfly prefers Milk Parsley plants of which the concealment factor is low, in other words, where the host plant protrudes above the surrounding vegetation and/or where the immediate surrounding vegetation is low. When the surrounding vegetation grows up vigorously, Milk Parsley can compensate for this by its 'bolting' behaviour. However, when the surrounding vegetation grows up too high Milk Parsley can not keep up. This seems to be the fact in parts of Shapwick Heath where the vegetation is unmanaged. In order to keep the fen habitat open, the vegetations in the Norfolk Broads are cut regularly. This reduces the dominance and vigour of the vegetation, thus maintaining and/or enhancing the performance of Milk Parsley. It is likely that if an appropriate management regime would be applied to the reed bed vegetations on Shapwick Heath, the amount of 'suitable' Milk Parsley plants available would be enhanced significantly.

Although this study is carried out on a small scale and only to certain aspects of the ecology of the butterfly, the results indicate that suitable habitat in terms of these aspects of the ecology of the butterfly is present and/or could be created on Shapwick Heath NNR. However, before any conclusion can be drawn about, further research is needed. There are gaps in the knowledge about the ecology of the species and about optimal management of its habitat. Research is needed to investigate the following points:

Norfolk Broads

- What is the minimum total area of habitat required for a viable meta-population of Swallowtail butterflies and how should this habitat be arranged in space?
- What criteria have to be met for a patch too be classified as suitable, eg nectar plant abundance, host plant abundance etc?

Shapwick Heath/ Somerset Levels

- How do the Milk Parsley variables vegetation height, Milk Parsley height, concealment factor and flowering Milk Parsley abundance at Shapwick Heath react to cutting management?
- What amount of potential habitat is available in the Somerset Levels?
- What amount of habitat could be created in the future, what actions and management are necessary and what would be the costs of management and creation of Swallowtail habitat?

The proposed research will yield valuable knowledge of the ecology and requirements of the Swallowtail butterfly. This can be applied to the conservation of the Swallowtail in the Norfolk Broads, and to assess the feasibility of a re-establishment of the species in the Somerset Levels.

1 Introduction

The Swallowtail *Papilio machaon britannicus* is one of the rarest butterflies in the United Kingdom, it is now restricted to the Norfolk Broads. It is thought that the species was once far more widespread, probably occurring throughout the East Anglian fenland, in the marshes along the rivers Thames and Lea, in the Somerset Levels and as far north as Beverly in Yorkshire (Asher and others 2001). It is impossible to say how widespread the Swallowtail used to be in British wetlands, as many breeding sites were probably inaccessible to early butterfly collectors, and most of the vast drainage schemes were completed before systematic recording began (Thomas & Lewington 1991).

The extended marshes of the Somerset Levels must have formed ideal habitat for the species in the past. James Duncan, in volume 3 of his book "British Butterflies", 1835, states that, "although it is a somewhat local insect, it seems to be widely distributed throughout southern England". He mentions a long list of sites, among which "Somersetshire, at Weston-Super-Mare" (West 1993). Moreover, the Somerset Levels are one of the long-standing main centres of distribution of the butterfly's host plant Milk Parsley *Peucedanum palustre* (Meredith & Grubb 1993).

The Somerset County Museum possesses specimens of the species, but as a result of deterioration it is not possible to clarify if they are the continental *gorganus* or the British *britannicus* subspecies, and because most of them are not labelled, it is not clear where the specimens were collected. It is known that Victorian butterfly collectors sometimes bought or collected specimens from the continent. Furthermore, it is thought that pupae of Swallowtail have been transported to other parts of the country along with reeds for thatching.

The Swallowtail is listed as a Species of Conservation Concern in the UK Biodiversity Action Plan. According to Barnett & Warren (1995) the species is holding its own and appears to be under no immediate threat. However, the areas to which it is now restricted continue to be at risk from factors as a lowering water table, invasion of scrub and pollution of surface and ground water by nitrates and phosphates (Asher and others 2001). Problems that arose more recently are prolonged winter flooding and the increasing salinity of water in some areas as a result of seal level rising (pers. comm. R. Southwood). With this in mind it seems useful to investigate the potential for (re-)establishment (further referred to as re-establishment) of populations of this beautiful "flagship" species in the Somerset Levels, as a means of risk spreading aimed at conserving this unique subspecies. The re-establishment of the Swallowtail would fit in well with the objectives for the Somerset Levels Natural Area; the aim is to encourage additional fen creation schemes (English Nature 1997). Two of the key habitats, fens and open water and swamp and reed beds, can form habitat for the species, given that the host plant Milk Parsley is present.

There is relatively not so much known of the autecology of the Swallowtail butterfly, especially not on the species' landscape-scale requirements. As a result of this, and the time-scale of this research, it is not possible to investigate the possibilities of re-establishment in detail. However, some explorative research will be carried out to obtain insight in the usefulness of more extensive research on the re-establishment potential for the butterfly in the Somerset Levels.

The objectives of this study were

- To study the properties of Milk Parsley plants that were selected by female Swallowtail butterflies for egg-laying in three areas in the Norfolk Broads,
- To compare these suitable host plants with the Milk Parsley plants present on Shapwick Heath NNR in the Somerset Levels, and to conclude whether plants with similar properties occur on Shapwick Heath,
- To conclude whether more extensive research into the re-establishment possibilities of the species in the Somerset Levels is desirable.

2 Ecology of the Swallowtail butterfly

2.1 Introduction

The Swallowtail is a butterfly from the family *Papilionidae* and the genus *papilio* (Emmet & Heath 1990). It is a widespread species, occurring across Europe and temperate Asia to Japan (Dempster and others 1976). Two different subspecies are recorded in Britain; subspecies *gorganus* and subspecies *britannicus*. Subspecies *gorganus* is an active migrant that can be found in a wide range of habitats in the southern counties of Britain, eg meadows, cliffs and hillsides. These habitats are often very arid (Dempster 1995). In some years, the subspecies breeds in Britain, usually during its second generation (Dempster and others 1976). Then, the larvae feed on a large range of plants belonging to the Umbellifers (Dempster 1995). The British subspecies *britannicus* is endemic to Britain and is a specialized fenland insect. Its host plant is Milk Parsley. Although superficially similar, the two subspecies can be distinguished by the dark markings being broader and heavier in *britannicus* (Dempster 1995). As this study concentrates on *britannicus*, only this subspecies is discussed in this chapter.

2.2 Life cycle

The adults emerge from early June to mid-July, depending on the weather. The males are often the first to appear (Emmet & Heath 1990). They are territorial and centre their territories around a landmark such as a large bush or a tree, from which they intercept any flying adult (Dempster and others 1976). Pairing usually takes place early in the day on which the female has emerged and they may remain together for several hours. Then, the females skim low over the vegetation in search of suitable sites to oviposite her eggs (Emmet & Heath 1990). The eggs are large and conspicuous, being pale yellow at first. During their development, which takes approximately 10 days (Nicholls & James 1996), depending on temperature (Emmet & Heath 1990), they gradually darken through brown and plum colour to black (Dempster and others 1976). The larval phase of the life cycle is typically of between 45 and 55 days duration, during which the caterpillar passes through five discrete instars (Nicholls & James 1996). The first three instars are black with a broad white band across the middle and look rather like a bird dropping (Dempster and others 1976; Emmet & Heath 1990). They feed on the upper surfaces of leaves (Emmet & Heath 1990). Dempster and others (1976) found spiders to be important predators in the bird-dropping stage.

The final two instars are markedly different in appearance as the larva acquires warning coloration (Emmet & Heath 1990; Nicholls & James 1996). The ground colour varies from lime green to turquoise, with a series of black dorso-ventral bands flecked with tangerine. If the larva is irritated, it will protrude an orange-coloured osmaterium, emitting a scent that has been compared with that of rotting pineapple (Emmet & Heath 1990). At this stage, the larvae usually move up to the top of the plant and feed on the flower heads (Dempster and others 1976). Birds, especially Reed Buntings *Emberiza schoeniclus* are significant predators at this stage, particularly in years of larval abundance, as the birds develop a searching image for Swallowtail larvae (Dempster and others 1976). In late July and early August, the fully-grown larvae leave the plant to pupate on reed, sedge or the lower twigs of bushes, usually within 60 centimetres from the ground (Dempster and others 1976) and within a 10 meter radius from the host plant (Emmet & Heath 1990; Nicholls & James 1996). The species over winters as a pupae with adults emerging in the following May, but in some years a few may produce adults in August. Pupal diapause is determined by day length during the larval period, so there tends to be a larger second generation in early years (Dempster 1995). Predation during the pupal stage appears to be mainly from small mammals (Dempster and others 1976). Pupae may survive several months totally submerged in water. However, once the imago starts to develop, the pupae are very susceptible to damage by flood and frost.

2.3 Mobility

Although the British race of the Swallowtail is clearly far less mobile that the continental form, it is a large insect capable of covering considerable distances. Adults are regularly seen in gardens, away from their fen habitats (Dempster 1995). Research by Hoole and others (1999) has given some insight in the consequences of the considerable mobility of the species. They have shown that the amount of genetic variance between the reserves Hickling Broad, Woodbastwick Fen and Catfield Fen in the Norfolk Broads is very small. It has been estimated that any one colony will contain 89.3% of the gene variability present in the whole population and there has been little population subdivision. Moreover, very low values of genetic distance obtained for the three populations at the above mentioned reserves and the lack of correlation between genetic and geographical distance suggest that there is considerable gene flow between the colonies in the Broads (Hoole and others 1999).

2.4 Habitat & ecological requirements

The Swallowtail inhabits fens and marshes where its sole host plant Milk Parsley can be found. For oviposting, the females usually select large specimens of Milk Parsley, and they generally lay only on those parts of the plants that are exposed above the surrounding vegetation (Dempster and others 1976). Moreover, they are only interested in plants that flower, and in each year during a four year study, most eggs were laid in those transects containing most flowering plants (Dempster and others 1976). Wiklund (1974) mentions that Swallowtails approach only those host plants that can be oriented towards and horizontally alighted upon. Both upper and lower leaf surfaces are equally utilized for egg laying (Nicholls & James 1996). Ovipositing females typically deposit a single egg per host plant, and are frequently observed to reject plants already bearing conspecific eggs (Nicholls 1994). Nicholls and James (1996) showed that exposure of Milk Parsley plants, by removing occluding vegetation, has a significant effect on host plant choice by ovipositing females. Disparity between exposed and control plants was less marked for host plants growing in more open vegetation. This might suggest that open vegetation is more suitable for the species. Nicholls & James (1996) found a positive relationship between vegetation density and mortality. Dempster and others (1976) also suspect that mortality during the first three instars was high in a study on Wicken Fen due to the way plants were swamped by surrounding vegetation. It might be possible that complexity of background vegetation serves as a proximate indicator of the potential risk of predation, and consequently constitutes a facet of host plant selection (Nicholls & James 1996). However, the latter authors mention that, superimposed on this enemy reservoir effect is the potential for adjacent vegetation to modify both local microclimate and the nutritional quality of host plant foliage. Work by Gaffron (1993) has found no evidence that females prefer nitrogen-fertilized specimens of Milk Parsley over controls. This might suggest that nutritional quality (at least in terms of nitrogen) is not of overriding importance in host plant selection.

Another factor of importance for the species might be the abundance of nectar plants. The butterfly shows a preference for feeding on pink and mauve flowers, with Meadow Thistle *Cirsium dissectum*, Marsh Thistle *Cirsium palustre* and Ragged Robin *Lychnis flos-cuculi* being particularly favoured nectar sources (Emmet & Heath 1990; Nicholls 1994). The results of a study by Nicholls (1994) suggest that, in spite of their mobility, swallowtails spend a substantial proportion of their time in well-defined areas. It is assumed that these areas serve to accommodate all, or most of the butterfly's resource requirements with respect to nectar and larval host plants. Nicholls (1994) found no relationship between adult abundance and the distribution of Milk Parsley. However, a strong association was found between mean adult abundance and abundance of their preferred nectar plants. Research by Hoole and others (1999) has shown that there is considerable gene flow between three colonies in the Broads, suggesting that frequent movement between patches occur. Although this does not provide evidence, it suggests that the species occurs in a meta-population structure, in which persistence of the meta-population as a whole is dependent on a balance between local extinctions and colonisations of the habitat patches in the network.

2.5 Distribution and Status

The Swallowtail is dependent on the distribution of its host plant Milk Parsley which is a nationally scarce plant restricted to fens (Dempster 1995; Barnett and Warren 1995). The distribution of Milk Parsley in Britain is centred on the flood-plain fens of East Anglia and it is particularly abundant in the Norfolk Broads (Meredith and Grubb 1993). It is in the latter region, particularly in the Bure, Ant and Thurne valleys and the Mid-Yare, that the butterfly is found (Dempster 1995). It is impossible to say just how widespread the Swallowtail used to be in British wetlands, for many breeding sites would have been inaccessible to early butterfly collectors, and most of the vast drainage schemes were completed before systematic recording began (Thomas & Lewington 1991). However, it is thought that the butterfly was once far more widespread, probably occurring throughout the East Anglian fenland, in the marshes along the rivers Thames and Lea, in the Somerset Levels and as far north as Beverly in Yorkshire (Dempster 1995; Asher and others 2001). As these areas are the main centres of long-standing distribution of the Swallowtail's host plant Milk Parsley (Meredith & Grubb 1993), it is reasonable to assume that the butterfly once occurred in these areas as well. Moreover, there are written sources that refer to these areas in relation to the butterfly. Unfortunately, it is very difficult or impossible to classify these records as *gorganus* or *britannicus*. In the case of the sources that refer to breeding in Beverly in Yorkshire, there is somewhat more clarity. These are more likely to refer to *britannicus*, as this area is probably too far north for *gorganus* to breed.

Before the first significant reclamation attempts started in the 17th century, the Swallowtail's fenland habitat would have been very extensive and the butterfly's mobility was commensurate with the transient nature of the butterfly's habitat. The butterfly probably occurred as a shifting mosaic of fluctuating populations that exploited the localized and transient patchwork of Milk Parsley (Nicholls 1994). Today, lowland fen persists only as a few scattered remnants; the largest area in East Anglia had shrunk from over 3000 square kilometres in 1930 to about 10 square kilometres in 1984, a loss of 99.7% (Ratcliffe 1984). It is thought that the major stronghold for the butterfly was in these ancient fenlands in East Anglia. As the great drains were dug, the swamps were reclaimed, and the butterfly became increasingly confined to isolated fragments, resulting in its present restriction to the Norfolk Broads.

However, the once extensive fenland vegetation in the Broads has largely been replaced by woodland and scrub. This loss and fragmentation of habitat has been occurring over the past 100 years (Dempster and others 1976). As a result, the butterfly declined considerably, and its position was causing great concern in the 1970s. Fortunately, the Broads Authority, a new body formed in 1978, achieved the same status as a national park for the whole area, with the resultant flow of funds from government to conserve the area. Over the last 10 to 20 years conservation management in the Broads has increased the amount of breeding habitat for the species. In consequence the butterfly appears to be stable and is increasing in several areas (Barnett & Warren 1995).

The Swallowtail butterfly is listed as Vulnerable in the British Red Data Book of Insects (Shirt 1987). In the UK Biodiversity Action Plan the butterfly is listed as a Species of Conservation Concern. The species is listed on Schedule 5 of the Wildlife and Countryside Act, 1981, and is thus fully protected in Great Britain.

2.6 Factors affecting the butterfly's habitat

There has been an enormous decline in the area of fen habitat as a result of the reclamation and agricultural improvement of the fens. It is estimated that only 1 percent of the Swallowtail's former habitat remains nationally as a result of fen drainage in past times (Watts & McIlwrath 2002). Before man set out to 'improve' the inhospitable fens, there would have existed a delicate balance between inundation on the one hand and desiccation leading to the development of fen carr on the other. This hydrological equilibrium favoured a steady state in the hydroseral vegetational succession, yielding optimal conditions for the Swallowtail butterfly (Nicholls 1994). With the reclamation of the

fens this balance was gone and naturally the fens would develop into (wet) woodland, the climax vegetation. However, this process was counterbalanced by peat cutting and the annual harvesting of 'marsh hay', a mixture of plants that was cut annually as fodder and bedding for livestock, and Common Reed *Phragmites australis* and Great Fen Sedge *Cladium mariscus* for thatch roofing. Consequently, the persistence of the Swallowtail butterfly into the present century was dependent upon management of the fens by man. After the Second World War, most mown areas were abandoned and the neglected areas were invaded by scrub, thus reducing the area of open fen habitat. There was however a continuing demand from thatchers for reed and sedge since the war, and these crops continued to be harvested. Unfortunately, in the 1970s, the demand for reed and sedge almost ceased and there were no funds or manpower available to manage all of the Broads. In 1995, half of the Broadland fens consisted of mature willow scrub (Barnett & Warren 1995). This process of scrub invasion due to drying out is exacerbated by the low water tables in the surrounding arable areas. However, the Broads Authority, working in partnership with English Nature, is committed to halting the decline of open fens and restoring all open fen that has been recently lost to scrub. On many sites, areas of scrub have been cleared and the area of open fen has been increased by regular cutting. As a result, the Swallowtail appears to have increased substantially in several areas. Unfortunately, there are still limiting factors (Barnett & Warren 1995). The marshes remain vulnerable to becoming drier, either by natural processes, such as peat formation, or as a result of human activities and scrub encroachment is still a considerable problem. This reduces the areas of open fen vegetation. The maintenance of a stable market for sedge and reed is important, as are the financial resources for conservation management work. Unfortunately, there is still a lack of knowledge about certain aspects of the ecology of the species, which makes it difficult to design and implement suitable management. A more recent threat is formed by sea level rise, resulting in generally higher water tables in fen habitat resulting in prolonged periods of flooding in autumn and winter, and increasing salinity of the Broads. Pupae can survive long periods submerged, however, when the adult starts to develop, it is very susceptible to flood. Increasing salinity could lead to the deterioration or even disappearance of Milk Parsley in certain areas (pers. comm. R. Southwood).

The Swallowtail butterfly (picture by Roger Key).

3 Ecology of the host plant Milk Parsley

Milk Parsley is the main host plant of the Swallowtail butterfly, subspecies *britannicus*. In England, the survival of the species depends on the successful growth of large flowering specimens of Milk Parsley. Occasionally, second generation larvae can be found on other umbelliferous plants, but Dempster and others (1976) mention that, to their experience, that only happens when a larva has run out of food on a Milk Parsley plant, and is forced to search for a fresh host plant. At that time of year, Milk Parsley begins to die, so the larvae have to accept other host plants. In this study, Milk Parsley is considered to be the sole host plant for the Swallowtail butterfly, and its ecology is discussed below.

Milk Parsley is a perennial with one or more erect, hollow, ridged stems. Vigorous plants produce 1-8 lateral flowering branches, each inflorescence a terminal compound umbel (Meredith & Grubb 1993). In the field, two or more years are required before plants are large enough to flower, and mature plants do not necessarily flower each year (Dempster & Hall 1980). The leaves have a pinnate structure, and it is thought that this is of value in maximizing use of sun flecks low in the canopy, so minimizing the effect of the height of the surrounding vegetation. A milky, sticky fluid exudes from the broken tissues of young plants, hence the common name Milk Parsley (Meredith & Grubb 1993).

Seedlings germinate between mid-April and late August. The aboveground parts of the plant die down between October and December, depending on the weather. Only the root and shoot apex remain until between late January and March a single leaf emerges, often through a covering of water. This leaf remains undeveloped until rapid leaf expansion begins in April or May. On flowering plants, stems begin to elongate in June and in July the umbels begin to enlarge. Plants are in flower from early July to early October. Seed begins to ripen in mid-August, and dispersed between then and early November (Meredith & Grubb 1993).

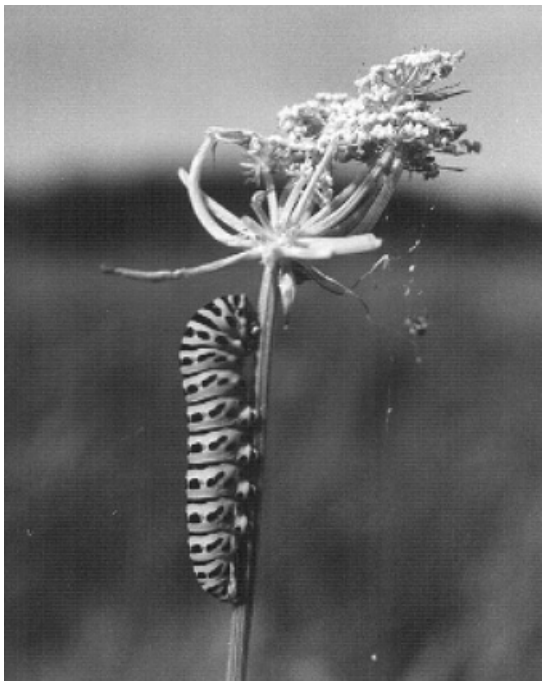
Milk Parsley seems to be primarily limited by the availability of wide floodplains. The distribution in Britain is centred on the flood-plain fens of East Anglia and it is particularly abundant in the Norfolk Broads. It is thought that the species extended through Lincolnshire and Yorkshire to the Lancashire coast. Nowadays however, Milk Parsley only persists in at least one locality in Yorkshire (Meredith & Grubb 1993). A separate longstanding centre of distribution is on the Somerset Levels, where it is now scarce overall (Roe 1981), however, it seems to be coming back in the wetland restoration areas in the Avalon Marshes.

In Britain, Milk Parsley grows mainly on peat but also in the peat-like material that accumulates in the ‘trunks’ of large tussock-forming sedges. It occurs in fen, fen scrub and fen woodland (carr). The species does not occur in pure stands but is typically ‘patchily abundant’ in the community. This can be determined by the distribution of suitable microhabitat, seed dispersal or clonal development. The ability of the species to persist in tall dense stands of reed and sedge may be related to the etiolating response of the species; internodes and petioles of seedlings grown with low radiant flux density can elongate appreciably (Meredith 1976). The ‘bolting’ behaviour at the time of flowering, by using storage in the roots, enables the plant to overtop the surrounding vegetation to attract pollinators (Meredith & Grubb 1993).

The species is typically found where the water table in winter is between 10-15 centimetres above peat surface and in summer a few centimetres below. At Wicken Fen in Cambridgeshire, the desiccation of the habitat has had a negative effect on Milk Parsley; studies by Dempster and others (1976) have shown that the species was smaller, produced less seed an was shorter-lived at Wicken Fen than in Norfolk. There was a strong relationship between the change in plant numbers from one year to the next and rainfall during that year. They also found that there was a positive correlation between percentage flowering and winter rainfall. Flooding in winter or early spring seems to benefit the species, but maybe only because the growth of Milk Parsley is indifferent to flooding, whereas that of other species is reduced (Meredith & Grubb 1993).

Research at Wicken Fen has shown that there is a potential seed input of about 5000 seeds per square metre and from the short-term seed bank in the topsoil at Wicken Fen the number of seeds available for germination was estimated to be 24 seeds per square metre. Many species of the genus *Peucedanum* have seeds that are thought to be adapted for wind dispersal. The seeds of Milk Parsley also contain sponge-like tissue that enhances buoyancy, which is thought to be assisting water dispersal. (Meredith & Grubb 1993). Experiments by Meredith & Grubb (1993) showed that germination was much more likely in open habitats, where there were marked diurnal temperature fluctuations and full daylight, than in closed habitats where light levels are very low and temperatures relatively constant.

The habitat of the species has traditionally been disturbed by man digging for peat and/or by cutting reed and 'sedge' (Great Fen Sedge). Peat digging can affect Milk Parsley in different ways; it exposes viable buried seed, it provides suitable conditions for germination, it removes competing species and it provides channels for dispersal of floating seed (Meredith & Grubb 1993). Peat digging however is no longer practised on a significant scale in most areas. Dempster and others (1976) mention that, once an area has dried out enough to allow the growth of carr, the best long-term solution to maintain numbers of Milk Parsley there is to reduce the height of the land's surface by peat cutting. Mowing and cutting can also influence the composition of the vegetation, and thereby the viability of Milk Parsley (Meredith & Grubb 1993); periodic cutting prevents or delays carr invasion in dry areas and thereby promotes Milk Parsley. However, the more frequent the cutting, the more likely Great Fen Sedge is becoming extinct and the less likely is Milk Parsley to survive (Meredith & Grubb 1993). According to the latter authors, the population biology of the plant is related to a three yearly cycle. However, Dempster and others (1976) mention that the sedge fields in Wicken Fen are cut every four years and this appeared to be enough to hold plant numbers constant. For the Swallowtail butterfly though, it is not the number of plants that is important, but the number of flowering plants. In terms of management for Milk Parsley and the Swallowtail butterfly, the relative importance of cutting and water regimes and their interaction have not yet been well established (Meredith & Grubb 1993; Barnett & Warren 1995).



Swallowtail larvae (final instar) on the host plant Milk Parsley.

4 Methods

The aim of this study is to investigate the properties of Milk Parsley plants that were selected by female Swallowtail butterflies for egg-laying, to compare the properties of these plants with the plants present on Shapwick Heath NNR, and to conclude whether plants with similar properties occur on Shapwick. This will give insight into whether more extensive research into the re-establishment possibilities is desirable.

Adults of the Swallowtail butterfly are very mobile; they are often seen in gardens, well away from their fen habitat. Therefore, sightings of adults are not suitable to locate suitable habitat for the species. The presence of larvae alone is used to indicate suitable habitat. The fieldwork was timed in the period when late instar larvae can be encountered in late July. The fact that the caterpillars are able to go through all the stages of their larval development indicates that the habitat in which they are found is suitable. Within the habitat, the host plants bearing larvae are considered to be the most suitable available and therefore selected by the female. A disadvantage of this approach is that it is possible that a larva has been forced to move from a completely consumed host plant to a fresh one. The plant on which the larva is found might not have been the selected plant for ovipositing by a female. However, if a larva does move, it is typically in the final instar and a completely consumed host plant nearby usually indicates that this has happened (Dempster and others 1976).

The properties of suitable host plants were studied in three nature reserves in the Norfolk Broads; a part of Hickling Broad near Chapman's which is owned by the Norfolk Wildlife Trust; Catfield Common, which is also located in Hickling Broad and owned by the Broads Authority; and Woodbastwick fens and marshes which is owned by English Nature.

In all three areas, the field was first walked to locate host plants where caterpillars were present. Around the area where the caterpillars were most abundant (here assumed to be the most suitable habitat available), a 625 square metres plot was located, mostly consisting of a 25 by 25 metres square. Because of safety reasons it was not always possible to obtain a square plot. In the plots, all flowering Milk Parsley plants were counted, and their height was measured from ground level to the top terminal umbel with a graduated pole. Height of the surrounding vegetation was assessed with a graduated pole and a drop disc (polystyrene foam, weight 5 grammes, diameter 10 centimetres) from four randomly located measurements taken within a 1 square metre quadrat centred on each host plant. From the four vegetation measurements that were obtained around each host plant in the field, the mean was calculated and further used as the variable vegetation height. By dividing the variable vegetation height by the variable Milk Parsley height for each plant, a new variable is obtained which is named 'concealment factor'. This variable gives a value for the proportion between the surrounding vegetation and the host plant. A low concealment factor means that the vegetation in a square meter around the host plant is relatively low, or the host plant protrudes above the surrounding vegetation, thus making the plant well visible. If the concealment factor is high, the host plant is small or the vegetation immediately around it is very high, hence hiding the host plant.

Each plant was searched thoroughly for the presence of larvae, and if any were encountered, the number of larvae were noted as well as their larval stage (bird dropping (first and second instar), third, fourth or final (fifth) instar. Literature suggests that ovipositing females typically lay a single egg per host plant, and are frequently observed to reject plants already bearing conspecific eggs. However, research by Nicholls (1994) showed that in 22% of cases, more than one egg was deposited on a host plant. When the study areas were visited in early July, host plants were encountered bearing more than one larva. It is assumed that two or more females selected this plant for oviposting over the others available. Therefore, when the fieldwork was carried out in late July, plants on which two or more larvae were found were recorded as two or more sightings of the plant bearing one larva, with the concerning characteristics. However, if a host plant was encountered bearing two or more larvae in the

same larval instar, it is possible that the larvae originate from eggs of the same female, and thus the plant was only selected once for ovipositing by a female. Therefore, the plant is recorded only once. These ‘extra sightings’ are only used in the analysis where it is the aim to detect what the female selects for when ovipositing.

Exactly the same procedure (except for the counting of the larvae) was followed in three areas of potential habitat at Shapwick Heath NNR.

Statistical tests in SPSS 12.0.1 were carried out to detect any significant differences between plants bearing larvae and those without larvae in terms of the variables Milk Parsley height, vegetation height and concealment factor, and the properties of Milk Parsley plants in Norfolk on which larvae were recorded were compared with the properties of Milk Parsley plants at Shapwick Heath NNR.

5 Results Norfolk

5.1 The plots in the Norfolk Broads

Hickling
Plot Hickling was situated near Chapman's in Hickling Broad (grid reference TG426222). The area is owned by the Norfolk Wildlife trust. Management in the area consists of light grazing by cattle and the vegetation consisted primarily of relatively dense stands of Common Reed. However, where the larvae were found (and thus the plot was laid out) the vegetation was more open, presumably as a result of trampling and the creation of paths by cattle. In the plot of 625 square metres, 112 flowering Milk Parsley plants were encountered, resulting in an abundance of 17.92 flowering plants per 100 square metres. In this plot, seven larvae were recorded of which two were in the third instar and five in the final instar. The descriptive statistics of the measured Milk Parsley plants in this plot can be found in table 5.1.

Table 5.1 Descriptive statistics of the measured Milk Parsley plants in plot Hickling

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	112.00	217.00	171.44	23.39
Vegetation height (cm)	73.25	149.50	113.81	15.85
Concealment factor	0.49	1.01	0.67	0.11

Woodbastwick
Plot Woodbastwick (grid reference TG335166) was situated in the Bure Marshes NNR in an area known as Woodbastwick Fens and Marshes, and is owned by English Nature. The vegetation in the area consisted of a mixture of Common Reed and Great Fen Sedge with abundant Marsh Fern *Thelypteris palustris*. The number of flowering host plants for the butterfly found in this plot was relatively low compared to the other plots; a total of 30 flowering plants was encountered, resulting in an abundance of only 4.8 flowering plants per 100 square meters. However, the number of larvae encountered in this plot was relatively high; five larvae were in the bird dropping stage, two were third instar, four were in the fourth instar and two larvae had reached the final instar, resulting in a total of 13 larvae. For the descriptive statistics of the measured Milk Parsley plants in this plot, see table 5.2.

Table 5.2 Descriptive statistics of the measured Milk Parsley plants in plot Woodbastwick

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	108.00	205.00	155.40	25.85
Vegetation height (cm)	72.00	144.25	107.67	18.68
Concealment factor	0.50	0.89	0.70	0.09

Catfield Common
Plot Catfield Common (grid reference TG404218) was also situated in Hickling Broad, but in an area known as Catfield Common. The Broads Authority owns the area. The vegetation here could be described as sedge fen; the vegetation was a mixture of Great Fen Sedge and Common Reed. The number of flowering host plants encountered was 109, resulting in an abundance of 17.44 flowering Milk Parsley plants per 100 square meters. A total of eight larvae was found, one larva in the bird dropping stage, five in the fourth stage and two in the final stage. The descriptive statistics of the measured Milk Parsley plants in this plot can be found in table 5.3.

Table 5.3 Descriptive statistics of the measured Milk Parsley plants in plot Catfield Common

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	112.00	205.00	155.41	21.11
Vegetation height (cm)	77.75	147.75	112.60	13.22
Concealment factor	0.49	1.02	0.74	0.11

5.2 Analysis – what does the female select for?

The variables Milk Parsley height, vegetation height and concealment factor are normally distributed (Shapiro-Wilk tests). The variances are equal for the variables Milk Parsley height and concealment factor, but not for the variable vegetation height (Levene's tests).
Significant differences exists between the plots concerning the variables Milk Parsley height and concealment factor. Woodbastwick and Hickling differ in terms of Milk Parsley height ($t=3.26$, $df=140$, $p=0.001$) and Catfield Common and Hickling differ in terms of Milk Parsley height ($t=5.34$, $df=219$, $p<0.000$, see figure 5.1) and concealment factor ($t=-4.29$, $df=219$, $p<0.000$ see figure 5.2). The plots do not differ in terms of vegetation height. The plots Woodbastwick and Catfield Common do not differ in any of the measured variables.

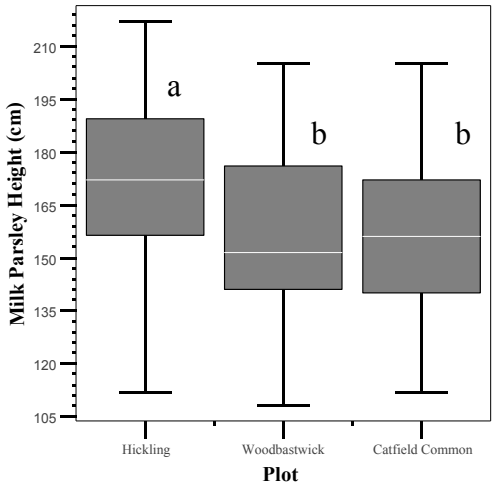


Figure 5.1 Boxplots for the variable Milk Parsley height (cm) in the three plots in the Norfolk Broads. Boxplots with the same letter do not differ significantly. # plants per plot is shown in table 5.4.

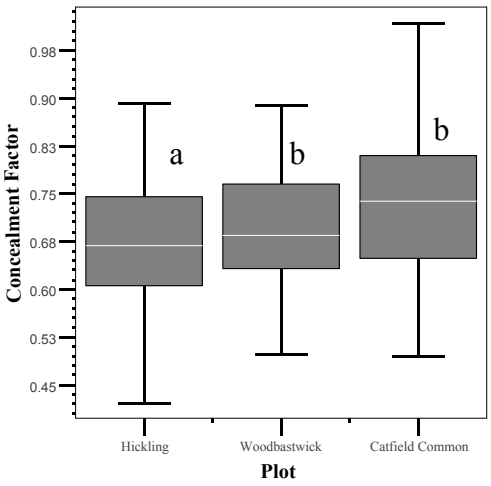


Figure 5.2 Boxplots for the variable concealment factor in the three plots in the Norfolk Broads. Boxplots with the same letter do not differ significantly. # plants per plot is shown in table 5.4

No positive relationship between abundance of flowering host plants and the number of larvae

No positive relationship could be detected between the abundance of flowering Milk Parsley and the number of larvae encountered. On the contrary; most larvae were found in plot Woodbastwick with the lowest abundance of Milk Parsley (see table 5.4) Interestingly, in the area adjacent to the Woodbastwick plot, much higher abundances of Milk Parsley were encountered, but no larvae were found in this area.

Table 5.4 The abundance of flowering Milk Parsley (MP) and the number of larvae encountered in the plots in the Norfolk Broads.

Plot	# flowering MP	# flowering MP/100m2	# larvae
Hickling	112	17.92	7
Woodbastwick	30	4.80	13
Catfield Common	109	17.44	8

Differences between host plants bearing larvae and those without

Comparison of the variables Milk Parsley height, vegetation height and concealment factor for the different plots in Norfolk has shown that differences exist between the plots. Therefore, the comparison of the variables Milk Parsley height, vegetation height and concealment factor of host plants bearing larvae and those without is carried out within each plot. The results of this analysis are summarized in table 5.5 and visually presented in figure 5.3 until 5.5.

Table 5.5 The results of the comparison of Milk Parsley plants with and without larvae (t-tests, α=0.05, $n_{Hickling}$=112, $n_{woodbastwick}$=30, $n_{catfield\ common}$=109). The statement in *italics* refers to the Milk Parsley plants bearing larvae, eg for Hickling and variable Milk Parsley height: plants on which Swallowtail larvae were recorded were significantly *higher* than plants without larvae.

Variable	Hickling	Woodbastwick	Catfield Common
Milk Parsley height	T=2.32 df=112 p=0.022 **Sig *higher***	T=0.02 df=30 p=0.985 Not sig	T=10.25 df=43.9 p<0.000 **Sig *higher***
Vegetation height	T=2.22 df=112 p=0.029 **Sig *lower***	T=1.80 df=30 p=0.083 Not sig	T=-1.96 df=109 p=0.052 Not sig
Concealment factor	T=3.68 df=112 p<0.000 **Sig *lower***	T=2.22 df=30 p=0.034 **Sig *lower***	T=2.86 df=12.56 p=0.014 **Sig *lower***

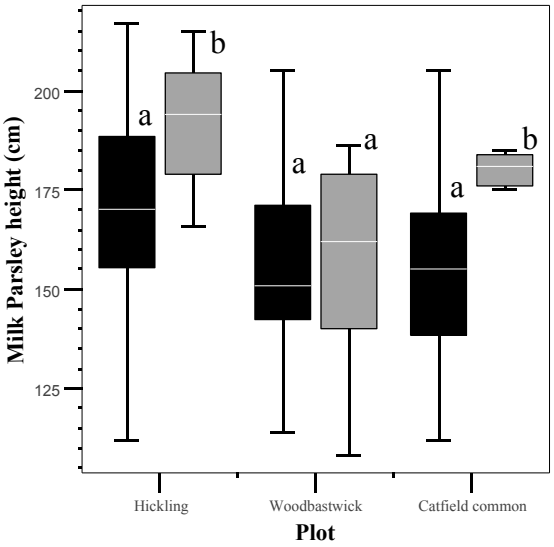


Figure 5.3 Boxplots for the variable Milk Parsley height (cm). Grey plots represent Milk Parsley plants on which Swallowtail larvae were recorded, black plots refer to Milk Parsley plants without larvae. Only tested for significant differences within a plot; boxplots with the same letter do not differ significantly.

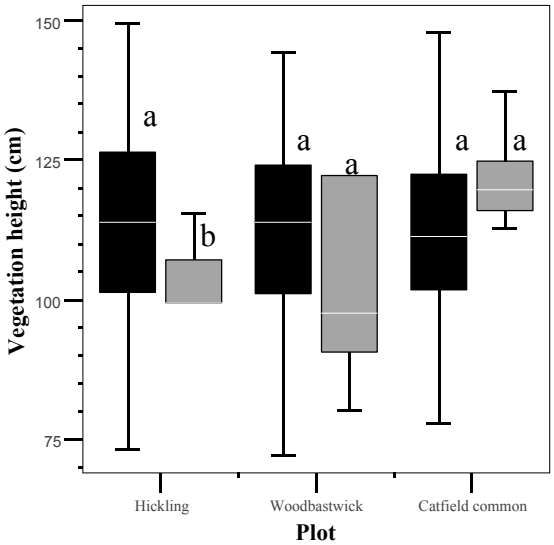


Figure 5.4 Boxplots for the variable vegetation height (cm). Grey plots for Milk Parsley plants on which Swallowtail larvae were recorded, black plots refer to Milk Parsley plants without larvae. Only tested for significant differences within a plot; boxplots with the same letter do not differ significantly.

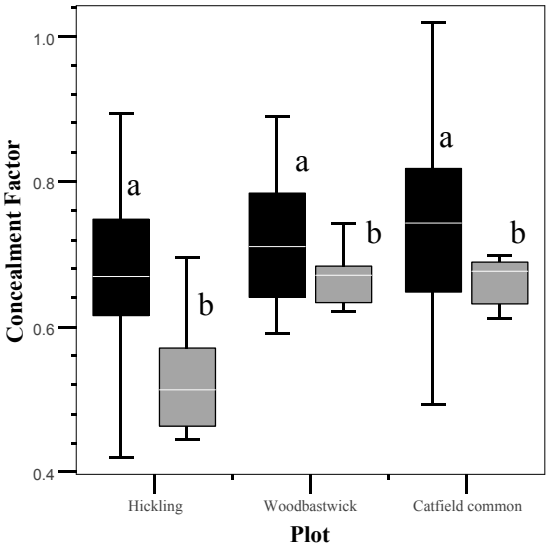


Figure 5.5 Boxplots for the variable concealment factor. Grey plots represent Milk Parsley plants on which Swallowtail larvae were recorded, black plots refer to Milk Parsley plants without larvae. Only tested for significant differences within a plot; boxplots with the same letter do not differ significantly.

The results for the variable Milk Parsley height suggest that female Swallowtails do not only select large host plants. In Woodbastwick, three larvae were found on three of the five smallest (108, 116 & 126 centimetres) plants in the sample. One of these larvae was a fifth instar, so this sighting should be interpreted with caution. This specimen could have moved from a completely consumed host plant, so the plant on which it is found now might not have been the selected plant by the female to deposit an egg. However, the other two are of earlier instars (bird dropping stage and third instar), indicating that the female selected these plants above others available. These results also suggest that the surrounding vegetation around host plants with larvae is not significantly lower (in all plots) than plants without larvae, suggesting that the female doesn't select suitable host plants purely on the height of the vegetation around it. The results for the variable concealing factor suggest that it is a *combination* of the properties height of the host plant and height of the surrounding vegetation that matters; the value of the concealing factor is significantly lower for plants with larvae than for those without. It seems that the butterfly selects for plants that protrude more above the surrounding vegetation than others and/or plants of which the immediate surrounding vegetation (within 1 square metre) is relatively low and/ or open. Figure 5.6 suggests that the butterfly selects plants with a concealment factor within the range 62.5-72.5 more often than plants with another concealment value. However, it is difficult to draw a conclusion because of the small sample size (n=22). Figure 5.7 (the frequencies of the concealment factor for all the Milk Parsley plants in the study) shows that a lot of plants in this ratio category were available, so it could be more a reflection of what was available to the butterfly then what the butterfly actually selected for. In table 5.6, the minimum, maximum and mean value for the variables Milk Parsley height, vegetation height and concealment factor for the host plants bearing larvae can be found.

Table 5.6 Properties of the Milk Parsley plants on which larvae were recorded.

Variable	Min	Max	Mean
Milk Parsley height (cm)	108.0	215.0	168.0
Vegetation height (cm)	78.5	137.3	105.7
Concealment Factor	45	78	64

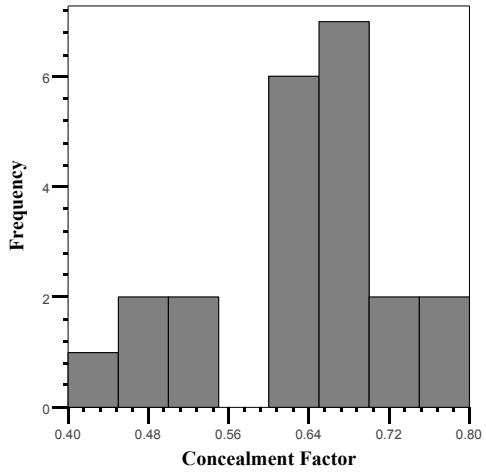


Figure 5.6 Histogram of the variable concealment factor for Milk Parsley plant on which Swallowtail larvae were recorded in the plots in Norfolk.

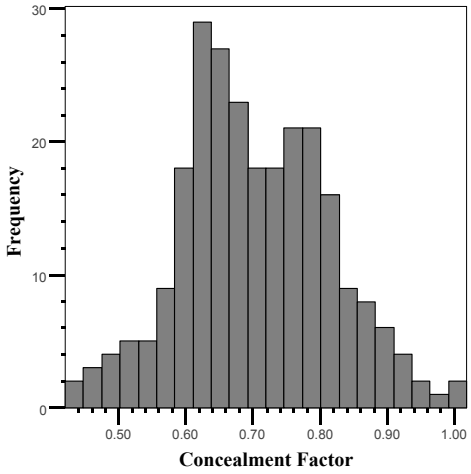


Figure 5.7 Histogram of the variable concealment factor for all Milk Parsley plants in the plots in Norfolk.

5.3 The criteria ranges

The results from this study are well in accordance with the observations that, for ovipositing, the butterfly selects large, flowering specimens of Milk Parsley that protrude above the surrounding vegetation (Dempster and others 1976) and that females only approach those host plants that can be oriented towards and horizontally alighted upon (Wiklund 1974). Moreover, Nicholls & James (1996) found that removing the occluding vegetation around a specimen of Milk Parsley had a significant positive effect on host plant choice by ovipositing females. Removing the surrounding vegetation could be interpreted as lowering the concealment factor of that host plant drastically.
When a Milk Parsley plant bearing a larva was encountered, it was assumed that the butterfly had selected that plant for ovipositing above other plants available and consequently that this plant was a suitable host plant. However, it is possible that the larva originated from another plant in the neighbourhood. In the final instar, it might happen that a larva has to move to another plant because it has consumed its host plant completely. The plant on which the larva was recorded might then not be a plant that was selected by a female. If the characteristics of these plants are significantly different from the plants suitable for egg laying, they could have biased the mean and the minimum and maximum value of the variables Milk Parsley height, vegetation height and concealment factor of the specimens of Milk Parsley that are here considered to be suitable host plants. However, a completely consumed host plant, an indicator that movement might have occurred, was only encountered once, indicating that this has not biased the results severely.

Concealment factor was the only variable that differed significantly for Milk Parsley plants bearing larvae and those without larvae in all plots in Norfolk. Therefore, concealment factor is the variable that is most useful to assess the suitability of the Milk Parsley plants on Shapwick Heath NNR as host plants for the Swallowtail butterfly. However, the variables Milk Parsley height and vegetation height have also been taken into account, especially because the variable Milk Parsley Height was significant in both Hickling and Catfield Common. Because the variables measured in the different plots in Norfolk differ significantly between the plots and between the plants bearing larvae, it is not possible to give exact requirements that the Milk Parsley plants have to meet in order to be selected for ovipositing. To judge the suitability of the Milk Parsley plants on Shapwick as host plants for the butterfly, the approach is adopted to test whether the recorded values for Milk Parsley height, vegetation height and concealment factor of the Milk Parsley plants that occur on Shapwick Heath fall within the ranges for Milk Parsley height, vegetation height and concealment factor as recorded on host plants bearing larvae in actual habitat in Norfolk. These ‘suitable host plant ranges’ are presented in table 5.6.

Table 5.6 Suitable host plant ranges for Milk Parsley plants

Variable	Range
Milk Parsley height	108-215 cm
Vegetation height	79-137 cm
Concealment Factor	45-78 %

6 Results Shapwick Heath

6.1 The plots at Shapwick Heath NNR

Seventy acres
Plot Seventy Acres is located in a part of the reserve that is known as Seventy acres, the grid reference is ST444400. The vegetation consisted of abundant Common Reed and frequent Bulrush *Typha latifolia* with some Yellow Flag *Iris pseudacorus* and Skullcap *Scutellaria galericulata*. Seedlings and young Milk Parsley plants were very abundant in the area. A total of 31 flowering plants were encountered, resulting in an abundance of 4.96 flowering Milk Parsley plants per 100 square meters. Some specimens of Milk Parsley were encountered of which the main stem was bitten off, presumably by Roe Deer *Capreolus capreolus*. These specimens were not recorded. The descriptive statistics of the measured Milk Parsley plants in this plot can be found in table 6.1.

Table 6.1 Descriptive statistics of the measured Milk Parsley plants in plot Seventy Acres.

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	109.00	229.00	176.71	30.53
Vegetation height (cm)	65.00	166.00	126.66	18.13
Concealment factor	0.74	1.25	0.74	0.17

Sweet Track
The grid reference of plot Sweet Track is ST425404. The vegetation consisted primarily of Common Reed, with frequent Hemp Agrimony *Eupatorium cannabinum*, Marsh Thistle and some Bittersweet *Solanum dulcamara*, Common Comfrey *Symphytum officinale* and Hedge Bindweed *Calystegia sepium*. In this plot, 73 flowering Milk Parsley plants were recorded; an abundance of 11.68 flowering Milk Parsley plants per 100 square meters. The descriptive statistics of the measured Milk Parsley plants in this plot can be found in table 6.2

Table 6.2 Descriptive statistics of the measured Milk Parsley plants in plot Sweet Track.

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	120.00	237.00	182.85	24.99
Vegetation height (cm)	79.00	167.00	125.93	21.38
Concealment factor	0.44	0.97	0.70	0.12

The Roughet
The vegetation in plot the Roughet (grid reference ST433402) consisted of abundant Common Reed, with some Yellow Flag, Skullcap and Hedge Bindweed (*Calystegia sepium*). The vegetation was relatively high and dense. Sixteen flowering Milk Parsley plants were recorded, an abundance of only 2.56 flowering Milk Parsley plants per 100 square meters. However, a lot of seedlings and young plants were present. For the descriptive statistics of the measured Milk Parsley plants in this plot, see table 6.3.

Table 6.3 Descriptive statistics of the measured Milk Parsley plants in plot The Roughet.

Variable	Min	Max	Mean	SD
Milk Parsley height (cm)	111.00	213.00	165.00	31.18
Vegetation height (cm)	104.00	187.00	140.73	22.36
Concealment factor	0.64	1.44	0.88	0.20

6.2 Analysis

The variances between the plots in Shapwick are equal (Levene's tests). The data of vegetation height is not normally distributed for plot Seventy Acres, and the data for concealment factor is not normally distributed for plot Seventy Acres and the Roughet (Shapiro-Wilk tests). The plots do not differ significantly in terms of Milk Parsley height (One way ANOVA, F=2.93, p=0.058, see figure 1), neither in terms of vegetation height (Kruskal-Wallis, Chi^2=5.07, df=2, p=0.079, see figure 6.2). However, plot the Roughet differs significantly in terms of concealment factor from the plots Sweet Track and Seventy Acres (Kruskal-Wallis, Chi^2 =12.56, df=2, p=0.002) (see figure 6.3).

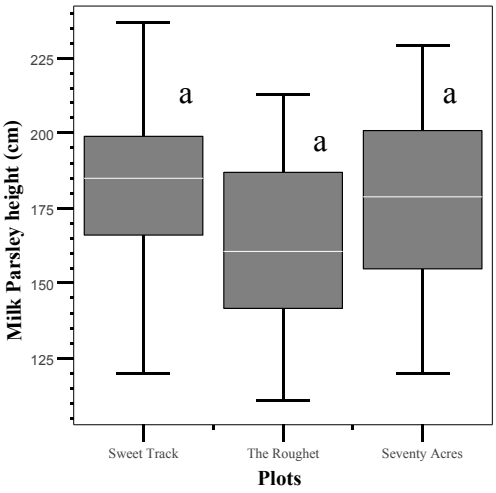


Figure 6.1 Boxplots for the variable Milk Parsley height (cm) for the Milk Parsley plants recorded in the three plots on Shapwick Hearth NNR. Plots with the same letter do not differ significantly. $n_{seventy\ acres}$=31, $n_{sweet\ track}$=73 and $n_{roughet}$=16.

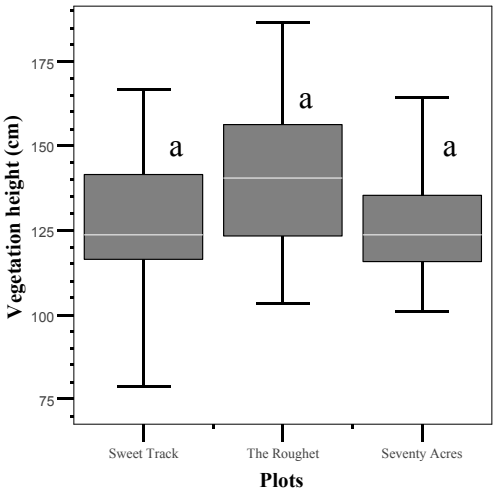


Figure 6.2 Boxplots for the variable vegetation height (cm) for the Milk Parsley plants recorded in the three plots on Shapwick Hearth NNR. Plots with the same letter do not differ significantly. $n_{seventy\ acres}$=31, $n_{sweet\ track}$=73 and $n_{roughet}$=16.

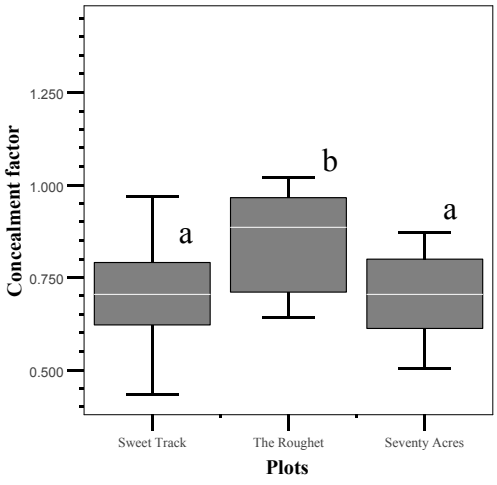


Figure 6.3 Boxplots for the variable concealment factor for the Milk Parsley plants recorded in the three plots on Shapwick Hearth NNR. Plots with the same letter do not differ significantly. $n_{seventy\ acres}$=31, $n_{sweet\ track}$=73 and $n_{roughet}$=16.

7 Comparison Norfolk Broads and Shapwick Heath NNR

7.1 The abundance of Milk Parsley in the Broads and on Shapwick

The data in table 7.1 shows the abundance of flowering specimens of Milk Parsley per 100 square metres. The abundance of flowering Milk Parsley plants is highest in plots Hickling and Woodbastwick .The abundance in the plots on Shapwick Heath is relatively lower, with the abundance in plot the Roughet even lower than the lowest abundance encountered in Norfolk (Woodbastwick). However, in two of the Shapwick plots, the recorded abundance of flowering Milk Parsley plants was higher than the minimum abundance encountered in the Swallowtail habitat in Norfolk while the plots in Shapwick are not managed or not managed in a way that encourages or maintains Milk Parsley abundance.

Table 7.1 The abundance of flowering Milk Parsley plants recorded in the plots in the Norfolk Broads and on Shapwick Heath NNR.

Area	Plot	abundance MP (#/100m2)
Norfolk Broads	Hickling	17.92
	Woodbastwick	4.80
	Catfield Common	17.44
Shapwick	Seventy Acres	4.96
	Sweet Track	11.68
	The Roughet	2.56

7.2 The suitability of Milk Parsley plants on Shapwick Heath NNR

Table 7.2 shows the percentage of suitable host plants in the plots on Shapwick Heath concerning Milk Parsley height, vegetation height and concealment factor, according to the criteria ranges for these variables found in suitable habitat for the Swallowtail butterfly in the Norfolk Broads.

Table 7.2 The percentage suitable host plants in the plots in the Norfolk Broads and on Shapwick Heath NNR regarding the variables Milk Parsley height, vegetation height and concealment factor.

Area	Plot	Milk Parsley height	Vegetation height	Concealment factor
Norfolk Broads	Hickling	99%	92%	88%
	Woodbastwick	100%	87%	83%
	Catfield Common	100%	96%	66%
Shapwick	Seventy Acres	90%	81%	68%
	Sweet Track	90%	67%	73%
	The Roughet	100%	44%	38%

It immediately attracts attention that the percentage of Milk Parsley plants within the suitable height range is high. This is even more profound if table 7.3 is examined, which shows for each category which percentage of the unsuitable plants was higher respectively lower than the ‘suitable range’.

Table 7.3 The percentage of Milk Parsley plants on Shapwick Heath NNR for which the recorded Milk Parsley height classified them as unsuitable, with the percentages for which the height of the plant was higher or lower respectively than that of suitable host plants in the Norfolk Broads.

Plot	Milk Parsley height		
	unsuitable	< than range	>than range
Seventy Acres	10%	0%	100%
Sweet Track	10%	0%	100%
The Roughet	0%	-	-

All the Milk Parsley plants that are classified as unsuitable are larger than the plants encountered in the plots in Norfolk on which larvae were recorded. It seems reasonable to assume that these plants are suitable as well. The female selects for large flowering plants and it has not been found that the butterfly is limited by host plants being too large. On the other hand, the butterfly does seem to have problems with host plants being too small. Dempster and others (1976) have shown that in Wicken Fen, where the Swallowtail became extinct in the 1950s, the performance of Milk Parsley was much poorer than in the Broads, with the plants being much smaller (mean height 122.2 centimetres) than those in the Norfolk Broads. On Shapwick Heath, there seems to be nothing wrong with the vitality of Milk Parsley plants (see figure 7.1).

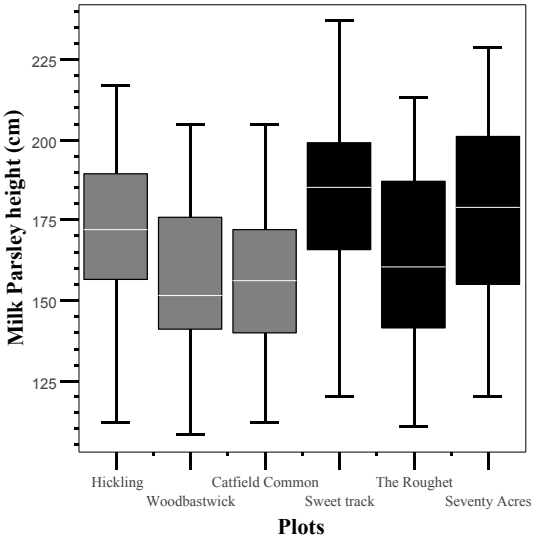


Figure 7.1 Boxplots for the variable Milk Parsley height (cm) for plants measured in the Norfolk Broads (grey) and on Shapwick Heath NNR (black).

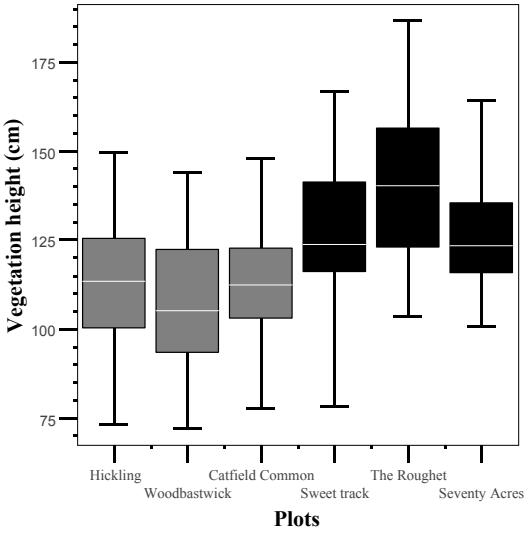


Figure 7.2 Boxplots for the variable vegetation height (cm) for plants measured in the Norfolk Broads (grey) and on Shapwick Heath NNR (black).

The percentage of host plants that occur in the suitable range of vegetation height is lower in Shapwick than in the Broads, the vegetation on Shapwick Heath is in all the unsuitable cases too high (see table 7.4 and figure 7.2).

Table 7.4 The percentage of Milk Parsley plants on Shapwick Heath NNR for which the recorded vegetation height classified them as unsuitable, with the percentages for which the vegetation was higher or lower respectively than that of suitable host plants in the Norfolk Broads.

Plot	Vegetation height		
	unsuitable	< than range	>than range
Seventy Acres	19%	0%	100%
Sweet Track	33%	0%	100%
The Roughet	62%	0%	100%

This is not really surprising. After all, vegetation management in the Norfolk Broads is aimed at maintaining open fen habitat, and encouraging or maintaining Milk Parsley abundance and quality. The vegetation in which Milk Parsley is found on Shapwick Heath is not managed at all or very seldom, giving Common Reed, Bulrush and other large species the chance to swamp the Milk Parsley plants. Milk Parsley is a species that can 'bolt' considerably to compete with Common Reed and Bulrush. However, there are limits to this ability and there is a point where Milk Parsley cannot compensate for the growth of the surrounding vegetation. This seems to be the case in some of the plots on Shapwick Heath, where the percentage of Milk Parsley plants that grow in a suitable proportion to the surrounding vegetation (concealment factor) drops considerably (see table 7.4). For example in plot the Roughet, where 62% of the Milk Parsley plants is classified as unsuitable concerning vegetation height, 56 % of the Milk Parsley plants have a concealment factor that is too high to be suitable for the butterfly (see table 7.5). In total 38% of the flowering host plants in the three Shapwick plots grow in an unfavourable condition concerning concealment factor.

Table 7.5 The percentage of Milk Parsley plants on Shapwick Heath NNR for which the recorded concealment factor classified them as unsuitable, with the percentages for which the vegetation was higher or lower respectively than that of suitable host plants in the Norfolk Broads.

Plot	Concealment Factor		
	unsuitable	< than range	>than range
Seventy Acres	32%	50%	50%
Sweet Track	27%	5%	95%
The Roughet	56%	0%	100%

It is interesting to note that in the plots Seventy Acres and Sweet Track, respectively 50% and 5% of the cases classified as unsuitable concerning concealment factor, have a smaller value than the smallest value for concealment factor encountered for host plants bearing larvae (see also figure 7.3). The host plants with a very low concealment factor are plants that protrude above the surrounding vegetation, and/or plants of which the immediate surrounding vegetation is very low. It is likely that host plants with a lower concealment factor than the lowest concealment factor encountered during this study (0.45) are also suitable host plants for the butterfly. Nicholls and James (1996) showed that when the vegetation around host plants was removed (which comes down to reducing the ratio between the vegetation height and the Milk Parsley height, and thus the concealment factor very drastically), these plants were selected by ovipositing females over controls. Moreover, Dempster and others (1976) mention that they suspect that plants that are very swamped by surrounding vegetation have a higher rate of mortality of larvae, and Nicholls & James (1996) have shown that a positive correlation exists between vegetation density and mortality of larvae. They mention that background vegetation might be a facet of host plant selection by female butterflies. This suggests that there might in fact be more suitable host plants available in plot Seventy acres and Sweet Track than table 7.2 suggests.

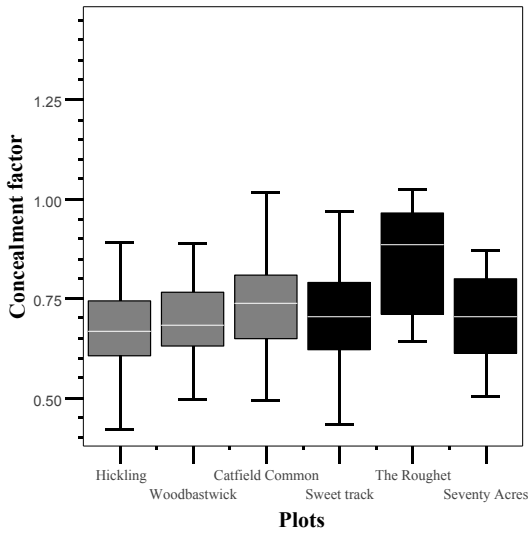


Figure 7.3 Boxplots for the variable concealment factor for plants measured in the Norfolk Broads (grey) and on Shapwick Heath NNR (black).

8 Discussion, conclusion and recommendations

The purpose of this research was to study the properties of Milk Parsley plants that were selected by female Swallowtail butterflies for egg-laying in three areas in the Norfolk Broads, to compare these suitable host plants with the Milk Parsley plants present on Shapwick Heath NNR in the Somerset Levels and to conclude whether plants with similar properties occur on Shapwick Heath, thus giving insight into whether more extensive research into the re-establishment possibilities of the species in the Somerset Levels is desirable.

In Norfolk, no positive relationship could be detected between the abundance of flowering Milk Parsley plants and the number of larvae recorded. In all three plots in Norfolk, Milk Parsley plants on which larvae were recorded had a significantly lower concealment factor than plants without larvae. The results for the variable concealment factor suggest that it is a *combination* of the properties height of the host plant and height of the surrounding vegetation that matters; it seems that the butterfly selects for plants that protrude more above the surrounding vegetation than others and/or plants of which the immediate surrounding vegetation (within 1 square meter) is relatively low and/ or open. Milk Parsley height was found to be significantly higher in two of the plots while the surrounding vegetation height was found to be significantly lower in one of the plots for plants on which larvae were recorded.

The Milk Parsley plants encountered on Shapwick Heath were as large, if not larger than those encountered in the Norfolk Broads. Dempster and others (1976) has shown that the vitality of the Milk Parsley plants in Wicken Fen, where the butterfly became extinct in the 1950s, was much reduced with the plants being much smaller than those in the Norfolk Broads. There seems to be nothing wrong with the vitality of the Milk Parsley plants on Shapwick Heath, on the contrary, they grow vigorously.

The abundance of flowering Milk Parsley plants is lower in Shapwick than in the Broads. However, the habitat has only been created recently, the distribution and abundance of Milk Parsley probably hasn't reached its maximum potential in the area. The observation that seedlings and young plants occurred abundantly in the plots supports this view. Moreover, at the moment, the area isn't managed in a way that would encourage the recruitment and performance of Milk Parsley.

Part of the available flowering host plants (38% of all flowering host plants in the three plots at Shapwick) occur in unfavourable conditions concerning the ratio between the surrounding vegetation and the height of the Milk Parsley plant (concealment factor). The butterfly prefers Milk Parsley plants with a low concealment factor. When the surrounding vegetation grows up vigorously, Milk Parsley can compensate for this by its 'bolting' behaviour. However, there are limits to this ability; when the surrounding vegetation grows up too high Milk Parsley can not keep up. This seems to be the fact in parts of Shapwick Heath where the vegetation is now relatively high. This is probably due to the unmanaged state of these areas. In order to keep the fen habitat open, the vegetations in the Norfolk Broads are cut regularly. This reduces the dominance and vigour of the vegetation, thus maintaining and/or enhancing the performance of Milk Parsley. It is likely that if an appropriate management regime would be applied to the reed bed vegetations at Shapwick Heath, the amount of 'suitable' Milk Parsley plants available would be enhanced significantly.

Although this study is carried out on a small scale and only to certain aspects of the ecology of the butterfly, the results indicate that suitable habitat in terms of these aspects of the ecology of the butterfly is present and/or could be created on Shapwick Heath NNR. However, before any conclusion can be drawn about the possibilities for re-establishment of the Swallowtail butterfly, further research is needed.

There are gaps in the knowledge about the ecology of the species, especially its landscape-scale requirements, and about optimal management of its habitat. Research is needed to investigate the following points:

Norfolk Broads

- What is the minimum total area of habitat required for a viable meta-population of Swallowtail butterflies and how should this habitat be arranged in space?
- What criteria have to be met for a patch too be classified as suitable, eg nectar plant abundance, host plant abundance etc?

Shapwick Heath/ Somerset Levels

- How do the Milk Parsley variables vegetation height, Milk Parsley height, concealment factor and flowering Milk Parsley abundance at Shapwick Heath react to cutting management?
- What amount of potential habitat is available in the Somerset Levels?
- What amount of habitat could be created in the future, what actions and management are necessary and what would be the costs of management and creation of Swallowtail habitat?

The proposed research would yield valuable knowledge of the ecology and requirements of the Swallowtail butterfly. This can be applied to the conservation of the Swallowtail in the Norfolk Broads, and to assess the feasibility of a re-establishment of the species in the Somerset Levels.

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Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888