

FLIGHT BEHAVIOUR OF THE WOODLAND BUTTERFLY *NEPTIS RIVULARIS* (SCOPOLI, 1763) (NYMPHALIDAE) WITHIN RESIDENTIAL GARDENS

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Abstract Natural habitats of woodland butterflies are becoming more and more reduced because of progressive changes due to human activities. For long-term survival, the butterflies may be required to adapt to cultural landscapes. We investigated the woodland butterfly *Neptis rivularis* (Scopoli, 1763) as a good example of a cultural follower. The focus was on the adaptation of the flight behaviour within a residential garden as a new habitat. The results indicate that *N. rivularis* is adapted well to small-scale habitat such as garden areas. Instead of flights dispersed over open area accompanied by typically extended gliding, the butterfly maintained close contact with shrubs and bushes. The flight paths were always similar. Thus, the butterflies circled around shrubs repeatedly and used corridors to reach other gardens. They adapted their daily flight activity to the temperature of the garden area. It was evident that the butterflies preferred ornamental spiraea shrubs as targets. From flight behaviour, it is suggested that the permanent scanning of structures is necessary for spatial orientation and host-learning. The small-scale flights at certain times of the day may be a protection against insectivorous birds. The presence of ornamental spiraea shrubs is the prerequisite for the acceptance of the new habitat because they can replace the natural hosts. Residential gardens that fit the needs of woodland butterflies can contribute to their conservation.

KEY WORDS: woodland butterfly, *Neptis rivularis*, residential garden, hostplant, *Spiraea* spp., behavioural adaptation

Izvešček – LETALNO VEDENJE GOZDNEGA METULJA VELIKEGA KRESNIČARJA, *NEPTIS RIVULARIS* (SCOPOLI, 1763) (NYMPHALIDAE) V HIŠNIH VRTOVIH

Zaradi človeške dejavnosti se naravni habitati gozdnih metuljev vedno bolj krčijo. Dolgoročno se bodo morda metulji morali prilagoditi kulturni krajini. Kot predstavnik takšnih metuljev sem preučeval velikega kresničarja – *Neptis rivularis* (Scopoli, 1763), s poudarkom na spremljanju adaptacije letalnega vedenja v hišnih vrtovih kot novem habitatu. Izsledki kažejo, da se je *N. rivularis* sposoben prilagoditi že majhnim vrtnim površinam. Namesto da bi metulji letali na relativno veliki površini, so raje ohranjali tesni stik z grmičevjem. Poti letenja so bile vedno podobne. Metulji so večkrat krožili okoli grmovja in se posluževali koridorjev za doseganje sosednjih vrtov. Svojo dnevno letalno aktivnost so prilagodili temperaturi na območju vrta. Očitno je bilo, da so bili njihov cilj okrasni grmički medvejke (*Spiraea* spp.). Izkazalo se je, da je za učenje in prostorsko orientacijo metuljev glede na gostiteljsko rastlino potrebno trajno pregledovanje (skeniranje) okolice. Letalna aktivnost na majhni površini in ob določenem dnevnem času bi lahko bila učinkovita zaščita pred žuškojedimi ptiči. Prisotnost okrasnih grmičkov medvejke (*Spiraea*) je predpogoj za poselitev novega habitata, saj le-ti lahko nadomestijo gostiteljske rastline v naravnem okolju. Hišni vrtovi, ki ustrezajo potrebam gozdnih metuljev, lahko prispevajo tudi k njihovemu ohranjanju.

KLJUČNE BESEDE: gozdni metulji, *Neptis rivularis*, hišni vrtovi, gostiteljska rastlina, *Spiraea* spp., vedenjska adaptacija

Introduction

The Hungarian glider *Neptis rivularis* is a medium-sized butterfly native in the open woodland of hills and mountains. Here in Styria, we observed *N. rivularis* around the hills and mountains of Graz, in Sausal and in regions of the Koralpe mountains in immediate proximity of rivers in sun-drenched valleys, woodland clearings, or at woodland edges (see also Habeler, 1965; Kühnert, 1978). *N. rivularis* is also present in the Vienna Woods and in the Karawanken mountains in undulating deciduous forests, especially near brooks or springs in gorges and ditches (Höttinger, 1998; Hassler & Tschinder, 1998; Wieser, 2008). In Slovenia *N. rivularis* is present in similar open woodland. The butterfly is most frequently found in the pre-alpine mountain region like the Škofjeloško hills, the southern slopes of the Pohorje and Kozjak Mountains and in the Koroška region. It is, however, also found in parts of the Posavje region, in the lowlands of the Ljubljana basin, and Vipava valley (see the detailed distribution map by Verovnik et al., 2012; see also Čelik, 2014; Verovnik, 2019). The green leaves of the bridewort (*Spiraea salicifolia*), goat's beard (*Aruncus dioicus*) and meadowsweet (*Filipendula ulmaria*) are the native hostplants for the larvae of *N. rivularis*. However, natural habitats of *N. rivularis* are becoming more fragmented and are reduced because of progressive changes (e.g., increased density of tall trees; increased canopy cover; drained wetlands; loss of hostplants) by human activities (Fartmann et al., 2013). The increasing popularity of ornamental spiraea shrubs in residential gardens and urban parks might be a reason for the increasing immigration of *N. rivularis* into such artificial environments. The leaves of ornamen-



Fig. 1: A row of various shrubs along which *Neptis rivularis* frequently flew (photo: K. Kral).

tal spiraea shrubs seem to provide an adequate food source for the larvae (Räuschl, 2002; Straka, 2010). Verovnik et al. (2012) wrote that in recent years *N. rivularis* has moved in Slovenia into urban areas, presumably because of the planting of ornamental spiraea shrubs as potential larval host plant.

Methods

We investigated the woodland butterfly *Neptis rivularis* (Scopoli, 1763) in the study area ($\sim 1500 \text{ m}^2$) within residential gardens in Seckau ($47^{\circ}17'N$, $14^{\circ}47'E$; $\sim 850 \text{ m}$ above sea level). The village is on a plateau on a sunny side of the Upper Mur Valley in Styria, Austria. In the study area there is a mixture of sunny and shady green meadows with higher grasses and bare earth patches in between, flower beds and various herbaceous perennials, trees, bushes, and shrubs, as ornamental spiraea (six shrubs of *Spiraea x vanhouttei*, a Belgium hybrid of *S. cantoniensis* and *S. trilobata*; four shrubs of *S. x cinerea*, a hybrid of *S. hypericifolia* x *S. cana*; two shrubs of *S. nipponica*; three shrubs of *Physocarpus opulifolius*). Similar planted vegetation is also present in gardens outside the study area. In each garden, a single-family house is located. House driveways are paved or asphalted, and terraces are paved or tiled. Pathways form free corridors also to gardens further away. Figure 1 shows a

row of various shrubs. At one side of the study area to the northwest, managed hay meadows extend.

We recorded the flight period of *N. rivularis* within the study area. The daily flight activity was estimated by monitoring the number of specimens with the aid of a digital voice tracer equipped with a timestamp. Flight duration and speed were measured with an electronic stopwatch. For the latter, straight flights of known distance along a hedgerow were considered. The butterfly was followed visually from a raised terrace with an almost all-around view. Where that was not possible, butterflies were followed by walking. The local weather station of the ZAMG/ORF, which was based next to the study area (<https://wetter.orf.at/steiermark/seckau/>) provided the daily measured data of air temperature (°C) and wind condition (km/h; direction). We calculated the natural illumination with a lux-meter, whereby the sensor upwards to the free sky was always directed at the same position within the study area.

Results

Larvae, prepupae, and pupae of *N. rivularis* experienced a cool April and May in the year 2021 with ambient temperatures of $4.3 \pm 3.5^\circ\text{C}$ (mean \pm SD) and $9.1 \pm 2.7^\circ\text{C}$ respectively. June was significantly warmer with $17.8 \pm 3.1^\circ\text{C}$. July temperature was on average $18.2 \pm 2.0^\circ\text{C}$. Adults of *N. rivularis* were seen for the first time on a sunny afternoon in the middle of June and the last time towards the end of July. The flight activity reached a peak during the second half of June (Table 1). *N. rivularis* specimens with damaged and worn wings were sometimes seen already at the end of June, but not until July (Fig. 2). The damaged wings did not deter the butterflies from flying around.

Table 1: Number of *Neptis rivularis* in flight at the study area from the middle of a sunny morning to a sunny noon

2021	Total number	Rel. frequency at spiraea shrubs	Rel. frequency at other shrubs	Rel. frequency elsewhere	Gender
June 16	1	1.0	-	-	♂
June 20	8	0.75	0.25	-	♂♀
June 23	20	0.65	0.15	0.2	♂♀
June 28	14	0.643	0.214	0.143	♂♀
July 3	11	0.727	0.182	0.091	♂♀
July 7	8	0.75	0.25	-	♂♀
July 13	4	0.75	-	0.25	♀
July 19	2	1.0	-	-	♂♀
July 23	3	1.0	-	-	♂♀



Fig. 2: *Neptis rivularis* with completely intact wings resting on *Spiraea x cinerea* (June 30, 2021) and with damaged and tattered wings ‘bleached’ by lost scales, resting on *Spiraea x vanhouttei* (July 9, 2021) (photos: K. Kral).

Flight activity of *N. rivularis* could be observed only during sunny weather. The measured sky illumination during flight activity was from 140×10^2 lux to 1400×10^2 lux ($N = 50$). The lowest measured air temperature at which specimens flew was at 13°C . When the illumination was too low, as under an overcast sky, even optimal air temperature could not stimulate the butterflies to take flight. In the early morning (from an hour and a half to two hours after sunrise), even on sunny days no flight activity could be observed. As Figure 3 shows, highest flight activity was from mid-morning to noon and flight activity decreased over the afternoon. On the four days in June when the afternoon temperature reached 30°C in the shade no flight could be observed.

We observed that specimens, when flying around, always maintained close contact with shrubs, bushes, and trees, often within less than 10 cm distance. The butterflies frequently flew around the same shrub. They quickly crossed open areas such as meadows and paved or asphalted pathways flying close to the ground. Otherwise, they avoided bare features like walls and roofs of buildings. *N. rivularis* never flew towards and over the adjacent hay meadows.

The flight path was irregular in zigzags, turns, and loops. Short gliding phases interrupted fluttery flight. The flight speed was at air temperatures of 20 to 25°C and wind speed less than 5 km/h in average 2.7 ± 1.4 msec⁻¹ (mean \pm SD, $N = 30$). The

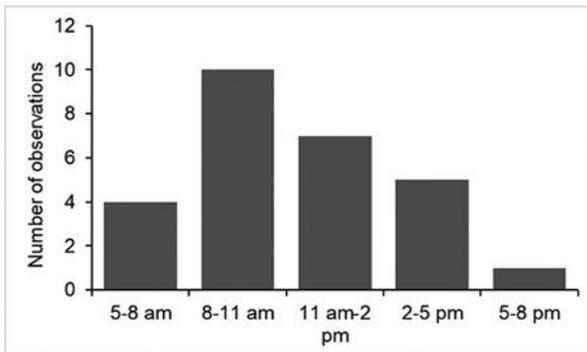


Fig. 3: Daily flight activity of *Neptis rivularis* in the study area (standard time).

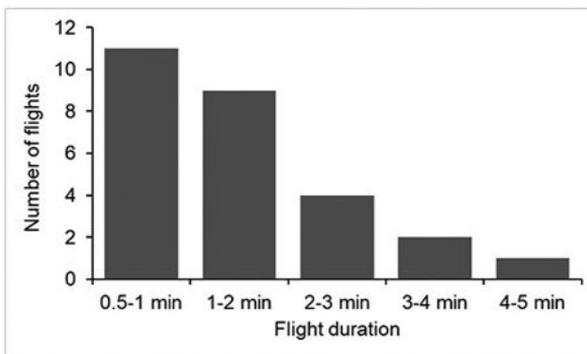


Fig. 4: Duration of flights of *Neptis rivularis* in the study area.

slowest flight speed was 1.5 msec^{-1} and the fastest 5.0 msec^{-1} . *N. rivularis* maintained flight also under windy conditions, even with wind gusts of $\sim 30 \text{ km/h}$. Figure 4 shows the number of flights as a function of flight duration (from take-off to landing). For flight durations of less than one minute to two minutes the butterflies usually were surrounding one or two free-standing spiraea shrubs, whereby they also performed hovering. Longer flight durations were usually measured when specimens were flying around in the garden area. Moments of rest lasted often only for a split second to some seconds. For longer flight disruption, the butterfly usually disappeared within shrubs like spiraea, forsythia, or lilac where leaves offered protection. We failed to see any specimen perching on exposed sites, neither on shrubs and trees nor on the ground. To bridge larger distances *N. rivularis* preferred to fly close along hedgerows and fences, which performed the function of corridors (Fig. 1). We did not observe *N. rivularis* being attacked and caught by insectivorous birds, which were present within the study area.

Among all shrubs, ornamental spiraea were the primary target of males and females throughout the entire flight period. We should note that spiraea formed one third of the shrubs in the study area. The relative frequency of *N. rivularis* specimens on spiraea shrubs was in all counts always above 0.6, in most cases above 0.7 (Table 1). We observed specimens at *S. x vanhouttei*, *S. x cinerea* and *Ph. opulifolius*, although not at *S. nipponica*. However, *S. x vanhouttei* was three-quarters of times more often the target than the other spiraea shrubs. Only once could mating behaviour be observed, and this on the yellow leaves of *Ph. opulifolius*. In six cases we saw females laying single eggs on the upper side of green leaves of *S. x vanhouttei*. We found three brown larvae of the first stage (4-5 mm) on freshly nibbled leaves of *S. x vanhouttei* at the end of July and at the beginning of August.

Discussion

The cool April and May in the year 2021 induced a prolonged pupal stage and was the reason for a delayed flight season of *N. rivularis* (see Räuschl, 2002). This time lag did not lead to a shift of the flight period into August (Table 1). The early wing damage probably caused by frequent touch with branches, twigs, or fences might have resulted from an increased flight activity. But it may also be that the wings were not protected enough from damage by bad weather, such as thunderstorms. Obviously, oviposition and developmental processes must start on time to ensure an optimal life cycle. Thus, synchrony with plant growth might be essential to ensure that larvae have access to fresh leaves of young hostplant shoots before hibernation (K. Kral, unpubl. obs.).

An important factor was sufficient sky illumination to trigger flights, which was only the case under sunny conditions. Interestingly, in the early morning despite supra-threshold air temperatures and sky illumination, the butterflies remained inactive. Perhaps they were still in an inactive phase due to insufficiently high metabolic state for courtship, mating, and oviposition. However, it is known that woodland butterflies can even fly at suboptimal temperatures (Merckx et al., 2006). A positive

side-effect could be that the butterflies avoided flying during the early morning high activity period of birds. For example, the house sparrow (*Passer domesticus*) has the highest activity in the first hour after sunrise (Robbins, 1981; K. Kral, unpubl. obs.). *N. rivularis* avoided flying around in the blazing sun with high radiation, presumably to prevent excessively high heat input. If too much heat is transferred from the heat storage areas of the dark wing surface through the wing veins to the wing base and thorax, the flight muscles could be damaged (Liao et al., 2019). Thus, the residential gardens and urban parks can only be an adequate habitat for *N. rivularis* and other woodland butterflies when they provide sufficient shade (Kleckova & Klecka, 2016).

It has to be kept in mind that the dark colour of *N. rivularis* is an adaptive trait developed for living primarily in deciduous and mixed woodland and at woodland edges, often in valleys and along rivers. There, the morning hours can be very cool when little sun can penetrate the canopy. In the middle of hot, sunny summer days the sheltering effect under the canopy, and the evaporative cooling effect of tree leaves, makes the environment by some degrees Celsius cooler than is the case in open grassland (Morecroft et al., 1998). As mentioned above, enough sky illumination is necessary for triggering flight activity. Thus, important prerequisites are open forests and clearings with light providing adequate illumination levels also near the ground. At this point, it is worth emphasizing again that *N. rivularis* and other woodland butterflies lose their habitats by reduced coppicing activity, leading to an increase in forest density (Fartmann et al., 2013).

The *N. rivularis* erratic fluttery flight with the ability to change the speed within a relatively large range is much like in other butterflies (Johansson & Henningsson, 2021). However, the insistent narrow proximity to trees, shrubs, bushes and the ground is remarkable. Obviously, the observed flight behaviour is an adaptation to the small-scale structures of the garden. It seems also to be a protective reaction to resident birds. Apart from the erratic fluttery flight, *N. rivularis* can also fly straight forward but then parallel to hedgerows or fences, as known also from other lepidopterans (Coulthard et al., 2016).

Is the scanning of the spiraea shrubs while in flight a necessary host selection behaviour with the purpose of learning? And is the purpose of touching the surface of leaves observed here to learn the shape, structure, odour, and taste as cues for the right oviposition site? Learning may be necessary because cues are different from those of the familiar natural hosts such as bridewort, goat's beard, and meadowsweet. Host-finding by learning is not at all unusual in butterflies (e.g., Snell-Rood et al., 2011). Finding, with increasing certainty, the spiraea shrubs among all the other shrubs, and then the increasing preference for distinct spiraea shrubs, as *S. x vanhouttei*, might support this idea. A quantitative analysis would be necessary, however, to confirm that.

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