Supporting Information

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SI Text

Maintenance and Tracking of Butterflies. The parent generation of individuals from Åland was collected in the field as 5th instar larvae and reared in common garden conditions until pupation. The butterflies were released in a large outdoor cage where all matings and ovipositions were monitored (1). The offspring were reared in common garden conditions in the laboratory and used in this study in the following year. The "new population" individuals were thus the F_2 offspring of the original colonizers of unoccupied habitat patches in the field. Chinese and Estonian individuals were collected as larvae at their respective locations in the previous autumn before diapause. All larvae spent the winter in the same conditions and were reared in common garden conditions from diapause onward.

In the spring, larvae were reared in growth chambers with a cycle of 16 h light and 8 h darkness. The temperature was set at 12°C in the night and 28°C at midday. The relative humidity varied from 60% at night to 40% at midday. Sibling groups were reared in plastic boxes with fresh *Plantago lanceolata* leaves provided *ad libitum*. When the larvae reached the final instar, sibling groups were split into smaller groups. Pupae were weighed on the day after pupation and placed in individual plastic cups. Pupae were transferred from Finland to England. After eclosion, butterflies were sexed and males were discarded. Females were numbered underside the hind wing with a felt-tipped pen, and a small wing tip sample was taken for DNA analysis. Insects were placed in holding cages (Watkins and Doncaster). The flight metabolic rates of the butterflies were measured for a parallel study (K. Niitepold *et al.,* unpublished work).

Butterflies were chilled in a refrigerator (4°C) for 15 min. They were then placed on a soft foam mat, dorsal side uppermost, and the wings were gently opened with forceps. A piece of plastic mesh (4 mm, Netlon) with a hole in the center (7 mm) was placed over the insect and held down with an open pair of scissors. This held the insect immobile, with the thorax exposed. A narrow strip of double-sided sticky tape was wound around the end of a mixture stick, and carefully rolled over the thorax to remove scales. The thorax was then wiped with a cotton bud moistened with alcohol to remove cuticular wax and any remaining scales, and left to dry for 60 s. The thorax was carefully coated with a thin layer of impact adhesive (Evo-stick) and left for 60 s to cure. Light-weight radar transponders (2) were prepared by carefully trimming circular numbered discs (Opalithplättchen, from EH Thorne Ltd.) to an oval shape to fit better onto the thorax of the butterflies, and attached by using a disk of double-sided sticky foam (3). The butterflies were then placed in a holding cage with food (honey solution) in a sunny location until required for tracking.

Butterflies from all four groups were not available every day, so we tested butterflies in the order in which they emerged. The origin of the butterflies in the different release groups is shown in supporting information (SI) Table S1. The butterflies were transported to the release points in the arena in a steel tin, which screened the transponders from the radar, preventing the recording of spurious tracks before butterflies were released.

The radar operators stayed in constant radio contact with field observers and maintained a detailed log of all releases, flight activity, and butterfly locations. Field observers ranged around the study area and if necessary recaptured and re-released insects to identify them if their tracks had crossed. All observations were referenced to the radar master clock (British Summer Time; UTC + 1) on the radar PPI display. Sampled "radar video" data from the radar was continuously recorded onto a PC which after processing allowed the flight positions of each butterfly to be determined every 3 s over distances of up to 900 m. The field team was unaware of the population group from which the individual butterflies came.

Data Selection and Correction. Some butterflies stayed in the field for 2 days, and in these cases only the data from the first day were used. The exception was one individual, which was released in the afternoon, and did not move at all during its first day, at least partly because of unfavorable weather conditions. For this individual we used the data from the second day. Furthermore, there was a possibility that the population origin of two individuals was mixed, and these individuals were excluded from all analyses for which the population origin was needed.

There were a few cases in which the estimated ground speed of an individual was unrealistically high between two consequent observations. To eliminate such erroneous observations, we truncated the speeds of the individual steps to the maximum value of 10 m/s (applied to 7 of the total of 4,755 movement steps).

Meteorological Measurements. Wind speeds and directions were measured with cup anemometers and wind vanes at 2.7 m above the ground level (agl) at four sites within the study area (Fig. 1). Additional instruments at one site monitored wind speed at 0.36 m, 1.1 m, and 1.8 m agl and temperature at 1.5 m agl. Running averages of wind speed were calculated every 10 s and recorded on Skye Instruments data loggers together with instantaneous values of wind direction and temperature. The data logger clocks were synchronized with a master clock in the radar cabin each morning.

Reconstruction of Flight Paths from the Radar Data. The harmonic radar enables real-time tracking of insect flight at low altitudes (2–4). In the raw data, the location of a transponder is represented by a cloud of some 5–20 sample points above the noise threshold (hits) representing a single radar "paint" on the radar Plan Position Indicator (PPI) display. The sample point nearest to the radar was considered to approximate the true location of the target (Fig. 1 *Inset*). A few individual hits may appear simply due to radar receiver noise and hence must be ignored. We set a threshold number of hits (n = 5) and a threshold distance between the hits (20 m) to determine whether a cloud of hits was considered to represent a spatial location of a target. For each time step (revolution of the radar antenna), the locations were extracted from the set of hits by using the algorithm "from hits to locations" described below.

- Set the clouds to an empty set.
- Loop over all hits. If the current hit is within the threshold distance from the mean location of hits in an existing cloud, add the hit to that cloud. If not, start a new cloud consisting of the current hit.
- Exclude the clouds that have less hits than the threshold number. For the remaining clouds, select the hit that is closest to the radar.

In the next step, we constructed the movement paths of individuals from the set of spatial locations (Fig. 1). We first constructed pieces of flight paths (to be called tracks) by using the following algorithm "from locations to tracks," which connects points within a threshold distance (25 m) from each other.

- Let the tracks consist of the locations in the first time step.
- Loop over all time steps.
- Loop over all locations in the time step. Check whether the location is within the threshold distance from the endpoint of an existing track. If yes, add the location to that track. If there are many such tracks, choose the one to which the endpoint was added at the most recent time step. If there are no matching tracks, start a new track consisting of the current location.

The tracks were manually combined to represent the full paths of the individuals for each day. In this step, information about the release locations and the confirmed observations of the individuals were used. The data were discarded if it was not possible to reliably associate a track to a particular individual. For example, if two individuals moved close to each other, it was not always possible to tell their subsequent flight paths apart unless the identity of either of the individuals was later confirmed.

Accuracy of Radar Data. The radar transmitter was operated for at least 5 min before recordings were started to allow its temperature to stabilize, thus providing improved range accuracy. The accuracy of the radar data were examined by analyzing data from a transponder that was held in a constant position throughout the experiment (fixed to a meteorological station 320 m from the radar, see Fig. 1). Of the daily 5,500 to 8,900 locations, as estimated by the algorithm "from hits to locations," we dropped the first and the last 500 ones to exclude possible effects of the start-up and shut-down procedures. The mean distance of the locations from the daily mean was 2.7 m (standard deviation over the days ± 0.3 m), and the mean (over days) maximum distance from the daily mean was 19.3 (± 5.7) m. The mean distance between consecutive locations was 2.5 (± 0.4) m. There was some degree of spatial autocorrelation in the location estimates, as the distance between the means of the first 500 and last 500 locations for each day was 1.8 (± 1.2) m, whereas the corresponding figures for two randomly selected sets of 500 locations (from the same day) was 0.17 (± 0.14) m. The distance between the daily means was 2.5 (± 1.5) m.

1. Saastamoinen M (2007) Mobility and lifetime fecundity in new versus old populations of the Glanville fritillary butterfly. *Oecologia* 153:569–578.
2. Cant ET, Smith AD, Reynolds DR, Osborne JL (2005) Tracking butterfly flight paths across the landscape with harmonic radar. *Proc R Soc Ser B* 272:785–790.
3. Capaldi EA, *et al.* (2000) Ontogeny of orientation flight in the honeybee revealed by harmonic radar. *Nature* 403:537–540.
4. Riley JR, Smith AD (2002) Design considerations for an harmonic radar to investigate the flight of insects at low altitude. *Comput Electron Agric* 35:151–169.

Table S1. The origin of butterflies in the different release groups

Day (time)	Release group
1 (10:40)	Åo (1, 23) S (6, 49) S (17, 42)
2 (10:45)	Ån (16, 11) S (10, 41) S (12, 45) S (22, 45) C (8, 33)
3 (10:40)	Ån (29, 11) Ån (35, 13) Åo (37, 25) Åo (39, 23) S (34, 43)
3 (13:50)	Åo (25, 24) S (26, 45) C (28, 33) ? (42, X1)
4 (10:55)	Ån (45, 15) Ån (47, 12) S (24, 42) S (27, 43)
4 (13:45)	Ån (51, 17) Åo (52, 23) Åo (59, 21) S (64, 42) C (54, 31) C (60, 31)
5 (10:40)	Ån (65, 14) S (67, 40) S (77, 47) C (71, 33) C (73, 32)
5 (13:05)	Ån (75, 17) Åo (84, 22) S (68, 47) C (72, 31) C (76, 32)
6 (10:40)	Åo (50, 25) Åo (56, 23) S (55, 48) C (66, 33)
6 (13:25)	S (44, 49) S (62, 42) S (86, 43) C (63, 33)
7 (10:45)	Ån (61, 14) Ån (88, 16) Åo (91, 21) S (48, 46) S (85, 44)
7 (13:50)	Ån (80, 16) Ån (89, 17) Ån (101, 25) Åo (102, 25) Ån (103, 15)
8 (10:25)	Ån (82, 11) Åo (83, 23) S (38, 45) S (41, 45) S (79, 44)
9 (10:15)	Ån (90, 15) Åo (49, 25) Åo (99, 22) Åo (100, 22) S (96, 50)
9 (13:35)	? (93, X2)

The letters Åo, Ån, S, and C stand for Åland old, Åland new, Saaremaa, and Chinese populations, respectively. The numbers in the parentheses refer to the identity number used for the individual and the family number of the individual. Unknown population origin is indicated by ''?''.