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Colonisation capacity of the Greater white toothed shrew *Crocidura russula*: an experimental study

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Zusammenfassung:

Kolonisierungskapazität der Hausspitzmaus *Crocidura russula*: eine experimentelle Studie

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Colonisation capacity of the Greater white toothed shrew *Crocidura russula*: an experimental study

P. Vogel

Abstract - Since the last glaciation, many of the large Mediterranean islands have been colonised by shrews of the genus *Crocidura*. The probability of successful colonisation depends on the probability of an accidental transfer with human agricultural goods and the probability of reproductive success of immigrants released on an island. Settlement success of reproductive units consisting of single pairs of *Crocidura* was tested in a model of habitat islands. Mountain summer farms which offer a suitable habitat during four months, were used as habitat islands. According to our knowledge on winter survival of *Crocidura*, a shrew population living at such a locality should die out over winter. Pairs of shrews were experimentally released at each of 9 localities in June. A survey in October revealed presence of young shrews at 6 localities equivalent to a success of 66%. This is a high score for such a small reproductive unit. Monogamous pair bonds and the helper activity of the males may have contributed to this high success. These results suggest that the reproductive unit necessary for successful colonisation may be very small. In Spring, the 9 localities were free of shrews as predicted.

Introduction

European shrews of the genus *Crocidura* are widespread in the Mediterranean region including most larger Mediterranean islands. The question arises whether or not the equilibrium theory of Macarthur and Wilson (1967), in which colonisation probability is dependent on the distance to the source population, can be applied to these populations. What do we know about colonisation events for this taxon? Crete and the Siculo-Maltese archipelago are inhabited by two endemic species (*C. zimmermanni*, *C. sicula*), the only survivors of the old Pleistocene fauna (Vogel 1986, Vogel 1988, Vogel et al. 1990, Sarà et al. 1997), but most of the larger islands were colonised after the last glaciation by one of the three continental species, the majority by *C. suaveolens* or by *C. russula*. The distances from the next continent to these islands are far too great for an autonomous dispersal. Introductions since the Neolithic period are due to man (Vigne et Alkover 1985). The continental region from which colonisation occurred was ~~be~~ determined for some island population by genetic studies. For example, *C. suaveolens* of Crete was introduced during the Minoan period from Turkey (Vogel et al. 1986); *C. russula* of Pantelleria and Sardinia were introduced from North Africa (Sarà & Vogel 1996). Multiple introductions may have occurred, e.g. *C. suaveolens* in Corsica (Catzeflis 1984). However, the absence of living and fossil shrews of the genus *Crocidura* from Mallorca (Alcover 1982) suggests that colonisation events may be very rare.

It would therefore be of interest to assess the probability of a successful introduction by man to a far distant island. Colonisation depends on two quite different events: first the probability of a transfer of *Crocidura* by a shipment of agricultural goods, and second the probability with which accidentally released individuals may settle and reproduce. The aim of this study is to experimentally investigate the second question.

Success of releasing experiments carried out with game birds have been documented by Pimm (1991). This author came to the conclusion, that in general, a high number of initial animals are necessary to get a positive result. Game birds generally reproduce once an year, and their population dynamics are rather slow. Small mammals may therefore respond more quickly. Few data are available, e.g. Crowell (1973) and Ebenhard (1991). These data make clear that mortality resulting from the sensitivity of a species and the intrinsic rate of its population growth are important factors.

In the family Soricidae, as for mammals in general, the smallest and therefore the most probable reproductive unit forming a propagule (colonisation unit) is a pregnant female. This is certainly the case for the most solitary, but also for promiscuous species with female territoriality. In the monogamous *Crocidura russula*, where a male and female share the nest during the whole reproductive period (Cantoni & Vogel 1989), the accidental transfer of a pair may be almost as probable as that of a single pregnant female and much more probable than the independent simultaneous transfer of one male and one female to the same locality. I therefore assessed the probability that a pair, during the reproductive period, settles in an unknown but hopefully suitable habitat, raises their offspring and to form in one summer, ~~form~~ a local population of descendants.

To assess this probability, the most realistic experiment would be the introduction of shrews on real Mediterranean islands where shrews are lacking, e.g. the Eolian Islands of Italy. But from an deontological point of view, this is not allowed, it would damage the autochtonous fauna which was preserved from such a predator. In contrast to Finland where thousands of islands are available for experimental work (Peltonen & Hanski 1991), we do not have enough islands on our Swiss lakes to conduct comparable observations. Therefore, the experiment has to be conducted not on real islands but in adequate habitat islands. The main aim of the study is to design and evaluate an experimental model, with which further investigations can be conducted.

In western Switzerland, *Crocidura russula* is confined to lowlands, up to an elevation of about 800 m (Genoud & Hausser 1978, Genoud 1982). During the cold season, in the range of 500 to 800 m, this species is dependent on man made structures, living particularly in gardens of villages and taking advantage in winter from microclimatic favourable places, e.g. compost heaps, barns and stables. At this altitude, some closely situated habitats are colonised during summer time by dispersal, leading to temporary human independent populations which suffer extinction during winter.

Given this climate dependant behaviour, isolated summer farms, located in the Jura mountains at an altitude between 900 and 1400 m, should represent suitable experimental habitat islands. They are inhabited by farmers for 4 months, from June to September, in order to exploit the alpine meadows with cattle during the short vegetation season. During summer, this type of habitat may permit the constitution of a small resident shrew population. A prognostic on the probability of success cannot be given, since nothing is known about the possibility of insertion of released shrews, even in a excellent habitat. Moreover, animals from captivity may be unfit for experimental release. Concerning the winter period, the cold conditions should theoretically not allow survival of any *Crocidura*. This is a particularly important condition, because the experiment should not lead to a stable population of this shrew outside of its altitudinal range. Therefore, the second aim of the study

Table 1. Small mammals trapped in autumn (October) and in spring (May). Abreviations: *A. flav.*: yellow necked mouse; *A. sylva.*: wood mouse, *C. glar.*: bank vole, *M. arv.*: field vole, *S. aran.*: common shrew, *C. russ.*: greater white-toothed shrew.

Cottage	Altitude	*A. flavi.*		*A. sylva.*		*C. glar.*		*M. arv.*		*S. aran.*		*C. russ.*		Total	
		Oct.	May	Oct.	May	Oct.	May	Oct.	May	Oct.	May	Oct.	May	Oct.	May
1	1345	6	2	2					2			1		9	4
2	1269	4	2	4	1			1	2	1				10	5
3	1383	3		1		2	3			1				7	3
4	1350	6		2						1		1		10	0
5	1324	6						1	2		1	2		9	3
6	1314	3		2								2		7	0
7	1271	4	6	3								3		10	6
8	995	3		4	5							1		8	5
9	980	5		3				1						9	0
Total		40	10	21	6	2	3	3	6	3	1	10	0	79	26

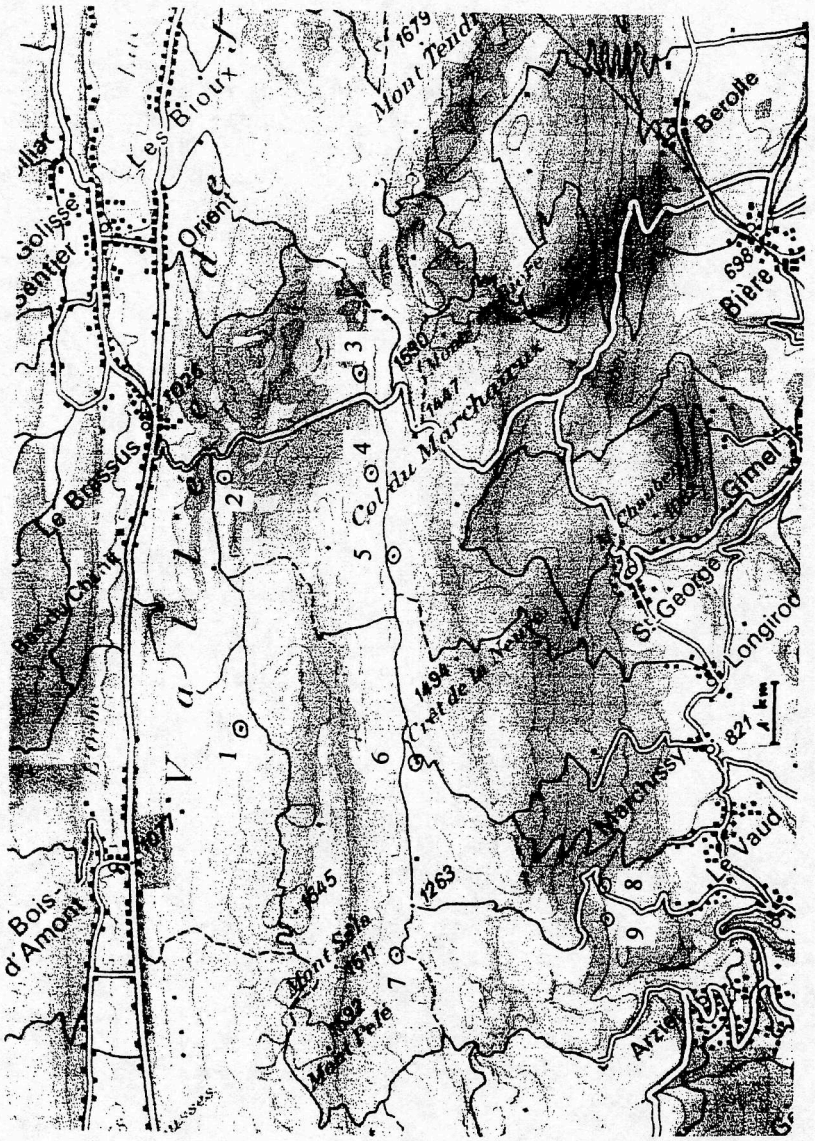

Fig. 1

Map of the Col de Marchairuz in the Jura Mountains with the 9 experimental cottages.

is to verify the prediction that in the consciously chosen special condition the populations should go extinct during winter.

As no data exist on small mammal communities in summer farms of the Jura mountains, this study may also finally contribute to the knowledge of the local fauna.

Material and methods

Geographical situation - The study was carried out in the region of the Col de Machairuz, close to the locality in which ecological studies on the upper limit of *C. russula* were carried out (Genoud & Hausser 1978). Here, easily accessible summer farms (cottages) were selected, spaced at a distance of at least one kilometre a part (Fig. 1).

Propagule design - During the reproductive season, female shrews are in general pregnant and lactating (Vogel 1972). Therefore the releasing unit consisted of a pregnant female with its male. Initially, 10 such units were formed, five pairs of overwintered adults, captured in January, and kept in captivity until the experiment, and five pairs formed from the first litter of these shrews. The pair formation of the second group was performed 20 days before release. Pregnancy was therefore in an advanced stage for all females. The gestation length of this species is 30 days (Vogel 1972). Due to early arrival of a farmer and his dogs not allowing the release of the last pair, this group consisted of only four pairs.

Releasing procedure - All shrews were individually marked with passive induced transponders PIT (Trovan®, formerly Euro I.D: Dorn 1987). The pairs were released at an appropriate place close to the house some two weeks before the arrival of the farmers and their cattle. Heaps of fire wood and stony walls adjoining the house wall were considered as optimal release points. They offer shelter and natural food (spiders and insects). In order to avoid any conscious positive or negative management, the farmers were not informed.

Success control - During the summer, the evolution of the shrew population was not followed. Experimental success, defined as presence of young shrews in autumn, was measured in October, after the farmers had left the region. Per farmhouse, 10 Longworth traps were set along the walls in prebaiting position during a period of three days. They were activated in the afternoon, 3 hours before the onset of activity of *Apodemus* which may occupy all the traps when at high density. As *C. russula* is partially day active (Genoud & Vogel 1981), it can enter before the arrival of mice. The traps were checked early in the morning, and the small mammals captured were released after identification.

The evaluation for winter survival was performed in spring, 11th of May, long before the arrival of the farmers, with exactly the same procedure as in autumn.

Results

The autumn community - With 90% of the traps occupied (Table 1), the October session revealed a high density of small mammals. This means that only a part of the local population was captured and the real number of small mammals was certainly much higher. The most widely distributed species was the yellow necked

mouse (*Apodemus flavicollis*), the second species the wood mouse (*A. sylvaticus*). These species were syntopic in 8 localities. The third species was the introduced *Crocidura russula*. This shrew was present at 6 of the 9 localities. With exception of one tagged adult female, accompanied by two young-of-the-year, all shrews were young adult, born during the summer. The native common shrew (*Sorex araneus*), which is frequent in neighbouring forests, but not found in the vicinity of houses at lower altitude, was trapped at 3 places. In one locality *Clethrionomys glareolus* occurred. The concerned cottage is used as scientific station for ant research (Cherix & Gris 1994) and for more than 10 years has been without cattle. The presence of this vole is explained by the immediate surrounding of the house, natural soil and dense vegetation, not covered with asphalt as at the other places.

The spring community - The trapping session in May showed a much lower score with only 28% of the traps occupied. Cumulated *Apodemus* species were again on top position, however with a severe reduction. The disappearance of *A. flavicollis* in 6 localities (66%) and also of *A. sylvaticus* in 6 localities (75%) shows that for granivorous rodents the houses are not favourable winter habitats. Only cottage No. 7, used by a ski club, offered particularly good conditions during winter: in May, a female at its third pregnancy, lactating the second litter and two post-weaned juveniles of the first litter with a body weight of 15 g were trapped. The occurrence of *Microtus arvalis* reveals an exploitation of the meadows adjoining to the houses, a habitat which is much too disturbed by cows in summer. The greater white toothed shrew (*C. russula*) went extinct in all localities. In unsaturated trap conditions, the trappability is very high and the possibility of unverified survival is negligible.

Discussion

The natural small mammal community in the farm houses - The trapped native mammals are representative for forests and meadows of the region (Meylan 1994), but not in comparable distribution. During July/August 1996, Patthey (1997) trapped small mammals in Jura forests close to the Col de Marchairuz. The sample of 582 small mammals was composed of 55% *Clethrionomys*, 21% *Apodemus*, 22% *Sorex* and 2% *Eliomys*. Within the *Apodemus* sample, only 4% were *A. sylvaticus*. It is therefore highly probable that the higher percentage of this species in the cottages is due to local reproduction, whereas *A. flavicollis* probably joined the houses in autumn as shown by Vlasak & Porkert (1973). A native species lacking in the sample is the garden dormouse (*Eliomys quercinus*). In previous years it was regularly present in cottage No 1 (Vogel 1997) and I trapped it again in autumn 1997. Obviously both trapping sessions were situated within the hibernation period of this species. Lack of rats (*Rattus sp.*) and the house mouse (*Mus domesticus*) are not only due to altitude, but also to the fact that the buildings are only occupied during a short period of the year and that there are no village or town in the the neighbouring.

The rigorous winter conditions severely affected mice of the genus *Apodemus*, as is shown by a strong reduction of the trapping success (74%) and by the extinction of most of the populations. Due to trap saturation in autumn, the percentage of the population reduction is quite below the real level. It is not clear, whether during food shortage the mice disperse back to the forest or if their foraging behaviour leads to heavier predation by fox and weasel. Presence of both predators was evident by snow tracks and scats. In one house (cottage No. 9, lowest altitude) a cat was regularly observed during the whole winter period (A. Meylan, pers. comm.), living on wild food, e.g. *Arvicola terrestris* which were at a top of a population cycle

(Ecoffey 1997). On the other hand, cottage No. 7 was often occupied during the week-end by members of a ski club. Remains of a sandwich are not edible for shrews, but are appreciated by *Apodemus*. This may explain the occurrence of reproduction of *A. flavicollis* starting here as early as March. No other female of any species had signs of sexual activity in early May.

The experimental result - The autumn session revealed excellent colonisation ability of *C. russula*. It is a bit problematic to compare our results with those from authors, who defined colonisation success as survival until spring. Admitting that an autumn population of young is able to over-winter in mild Mediterranean conditions, we however make a comparison. Crowell (1973) experimentally introduced*Peromyscus maniculatus* and *Clethrionomys gapperi* on small islands. For the first, he got a success of 33% (n=6) with single pairs, 66% (n=3) with 2 pairs and 100% (n=2) with 3 pairs. For *Clethrionomys*, no success with one (n=3) or two pairs (n=3), but 50% success with 3 pairs (n=2). Compared to these results, the score of *C. russula* with 66% success by single pairs (n=9) in a very short summer period is much higher than expected. It shows that the probability of settling with success on a Mediterranean island is very high.

Crowell (1973) came to the conclusion that high natality is an advantage, but that a species must not be an r-strategist. In fact, *Peromyscus maniculatus* did better than *Clethrionomys gapperi* because of its lower mortality, therefore λ/μ (reproductive rate over mortality rate) is important as pointed out by Ebenhard (1991).

The question arises as to whether or not the pair is a frequent unit. Most soricine shrews are very solitary and territorial (Croin Michielsen 1966), and they never share a nest (Cantoni 1993), thus the probability that a male and female are introduced at the same time at the same place must be extremely rare. In contrast, the crocidurine shrews are more social, and in particular the monogamous *C. russula* naturally lives in pairs (Ricci & Vogel 1984, Cantoni & Vogel 1989) a situation which strongly increases the probability of a common transfer. Monogamous social organisation in mammals is rare and implies that survival of the offspring is higher in the presence of the father (Vogel, in preparation). Pair bond and helping behaviour of the male (nest construction, thermoregulation) may increase the success of such a pairwise introduction.

As stated by Sarrazin & Barbault (1996), translocation experiments should help to test ecological models and predictions. Whereas the target of a reintroduction is normally the settlement of a stable population, our experiment should end up with the extinction of the introduced species. The island habitat was chosen based on the data of Genoud & Hausser (1978), showing that *C. russula* do not survive in cold winter without human created mild microclimatic conditions. The Jura mountains are particularly cold, and the extinction of the 6 implanted populations is therefore an experimental confirmation of the results in the above mentioned study.

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Zusammenfassung

Kolonisierungskapazität der Hausspitzmaus *Crocidura russula*: eine experimentelle Studie.

Viele grosse Mittelmeerinseln sind erst seit der letzten Eiszeit durch Spitzmäuse der Gattung *Crocidura* besiedelt worden. Die Wahrscheinlichkeit einer geglückten Kolonisierung hängt von der Wahrscheinlichkeit eines zufälligen Transfers mit landwirtschaftlichen Kulturgütern zusammen, sowie von der Wahrscheinlichkeit des Fortpflanzungserfolges des auf der Insel eingeführten Propaguls. In der vorliegenden Studie wird experimentell am Modell von Habitatinseln die Erfolgsaussicht eines eingeführten Paars von *Crocidura russula* geprüft. Als Habitatinseln wurden im Jura gelegene Alphütten gewählt, die während der begrenzten Dauer von vier Monaten für die Hausspitzmaus ein günstiges Habitat bieten. Aufgrund unseres Wissens über die Winteransprüche dieser Spitzmaus sollte eine im Sommer etablierte Population über den Winter erlöschen. Experimentelle Freisetzung je eines Paares erfolgte an 9 Lokalitäten im Juni. Eine Kontrolle im Oktober ergab eine etablierte Lokalpopulation mit Jungtieren in 6 Lokalitäten, was einem Erfolg von 66% entspricht. Dies ist ein hoher Wert für eine so kleine Fortpflanzungseinheit. Monogame Paarbindung und Helferaktivität des Männchens sind möglicherweise für diesen grossen Erfolg verantwortlich. Im Frühjahr waren die 9 Lokalitäten wie vorgesehen spitzmausfrei.

Résumé
Capacité de colonisation de la Musaraigne musette *Crocidura russula* : une étude expérimentale.

Depuis la dernière glaciation, les musaraignes du genre *Crocidura* ont colonisé de nembreuses grandes îles méditerranéennes. La probabilité d'une colonisation dépend de la probabilité d'un transfert accidentel avec des produits agricoles ainsi que de la probabilité d'un succès de reproduction du propagule introduit. L'étude examine dans un modèle d'île d'habitats le succès d'implantation à partir d'un couple de *Crocidura russula*. Comme îles d'habitat, ont été choisit des chalets d'alpage, situés dans le Jura entre 900 et 1200 m, offrant durant une période estivale de 4 mois de bonnes conditions. Selon nos connaissances sur les exigences hivernales de cette espèce, une population établie à une telle altitude durant l'été devrait s'éteindre durant l'hiver. Un lâché expérimental d'un couple a été fait en juin sur 9 sites. Un contrôle en octobre a mis en évidence la présence de jeunes en 6 sites ce qui correspond à un succès de 66%. Pour une unité de reproduction aussi réduite, c'est une valeur élevée. La monogamie de cette espèce avec une contribution active du mâle est éventuellement responsable de ce succès. Au printemps, les musaraignes avaient disparu, comme prédit sur les 9 sites.

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