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Infestation by the mite *Harpirhynchus nidulans* in the Bearded Tit *Panurus biarmicus*

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Capsule Mites sometimes induced voluminous subcutaneous cysts in featherless parts.
Aims To describe the first reported infestation by the skin-dweller mite *Harpirhynchus nidulans* in Bearded Tits *Panurus biarmicus* and for the Timaliidae family, to detect possible fitness costs for the host and to determine the distribution of the parasite within the distribution range of the host.
Methods Parasites were identified using a microscope. Wing-length and body mass were recorded on both uninfected and infected birds captured at different times during the year. We also considered historical data, and contact was made with 32 European ringing stations to identify the distribution range of the parasite.
Results Subcutaneous reproduction of the mite *Harpirhynchus nidulans* induced the development of voluminous dermal nodules in *Panurus biarmicus*. There were no differences in body mass or wing-length with respect to infestation. In the south of France, prevalence changed from 10.6% in spring to 4.7% in autumn. Both sexes are equally parasitized. Occurrence of dermal cysts is reported from several southern European populations of Bearded Tits, whereas it seems to be absent from northern latitudes.
Conclusion The occurrence of a *Harpirhynchus* mite in wild bird populations is reported for the first time. We consider aspects of its biology, host–parasite system, host-specificity, co-adaptation of the mite reproductive cycle to the social dynamics of its host and metapopulational host–parasite dynamics.

Mites from the family Harpirhynchidae (Prostigmata, Acari) are bird parasites, usually found in feather follicles or skin (Fain 1999). Whereas most are ectoparasites, some induce voluminous subcutaneous cysts, located in featherless parts of the body, mainly on the breast and underwing (Fain 1994). Occurrence of such voluminous dermal cysts has long been observed from Mediterranean French populations of Bearded Tits (*Panurus biarmicus*, Timaliidae, Passeriformes; Lucchesi pers. comm.). However, before this study, the causative agent had not been identified. Also, ecological data from wild populations of birds hosting the *Harpirhynchus* group are lacking. Given the few data available on this widespread and potentially deleterious infestation, we undertook field surveys of parasite prevalence in several Bearded Tit populations. These surveys were designed to identify the parasite inducing the cutaneous cysts, describe the dermatological manifestation, document any detrimental impact on the condition of the host and estimate the prevalence of dermal cysts and document temporal variations. Additionally, to assess whether the infestation by *Harpirhynchus nidulans* is a regional phenomenon or a common feature within the range of the host species, we conducted a European-wide survey through the network of field ringing stations. This gives an overview of the distribution of the parasite within the distribution range of the host, a rarely documented feature in mite–bird systems from natural populations.

METHODS

Sampling of Bearded Tits and description of pathology

Several sources of data are exploited herein. Historical data are available from the ringing station of Marais du

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Vigueirat (Camargue, France; Appendix 1), comprising the occasional reports of parasitized birds (minimum measure of prevalence) in ringing notebooks from 1987–93 (n = 1849). A systematic search of cysts on captured birds was made in 1998 (n = 249), complemented with a survey in autumn 2000 (n = 38). Additionally, Bearded Tits were sampled at seven other localities in Mediterranean France (n = 414; Appendix 1). Samples of cyst matrix were collected from two different birds at Marais du Vigueirat (autumn 1998 and autumn 2000) and were sent to acarologists (R. Ubeda, University of Pharmacy, Seville, Spain and A. Fain, I.R.S.N.B., Brussels, Belgium) for identification. During the systematic surveys, sex, maximum wing-length, body mass and parasitism status (with or without cyst) were reported for all birds. As both juveniles and adults undertake a complete summer–autumn moult (Cramp & Perrins 1993), age was classified as follows: 'juvenile' for individuals with unmoulted juvenile feathers, 'adult' for individuals with unmoulted breeding plumage or ringed birds that were recaptured. When birds were parasitized, the number and maximum length of cysts were reported. Depending on the time-scale considered in the analysis, only one record per individual per month (i.e. January, April, May, June, August, September, October) or per season (winter, spring, summer and autumn) was used.

Impact of parasite on host condition

We collected data on wing-length and body mass and compared birds with and without external cysts after correcting for confounding variables (size, sex and season). Only adults were included in these analyses, since juveniles were never found to be parasitized (cf. Results). Wing-length measures were standardized across observers by subtracting the difference in mean wing-length between each ringer and a reference measurer (P.-Y.H.).

Prevalence

Prevalence is defined as the percentage of individuals presenting at least one dermal cyst in a given sample of birds. Minimum prevalence was computed from the historical data for Marais du Vigueirat. Real prevalence was computed over all other data, testing for sex-dependence and seasonal variation. Statistical analysis was performed using software JMP IN 3.2.1 (SAS Institute 1996).

Distribution of the parasite within the distribution range of the host

Assuming that the presence of dermal cysts is a reliable indicator of the presence of *H. nidulans* in a given host population, the mite's distribution within the range of its host can be inferred from spatial patterns of dermal cyst occurrence. Thirty two European field ornithologists, were asked whether they had observed dermal cysts in Bearded Tits (they were shown Fig. 1) and to provide the number of birds handled; they were also asked to report any observation of such a pathology in other bird species. This inquiry allowed us to collect information on cyst occurrence in 45 localities or areas of Europe and Ukraine (Appendix 1). Based on our estimate of 0.02 for minimal prevalence p (cf. historical data for Marais du Vigueirat)[a] and on the n values provided, we fixed the minimum sample size needed to confirm the absence of parasite at 342 handled individuals. By following this rule, the probability that the pathology was not reported whereas it was present in the population was lower than 0.001. Formally, this probability is the probability of sampling 0 parasitized birds among n captured birds given the prevalence p.

RESULTS

Identification of pathogen

Microscopic observations of samples of cyst matrix revealed the presence of mites at various developmental stages (from egg to imago) scattered in a compacted mixture of moults (Fig. 2). Relying on morphological traits, the two acarologists independently identified the sampled mites as *Harpirhynchus nidulans* (Harpirhynchidae; Fain 1999).

Description of the dermatological pathology

Dermal cysts were located in featherless parts of the body, i.e. under axillaries or scapulars. Location on rump was reported once. Among all parasitized birds, 46 had one cyst, and nine had two. Cyst walls are made of stretched poorly vascularized skin. They are yellowish-orange in coloration, being lighter where the skin is thinner. As the cyst reaches over 10 mm in length, the skin breaks in the apical region releasing a powder-like mixture composed essentially of larval moults (Fig. 1). After breaking, cysts may disappear completely (two individuals had scars that we attrib-

Figure 1. Subcutaneous cysts induced by *Harpirhynchus nidulans* in *Panurus biarmicus*. These are the pictures that were shown to field ornithologists for the European survey on cyst occurrence in Bearded Tit.

uted to resorbed cysts). Cyst size changes over time (measurements between seasons were made on different individuals), increasing from spring (mean = 4.39 ± 2.84 sd, n = 27) to autumn (mean = 11.4 ± 4.24 sd, n = 21; Welch ANOVA test, $F_{1,33.3} = 43.0$, $P < 0.0001$) and decreasing from autumn to winter (mean = 3.00 ± 1.73 sd, n = 3; Kruskal–Wallis two-sample test, $Z = -2.5$, $P = 0.01$).

Impact of parasite on host

There is no evidence of impaired health status in parasitized individuals based on body mass (Table 1) or feather growth (Table 2). Three recaptures of parasitized birds in subsequent years showed that cysts are not a systematically lethal handicap.

Sources of variation of prevalence

For the period 1989–93, minimal autumnal prevalence at Marais du Vigueirat was 2.3% (n = 1849). At the same locality, an exhaustive survey revealed a prevalence of 5.9% during autumn 1998 and 2000 (n = 287). Prevalence was higher in spring than in autumn (p_{spring} = 0.106, n = 245, p_{autumn} = 0.047, n = 427; logistic regression LRT = 8.177, df = 1, P = 0.004). No reliably identified juvenile bird was found to be parasitized (n = 189). Nonetheless, the decrease in prevalence in autumn is not due to a higher proportion of uninfected juveniles in the population as prevalence remains identical even if we include only adult birds in the analysis (p_{spring} = 0.123, n = 244, p_{autumn} = 0.049, n = 150; logistic regression LRT = 5.348, df = 1, P = 0.02). Prevalence was similar in both sexes (historical data: 2.0% of 1009 males, 2.4% of 838 females, Fisher's exact test, P = 0.63; specific survey data: 5.6% of 480 males, 6.6% of 305 females, P = 0.64).

Distribution of the parasite within the distribution range of the host

Dermal cysts were observed (Fig. 3) in all eight Mediterranean French localities sampled, in one Atlantic French population and in populations from Croatia (1), Austria (1), Czech Republic (2) and Poland (1). No dermal cyst manifestation was reported from northern Europe, i.e. Sweden, Denmark, northern Germany, The Netherlands, Great Britain and northern France, in spite of the large sample size (Appendix

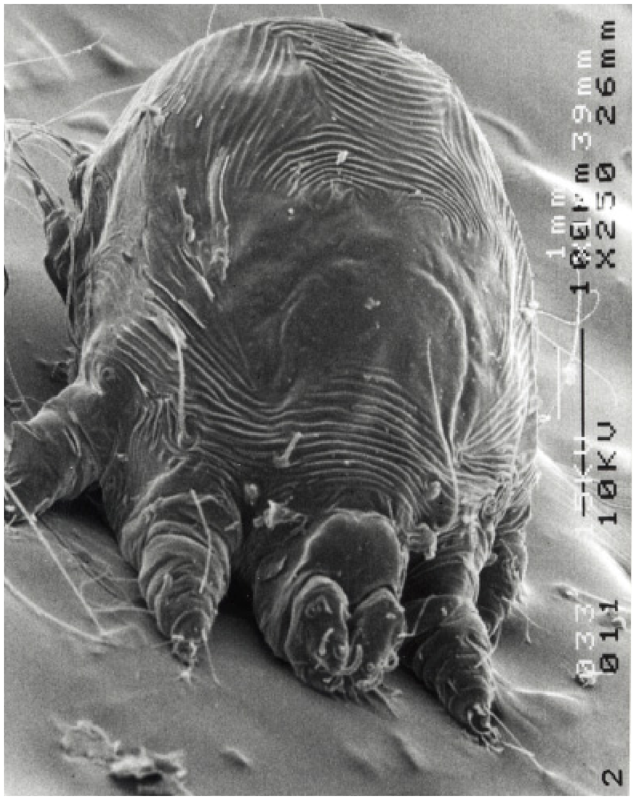

Figure 2. Adult *Harpirhynchus nidulans* mite (electronic microscopy).

1). All negative reports from southern countries (Spain, Italy) rely on too small sample sizes ($n < 342$) to be considered as reliable indices of absence.

DISCUSSION

The skin-dweller mite *Harpirhynchus nidulans* is described for the first time in the Bearded Tit *Panurus biarmicus*, which also represents the first report for the Timaliidae family. This mite is known to parasitize mostly Fringillidae (*Fringilla coelebs*, *Carduelis chloris*, *Coccothraustes coccothraustes*; Nitzsch 1818, Fritsch 1954 *in* Fain 1995, Fain 1994, pers. comm. and the report of at least 13 cutaneous cyst cases for this family during the present European survey), but was also found in Alaudidae (Megnin 1877, 1878 *in* Fain 1995). Development of voluminous dermal cysts is a pathological peculiarity of the genus and is particularly known from *H. nidulans*, although it remains rarely documented (but see Fain 1995, 1999). During the present European survey, the occurrence of cysts was reported in four other families, all Passeriformes: Hirundinidae (*Hirundo rustica)*, Turdidae (*Erithacus rubecula*), Sylviidae (*Acrocephalus melanopogon*, *A. schoenobaenus*, *A. scirpaceus*, *Sylvia atricapilla)*, Emberizidae (*Emberiza schoeniclus*

Table 1. Analysis of variance on body mass in relation to parasitism status (uninfected versus with cyst) and other confounding factors.

Effect	SS	df	*F*	*P*
Season	0.432	1	0.402	0.527
Sex	3.565	1	3.31	0.007
Wing-length	9.111	1	8.46	0.004
Season*Sex	26.07	1	24.208	< 0.0001
Season*Wing-length	0.389	1	0.361	0.548
Sex*Wing-length	3.584	1	3.328	0.069
Parasitism status	0.134	1	0.125	0.724
Parasitism status*Season	1.221	1	1.134	0.288
Parasitism status*Sex	0.717	1	0.666	0.415
Parasitism status*Wing-length	0.122	1	0.113	0.737
Parasitism status*Sex*Wing-length	0.654	1	0.607	0.436
Residual error	373.689	347		

SS, sum of squares.

Table 2. Analysis of variance on maximum wing-length in relation to parasitism status (uninfected versus with cyst) and other confounding factors.

Effect	SS	df	*F*	*P*
Season	9.659	1	5.885	0.016
Sex	23.244	1	14.161	0.0002
Season*Sex	0.396	1	0.241	0.624
Parasitism status	0.024	1	0.014	0.904
Parasitism status*Season	0.842	1	0.513	0.474
Parasitism status*Sex	2.354	1	1.434	0.232
Residual error	582.678	355		

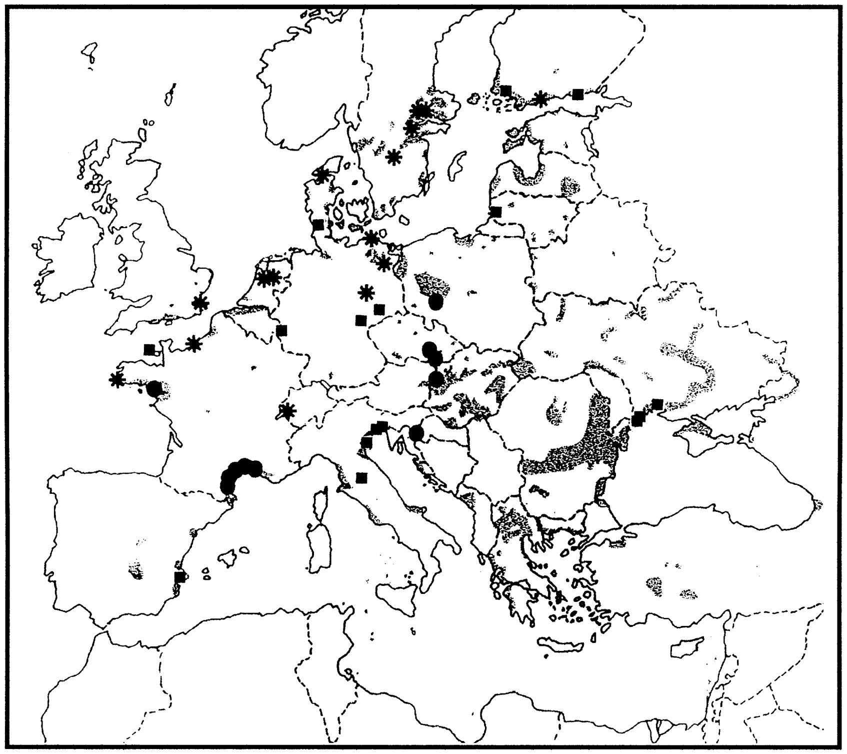

Figure 3. Distribution of cyst occurrence within the European distribution of the Bearded Tit. Stippled areas, distribution range (from Snow & Perrins 1998); ●, cyst occurrence reported; ⋆, cyst never encountered and not likely to ocur (i.e. $n > 342$, see Methords; ■, cyst never encountered but small sample size (i.e. $n < 342$).

subsp. *schoeniclus and* subsp. *whiterbyii*). While *Harpirhynchus* species are generally described as highly host-specific parasites (Fain 1994, 1995), *H. nidulans* appears to exploit several host species from separate families and ecological environments (e.g. the Greenfinch *Carduelis chloris* on farmland as opposed to the Bearded Tit exclusive to reedbed *Phragmites*). Hence the barriers to host-specificity in the *Harpirhynchus*–passerine system are not clear. As stressed by Proctor & Owens (2000), molecular phylogenetic analysis, in addition to morphological classification, are required to clarify the co-evolutionary processes between mites and birds. Given the wide spectrum of host-bird species exploited, the ease in detecting cysts and sampling mites, as well as the existence of well-organized networks of motivated field ornithologists all across Europe (EURING) and North America (USFWS), the *Harpirhynchus*–Passeriformes system may be a potentially fruitful candidate for such a phylogenetic and phylogeographic approach of mite–bird co-evolution.

From an ecological and life history perspective our data suggest that in French Mediterranean populations of Bearded Tit, *H. nidulans* undergoes a reproductive cycle related to the one of its host. Evidence of a reproductive cycle in *H. nidulans* is given by the increase in mean size of dermal cysts between spring and autumn, and the absence of cyst formation in juvenile birds. This suggests that the development of dermal cysts takes several months. Whether the increase in cyst size is due to reproduction or to the growth of existing larvae cannot be determined from our data. Synthesizing our observations, we can however propose a general pattern for the reproductive cycle of the mite. During winter and spring (January–April), small dermal cyst-like protuberances start to appear. That would be the beginning of the mite reproductive cycle, with larval moults starting to accumulate inside the skin of the host. In spring (May–June), medium-sized cysts would indicate active reproduction. In summer and autumn (July–October), cysts reach a maximum size, limited by skin resistance to stretching, resulting in the breaking of the cysts and the release of descendants outside from the host. Suggestion of synchronization with the host reproductive cycle comes from the fact that, at the same time as cysts break, populations of Bearded Tits reach their highest level with all juveniles being fledged and birds aggregating in flocks of several tens of individuals (Cramp & Perrins 1993). Moreover, the

Bearded Tit is highly gregarious outside the breeding season, gathering in communal autumnal and winter roosts where individuals cluster in close contact (Cramp & Perrins 1993). Hence, descendants would be released when chances of colonizing a new host are the highest. Such an adaptation of a mite cycle to its host population dynamics and sociality to maximize horizontal transmission was suggested by Blanco & Frias (2001) in the Swallow *Hirundo rustica*, a migratory socially roosting passerine. However, this hypothetical reproduction cycle and congruence with host population dynamics are only a synthesis of our observations and has yet to be demonstrated.

The fact that no apparent health impact (wing-length and body mass) was detected on parasitized birds is surprising given the handicap that such voluminous cysts located under wings might represent (mean length in autumn equals *c*. 20% of mean wing-length of the host). However, we must be cautious before concluding that this parasite has little effect on its host's fitness given that many other fitness implications were not studied here (e.g. sexual selection, susceptibility to other infections or to predators, parental abilities, see Møller *et al.* 1990 for further details). In addition deleterious effects of cysts cannot be ruled out given our small and heterogeneous (across seasons and localities) sample size of parasitized birds (n = 48). Thus, further studies are clearly needed to clarify this point. We hope that this study will motivate the systematic collection of data that would make it possible to identify eventual changes in the occurrence and virulence of *Harpirhynchus nidulans* in Bearded Tits. The fragmented geographical distribution and high sensitivity of Bearded Tits to habitat management (Poulin & Lefebvre 2002, Poulin *et al.* 2002) further add to the interest of monitoring the evolution of parasite prevalence and virulence in this species. Further studies are necessary to determine whether birds with large autumnal cysts are less likely to survive the winter due, for instance, to an inability to fly rapidly away from predators or to a loss of body heat at night due to impaired roosting efficiency.

Finally, data from our European survey indicate that several northern populations (Baltic Sea, North Sea, English Channel) are free from the parasite. If the parasite is truly absent from northern populations, it is suggested that it has been eliminated by hazard subsequent to strong depletion or extinction of local populations of Bearded Tit during severe winters. Northern populations (e.g. Britain, Belgium, Denmark, eastern Germany and Sweden) are known to be unstable and not resilient to severe winters (reviewed in Cramp & Perrins 1993). Additionally, long-distance recoveries of ringed birds suggest that recolonization of extinct or depleted populations by immigration occur among northern populations themselves (see Cramp & Perrins 1993, Wernham *et al.* 2002). Conversely, eastern populations that harbour the parasite, are also known to be interconnected (Cramp & Perrins 1993, Wernham *et al.* 2002). Hence, sensitivity to winter severity because of latitudinal location and opportunities of recolonization through population exchange provide a likely metapopulational scenario to explain the absence of the parasite at northern populations. An alternative explanation might be that the mite is present in northern populations but that it does not induce cyst formation there. Nonetheless, whatever the real distributional pattern, there is a puzzling absence of the parasite at northern latitudes worthy of further investigation.

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ENDNOTE

a. Without specifically searching for dermal cysts, 2% of the handled birds were given as parasitized by ringers from Marais du Vigueirat.

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APPENDIX

Cyst occurrence in European populations of Bearded Tit.

Country	Locality	Geographical coordinates	Cyst reported	Years	*n*	Informant
Austria	Lake Neusiedl, Vienna	47°56′N–16°45′E	Yes	Until 1998		Hoi
Croatia	Slavonija	45°46′N–18°10′E	Yes	1973–98	2000	Tadic Dida
Czech Republic	Nesyt fishpond, Lednice, South Moravia	48°47′N–16°42′E	Yes	1998–99	478	Chytil
Czech Republic	Zehunsky fishpond, South Moravia	50°09′N–15°19′E	Yes	1999		Chytil
Denmark	Vejlerne Nature Reserve, North Jutland	57°06′N–9°03′E	No	1990–96	1624	Kjeldsen
Finland	Laajalahti, Espoo	60°12′N–24°49′E	No	1990–98	442	Topp
Finland	Kovinsaari, Kotka	60°29′N–26°56′E	No	1990–98	240	Lehtinen
Finland	Turku, southwest Finland	60°44′N–22°26′E	No	Up to 1998	250	Normaja
France	Etang de Salse, Salses, Aude	42°51′N–2°58′E	Yes	1998	97	Present study
France	Marais du Vigueirat, Arles, Bouches-du-Rhône	43°30′N–4°48′E	Yes	1984–98	*c.* 2000	Present study
France	Sollac, Fos-sur-Mer, Bouches-du-Rhône	43°27′N–4°52′E	Yes	1998	31	Present study
France	Aigues-Mortes, Gard	43°31′N–4°15′E	Yes	1998	11	Present study
France	Etang du Charnier, Gard	43°37′N–4°18′E	Yes	1998	12	Present study
France	Etang du Bagnas, Agde, Hérault	43°19′N–3°30′E	Yes	1998	84	Present study
France	Etang de l'Or, Lunel, Hérault	43°36′N–4°05′E	Yes	1998	3	Present study
France	Etang de Vendres, Hérault	43°16′N–3°13′E	Yes	1998	73	Present study
France	Marais de Guérande, Loire-Atlantique	47°00′N–2°27′W	Yes	1999	*c.* 40	Musseau
France	Baie d'Audierne, Finistère	47°54′N–4°21′W	No	1988–98	*c.* 6000	Barguain
France	Estuaire de la Seine, Seine-Maritime	49°28′N–0°15′E	No	1983–98	*c.* 3000	Frebourg
Germany	Brandenburg		No	1994–98	4764	Dürr
Germany	Mecklenburg-Vorpommern		No	1994–98	2028	Dürr
Germany	Nodrhein-Westfalen		No	1996–98	35	Dürr
Germany	Sachsen		No	1994–98	218	Dürr
Germany	Sachsen-Anhalt		No	1994–98	1150	Dürr
Germany	Schleswig-Holstein		No	1996–98	53	Dürr
Germany	Thüringen		No	1994–97	17	Dürr
Italy	Val Campotto marshlands, Ferrara		No	Until 1998	> 100	Baccetti
Italy	Isonzo, Gorizia	45°45′N–13°31′E	No	1987–89	80	Kajetan
Italy	Marano Lagunare, Nord Est (UD)	45°46′N–13°9′E	No	1992–97	153	Guzzon
Italy	Lago Trasimeno, Perugia	43°07′N–12°11′E	No	1995	138	Velatta
Lithuania	Ragas Ornithological Station	55°21′N–21°13′E	No	1998	63	Patapavicius
Poland	Lake Loniewskie, Osieczna	51°54′N–16°41′E	Yes	1997–99	493	Stepniewski
Spain	El Hondo Nature Reserve, Alicante	38°10′N–0°42′W	No	1998	51	López
Sweden	Lake Mälaren, Asköviken	59°31′N–16°28′E	No	1990–98	2178	Pettersson
Sweden	Lake Kvismaren	59°11′N–15°24′E	No	Until 1998	2733	Nielsen
Sweden	Lake Mälaren, Söderfjärden	59°23′N–16°48′E	No	1989–98	4535	Broberg
Sweden	Lake Takern	58°19′N–14°46′E	No	Until 1998	*c.* 9500	Gezelius
Switzerland	Lac de Neuchâtel, Fribourg, Vaud	46°50′N–6°50′E	No	1976–98	450	Antoniazza
The Netherlands	Oostvaardersplassen, Zuidelijk Flevoland	52°28′N–5°22′E	No	1971–98	23 179	Liebregts-Haaker
The Netherlands	Zwarte Meer, Kampen	52°38′N–5°59′E	No	1994–98	705	Nap
Ukraine	Sivash Lagoon, Crimea		No	Until 1998	5	Baccetti
Ukraine	North Sea Nature Reserve	46°18′N–31°45′E	No	Until 1998	*c.* 200	Ardamatskaya
Ukraine	Danube Nature Reserve	45°30′N–29°30′E	No	1995–96	125	Poluda
United Kingdom	North Kent	51°18′N–1°09′E	No	1984–98	1607	Pritchard
United Kingdom	Jersey, Channel Islands	49°13′N–2°13′W	No	Until 1998	50	Buxton