

POST-FLEDGING DEPENDENCE PERIOD OF OSPREYS
PANDION HALIAETUS RELEASED IN CENTRAL ITALY:
HOME RANGES, SPACE USE AND AGGREGATION

PERÍODO DE DEPENDENCIA DURANTE LA FASE DE VOLANTÓN
EN ÁGUILAS PESCADORAS *PANDION HALIAETUS*
LIBERADAS EN ITALIA CENTRAL: ÁREAS DE CAMPEO,
USO DEL ESPACIO Y AGREGACIÓN

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SUMMARY.—Space-use strategies are essential behavioural skills during the fledging-to-dispersal period, when physical capabilities and the ability to explore the external world are developed. Here we describe the space-use strategies of 13 radio-tagged ospreys *Pandion haliaetus*, released as part of a reintroduction project in Central Italy, during their post-fledging dependence period. The ospreys remained within a radius of about 1 km of the hacking tower for about twenty days after release. Later they began to explore more of their surroundings. The occurrence and frequency of explorations further than 1 km from the release point generally increased with time, even though juveniles continued to frequent the vicinity of the release pens. The translocated ospreys showed marked aggregation perhaps because the period spent at the hacking tower could have reinforced the feeling of belonging to the same brood, promoting a consequent strong association among the young. Also, the absence of parents may have led juveniles to aggregate as a compensation behaviour for the lack of parental care. These explanations, which are not mutually exclusive, may have resulted in more time being spent in intra-specific interactions, accounting for the long pre-dispersal phase that we observed in the present study.

Key words: osprey, space-use, radio-telemetry.

RESUMEN.—Las estrategias de uso del espacio resultan esenciales durante la fase que abarca desde el abandono del nido (volantón) a la dispersión, cuando se desarrollan tanto las capacidades físicas como la habilidad para explorar el mundo externo. Aquí describimos las estrategias de uso del espacio de 13 águilas pescadoras *Pandion haliaetus* marcadas con radio-emisores y liberadas como parte de un proyecto de reintroducción en Italia central, durante su fase como volantones. Las águilas permanecieron durante los 20 días posteriores a la suelta en un área de casi 1 km alrededor del sitio de crianza campestre. Con posterioridad, empezaron a explorar más los alrededores distantes. La ocurrencia y frecuencia de exploraciones a más de 1 km del sitio de suelta se incrementó por lo general a lo largo del tiempo, incluso aunque los juveniles continuaron visitando la vecindad del sitio de crianza. Las águilas pescadoras translocadas exhibieron una marcada agregación, tal vez porque el período pasado en la torre de

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crianza campestre podría haber reforzado el sentimiento de pertenencia a la misma nidada, promoviendo en consecuencia una fuerte asociación entre los jóvenes. Además, la ausencia de padres podría haber conducido a la agregación de los juveniles como compensación de la falta de cuidado parental. Estas explicaciones, que no son mutuamente excluyentes, pueden haber resultado en un mayor tiempo dedicado a interacciones intraespecíficas, lo que explicaría la larga duración de la fase de pre-dispersión observada en el presente estudio.

Palabras clave: águila pescadora, radio-telemetría, uso del espacio.

INTRODUCTION

The post-fledging dependence period is one of the most critical stages in bird life histories and is often associated with high mortality rates (Penteriani *et al.*, 2005). Leaving the nest to explore the external world exposes juveniles to many potential hazards (Penteriani *et al.*, 2005; Delgado *et al.*, 2009). This is especially true for species such as raptors, which explore a large area around their nest site before dispersal. During this period fledglings tend to increase the length and frequency of movements from the nest and decrease their dependence on their parents (Bogner and Baldassarre, 2002; Myers and Vaughan, 2004). In addition, they start to develop social skills and they undergo the important physiological and behavioural changes essential to the dispersal process (Newton, 2010), for example muscle and body mass development and improvement of flight skills.

Understanding the pre-dispersal behaviour of a species is therefore of great importance for planning management and conservation strategies that aim at reducing post-fledging mortality (Soutullo *et al.*, 2006). Some previous studies of the post-fledging dependence period in raptors have mainly focused on survival rate (e.g. Sunde, 2005) and the length of the dependence period (Bustamante and Hiraldo, 1989; Ferrer, 1992; Bustamante, 1993; Bustamante and Negro, 1994; Wood *et al.*, 1998). However, information about space-use and movement patterns before dispersal is still poor and fragmentary, despite the biological

relevance of this period (e.g. Bustamante and Hiraldo, 1989; Delgado *et al.*, 2009). Reintroduction programs can offer an interesting framework to study such behaviours, because naive animals are released at a new site without any experience and/or information from already established conspecifics (Sarrazin and Barbault, 1996).

Although the osprey is widely distributed across different biogeographical regions of the world, it has historically suffered demographic decreases (Ames, 1966; Wiemeyer *et al.*, 1975; Spitzer *et al.*, 1977; Saurola, 2005) leading to local extinctions (e.g. in Portugal, Italy and mainland Spain; Saurola, 1997; Palma, 2001; Bricchetti and Fracasso, 2003; Muriel *et al.*, 2006). Since the late 1970's important reintroduction projects have been carried out in North America (Poole, 1989; Martell *et al.*, 2002) and, more recently, in some parts of Europe (Dennis and Dixon, 2001; Muriel *et al.*, 2010). In 2006 an osprey reintroduction program was launched in Central Italy, aiming at re-establishing a breeding population inter-connected with the nearest existing birds, the small and vulnerable Corsican breeding population (Sforzi *et al.*, 2007). Gathering information on the post-fledging behaviour of ospreys might be an important tool to enhance the survival expectation of young birds, hence enabling the success of the reintroduction project. We postulated that reintroduction, and in particular the hacking technique used to release young birds, may affect space-use patterns and intraspecific behaviour.

Between 2008 and 2009, we studied the space-use and ranging movements of 13 translocated young ospreys *Pandion haliaetus* from fledging to dispersal, i.e. throughout the post-fledging dependence period. The only study that previously investigated this behaviour in ospreys mainly focused on the duration of the post-fledging dependence period (c. 30 days; Bustamante, 1995). Through intensive monitoring of released juveniles, we collected data on space-use, home range and behaviour, with particular attention to: (1) the temporal variation of home range sizes during the post-fledging dependence

period; (2) describing movement patterns of young during this time and (3) analysing the spatio-temporal interactions among juveniles by assessing home range overlap and association between individuals.

MATERIAL AND METHODS

Study area

The study area is located in central coastal Italy (Tuscany) and includes one of the Integral Reserves of the Maremma Regional Park

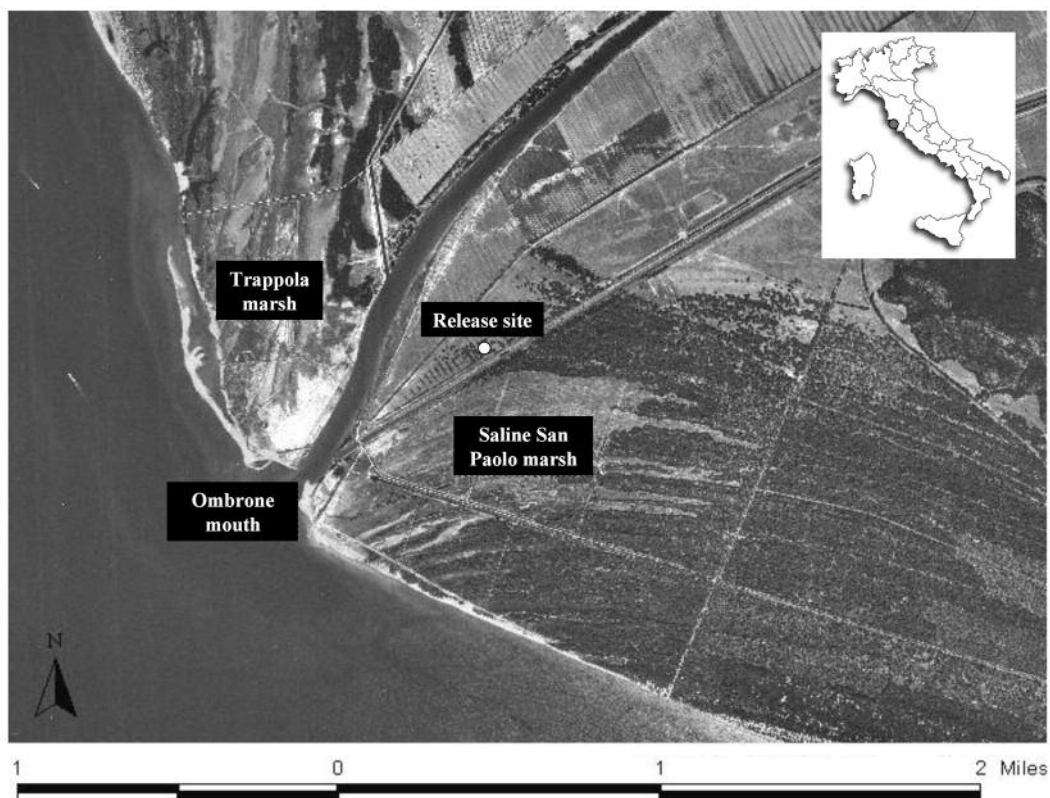


FIG. 1.—Map of the study area. Principal features and the position of the hacking tower are indicated. [Mapa del área de estudio. Se indican las principales características y la situación de la torre de crianza campestre.]

(42° 39' N, 11° 05' E). It comprises 490 ha including the Ombrone river estuary, some scattered mediterranean pinewood, pastures, and two adjacent wetlands: Palude della Trappola and Saline San Paolo (north and south of the river respectively; fig. 1). These wetlands are salty swamps characterised by a succession of emerged and depressed zones that are flooded for much of the year and covered by principally halophytic vegetation. Some parts of the wetlands, ditches and the river offer good foraging areas for the osprey. The fish fauna is particularly rich and includes both marine and freshwater species. The most prevalent fish are grey mullet *Mugil cephalus* and European seabass *Dicentrarchus labrax*. In the study area, where many natural perches are available (dead umbrella pines *Pinus pinea*, maritime pine *Pinus pinaster* trunks and branches), six artificial nests were built by reserve managers to encourage osprey breeding.

Osprey translocation and monitoring

Juvenile ospreys (35-42 days old) were taken from the Corsican wild population (Scandola Natural Marine Reserve; 42° 25' N, 8° 36' E) and translocated by helicopter at the beginning of June. Osprey nests in Corsica were regularly monitored. Broods that comprised three nestlings were the ones chosen to provide a chick for translocation. Once arrived in the study area, chicks were placed in a hacking tower for approximately three weeks. Their behaviour was closely monitored during the pre-release phase. Birds were fed with fresh fish deposited into the cages twice a day. Artificial feeding was also carried out throughout the post-release period by laying fish on platforms situated in front of the hacking towers.

The day before release, each individual was measured, weighed and equipped with a 10g tail-mounted VHF radiotransmitter

(Biotrack Ltd, UK). Tag mass was 0.57% of the mean mass of the translocated ospreys (mean = 1.73 ± 0.27 kg; N = 26). Feather samples were collected for the genetic determination of sex (Griffiths *et al.*, 1998), which was performed by the genetic laboratory of the Italian Institute for Environmental Protection and Research, ISPRA. Each Osprey was also ringed with both a metal EURING and a coloured darvic ring with an alpha-numeric code, for individual identification.

After release, birds were monitored both through radiotracking and by direct observation. During the first week they were kept under surveillance from dawn to dusk by means of visual contact and continuous radiotracking. Later on, we adopted a standardised radiotracking monitoring protocol consisting of four twelve-day periods. Each period included 16 four-hour telemetry sessions giving a total of 64 hours per period (256 hours in total per year). Radiotracking periods were uniformly distributed during daylight, in order to cover four full days per period. Each osprey was detected twice within each session. This schedule provided the minimum of 30 fixes/period/individual that is required to perform least-square cross-validation (LSCV) kernel estimates (Seaman *et al.*, 1999). More than 95% of the localisations were confirmed by direct observation to avoid or strongly reduce possible errors due to misinterpretation of radio signal sources (Schmutz and White, 1990; Kenward, 2001). In particular, all perches used by ospreys in the area were identified and their positions recorded by means of GPS after the monitoring period. Data on behaviour and patterns of association among individuals were also recorded during observations. Ospreys were considered 'associated' when perched close together (approximately within 80 m, which corresponds to the maximum inter-individual distance recorded for a group of young) or when observed to be interacting with each other. We defined the pre-dispersal phase as the period from the time of

the release to the onset of the dispersal. A bird was considered definitely dispersed when the following occurred together: (i) no radio signal was recorded within the study area, (ii) no observation was registered within the study area, and (iii) no sighting from other wetlands outside the Park was reported.

Data analysis

Spatial analyses were performed by the GIS using Arcview 3.2 software (Environmental Systems Research Institute, Inc.) and its extensions *Spatial Analyst* and *Animal Movement* (Hooge and Eichenlaub, 1997). Home ranges (at 95%, abbreviated K95%) and core areas (at 50%, abbreviated K50%) were estimated by *Fixed Kernel* (Worton, 1989) and least-squares cross-validation methods for determining the amount of smoothing (Seaman *et al.*, 1999).

Movements from the hacking tower were described by *Spider Diagrams* (*Animal Movement*; Hooge and Eichenlaub, 1997). They were also ranked into five different distance classes (1 = 0-0.5 km; 2 = 0.5-1 km; 3 = 1-5 km; 4 = 5-10 km; 5 > 10 km).

We used the Minta index (Minta, 1992) to estimate the overlap between home ranges. Spatial overlap is not sufficient to assess a direct associative behaviour, since animals may use the same areas at different times. Taking into consideration the temporal aspect of the question, aggregation was evaluated from the percentage of fixes in which ospreys were associated. We recorded all cases of association among released ospreys by means of direct observations. Statistical analyses were carried out by SPSS 16.0 software. Data were tested for normality and non-parametric statistics were adopted where appropriate (Sokal and Rohlf, 1995). Statistical significance was set at $\alpha < 0.05$, and \pm deviations for means are standard deviations (SDs).

RESULTS

Between 2008 and 2009, 14 juvenile ospreys (11 females and 3 males) were released. One female was killed by a predator 10 days after release; the monitored sample hence comprised 13 individuals (10 females and 3 males). A total of 1,280 fixes were collected during 96 monitoring days. The mean fix number per individual was 98.5 ± 27.9 ($N = 13$). Differences in the number of fixes were due to the different durations of the post-fledging dependence period (fig. 2).

Space use

Total median home range (HR) sizes for the whole pre-dispersal phase were 501.6 ha (K95%) and 93.4 ha (K50%) in 2008 ($N = 7$) and 57.7 ha (K95%) and 8.6 ha (K50%) in 2009 ($N = 6$), respectively. In 2008, home ranges were 8.7 (K95%) and 10.9 (K50%) times larger than in 2009 (Mann-Whitney U test: K95%: $U = 2$, $N = 13$, $P = 0.007$; K50%: $U = 1$, $N = 13$, $P = 0.004$). Home range sizes were not correlated with the number of fixes (Spearman Correlation: K95%: $r_s = 0.025$, $N = 13$, $P = 0.93$; K50%: $r_s = 0.006$, $N = 13$, $P = 0.98$). Differences in home range sizes between years were significant for the first three sampling periods (Mann-Whitney U test: first period, $U = 6$, $N = 13$, $P = 0.032$; second period, $U = 4$, $N = 13$, $P = 0.015$; third period, $U = 0$, $N = 9$, $P = 0.014$). The test was not calculated for the fourth period, due to the small sample size ($N = 3$ individuals in both years).

Individual variability in home range sizes was recorded throughout the sampling periods (fig. 2). Nevertheless, juveniles showed similar patterns of space-use, with a significant increment in HR size from the first to the second period (increment for K95%: 225.3 ± 377 ha; increment for K50%: 40.7 ± 68.1 ha; Wilcoxon Test: $Z = -2.271$, $N = 13$, $P = 0.023$). Individuals showed different dimensional

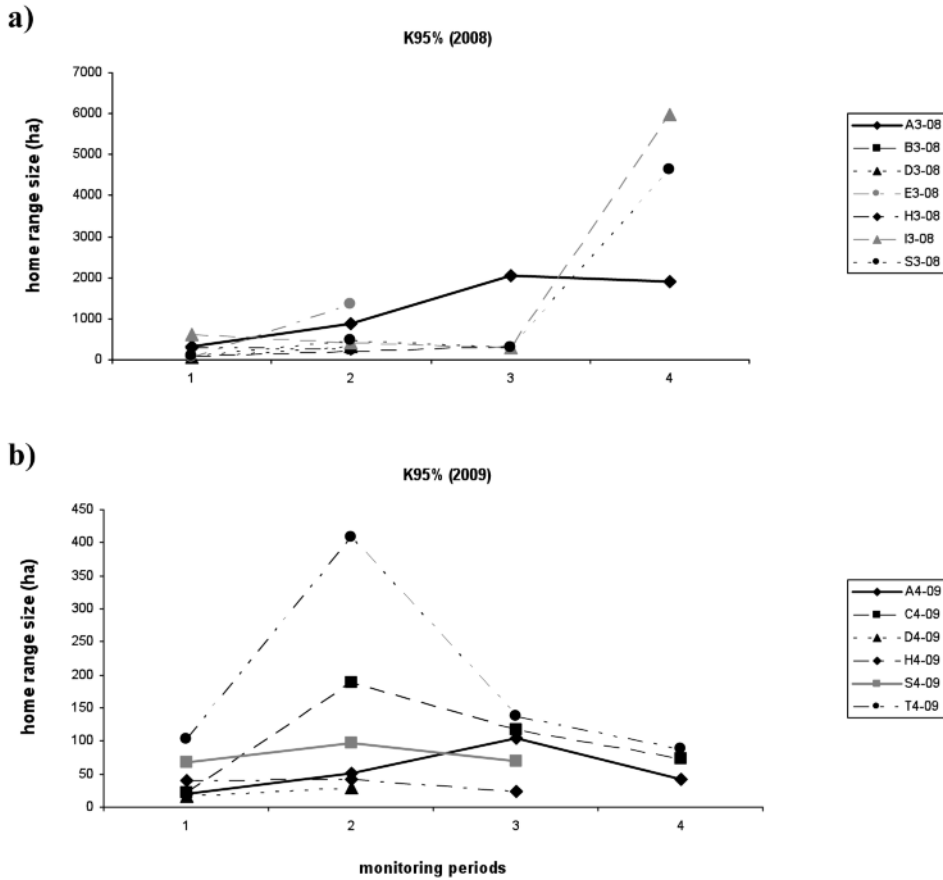


FIG. 2.—Individual variability in home range sizes of young ospreys throughout the monitoring periods. Letter codes indicate individual birds. Differences in graph scales are due to the wide disparity in home range sizes recorded between years. Black lines: females; grey lines: males. (a) and (b): individual home range sizes (K95%) in 2008 and 2009, respectively; (c) and (d): individual home range sizes (K50%) in 2008 and 2009, respectively.

trends during successive periods. Figure 3 gives a graphical interpretation of this phenomenon: individual variability is represented by three different types of curves: ‘Gaussian’ (HR sizes increase in the first two monitoring periods, then decrease), ‘sinusoidal’ (HR sizes increase from the first to the second period, decrease from the second to the third period and increase again at the

end of the pre-dispersal phase), ‘inverse Gaussian’ (HR sizes decrease in the first two monitoring periods, then increase).

Movements

Movements from the release pens increased significantly only during the first two moni-

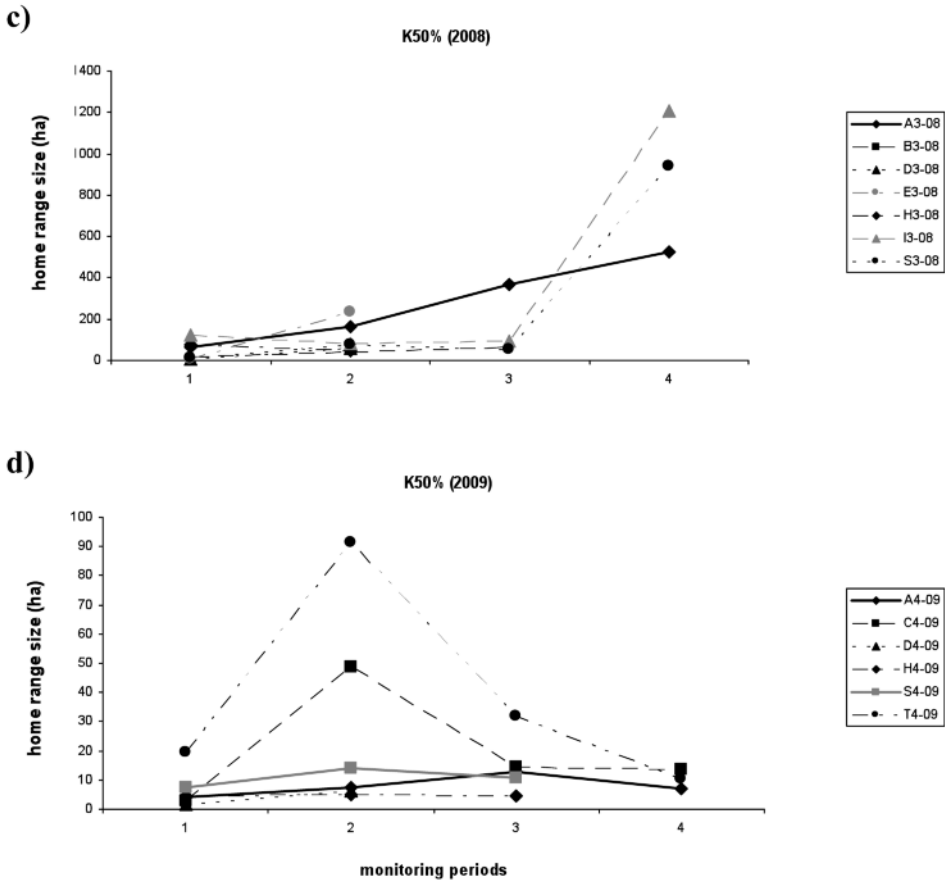


FIG. 2. (cont.)—[Variabilidad individual en el tamaño de las áreas de campeo de águilas pescadoras jóvenes durante los períodos de seguimiento. Los códigos de letras indican aves individuales. Las diferencias en las escalas de las gráficas se deben a la disparidad en áreas de campeo registradas entre años. Líneas negras: hembras; líneas grises: machos. (a) y (b) tamaños de áreas de campeo (K95%) individuales en 2008 y 2009, respectivamente; (c) y (d) tamaños de áreas de campeo (K50%) individuales en 2008 y 2009, respectivamente.]

toring periods (mean increase: 1.42 ± 0.45 ; $N = 13$; Wilcoxon Test: $Z = -2.55$, $N = 13$, $P = 0.011$), which also differed between years (Mann-Whitney U test: first period: $U = 1$, $N = 13$, $P = 0.004$; second period: $U = 3$, $N = 13$, $P = 0.010$). Annual differences between the succeeding periods were not significant (Mann-Whitney U test: third period: $U = 3.5$, $N = 9$, $P = 0.108$; fourth period: $U = 3$, $N = 6$,

$P = 0.487$). Individual movements from the release pens were less variable during the remainder of the pre-dispersal phase, with no significant differences between periods (Wilcoxon Test: $Z = -0.674$, $N = 6$, $P = 0.5$).

Throughout the whole pre-dispersal phase, most movements occurred within a radius of 1 km from the release pens, both in 2008 and 2009 (fig. 4). Individual explo-

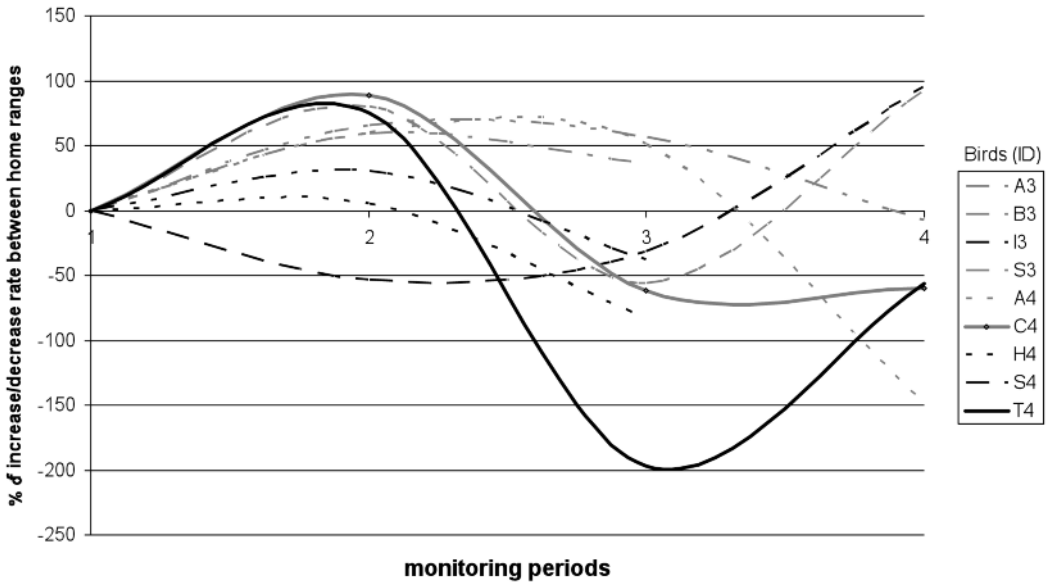


FIG. 3.—Dimensional trends (percentage of increase/decrease rate between successive monitoring periods) of individuals' home range (HR) sizes (K95%). Data are reported for birds monitored for at least three periods. Individual variability is represented by three different types of curves: “Gaussian” (HR sizes increase in the first two monitoring periods, then decrease), “sinusoidal” (HR sizes increase from the first to the second period, decrease from the second to the third period and increase again at the end of the pre-dispersal phase), “inverse Gaussian” (HR sizes decrease in the first two monitoring period, then increase).

[Tendencias de la dimensión (porcentaje de la tasa de incremento/descenso entre períodos de seguimiento) de los tamaños (K95%) de las áreas de campeo (HR) individuales. Se presentan datos de águilas pescadoras seguidas durante al menos tres períodos. La variabilidad individual se indica por tres tipos de curvas diferentes: “Gaussiana” (el tamaño de HR aumenta durante los dos primeros períodos de seguimiento y luego disminuye), “sinusoidal” (el tamaño de HR aumenta del primer al segundo período, disminuye del segundo al tercero y aumenta al final de la fase de pre-dispersión) y “Gaussiana inversa” (el tamaño de HR disminuye durante los dos primeros períodos de seguimiento y luego aumenta).]

rations, covering greater distances, occurred mainly after the second period. The maximum distance covered was 14.3 km.

Dispersal started on average 48.7 ± 12.7 (N = 13) days after release (range: 30-73 days), when the ospreys were about 90-110 days old. No significant differences between sexes were found in the onset of dispersal (mean male = 39.3 ± 3.5 days, N = 3; mean female = 51.5 ± 13.2 days, N = 10; Mann-

Whitney U test: $U = 7.5$, $N = 13$, $P = 0.201$). The onset of dispersal in the translocated ospreys occurred later (mean = 48.7 days) than reported by Bustamante (1995), who recorded a dependence period of 30.4 days for wild juveniles in Scotland. The difference is even greater if we include all the young successfully monitored during the whole project (2006-2010: mean dispersal = 54.4 days, N = 25). In this case too, no differences

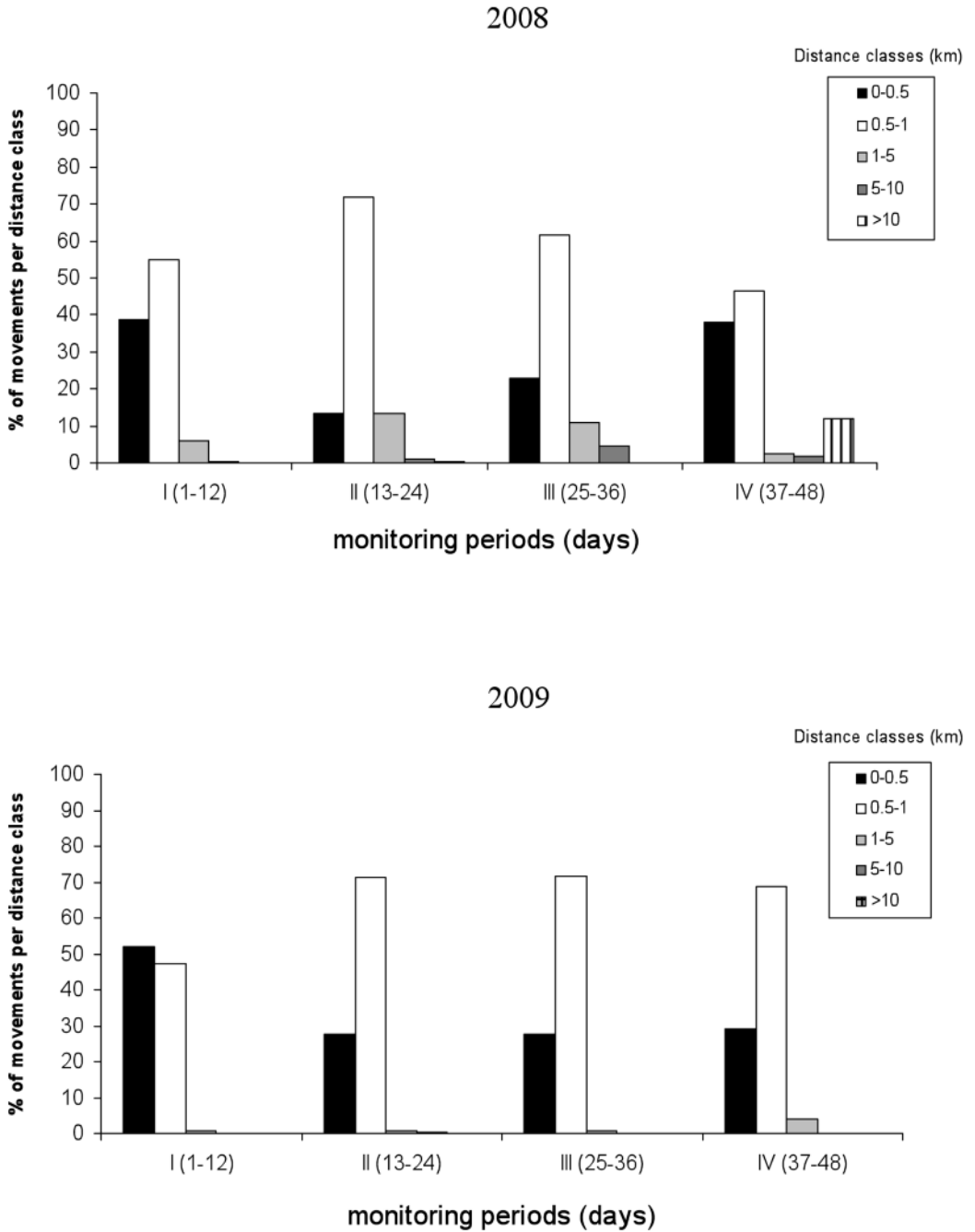


FIG. 4.—Distribution of distance classes of movements recorded during the different monitoring periods in 2008 (a) and 2009 (b).
 [Distribución de las clases de distancia de los movimientos de águilas pescadoras registrados durante períodos de seguimiento en 2008 (a) y 2009 (b).]

between sexes were recorded (mean male = 56.5 ± 18.8 days, $N = 8$; mean female = 53.5 ± 14 days, $N = 17$; Mann-Whitney U test: $U = 61.5$, $N = 25$, $P = 0.704$).

Home range overlap and aggregation

Juvenile ospreys showed home range overlaps in 97.8% of cases in both years and during each period. In total, we performed 188 different possible pair-combinations among individuals (Minta, 1992). HR overlap was total in two cases (1.06%). An evident aggregation was documented by means of direct observations. Ospreys were classified as 'associated' in at least 45.8% of fixes (fig. 5).

DISCUSSION

The post-fledging dependence period in birds involves the development of both physical capabilities and abilities to explore the wider world. Despite the importance of this phase from the point of view of conservation, little has been published on the subject. Young ospreys remained near the hacking tower for about twenty days after release. Later they started to explore further afield, covering greater distances; they also showed marked aggregation. Although a generalised linear mixed model (GLMM) would have improved our data analyses, we preferred not to employ it here since the number of individuals was not very large. Moreover, in this paper we

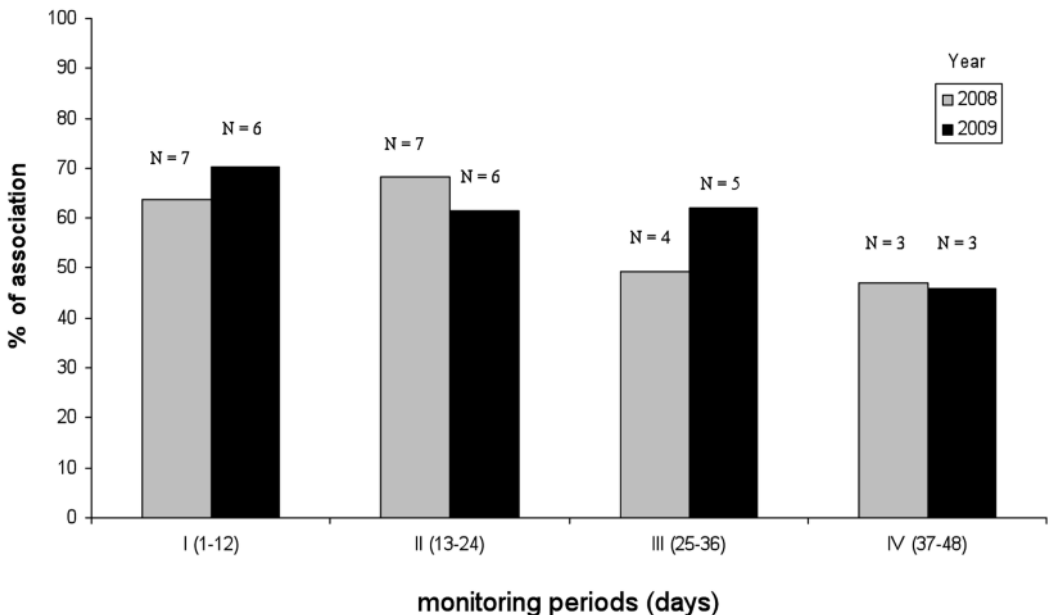


FIG. 5.—Degree of association between juvenile ospreys during the four monitoring periods. Osprey were considered associated when perched close together—approximately within 80 m— or when observed to be interacting with each other.

[Grado de asociación entre águilas pescadoras juveniles durante los cuatro períodos de seguimiento. Se consideró que las águilas estaban asociadas cuando estaban posadas cerca unas de otras—a menos de 80 m— o cuando se observaron interaccionando entre ellas.]

were mostly interested in finding individual variation in post-fledging behaviour.

Space-use

In the period immediately after release and during the first monitoring period, young ospreys remained in close proximity to the hacking tower. During the second period (13 to 24 days), the birds started to explore larger areas, covering greater distances. The occurrence and frequency of explorations greater than 1 km generally increased throughout sampling periods. This is probably linked to improvement of flight skills. Belthoff *et al.* (1993) found a similar pattern in juvenile eastern screech-owls *Otus asio*: after an initial short period characterised by limited activity, movements from the nest site increased in length with time. Similar results have also been described for other raptor species (black kite *Milvus migrans*: Bustamante and Hiraldo, 1989; Spanish imperial eagle *Aquila adalberti*: Ferrer, 1992; eastern screech-owls: Ritchison *et al.*, 1992; golden eagle *Aquila chrysaetos*: O'Toole *et al.*, 1999; Soutullo *et al.*, 2006; eagle owl *Bubo bubo*: Penteriani *et al.*, 2005; Delgado *et al.*, 2009). Notwithstanding, during the overall pre-dispersal phase, juveniles mainly frequented the area surrounding the release pens: over 90% of locations were within 1km of it, and the birds always returned to the pens after more wide-ranging excursions. This may corroborate the hypothesis that the release site could play the role of a focal area throughout the pre-dispersal phase, as suggested for natural nests in other studies. In a natural situation, male breeding ospreys take fish to the nest; meaning that young ospreys do not usually start fishing properly until dispersal, instead remaining dependent on parental provision. Similar behaviour patterns were reported for the eagle owl (Penteriani *et al.*, 2005; Delgado *et al.*, 2009): in this species, although the

young gradually increased their home range sizes after fledging, they continued to frequent an area close to the nest during the post-fledging dependence period.

Home-ranges (K95%) and core areas (K50%) were generally larger in 2008 than in 2009 during all periods. This difference could be due to three main factors: 1) the abundant rainfall that occurred in 2009, together with local floods of the Ombrone river, kept the Saline San Paolo area covered with water until the end of August. In the previous year the same area was completely dry from June onwards. This peculiar situation would have attracted ospreys to this unusually 'late' and shallow wetland. 2) In 2009 an adult osprey (previously released in 2006) delivered fish to juveniles while they were on an artificial nest in Saline San Paolo. This behaviour would have influenced the juveniles' space use, concentrating them in this area; and finally, 3) in 2009, dreadful weather in Corsica during the first days after osprey eggs hatched made fishing difficult for parents, resulting in the chicks being underfed, which had a negative influence on their physical growth (Jean-Marie Dominici, pers. obs.). This poor fitness was evident in the translocated chicks, given the lower weights and smaller body measurements recorded in 2009 in comparison with those of the previous years. The poorer body condition would have been reflected in smaller home range sizes after they fledged.

Home range overlap and aggregation

Overlap analyses revealed a high degree of association between individuals, confirmed by an evident aggregation observed throughout the whole post-fledging dependence period. In the wild, siblings tend to stay together, using common areas, perching close to each other (Edwards, 1989) and moving around the vicinity of the eyrie and back to the nest to

be fed by parents (Bustamante, 1995). In contrast to other studies on raptors (Bustamante and Hiraldo, 1990; Bustamante and Negro, 1994) in our study juvenile ospreys also associated during the last stages of the post-fledging dependence period, similar to behaviour described by O'Toole *et al.* (1999) in golden eagles. Some individuals, that had dispersed to other nearby wetlands, both north and south of the release site, were found perching together there (Monti and Sforzi, pers. obs.).

In nature the family represents the principal aggregation unit for siblings, which mainly interact with each other and with their parents (Bustamante, 1995). Other intraspecific interactions may occur in the case of colonially breeding ospreys (Hagan and Walters, 1990; Bretagnolle *et al.*, 2008). One could hypothesise that interactions between fledged individuals coming from different nests would be less relevant and less frequent when compared with those between siblings. In this study, translocated ospreys that had been born in different nests in Corsica showed marked aggregation. This could be explained in two possible ways that are not mutually exclusive: 1) the period spent in the hacking tower could have reinforced a feeling of belonging to the same brood, promoting a consequent strong association between young; 2) the absence of parents may have led juveniles to aggregate as a compensatory behaviour for the lack of parental care.

A possible explanation of this phenomenon could be found in the already mentioned aggregation showed by young. In our study the absence of parental care, together with associative behaviour, may have increased the time spent in intra-specific interactions, resulting in a longer post-fledging dependence period (even though it fell within the range reported for the species: see Cramp and Simmons, 1980). Nevertheless, the geographical location of the populations under study may also be relevant. In Central/Northern Euro-

pean areas, the onset of dispersal behaviour may be prompted by climatic or day-length triggers. Moreover, the markedly migratory behaviour of those populations may have a significant effect on the timing of their dispersal. Corsican ospreys are thought to be mainly sedentary within the Mediterranean Basin (Thibault *et al.*, 1996). That could also lead them to stay longer in the native area. More detailed studies of populations located at similar latitudes are hence needed to understand the underlying mechanism of this phenomenon better.

The post-fledging dependence period represents an important phase in the life-history, during which behavioural skills are developed by the fledglings to cope with novel environmental conditions. To enhance the success of reintroduction programs is hence essential to monitor these aspects to assure the survival of the released young. Post-release monitoring needs however to be calibrated on the basis of the specific environmental context. The probability of success of a conservation programme is strongly dependent on the level of local knowledge that arises from regularly recorded behavioural data.

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