Habitat characteristics of nesting areas and of predated nests in a Mediterranean population of the European pond turtle, *Emys orbicularis galloitalica*

Marco A.L. Zuffi [1], Laura Rovina [1,2]

[1] *Museo di Storia Naturale e del Territorio, Università·di Pisa, via Roma 79, 56011 Calci (Pisa)-Italy*; E-mail: marcoz@museo.unipi.it

[2] *present address: Lungarno Galilei 14, 56125 Pisa-Italy*

Abstract. One of the largest population of *Emys orbicularis galloitalica* of central Italy inhabits the canal system wet areas within a natural protected park. Features of nesting habitats, nest structure, and predation patterns of 209 nests of a large population of the European pond turtle are here presented and analysed. Nest sites were characterised by sunny bushy areas in strip habitat, digged along north-south oriented canals, on average with about 26% of the area covered by vegetation, less than one meter distant from 30 cm height bushes, at about 11 m from water and at about 13 m distance from wooded areas, 28 m away from a road. Principal Component and Discriminant analyses were used on 20 selected variables in order to reduce the number of physical variables, and indicate that canal border, strip habitat, and canal orientation are grouping variables, that correctly classified 41.6%, 66.5%, and 100 % respectively of nest presence.

Keywords. Mediterranean *Emys orbicularis*; nesting habitat; nest predation.

INTRODUCTION

The study of life-history traits in Chelonians has longly stimulated the interest of herpetologists (Ernst and Barbour, 1989; Iverson et al., 1993; Ernst et al., 1994; Forsman and Shine, 1995). Research, which has been focused on clutch size-maternal body size relations and latitudinal variation of reproductive traits on most of the freshwater turtles, has paid special attention to frequency of reproduction, relative clutch mass, egg mass and egg size. The nesting activity represents the most important and necessary behavioral pattern between egg production and reproductive success. Nesting activity covers both the choice of suitable areas, the physical burrowing of the nest chamber, and egg deposition.

In freshwater turtles of the family Emydidae, the largest family of Chelonians (Ernst and Barbour, 1989), the nest differs between genera and species, mainly in average width and depth: the smaller the species, the smaller the clutch (Iverson et al., 1993), and accordingly, the smaller the nest, which hosts from 3 to 19 eggs (*Emys orbicularis*: Jablonski and Jablonska, 1998), depending on latitude and maternal body size (Iverson et al., 1993).

The European pond turtle, *Emys orbicularis*, ranges from Portugal in the west to the area of the Aral Sea (Kazakhstan) in the east, from northern Germany and Denmark to southern Italy, Sicily and northern Africa and south-eastwards from Turkey to the eastern Caucasus Republics and the southern shore of the Caspian Sea (Podloucki, 1997; Kuzmin, 2002; Fritz, 2004). Populations of *E. orbicularis* are mainly distributed along coastal areas and across many internal plain areas of the region. Populations of *E. orbicularis* in Italy live mainly in marshy lands, humid areas, ponds, large rivers of both coastal and plain habitats, but also in mountainous areas (Zuffi, 2000). They are found in two main types of habitat: the "pond" system, consisting of one or more natural, shallow bodies of water (ponds and marshy areas) with abundant water and riparian vegetation in forested areas, and in open areas, and the "canal" habitat (Lebboroni and Chelazzi, 1998), which is characterised by artificial canals of drainage waters, generally in open or marginal areas. Furthermore, it is also possible to find pond turtles in altered habitats, like in old caves, abandoned fisheries, springs and sources. It is often very hard for researchers to locate intact nests, but on average, it has been found that selected habitats for nesting are close to, or not very far from, the water, where *E. orbicularis* females usually live (Rovero and Chelazzi, 1996; Schneeweiss and Steinhauer, 1998; Schneeweiss et al., 1998; Kotenko, 2000). In some cases, females can migrate to considerable distances from basking areas to nest, and come back after deposition (Rovero and Chelazzi, 1996; Schneeweiss, 1998; Chelazzi et al., 2000). Information about nest size and nest architecture, as well as nesting habitats, is to date either anecdotal or fairly descriptive, even if it agrees with similar data available for most regions of Europe. In central Italy are reported first data on a small mountainous population, but with raw data on high predation rate and apparently small clutch size (e.g. 3-4 eggs per average clutch) (Rovero and Chelazzi, 1996), and other preliminary data on a large populations of plain Italy with larger clutch size (e.g. 5-6 eggs per average clutch), and high predation rate (Zuffi et al., 1999; Gianatti et al., 2000). Also in most of the known populations of central and northeastern Europe, available data on nesting habitats or on nest features mainly refer to small data set. Nevertheless, some interesting data emerge from these reports. In Poland and in Germany it has been mainly referred to reproductive output and on reproductive success, with females *Emys orbicularis* that lay larger clutch size (e.g. 9 to 12 eggs per average clutch) than the studied Mediterranean populations (Jablonski and Jablonska, 1998; Mitrus and Zemanek, 1998; Schneeweiss et al., 1998). Similar data has been reported for Ukraine (Kotenko, 2000), with high clutch size and high predation estimation. Basic description of nest chamber of intact nest in Germany is given by Andreas and Paul (1998). The presence of potential predators, like mammals or birds (Chelazzi et al., 2000; Rössler, 2000a; Zuffi, 2000), is, on average, common in natural and semi-natural habitats, and it is assumed that predators may damage 75-95% of intact nests (Rovero and Chelazzi, 1996; Zuffi and Odetti, 1998; Zuffi et al., 1999; Kotenko, 2000; Rössler, 2000a), but further specific analyses are still lacking. Man and his associated activities may represent a significant additional source of disturbance and injury, reducing, modifying, polluting or destroying suitable habitats (Cheylan and Poitevin, 1998; Najbar and Maciantowicz, 2000). We then considered that the analysis of predated nest characteristics could be likely a direct estimator of suitable nesting features in an area, being predation on the nest a constant in all the populations studied up to now.

This research has been planned to underline the pattern for selection of suitable nesting areas comparing most of the European pond turtle populations, using this study data set and discussing them with available data from literature. We selected the canal system because it is more abundant in natural protected areas of Italy than the pond system (Lebboroni and Zuffi, unpubl.). More specifically, our work has been aimed at verifying if i) there is a significant habitat preference (i.e. a choice between N-S or E-W oriented canals) during the nesting activity ; ii) if the frame of nesting ground is randomly selected among different types; iii) if there is any role of water proximity to the nest. We also tried to investigate all tracks and signs around and on nests and eggs in order to identifying predator species. Our contribution will show one of the largest available data set on nesting habitats, nest structure, and predation on nests of the European pond turtle in central Italy (*Emys orbicularis galloitalica,* Fritz, 1995). Such a set of information may certainly help in describing the actual role of artificial rectilinear water systems of protected areas in Italy, especially in the light of management and protection of these environments.

MATERIALS AND METHODS

Study site

The study was conducted from 1998 to 1999 in the U.S. Army "Camp Darby" area, approximately 10 Km^2, about 10 Km South West of Pisa and 4 Km East and inland from the Ligurian Sea coast. This site (Fig. 1) is included in the Regional "Parco Naturale di Migliarino, S. Rossore, Massaciuccoli", in western Tuscany, central Italy (43° 39' 48" N, 10° 16' 06" E), one of the largest protected coastal areas of Italy. The site is connected to the coast, and is characterised by an evident alteration of past centuries, with introduced pine woods (*Pinus pinea*), and rectilinear drainage canals. The terrestrial vegetation is mature Mediterranean woodland (*Pinus pinea*, *P. pinaster*, *Quercus ilex*), while that around canals and in water is typical of wet areas. On average, trees that naturally fall or die are maintained *in situ*, with the exception of those that interrupt any military road within the US Army area. Natural vegetation on river banks is here reduced to a minimum due to excessive grazing of hundreds of fallow deers, *Dama dama*, introduced around the '70ies. No drainage or management of canals have been yet observed. Each canal, pond or marshy area was recorded and classified, and its width and length and the depth of the water were recorded.

Population features

During present research we considered 256 adult females, according to external sexual characteristics. We considered standard measurements of carapace and body mass with accuracy of ± 1 mm and ± 1 g respectively (see Zuffi et al., 1999). Each marked female has been also provided with numbered white labels on both sides of carapace for recognition at distance.

Nest identification

Nests were visually searched, along canals where the presence of adult females was usually common. Additional random routes were added searching for nests in both favourable, even with scarcity of turtles, as well unfavourable, as wooded areas or open areas close to dried canals. Intact nests were occasionally found within one to two days after deposition, and were externally characterised by the soft and humid, plain, slightly encircled sandy area, that females handled with their feet. Due to small sample size, intact nests were not considered in this paper. Then we refer to predated nests only. They appear as small holes in the ground, often irregularly shaped, with a sort of asymmetric opening that brings to the bottom of the nest chamber; in most cases predated eggs lay in the immediate neighbouring of the nest. Maximum width, depth, and length of chamber pavement, in addition to the number of predated as well intact eggs were counted. Predated eggs may have resulted broken in the middle or at one cap, or divided in two or even more parts. Only pairs of half eggs were considered as single eggs. Results obtained from the morphological analysis of predated eggs (Zuffi and Rovina, unpubl. data) were used for data interpretation.

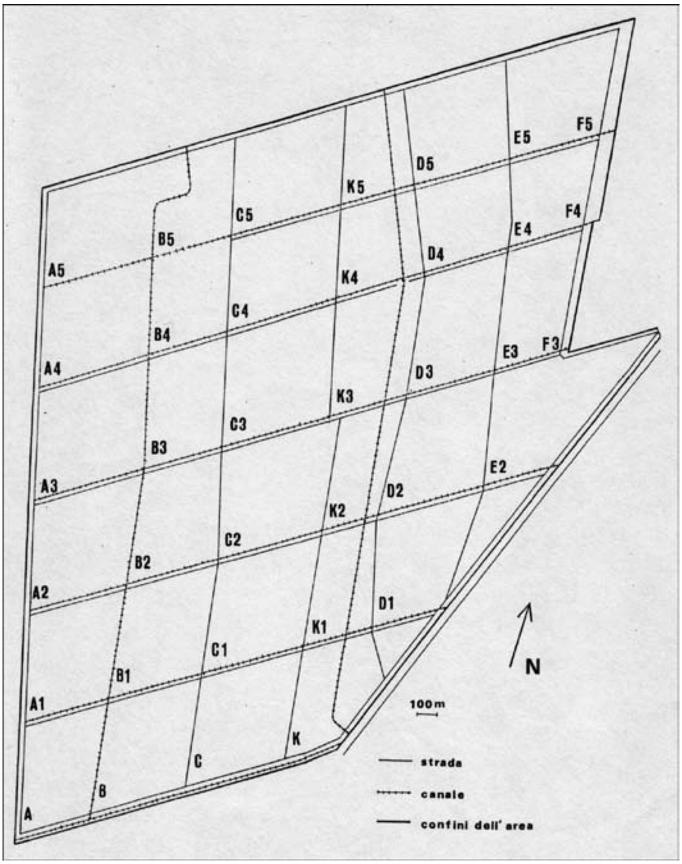

Fig. 1. Map of Camp Darby. Letters represent canal and road numbers and numbers represent intersection with canals and roads. Canals as dots on thin line; roads as thin line; area margins as thick line.

Environmental variables

Nest position with respect to main environmental features, as canal border, bush, tree, or proximal nest was considered. This basic data set was necessary in order to establish a first, fairly complete information data set on habitat characteristics for future comparisons. Due to environmental complexity, we measured many variables directly in the field, while others, as i.e. distance to the nearest road, were calculated using local topographic maps. The following data were recorded for each nest as: distance to the nearest water site (DNW); distance to the nearest tree (DNT); distance to the nearest wood margin (DNWD); distance to the nearest road (DNR); distance to the nearest path (DNP); distance to the nearest vegetation > 15 cm height (DNV); height of the nearest vegetation (HNV); mean height vegetation in an area of 9 m^2 around the nest (MHV); percent cover of vegetation in the area of 9 m^2 around the nest (PCV): we divided this area into a 0,5 x 0,5 grid, then we counted and summed the squares containing any vegetation > 15 cm height (Table 1). Soil type (ST): we considered three categories: i) sandy soil, ii) compact soil, iii) stony soil. Canal orientation (CO): north-south oriented, east-west oriented. Canal (C): distance to the nearest canal. Canal vegetation (CV): type of vegetation of the nearest canal; we considered four vegetation characteristics: i) no vegetation, ii) bank vegetation (rush), iii) bank vegetation and "sparse" emergency reeds (where the distance between two adjacent reeds was greater than 20 cm), iv) bank vegetation and "thick" emergency reeds (where inter-reed distance was less than 10 cm) as in Di Trani and Zuffi (1997). Ground slope (GS): slope of nest ground with respect of the horizontal ground. Type of vegetation in the 9 m^2 around the nest (TVC), with four different categories, that are i) grass (height < 15 cm), ii) short bush (height between 15 and 30 cm), iii) high bush (height > 30 cm), and iv) shrub. Light intensity (LI): we coded four categories, i) shade, ii) half shade, iii) sunlight, iv) full sunlight. Canal margin (CM): northern, southern, eastern and western margin. Habitat (H): we classified nest sites as being in strip or non strip habitats; strip habitats were 1-7 m wide and > 15 m long, included for example roadsides; and non strip habitats were all open areas (Congdon et al., 1983). Rubble (i.e. short cuts of building remains) cover (RC): presence of rubble in the 9 m^2 around the nest, we identified three categories i) no rubble, ii) intermediate cover (< 50%), and iii) high cover (> 50%) (Table 2).

Statistical procedures

All considered parameters were tested for normality and processed accordingly with parametric or non parametric statistics. Comparison of observed differences of a given nesting area feature,

Table 1. Frequency of quantitative variables

Nest characteristics	Means ± 1 SD	Min.	Max.	N size
Distance to nearest water (DNW) (m)	11.53 ± 20.97	1.5	200	209
Distance to nearest tree (DNT) (m)	11.47 ± 10.83	1.5	95	209
Distance to nearest wood (DNWD) (m)	12.83 ± 11.04	1.5	95	209
Distance to nearest road (DNR) (m)	28.08 ± 28.84	0.15	100	131
Distance to nearest path (DNP) (m)	4.05 ± 5.70	0	40	209
Distance to nearest vegetation (DNV) (m)	0.70 ± 0.70	0	3	179
Distance to nearest nest (DNN) (m)	8.79 ± 8.81	0.7	40	154
Height of nearest vegetation (HNV) (m)	0.61 ± 0.37	0.10	2	179
Mean eight vegetation (MHV) (m)	0.85 ± 0.40	0.10	2	179
Percent cover vegetation (PCV)	25.90% ± 8.81	0%	90%	209

Table 2. Means values of qualitative variables

Variable	n
Soil type (ST)	209
Sandy soil	119
Earthy soil	50
Stony soil	40
Canal orientation (CO)	209
North-south	155
East-west	54
Canal vegetation (CV)	209
No vegetation	0
Banks vegetation	41
Banks vegetation and sparse reeds	85
Banks vegetation and tick reeds	83
Ground slope (GS)	209
Slope	62
Flat	147
Type vegetation cover (TVC)	209
Grass (h< 15 cm)	30
Short bush (15 < h < 30 cm)	4
High bush (h> 30 cm)	139
Shrubs	36
Light intensity (LI)	209
Shade	34
Half shade	29
Sunlight	101
Full sunlight	45
Canal margin (CM)	209
Northern margin	12
Southern margin	42
Eastern margin	61
Western margin	94
Habitats (H)	209
Strip habitats	127
Non strip habitats	82
Rubble (R)	209
No rubble	153
Rubble cover < 50%	25
Rubble cover > 50 %	31

for instance the distribution of nests between the opposite sides of a canal, has been processed with χ^2 with Yate's correction, or with Mann-Whitney U test.

In order to reduce the number of variables for nest characteristics, and with the aim at classifying most of the canals and habitats, with a reduced number variables, two multivariate methods were used: factor analysis (Principal Component Analysis: PCA; Lenk and Wüster, 1999) and the Discriminating Analysis (DA) (Disi, 1987; Marnell, 1998). PCA was run after VARIMAX rotation of all considered characters. Factor extraction was performed on data with eigenvalues larger than one, and it was used to verify whether environmental variables did really contribute to the description of nesting habitats. DA was used to verify which variable actually had a role in the discrimination (Marnell, 1998). This analysis was carried out using stepwise method. Significance level was set at $\alpha = 0.05$. Statistical analyses were performed with SPSS 6.1.2 for Windows 95.

RESULTS

Female population features

On average, females of this area displayed secondary sexual characteristics at 99-100 mm carapace length, and have been then considered adult. The first reproductive female was captured at 112 mm carapace length (Zuffi and Odetti, 1998; Rovina, 1999; Zuffi et al., 1999). Adult females measured (n = 256; average ± 1 SD) 133.1 ± 10.2 mm carapace length (range 100-155 mm), and 54 ± 4.5 mm carapace height (range 41-68 mm), and weighed 425.14 ± 88.88 g (range 160-660). Clutch size ranged from four to nine eggs (43 clutches from 24 gravid females and 19 intact nests; mean = 5.72 ± 1.28, mode = 5, Coefficient of Variation = 22.4 %; Zuffi et al., 1999). Even if home-range estimation was not considered as a priority in our study, females seemed to move only slightly within their main area along a same canal: most marked females were observed in the same area during the whole active season. Nevertheless we could not exclude *a priori* any long term movement as found in other populations (Lebboroni and Chelazzi, 1991; Rovero and Chelazzi, 1996; Schneeweiss and Steinhauer, 1998).

Predated nests

Predated nests averaged 120 ± 40 mm width (range 50-360 mm, n = 202), 100 ± 20 mm depth (range 50-170 mm, n = 202), and 120 ± 40 mm length (range 40-360 mm, n = 202). The average estimation of nest clutch size was 3.19 ± 1.83 eggs (range 0-8, n = 184), suggesting that a significant part of layed eggs has been removed by the predator far from the nest. We found infact that main predators' signs on eggs belonged at least to birds (*Garrulus glandarius*, *Corvus corone*), rodents (*Rattus* and *Microtus*), ungulates (*Sus scrofa*) and carnivores (*Mustela nivalis*, *Vulpes vulpes*), that likely bring elsewhere part of their preys (Rovina and Zuffi, submitted). Average untransformed data were as follows for predated nests: distance to the nearest water site was within 6 m for 50% nests and within 21 m for 90% nests; distance to the nearest tree ranged from 1.5 to 95 m and was within 9 m for about 50% nests, while was within 22 m for 90% nests; distance to the nearest wood margin ranged from 1.5 to 95 m and was within 10 m for 50% and within 22 m for

90 nests; 56.9 % nests were in sandy soil, while 19% was in stony soil and 24.1% was in compact soil.

Table 3. Rotated Factor matrix.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
DNW	- 0.12986	0.01539	0.56873	0.09502	0.30620	0.07942	0.24861
DNT	0.11258	0.03699	0.15997	0.89306	0.16347	- 0.09049	- 0.01861
DNWD	0.36089	- 0.07443	0.02411	0.81579	0.01816	0.09754	0.00432
DNR	0.69397	- 0.46543	- 0.20733	0.15110	- 0.01313	- 0.11262	0.12452
DNP	- 0.08890	- 0.46508	0.57768	- 0.10282	- 0.41495	0.23140	0.08526
DNV	- 0.30537	- 0.01293	- 0.65348	- 0.10864	- 0.06269	0.39255	0.16482
DNN	- 0.10598	0.14878	- 0.05425	0.00418	- 0.02834	- 0.05544	- 0.92211
HNV	0.02064	- 0.11103	- 0.06020	0.04647	0.08784	0.85896	0.04054
MHV	0.23494	0.01828	0.45860	- 0.09256	0.10921	0.60604	0.01107
PCV	0.43277	- 0.10599	0.70344	0.22658	0.00628	0.13036	- 0.01396
ST	- 0.09329	0.75347	- 0.21962	- 0.17612	- 0.41997	- 0.04997	0.00423
CO	0.87488	- 0.10252	0.26392	0.13181	0.06116	0.08135	0.02468
C	0.60259	0.00674	0.36267	0.07800	0.41865	0.03436	- 0.2721
CV	0.60691	- 0.01574	0.06575	0.25394	0.55083	0.27381	0.09033
GS	- 0.21356	0.37964	- 0.08653	- 0.29337	- 0.17184	- 0.32119	0.31668
TVC	- 0.46389	0.19009	- 0.39893	0.25394	- 0.22485	- 0.28793	0.14575
LI	0.15798	- 0.23932	0.10552	0.09225	0.75292	0.11839	- 0.01650
CM	0.89630	0.06403	0.04918	0.24970	0.11478	0.04407	0.01916
H	0.04343	0.88961	0.01546	0.10650	0.08742	- 0.04235	- 0.09267
R	- 0.27494	0.64362	- 0.03085	- 0.04051	- 0.42897	- 0.08943	- 0.10738

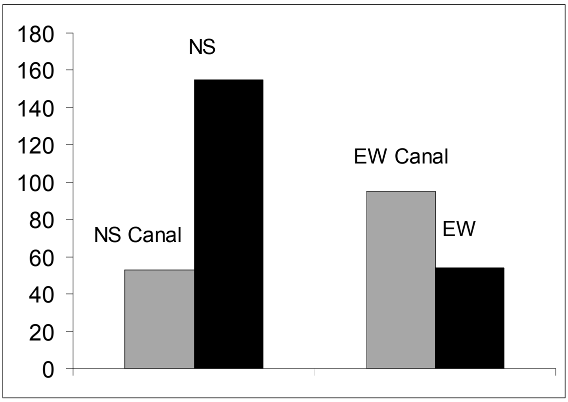

Fig. 2. Frequency of distribution of predated nests in North-South and East-West canals. Ordinate represents the amount of canal types expressed in meters x 100 and the absolute frequency of predated nests per canal type.

Canals

Canals are of a same type, that is rectilinear artificial type, and the main difference between them regards their distributive patterns: type 1) are mainly North-South (NS) oriented; type 2) are mainly East-West (ES) oriented. Overall length of NS oriented canals with water is 5300 m and EW oriented canals with water is 9500 m. We recorded 209 predated nests, 155 of them along NS canals and 54 along EW canals (Fig. 2). The difference of number of nests and their relative distribution versus availability of two canal types, is highly significant (χ^2 with Yate's correction = 132.09, 1 df, $P < 0.001$). Nests of NS oriented canals were distributed on western (N = 94) and eastern (n = 61) sides; nests of EW oriented canals were distributed on northern (n = 12) and southern (n = 42) sides. The difference in nest distribution between sides of NS and EW oriented canals is significant (χ^2 with Yate's correction = 15.57, $P < 0.01$; χ^2 with Yate's correction = 6.61, $P < 0.05$, respectively), clearly indicating a marked preference for warmer sun exposed areas.

Habitat and canal classification

PCA analysis found that habitat, canal margin, average height of the closest bush, distance to the nearest tree, percentage of vegetation coverage, light intensity and inter nest distance, among other parameters, explained more than 70 % of the observed variability of

Table 4. Eigenvalues and variance of the overall factors.

Factor	Eigenvalue	Pct of Var.	Cum. Pct
1	6.1464	30.7	30.7
2	2.33321	11.7	42.4
3	1.73466	8.7	51.5
4	1.41025	7.1	58.1
5	1.24647	6.2	64.4
6	1.06170	5.3	69.7
7	1.02837	5.1	74.8
8	0.95043	4.8	79.6
9	0.71653	3.6	83.1
10	0.67844	3.4	86.5
11	0.48190	2.4	88.9
12	0.44274	2.2	91.2
13	0.36934	1.8	93.0
14	0.35278	1.8	94.8
15	0.27894	1.4	96.2
16	0.23978	1.2	97.4
17	0.23471	1.2	98.5
18	0.14861	0.7	99.3
19	0.10231	0.5	99.8
20	0.04247	0.2	100.0

nesting area feature. The rotated factor matrix (Table 3) indicated that nests were positively selected for sunny bushy areas, with proximity to moderately high bush, distant from the wood, relatively distant from the road, and scarce in habitats with grounds covered by rubble.

Discriminant Analysis were carried out using the seven most informative variables (see Table 4), and considering habitat (H), canal orientation (CO) and canal margin (CM) as grouping variables. Habitat correctly classified 66.5 % of considered cases (n = 139 out of 209; after Function 0, Wilks' λ = 0.799178, χ^2 = 29.254, 3 df, P = 0.00001). Canal orientation correctly classified 100 % of considered cases (n = 209 out 209; after Function 0, Wilks' λ = 0.213841, χ^2 = 201.299, 3 df, P = 0.00001). Canal margin classified 41.6 % of considered cases (n = 87 on 209; after Function 0, Wilks' λ = 0.649133, χ^2 = 55.743, 12 df, P = 0.00001).

East West canals

The average distance to the nearest path (DNP) is greater in northern than southern margins of EW canals (Mann-Whitney Z test = -2.79, $P < 0.01$); the average height of the closest bush (HNV) is significantly greater in northern than southern margins of EW canals (Mann-Whitney Z test = -2.65, $P < 0.01$). The average bush coverage (MHV) is significantly wider in northern than southern margins of EW canals (Mann-Whitney Z test = -2.13, $P < 0.05$); the percentage of vegetation coverage (PCV) is significantly greater in northern than southern margins of EW canals (Mann-Whitney Z test = -2.33, $P < 0.05$). ST: Stony soil is more abundant, and sandy soil is less abundant on southern than northern canal borders (χ^2 = 7.96, 2 df, $P < 0.05$). CV: bank vegetation and sparse emergent reeds (category 3) are less common than expected, while bank vegetation only (category 2) is more abundant than expected on northern margins (χ^2 = 6.1, 2 df, $P < 0.05$). TVC: high bush is more distributed on northern than southern margins, and shrubs are less abundant than on northern margins (χ^2 = 21.35, 3 df, $P < 0.01$). LI: sun light is more intense than expected on northern margins, and less intense than expected on southern margins; full sunlight is more evident on southern margins (χ^2 = 15.76, 3 df, $P < 0.01$). H: strip habitat is more frequent on southern margins, and non strip habitat is more frequent on northern margins (χ^2 = 4.36, 1 df, $P < 0.05$).

North South canals

The distance from a road (DNR) is greater in western than in eastern margins of NS oriented canals (Mann-Whitney Z test = -2.87, $P < 0.01$); the average distance to the nearest path (DNP) is lower in western than in eastern margins of NS oriented canals (Mann-Whitney Z test = -3.5, $P < 0.01$). The inter nest distance (DNN) is lower in western than in eastern margins of NS oriented canals (Mann-Whitney Z test = -2.12, $P < 0.05$); the average height of the closest bush (HNV) is significantly greater in western than eastern margins of NS oriented canals (Mann-Whitney Z test = -2.18, $P < 0.05$). The percentage of coverage (PCV) is significantly greater in western than eastern margins of NS oriented canals (Mann-Whitney Z test = -2.77, $P < 0.01$). ST: stony soil is less abundant on western margins, than on eastern margins; earthy soil is less abundant than expected on eastern margins (χ^2 = 26.3, 2 df, P < 0.01). CV: bank vegetation and thick emergent reeds (canal vegetation, category 4) is less abundant on eastern margins than on western margins; bank vegetation and sparse emergent reeds (canal vegetation, category 3) is less frequent than expected on western margins than on eastern margins (χ^2 = 12.39, 2 df, P < 0.01). TVC: grass is less distributed on western margins than on eastern margins (χ^2 = 15.14, 3 df, P < 0.01). Light intensity (LI): was not different between eastern and western margins (χ^2 = 4.89, 3 df, not significant). H: strip habitat is more frequent on eastern margins, than on western margins (χ^2 = 7.83, 1 df, P < 0.01). RC: high cover rubble (category 3) is more frequent on eastern than western margins (χ^2 = 19.99, 2 df, P < 0.01).

Comparison between NS and SW Canals. The occurrence of several considered parameters (e.g., DNW, DNR, DNP, HNV, MHV, PCV) in NS canals was significantly greater than that observed in EW canals (Mann-Whitney Z test, P ranging from < 0.05 to < 0.001); only DNV was significantly lower in NS than in EW canals (Mann-Whitney Z test = -3.84, P < 0.001). ST: stony soil is less abundant on NS oriented canal than on EW canals, and earthy soil is less frequent on EW oriented canals (χ^2 = 29.89, 2 df, P < 0.01). CV: category four (bank vegetation and thick emergent reeds) is less frequent on EW canals as well as category two is more frequent on EW oriented canals (χ^2 = 51.67, 2 df, P < 0.01). TVC: high bush is less frequent than expected on EW oriented canals; shrub is less abundant on NS oriented canals (χ^2 = 48.9, 3 df, P < 0.01). LI: sunlight is more abundant, but full sunlight is less abundant on EW canals (χ^2 = 12.07, 3 df, P < 0.01). RC: category one is less abundant, and category three is more abundant on EW canals (χ^2 = 20.04, 2 df, P < 0.01).

DISCUSSION

Our work allowed us to construct, probably for the first time with this wide number of variables, the main largest available database of physical characteristics that describe nesting habitats and predated nests of the European pond turtle. These nesting habitats describe with particular accuracy the canal habitat, one of the two main habitat systems recorded for *Emys orbicularis* in Italy (Lebboroni and Chelazzi, 1998). Because of the relatively common occurrence of canal habitat in several parts of the European distribution area of the species (Austria: Rössler, 2000b; France: Servan, 2000; Hungary: Farkas, 2000; Italy: Lebboroni and Chelazzi, 1998; Ukraina: Kotenko, 2000), our information set arises to a particular relevance.

Our data set confirms the few scattered information available up to date on nesting habitats, and on nest size (Rovero and Chelazzi, 1996; Lebboroni and Chelazzi, 1998; Zuffi et al., 1999; Ballasina and Lopez-Nunes, 2000; Gianatti et al., 2000; Rössler, 2000c; but see also Andreas, 2000). A specific interest on the role of reproductive migrations, in the light of the spatial organisation of movement, has been recently increased (Lebboroni and Chelazzi, 1991, 1998; Rovero and Chelazzi, 1996; Schneweiss, 1998), adding further information on the use and the characteristics of nesting areas. It has also been reported that fidelity to the nesting sites is a frequent pattern, with preferred migration routes (Rovero and Chelazzi, 1996; Schneeweiss et al., 1998). This implies a specific pattern of habitat use following the preferred paths.

Canal habitats north-south oriented were the most important habitat feature regarding nesting areas for *Emys orbicularis*. Particularly important were the western sides of north-south canals and southern sides of east-west canals (see Gianatti et al., 2000).

There is evidence that nests were positively selected in sunny bushy areas, in proximity to moderately high bush structure, distant from the wood, relatively distant from the road, but were scarce in habitats with grounds covered by rubble. The high occurrence of predation on nests reflects a typical, natural condition of the life history traits of most of the studied fresh water turtles (Ernst and Barbour, 1989). Nevertheless, in *Emys orbicularis*, observation of juveniles is often scarce or not common; this fact has been assumed to be the result of sampling bias and low recruitment rate or due to environmental pollution or habitat alteration (Devaux and Bley, 1998; Keller et al., 1998). Large pond turtle populations do not seem to suffer even of an intense predatory activity on nests, while small, scattered, and sparse populations, may be endangered by both nest predation, and by habitat alteration (Andreas and Paul, 1998; Cheylan and Poitevin, 1998; Devaux and Bley, 1998; Jablonski and Jablonska, 1998; Mascort, 1998; Schneeweiss, 1998; Mitrus and Zemanek, 2000).

In most of these cases, the protection of nests against predators has been claimed by several authors as a necessary procedure towards the protection and management of wild populations (see Mitrus and Zemaneck, 1998; Mitrus, 2000; Rössler, 2000c). Furthermore, habitat protection should be primarily considered especially in all those cases where human action has been markedly negative.

We now suggest that the habitats to be protected should cover both primary aquatic habitats, with a special emphasis to nursery sites (Lebboroni and Chelazzi, 1998), and to routes of migration to and from nesting areas (Schneweiss, 1998; Rössler, 2000), as well as to and from nursery areas.

It also emerges that most nature parks and protected areas may arise to the natural role of core of production of both turtle eggs and hatchlings: the higher presence of nests and eggs, in areas with high turtle frequency, should stimulate the idea of an import/export trade of eggs and hatchlings to those areas where living specimens of the same taxon are scarce. On average, the searching for a nesting area, could be easily performed following a relatively small number of radiotracked females, captured prior to their pre-reproductive migration (usually from May to July), collecting the layed eggs and store them in incubatory chambers; alternatively or in parallel, several reproductive females carrying detectable eggs (Zuffi et al., 1999), can be brought to individual terraria, where they can lay their eggs, and then to put the layed eggs into incubatory chambers.

Any future management plan, should be mostly tested in protected areas, in order to assess any possible problems due to technical procedures; in protected areas, it should be possible to increase the experimental didactic information to local people. The system could be then exported to non protected, or altered areas.

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