A management plan for the European pond turtle (*Emys orbicularis*) populations of the Louro river basin (Northwest Spain)

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Cordero Rivera, A. & Ayres Fernández, C., A management plan for the European pond turtle (*Emys orbicularis*) populations of the Louro river basin (Northwest Spain). Biologia, Bratislava, **59/Suppl. 14:** 161—171, 2004; ISSN 0006-3088.

Emys orbicularis is the most endangered reptile in Galicia (Northwest Spain). Only two large population groups are known in the region, and the species is also rare in the north of Portugal, suggesting that Galician populations are currently isolated. Here we present an analysis of the Louro river populations (Pontevedra province), which consist of approximately 100 turtles. Fieldwork from 1996 to 2002 allowed us to estimate sex ratio, survivorship and recapture rates, reproduction, mobility between ponds, and size distribution. We were unable to find nesting sites and therefore have very limited information about clutch size. Based on these demographic parameters and literature data, we performed a population viability analysis for a local population with Vortex software. It helped to identify six major conservation problems in the study area: (i) introduction of exotic species (predators: black-bass; competitors: *Trachemys scripta*); (ii) capture of turtles for pet trade; (iii) direct disturbance; (iv) increased extinction risk due to small population size; (v) habitat destruction; (vi) water and soil pollution. A management plan is proposed to minimize the impact of these factors.

Key words: *Emys orbicularis*, population structure, survivorship, population viability, Spain.

Introduction

Emys orbicularis (L., 1758) is found in East and Central Europe, the Mediterranean countries (including some islands) and North Africa (Fritz, 2001, 2003). Formerly the range was more extensive as indicated by postglacial remains found in North Europe, including England, Denmark, and Sweden (Fritz, 1995, 2001, 2003). In prehistoric times this species was probably a common food item for humans (Schleich & Böhme, 1994; Cheylan, 1998; Fritz, 2003), and was also commonly eaten in Central and East Europe during the past (because it was considered fish by the Catholic Church). Already in 1792 it was recognized that collecting was out of control and turtles were becoming rare (Bringsøe, 1997; Fritz, 2003). Even today *E. orbicularis* is captured for food in some areas of southern Spain (Keller & Andreu, 2002), and this type of exploitation is of great concern for turtle conservation (Burke et al., 2000). At present, *E. orbic-*

ularis is threatened and declining in several regions of its range, mainly due to habitat destruction: Italy (GARIBOLDI & ZUFFI, 1994; CHELAZZI et al., 2000), France (CHEYLAN, 1998; GAY & LEBRAUD, 1998), Poland (MITRUS, 2000), Germany (HANKA & JOGER, 1998; SCHNEEWEISS, 1998; SCHNEEWEISS & FRITZ, 2000), the former Soviet Union (SNIESHKUS, 1993; SHCHERBAK, 1998; KOTENKO, 2000), and Turkey (TAŞKAVAK & REIMANN, 1998). It is therefore included in the Bern Convention and protected by European Union laws. The status of the species has recently been reviewed for the entire range (FRITZ, 2001, 2003).

E. orbicularis is common in some parts of the Iberian peninsula (ANDREU, 1997; ANDREU & LÓPEZ-JURADO, 1998; KELLER & ANDREU, 2002). However, with the exception of the work of Claudia KELLER (KELLER, 1997; KELLER et al., 1998), very little is known about its ecology and behaviour. Generally, the numbers of *E. orbicularis* are thought to be decreasing in Spain (MASCORT, 1998; GÓMEZ-CANTARINO & LIZANA, 2000; BERTOLERO, 2000), except for Huelva province (KELLER & ANDREU, 2002). Already the earliest published information on this species in Galicia (Northwest Spain) stated that it is rare due to human persecution (LÓPEZ SEOANE, 1877). GALÁN (1999) pointed out that *E. orbicularis* is the most endangered reptile species in Northwest Spain.

Our previous work demonstrated that Galician *E. orbicularis* differ morphologically from other populations (AYRES FERNÁNDEZ & CORDERO RIVERA, 2001). As these populations are rather isolated and several other endemic amphibians and reptiles are known from the northwestern Iberian peninsula (e. g. *Chioglossa lusitanica* Bocage, 1864, *Rana iberica* Boulenger, 1879, *Lacerta lepida iberica* López Seoane, 1884, *Podarcis bocagei* López Seoane, 1884), it has been suggested that Galician pond turtles might represent a distinct subspecies (FRITZ et al., 1996; AYRES FERNÁNDEZ & CORDERO RIVERA, 2000).

There is general concern about the decline of amphibian and reptile populations (WYMAN, 1990; GIBBONS et al., 2000), but the causes for this decline are poorly known. In turtles, population declines are thought to be related to human disturbance, and this is particularly likely in some cases. For instance, in *Glyptemys insculpta* (LeConte, 1829) long-term data showed a clear relationship between human recreation and turtle extinction (GARBER & BURGER, 1995). Other emydids have been negatively affected by human disturbance of their habitats (JACKSON & WALKER, 1997). When at the end of 1996 the Galician government asked us for a report on the conservation status of *E. orbicularis* in Northwest Spain, we decided to carry out fieldwork to determine the number of remaining turtles in one of the last known localities. Our aim was to obtain basic demographic information for population viability analysis and to establish conservation guidelines. The aim of the management plan was to guarantee the long-term (i. e., 100 years) survival of *E. orbicularis* in the Louro river basin. The main results of this work are presented here.

Methods

We follow SUTHERLAND (2000) for a conceptual model to develop our management plan. In brief, we identified the main factors that might impede the long-term population survival (over 100 years), clarified the causes behind these factors, and evaluated different measures to minimize their impact.

The study area is the Louro river valley, near Porriño in the southwest of Galicia (NW Spain; 42°10′ N, 8°37′ W), where *Emys orbicularis* survives in a natural wetland (Gándaras de Budiño) and in old clay pits, surrounded by a dense industrial landscape. We studied pond turtles in three artificial ponds: O Cerquido (1996–1998), Centeáns (1997–2002), and Orbenlle (1997–2002). These water bodies are deep (more than 5 m in some cases), with almost vertical banks and therefore not easily accessible. The ponds are at least 20 years old. Turtles have been observed to colonize ponds that are still under clay exploitation. The Centeáns pond is in fact a group of six ponds, some of which were still used for clay mining in 2003. Turtles can easily change between the Centeáns ponds and are therefore considered a single population. We did not sample in the natural wetland area because it is mostly inaccessible and, moreover, protected as bird reserve. Our continuous presence would have resulted in heavy disturbance to bird nesting. However, we know that some turtles are living there.

European pond turtles are very shy and difficult to capture. Therefore, turtles were attracted to the shore by bait (meat and fish), and captured with a net, or by placing baited traps on the coastline that were controlled every 1–2 days. Sampling intensity varied between years (29, 99, 155, 84, 78, 111, and 103 days of sampling from 1996 to 2002). One observer (CAF) spent between 2 and 10 hours in the field per day.

Captured turtles were weighed (± 5 g), measured with a calliper (± 1 mm), photographed and individually marked with two numbered small plastic labels (25 × 15 mm) glued to the dorsal carapace with cement adhesive (UTZERI, pers. comm.). This marking system allows an easy identification of individuals by reading the numbers with binoculars. It therefore reduces handling and stress. Furthermore, it has the advantage of being reversible: turtles can be unmarked

Table 1. Values of population parameters entered into population viability analyses using Vortex software (Miller & Lacy, 2003). SCL: straight-line carapacial length.

Variable	Value	Explanation/Reference
Inbreeding	No	
Correlation Environmental Variation (EV) (reproduction) – EV (survival)	Yes	Good survival years = good reproduction years
Catastrophes	No / Yes	
Mating system	Polygamous	
Age at first reproduction, males	4 years	Keller (1997)
Age at first reproduction, females	6 years	Keller (1997)
Maximum breeding age	29	Keller (1997)
Sex ratio at birth (% males)	60%	Field data
Maximum clutch size per year	12	Estimated from maximum SCL (173 mm)
Reproduction density-dependent?	No	Optimistic scenario
% females breeding per year	50%	Literature review
SD breeding annually	12.50%	No data available
Clutch size distribution		Estimated from female size
Mortality rate nests	90%	Literature review
Mortality rate males	16.29%	Estimated from mark-recapture data
Mortality rate females	4.13%	Estimated from mark-recapture data
Mortality rate juveniles	2.14%	Estimated from mark-recapture data
SD in mortality rate due to EV	1.00%	EV in survival estimated from mark-recapture data, model Phi(t) p(.) (Cooch & White, 2002)
All adult males in the breeding pool?	Yes	Optimistic scenario
Start at a stable age distribution?	No	Estimated from size distribution
Carrying capacity?	60	Literature review
SD in K due to EV	5	No data available
Trend in K?	No	Optimistic scenario
Harvest in the population?	No	
Supplement the population	No / Yes	

by removing the labels at the end of the study. Labels remain attached to the individuals for at least six years after marking. Turtles were sexed by using the different morphology of the tail and plastron (Andreu & López-Jurado, 1998).

We used Vortex 8.41 (Miller & Lacy, 2003) to model the viability of the *E. orbicularis* population in Centeáns. Simulation data were based on our fieldwork (survival rate, sex ratio, age structure) or on literature references (sexual maturity age, clutch size, maximum reproduction age). Survival rate was estimated from the mark-recapture histories of 35 males, 21 females and 14 juveniles (1997–2002) from the Centeáns population, using MARK 3.1 (Cooch & White, 2002). Parameter estimates were derived from a model where the recapture rate was constant over time identical for all turtles (i. e., only one recapture parameter was estimated for both sexes and juveniles). Survival rate was constant over years but differed between sexes and juveniles (model Phi(g) p(.); Lebreton et al., 1992). For an approximation of environmental variation (EV) in survival, we estimated survival rate from a model with temporal variation in this parameter but no effect of group (model Phi(t) p(.)). From Box D in the Vortex manual (Miller & Lacy, 2003) we calculated that EV was less than 1%, and this value was entered as a conservative estimation. There is a lack of precise information on many population parameters in turtles (Shine & Iverson, 1995) and this is a problem for constructing realistic population viability analyses (Boyce, 1992). Therefore, we started with an optimistic simulation (50% females reproducing every year, no catastrophes) and conducted a sensitivity analysis. Table 1 summarizes values entered in the simulations. We did not include density-dependent reproduction in our model, but included a carrying capacity of 60 ± 5 turtles. This value was estimated from a density of 5–7 individuals per hectare (Mazzotti, 1995; Duguy, 2000). Only one local population was modelled (Centeáns ponds) because we did not record any individuals changing between Centeáns, O Cerquido, or Orbenlle water bodies. Simulations were run 500 times during 100 years.

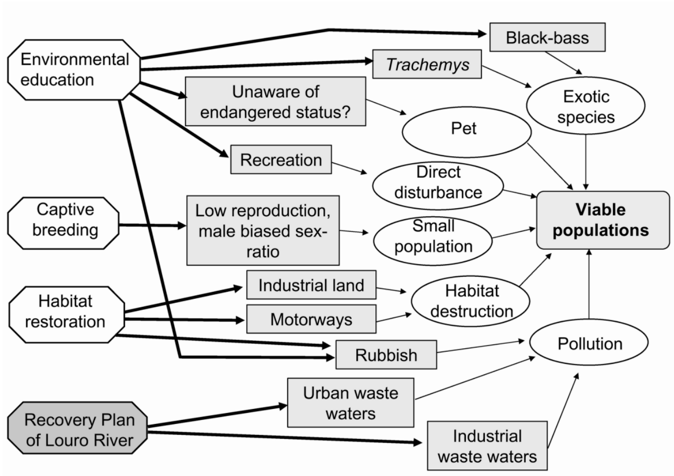

Fig. 1. Conceptual model of the management plan for *Emys orbicularis* in the Louro river basin to maintain viable populations in the long-term. Six major problems were identified, and causes and proposed solutions are indicated.

Results

Identification of conservation problems and their causes (Fig. 1)

Introduced exotic species

Allochthonous populations of a predatory fish, the black-bass (*Micropterus salmoides* [Lacepède, 1802]), of the red swamp crayfish (*Procambarus clarkii* [Girard, 1852]), and of the red-eared slider (*Trachemys scripta elegans* [Wied, 1839]) exist in the study area. The first two species have been introduced by anglers, and the presence of the American slider is the consequence of pet trade (Bringsøe, 2001).

Pet trade

During the 1980s, *Emys orbicularis* was frequently sold in local pet shops. Now it is forbidden to trade native terrapins, i. e., *E. orbicularis* and *Mauremys leprosa* (Schweigger, 1812). However, sporadic captures of turtles with clear symptoms of having lived in captivity far away from any populations suggests that some turtles are still kept in private hands.

Direct disturbance

The artificial ponds are used by fishermen, looking for black-bass. There is also evidence that some turtles have been captured in crab traps, but the intensity of mortality caused by fishing (Nemoz et al., 2002) and drowning in crab traps is unknown. Furthermore, basking is a basic behaviour in pond turtles (di Trani & Zuffi, 1997), and therefore the continuous presence of people might impede these turtles' ability to thermoregulate.

Small population size

Population size is clearly related to extinction probability (Brook et al., 2000). If populations have a very small size and there is an unbalanced sex ratio, both factors might combine to increase extinction risk, due to stochastic processes. Table 2 indicates that all populations are small and have more males than females. According to Mazzotti (1995), turtles with a carapace length below 80 mm were considered juveniles. The sex ratio expressed as relative male frequency, males/(males + females), was 0.64. It deviates significantly from an even sex ratio of 0.5 ($\chi^2 = 6.55$, d.f. = 1, $P = 0.011$). Keller (1997) considered all individuals under 130 mm carapace length to be juveniles. Following Keller's approach, the sex ratio would be even more male-biased (0.74 males/total, $\chi^2 = 11.08$, d.f. = 1, $P < 0.001$).

Habitat destruction

Most wetlands have been converted to agricultural, industrial, or urban areas during the last 50 years. This is the problem most commonly cited to explain the decline of *E. orbicularis* populations (Fritz, 2001, 2003). Habitat reduction for turtles is evident comparing aerial photographs taken by military or geographic services between 1945 and 1996 (Fig. 2). Direct destruction of ponds also occurs: In December 1997 the O Cerquido pond was completely covered by gravel and other residual materials from companies that cut granite blocks. We were unable to stop these activities, even after repeated requests. By July 1998, almost no water remained. We captured seven turtles and released them at Centeáns in 1999 (five were resighted un-

Table 2. Population structure of *Emys orbicularis* in three artificial pond systems in Northwest Spain. In brackets data for (males : females : juveniles : hatchlings)

Population	Recorded numbers							Total
	1996	1997	1998	1999	2000	2001	2002	
O Cerquido	19 (11:7:1:0)	recaptured 14 (7:7:0:0)	recaptured 13 (6:6:1:0)	pond destroyed in 1998; 7 turtles released in Centeáns (not included in this table)				25 (12:8:5:0)
	–	new 2 (0:1:1:0)	new 4 (1:0:3:0)	–	–	–	–	
Centeáns	–	22 (17:4:1:0)	recaptured 18 (14:3:1:0)	recaptured 24 (11:7:6:0)	recaptured 27 (12:8:7:0)	recaptured 27 (12:9:6:0)	recaptured 34 (12:14:8:0)	79 (30:18:13:18)
	–	new 22 (3:7:5:7)	new 14 (2:1:3:8)	new 3 (3:0:0:0)	new 14 (4:5:2:3)	new 4 (1:1:2:0)		
Orbenlle	–	5 (3:2:0:0)	recaptured 3 (3:0:0:0)	–	recaptured 4 (2:2:0:0)	recaptured 2 (1:1:0:0)	recaptured 8 (5:3:0:0)	19 (11:8:0:0)
	–	–	new 6 (3:3:0:0)	–	new 1 (1:0:0:0)	new 5 (3:2:0:0)	new 2 (1:1:0:0)	

til 2002). The O Cerquido habitat was completely lost, and 13 turtles most likely died.

Pollution

The river Louro is one of the most polluted rivers in Spain, receiving residual waters from many industries (ALVAREZ-CAMPANA GALLO, 1996), and urban waste waters from O Porriño (population: 17,000), that produce a drastic reduction in the diversity of macro-invertebrates in the lower course of the river (PARDO, 1994). Furthermore, high concentrations of pesticides (mainly lindane) have been detected in ground water (GONZÁLEZ RODRÍGUEZ, 1999), derived from a pesticide industry that existed in the 1960s.

Population viability analysis

This analysis was done to predict how different management strategies could affect the survival probability of the population. Figure 3 shows the results of simulations. We started with a conservative situation (Tab. 1), and modelled the future of the Centeáns ponds, starting with 60 turtles with a known age structure (as in 2000). This "optimistic" simulation suggests that the Centeáns population has a 98% probability of surviving 100 years, even if nest mortality was entered as 90%, similar to field data from other populations (ROVERO & CHELAZZI, 1996; JAB3OSKI & JAB3OSKA, 1998; ZUFFI et al., 1999; RÖSSLER, 1999; CHELAZZI et al., 2000). Reducing mortality of neonates to 25% increases survival probability to 100% (Fig. 3). The model is very sensitive to changes in adult and juvenile survivorship. If the original analysis is repeated increasing mortality to 5% in juveniles, 10% in females and 20% in males, then we have only 51% probability of maintenance after 100 years (Fig. 3). If two kinds of catastrophes are included (the first occurring with 0.05 annual probability, reducing reproduction and survival by 25%; the second with 0.01 annual probability, reducing reproduction by 50% and survival by 75%), survival probability for 100 years drops to 8%. We modelled the effect of population restocking for 10 years (from year 10 to 20), adding 20 males and 20 females of one year of age to the realistic scenario with catastrophes (head-starting, see HEPPELL & CROWDER, 1996). This measure had a limited effect on the long-term maintenance probability of the population (17.6%; Fig. 3).

Discussion

The three local Galician populations suffer from

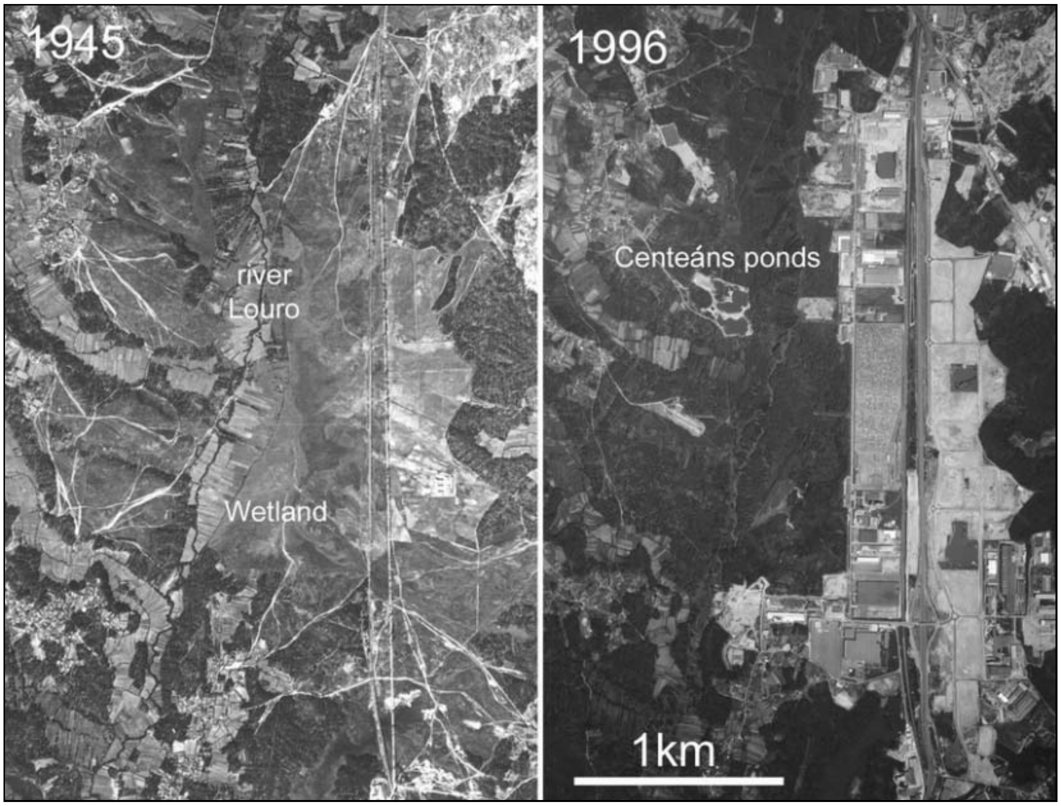

Fig. 2. Aerial photographs of the valley of the Louro river in 1945 and 1996. Note heavy industrialization and wetland reduction. Photos by Spanish Army (1945) and Sociedade de Desenvolvemento Comarcal de Galicia (1996).

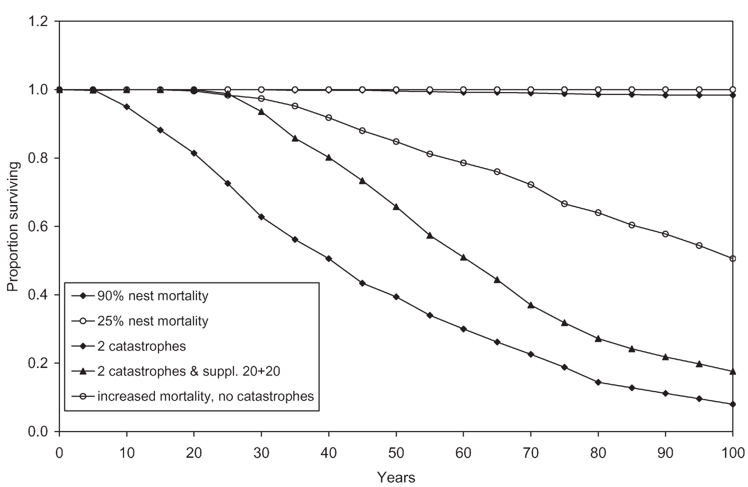

Fig. 3. Results of the population viability analysis for the Centeáns population. We started with an optimistic situation and assumed that 50% of females reproduce every year. Nest mortality has a limited effect on survival probability. Including two catastrophes suggests only 8% of populations would survive 100 years. Supplementing these populations with 20 males and 20 females of one year of age from year 10 to 20 has a limited effect on the long-term maintenance if catastrophes are not avoided. The model is very sensitive to increased adult mortality.

the same problems: the individual numbers are very low, and the sex ratio is male-biased. The sex ratio varies considerably between different *Emys orbicularis* populations. In Italy it is female-biased, in some cases up to 2 : 1 (Utzeri, unpubl. data; Mazzotti, 1995). In France, the percentage of males may be only 30–40% of adults in one population (GIRONDOT & PIEAU, 1993; SERVAN, 1998; PARDE et al., 2000). In the former USSR, SNIESHKUS (1998) found female-biased sex ratios in six out of eight populations. In contrast, in Central Anatolia males outnumbered females in two out of three localities (TAŞKAVAK & REIMANN, 1998), and in Southwest Spain the sex ratio is also male-biased (62% males; KELLER, 1997), but not in Catalonia (40% males; MASCORT, 1998).

Population density in Galicia resembles densities in other parts of the species' range. In Central Italy, UTZERI (pers. comm.) found an average population size of 22.7 individuals in seven ponds of similar size to ours, and between 7 and 11 individuals were counted in ponds of 65–90 m^2 in Central France (NAULLEAU, 1991). Other authors indicate variable densities, probably due to local habitat characteristics (MAZZOTTI, 1995; SERVAN, 1998; DUGUY, 2000).

Related to small population size is the fact that turtles reproduce only rarely in Galician populations. This problem seems common for terrapins in Iberia, as indicated by KELLER's (unpubl. data) finding of only six hatchlings from 1991 to 1995 (an unusual series of dry years) in the Doñana National Park. The percentage of females that reproduce every year seems, therefore, very low. As a conservative estimate, 50% of females reproduced every year in our model, but this might be an overestimation. This is in contrast to other emydids, where most or all females nest annually (JACKSON & WALKER, 1997).

Our data indicate six major problems for the survival of *E. orbicularis* in Northwest Spain (Fig. 1). First, the introduction of exotic predatory fishes (*Micropterus salmoides*) and other species is likely to explain the low recruitment of hatchlings. Furthermore, one big male was found moribund and one female dead (with our plastic tags forcibly removed) probably after having been captured in a crayfish trap (ROOSENBURG et al., 1997). It is obvious that fishing and crayfish trapping should be forbidden in areas where *E. orbicularis* populations are known (Fig. 1). *Trachemys scripta* (Schoepff, 1792) is already common in the area, and it has successfully reproduced in outdoor ponds in Northwest Spain (AYRES, unpubl. data, but see LUISELLI et al., 1997). The effect of this species on *E. orbicularis* is still poorly known, but recent experiments suggest that it is a strong competitor (CADI & JOLY, 2003). We suggest an environmental education plan to minimize these threats (Fig. 1).

Second, human activity is also directly negative for turtles (GARBER & BURGER, 1995; JACKSON & WALKER, 1997). *E. orbicularis* is still captured as a pet, despite it being illegal. Furthermore, most of the individuals from the Centeáns population had been illegally marked before 1999 by unknown people by writing numbers on the carapace and plastron, probably using a pyroengraving device. This harmful marking method was very probably applied by environmentalists with the objective of obtaining information that would help to conserve the turtles, but paradoxically it has resulted in damaging them. The hurt shell area was infected in some individuals.

The third problem is direct human disturbance. The last colonies of *E. orbicularis* survive in an industrial area. Clay pits are common and act as a substitute for the original wetlands that were formerly widespread. But these artificial ponds are ephemeral. During 1997 one pond dried up in just one day (we were informed that some terrapins were captured), and in 1998 the O Cerquido pond was destroyed. These are the kind of catastrophes that we included in the simulations. In recent years some ponds were destroyed as a consequence of road construction, and most of the remaining ponds are heavily polluted or inaccessible. The natural corridor of the Louro river is highly polluted (PARDO, 1994) and probably does not help turtle dispersal very much. Some ponds that could be a good habitat for the turtles are now inside the industrial area. Therefore, they cannot be reached by natural dispersal (Fig. 2). Again, an environmental education plan seems appropriate to minimize human disturbance to terrapins.

Stochastic demographic processes might combine to increase extinction probability in small populations. We never observed nesting behaviour, although hatchlings were found in 1998, 1999, 2001, and 2004 in Centeáns. Males were observed courting and mounting females, even when two individuals were temporarily maintained in a container for marking procedures. Moreover, the number of females is too low. This could be partially corrected by captive breeding of females and the supplementation of the population with more females than males (VOGT, 1994). Nevertheless, our simulations do not suggest the release of hatchlings to be a good management measure. Also head-starting is not a good management tool for long-lived animals if adult mortality remains high (HEPPELL & CROWDER, 1996). Further, GIRONDOT et al. (1998) suggested that feminizing embryos of *E. orbicularis* is not a good strategy because with artificial incubation many phenotypically female turtles are produced but these individuals are unable to reproduce normally and therefore do not contribute to the population.

We are confident that our sampling procedure is not male-biased. Capturing was nearly complete in all populations. Thus, the recorded sex ratio is the real sex ratio of the population, and males outnumber females indeed. There are four factors influencing adult sex ratio: hatchling sex ratio, differences in male and female mortality and emigration rates, and different maturity ages of males and females (GIBBONS, 1990). Moreover, temperature affects the primary sex ratio in *E. orbicularis*. Incubation temperatures of 25 °C produce 100% males, 30 °C produce 100% females, and 28.5 °C result in 50% of each sex (GIRONDOT & PIEAU, 1993; PIEAU, 1998). The studied populations occur at the northern distribution limit of *E. orbicularis* in Spain. Here, high temperatures are rare in spring, suggesting that climate may favour the production of males. Interestingly, male-biased sex ratios were also found in northern populations of *Sternotherus odoratus* (Latreille, 1801) in Canada (EDMONDS & BROOKS, 1996). The observed low number of females could also be explained by a higher mortality rate during reproduction. Females move long distances to find suitable nesting sites, and show high nesting site fidelity (ROVERO & CHELAZZI, 1996). Nesting females are highly vulnerable to predation (JACKSON & WALKER, 1997). If a higher adult female mortality occurs in our populations, then we would expect females to be rarer among old age classes. However, our data do not support this hypothesis: females are rare among young and old individuals. Our results rather suggest a male-biased hatchling sex ratio or a greater juvenile mortality of females as causes for the male-biased adult sex ratio.

The maintenance of viable populations of the European pond turtle in Northwest Spain is, therefore, dependent on protection measures for the artificial ponds, and also an ecological restoration of the area. Our population viability analysis suggests that the crucial management measures are diminishing mortality and increasing carrying capacity. Turtles are sometimes killed on roads or are captured when they move between ponds. Creating a reserve in this area and talking to local people to convince them to release captive animals could be helpful. Increasing the number of suitable nesting sites could also increase population size (the artificial ponds have almost vertical banks). This could be achieved by reconstructing pond banks, building new ponds, or facilitating the colonization of already available ponds. Supplementing the population with captive-bred turtles does not seem to be a good strategy if mortality remains high, but this activity might have important social effects and could be important for environmental education. Avoiding catastrophes, such as the destruction of the O Cerquido pond in 1998, should also be addressed. Fortunately, the area has been included in the NATURA 2000 list of protected habitats.

Finally, given the deterministic nature of habitat destruction and pollution, measures to correct these problems are a priority. Currently there is a plan to eliminate all pollution sources from industrial and urban waste waters (Fig. 1). Therefore, we suggest that a project of ecological restoration of wetlands is the most important component of the management plan for these populations.

Acknowledgements

We are grateful to the Dirección Xeral de Medio Ambiente Natural of the Galician Government (Xunta de Galiza) for providing funding and permission to capture and mark the turtles. Part of this work (2001-2003) was funded by a research project to ACR from Xunta de Galiza (PGIDT01MAM37101PR). We thank C. UTZERI, M. A. L. ZUFFI and U. FRITZ for their expert suggestions and help with the bibliography.

References

ALVAREZ-CAMPANA GALLO, M. 1996. La contaminación de las aguas subterráneas en Galicia. Caso del entorno hidrogeológico del río Louro. Tierra y Tecnología **12**: 57–66.

ANDREU, A. C. 1997. *Emys orbicularis* (Linnaeus, 1758), pp. 172–174. In: PLEGUEZUELOS, J. M. (ed.) Distribución y Biogeografía de los Anfibios y Reptiles en España y Portugal, Universidad de Granada y Asociación Herpetológica Española, Granada.

ANDREU, A. C. & LÓPEZ-JURADO, L. F. 1998. *Emys orbicularis* (Linnaeus, 1758), pp. 94–102. In: SALVADOR, A. (ed.) Fauna Ibérica, Vol. 10, Museo Nacional de Ciencias Naturales, CSIC, Madrid.

AYRES FERNÁNDEZ, C. & CORDERO RIVERA, A. 2000. A new subspecies of *E. orbicularis* in the Iberian peninsula? pp. 20–22. In: Proceedings of the 2nd International Symposium on *Emys orbicularis*, Chelonii **2**.

AYRES FERNÁNDEZ, C. & CORDERO RIVERA, A. 2001. Sexual dimorphism and morphological differentiation in European pond turtle (*Emys orbicularis*) populations from northwestern Spain. Chelon. Conserv. Biol. **4**: 100–106.

BERTOLERO, A. 2000. Suivi de la population de Cistude *Emys orbicularis* dans le delta de l'Ebre (NE

Espagne), pp. 63–68. In: Proceedings of the 2nd International Symposium on *Emys orbicularis*, Chelonii **2**.

BOYCE, M. S. 1992. Population viability analysis. Annu. Rev. Ecol. Syst. **23**: 481–506.

BRINGSØE, H. 1997. Forekomst af europaeisk sumpskildpadde, *Emys orbicularis*, i Danmark. Nord. Herpetol. Foren. **40**: 57–64.

BRINGSØE, H. 2001. *Trachemys scripta* (Schoepff, 1792) – Buchstaben-Schmuckschildkröte, pp. 525–583. In: FRITZ, U. (ed.) Handbuch der Reptilien und Amphibien Europas, Band 3/IIIA: Schildkröten I, Aula, Wiebelsheim.

BROOK, B. W., O'GRADY, J. J., CHAPMAN, A. P., BURGMAN, M. A., AKÇAKAYA, H. R. & FRANKHAM, R. 2000. Predictive accuracy of population viability analysis in conservation biology. Nature **404**: 385–387.

BURKE, V. J., LOVICH, J. E. & GIBBONS, J. W. 2000. Conservation of freshwater turtles, pp. 156–179. In: KLEMENS, M. W. (ed.) Turtle Conservation, Smithsonian Institution, Washington, D. C.

CADI, A. & JOLY, P. 2003. Competition for basking places between the endangered European pond turtle (*Emys orbicularis galloitalica*) and the introduced red-eared slider (*Trachemys scripta elegans*). Can. J. Zool. **81**: 1392–1398.

CHELAZZI, G., LEBBORONI, M., TRIPEPI, S., UTZERI, C. & ZUFFI, M. A. L. 2000. A primer on the conservation biology of the European Pond Turtle, *Emys orbicularis*, of Italy, pp. 101–104. In: Proceedings of the 2nd International Symposium on *Emys orbicularis*, Chelonii **2**.

CHEYLAN, M. 1998. Evolution of the distribution of the European pond turtle in the French Mediterranean area since the post-glacial, pp. 47–65. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

COOCH, E. G. & WHITE, G. C. 2002. Program Mark. Analysis of Data from marked individuals. http://canuck.dnr.cornell.edu/mark.

DI TRANI, C. & ZUFFI, M. A. L. 1997. Thermoregulation of the European pond turtle, *Emys orbicularis*, in Central Italy. Chelon. Conserv. Biol. **2**: 428–430.

DUGUY, R. 2000. Cycle d'activité de la Cistude, *Emys orbicularis*, dans le marais de Brouage (Charente-Maritime, France), pp. 55–57. In: Proceedings of the 2nd International Symposium on *Emys orbicularis*, Chelonii **2**.

EDMONDS, J. H. & BROOKS, R. J. 1996. Demography, sex ratio, and sexual size dimorphism in a northern population of common musk turtles (*Sternotherus odoratus*). Can. J. Zool. **74**: 918–925.

FRITZ, U. 1995. Kritische Übersicht der Fossilgeschichte der Sumpfschildkröten-Gattung *Emys* A. Duméril, 1806. Zool. Abh. Mus. Tierkd. Dresden **48**: 243–264.

FRITZ, U. 2001. *Emys orbicularis* (Linnaeus, 1758) – Europäische Sumpfschildkröte, pp. 343–515. In: FRITZ, U. (ed.) Handbuch der Reptilien und Amphibien Europas, Band 3/IIIA: Schildkröten I, Aula, Wiebelsheim.

FRITZ, U. 2003. Die Europäische Sumpfschildkröte. Laurenti, Bielefeld, 224 pp.

FRITZ, U., KELLER, C. & BUDDE, M. 1996. Eine neue Unterart der Europäischen Sumpfschildkröte aus Südwestspanien, *Emys orbicularis hispanica* subsp. nov. Salamandra **32**: 129–152.

GALÁN, P. 1999. Conservación de la Herpetofauna Gallega. Universidade da Coruña, A Coruña, 286 pp.

GARBER, S. D. & BURGER, J. 1995. A 20-yr study documenting the relationship between turtle decline and human recreation. Ecol. Appl. **5**: 1151–1162.

GARIBOLDI, A. & ZUFFI, M. A. L. 1994. Notes on the population reinforcement project for *Emys orbicularis* (LINNAEUS, 1758) in a natural park of northwestern Italy. Herpetozoa **7**: 83–89.

GAY, S. & LEBRAUD, C. 1998. Some notes on the European pond turtle (*Emys orbicularis*) in Gard and Hérault, p. 297. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

GIBBONS, J. W. 1990. Sex ratios and their significance among turtle populations, pp. 171–182. In: GIBBONS, J. W. (ed.) Life History and Ecology of the Slider Turtle, Smithsonian Institution Press, Washington, D. C. and London.

GIBBONS, J. W., SCOTT, D. E., RYAN, T. J., BUHLMANN, K. A., TUBERVILLE, T. D., METTS, B. S., GREENE, J. L., MILLS, T., LEIDEN, Y., POPPY, S. & WINNE, C. T. 2000. The global decline of reptiles, dejà vu amphibians. BioScience **50**: 653–666.

GIRONDOT, M., FOUILLET, H. & PIEAU, C. 1998. Feminizing turtle embryos as a conservation tool. Conserv. Biol. **12**: 353–362.

GIRONDOT, M. & PIEAU, C. 1993. Effects of sexual differences of age at maturity and survival on population sex ratio. Evol. Ecol. **7**: 645–650.

GÓMEZ-CANTARINO, A. & LIZANA, M. 2000. Distribución y uso del hábitat de los galápagos (*Mauremys leprosa* y *Emys orbicularis*) en la provincia de Salamanca. Bol. Asoc. Herpetol. Esp. **11**: 4–8.

GONZÁLEZ RODRÍGUEZ, M. O. 1999. Informe-resumen de los trabajos realizados con relación a la investigación de detalle de la contaminación por HCH en el entorno del polígono de Torneiros -O Porriño- (Pontevedra). Unpublished report available at http://www.xunta.es/conselle/cma/CMA04d/CMA04dh/p04dh03b.pdf

HANKA, S. & JOGER, U. 1998. *Emys orbicularis* in the Enkheimer Ried near Frankfurt/Main, Hesse, pp. 135–140. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

HEPPELL, S. S. & CROWDER, L. B. 1996. Models to evaluate headstarting as a management tool for long-lived turtles. Ecol. Appl. **6**: 556–565.

JABŁOŃSKI, A. & JABŁOŃSKA, S. 1998. Egg-laying in the European pond turtle, *Emys orbicularis* (L.), in Łęczyńsko-Włodawskie Lake District (East Poland), pp. 141–146. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

JACKSON, D. R. & WALKER, R. N. 1997. Reproduction in the Suwannee cooter, *Pseudemys concinna suwanniensis*. Bull. Florida Mus. Nat. Hist. **41**: 69–167.

KELLER, C. 1997. Ecología de poblaciones de *Mauremys leprosa* y *Emys orbicularis* en el Parque Nacional de Doñana. PhD Thesis, Univ. Sevilla, 197 pp.

KELLER, C., ANDREU, A. C. & RAMO, C. 1998. Aspects of the population structure of *Emys orbicularis hispanica* from southwestern Spain, pp. 147–158. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

KELLER, C. & ANDREU, A. C. 2002. *Emys orbicularis* (Linnaeus, 1758). Galápago europeo, pp. 181–186. In: Atlas y Libro Rojo de los Anfibios y Reptiles de España. Organismo Autónomo Parques Nacionales, Madrid.

KOTENKO, T. I. 2000. The European pond turtle (*Emys orbicularis*) in the steppe zone of the Ukraine, pp. 87–106. In: HÖDL, W. & RÖSSLER, M. (eds) Die Europäische Sumpfschildkröte, Stapfia **69**.

LEBRETON, J. D., BURNHAM, K. P., CLOBERT, J. & ANDERSON, D. R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecol. Monogr. **62**: 67–118.

LÓPEZ SEOANE, V. 1877. Reptiles y anfibios de Galicia. An. Soc. Esp. Hist. Natural. **6**: 349–358.

LUISELLI, L., CAPULA, M., CAPIZZI, D., FILIPPI, E., TRUJILLO, J. & ANIBALDI, C. 1997. Problems for conservation of pond turtles (*Emys orbicularis*) in Central Italy: is the introduced red-eared turtle (*Trachemys scripta*) a serious threat? Chelon. Conserv. Biol. **2**: 417–419.

MASCORT, R. 1998. Distribution and status of the European pond turtle, *Emys orbicularis*, in Catalonia, pp. 177–186. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

MAZZOTTI, S. 1995. Population structure of *Emys orbicularis* in the Bardello (Po Delta, Northern Italy). Amphibia-Reptilia **16**: 77–85.

MILLER, P. S. & LACY, R. C. 2003. VORTEX: A stochastic simulation of the extinction process. User's Manual. Apple Valley, MN, Conservation Breeding Specialist Group (SSC/IUCN), 174 pp.

MITRUS, S. 2000. Protection of the European pond turtle *Emys orbicularis* (L.) in Poland, pp. 119–126. In: HÖDL, W. & RÖSSLER, M. (eds) Die Europäische Sumpfschildkröte, Stapfia **69**.

NAULLEAU, G. 1991. Adaptations écologiques d'une population de cistudes (*Emys orbicularis* L.) (Reptilia, Chelonii) aux grandes variations de niveau d'eau et á l'assèchement naturel du milieu aquatique fréquenté. Bull. Soc. Herpétol. Fr. **58**: 11–19.

NEMOZ, N., CADI, A. & THIENPOT, S. 2002. Has fishing an effect on the survival of *Emys orbicularis*? pp. 36–37. In: Programme and Abstracts, 3rd International Symposium on *Emys orbicularis*, 18–20 April 2002, Košice.

PARDE, J.-M., HURSTEL, S. & LEFÈVRE, A.-C. 2000. Etude éco-éthologique de la Cistude d'Europe dans le Bas-Armagnac (Gers, France), en vue de sa conservation, pp. 73–82. In: Proceedings of the 2nd International Symposium on *Emys orbicularis*, Chelonii **2**.

PARDO, I. 1994. Comparative water quality characterization by PCA of an unperturbed and a polluted stream. Arch. Hydrobiol. **132**: 95–114.

PIEAU, C. 1998. Temperature-dependent sex determination in *Emys orbicularis*: laboratory and field studies, pp. 199–207. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

ROOSENBURG, W. M., CRESKO, W., MODESITTE, M. & ROBBINS, M. B. 1997. Diamondback terrapin (*Malaclemys terrapin*) mortality in crab pots. Conserv. Biol. **11**: 1166–1172.

RÖSSLER, M. 1999. Populationsökologische Untersuchung von *Emys orbicularis* (LINNAEUS, 1758) in den österreichischen Donau-Auen. Faunist. Abh. Mus. Tierkd. Dresden **21**: 283–304.

ROVERO, F. & CHELAZZI, G. 1996. Nesting migrations in a population of the European pond turtle *Emys orbicularis* (L.) (Chelonia Emydidae) from central Italy. Ethol. Ecol. Evol. **8**: 297–304.

SCHLEICH, H. H. & BÖHME, W. 1994. Kupferzeitliche Schildkrötenreste aus der Grabung von Durankulak bei Tolbuchin in NO-Bulgarien (Reptilia: Testudines: *Testudo graeca*, *Emys orbicularis*). Mitt. Bayer. Staatsslg. Paläont. hist. Geol. **34**: 199–211.

SCHNEEWEISS, N. 1998. Status and protection of the European pond turtle (*Emys o. orbicularis*) in Brandenburg, Northeast Germany, pp. 219–226. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

SCHNEEWEISS, N. & FRITZ, U. 2000. Situation, Gefährdung und Schutz von *Emys orbicularis* (L.) in Deutschland, pp. 133–144. In: HÖDL, W. & RÖSSLER, M. (eds) Die Europäische Sumpfschildkröte, Stapfia **69**.

SERVAN, J. 1998. Ecological study of *Emys orbicularis* in Brenne (Central France), pp. 245–252. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

SHINE, R. & IVERSON, J. B. 1995. Patterns of survival, growth and maturation in turtles. Oikos **72**: 343–348.

SNIESHKUS, E. 1993. The possibilities of reacclimatisation of pond turtles (*Emys orbicularis*, Emydidae, Testudines). Atti Soc. It. Sci. Nat. Mus. Civ. Storia Nat. Milano **134**: 131–134.

SNIESHKUS, E. 1998. Some observations on secondary sexual characteristics, sex ratio, and reproductive aspects of European pond turtles, *Emys orbicularis* (LINNAEUS, 1758) in the former USSR, pp. 253–258. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

SUTHERLAND, W. J. 2000. The Conservation Handbook: Research, Management and Policy. Blackwell Science, Oxford, 278 pp.

SHCHERBAK [SZCZERBAK], N. N. 1998. The European pond turtle (*Emys orbicularis*) in Ukraine, pp. 259–266. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

TAŞKAVAK, E. & REIMANN, M. J. 1998. The present status of *Emys orbicularis* (LINNAEUS, 1758) in southern Central Anatolia, pp. 267–278. In: FRITZ, U., JOGER, U., PODLOUCKY, R. & SERVAN, J. (eds) Proceedings of the EMYS Symposium Dresden 96, Mertensiella **10**.

VOGT, R. C. 1994. Temperature controlled sex determination as a tool for turtle conservation. Chelon. Conserv. Biol. **1**: 159–162.

WYMAN, R. L. 1990. What's happening to the amphibians? Conserv. Biol. **4**: 350–352.

ZUFFI, M. A. L., ODETTI, F. & MEOZZI, P. 1999. Body size and clutch size in the European pond turtle (*Emys orbicularis*) from central Italy. J. Zool. Lond. **247**: 139–143.