Distribution, natural history and morphometrics of the critically endangered *Coluber hippocrepis* populations of Sardinia: a review, with additional data and conservation implications

Claudia Corti[1], Luca Luiselli[2], Ernesto Filippi[3], Massimo Capula[4]

[1] Dipartimento di Biologia Animale e Genetica, Università degli Studi di Firenze, via Romana 17, I-50125 Firenze, Italia
e-mail: claudia.corti@unifi.it
[2] Centro di Studi Ambientali "Demetra", via dei Cochi 48/B, I-00133 Roma, Italia; and F.I.Z.V., via Cleonia 30, I-00152 Roma, Italia; and Museo Civico di Storia Naturale, piazza Aristide Frezza 6, I-00030 Capranica Prenestina, Roma, Italia
e-mail: lucalui@iol.it
[3] via Gabrio Casati 43, I-00139 Roma, Italia
e-mail: e.filippi@iol.it
[4] Museo Civico di Zoologia, Sezione di Erpetologia, via Ulisse Aldrovandi 20, I-00197 Roma, Italia
e-mail: m.capula@comune.roma.it

Abstract. The horseshoe snake (*Coluber hippocrepis*) is one of the most threatened Italian snakes, especially in Sardinia where its present occurrence was unclear. This paper reviews the current distribution of *C. hippocrepis* in Sardinia, and confirms that this species is still found in a limited number of sites of Cagliari province. Its actual presence in Oristano province, on the contrary, is still in doubt. Statistical analyses on several morphometric measurements taken from museum specimens suggest that snakes from the central Mediterranean area (Sardinia, Pantelleria, and Tunisia) are distinguished from those of the western Mediterranean area (Portugal and Morocco) by having significantly higher numbers of ventrals. A few natural-history notes on Sardinian specimens are presented, and a rationale for an urgent conservation plan is given.

Introduction

The snake fauna of Sardinia island (Mediterranean Sea) is quite depauperate in terms of specific diversity (Bruno and Maugeri, 1990; Poggesi et al., 1995). Nevertheless, Sardinia houses two species of snakes of the genus *Coluber*, the western whip snake *Coluber* (*Hierophis*) *viridiflavus*, and the horseshoe snake *Coluber* (*Haemorrhois*) *hippocrepis*,

which are normally allopatric in other European regions (Bruno and Maugeri, 1990; Schätti, 1993).

This coexistence of two *Coluber* species is relevant both in ecological and conservation terms. In ecological terms, it deserves attention because of the presence of all the basic conditions for strong interspecific competition, as both these potential competitors are large predators, phylogenetically related, similarly sized (up to 2 m long, Bruno and Maugeri, 1990), terrestrial and good climbers, prey-limited, and with similar natural history traits (Bruno and Maugeri, 1990; Schätti, 1993). In terms of conservation, this case of coexistence is also important as one of the two species, *C. hippocrepis*, is critically endangered in Italy (Filippi and Luiselli, 2000), where, according to some authorities, it was passively introduced during the historical age (Lanza, 1983; Gruber, 1989). In Italy, *C. hippocrepis* is nowadays known from only a limited number of sites in Sardinia and in Pantelleria island (Bruno and Maugeri, 1990). However, although it has been officially protected by law since 1982 in the whole Italian range (Berne Convention), up to now nothing has been done to functionally protect its remnant populations.

With regard to Sardinian *C. hippocrepis*, in this report we offer:

(1) a review of its present distribution, with an emphasis on its potential distribution in relation to the species-specific ecological characteristics and to the concurrent presence of *C. viridiflavus*;
(2) a preliminary morphometric analysis;
(3) a preliminary survey of its natural history;
(4) a concise definition of the guidelines of an immediate working project which is thought to be essential for saving it.

Materials and methods

This study is based on both literature and original data, collected mainly from museum specimens but also from free-ranging individuals. Bibliographic research was conducted over several hundreds of contributions concerning the Sardinian herpetofauna (in part summarized by Poggesi et al., 1995), and was devoted mainly to collate any reliable distribution records and natural history information of *C. hippocrepis* in Sardinia.

Detailed morphometric data on Sardinian *C. hippocrepis* are not available in the literature, given also the extreme rarity of such specimens in worldwide museum collections (see also Schätti, 1986). Thus, we measured all the specimens in the collections of the Zoological Museum "La Specola", Florence (MZUF), which is likely to store the highest number of Sardinian specimens available in the world's public collections. The examined specimens were labelled as follows: MZUF 446, MZUF 2924 (both from Morocco), MZUF 29056, MZUF 28855, MZUF 29057 (all from Portugal), MZUF 7984, MZUF 7985, MZUF 7884, MZUF 7885, MZUF 7886, MZUF 7887, MZUF 7888 (all from Sardinia), MZUF 19533, MZUF 35543, MZUF 35094, MZUF 7998, MZUF 7997, MZUF 7996, MZUF 7999 (all

from Pantelleria Island), MZUF 2626, MZUF 2628 (both from Tunisia). Every specimen was measured to snout-vent-length (SVL, to ± 0.5 cm), tail length (tL, to ± 0.1 cm), head length (HL, to ± 0.1 cm), head width (HW, to ± 0.1 cm), interorbital length (INT-ORB, to ± 0.1 cm), and number of ventrals. Tails of several specimens were broken (a common event also in free-ranging *C. hippocrepis*, see Capula et al., 1997), and thus tail length was removed from any analyses.

Field research was conducted throughout several discrete survey periods (March and August from 1983 to 1986, April 1990, April and June 1992, March, April, and June 1993, October 1996, May 1998, March, October, and November 1999), devoted to study the reptile ecology in areas potentially inhabited by *C. hippocrepis* (Capula and Luiselli, 1994; Poggesi et al., 1995).

Statistical analyses were done by using SPSS for Windows PC package, with alpha set at 5% and all tests being two tailed.

Results and discussion

Distribution in Sardinia

Satellite islets. *Coluber hippocrepis* is known only from Isola di San Pietro (Poggesi et al., 1995), where it was originally collected by Stefani (1971). In this islet, it was found multiple times during recent years (G. Serra, in Poggesi et al., 1995), but never by other searchers (Bruno and Maugeri, 1990; Entomosarda s.n.c., 1993; Societas Herpetologica Italica, 1996; Corti et al., unpublished). According to Bruno and Maugeri (1990), the reliability of this record is doubtful. Isola di San Pietro is inhabited by *C. viridiflavus* (Entomosarda s.n.c., 1993; Poggesi et al., 1995; Societas Herpetologica Italica, 1996).

Mainland Sardinia. *Coluber hippocrepis* was known to occur in southwestern Sardinia a long time ago (Gené, 1834, 1839; Camerano, 1891), but was thought to be extinct by Mertens and Wermuth (1960). However, Bruno and Hotz (1976) rediscovered *C. hippocrepis* in sixteen localities situated between Cagliari and Oristano, and confirmed that it inhabited primarily coastal sites with ponds, water bodies, and lagoons (see also Gené, 1834). A few mountain sites in central Sardinia were recorded.

More recently, the distribution of *C. hippocrepis* in Sardinia remained a dispute. Puddu et al. (1988) stated *C. hippocrepis* to be present in coastal southwestern Sardinia, but seemed to roughly follow Bruno and Hotz's (1976) data. Bruno and Maugeri (1990) confirmed its presence in some of the sites where it was observed previously (Bruno and Hotz, 1976). Lanza (1993) did not account *C. hippocrepis* as a species of Sardinia, but failed to express any reliable reason for this deletion. Also Societas Herpetologica Italica (1996) was not able to report its presence in any Sardinian locality after the year 1982. However, the species was certainly found in the early 90's in at least nine different areas of the province of Cagliari (Entomosarda s.n.c., 1993).

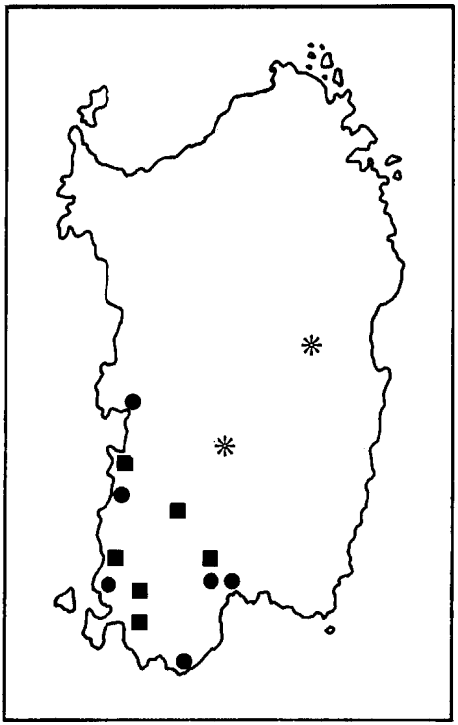

Figure 1. Current distribution of *C. hippocrepis* in Sardinia. Black squares indicate recent records (years 1990 to 1999, data from Entomosarda s.n.c., 1993), black circles indicate old records still to be confirmed (Bruno and Hotz, 1976), and asterisks indicate old records from mountainous sites which are considered unreliable by the present study.

For practical reasons, it seems better to examine separately the three main areas of this species' supposed distribution, i.e. (i) the province of Oristano, (ii) the province of Cagliari, and (iii) the internal mountainous sites of central Sardinia. The recent records (after 1990) of *C. hippocrepis* in Sardinia are presented in figure 1, and compared with old distribution records.

Province of Oristano. *Coluber hippocrepis* is known from coastal lakes and ponds in the surroundings of Oristano (Stagno di Cabras, Stagno di Sale Porcus, Stagno di Pauli Maiori, see Bruno and Hotz, 1976; Bruno and Maugeri, 1990; Schätti, 1993), where it was discovered a long time ago (Gené, 1834). No vouchers from this area are stored in MZUF. Moreover, we were unable to find any specimen on Oristano area, neither are we aware of any recent record. However, *C. hippocrepis* was recently captured in the surroundings of S. Antonio di Santadi (Entomosarda s.n.c., 1993), a town which, although belonging to the province of Cagliari, is situated in the southern part of the Gulf of Oristano.

Province of Cagliari. The knowledge of its distribution in the province of Cagliari is better (fig. 1). If we compare data presented by Bruno and Hotz (1976) with those of Entomosarda s.n.c. (1993), a remarkable similarity in the local distribution patterns could be observed. *C. hippocrepis* was found in 9.8% of the "Unità Cartografiche di Base" (total $n = 92$) of the province of Cagliari, and the sites of capture were situated along the coast (e.g. surroundings of Cagliari) as well as in the inner territories (e.g. Villacidro), and on both flat areas and in the Sulcis-Iglesiente massif (fig. 1; Entomosarda s.n.c., 1993). In every site of ascertained presence of *C. hippocrepis*, *C. viridiflavus* was also found (Entomosarda s.n.c., 1993). During October 1999, two *C. hippocrepis* (an adult male and a juvenile, both of them with blood sampled for future analyses) were captured by one of us (MC) in the surroundings of Cagliari (Elmas), thus definitely confirming Bruno's view that *C. hippocrepis* is still present in Sardinia.

Internal mountainous sites of central Sardinia. Up to now, *C. hippocrepis* was known from a few sites: Giara di Gesturi and Fonni, both in the province of Nuoro (Bruno and Hotz, 1976). The latter locality was considered unreliable by some authorities (Bruno, 1977; Bruno and Maugeri, 1990), but not by Schätti (1993) because of the existence of a voucher (MZUF 7985 — Conte Ugolino Martelli legit, 16. VIII. 1894; this specimen was also examined by us). Two of us (MC and LL) and their associates surveyed carefully both these areas (e.g. Capula and Luiselli, 1994), but did not find any *C. hippocrepis*. Thus, we are led to agree with Bruno (1977) that these localities of capture are unreliable, or that, at least, the species is actually extinct there.

It is noteworthy that *C. hippocrepis* is known for most sites with single individuals, which suggests a very low population density at each site (Bruno and Maugeri, 1990).

Morphometry

A total of 21 *C. hippocrepis* was examined (see table 1 for summarized morphometric measurements). Since SVL was significantly correlated with tL, HL, HW, and INT-ORB (in all cases at least $r > 0.87, P < 0.0001$), residual scores from the general regressions of

Table 1. Summary of the morphometric and meristic characteristics of 21 specimens of *Coluber hippocrepis* stored in the collections of the "Museo Zoologico La Specola", Florence. Tail length is not presented because several specimens had broken tail. All measures are expressed in mm. Symbols: MR = Morocco, PO = Portugal, SA = Sardinia, PT = Pantelleria, TU = Tunisia; SVL = snout-vent length, HL = head length, HW = head width, INT-ORB = interorbital length, VTR = numbers of ventrals.

Parameter	MR ($n = 2$) $\bar{x} \pm s$	PO ($n = 3$) $\bar{x} \pm s$	SA ($n = 7$) $\bar{x} \pm s$	PT ($n = 7$) $\bar{x} \pm s$	TU ($n = 2$) $\bar{x} \pm s$
SVL	93.5 ± 30.4	68.6 ± 24.5	69.1 ± 30.5	86.2 ± 16.4	94.0 ± 56.6
HL	2.4 ± 0.7	1.9 ± 0.5	2.0 ± 0.6	2.4 ± 0.3	2.5 ± 0.0
HW	1.8 ± 0.4	1.5 ± 0.4	1.8 ± 0.6	1.9 ± 0.3	1.9 ± 0.1
INT-ORB	1.1 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	1.1 ± 0.0	1.0 ± 0.2
VTR	223.0 ± 0.0	231.3 ± 2.9	236.1 ± 4.6	237.8 ± 4.9	234.5 ± 4.9

these parameters to SVL were used to test for size-corrected intergroup differences. Once SVL was taken into account, the various populational groups (Portugal, Morocco, Tunisia, Sardinia, and Pantelleria) did not differ significantly in any of the examined parameters (MANOVA, $F_{4,16} = 1.079$, $P = 0.279$). SVL was not correlated with the number of ventrals ($r = 0.190$, adjusted $r^2 = -0.014$, ANOVA $F_{1,19} = 0.716$, $P > 0.4$), and sexes did not differ in terms of numbers of ventrals ($P > 0.4$, Student t-test). The various populational groups differed significantly in terms of numbers of ventrals (ANOVA, $F_{4,16} = 5.044$, $P = 0.0079$), and unequal sample Tukey HSD post-hoc test indicated that specimens from Pantelleria, Sardinia, and Tunisia had significantly higher numbers of ventrals than specimens from Portugal and Morocco. These data suggest that specimens from central Mediterranean area (Sardinia, Pantelleria, and Tunisia) are distinguished from those of western Mediterranean area (Portugal and Morocco). A much larger sample of both sexes is required to confirm this preliminary evidence, also in consideration of the fact that, contrary to our limited central Mediterranean sample, in Iberian specimens the females had higher numbers of ventrals than males (Feriche et al., 1993).

Natural history

Data on Sardinian *C. hippocrepis* are extremely scanty, and, in practice, we can only avail ourselves of the few comments by Bruno and Hotz (1976), Bruno (1977, 1984) and Bruno and Maugeri (1990). According to these sources, these snakes inhabit only coastal lagoons and ponds, where they feed upon frogs, lizards, and rodents. However, all this information is anecdotal, and quantitative data are not presented. According to Bruno (1977, 1984), and Bruno and Maugeri (1990), the reasons of this unusual habitat use should be (i) the claimed competition with *C. viridiflavus* constraining *C. hippocrepis* to refuge into quite inhospitable sites, and/or (ii) the claimed passive introduction of this species in Sardinia (Lanza, 1983), which was thus constrained to colonize suboptimal habitats.

Based on original data (from both museum vouchers and free-ranging specimens), information from local zoologists, and data from Entomosarda s.n.c. (1993), it appears that Sardinian *C. hippocrepis* inhabit not only ponds and coastal lagoons, but also dry sites with evergreen Mediterranean maquis and sandy soil along the coasts, and rocky and stony areas with scattered spiny vegetation in the hills of Iglesiente-Sulcis massif. The fact that this species is also observed around ponds and coastal lagoons does not imply necessarily that it shows unusual habitat preferences in Sardinia, as previously supposed (Bruno and Hotz, 1976). In fact, we think that these snakes, being quite sensible to habitat alteration, could become extinct in dry sites which are strongly altered by human activities (industry, agricultural practices, and tourism), but persist in "natural refuges" around water bodies, where also many other rare vertebrates (e.g. birds) tend to concentrate.

Two specimens had three undetermined murid rodents in the guts, thus suggesting a rodent-based diet for these animals. This is in agreement with data available from *C. hippocrepis* of Pantelleria (Capula et al., 1997) and Spain (Pleguezuelos and Moreno, 1990).

Conclusion and a conservation project rationale

From all this evidence, it is clear that Sardinian *C. hippocrepis* should be regarded among the most critically endangered snakes of Europe, and thus requires an immediate conservation project by the pertinent authorities. We suggest that this project should work throughout some major phases of conservation oriented research that could be summarized as follows:

(1) evaluation of the macroecological determinants of its local distribution in Sardinia, by recording vegetation and landscape characteristics of a large amount of sites (with known *C. hippocrepis* presence or absence) within its potential range, and then applying a rigorous predictive statistical model (logistic regression, see Hosmer and Lemeshow, 1989) on these sites, to predict which macroenvironmental parameters may influence its presence/absence (Luiselli and Angelici, 2000; Luiselli et al., 2000).

(2) evaluation of the microecological determinants of its local distribution in Sardinia, by radiotracking some wild specimens, and thus defining their activity patterns and microhabitat selection in a conservation perspective (Nilson et al., 1999; Angelici et al., 2000).

(3) evaluation of the genetic divergence of Sardinian populations from conspecifics from elsewhere, by applying molecular techniques to blood samples of free-ranging individuals (Lenk and Joger, 1994; Lenk et al., 1999).

(4) evaluation of its extinction probability in Sardinia, by applying stochastic models already used for predicting amphibian populations decline.

After having collected solid data for points (1) and (2), it will arguably be possible to identify priority areas to be protected, as already suggested for other threatened populations of European snakes (Corbett, 1989; Nilson et al., 1999). Moreover, the collection of solid data on point (3) will permit to recognize whether snake specimens from elsewhere could be used to "import new blood" to the Sardinian populations. We have already started to collect such data, but require that the Societas Europaea Herpetologica will act as soon as possible towards the Italian government and the Sardinian authorities in order to effectively preserve the remnant populations of Sardinian *C. hippocrepis*.

Acknowledgements. We are gratefully indebted to M. Poggesi (MZUF), who permitted examination of specimens stored in the collections under her care, and to L. Rugiero, G. Paoloni, D. Persichetti, and F.M. Angelici who co-worked in the field. F.M. Angelici, D. Capizzi, G. Gollmann, C. Jäggi, L. Rugiero, and an anonymous referee critically commented on previous drafts.

Note added in proof

A recent record of a probable *Coluber hippocrepis* was communicated to one of the authors (CC, who is the responsible for Sardinia of the "Atlas of Amphibians and Reptiles of

Italy" in prep. and edited by the Societas Herpetologica Italica) for a northern locality of the island, characterised by a wet environment.

References

Angelici, F.M., Inyang, M.A., Effah, C., Luiselli, L. (2000): Analysis of activity patterns and habitat use of radiotracked African burrowing pythons, *Calabaria reinhardtii.* Isr. J. Zool. **46**: in press.

Bruno, S. (1977): Rettili d'Italia: Serpenti. Florence, Aldo Martello Editore.

Bruno, S. (1984): Guida ai Serpenti d'Italia. Florence, Giunti Martello.

Bruno, S., Hotz, H. (1976): *Coluber hippocrepis* auf der Insel Sardinien. Salamandra **12**: 69-86.

Bruno, S., Maugeri, S. (1990): Serpenti d'Italia e d'Europa. Milan, Editoriale Giorgio Mondadori.

Camerano, L. (1891): Monografia degli Ofidi italiani — Parte seconda: Colubridi e Monografia dei Cheloni italiani. Mem. r. Accad. Sci. Torino **41**: 403-480.

Capula, M., Luiselli, L. (1994): Resource partitioning in a Mediterranean lizard community. Boll. Zool. **61**: 173-177.

Capula, M., Luiselli, L., Rugiero, L., Evangelisti, F., Anibaldi, C., Trujillo Jesus, V. (1997): Notes on the food habits of *Coluber hippocrepis nigrescens* from Pantelleria Island: a snake that feeds on both carrion and living prey. Herpetol. J. **7**: 67-70.

Corbett, K. (1989): Conservation of European Reptiles and Amphibians. London, Cristopher Helm.

Entomosarda s.n.c. (1993): Anfibi e Rettili. In: Atlante Faunistico della Provincia di Cagliari (Autori Vari, Eds). Assessorato Tutela e Ambiente, Provincia di Cagliari, Cagliari.

Feriche, M., Pleguezuelos, J.M., Cerros, A. (1993): Sexual dimorphism and sexing of Mediterranean colubrids based on external characteristics. J. Herpetol. **27**: 357-362.

Filippi, E., Luiselli, L. (2000): Status of the Italian snake-fauna and assessment of conservation threats. Biol. Conserv. **93**: 219-225.

Gené, J. (1834): Description d'un reptile mal connu et d'un poisson nouveau. Mem. regia Accad. Sci. Torino **1, 37**: 299-305.

Gené, J. (1839): Synopsis reptilium Sardinae indigenorum. Mem. regia Accad. Sci. Torino **2, 1**: 1-31.

Gruber, U. (1989): Die Schlangen Europas. Stuttgart, Kosmos Naturfuehrer.

Hosmer, D.W., Lemeshow, S. (1989): Applied Logistic Regression. New York, Wiley & Sons.

Lanza, B. (1983): Ipotesi sulle origini del popolamento erpetologico della Sardegna. Lavori Soc. it. Biogeogr. **8** (1980): 723-744.

Lanza, B. (1993): Anfibi e Rettili. In: Vertebrata — Checklist delle specie della fauna italiana. Minelli, A., Ruffo, S., La Posta, S., Eds, Bologna, Calderini.

Lenk, P., Herrmann, H.-W., Joger, U., Wink, M. (1999): Phylogeny and taxonomic subdivision of *Bitis* (Reptilia: Viperidae) based on molecular evidence. Kaupia **8**: 31-38.

Lenk, P., Joger, U. (1994): Genetic relationships between populations and intraspecific subdivision of *Elaphe longissima* (Laurenti, 1768) as suggested by plasma protein electrophoresis and DNA fingerprinting. Amphibia-Reptilia **15**: 363-373.

Luiselli, L., Angelici, F.M. (2000): Ecological relationships in two Afrotropical cobra species (*Naja melanoleuca* and *Naja nigricollis*). Canad. J. Zool. **78**: 191-198.

Luiselli, L., Angelici, F.M., Akani, G.C. (2000): Large elapids and arboreality: The ecology of Jameson's green mamba, *Dendroaspis jamesoni*, in an Afrotropical forested region. Contrib. Zool. **69**: in press.

Mertens, R., Wermuth, H. (1960): Die Amphibien und Reptilien Europas. Frankfurt am Main, Kramer.

Nilson, G., Andrén, C., Ioannidis, Y., Dimaki, M. (1999): Ecology and conservation of the Milos viper, *Macrovipera schweizeri* (Werner, 1935). Amphibia-Reptilia **20**: 355-375.

Pleguezuelos, J.M., Moreno, M. (1990): Alimentación de *Coluber hippocrepis* en el SE de la peninsula Ibérica. Amphibia-Reptilia **11**: 325-337.

Poggesi, M., Agnelli, P., Borri, M., Corti, C., Finotello, P.L., Lanza, B., Tosini, G. (1995): Erpetologia delle isole circumsarde. Biogeographia **18**: 583-618.

Puddu, F., Viarengo, M., Erminio, C. (1988): Animali di Sardegna: gli Anfibi e i Rettili. Cagliari, Edizioni Della Torre.

Schätti, B. (1986): Morphologie und Systematik von *Coluber algirus* und *C. hippocrepis* (Reptilia: Colubridae). Bonn. Zool. Beitr. **37**: 281-293.

Schätti, B. (1993): *Coluber hippocrepis* (Linnaeus, 1758) — Hufeisennatter. In: Handbuch der Reptilien und Amphibien Europas, Band III/1. Schlangen (Serpentes), p. 115-130. Boehme, W., Ed., Wiesbaden, Aula Verlag.

Societas Herpetologica Italica (1996): Atlante provvisorio degli anfibi e dei rettili italiani. Ann. Mus. Civ. St. Nat. "G. Doria" **91**: 95-178.

Stefani, R. (1971): Ricerche zoologiche e botaniche nelle isole sarde di S.E. e S.O. In: Relazione preliminare delle ricerche sulle popolazioni insulari compiute nel triennio 1965-1968 (Pasquini, P., Ed.). Quaderni de "la Ricerca Scientifica", C.N.R., Roma **73**: 30-36.

Received: November 10, 1999. Accepted: January 7, 2000.