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The Italian batrachofauna and its conservation status: a statistical assessment

Franco Andreone [a], Luca Luiselli [b,c,*]

[a]Laboratory of Vertebrate Taxonomy and Ecology, Museo Regionale di Scienze Naturali, Via Giovanni Giolitti, 36, I-10123 Turin, Italy
[b]FIZV, via Olona, 7, I-00198 Rome, Italy
[c]Environmental Studies Centre "DEMETRA", Via dei Cochi, 48/B, I-00133 Rome, Italy; and Museo Civico di Storia Narurale, Piazza Aristide Frezza, 6, I-00030 Capranica Premestina, Rome, Italy

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Abstract

The status of the Italian autochtonous batrachofauna has been analysed taking into consideration a set of 13 variables, ranging from natural history traits (e.g. type of reproduction, number of eggs, frequented habitat), to distribution and areal fragmentation, taxonomic uniqueness and insularity. Each variable was categorized into four ranks (0–3) of increasing risk for survival. Urodeles and anurans were treated separately for both univariate and multivariate analyses. The results confirm a general sensitivity of urodeles, although in many cases newts and salamanders may react more promptly to habitat alteration and human disturbance. On the other hand, the anurans, except for three species that are widely distributed and largely euryecious (*Bufo bufo, Rana temporaria, R. "esculenta"*), appear more sensitive than urodeles for a series of factors. Some anurans (such as *Pelobates fuscus insubricus* and *R. latastei*) are restricted to low altitude habitats (which are in general more subject to alteration), or are restricted to islands. Conservation actions should be applied for protecting *Salamandra lanzai, S. atra aurorae,* the Sardinian plethodontids (genus *Speleomantes*), and *Euproctus platycephalus*. For the anurans, the most endangered taxon appears to be *P. fuscus insubricus*, while some insular species such as *Discoglossus pictus, D. sardus*, and *Hyla sarda* should be carefully managed by the creation of protected areas.

Keywords: Amphibians; Conservation; Italy; Distribution; Ecology; Threats

1. Introduction

The conservation of amphibians and reptiles is a topic of particular interest, as stressed by the publication of several contributions and many international initiatives, including, for example, the publication of a specific text on the European species (Corbett, 1989), and their inclusion in the recent IUCN Red Data Books (Groombridge, 1993; Baillie and Groombridge, 1996). The contributions on the Italian batrachofauna are still at a preliminary phase, and we may cite the pioneering works by Bruno (1973, 1983), where merely qualitative considerations were given with a list of endemic taxa. Andreone (1995), Doria and Salvidio (1994), and Andreone and Fortina (1999) proposed some categorisations of the amphibian species in Piedmont and Aosta Valley (NW Italy), and actions for conserving the Italian spadefoot toad (*Pelobates fuscus insubricus*) were summarised by Andreone et al. (1993).

Indeed, amphibians deserve particular attention, since a large part of the European herpetofauna is threatened by the disappearance or the alteration of their habitats. In our opinion the incidence of illegal capture and trade, elsewhere important (e.g. for exotic species and, still today, for some Italian snakes: see Filippi and Luiselli, 2000), is not very high for the Italian amphibians (pers. observ.). Several species are clearly vulnerable, because of their distribution and natural-history traits and/or because they occupy marginal territories and/or because they are substantially philopatric. In fact, with the exception of some species of the genera *Triturus* (newts) and *Bufo* (toads), which make conspicuous migrations from and to their breeding sites, amphibians show limited locomotory capacities (e.g. Joly and Miaud, 1989).

* Corresponding author. Fax: +39-6-841-1964.
E-mail address: frand@tin.it; franco.andreone@regione.piemonte.it (F. Andreone), lucalui@iol.it; lucamlu@tin.it (L. Luiselli).

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For this reason they show a general low capacity to survive substantial environmental alteration. More than other vertebrates, amphibians are often considered good bio-indicators, since they have both an aquatic larval phase, and a terrestrial phase. In several areas of the World there is an evident decline of some populations or even the disappearance (perhaps extinction) of some species (such *Bufo periglenes* in Costa Rica, or *Rheobatrachus silus* in Queensland), without having clearly and definitely identified an evident and unique cause (Barinaga, 1990; Blaustein and Wake, 1990). The need for monitoring the trends of this demographic decrease and/or the extinctions of amphibians has been among the reasons for the creation of the DAPTF Declining Amphibian Population Task Force (DAPTF), which operates at an international level. A continuous monitoring of the populations is undoubtedly necessary to distinguish between natural fluctuations and anthropogenic influences (e.g. Pechmann et al., 1991). At the European level, little is known about the decline in autochtonous species (cf. Fog and Arntzen, 1997; Grossenbacher, 1997), even if the negative effect of direct anthropic activities has been repeatedly stressed.

It is often difficult to obtain data concerning the decrease in Italian amphibian populations, since historical data (badly needed; see Shaffer et al., 1998) are usually missing except for some geographical areas, e.g. Piedmont in NW Italy (Andreone and Sindaco, 1999). In this paper, following the methods used in a previous contribution on the Italian snakes (Filippi and Luiselli, 2000) we present a categorisation of the Italian batrachofauna basing our judgement upon the species' ecological constraints and distributions.

2. Materials and methods

2.1. Analysed factors and variables

As in our previous study (Filippi and Luiselli, 2000) we analysed a series of 13 independent variables. These were distributional (1, 8, 12, 13), demographic (2, 3, 6), ecological (4, 5, 7, 9, 10), and taxonomic (11). They are well known to influence the survival of amphibian populations (e.g. Andreone, 1995), and were each classified into four categories ranging from 0 least risk to 3 highest risk. Intermediate scores (i.e. scores 1.5 and 2.5) were sometimes used when an unequivocal assignation was not possible for a series of reasons. The categories were based on published average conditions for the various species, or on direct experience of the authors (see Tables 1 and 2). The rationale for the choice of some of these scores is given below.

1. *Distribution breadth of occupancy in Italy* (DB): 0 = present in > 50% of the country; 1 = present in 10–50%; 2 = present in 5–10%; 3 = present in < 5% of the country. Maps of distribution used for the various taxa were those of Societas Herpetologica Italica (1996).
2. *Reproductive mode* (RM): 0 = opportunistic taxon with several reproduction events throughout the active season; 1 = taxon with 2–3 reproductive events in each year; 2 = taxon with a single reproduction event in each year; 3 = taxon with long gestation (viviparous species), or long larval development within the eggs (direct developers). We assume that a taxon that breeds several times a year may recover more easily when habitats are altered.
3. *Eggs* (*offspring*) *number* (EN): 0 = > 200 eggs/newborns; 1 = 50–200; 2 = 10–50; 3 = < 10.
4. *Habitat breadth* (HB): based on occurrence in four climatic zones of Italy, viz. Mediterranean, mid-elevation Apennine mountains, Po Plain, Alpine zone (Accordi and Lupia Palmieri, 1986): 0 = species found in all four habitats; 1 = species found in three habitats; 2 = species found in two habitats; 3 = species found in a single habitat. This variable reflects a tendency towards an euryoecy of the species.
5. *Habits* (HT): categorised on the basis of the type of general phenology exhibited by amphibians in the wild; 0 = species with fossorial–nocturnal or aquatic activity; 1 = species with above ground–nocturnal activity; 2 = species with diurnal secretive activity; 3 = species with diurnal and obvious above ground activity. This variable appears less intuitive, but we assume that secretive species are in general less subject to a series of direct disturbances, such as predation or collection for food, pets, etc.
6. *Maximum age* (MA), from skeletochronological studies and observations of animals kept in captivity: 0 = species with > 15 years of maximum age; 1 = species with 11–15 years of maximum age; 2 = species with 6–10 years of maximum age; 3 = species with 1–5 years of maximum age.
7. *Adaptability to altered environments* (AH): categorized on the basis of the personal experience of the authors (years 1975–1999), and/or data available in literature; 0 = species extremely adaptable (found even in urban centres); 1 = species adaptable (found also in suburbia if small natural fields are available); 2 = species scarcely adaptable [found at best in average sized (≅50 ha) natural woodlands]; 3 = species virtually unadaptable (found only in large patches of well preserved natural habitat).
8. *Endemicity* (E): 0 = 0–10% of the whole taxon distribution occurs in Italy; 1 = 10–50%; 2 = 50–80%; 3 = only in Italy and Italian islands.
9. *Elevational distribution* (ED): 0 = ubiquitous; 1 = present only at high altitudes (> 1000 m);

Table 1
Literature sources used to define scores for thirteen threatening factors for various urodeles, with species abbreviations used in the figures[a,b,c]

Taxa and abbreviations		DB	RM	EN	HB	HT	MA	AH	E	ED	AHR	TU	I	AF
Proteidae														
Proteus anguinus	PROANG	33	22	22	22	22	22	*	15, 27	15, 22	22	15	15	34
Plethodontidae														
Speleomantes "genei"	SPEGEN	23, 33	23	22, 23	22	22	39	*	15, 27	15, 23	15, 23	15	15	34
Speleomantes "italicus"	SPEITA	23, 33	23	22, 23	22, *	22, *	39	*	15, 27	15, 23	15, 23	15	15	34
Salamandridae														
Euproctus platycephalus	EUPPLA	33	22	22	22, 36	22, 36	36	36, *	15, 27	15, 22	22	15	15	34
Salamandra a. atra	SALATR	33	9	*	9, *	9, *	*	*	15, 27	9, 15	9	15	15	34
Salamandra a. aurorae	SALAUR	9, 33	9	*	9, *	9, *	*	9, *	15, 27	9, 15	9	15	15	34
Salamandra lanzai	SALLAN	4, 33	4	*	4, 12, *	4, 12, *	4, 12, 25	4, 13, *	15, 27	4, 15, *	4, 15, *	4, 15	15	34
Salamandra salamandra	SALSAL	33	22	22	22	22	22, 30	27, *	15, 27	22	22	15	15	34
Salamandrina terdigitata	SALTER	33	22	15, 22	15, 22	15, 22	22	22	15, 27	15, 22	15, 22	15	15	34
Triturus a. alpestris	TRIALP	33	1, 2	1, 22	1, 2	1, 2	2, 3, 24	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	34
Triturus a. apuanus	TRIAPU	33	1, 2	1, 22	1, 2	1, 2	2, 3	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	34
Triturus a. inexpectatus	TRIINE	33	1, 2	1, 22	1, 2	1, 2	2, 3	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	34
Triturus carnifex	TRICAR	33	1, 22	22	22, *	22, *	10, 28	4, *	15, 27	22	22	15	27	34
Triturus italicus	TRIITA	33	22	22	22	22	38	22	15, 27	22	22	15	15, 27	34
Triturus v. meridionalis	TRIMER	33	22	22	22, *	22, *	22	4, *	15, 27	15, 22	22	15	15	34
Triturus v. vulgaris	TRIVUL	33	22	22, 27	22	22, 27	20, 35	27	15, 27	*	15, 22	15	15	34

[a] The term *Speleomantes "genei"* here includes all the Sardinian plethodontids (*Speleomantes genei, S. flavus, S. supramontis, S. imperialis*) pooled together, while *Speleomantes "italicus"* includes all the mainland species (and semi-species) (*S. strinatii, S. ambrosii, S. italicus*).

[b] Symbols: DB, distribution breadth of occupancy in Italy; RM, reproductive mode; EN, eggs (offspring) number; HB, habitat breadth; HT, habits; MA, maximum age; AH, adaptability to altered environments; E, endemicity; ED, elevational distribution; AHR, aquatic habitat (for reproduction); TU, taxonomic uniqueness; I, Insularity; AF, Areal Fragmentation.

[c] Literature cited: 1, Ambrogio and Gilli, 1998; 2, Andreone, 1990; 3, Andreone et al., 1996; 4, Andreone and Sindaco, 1999; 5, Andreone et al., 1993; 6, Augert and Joly, 1993; 7, Balletto and Giacoma, 1993; 8, Barbadillo Escriva, 1987; 9, Bonato, 1998; 10, Cavallotto et al., 1992; 11, Cavallotto et al., 1990; 12, Doglio et al., in press; 13, Francillon-Vieillot et al., 1990; 14, Fretey and Le Garff, 1996; 15, Gasc et al., 1997; 16, Gibbons and McCarthy, 1983; 17, Guarino et al., 1995a; 18, Guarino et al., 1995b; 19, Guarino and Mazzotti, 1999; 20, Hagström, 1977; 21, Hemelaar, 1988; 22, Lanza, 1983; 23, Lanza et al., 1995; 24, Miaud, 1992; 25, Miaud et al., 1997; 26, Neveu, 1992; 27, Nöllert and Nöllert, 1992; 28, Pagano et al., 1990; 29, Plytycz and Bigaj, 1993; 30, Rebelo and Caetano, 1995; 31, Ryser, 1988; 32, Ryser, 1996; 33, Societas Herpetologica Italica, 1996; 34, Sindaco, 2000; 35, Verrell and Francillon, 1986; 36, S. Bovero, pers. comm.; 37, N. Bressi, pers. comm.; 39, F. Guarino, pers. comm.; 40, B. Lanza, pers. comm.; * Authors' own experience.

2 = present on hills and reliefs up to 1000 m; 3 = restricted to planes (< 200 m elevation). Taxa living at low altitudes are more subject to a set of anthropogenic disturbance related to town construction, such as chemical, thermal, and organic pollution, road traffic, habitat alteration and destruction, and introduction of exotic species.

10. *Aquatic habitat* (*for reproduction*) (AHR): 0 = no free larval phase; 1 = taxon which utilises temporary water bodies; 2 = taxon which utilises permanent water bodies; 3 = taxon which utilises oxygenated water bodies or slow running streams.
11. *Taxonomic uniqueness* (TU): 0 = species (of a polytypic genus) with more than three clearly recognized subspecies; 1 = species (of a polytypic genus) with 1–3 clearly recognized subspecies; 2 = species monotypic of a polytypic genus; 3 = species of a monotypic genus. This variable gives more importance from a conservation point of view to taxa recognised as representing a monotypic genus, and so on.
12. *Insularity* (I): 0 = taxon with 100% of the distribution area on the mainland; 1 = taxon with distribution area > 50% on the mainland; 2 = taxon with distribution area < 50% on the mainland; 3 = taxon present only on islands. We assume that island taxa are generally more endangered and ecologically sensitive, since the insular environment may be more easily affected by alteration due to human activities. Although insularity is not ipso facto a cause of an animal being endangered or more vulnerable, by attributing numeric codes to insularity we wished to stress the "political" importance of taxa living on islands. Amphibian taxa living on Mediterranean islands are often endemic, and it is important to give them an additional value in terms of conservation, although in some cases (e.g. *Discoglossus sardus*, *Hyla sarda*) they show a wide ecological valence, and may occur almost everywhere in a given island.
13. *Area fragmentation* (AF): 0 = fragmentation < 20%; 1 = fragmentation 21–50%; 2 = fragmen-

Table 2
Literature sources used to define scores for thirteen threatening factors for various urodeles, with species abbreviations used in the figures[a]

Taxa and abbreviations		DB	RM	EN	HB	HT	MA	AH	E	ED	AHR	TU	I	AF
Pelobatidae														
Pelobates fuscus	PELFUS	33	5	5	5	5	*	5, *	5	5	5	4	33	34
Pelodytidae														
Pelodytes punctatus	PELPUN	33	22, *	22	22, *	22	22	*	15, 22, 27	22	22, *	4	33	34
Discoglossidae														
Bombina v. variegata	BOMVAR	33	22	22	22	22	29	*	15, 22, 27	22	22, *	15	33	34
Bombina v. pachypus	BOMPAC	33	22	22	22	22	17	*	15, 22, 27	22	22, *	15	33	34
Discoglossus pictus	DISPIC	33	22	22	22	22	22	*	15, 22, 27	22	22, *	15	33	34
Discoglossus sardus	DISSAR	33	22	22	22, *	22	22	*	15, 22, 27	22	22, *	15	33	34
Hylidae														
Hyla arborea	HYLARB	33	22	22	22	22	22	*	4, *	22	22, *	4	33	34
Hyla intermedia	HYLINT	33	22, *	22	*	*	22	*	4, *	22	22, *	4	33	34
Hyla meridionalis	HYLMER	33	22	22	22, 8	8, 22	22	*	15, 22, 27	22	22, *	15	33	34
Hyla sarda	HYLSAR	33	22	22	22, *	22	22	*	15, 22, 27	22	22, *	15	33	34
Bufonidae														
Bufo bufo	BUFBUF	33	22	22	22	22	21, 13, 14	*	15, 22, 27	22	22, *	4	33	34
Bufo viridis	BUFVIR	33	22	22	22	22	7, 11	*	15, 22, 27	22	22, *	4	33	34
Ranidae														
Rana dalmatina	RANDAL	33	22	22	22	22	7	*	15, 22, 27	22	22, *	4	33	34
Rana italica	RANITA	33	22	22	22	22	17, 18	*	15, 22, 27	22	22, *	4	33	34
Rana latastei	TANLAT	33	22	22	22, *	22	19	*	15, 22, 27	22	22, *	4	33	34
Rana temporaria	RANTEM	33	22	22	22, *	22	6, 16, 31, 32	*	15, 22, 27	22	22, *	4	33	34
Rana "esculenta"	RANESC	33	22	22	22, *	22	26	*	15, 22, 27	22	22, *	4	33	34
Rana ridibunda	RANRID	33	37	37	37	37	37	37	37	37	37	37	33, 37	34

[a] Number codes and factor abbreviations as in Table 1. *Rana "esculenta"* is used here to include all the autochtonous populations of green frogs (excepting for *R. ridibunda*).

tation 51–75%; 3 = fragmentation 76–100%. The fragmentation and consequent isolation of populations prevent biotic exchanges and therefore affect the population survivorship and diversity: the more habitat (and original species distribution area) is fragmented, the more the populations are isolated and subject to local extinctions. Area fragmentation is usually considered an important index of species vulnerability (IUCN, 1994). We evaluated the scores of areal fragmentation for each species by using the most up-to-date and theoretically oriented data available (Sindaco, 2000). These data are based on the species-specific outputs of a specific software that calculates, for each of the maps of Italy (scaled 1:100,000, "Quadranti") occupied by a given species, the numbers of adjacent maps (scaled 1:100,000) occupied by the same species, giving directly the relative area fragmentation scores.

The percent index of areal fragmentation is calculated as follows: $If = 100-[(\sum n\ V/n\ O)/n\ T)\ 100]$, where $n\ V$ is the number of maps adjacent to the one considered (range 0–8), $n\ O$ is the total number of maps occupied by the considered species, and $n\ T$ is the maximum theoric number of adjacent maps.

The scores used in this paper were finally attributed by dividing the index of area fragmentation reported in Sindaco (2000) by 10, and then approximating to unity. This methodology allows species that could appear very similar (e.g. *Salamandra atra aurorae* and *Proteus anguinus*) to score differently, in terms of area fragmentation.

2.2. Literature sources and taxonomy

Data here treated were derived mainly from literature sources, plus several original observations by the authors. For a few species where no data on Italian populations were available, we used data derived from other countries with climatic and environmental conditions comparable to those available for conspecifics in Italy.

We took into consideration 40 taxa occurring in mainland Italy and its islands. Our study is concerned only with autochtonous amphibian species. Thus, the taxa introduced into Italy, such as *Rana catesbeiana,* (Lanza and Ferri, 1997), and the populations nowadays widespread in a given part of Italy, where they were not originally present (e.g. *Rana* cf. *ridibunda* in Piedmont, see Andreone, 1999b), have not been included in the present study. From a conservation point of view these taxa should be eradicated, or, at least, limited in their colonisation process, taking in mind the concrete possibility of direct disturbance (such as predation on other species and competition for food resources in *R. catesbeiana*), or even the genetic pollution for the case of introduced green frogs of the *lessona-ridibunda-esculenta* synklepton, and *R. bergeri, Rana* kl. *hispanica* (e.g. Dubois, 1983; Arano et al., 1995).

We analysed species and some endemic subspecies, which, by their diagnostic characters, ecological differentiations and conservation importance, are considered as basic evolutionary units, corresponding to phylogenetic species (see Cracraft, 1983). The batrachofauna taxonomy follows in general Lanza (1983, 1993), and Andreone and Sindaco (1999), taking into account some recent taxonomic changes. We analysed the following subspecies: *Bombina variegata variegata* and *B. v. pachypus*, *Triturus alpestris alpestris, T. a. apuanus*, and *T. a. inexpectatus*, *T. vulgaris vulgaris* and *T. v. meridionalis*, *S. atra atra* and *S. a. aurorae*. We did not consider some "subspecies" which do not have a clear and separate distribution area, and may therefore be part of a cline, such as *S. salamandra salamandra* and *S. s. gigliolii*, *Bufo bufo bufo* and *B. b. spinosus*. Concerning the European cave salamanders we agree with the classification proposed by Lanza et al. (1995) who recognised six species (in Sardinia: *S. flavus, S. genei, S. supramontis, S. imperialis*; in continental Italy: *S. strinatii, S. italicus*), with a supplementary seventh taxon (*S. ambrosii*) for which the status of semi-species was suggested. Since their ecology is substantially similar, we treated them respectively under the name *S. "genei"* (including the four Sardinian species), and *S. "italicus"* (including the three mainland taxa). For these taxa the final values for each of the considered variables are a mean of the values estimated for each of the species.

Finally, the situation about the knowledge on the Italian green frogs is still in a state of confusion, although it is more or less accepted that in northern Italy mixed populations of *R. lessonae* and *R.* kl. *esculenta* occur, while in central and southern Italy there should be *Rana* kl. *hispanica* and *R. bergeri* (Andreone and Sindaco, 1999). Here, we prefer to treat all together these Italian green frogs, taking into consideration that their ecological requirements are more or less similar. For them we assign the operational name of *R. "esculenta"*.

2.3. Statistical procedures

Mean scores from independent variables were used to determine threat levels for each species of Italian amphibians. Given that scores 0 and 1 were always associated with least or moderate risk, and scores 2 and 3 with high or extremely high risk, it was stated that: (a) a mean score <1 indicates a species with no risk of decline, (b) a mean score $1< S>1.6$ indicates a species that is vulnerable to decline, and (c) a mean score >1.6 indicates a species seriously exposed to decline or even extinction.

Factor analysis [principal component analysis (PCA)] was used to classify the various amphibian species in terms of their similarity as to particular threats. We treated urodeles and anurans separately, since they exhibit major differences in terms of natural history traits and sensitiveness to habitat degradation. Standard VARIMAX rotation of the data (Focardi, 1993) was applied to the PCA model. Rank data matrix was log-transformed prior to apply any analysis, as PCA is devised to analyse continuous data-sets only. All data were analysed by a STATISTICA software package, with α set at 5%.

3. Results

3.1. Analysis of scores for individual variables in the various amphibian species

3.1.1. Urodeles

The scores for 13 variables for the 16 urodele taxa in Italy (including *Speleomantes* from Sardinia and mainland) are presented in Table 3. Mean score values ranged from 1.11 (*Triturus alpestris alpestris*) to >2.00 (e.g. *Salamandra atra aurorae* and *Euproctus platycephalus*). Most of the taxa (66.7%) had a mean score >1.50, which means that they could be considered at least as vulnerable. *T. a. alpestris* is one of the most adaptable urodeles in Europe, being widespread in many countries and in a wide set of habitats and at different altitudes (Nöllert and Nöllert, 1992). On the other hand, *E. platycephalus, S. atra aurorae* and *Salamandrina terdigitata* are endemics to Italy and therefore deserve particular attention, due to their limited distribution and peculiar reproductive characteristics (*S. a. aurorae* is viviparous). Interestingly also, *Speleomates "genei"* reaches a high score (2.00), which is largely because it is composed of four species all of which are restricted to Sardinia.

Moreover, mean scores per variable, calculated among the 16 urodele taxa (Table 2), show that several variables have very high scores (e.g. DB, RM, HB, AH, E), indicating that Italian urodeles are threatened by a wide range of factors, and that they are also very different in terms of ecological adaptations.

Plotting the mean values per species of ecological factor scores against the mean values per species of non-ecological factors, there was no significant relationships ($r=0.081$, $P>0.74$), which indicates that the ecological factors were in general completely independent from non-ecological factors in threatening the various urodeles of Italy.

3.1.2. Anurans

The variable scores relative to the 18 autochtonous taxa (including the green frogs of the *Rana esculenta* synklepton) in Italy are presented in Table 4. Mean

Table 3
Scores for the variables affecting survival of the Italian urodele fauna[a]

Taxon	DB	RM	EN	HB	HT	MA	AH	E	ED	AH	TU	I	AF	Mean Score
Triturus a. alpestris	1	2	1	1	0	1	2	1	2	1.5	0	0	2	1.11
Triturus a. apuanus	2	1	1	1	0	2	2	2	2	1.5	0	0	1	1.19
Triturus v. meridionalis	1	2	1	1	0	2	1	2	2	1.5	0	0	2	1.19
Triturus carnifex	1	2	1	1	0	1	1	2	2	1.5	2	0	2	1.27
Salamandra salamandra	1	3	2	2	1	0	2	0	2	3	0	0	1	1.31
Triturus v. vulgaris	3	2	1	3	0	2	3	0	2	1.5	0	0	1	1.42
Salamandra a. atra	2	3	3	3	1	1	2	1	1	0	1	0	1	1.46
Triturus italicus	1	2	1	2	0	2	2	3	2	1.5	2	0	2	1.57
Salamandra lanzai	3	3	3	3	1	0	3	2	1	0	2	0	0	1.61
Proteus anguinus	3	2	2	3	0	0	3	0	2	3	2.5	0	1	1.65
Triturus a. inexpectatus	3	1	1	3	0	2	3	3	2	1.5	0	0	2	1.65
Euproctus platycephalus	3	2	1	3	0	1	2	3	1.5	2	2	3	3	2.26
Speleomantes "italicus"	2	3	3	3	0	0	3	3	2	0	2	0	2	1.77
Speleomantes "genei"	3	3	3	3	0	0	3	3	2	0	2	3	1	2.00
Salamandra a. aurorae	3	3	3	3	1	1	3	3	3	0	1	0	3	2.08
Salamandrina terdigitata	1	2	2	3	1	2	3	3	2	3	3	0	3	2.15
Mean variable value	2.14	2.43	2.09	2.52	0.24	0.81	2.57	2.14	1.88	1.02	1.40	0.71	1.57	

[a] Abbreviations for the variables are as in Table 1.

Table 4
Scores for the variables affecting survival of the Italian anuran fauna[a]

Taxon	DB	RM	EN	HB	HT	MA	AH	E	ED	AH	TU	I	AF
Bufo bufo	0	2	0	0	1	2	0.5	1	0	1.5	1	0	2
Rana temporaria	1	2	0	0	1.5	2	2	0.5	0	1.5	1	0	1
Bufo viridis	1	2	0	1	1	2	0.5	1	2	1	2	1	2
Bombina v. variegata	2	1	2	3	2	0	2	1	2	1	1	0	1
Rana "esculenta"	0	0.5	0	1	3	3	0.5	1	2	2	2	1	2
Hyla arborea	3	1	1	3	1	2	0.5	0	3	1.5	1.5	0	1
Hyla intermedia	0	1	1	2	1	2	0.5	3	2.5	1.5	2	0	2
Rana dalmatina	1	2	0	2	1	2	2	1	2	1.5	2	0	2
Pelodytes punctatus	3	1	1	2	0	2	3	0	2	1	2	0	3
Hyla meridionalis	3	1	1	3	1	2	2	0	2.5	1.5	2	0	2
Bombina v. pachypus	1	1	2	3	2	0	2	3	2	1	1	0	3
Pelobates f. insubricus	3	2	0	3	0	2	2	1.5	3	1	1	0	3
Discoglossus pictus	2	2	1	2	1	1	2	1	2	1.5	1.5	3	2
Rana ridibunda	3	0.5	0	3	3	2	1.5	0	2.5	2	2	1	3
Hyla sarda	3	1	1	3	1	2	2	2	2.5	1.5	2	3	2
Rana latastei	1	2	1	3	2	3	3	2	3	2	2	0	2
Rana italica	1	2	1	3	2	2	3	3	2	3	2	0	2
Discoglossus sardus	3	2	1	2	1	2	2	3	2	1.5	2	3	3
Mean variable value	1.72	1.44	0.72	2.16	1.36	1.83	1.72	1.33	2.05	1.53	1.55	0.66	2.11

[a] Abbreviations for the variables are as in Table 1.

score values were generally lower than those observed for urodeles, a fact which suggests that anurans appear generally less threatened than urodeles. The higher mean scores were attributed to *Discoglossus sardus, Rana italica,* and *R. latastei,* all exceeding a score of 2. These taxa should be considered as extremely vulnerable, especially because of intrinsic ecological factors (see Table 3). Most of the taxa had a mean score <1.6, which means that they could be lower risk species. Interestingly, even the endemic Italian spadefoot toad (*Pelobates fuscus insubricus*) did not attain a high score (Table 3), thus suggesting that its populations could be increased, with careful conservation operations, because the species has no strong intrinsic ecological characteristic that constrain its survival.

Several of the mean scores per variable were low, but the variables HB (habitat breadth), ED (altitudinal distribution), and AF (area fragmentation) had very high scores, suggesting that they are crucial factors in the survival of Italian Anura. As observed for urodeles, if we plot the mean values per species of ecological factor scores against the mean values per taxon of non-ecological factors, we do not find any significant relationship ($r = 0.107$, $P > 0.65$).

3.2. Principal component analyses

3.2.1. Urodeles

Application of a standardised VARIMAX rotation on a PCA model to the data matrix in Table 2 ($\log_{10}$ det. corr. matrix = −8.3622; eigenvalues: 6.6387 and 3.0402) shows the 16 taxa falling into three major groups (Fig. 1). Scores of the first two factors on the various cases (variables) are presented in Table 5. In the plot of scores of individual species on factors, the main variables ordering the various species along Factor 1 were the habits (HT) and the insularity (I). Factor 2 is loaded by the endemicity (E) and the elevational distribution (ED). From this analysis, we can identify three groups of urodeles, which are roughly distributed along a decreasing diagonal. High values of Factor 2 and low values of Factor 1 distinguish a first group represented by *Salamandra lanzai, S. atra aurorae*, and *Speleomantes "genei"*. These taxa are endemic, have a very narrow distribution and have peculiar reproductive traits (the two salamanders are viviparous), while *S. "genei"* is peculiar, as already observed at the univariate analysis, for a set of characters related to insularity, number of included species, and endemicity. The second group is represented by five taxa, which are potentially endangered, since they are taxa at the edge of their main distribution area (*S. atra atra* and *Proteus anguinus*), or prevalent Italian endemics (*Speleomantes "italicus"*). Interestingly in this group, we find a species (*S. salamandra*) that is widespread in Europe but has a "K-oriented" reproduction, since it gives birth to fully developed aquatic larvae. The Sardinian newt (*Eeuproctus platycephalus*) is indeed another of the most endangered urodele species, especially taking into account that its breeding sites are disappearing or are highly contaminated (Corbett, 1989; Bovero, pers. comm.). Finally, the third group is composed almost entirely by the mainland newts (genus *Triturus*), which are not greatly sensitive to habitat alteration. Among these species, *T. alpestris inexpectatus* appears to be the most endangered one.

3.2.2. Anurans

The PCA factor scores relative to all the autochtonous Italian anurans are presented in Table 5. In the plot of scores of individual species on factors (Fig. 2), the main variables ordering the various species along Factor 1 were insularity (I), and the number of eggs (EN), while those ordering the species along Factor 2 were the distribution breadth in Italy (DB), the habitat breadth (HB), and the elevational distribution (ED).

The standardised VARIMAX rotated PCA for anurans ($\log_{10}$ det. corr. matrix = −9.5993; eigenvalues: 5.5829 and 3.2695) orders the various taxa into two main groups in terms of threat similarity: (a) a group constituted by *Rana "esculenta"*, *R. temporaria*, and *Bufo bufo*, and (b) a second group represented by all the other species. However, this does not reflect clearly the interrelationships among the anurans. This, in our opinion, is because *R. temporaria, R. "esculenta", B. bufo, B. viridis*, and *Hyla intermedia*, influence the plot distribution since they are characterised by wide geographical distribution, quite wide ecological adaptability and large

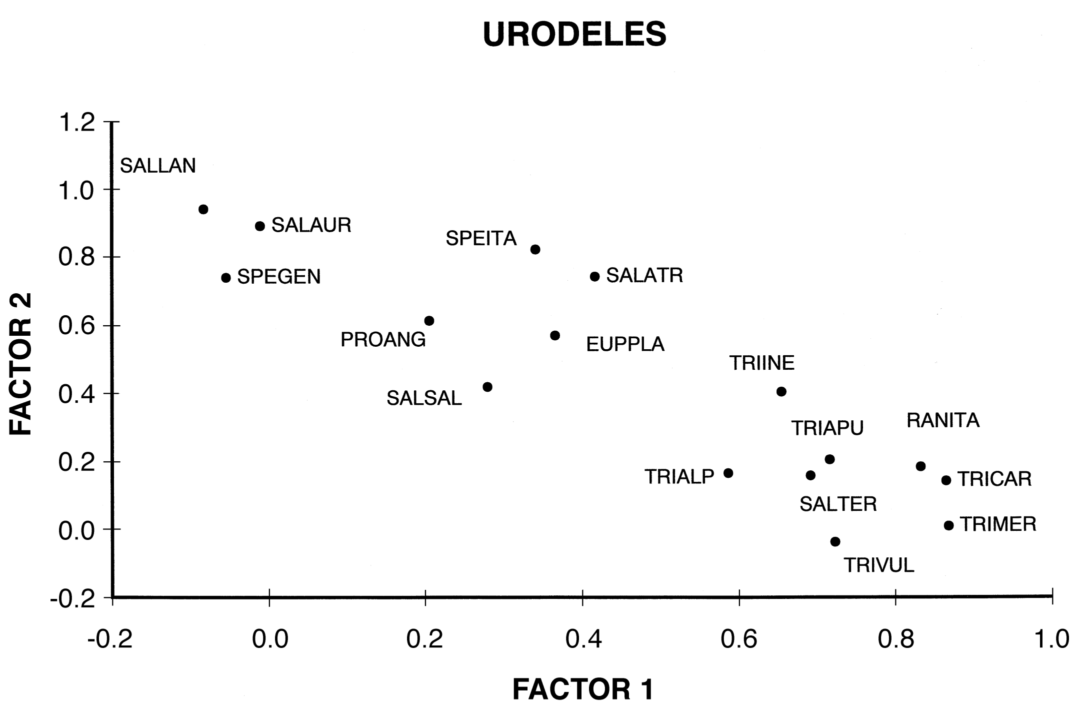

Fig. 1. Two-dimension plot of scores for individual species of Italian urodeles on factors using a standardized VARIMAX rotated model PCA. Abbreviations for taxa are reported in Table 1.

Table 5
Scores of Factor 1 and Factor 2 for 13 variables affecting Italian amphibians, after VARIMAX normalized rotation, in the sets of Principal Component Analyses performed[a]

	URODELES		ANURANS	
Variable	Factor 1	Factor 2	Factor 1	Factor 2
DB	−0.476	1.104	1.066	−1.527
RM	0.302	1.047	−0.511	0.264
EN	−0.806	1.153	−1.371	0.680
HB	0.129	1.314	1.559	0.354
HT	−1.900	−0.820	−0.809	1.227
MA	0.420	−1.266	0.229	0.155
AH	0.412	1.142	0.538	0.524
E	1.119	−0.224	−0.941	0.541
ED	1.091	−0.148	1.186	−0.003
AH	0.856	−1.264	−0.295	0.638
TU	−0.703	−0.175	0.817	0.051
I	−1.591	−1.107	−1.515	−2.520
AF	1.147	−0.654	0.781	−0.387
Percentage of explained variance	41.49	19.00	40.56	21.75

[a] For abbreviations see previous tables.

number of eggs per deposition. Clearly, these anurans are currently not endangered, although we can locally observe well known situations of massive mortality due to road traffic. However, excepting for their significance in terms of "flags" used by conservationists to dress amphibian safeguard, they do not have any real conservation implication. *Bufo viridis* and *Hyla intermedia* occupy an intermediate position, and they are, anyway, not very endangered, especially in the core of their Italian distribution area. Nevertheless, they are sensitive species, which in some cases may disappear (at least locally) from disturbed localities. *H. intermedia,* as an example, has disappeared from some Alpine valleys from which they were formerly present (e.g. their disappearance from Aosta Valley and Ossola Valley in NW Italy: see Andreone and Sindaco, 1999).

Apart for the above-mentioned unthreatened species, we can identify three groups with different degrees of threat. One group consists of *Discoglossus sardus, D. pictus* and *Hyla sarda*, which are endangered due to their "insular" status. Another group is composed by *Rana italica, R. latastei,* and *Bombina variegata pachypus*, which deserve attention due to their endemicity, and *B. v. variegata,* which is marginal in respect to the general species distribution.

A third group is represented by species which, although locally endangered, still have a wide distribution. Indeed, *Rana dalmatina, R. ridibunda, Hyla arborea, H. meridionalis* and *Pelodytes punctatus* have the boundary of their distribution in Italy, and thus deserve attention, particularly at a local level, but they are not really endangered at a higher level. Moreover, it is likely that they exhibit natural fluctuations over the years, due to their marginal position. This is what probably happened for *P. punctatus*, which at the end of the 18th century was present in southern Piedmont too, but now appears to be extinct in this northwestern region (Andreone and Sindaco, 1999). The relative position of *Pelobates fuscus insubricus*, a taxon which is said to be extremely endan-

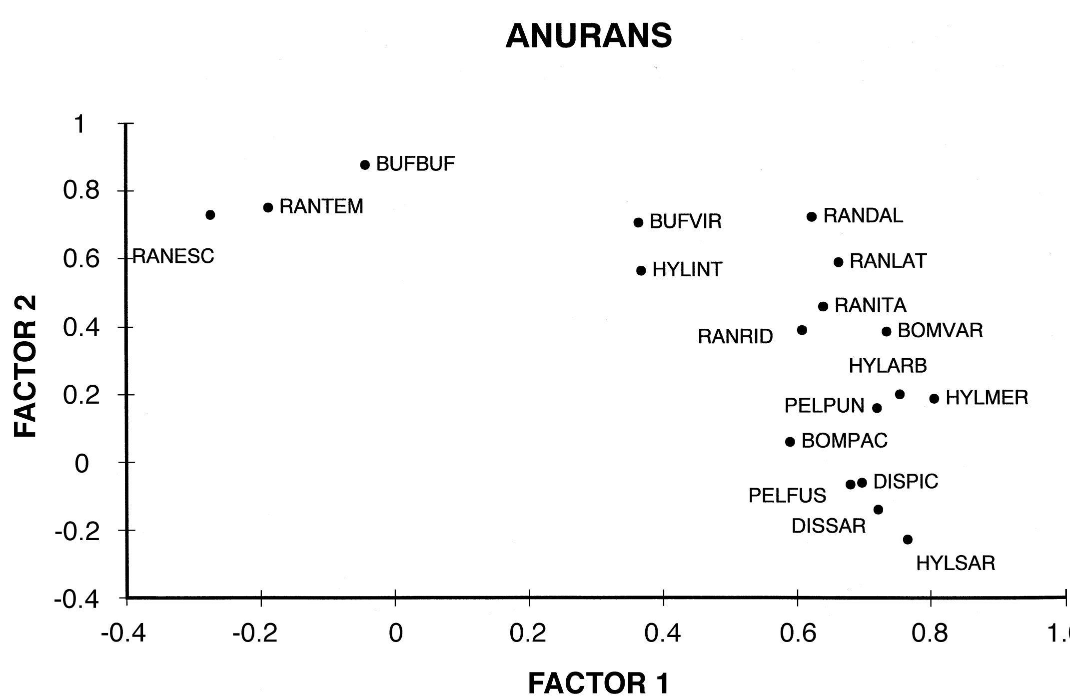

Fig. 2. Two-dimension plot of scores for individual species of Italian anurans on factors using a standardized VARIMAX rotation model PCA. Abbreviations for taxa are reported in Table 1.

gered in Italy, is intriguing but unresolved. It may partly depend on the taxonomic position of this toad, which is not sufficiently clear; it is still uncertain whether it should merit a full specific status or whether it should be treated as part of the more widely distributed nominative subspecies (Odierna et al., pers. comm.)

4. Discussion

The analysis carried out on the Italian batrachofauna provides some interesting insights into the ecological sensitivity of several taxa, and the major threats which currently affect them. The use of both univariate and multivariate methods sufficiently characterize their status. Until now the few contributions such as those of Doria and Salvidio (1994), Andreone (1995), Andreone and Fortina (1999), and Sindaco (2000) have used a simple univariate approach, and it is interesting to look at both the datasets, and briefly comment on them. Univariate mean score analysis highlighted two rather different situations for urodeles and anurans, which mirror also their different natural history and general sensitiveness to human disturbance.

Six out of 13 variables for urodeles (46.1%) had values of >2.0, which suggests that these are the most important for this group of amphibians. The highest mean scores are those relative to HB (habitat breadth) and AH (adaptability to altered environments), followed by RM (reproductive mode). On the other hand for the anurans only three factors (HB, E, and AF) are >2.0. There was no species with a mean score of <1.0, thus indicating that all the species are vulnerable, at least due to their peculiar biology. The species with a mean score >1.6 are *Salamandra lanzai, Proteus anguinus, Triturus alpestris inexpectatus, Euproctus platycephalus, Speleomantes "italicus", S. "genei", Salamandra atra aurorae,* and *Salamandrina terdigitata*. These taxa may be considered endangered, and for them particular attention is needed.

In contrast to urodeles, frogs, toads and treefrogs have species that are restricted to low altitude habitats (*P. fuscus insubricus* and *R. latastei*), while many others occur at low–mid altitudes, with no species living exclusively at high altitudes. This narrow altitudinal distribution, as well as a certain degree of habitat specialization, are among the reasons for the observed high habitat fragmentation (mean score = 2.11). *B. bufo, R. "esculenta",* and *R. temporaria*, have scores <1.0, and therefore are not at risk at all: they show in fact a wide distribution, a large altitudinal range, and are characterised by a set of ecoethological characteristics which make them able to adapt to a wide range of habitats. On the other hand, the taxa with score values >1.6 are *H. meridionalis, B. variegata pachypus, D. pictus, R. ridibunda, H. sarda, R. latastei, R. italica,* and *D. sardus*, and they have some moderate need of conservation like the equivalent urodeles. The remaining taxa are in a middle group with no immediate risk.

A clearer graphic resolution is given by the PCA, upon which some conservation actions can be based. Our opinion is that, while the univariate analysis add all the variables giving them an equal weight, the factorial analysis show in greater detail the more sensitive species in terms of ecological requirements, and therefore those on which our efforts should be addressed to warrant conservation actions. For urodeles, for example, we observe that the group with the highest potential risk is composed by *Salamandra lanzai, S. a. aurorae, Speleomantes genei, S. italicus, Proteus anguinus,* and *Euproctus platycephalus,* that are all "ecologically specialized" organisms. And, it is well known that life-history specialization is one of the major "reasons a priori" for making a species subjected to potential fast decline. *E. platycephalus,* is, according to K. Grossenbacher (pers. comm.), nearest to extinction of all European urodeles, and it merits immediate management planning. A strict protection of the pristine habitats of the above-mentioned species is urgently needed. Among these species, *S. lanzai* does not seem to be immediately endangered, although in some of its typical Alpine biotopes the road traffic and tourist pressure are high and it should be carefully monitored (Andreone, 1992, 1999a; Doglio et al., 2000). The same is even more true for *S. atra aurorae*, one of the most unusual European taxa. Finally, the Sardinian cave salamanders need strict protection, taking into account that *S. "genei"* is actually composed of four species, and for these reason they are the most immediate priorities for Italian urodeles.

Anurans are all more or less vulnerable, apart from *B. bufo, R. temporaria, R. "esculenta"*. At most of the protected areas where the other anurans occur, conservation plans to protect them should be applied, although urgent actions are especially needed for the two species of *Discoglossus* and for *H. sarda*. The latter three taxa occur in island habitats, and this, together with the high conservation priorities for the four Sardinian *Speleomantes* and for *E. platycephalus*, underlines the importance of the Italian islands, where several endemic forms occur. Attention should be paid to the two endemic Italian frogs *R. latastei* and *R. italica*, especially because the former lives only in the Po Plane, which is known to be highly affected by human disturbance. The current safeguard projects on *P. fuscus insubricus* (see Andreone et al., 1993, and Fortina and Marocco, 1994) should, of course, be continued and intensified, especially through the protection of the spadefoot's most significant biotopes. At the same time, taxonomic studies are urgently needed to determine the taxonomic status of the supposed *insubricus* subspecies. According to our data, the Italian spadefoot toad, although critically endangered and reduced in population numbers (see Andreone et al., 1993), has the possibility to recover to some extent when ecological conditions are improved.

Although our statistical procedure probably allows a more logical and objective global assessment of the threats and status of Italian batrachofauna, nevertheless it has some limitations. A potential problem with our type of approach has been that conservation status does not necessarily coincide with potential levels of threat derived from natural history parameters. For instance, of two amphibian species (*Bufo periglenes* and *Rheobatrachus silus*) often considered to have become extinct in recent years, at least one would have probably not scored high in this type of analysis (cf. data in Barinaga, 1990; Blaustein and Wake, 1990). Our type of analysis is mainly appropriate for species made vulnerable by their natural history features rather than by human agency. The position of *P. fuscus insubricus* is probably affected by the above-mentioned methodological approach. Indeed, it is much more seriously threatened than appears in our analysis, but its potential distribution range in Italy is still quite big. Thus, it is likely that this species can recover again if appropriate conservation measures are undertaken (natural habitat rehabilitation, etc.), especially if we consider that it is an *r*-strategist species (high numbers of eggs, explosive reproduction, high adaptability to live in unpredictable habitats). Moreover, genetic studies by Odierna and associates (pers. comm.) demonstrate that the genetic similarity between Italian and central European *P. fuscus* populations is high, and that the "endemic" status of the subspecies *insubricus* is seriously questionable. However, some recolonization projects for this species have already failed, and this will require accurate studies in the near future.

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