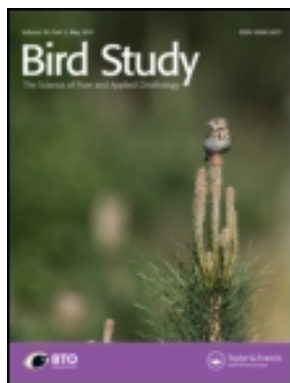


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Alexandre Roulin^a & Sylvain Dubey^a

^a Department of Ecology and Evolution, Building Biophore, University of Lausanne, 1015, Lausanne, Switzerland

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SHORT REPORT

Amphibians in the diet of European Barn Owls

ALEXANDRE ROULIN* and SYLVAIN DUBEY

Department of Ecology and Evolution, Building Biophore, University of Lausanne, 1015 Lausanne, Switzerland

Capsule: We present a review of the propensity to eat amphibians in the Barn Owl *Tyto alba* in Europe. Based on the analysis of 596 published studies reporting 3.32 million prey items identified in pellets, 17 869 amphibians (0.54%) were found. An analysis of 9036 amphibians identified to the species level showed that Barn Owls avoid consuming toxic species, and they are able to capture tree frogs (Hylidae) only rarely. The true frogs (Ranidae) are by far the most frequently captured amphibians followed by spadefoot toads (Pelobatidae) and Parsley frogs (Pelodytidae).

The Barn owl (*Tyto alba*) is a generalist predator feeding mainly upon small mammals (Glutz von Blotzheim & Bauer 1994). In an attempt to understand the circumstances in which other groups of animals can be an important food source, we reviewed the abundant literature about the diet in European owls. In a previous article (Roulin & Dubey 2012), we showed that reptiles are rarely captured by these owls (0.08%), but can be a non-negligible food source in southern Europe and on islands (maximum percentage of reptiles is 17.4%: Orti & Gonzales 2001). We also found that Barn Owls never consume venomous snakes. Here, our aim is to determine whether amphibians are a non-negligible prey in some countries or some circumstances and whether Barn Owls avoid consuming poisonous amphibians.

As stated in a previous article (Roulin & Dubey 2012), our review of Barn Owl diet in Europe is based on an extensive collection of studies published in all of the international and local journals that we could find. Among the 596 studies considered in the present review, 248 (41.6%; Table 1) reported at least one amphibian prey item (Figure 1), which is much more than the percentage of studies reporting at least one reptile (11.8%). This larger percentage is probably explained by the fact that contrary to reptiles most amphibians are nocturnal and slow-moving and hence easy to capture. Furthermore, on rainy nights when owls find it more difficult to capture agile prey such as small mammals, they may specialize on amphibians

that become abundant in the open landscape (pers. obs.).

Contrary to reptiles (that were mainly found in the diets of Barn Owls from southern Europe), the proportion of amphibians was not significantly associated with latitude (generalized linear model: $\chi^2_1 = 0.0002$, $P = 0.99$, after controlling for year: $\chi^2_1 = 92.65$, $P < 0.0001$). Note that the effect of year is due to a large proportion of amphibians consumed between 1940 and 1949 (out of 55 studies, 3 reported percentages of amphibians larger than 13% in the Barn Owl diet during this period) rather than any consistent change over time (Figure 2). Indeed, if we consider only those studies performed after 1949 there is no relationship between year and proportion of amphibians (Spearman's correlation: $r_s = -0.003$, $n = 478$, $P = 0.95$). Thus, declines in amphibian populations due to recent climate change, traffic mortality and habitat loss (Elzanowski et al. 2009, Curado et al. 2011) do not appear to have affected the Barn Owl's propensity to eat amphibians, which may not be surprising given that these owls capture amphibians relatively infrequently (Table 1, Figure 1).

Table 2 shows that the amphibian family that is most often consumed is the Ranidae or 'true frogs' ($n = 6669$ items; *Rana* spp. and *Pelophylax* spp.), with species of the genus *Rana* migrating in spring from forests to ponds to reproduce. Hence, large numbers of *Rana* spp. become available on rainy nights, probably explaining why Barn Owls can suddenly capture many of them. Interestingly, Barn Owls also consume an important number of *Pelophylax* spp., despite a lack of seasonal migration in these species that live strictly nearby

*Correspondence author. Email: Alexandre.Roulin@unil.ch

Table 1. Proportion of the Barn Owl diet composed of amphibians in different European countries and islands. Number of amphibian species present in each country is based on the Amphibian Database (<http://research.amnh.org/vz/herpetology/amphibia/>) (<http://www.reptile-database.org/>; Frost 2011). The references used to compile these tables can be found as supplementary material on the article's web page at: <http://dx.doi.org/10.1080/00063657.2013.767307>.

	Number of amphibian species present in the country/island	Number of studies	Number of amphibians as prey	Number of prey identified	% of amphibians in the diet
Albania	18	1	0	68	0
Austria	19	8	35	11298	0.31
Balearic Islands	2	3	2	10425	0.02
Belgium	17	10	687	155883	0.44
Bosnia	6	1	0	1782	0
Bulgaria	22	5	51	41787	0.12
Corfu	7	1	100	3097	3.23
Corsica	7	3	417	11295	3.69
Cos	2	1	9	2277	0.4
Crete	3	2	0	1284	0
Croatia	15	3	2	8633	0.02
Czech Republic	20	22	0	103037	0
Denmark	14	1	297	36173	0.82
France	34	88	9530	680353	1.4
Germany	19	149	2438	662271	0.37
Greece	24	11	22	9583	0.23
Hungary	16	23	121	107697	0.11
Ireland	3	16	239	25481	0.94
Italy	37	62	73	96460	0.08
Luxemburg	15	6	74	9678	0.76
Malta	3	2	0	424	0
Netherlands	16	10	623	126070	0.49
Poland	17	15	781	112769	0.69
Portugal	21	8	17	20343	0.08
Romania	19	3	29	3283	0.88
Sardinia	9	5	0	2415	0
Serbia	8	2	0	8576	0
Sicily	6	2	8	997	0.8
Slovakia	17	8	16	23431	0.07
Slovenia	16	6	7	6179	0.11
Spain	33	43	1376	166017	0.83
Sweden	11	1	0	1661	0
Switzerland	17	16	414	291168	0.14
Tenerife	2	1	34	2058	1.65
UK	11	58	467	571552	0.08
Total		596	17869	3315505	0.54

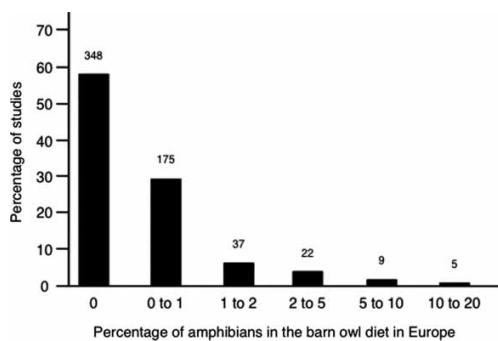


Figure 1. Frequency distribution of 596 studies reporting various percentages of amphibians in Barn Owl diet in Europe. Number above bars indicates the absolute number of studies.

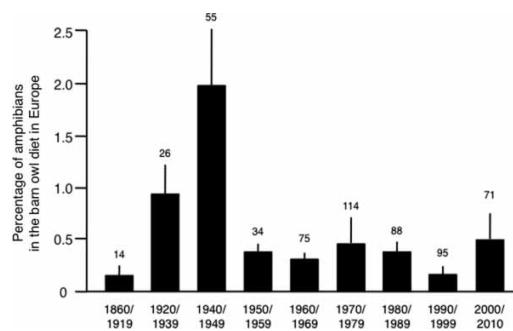


Figure 2. Mean (\pm se) percentage of amphibians in the Barn Owl diet in Europe between 1860 and 2010. Numbers above bars indicate the number of studies.

Table 2. Amphibians identified in Barn Owl pellets collected in different European countries and islands. Papers used to generate this table are reported in

	A	B	BU	Cor	Cos	Cr	F	G	Gr	H	Ib	Ir	It	L	N	P	Po	R	UK	S
<i>Anura</i> sp.	0	0	0	0	0	0	49	12	0	0	0	0	0	18	0	29	3	0	0	0
Bufonidae																				
<i>Bufo bufo</i>	0	0	0	22	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bufo calamita</i>	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Alytidae																				
<i>Discoglossus galganoi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Discoglossus jeannae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Discoglossus pictus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylidae																				
<i>Hyla arborea</i>	0	0	0	78	2	0	15	0	3	0	0	0	0	2	0	0	0	1	0	0
<i>Hyla meridionalis</i>	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelobatidae																				
<i>Pelobates cultripes</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0
<i>Pelobates fuscus</i>	0	0	0	0	0	2	1	173	0	25	0	0	0	1	1	595	0	12	0	4
<i>Pelobates syriacus</i>	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
<i>Pelobates</i> sp.	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Pelodytidae																				
<i>Pelodytes</i> sp.	0	0	0	0	0	0	301	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pelodytes punctatus</i>	0	0	0	0	0	0	168	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranidae																				
<i>Pelophylax esculenta</i>	2	0	0	0	0	0	524	120	0	0	0	0	1	0	0	0	0	0	0	0
<i>Pelophylax perezii</i>	0	0	0	0	0	0	47	0	0	0	1	0	0	0	0	0	5	0	0	0
<i>Pelophylax ridibunda</i>	0	0	27	0	0	0	0	1	0	0	0	0	9	0	0	0	0	0	0	0
<i>Pelophylax lessonae</i>	0	0	0	0	0	0	5	2	0	0	0	0	10	11	0	0	0	0	0	0
<i>Pelophylax</i> sp.	0	0	0	0	0	0	234	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rana dalmatina</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rana arvalis</i>	0	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rana dalmatina</i>	0	0	0	0	0	0	59	0	0	0	0	0	1	88	0	0	0	0	0	0
<i>Rana graeca</i>	0	0	0	0	1	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
<i>Rana temporaria</i>	0	3	0	0	0	0	1556	192	0	0	0	78	0	457	0	4	0	0	25	0
<i>Rana temporaria/agilis</i>	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rana</i> sp.	3	0	0	0	0	0	2259	66	0	3	0	0	3	0	144	27	0	13	0	3
Salamandridae																				
<i>Urodela</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
<i>Triturus marmoratus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Total	6	3	51	100	3	2	5607	622	18	28	1	78	24	577	145	655	15	28	25	7

A: Austria; B: Belgium; BU: Bulgaria; Cor: Corfu; Cos: Cos; Cr: Croatia; F: France; G: Germany; Gr: Greece; H: Hungary; Ib: Ibiza; Ir: Ireland; It: Italy; L: Luxembourg; P: Poland; Po: Portugal; R: Romania; UK: UK; S: Slovenia; SP: Spain; SW: Switzerland; T: Tenerife.

water bodies. Hence, it suggests that these birds are able to exploit various amphibian ecological niches. The second most frequent group is the Pelobatidae or spadefoot toads ($n = 1,041$) with fossorial adults and aquatic tadpoles. The third most frequent group is the Pelodytidae or Parsley frogs ($n = 544$) that are closely related to spadefoot frogs and, like them, live in open areas and sandy soils. The arboreal life of Hylidae (tree frogs) probably explains why this group of amphibians is less often captured ($n = 173$).

Three other groups of amphibians are rarely consumed: Bufonidae ($n = 44$), Alytidae ($n = 138$) and Salamandridae ($n = 3$), all of which include toxic species. Indeed, the diets of owls apparently do not include a number of very toxic species even though at the European scale the sample size is large ($n = 9036$, Table 2). Some of the toxic species are relatively common (e.g. the European Fire-bellied Toad *Bombina orientalis* and Yellow-bellied Toad *B. variegata*, Bombinatoridae), and species of the Green Toad complex *Pseudepidalea (Bufo) viridis*, Bufonidae; Obert & Schneider 1978, Balboni et al. 1992, Tashmukhamedov et al. 1994). In addition, in southeastern Europe, where *Pseudepidalea viridis* and *Pelobates syriacus* co-occur, only the latter non-toxic species (which is uncommon compared to *P. viridis*) is consumed (Miltshev & Georgiev 2009), reinforcing the hypothesis of toxic prey avoidance in Barn Owls. Another example is the absence of the Fire Salamander (*Salamandra atra*) that is large and easy to capture, but toxic (Mebs & Pogoda 2005). Because amphibians are not the primary source of food for the Barn Owl, it has apparently not evolved the ability to consume these toxic animals. In Australia some birds have learnt how to consume the non-toxic parts of extremely toxic invasive toads (such as the tongue; Beckmann et al. 2011). Toxic species are mostly consumed when the availability of alternative non-toxic prey is low, such as on islands (Corsica in this study). Such a switch has been documented in Australian bird species when the availability of non-toxic prey is low (Beckmann & Shine 2011). In addition, some of these animals are probably less likely to be captured because they live in water (e.g. newts and Bombinatoridae) or below stones and in holes (e.g. midwife toad; Alytidae; König et al. 2012) and so are relatively unavailable.

To conclude, amphibians are a more important food source than reptiles for Barn Owls in Europe. As for reptiles, our review emphasizes the fact that owls avoid consuming toxic prey. This challenges the idea that

the Barn Owl is strictly opportunistic by taking its prey only proportionally to their availability. It would be interesting to review the literature at the worldwide scale to see whether owls in some regions do consume toxic amphibians. This may be the case on islands where the diversity of prey species is lower than on mainland.

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