

Polecat predation on frogs and toads at breeding sites in western France

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Surveys of eight radiotracked polecats (*Mustela putorius*) showed that they caught mainly male terrestrial anurans at spawning sites. Agile frogs *Rana dalmatina* formed 77.5%, whereas common toads *Bufo bufo* represented only 14.6% of preyed anurans. Throughout the breeding period, male anurans were found to be predominant, representing 64.8% of available agile frog and 60.7% of common toad populations in the four ponds studied. The number of male frogs was significantly higher in two ponds which were not exploited by polecats in 1990. Polecats preyed selectively on anuran males (electivity index $D = 0.34$ in agile frogs and $D = 0.50$ in toads). Thus, the intensive predation of polecats at spawning sites can influence the sex-ratio of anuran populations.

KEY WORDS: *Mustela putorius*, cache behaviour, *Rana dalmatina*, *Bufo bufo*, selective predation.

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INTRODUCTION

Co-existence strategies of predators and prey involve a series of adjustments which allow predators to obtain sufficient prey but which also allow prey to survive

and to breed. Nevertheless, some periods, such as breeding season, appear more sensitive than others for prey survival and predators have shown inhabitual behaviour such as surplus killing (e.g. KRUK 1972).

In their natural habitat, European polecats *Mustela putorius* L. 1758 principally fed on anurans although they show some opportunism in diet (KRATOCHVIL 1952, DANILOV & RUSAKOV 1969, BLANDFORD 1987, JEDRZEJEWSKI et al. 1993). In western France, polecats foraged upon anurans, mostly during spring (LODÉ 1991) but several prey were not immediately consumed (LODÉ 1989). This predator, like various other carnivores (KRUK 1972, WAECHTER 1975, OKSANEN 1983), showed no inhibition in its killing behaviour (DANILOV & RUSAKOV 1969, LODÉ 1989, WEBER 1989a) when prey was easily accessible. Furthermore, this intensive predatory pressure coincided mostly with anuran breeding congregations (LODÉ 1994). Therefore, it seemed reasonable to expect that polecat predation could affect the frog populations.

The aims of this study were: (1) to show the selection of species and sex of amphibian prey by polecats in spring; (2) to estimate polecat impact on breeding adult anurans.

STUDY AREA

The study was performed in marshes of the lake of Grand-Lieu (47°05'N, 1°39'W), a natural eutrophic lake which lies 15 km south of Nantes, western France. Recent alluvium accumulated in a subsidence basin of the armorican peneplain. Marshes of *Scirpetum* were gradually invaded by reed beds and willows and give way to wooded farmland, consisting mainly of oaks, ashes and chesnuts. The climate is humid and mild, influenced by the nearby Atlantic ocean. Temperatures averaged 21.5 °C in August 1989, 6 °C in January 1989, 21.5 °C in August 1990 and 7.6 °C in January 1990, with 750 mm (1989) and 660 mm (1990) of precipitation per year, and about 2 snowy days (see MARION & MARION 1975). The Grand-Lieu lake has been a nature reserve since 1980.

All the three study ponds (A, B, C) and the ditch (D), used as spawning sites by anurans, were several hundred metres apart. The habitat surrounding the four sites consisted of deciduous woodland, flooded marshes and natural meadows. The sites A and C covered approximately 30 m² and shelved to a depth of 0.70 m, the site B reached 60 m² with a depth of 0.80 m and the spawning site in the ditch (D) stretched along 12 m of banks with a depth of 0.60 m. All the spawning sites were located in the shallower areas, little cluttered with aquatic vegetation in spring (*Typha*, *Scirpus*, *Potamogeton*).

METHODS

Polecats (four males and four females) were live-trapped in wooden box traps, fitted with radiotransmitters and radiotracked from 1988 to 1990 on the Grand-Lieu marshes (LODÉ 1993a, 1994, 1995). Following the nocturnal path of the animals, a daily search for faeces was performed the next morning and fresh droppings were collected in 1988 (n = 51), in 1989 (n = 236) and in 1990 (n = 203). Then, faecal material was dried, weighed, washed, and sieved (LOCKIE 1959). Remains were assigned to the lowest specific taxon by examining the external characteristics of hair (pigmentation and length of guard hair), feather, teeth, and bones (DAY 1966, CHALINE et al. 1974, RAGE 1974, BÖHME 1977) and by observing the microscopic structure and cross-section of medullary hair (DAY 1966, DEBROT et al. 1982). The form of pelvic girdle (pubis, ischium, ilium), 9th vertebra and the urostyle allowed discrimination among anurans (RAGE 1974, BÖHME 1977). Diet results are expressed as frequency of occurrence of each prey type (all prey specimens recovered = 100%).

Radiotracking surveys of polecats in the Grand-Lieu marshes allowed the discovery of 24 surplus killing which were often hidden by vegetation. Only caches produced by polecats around the studied period during the anuran breeding season from the end of February to June in 1989 and 1990 were considered. Several prey had been partially consumed but every species was easily identified by examining the bones and remains (RAGE 1974, BÖHME 1977). Various other remains of anurans eaten by polecats were also found around ponds and later examined. Determination of sex in anurans was facilitated by evidence of ova in the oviducts and of rough spots on the male thumbs. Data from remains and caches (the three main anuran species preyed by polecat i.e. *Rana dalmatina*, *Rana esculenta* and *Bufo bufo*) were pooled over two periods: (1) February 20th to March 20th and (2) March 21st to May 10th.

Studies of anuran populations were performed in spring 1989 and spring 1990, at three distinct ponds (sites A-C) and in a ditch (site D) exploited by polecats. These reference sites were chosen because the radiotracked polecats were found to exploit them in spring 1989 and because they constituted spawning sites for *Rana dalmatina*. Adult anurans were hand-caught at night (at about 20:30 hr) fortnightly from the last week of February to the first week of June. The individuals were counted and marked the first evening and a second counting was realized the day after. Number of individuals were estimated by the Lincoln Index and the sex-ratio was expressed as the proportion of males. Only the most common species, agile frog *Rana dalmatina*, green frog *Rana "esculenta"* and common toad *Bufo bufo* were considered. Although *Rana lessonae* was also found, no discrimination between its hybrid *R. "esculenta"* (BERGER 1973, BLANKENHORN 1977, LOW et al. 1989) was made. The breeding period estimate has been based on a daily survey of spawning sites (LODÉ 1993b).

Evidence of polecats feeding at sites A-D in spring 1989 was shown by live-trapping and radiotracking. Furthermore, the presence of tracks and faeces showed intensive exploitation of the sites. Although numerous predator species inhabited the Grand-Lieu marshes, such as the marsh harrier, common buzzard, long-eared owl, otter and genet, no evidence of other carnivores was shown around the studied ponds. The American mink *Mustela vison* was absent from the site. In spring 1990, polecats were found at sites B and C only, and no field signs were observed around pond A and ditch D. Two adult polecats were killed by trappers in January and February 1990 at pond A.

The Ivlev's Electivity index modified by JACOBS (1974) was calculated between the proportions of preyed anurans and available anurans: $D = (n - p)/(n + p - 2np)$ where n was a fraction of anuran males cached by polecats and p the fraction of anuran males in the community. The index D varies from -1 to 0 for avoidance and from 0 to $+1$ for positive selection. The sample size of *Rana esculenta* remained too small and no calculation was made.

RESULTS

Diet of polecats

A wide variety of prey was found but mammals formed the bulk of the diet (Table 1). Dietary patterns showed a clear seasonality ($\chi^2 = 148,7$, $df = 6$, $P < 0.0001$). Occurrences of mammals decreased from winter (93.2%) to spring (51.0%) (Kruskall-Wallis test, $H = 9.36$, $df = 3$, $P < 0.03$) while anurans were mainly eaten in spring (45.9%) ($H = 7.85$, $df = 3$, $P < 0.05$). Among amphibian remains, agile frogs *Rana dalmatina* formed 69.9% and common toads *Bufo bufo* 24.8%.

Prey remains

Agile frogs formed 77.5% of anuran remains found in caches (Table 2) whereas green frogs represented only 7.9% with no difference between 1989 and 1990 ($\chi^2 = 1.2$, $df = 2$, $P > 0.05$). Anuran occurrences in the diet did not significantly differ

Table 1.

Seasonal variations in the diet of radiotracked polecats expressed as percent of each prey specimens in the total number of identified prey.

Prey type	Spring	Summer	Autumn	Winter
Shrews	—	2.4	5.3	5.6
Rodents	49.0	54.8	56.8	87.6
Rabbits	2.0	17.8	17.4	—
Total Mammals	51.0	75.0	79.6	93.2
Birds	3.1	9.5	3.8	—
Common toads	12.2	—	—	2.5
Agile frogs	31.6	8.3	6.8	0.6
Green frogs	1.0	1.2	—	—
<i>Rana</i> sp.	1.0	—	0.8	—
Total amphibians	45.9	9.5	7.6	3.1
Invertebrates	—	6.0	6.1	3.1
Others	—	—	3.0	0.6
No. identified prey	(196)	(84)	(132)	(161)
No. scats analysed	(175)	(65)	(118)	(132)

from the whole of agile frog and toad remains found in caches ($\chi^2 = 1.03$, $P > 0.05$). Agile frogs were not caught earlier than common toads ($\chi^2 = 0.28$, $P > 0.05$), green frogs were preyed on significantly later than the two other species ($\chi^2 = 33.5$, $df = 2$, $P < 0.0001$, Table 3).

Anurans were sometimes found partially eaten (35.2%, $n = 267$) but polecats discarded oviducts. Toad epidermis was not ingested but turned over.

Anuran numbers in ponds

Agile frogs arrived at breeding sites at the beginning of March. Males arrived first (six individuals on March 2nd) whereas females came later (four females on March 10th). Males left the ponds in mid-April (no males on April 16th). Male common toads appeared near the end of February (two males on February 18th) and left the breeding sites at the beginning of April (no males on April 8th). Females

Table 2.

Proportions of a given species among anuran remains in polecats' caches.

	1989	1990	Total
<i>Rana dalmatina</i>	78.1	77.2	77.5
<i>Rana "esculenta"</i>	9.5	6.8	7.9
<i>Bufo bufo</i>	12.4	16.0	14.6
No. anuran remains	(105)	(162)	(267)

Table 3.

Proportions of anuran remains of each species found in polecats' caches in period 1 (February 20th-March 20th and period 2 (March 21st-May 10th).

Dates	<i>Rana dalmatina</i>	<i>Rana "esculenta"</i>	<i>Bufo bufo</i>
1989			
Period 1	62.2	0.0	69.2
Period 2	37.8	100.0	30.8
No.	(82)	(10)	(13)
1990			
Period 1	64.0	0.0	69.2
Period 2	36.0	100.0	30.8
No.	(125)	(11)	(26)
Data pooled			
Period 1	63.3	0.0	69.2
Period 2	36.7	100.0	30.8
No.	(207)	(21)	(39)

were present in ponds from March 7th to April 8th. Male agile frogs were always more numerous than females (Fig. 1). Common toads were only found in two ponds in 1989 and males also predominated. No significant difference was noted between the numbers of toads in 1989 and in 1990 ($\chi^2 = 0.08, P > 0.05$), whereas the numbers of agile frogs significantly varied at breeding ponds from 1989 to 1990 ($\chi^2 = 12.74, df = 3, P < 0.005$). This difference was mainly due to the increased number of males in the frog populations (males $\chi^2 = 12.18, df = 3, P < 0.007$; females, $\chi^2 = 2.81, df = 3, P > 0.05$).

Prey selectivity

In 1990, the frog numbers of both sexes significantly differed from one pond to another ($\chi^2 = 7.96, df = 3, P < 0.05$) whereas in 1989, numbers did not ($\chi^2 = 0.07, P > 0.05$). In 1990, males frogs were significantly more numerous in pond A and

Table 4.

Percentages of males and females in anuran populations in ponds and canals compared to the anuran prey of polecats.

Species	1989			1990			Pooled data		
	Males	Females	(No.)	Males	Females	(No.)	Males	Females	(No.)
<i>Rana dalmatina</i>									
In ponds	56.8	43.2	(132)	69.9	30.1	(209)	64.8	35.2	(341)
In caches	75.6	24.4	(82)	80.8	19.2	(125)	78.7	21.3	(207)
D index		0.40			0.29			0.34	
<i>Bufo bufo</i>									
In ponds	56.0	44.4	(25)	64.5	35.5	(31)	60.7	39.3	(56)
In caches	84.6	15.4	(13)	80.8	19.2	(26)	82.1	17.9	(39)
D index		0.62			0.40			0.50	

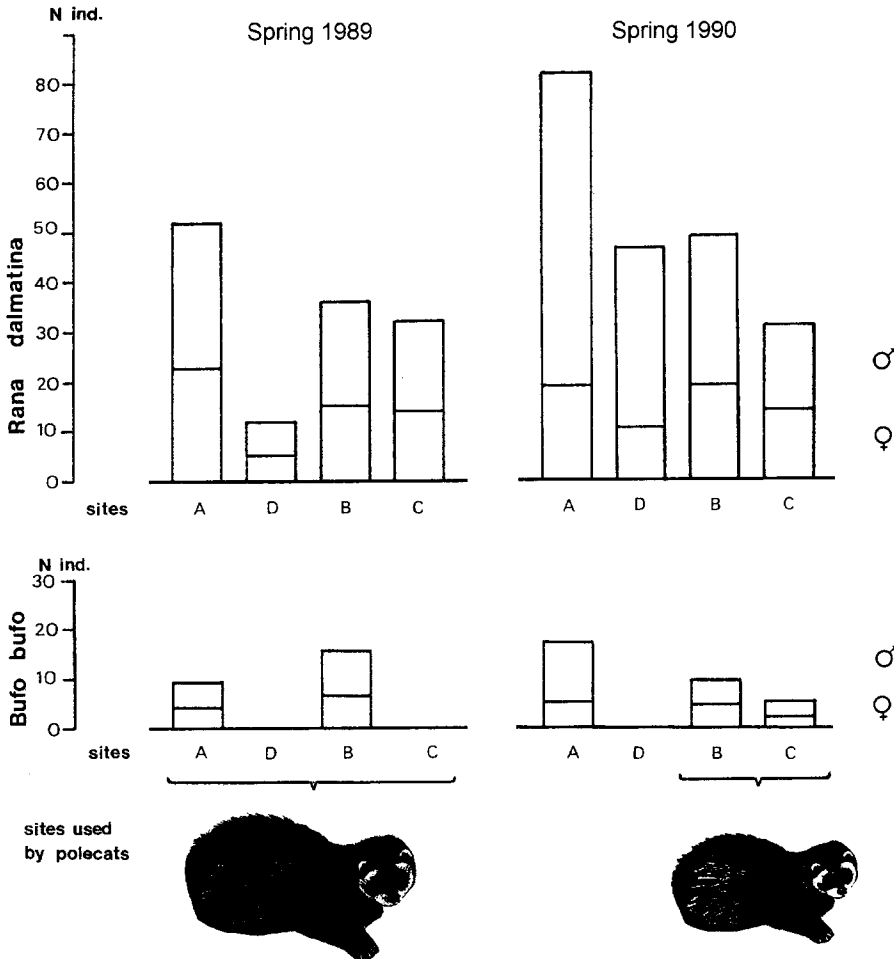


Fig. 1. — Changes in numbers of *Rana dalmatina* and *Bufo bufo* at four spawning sites between spring 1989 and spring 1990 in Grand-Lieu marshes, western France (Sites A and D were not exploited by polecats in spring 1990).

ditch D (not exploited by polecats) than in ponds B and C (exploited by polecats), ($\chi^2 = 6.76$, $P < 0.009$) while in 1989 (all ponds exploited by polecats), no difference was found ($\chi^2 = 0.02$, $P > 0.05$).

Examination of anuran remains showed that males were predominant among the agile frogs and toads cached by polecat (Table 4). Although males were found to be more numerous in ponds, their numbers significantly differed from the numbers of males frogs ($\chi^2 = 11.3$, $P < 0.001$) and of male toads ($\chi^2 = 4.3$, $P < 0.04$) that were preyed on by polecats. The calculation of the selectivity index revealed that polecats had a high selective predation upon anuran males in both for agile frogs ($D = 0.34$) and toads ($D = 0.50$) (Table 4).

DISCUSSION

Feeding habits of polecats

Although the polecats feed on anurans throughout Europe (KRATOCHVIL 1952, DANILOV & RUSAKOV 1969, BLANDFORD 1987), the species most frequently eaten differs according to the area. Common toads, occasionally associated with painted frogs *Discoglossus pictus*, were the chief prey in Spain (BALLARIN et al. 1980) whereas the presence of gregarious common frogs *Rana temporaria* entailed a strong consumption in Switzerland (WEBER 1989a, 1989b) and in Poland (JEDRZEJEWSKI et al. 1989).

In western France, terrestrial and nocturnal species such as agile frogs and common toads were preyed upon and their occurrences in the carnivore diet usually coincided with the anuran breeding season and the decline in rodent populations (LODÉ 1991, 1994). So polecats showed a rather opportunistic exploitation of prey in relation to the wider dispersion of frog populations and the longer breeding period in *Rana dalmatina* compared with *Rana temporaria* (BLAB 1986, GUYETANT 1986, LODÉ 1993c).

Numerous mustelids were found to prey upon anurans. Otters *Lutra lutra* captured some *Rana* sp. (ERLINGE 1969, WEBB 1975, JENKINS et al. 1979, WISE et al. 1981, ADRIAN & DELIBES 1987, LIBOIS & ROSOUX 1991, BREZINSKI et al. 1993), mainly during spring in relation to the availability of frogs (WEBER 1990). Although American mink *Mustela vison* or badger *Meles meles* sometimes consume a significant quantity of frogs and toads (KORSCHGEN 1958, HENRY 1984), the occurrences of amphibians in the diet of carnivores remained generally low (ERLINGE 1969, CHANIN & LINN 1980, WISE et al. 1981, PIGOZZI 1991, LODÉ 1993c) or absent (KRUUK & PARISH 1981, CIAMPALINI & LOVARI 1985). Only polecats are the most regular predators of anurans among European carnivores (BLANDFORD 1987; WEBER 1989a; LODÉ 1991, 1994; JEDRZEJEWSKY et al. 1993).

Prey selectivity

Polecats stored anurans near breeding sites. In polecats' caches, anuran males both toads and agile frogs were always more numerous than females. Male anurans arrive earlier than females at breeding sites (FRAZER 1966, HEUSSER 1968, STEWARD 1968, GEISSELMANN et al. 1971, RASTOGI et al. 1983). By staying longer at spawning ponds, male frogs could fertilize more than one female. Males were predominant at breeding sites in anuran populations. Such prevalence of males in anuran populations has been frequently observed (BLAB 1986, READING et al. 1991). In western France, numerical changes in frog populations chiefly resulted from an increase in males. The proportion of anuran males taken by polecats significantly exceeded the proportion of males at the spawning sites. Thus, polecats exhibited a clear selective predation upon anuran males. Anuran males might be more easily detected by predators because of their chorus and the increase in their movements that results from intraspecific antagonism.

Impact of polecats

In western France, in the absence of polecats, male frogs out-numbered females in the ponds. Therefore, it appears that polecat selective predation influenced the sex ratio of the frogs tending to equalize the proportion between sexes.

Predation by polecats should also have implications for population genetics. READING et al. (1991) emphasized that exchanges in toad populations only resulted from the migration of some males. Although anurans showed a great fidelity to breeding ponds (BLAB 1986, READING et al. 1991), an overabundance of males could provoke antagonistic interactions favouring migrations to new breeding sites. Thus, polecat predation upon male frogs may restrict local population exchanges.

Even though polecats preyed mainly upon males, the effect on the overall population was minimal because a single male frog could fertilize several females.

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