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PALMATE NEWT PREDATION ON COMMON FROG, *RANA TEMPORARIA*, AND COMMON TOAD, *BUFO BUFO*, TADPOLES

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ABSTRACT

In a series of laboratory experiments, male palmate newts that had no previous experience of anuran tadpoles as potential prey were conditioned for five days to small worms, common frog tadpoles, common toad tadpoles or a 50:50 mixture of frog+toad tadpoles. During three experiments, conditioned newts were offered 1) a 50:50 mixture of frog+toad tadpoles 2) only frog tadpoles or 3) only toad tadpoles.

The results showed that palmate newts with no previous experience of either frog or toad tadpoles very quickly learnt to distinguish between them and take only frog tadpoles. This was supported by the results of a fourth experiment using male palmate newts from a pond that contained both tadpole species. Common toad tadpoles were almost totally rejected.

The conclusion is, that common frog tadpoles gain no long term protection against predation from palmate newts through associating with common toad tadpoles.

INTRODUCTION

Three species of newt occur in Great Britain, the warty newt (*Triturus cristatus*), smooth newt (*T. vulgaris*) and palmate newt (*T. helveticus*). All three species are voracious predators and are known to take a wide range of aquatic invertebrates (Avery, 1968; Griffiths, 1986). In addition, smooth newts are also known to take frog tadpoles (Cooke, 1974) but, like palmate newts, reject toad tadpoles (Cooke, 1974; Griffiths, 1986) whilst warty newts will take both frog and toad tadpoles (Cooke, 1974; Heusser, 1971).

Unlike frog eggs and tadpoles, those of toads are generally thought to be unpalatable to many potential predators (Licht, 1968; Wassersug, 1971). The difference in palatability between common frog (*Rana temporaria*) and common toad (*Bufo Bufo*) tadpoles presents an interesting question: In ponds where both tadpole species occur together, do frog tadpoles gain any protection against predation by newts due to the presence of toad tadpoles?

This paper reports the results of a series of laboratory experiments designed to investigate tadpole predation by palmate newts.

METHODS

Four experiments were carried out in the laboratory under natural light conditions and at a temperature of 13.5-15.5°C. to determine whether palmate newts predate common frog and common toad tadpoles. The experiments were also designed to investigate whether mixed tadpole populations affected newt predation rates.

In experiments 1-3, male newts were obtained from a heathland pond that was not used as a breeding site by either common frogs or common toads. These newts therefore had no previous experience of frog or toad tadpoles as potential prey. Forty newts were used in each experiment (n = 3) and each newt was only used once. In each experiment, 10 newts were placed in each of four tanks containing 2 litres of pond water (pH = 7) and conditioned (fed) for five days on:

Tank 1 — 40 frog tadpoles
Tank 2 — 40 toad tadpoles
Tank 3 — 20 frog tadpoles + 20 toad tadpoles
Tank 4 — small earthworms

Twice each day at 10.00hrs and 22.00hrs the number and species of tadpoles remaining in each tank was recorded and any missing tadpoles replaced to maintain a constant prey density of 40. Missing earthworms were also replaced to maintain a constant food supply. After five days, each set of 10 newts were placed in four new tanks containing 1 litre of pond water and deprived of food for 24 hours.

Conditioned newts were then each placed in individual tanks (28 x 16cm) containing 1 litre of pond water (pH = 7) and 10 tadpoles of similar size (frog $\bar{x}$ = 22.6mm; SD = 4.01; N = 41; range = 15-29mm; toad $\bar{x}$ = 18.5mm; SD = 1.5; N = 30; range = 16-21mm). The number of tadpoles eaten by each newt was recorded each hour for 24 hours and missing tadpoles were replaced to maintain a constant prey density of 10/L. In the three experiments each newt was given:

Expt. 1 — 5 frog + 5 toad tadpoles
Expt. 2 — 10 frog tadpoles
Expt. 3 — 10 toad tadpoles

In experiment 4, 30 male newts were obtained from a pond which was also used extensively by both frogs and toads as a breeding site. Since these newts were already conditioned to a mixture of frog+toad tadpoles no further conditioning was done. All newts were deprived of food for 24 hours before being placed in individual tanks and given 10 tadpoles as in experiments 1-3.

The data were analysed using analysis of variance. Comparisons between the numbers of tadpoles eaten by newts under different conditioning regimes were made using Chi square analysis. Means were compared using Student's t test.

RESULTS

Conditioning

At the start of each conditioning period the newts immediately approached and seized the prey provided (worm or tadpole). Worms and frog tadpoles were subsequently eaten whilst, with the exception of 3 toad tadpoles, the toad tadpoles were released. Although worms and frog tadpoles continued to be taken throughout the conditioning periods, toad tadpoles were ignored after the initial captures.

During the 3 x 5 day conditioning periods, totals of 457 frog tadpoles and 3 toad tadpoles were eaten by the 60 newts presented with either all frog or a 50:50 mixture of frog+toad tadpoles. The 3 toad tadpoles were caught and eaten during the first 12 hours of the conditioning period. No tadpoles were eaten by the newts presented with only toad tadpoles.

The mean number of frog tadpoles eaten by 10 newts given either frog or frog+toad tadpoles during each 12 hour period of conditioning is shown in Fig. 1. During the first 12 hours of the conditioning period newts given only frog tadpoles ate significantly more than those given frog+toad tadpoles ($t = 6.81$; $df = 4$; $p<0.01$). After the first 12 hours of conditioning the mean numbers of tadpoles eaten during each subsequent 12 hour period stabilised and were not significantly different ($\bar{x}$ frog = 7.00; SD = 3.47; N = 27; range = 1-13; $\bar{x}$ frog+toad = 6.89; SD = 2.55; N = 27; range = 2-11; $t = 0.13$; $p>0.10$).

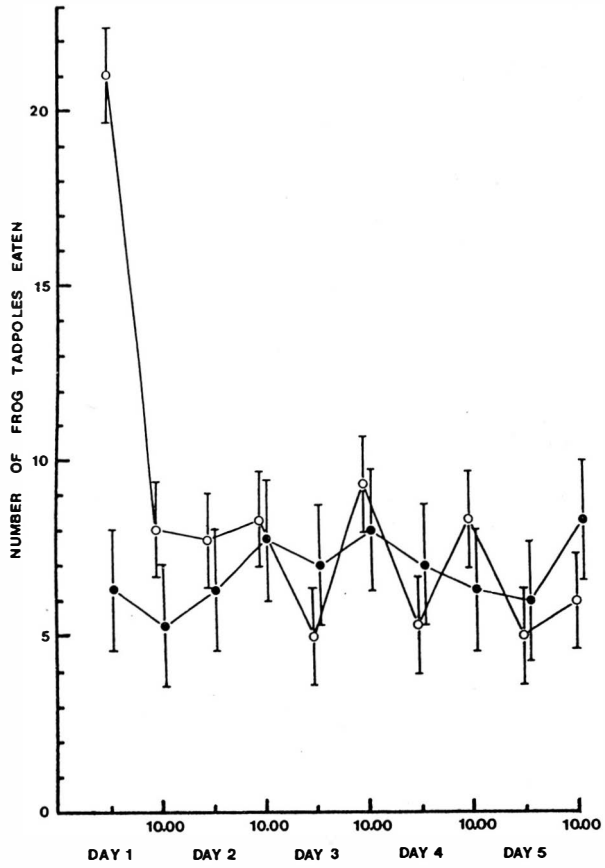

Fig. 1 Mean (± SD) number of frog tadpoles eaten every 12 hour by 10 male palmate newts given either frog (o) or frog+toad (●) tadpoles.

Experiments 1-3

In experiment 3 (toad tadpoles) only 1 toad tadpole was eaten and that was caught after 8 hours by a newt conditioned to frog+toad tadpoles.

Although no toad tadpoles were eaten in experiment 1, some frog tadpoles were caught in experiments 1 and 2 and either chewed and released or eaten and regurgitated. Three times as many tadpoles were rejected by the toad conditioned newts given frog tadpoles (N = 9) than by any other combination (N = 2-3). Rejected tadpoles were always dead and were therefore discounted from the final analysis of numbers consumed.

Conditioned to	*Expt. 1 (frog+toad)*	*Expt. 2 (frog)*	*Expt. 3 (toad)*
Worms	11	19	0
Frog tadpoles	23	27	0
Frog+toad tadpoles	29	31	1
Toad tadpoles	11	32	0

TABLE 1: Number of frog tadpoles eaten in experiments 1 and 2 and toad tadpoles eaten in experiment 3 by Palmate newts conditioned to worms, frog tadpoles, frog+toad tadpoles and toad tadpoles.

The total number of tadpoles eaten by each group of newts in each experiment is shown in Table 1. The null hypothesis in each experiment, tested using Chi square analysis, was that the expected number of tadpoles eaten by each group of newts was equal. Although significant differences were found between newt groups in experiment 1 (overall $\chi^2 = 13.14$, df = 3, $p<0.01$; Table 2), none were detected in experiment 2. Newts conditioned to either worms or toad tadpoles ate significantly fewer tadpoles than newts conditioned to either frog or frog+toad tadpoles.

	Frog	*Frog+Toad*	*Toad*
Worms	4.23 *	8.10 **	NS
Frog		NS	4.23 *
Frog+Toad			8.10 **

TABLE 2: Chi square (1df) values for comparisons between the numbers of frog tadpoles eaten by Palmate newts conditioned to worms, frog tadpoles, frog+toad tadpoles and toad tadpoles and given a 50:50 mixture of frog+toad tadpoles (expt. 1). $p<0.05$(*); $p<0.01$(**); NS = Not significant. Overall $\chi^2 = 13.14$, df = 3, $p<0.01$.

The mean total body lengths (BL = head+body+tail), excluding the tail filament, of newts used in experiments 1 and 2 were compared to determine whether differences in newt feeding rates between experiments might have been the result of differences in newt body size. The two means were not siginificantly different ($p>0.05$) and no significant correlation was found between newt body size and the number of tadpoles eaten.

Expt. 1 : $\bar{x}$ = 62.10mm; SD = 3.30; N = 40; range = 53-69mm

Expt. 2 : $\bar{x}$ = 60.72mm; SD = 3.66; N = 40; range = 51-68mm

Experiment 4

The results of experiments 1 and 2 show that palmate newts that have never encountered anuran tadpoles can learn, over a very short period, to distinguish between frog and toad tadpoles. The newts used in this experiment were from a pond which was also a traditional breeding site for both frogs and toads. Since they had been exposed to tadpoles of both species for at least two months before they were caught it was assumed that they were able to distinguish between them. Therefore, the null hypothesis for this experiment was that the numbers of tadpoles eaten by newts offered either frog or frog+toad tadpoles would be equal. The mean numbers of frog tadpoles eaten by newts given frog tadpoles or frog+toad tadpoles were 4.6 (SD = 1.26, N = 10) and 3.2 (SD = 1.75, N = 10) respectively. No significant difference ($\chi^2 = 2.51$; df = 1) was found between these two means. As in experiments 1 and 2, no toad tadpoles were taken.

DISCUSSION

Evidence for learning came initially from observing the behaviour of the newts when they were first presented with tadpoles at the start of the conditioning period. Tadpoles, irrespective of species or mix, were immediately seized and then either eaten, in the case of frog tadpoles, or released, in the case of toad tadpoles. After these initial encounters only frog tadpoles continued to be caught. This implied 1) that all tadpoles were initially recognised as potential prey and 2) that frog tadpoles were palatable whilst toad tadpoles were not.

Subsequently, the evidence from experiment 1 showed that newts conditioned to a mixture of frog+toad tadpoles ate more frog tadpoles than expected compared with newts conditioned to either worms or toad tadpoles. Furthermore, toad conditioned newts, that had learnt to avoid tadpoles, and worm conditioned newts, that had no prior experience of tadpoles, both ate fewer tadpoles than expected compared with frog conditioned newts.

The results of comparing the number of tadpoles eaten in experiment 1 by the frog conditioned and toad conditioned newts were interesting. Although the null hypothesis tested was that the number of tadpoles eaten by each group of newts should have been equal it might have been expected that the toad conditioned newts, that had been effectively deprived of food for six days, would have eaten at least as many tadpoles as the frog conditioned newts and perhaps more, rather than fewer, as observed. The difference between the two groups of newts was that the frog conditioned newts recognised all tadpoles as palatable whilst the reverse was true for the toad conditioned newts. Despite the toad conditioned newts being clearly hungry as demonstrated in experiment 2 they nevertheless largely ignored the palatable frog tadpoles. As a result of their conditioning, these newts had to overcome an aversion to tadpoles and learn to recognise frog tadpoles as palatable whilst the frog conditioned newts had no such aversion and only had to learn to recognise toad tadpoles as unpalatable. Furthermore, the toad conditioned newts aversion to tadpoles would also have been reinforced each time a toad tadpole was encountered.

Four clear conclusions can be drawn from the three five day conditioning periods and four one day experiments; 1) palmate newts readily catch and eat frog tadpoles, 2) palmate newts almost totally reject toad tadpoles, 3) recognition of distasteful prey by palmate newts is not innate but learnt and 4) because palmate newts can learn to distinguish between palatable and unpalatable prey, frog tadpoles gain no long term (only short term) protection against newt predation through mixing with toad tadpoles.

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THE POLYMORPHISM OF *PODARCIS PITYUSENSIS* AND ITS ADAPTATIVE EVOLUTION IN MEDITERRANEAN ISLES

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ABSTRACT

The variation in morphological and colouring features shown by the insular lacertid populations of *Podarcis pityusensis* is discussed from the point of view of their adaptive advantages to specific insular ecosystems. Insularity factors, i.e. area and island-age, have been found to be related to average body size, and the average luminosity of each population. Populations tend to show a size increase, a greater morphological homogeneity and darker dorsal colouring on smaller and older islands. The advantages of larger size and melanism are discussed as well as their possible causes in the insular microecosystems of the Pityusic Archipelago. Genetic drift seems to play a secondary role, whereas a positive selection in favour of melanism and giantism is observed. Both features are not linked as cause and effect, but seem to share a common cause: isolation and time enough to allow selection to take place. Predation, though slight in degree, does exist, and seems to be one of the selective pressures favouring melanism, together with the parallel trend towards an increase in body size and the need to an effective thermoregulation during the early hours of the day.

INTRODUCTION

The great morphological variety, number of dorsal scales and body colouring shown by insular lacertids has often been analysed exclusively using taxonomical criteria, without considering the adaptative significance that could lie behind these variations in most of the available reports. It has even been stated that some body size defining features (giantism and dwarfism in insular populations) or the number of dorsal scales showed a neutral selection (Radovanovic, 1954).

However, most authors nowadays accept that animal features are variable to a greater or lesser degree depending on their adaptative value. The adequate conditions for life in a specific environment must necessarily change if that environment changes.