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ESTABLISHMENT OF POPULATIONS OF THE COMMON FROG, *RANA TEMPORARIA*, AND COMMON TOAD, *BUFO BUFO*, IN A NEWLY CREATED RESERVE FOLLOWING TRANSLOCATION

A. S. COOKE[1] AND R. S. OLDHAM[2]

[1]*English Nature, Northminster House, Peterborough PE1 1UA, UK*

[2]*Department of Applied Biology and Biotechnology, De Montfort University, Scraptoft Campus, Leicester LE7 9SU, UK*

The establishment of large populations of common frogs *Rana temporaria* and common toads *Bufo bufo* was monitored for six years in a newly-created reserve, following stocking with spawn of both species and with toads rescued from a site to be destroyed. Frog spawn output reached a peak three years after the initial introduction. There was high mortality and/or emigration (64% loss) during the first year following translocation of over 5,000 adult male toads. Thereafter male mortality decreased and/or site fidelity increased: 39% loss year 2 to 3, 42% loss year 3 to 4. Comparable data were not available for the 795 females translocated, but there is no reason to believe their mortality was lower. Transfer of spawn is probably more effective as a means of establishing a new population of toads than transfer of adults. Counts of male toads peaked after three years, but delayed sexual maturity of females meant that counts of pairs and estimates of spawn output continued to increase for about six years. Age determination in a sample of 43 male toads showed that length was significantly related to age, but there were some notably disparate rates of growth. A sample of 16 females showed no correlation between age and length. The greatest recorded losses of naturally-laid spawn of both species (up to 16% in one year for the frog and 39% for the toad) were due to desiccation, presumed collection by people and fungal infestation.

INTRODUCTION

Amphibian translocations (*sensu* Griffith, Scott, Carpenter & Reed, 1989) are usually performed in response to the need to evacuate a threatened population. The familiar dilemma is to choose a suitable recipient site. If the target site does not contain a population already, the habitat may be unsuitable. On the other hand if a population already exists, introduction is likely to cause it to exceed the carrying capacity of the habitat; the introduction simply leads to increased mortality of either the introduced or the native population, or of both. A more promising situation exists if a new target site is created with "built in" maturity, or a degenerate site is enhanced. In our case the situation was propitious; the creation of an amphibian reserve in Peterborough, at a site previously unoccupied by amphibians, pre-dated by two years, the destruction of a large toad *Bufo bufo* breeding site 50 miles away in Leicestershire. Frogs *Rana temporaria* and smooth newts *Triturus vulgaris* were available for introduction from local threatened sites and from "surplus" spawn. There was no attempt to include crested newts *Triturus cristatus* because of the presence of fish in the new reserve. If rescue is the primary objective of translocation there is often no choice of the component of the population that is moved; only one life-history stage may be available. There was sufficient warning with the toads so that eggs were available in one year and adults the following year. For the frogs only spawn was available and for the newts only adults.

The Boardwalks Reserve was created in 1985 by the former Peterborough Development Corporation. Of its total area of 6 ha, about 3.5 ha was set aside for amphibian conservation. It is believed that this is the first reserve of this size in Britain to be specifically established for amphibians. Its creation was motivated by the fact that, with the exception of the common frog, all the native British amphibian species appear to be declining (Hilton-Brown & Oldham, 1991). Even for the frog, although there was an increase in many parts of lowland England in the 1980s, probably through its success in garden ponds, large populations in semi-natural habitat, readily accessible to the public, remain a rarity in many areas.

A review by Dodd & Seigel (1991) casts doubt on the effectiveness of RRT (relocation, repatriation and translocation) programmes as a conservation strategy; indeed they could find no recorded instances of success for amphibians (although Reinert, 1991, cites three instances). They emphasize the importance of defining criteria for successful RRT, and of long-term monitoring to determine success, and suggest that success should only be claimed if there is evidence of establishment of "a self-sustaining population" which is "at least stable". In Britain the crested newt has been the subject of nearly 100 translocation attempts in the late 1980's (Oldham, Musson & Humphries, 1991), but with inconclusive results owing to inadequate attention to monitoring. Dodd & Seigel (1991) recommend that introduced toad populations should be studied for 10 to 15 years. However, as pointed out by Burke (1991), stability is dependent upon timescale and no population is indefinitely and invariably stable. Our intention was to establish self-sustaining and relatively stable populations of significant size for two of the introduced species; frogs and toads. For the relocations to be judged successful, the frog population would need to number in excess of 100 adults and the toad population in excess of 1000 adults (Cooke, 1975). We decided to continue monitoring the site each breeding season until the translocations failed or until the populations stabilised. At the end of each breeding season we assessed whether monitoring would continue. This phase of monitoring is now complete and the results are presented in this paper.

In summary, our aims were: (1) to introduce a frog population using spawn, and to monitor its success at the new reserve; and (2) to introduce a toad population, monitor its success and, if possible, compare the relative merits of introducing spawn and adults.

MATERIALS AND METHODS

STUDY SITE

The Boardwalks Reserve is 6 ha site in size and occupies a low-lying marshy area on the north bank of the River Nene near the western edge of the city of Peterborough. A south-facing embankment runs along the entire northern boundary of the site; beyond that is a playing field. The western part of the reserve was designed as a scrape for wading birds, having a single large pool with an irregular edge and four small islands. The remainder of the site, about 3.5 ha, was created for amphibians in 1985 by excavating 13-16 pools (the number depends on the water level). The largest pool measures about 125 x 15 m with the smallest about 2 m across. The river frontage to the amphibian area is roughly 450 m and its width ranges from 70 to 100 m. In several winters the river has inundated the reserve and presumably as a direct consequence, fish have been recorded in most of the ponds. The marsh vegetation is dominated by common reed *Phragmites communis*, reed sweet-grass *Glyceria maxima* and reed canary-grass *Phalaris arundinacea*. Existing willows *Salix* sp. were retained and much tree planting and seeding of the ponds and their edges were undertaken. The vegetation is now managed by the Peterborough Wildlife Group.

TRANSLOCATION

In the spring of 1986 about 200 clumps of frog spawn were introduced, from garden ponds in the Peterborough area, with a further 150 clumps in 1987 (Table 1). In 1986 about half a million toad eggs were transferred from a site due to be opencast-mined in Leicestershire. In 1987, 5911 toads were rescued early in the breeding season from the same site and transferred to the Boardwalks reserve; 5116 were males and 795 females. The distal phalanx of one particular toe was removed from 76% of the toads. The remaining 24% were variously tagged as a result of natural injury or toe-clipping at the donor site in the previous year. Apart from relatively small numbers of smooth newts *Triturus vulgaris* released by the first author and small amounts of frog spawn deposited at the site by the public (eight clumps in 1990, four in 1991 and 14 in 1993), no other translocations were recorded. Such deposited spawn can be readily distinguished from spawn naturally laid (Cooke, 1985).

TABLE 1. Introductions of frog spawn, toad spawn and toads to Boardwalks Reserve.

Year	Frog spawn clumps	Toad spawn (approx. egg no.)	Toad adults
1986	200	500 000	0
1987	150	0	5911

MONITORING

Between 1986 and 1993 the reserve was visited from one to three times per week, from prior to the first spawn being laid until after the spawn had hatched. Monitoring input at other times of year was variable. Routine monitoring visits were always during daylight. In the early years the entire edge of every pool in the amphibian area could be checked easily. All of the edges to all of the ponds were shallow. It was also possible to see into the centre of each pond, water clarity always being good. As freshwater and terrestrial vegetation developed, it became more difficult to check the entire edge of each pond. Any floodwater was thoroughly checked for spawn or adults by wading.

Monitoring of frog reproduction was based on counting spawn clumps. For toads, insufficient time was available to permit mark-recapture estimates of population size during each breeding season. Instead, adults were counted and peak counts for all adults and for pairs were taken as measures of breeding activity that year. An attempt was made to undertake at least one count during peak season for toads during calm, mild and sunny conditions. The duration of the toad breeding season was recorded each year in an effort to assess whether the peak counts were comparable as indicators of the breeding population size. The season was deemed to have started when at least 10 toads were seen in the ponds on a single occasion and to have finished on the last day that new spawn was observed. As an additional measure of population size, particularly of the female component, an index of abundance of toad spawn was devised. The only reference found in the literature to counting strings of toad spawn was that of van Gelder (1973) and this gave no details about the method used. The technique developed at the Boardwalks reserve involved using a cane to probe through ponds to find and estimate spawn strings by gently lifting them to the surface. The estimation was based on being familiar with what appeared to be a single string and then using this knowledge to estimate by eye the content of masses. During the course of the study guidelines were developed. Thus a mass concentrated more or less in 0.2 m^2 was taken to be five strings, whereas a larger mass in 1 m^2 was counted as 20 to 30 depending upon the density of the strings. The total, a spawn count index, was expressed as a range. The technique was developed to make comparisons and was not intended as an absolute measure. One additional comparative use to which it was put was to permit determination of the percentage of spawn lost each year to human collection and other factors. It was of interest to calculate this for both species in view of the huge losses suffered by frogs during the 1970s at a similarly accessible site in the area (Cooke, 1985). The monitoring programme finished in 1993. During that year it was not possible to visit the reserve precisely at peak breeding time for toads, but spawn for both species was still recorded.

From 1988 to 1990 samples of between 100 and 200 toads were caught at the site at night. These were measured (snout to distal tip of the urostyle) and examined for earlier toeclips. Toads already marked were remarked using a "Panjet" and any new toads were marked using a year-specific toeclip. The toe tips removed in 1990 were frozen and a subsample subsequently examined using the technique of skeletochronology described by Hemelaar & van Gelder (1980).

Monitoring also provided a means to enable remedial action to be identified and then taken when necessary during the establishment phase. Examples of this included moving spawn to prevent desiccation, and provision of information on the behaviour of the populations that could be taken into account when planning management of the site.

MONITORING RESULTS

ESTABLISHMENT OF POPULATIONS

No adult frogs or naturally-laid spawn were recorded on the site in 1986 or 1987 (Table 2), but frogs of sub-adult size were seen in 1987. Emergence from the translocated spawn was judged to be good in 1986, with froglets being abundant in mid-summer all over the eastern half of the site. However, in 1987 emergence was evidently much poorer with froglets being hard to find. The population which became established

TABLE 2. Counts during the breeding season (N/A = not available).

Year	Frog spawn clumps	Peak total toad count	Peak count of pairs of toads	Spawn count index
1986	0	0	0	0
1987	0	N/A	N/A	30-50
1988	92	127	6	22-27
1989	162	311	7	29-34
1990	121	181	10	58-63
1991	147	328	34	100-105
1992	117	306	54	105-110
1993	112	N/A	N/A	107-114

was therefore assumed to have resulted from the translocated spawn, especially that introduced in 1986. In 1988 92 clumps were laid naturally (Table 2), indicating that many frogs matured in two years. A peak number of 162 clumps was reached in 1989, since when numbers have ranged 112-147.

In 1986 no adult toads were seen at the site, and no naturally laid toad spawn was noticed (Table 2). The first toad spawn recorded at the site was in 1987, presumably laid at least in the main by the introduced adults; no spawn was recorded that spring until after the first adults had been released. This spawn, as well as that introduced in 1986, produced good numbers of toadlets. Their numbers were not estimated, but in late May 1987 there was a visual assessment of tens of thousands of shoaling tadpoles in one pond and thousands in two others.

In 1988, 64% of a sample of male toads, and 89% of a sample of females, were found to be marked, indicating that the majority of the breeding population was originally from Leicestershire. The unmarked toads were either animals which had grown from the toad spawn introduced in 1986 or were "natives", immigrants from surrounding populations. A histogram of length measurements of these toads (Fig.1) suggests that both explanations might apply, with the smaller unmarked toads up to about 57 mm originating from the 1986 spawn and the few above 58 mm being local immigrants. The recaptured males from the original group, introduced in 1987, were clearly larger animals with mean length 59.4 mm (cf. 55.2 mm for all new males). Only adults were translocated from Leicestershire, so if the minimum adult age is assumed to be two

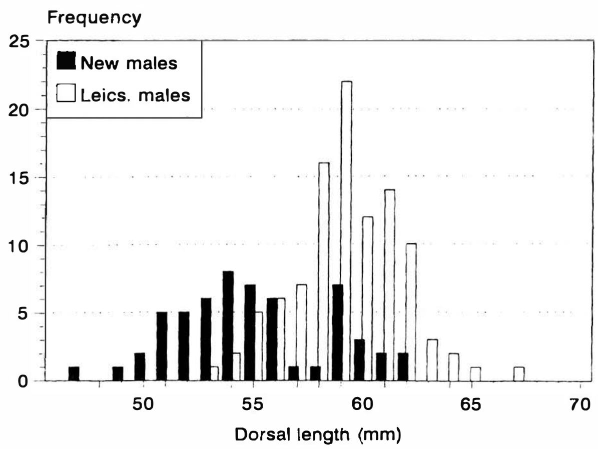

FIG. 1. Length frequency distribution of male toads caught in 1988.

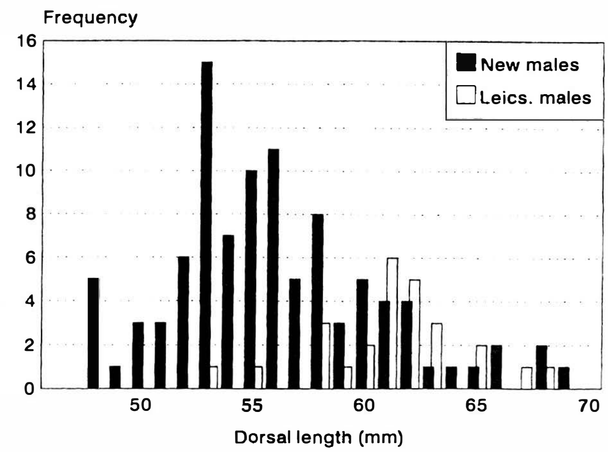

FIG. 2. Length frequency distribution of male toads caught in 1989.

years (Gittins *et al*., 1985; Reading,1991), the recaptured males were at least three years old in 1988. Considerably less spawn was apparent in 1988 than in 1987 (Table 2), probably reflecting a reduction in the female population, not yet augmented by new females developed from the 1986 or 1987 spawn.

The first 'peak count' of toads was derived in 1988 (127 total count including six pairs, Table 2). The use of peak counts as indicators of population sizes in successive years depends upon a comparable profile of breeding numbers during each season; a protracted season might result in lower counts than an "explosive" season. We accepted the peak count as a meaningful indicator of population size because the duration of the season each year was relatively constant, with a range from eight to 14 days (standard deviation of 2.5 days). There was no evidence of an inverse relationship between season length and peak count (r=0.01).

By 1989 only 21% of a sample of males caught comprised marked animals from the original Leicestershire group. Their mean length (Fig.2) was 61.5 mm (cf. 59.4 mm in 1988). The mean length of new males, including those few (2%) marked for the first time in 1988, was 56.8 mm (cf. 55.2 mm in 1988). The range of lengths of the new males had also increased, by 6 mm (48 to 69 mm, cf. 47 to 62 mm in 1988) and there was a complete overlap with the old Leicestershire males at the upper end of the scale. Either there was a disparate rate of growth within the population or there had been an influx of new large males. The wide frequency distribution of the Leicestershire males (Fig.2) adds weight to the former possibility. The smallest members of this founding population were still only 53 mm, yet they were at least four years old. In 1989, although there was little change in the number of pairs counted or the spawn count index, the maximum count of adults (mainly of unpaired males) more than doubled (Table 2). Most of the newcomers may have been males from the 1986 spawn returning to breed as three year olds, perhaps with some two-year-olds from the 1987 spawning.

By 1990 the proportion of recaptures from the Leicestershire group had fallen to 15% of the catch. The new males, including the small proportion (4%) first marked in 1988 or 1989, had an average length of 59.0 mm (Fig. 3), the Leicestershire males 61.4 mm, the length range of the former completely enveloping that of the latter.

Toe samples from 43 males and 16 females of the 1990 captures enabled ages to be estimated. 'New' males ranging between 53 and 62 mm in length had ages estimated between two and five years (Fig. 3) whilst eight of the founding population, between 56 and 64 mm, had ages between five and seven years. No allowance was made in the age estimation technique for the possibility of bone resorption (Hemelaar & van Gelder, 1980; Gibbons & McCarthy, 1983), so some of the ages may have been underestimated. Overall, for the males, although there was a significant correlation between estimated age and length (P<0.001), only 31% of the variation in length could be ascribed to age. There were several deviations from a straight line relationship (Fig. 3); two individuals had apparently achieved 57 mm in just two years, whilst at the other extreme a six year old was only 56 mm. All of the new males, except two, could have originated from Boardwalks spawn: the four-year-old animals from the spawn introduced from Leicestershire in 1986; the three- and two-year-olds from spawn laid in 1987 and 1988, respectively. Only the two five year old animals (56 & 61 mm, Fig. 3) would seem to have originated from a local site prior to the creation of the reserve. Ages of 16 unmarked females caught in 1990 were determined as three years (nine animals), four years (6) and five years (1). For the females there was no significant correlation between length and age. The smallest and largest females (67 and 85 mm, respectively) were each estimated to be four years old. The five-year-old animal was 77 mm long.

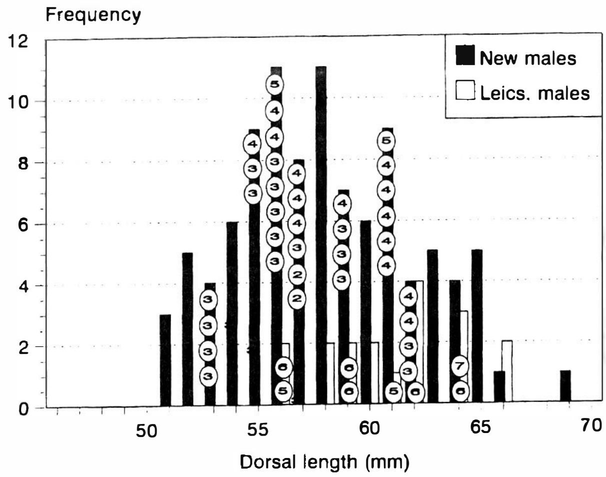

FIG. 3. Length frequency distribution of male toads caught in 1990. Ages of 43 males, estimated using skeletochronology, shown against the appropriate length.

The spawn count index in 1990 showed a considerable increase on 1989 (Table 2), probably a reflection of recruitment of females developed from the 1986 and 1987 spawn.

After 1990 no further captures were made to check for marked toads. There was a major increase in the spawn count index in 1991, coupled with an increase in the peak counts of adults and of pairs (Table 2). Although there was a comparable increase in the peak count of pairs from 1991 to 1992, increases in the spawn count were negligible in 1992 and 1993 (Table 2). It is possible that the population size had more-or-less stabilised by 1993.

Application of Jolly's mark, release and recapture method of population size determination (Blower *et al.*, 1981) to the male segment of the population between 1987 and 1989, if it is assumed that there were no native animals at the site in 1987, suggests the population and survival values shown in Table 3. There are large standard errors, especially for the 1989 estimate, a reflection of the relatively small samples taken (116 to 159) compared to the number originally marked. Tentative ranges of estimates for 1990 to 1992 are obtained by back calculation from the peak count records of males. We felt justified in this extrapolation since the ratios of peak count to population estimate for 1988 and 1989 (1:19 and 1:24, respectively) are reasonably consistent.

Table 3 also includes estimates of the founding population for males in the first three years following introduction. These are obtained from the ratio of marked to unmarked animals caught in the samples in these years. The proportion of recaptures declined each year, partly because of dilution by new recruits and partly because of mortality or emigration. The results indicate high mortality or emigration in the first year when there were losses of 64%, but reduced mortality or increased site fidelity thereafter; during the second year there was only a 39% loss and even in the third year the loss, estimated at 42%, was still not as high as in the first year, despite the fact that by this time the toads were at least five years old.

TOAD SPAWN ESTIMATION TECHNIQUE

For the period 1988-1992 mean spawn count index was significantly related to the peak count of pairs (P<0.01): $\log_{10}$ mean spawn index = 0.98 + 0.64 $\log_{10}$ peak count of pairs. The ability to find spawn was tested in 1989 and 1992 by netting and searching ponds for toad tadpoles in mid-May. During the springs of 1989 and 1992 there was a combined total of 27 separate water bodies. The ten in which spawn had been recorded earlier contained tadpoles in May. Six ponds in which unpaired toads had been recorded and nine others with no records of toads did not appear to contain tadpoles. However, the remaining two ponds (in which adults had been recorded, but no spawn) did

TABLE 3. Annual male toad population estimates. a, known no. introduced; b, Jolly's method; c, from peak count; d, from ratio in sample.

Year	Est. population size	Survival	Peak count	Founding pop. size	Founding pop. survival	New adults in population
1987	5116 [a]			5116 [a]		
		36%[b]			36% [b]	
1988	2890±1420 [b]		121	1840 [b&d]		36% [d]
		66%[b]			61% [d]	
1989	5620±4140 [b]		304	1120 [d]		79% [d]
					58%[d]	
1990	3180-4100 [c]		172	650 [d]		85% [d]
1991	5430-7010 [c]		294			
1992	4660-6010 [c]		252			

contain tadpoles in May. Thus 25 (93%) of the 27 ponds gave the expected qualitative result. Some toad tadpoles were also found in the wader scrape in 1992; although adults were recorded there in the breeding season, no spawn was ever found. Occasionally adult toads were noted in the river, but no spawn or tadpoles were recorded.

The data in Table 2 and the equation above indicate that the ratio, *spawn count index: maximum pairs*, decreases as the pair count increases. For example, from the equation: when the pair count = 5, then spawn index = 27 and ratio = 5.4 and when the pair count = 50, then spawn index = 117 and ratio = 2.3. If the counts are a genuine reflection of numbers present, this relationship suggests that the spawn count technique is less satisfactory as the density of spawn increases; or alternatively pairs may be easier to observe at higher population density. A similar relationship existed on an individual pond basis for water bodies in which both pairs and spawn were recorded between 1990 and 1992 ($n = 15$, $P<0.01$): $\log_{10}$ mean spawn index = 0.71 + 0.63 $\log_{10}$ peak count of pairs.

FATE OF SPAWN

Collection and desiccation proved the most serious forms of loss for frog spawn (Table 4). The only instances of a different type of loss was minor hatching failure in 1992 and 1993. Floodwater was available outside the confines of the ponds in 1988 and 1990, and in those two years frogs laid 88 and 12% of their spawn respectively in the floodwater. In 1988 the first author moved this spawn to deeper water; the floodwater dried out during the tadpole phase. The desiccation losses of spawn in 1990 were almost entirely due to floodwater disappearing during the spawn phase. In 1991 the spawn season coincided with a deliberate lowering of the water level in the River Nene by about 2 m in order to remove rubbish. The ponds are all within 100 m of the river bank. The local water table was evidently affected severely, with the levels in the ponds falling by 0.3-1.0 m depending on their location. As the levels receded, spawn became stranded. Without intervention, 74% of the spawn would have been lost; however, pushing spawn into deeper water restricted losses to 13-16%. Losses, assumed to be due to collection, occurred each year and ranged from 3% to 12%, with an overall loss of 8%.

Unlike frog spawn which suffered some losses every year, toad spawn had no recorded losses in three years out of seven (Table 4). Overall percentage loss of toad spawn did not, however, differ greatly from that of frog spawn. In 1990 up to 12% was lost through being deposited in the shallow edges of ponds in which the water level went down. Partial desiccation resulted in a further unquantified amount of spawn suffering fungal attack. Up to 13% was taken or broken up by people or other animals in the same year. In 1991 desiccation losses of about 31 to 39% occurred following the sudden lowering of the water level in the river (see above). Without intervention these losses may have reached 78%. Actual losses to desiccation in 1991 were thus at least twice as high as losses of frog spawn; the fine strings of toad spawn with a higher ratio of surface area: volume appeared less robust to desiccation stress. In 1993, 31 to 42% of the toad spawn suffered a low hatch rate following fungal infection.

CONCLUSIONS

Many frogs evidently matured in two years as there was substantial spawning in 1988 following the initial

TABLE 4. Percentage of spawn lost through various causes. (* = some loss due to fungal attack, not quantified).

Year	FROG SPAWN				TOAD SPAWN			
	Desiccation loss	Loss to humans	Fungus, low hatch	Total	Desiccation loss	Loss to humans	Fungus, low hatch	Total
1987	-	-	-	-	0	0	0	0
1988	0	8	0	8	0	7-9	0	7-9
1989	0	6	0	6	0	0	0	0
1990	12	10	0	22	11-12	12-13	*	23-25+
1991	13-16	12	0	25-28	31-39	0	2	33-41
1992	0	3	1	4	0	0	0	0
1993	1	0	2	3	0	0	31-42	31-42

introduction of spawn in 1986. This seems to be typical for introductions to good areas in lowland Britain (Beebee, 1980, 1986; Cooke, 1981). Beebee (1986) describes an introduction to a garden which took five years to attain peak numbers. This contrasts with the Boardwalks, where peak numbers were reached three years after the first introduction of spawn. Spawn introductions at the Boardwalks may have been sufficient for the carrying capacity of the environment to have been quickly attained, especially in view of the good metamorphosis in 1986. Amounts of spawn introduced in 1986 and 1987 were roughly comparable to amounts laid at the site later.

Assuming that all of the frog spawn was found, that an adult female frog lays one clump of spawn per annum and that there is a sex ratio of unity (see Savage, 1961; Blackith & Speight, 1974; but contrast Oldham, 1963; Heusser, 1970), the adult frog population numbers 200-300. Thus we achieved our aim of establishing a frog population with >100 adults. Based solely on the core area of the amphibian reserve, this represents a density during the breeding season of 60-90 adults/ha, but presumably they forage at other times of year into the wader scrape area and more widely too. The nearest spawn to the Boardwalks was found 400-500 m away.

The data on toad sizes (Figs. 1-3) and age distribution (Fig. 3) suggest that most of the population characteristics at the site were the result of introduced toads or of introduced spawn, with little contribution from toads native to the vicinity of the Boardwalks Reserve. The population fluctuations indicated by the data in Tables 2 and 3 can, to an extent, be explained on the basis of the difference between cohort success in successive years. The 1987 adult introductions (made up of a series of cohorts beginning life before 1986) provided large numbers of animals, but their success was limited partly because of the high male:female ratio (6.5:1) and partly because of high attrition, whether through mortality or emigration. On the other hand the cohorts starting in 1986 and 1987, when there were good numbers of eggs and evidence of high metamorph production were apparently very successful. The 1988 adult population was a small one because the introduced adults had substantially dispersed and there was still low recruitment from the 1986 cohort. Numbers of breeding females were particularly low in 1988. By 1989 the effect of recruitment from the two successful years (1986 and 1987) was probably having an impact, but mainly on the males. In Britain the age at which male toads attain sexual maturity is given as 2-3 years (Gittins, Kennedy & Williams, 1985), 3-6 years (Reading, 1988) and 2-6 years (Reading, 1991). For female toads, data are 3-6 years (Gittins *et al*., 1985) and 4-6 years (Reading, 1991). The increases in females after 1989 (Table 2) is consistent with them taking longer to reach maturity. By 1990 female numbers were increasing but the males were being affected by the poor 1988 cohort. In 1991 and 1992 both sexes were on the increase, but not dramatically so, either because of the continuing dampening effect of the 1988 cohort or alternatively because the population was close to the habitat's carrying capacity.

A total of 6000 male toads exceeded our establishment criterion of 1000 adults and represents approaching 2000 per hectare in the core area during the breeding season. But the toads clearly forage further afield after breeding; in the current study dead ones were found up to 400 m from the breeding ponds.

There was some loss of frog spawn to collection each year, the overall loss being 8%. This is similar to 7% collected at St Neots Common 1981-3, but is much less than the 24% recorded as collected at St Neots 1973-80 (Cooke, 1985). During the 1970s, St Neots Common was the best known site for frogs in the old county of Huntingdonshire, and was frequently raided by people requiring spawn for garden ponds. During the 1970s and 1980s, the establishment of frog populations in garden ponds probably resulted in general increases in frog numbers in suburban areas throughout lowland England (Cooke & Scorgie, 1983; Hilton-Brown & Oldham, 1991). Consequently the collection pressure has probably eased on large populations to which the public has access. Indeed, in 1987 and 1988 it proved relatively easy to find 350 clumps that were regarded as surplus in gardens in the Peterborough area for the initial stocking operation at the Boardwalks. During the period 1988-93, 26 clumps were deposited at the site by the public.

This is the first time that spawn losses for toads have been quantified. No loss was observed in three of the seven years but overall loss of toad spawn was similar to that of frog spawn. Desiccation, collection or destruction by humans and hatching failure were the factors recorded as responsible for greatest loss of toad spawn, but the deliberate lowering of the level of the River Nene represented an unusual local factor. Those responsible were notified of the implications of the lowering of the river and this operation was done about one month later in 1992 with no detrimental consequences being observed.

In 1993 there was significant hatching failure of toad spawn associated with fungal attack. Blaustein, Hokit, O'Hara & Holt (1994) documented even greater egg losses to the fungus *Saprolegnia ferax* in a population of the western toad *Bufo boreas* in Oregon. They speculated that such pathogens may be important in amphibian population declines worldwide. At the Boardwalks, however, major fungal infection has happened only sporadically.

For toads two methods of introduction were used; a large input of spawn in 1986 and a massive input of adults in 1987. It is difficult to unravel the relative contributions of each of these to the eventual success of the Boardwalks population. However, the evidence suggests that the adult introductions were relatively unsuccessful, with 64% loss of males in the first year. The eventual establishment of the population probably depended upon recruitment from the two sets of spawn in 1986 and 1987. It was not until the females from these cohorts became mature that the population began to stabilise. On the basis of the current study, we suggest the introduction of spawn on three successive years, given suitable habitat, as a means of establishing a viable toad population.

In conclusion, these introductions have succeeded in their primary aim of establishing frog and toad populations of reasonable size where they can be readily seen and enjoyed, especially when breeding, in attractive semi-natural surroundings. They contribute two instances of monitored translocation success, to add to the few available in the literature. The Boardwalks Reserve was declared a Local Nature Reserve in 1991.

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