How many frogs are killed on a road in North-east New South Wales?

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ABSTRACT

Road impacts on Australian frogs are poorly documented. This limits our ability to predict which species may be vulnerable to impacts and to develop strategies for mitigating impacts. We conducted foot-based surveys for road-killed frogs along two 100-m sections of a road that traverses known frog habitat near Lennox Head, in north-eastern New South Wales. More than 1000 dead frogs were counted over 13 mornings. Two threatened species, the Wallum Sedge Frog *Litoria olongburensis* and the Wallum Froglet *Crinia tinnula*, accounted for at least 60% of these road-kills. It is estimated that in an average summer period, there would be >40,000 frogs killed on the 4-km span of road through the heathland habitat. That is, >10,000 road-kills of each of the Wallum Sedge Frog and Wallum Froglet. Research is needed to ascertain how severe this impact is on these isolated populations and to determine how road mortality of frogs can be minimized.

Key words: frog road-kills, Wallum Sedge Frog, *Litoria olongburensis*, Wallum Froglet, *Crinia tinnula*

Introduction

Interest in the potential impacts of road mortality on vertebrate wildlife has grown steadily during the last decade (e.g. Fahrig *et al.* 1995; Foreman and Alexander 1998; Jones 2000; Taylor and Goldingay 2004). Much of this attention has been focused on mammalian fauna. To a large extent this is understandable because many species that are frequent victims of road-kill are quite large (e.g. ungulates, kangaroos), causing severe damage to vehicles, and injuries and death to occupants (Groot Bruinderink and Hazebroek 1996). This has led to the development of strategies, such as the installation of road underpasses and exclusion fencing, to minimize impacts on wildlife and vehicles.

Amphibians are more severely threatened globally than birds or mammals (Stuart *et al.* 2004). This should prompt biologists to consider road impacts on this wildlife group. To date, few studies have assessed road effects on amphibians. In Europe and North America, roads may restrict gene flow among local populations of frogs (Reh and Seitz 1990), and lead to negative associations with roads (Vos and Chardon 1998; Findlay *et al.* 2001) or traffic volumes (Fahrig *et al.* 1995; Carr and Fahrig 2001; Pellet *et al.* 2004). Gravel roads in forested areas may not affect frogs but appear to have a negative influence on salamander abundance and movement (deMaynadier and Hunter 2000).

In Australia, no similar studies have been conducted and there have been few published attempts to quantify frog road-kills. Ehmann and Cogger (1985) described single night surveys on four roads (two in Western Australia; two in New South Wales) from which they extrapolated to an annual road-kill across all of Australia of 4.45 million frogs. Taylor and Goldingay (2003) recorded 55 frog road-kills during a walked survey along a 1.4 km section of road in north-east New South Wales (NSW) on one wet night. In contrast, Taylor and Goldingay (2004) recorded a single frog during a 20-week driven road-kill survey of a 100-km road circuit. They concluded that driving surveys are inappropriate for small-bodied animals (see also Slater 2002).

It is clear that there is a substantial gap in our understanding of the impacts of roads on Australian frogs. It is impractical to conduct foot-based transects over large distances and across sites that do not offer potentially suitable habitat for frogs so it is appropriate to target specific sites. It is also of interest to know whether threatened species may be particularly frequent victims of road-mortality. In this study we chose a road in north-east NSW that traversed the habitat of two threatened frogs; the Wallum Sedge Frog *Litoria olongburensis* and the Wallum Froglet *Crinia tinnula*. The aim of our study was to determine the number of frogs of different species that were killed on this road.

Methods

The study area was located on the Coast Road between Lennox Head and Byron Bay (Fig. 1), approximately 5 km north of Lennox Head (28º 46'S, 153º 35'E). The habitat adjoining each side of the road is comprised of wallum heathland (see Griffith *et al.* 2003). The road traverses this habitat for approximately 4 km. The area is known to contain a large population of Wallum Sedge Frogs (Lewis and Goldingay 2005) (Fig. 2) and Wallum Froglets (Fig. 3) (Goldingay unpubl. obs.). Scattered through the heathland are many shallow sedge swamps that are preferred by sedge frogs (see Lewis and Goldingay 2005). The broader area is continuous with an area to the west known as the Newrybar Swamp, much of which has now been converted to sugar cane plantations.

Figure 1. A view of the Coast Road at Lennox Head. Photo: R. Goldingay.

Figure 2. A road-killed wallum sedge frog *Litoria olongburensis.* A significant population of this species occurs in the area. Photo: R. Goldingay.

Figure 3. Two individuals of wallum froglet *Crinia tinnula* killed on the road. Often the disintegrated remains could only be assigned to *Crinia sp.*. Photo: R. Goldingay.

Two 100-m transects were marked out along the side of the Coast Road. These transects were located 2.3 km apart and each was at least 500 m from the southern and northern boundary of the heathland. Each of the transects was traversed in the early morning after a night of rain or when there had been heavy rain the day before. Two preliminary surveys revealed no dead frogs on the road after 24 h periods without rain. The road transects were surveyed by slowly walking beside the road and looking for any dead frogs between the edge of the bitumen and the center of the road. One road half was walked in one direction and then the other half was traversed in the opposite direction. Any stains or irregularities on the road surface were investigated. All frogs or remains were counted and identified as far as possible. Surveys commenced before first light with the aid of a 50-watt spotlight so both transects could be surveyed before traffic frequency became too great, making it difficult to adequately survey the road surface and degrading frog carcasses beyond which they could be identified. This also allowed the surveys to be completed before Torresian Crows *Corvus orru* were able to remove any carcasses. These birds commonly patrolled along the road in the early morning. Slater (2002) cautioned that various factors including census technique, road traffic and scavengers can lead to severe underestimates of road mortality.

The Wallum Sedge Frog may be the frog species most vulnerable to population impacts from road-kill in the study area. Its habitat requirements are more specialised than that of any other local species (see Barker *et al.* 1995; Lewis and Goldingay 2005) and its habitat very restricted, which may lead to a smaller local population. On 5 March 2001, one additional survey was conducted to assess whether road-kills of this species were concentrated on our two transects or distributed along a much broader length of the road. This would indicate how representative the road-kill tally for the two census-transects was for this species. This survey was conducted along the eastern side of the road only (i.e. only half the road was examined). Sedge frogs were recorded along 15 road segments, each 50 m in length, with at least 100 m between adjacent segments. These segments did not include the two regular transect areas, but which were also surveyed for comparison.

We assessed whether Sedge Frog road-kills were dominated by dispersing subadults. Over the course of the survey, we classed sedge frog road-kills as subadults if <15 mm in length or adults if >15 mm, providing a carcass was sufficiently intact to enable its size to be assessed. We obtained long-term rainfall data for Ballina Airport from the Bureau of Meteorology. This allowed us to estimate the average number of wet days/nights that occur between 1 December and 31 March each year. We defined a wet day/night as one in which at least 5 mm of rain were recorded.

Results

Surveys conducted on 13 mornings revealed that 1029 frogs of eight species were killed on 200 m of the Coast Road (Table 1). Frog road-kills were observed in various states of dismemberment. Many were fully intact, many were partially dismembered (Fig. 4) and many occurred simply as a small piece of squashed tissue. The latter could often still be identified because the attached dorsal skin

Table 1. Number of road-killed frogs at Lennox Head in 2000/2001. Frogs not assigned to a species could not be identified beyond the designated group. *only *Litoria olongburensis* scored in the two transects on 2/2/01 (included in total in brackets). - = none identified.

Survey Date	29 Dec	21 Jan	30 Jan	1 Feb	*2 Feb	4 Feb	17 Feb	18 Feb	20 Feb	5 Mar	6 Mar	9 Mar	10 Mar	17 Mar	Total
Frog species															
Litoria olongburensis	1	1	1	22	68	8	59	20	30	37	23	16	20	5	**311**
Litoria freycineti	-	-	-	9		-	-	-	-	-	-	-	-	-	**9**
Litoria fallax	-	-	1	-		-	-	-	-	-	-	-	-	-	**1**
Crinia tinnula	4	-	-	11		-	20	11	15	1	6	8	28	12	**116**
Crinia sp.	-	3	-	28		-	67	20	27	12	3	25	64	10	**259**
Limnodynastes terraereginae	-	-	-	3		10	4	2	-	-	-	2	12	1	**34**
Limnodynastes peroni	-	1	-	1		-	1	-	-	-	-	1	8	1	**13**
Limnodynastes sp.	-	1	-	-		-	-	-	-	-	-	7	2	1	**11**
Pseudophryne coriacea	-	1	-	-		-	-	-	-	-	-	-	-	-	**1**
Non-tree frogs	9	1	2	58		-	50	1	8	9	9	18	41	7	**213**
Tree frogs	1	-	-	-		-	-	-	-	-	-	-	-	-	**1**
Unidentified frogs	29	-	2	-		2	17	7	6	5	5	8	34	7	**122**
Total	**44**	**8**	**6**	**132**	**68**	**20**	**219**	**61**	**86**	**64**	**46**	**89**	**211**	**44**	**1029 (1097)**

Figure 4. A road-killed wallum sedge frog *L. olongburensis*. The legs of this species are distinctive and often that was all that remained. Photo: R. Goldingay.

Figure 5. A brown-striped frog *Limnodynastes peroni*. Photo: R. Goldingay.

could be unfurled and a pattern identified. However, of the total number of frog road-kills observed, 31% could not be identified.

The species with the largest number of road-kills was the threatened Wallum Sedge Frog, though this species was surveyed by itself on one extra morning that produced the highest count for this species. This species was readily identified, even in highly dismembered carcasses. The skin from the flank and the thigh are highly distinctive (see Barker *et al.* 1995) and one or the other could be identified. Few if any of the unidentified frogs would have included this species. Road-killed sedge frogs were predominantly adults. Only 5 of 104 assessed were classed as subadults.

The threatened Wallum Froglet was the next most commonly recorded road-kill (Table 1). The number of road-kills of this species is likely to actually exceed that of the sedge frog because 259 carcasses could not be positively identified as *C. tinnula* so were recorded as *Crinia* sp. The Eastern Froglet *Crinia signifera* is known from the area, but only the calls of the Wallum Froglet were ever heard during this survey. There was also a large number of skins with toes attached that were recorded as non-tree frogs and many of these are likely to have been Wallum Froglets. The Northern Banjo Frog *Limnodynastes terraereginae* was the only other frog killed in relatively high numbers. Due to its large size (length >50 mm) and reddish colour in the groin, few if any would have featured among the unidentified frogs. A small number of Brown-striped Frogs *Limnodynastes peroni* was detected (Fig. 5).

The average number of frog road-kills for the 13 nights when all frogs were counted was 79.2 ± 19.3 (± s.e.) frogs per night. This equates to 1584 frogs per night for the 4-km section of road. We recorded an average of 6.5 ± 2.1 sedge frogs per 50-m half road segment (i.e. 26.0 ± 8.4 per 100 m of road) along the total length of the road where it traverses heathland habitat. Only two of the 15 segments did not contain sedge frogs. A 50-m half road segment in each of the two census-transects on the same morning averaged 4.5 sedge frogs. This demonstrated that the sedge frog road-kills extended along the total 4-km length of the road and that the two census-transects were representative. The mean of these two 100-m transects over the 14-night period for this species was 11.1 sedge frogs per 100 m per night. This suggests that 444 sedge frogs were killed along the 4 km of road per wet night.

Discussion

There are few published data on frog road-kills from detailed surveys. In Canada, >1700 frogs were reported killed per km near wetlands (Ashley and Robinson 1996, cited in Carr and Fahrig 2001). Fahrig *et al.* (1995) reported 4 dead frogs per km over 6 nights using a car-based survey method. Hels and Buchwald (2001) recorded 227 and 113 road-killed frogs and toads per km during 85 and 102 days of monitoring in consecutive years. Their control monitoring suggested that these counts underestimate the total number killed by at least 60%.

We provide the first detailed account for Australia. Extrapolating from our data suggests that 396 frogs were killed per km on each wet night in summer at Lennox Head. The long-term rainfall data suggest there would be an average of 27 wet nights/days during the summer period (Dec-Mar). We have assumed that road crossings occur predominantly under such conditions in summer and so have not attempted to incorporate values for other seasons. This assumption requires investigation. We estimate there would be 42768 (± 10422) road-killed frogs for the 4 km of road for a summer of 27 wet nights/days. This would amount to 10,093 (13-night mean x 27 nights) road-kills of the threatened Wallum Sedge Frog and it appears that 95% of these are adult frogs. It is unknown what impact this would have on the local sedge frog population. This species is quite specific in its habitat requirements with the nearest population about 8 km away (see Lewis and Goldingay 2005). We believe that most road-kills assigned to *Crinia* sp. were Walllum Froglets so the number of this threatened species killed over 27 wet nights would exceed 10,000 frogs. Detailed population censuses over several years are needed to determine the severity of the impact of this road mortality on these species. Such surveys would enable an assessment of the size of the local populations and therefore how robust they might be.

Our study was targeted at a location of known frog habitat. Many further studies of this kind are needed to assess the likely impacts of roads on frogs. The Green and Golden Bell Frog *Litoria aurea* is a species that occurs near many urban locations (White and Pyke 1996; Goldingay and Lewis 1999; Goldingay and Newell 2005) and its populations are likely to be affected by road-kill (e.g. Daly 1996). The effects of this on local population dynamics should not be ignored, particularly where small populations are involved.

Carr and Fahrig (2001) argued that amphibians are sensitive to road-kill because they readily attempt to cross roads and are slow moving. They hypothesized that amphibians may differ in their susceptibility to road mortality based on differing vagility. They suggested that habitat use may influence this; some species may disperse along drainage lines and therefore bypass roads, whilst others cross directly over roads. Unfortunately, little is known about the dispersal behaviour of Australian frogs. This would be a rich area for further research.

Several northern hemisphere studies have demonstrated a negative influence of roads on frog populations (Vos and Chardon 1998; Pellet *et al.* 2004). Roads with high traffic volumes are associated with low abundances of frogs (Fahrig *et al.* 1995; Carr and Fahrig 2001), presumably due to high road mortality. This can lead to genetic structuring of populations when roads create a barrier effect for some species (Reh and Seitz 1990).

Findlay and Bourdages (2000) suggested that there are time lags in impacts, possibly as long as several decades, associated with road construction near wetlands. A corollary of this is that if road traffic volume increases over time, as is likely to be occurring at Lennox Head, the impact will not be immediately detectable and may push the population beyond a sustainable level.

How should we reduce this kind of impact on frogs? Fahrig *et al.* (1995) suggested using either underpasses with barriers on the roadway or increasing the traffic volume on a few existing roads. The latter seems impractical if existing roads are threatening particular populations and with the increased use of roads in Australia, road impacts on wildlife will only increase. The use of underpasses seems the most logical way to proceed and has also been suggested by Reh and Seitz (1990). Indeed, most new highway construction in NSW incorporates wildlife underpasses and exclusion fencing (e.g. Taylor and Goldingay 2003). However, this kind of mitigation is currently ineffective for frogs. The fencing used has a mesh size that frogs can readily penetrate. Some type of sheeting needs to be added to the bottom of the fence, but this may not stop tree frogs. This was demonstrated by Dodd *et al.* (2004) who found that neither a metal barrier fence nor a concrete wall was sufficient to stop tree frogs entering the road-way. Further, it has been demonstrated that frogs living adjacent to concrete box culverts under a highway avoided using them, yet traversed a 3 m high embankment to cross the road surface (Taylor and Goldingay 2003). Placing rocks and gravel along the culvert floor may assist in creating a more amenable microhabitat and encourage frog thoroughfare. Lesbarreres *et al.* (2004) demonstrated in behavioural trials that several species of frogs and toad showed a preference for soil-lined compared to bare concrete tunnels. Trials are needed to determine whether a specific fence can be effective to exclude frogs from the road surface and whether a culvert floor substrate can facilitate thoroughfare. If further studies demonstrate that the level of road-kill on frogs at Lennox Head is not sustainable then culverts should be installed in conjunction with barrier fencing.

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