Causes of mortality and bodily injury in Grass snakes (*Natrix natrix*) from the 'Stawy Milickie' nature reserve (SW Poland)

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FRAGMENTATION and pollution of the natural environment, together with the expansion of urban conurbations, are generally assumed to be among the major causes of population decline in various vertebrates (Dodd, 1987). Much attention has been paid to the threats posed to populations of small, seasonally migrating species by the ever increasing density of road traffic (Dodd, 1987; Bonnet *et al.*, 1999). In particular, many articles relate to the spring migrations of amphibians (e.g. Fahrig *et al.* 1995; Buchwald & Hels, 2001; Jędrzejczyk & Radwańska, 2002). However, the mortality of snakes on roads has not been so intensively studied (e.g. Spellerberg, 1975; Bernardino & Dalrymple, 1992; Rosen & Lowe, 1994; Tucker, 1995; Bonnet *et al.* 1999).

Apart from the dangers faced by reptiles – in particular snakes – associated with the development of road transport, there is also a danger of intentional killing, since these are the species which arouse the most negative feelings amongst humans (Dodd, 1987; Pupina & Pupinsh, 2002).

The Grass snake (*Natrix natrix* L.) is one of the most well known European reptiles. Although it is one of the most common European snakes, it has been in decline over a long period in many regions (Spellerberg, 1975; Zuiderwijk *et al.* 1998; Sura & Zamachowski, 2003). This article presents the results of research concerning the influence of potential predators and humans on the Grass snake population from the 'Stawy Milickie' nature reserve.

MATERIALS AND METHODS

Study area – The research was carried out on the terrain of the ornithological reserve 'Stawy Milickie' (51°31'51" N; 17°20'12" E). This area is made up of a complex of lakes separated by dykes, on which there is a road. The dykes are overgrown with grass and in some places by rushes and small trees. Rubble and stacks of dry branches and reeds, which are used to strengthen the dykes, provide additional cover. Intensive carp farming is carried out in the lakes; however, since this is a nature reserve, human activity is subject to various constraints (e.g. the felling of trees, lighting of bonfires and tourist access is prohibited). The reeds growing on the dykes are cut down systematically once every few years and this is carried out either in late autumn or winter. The reeds are never all cut down at once, due to the need to protect the local fauna, particularly birds.

Field studies were carried out in 2001 and 2002 from the end of April until the end of September. Snakes were captured between 08:00 and 11:00 hrs and between 16:00 and 18:00 hrs, since they were most active in these periods. Observations were carried out at least once every two weeks, commonly more often. The Grass snakes were captured, measured to the nearest millimetre and marked by clipping ventral scales (Borczyk, 2000). All visible scars and bodily injuries were noted and some photographed. Fisher's exact test was used to test whether there was an association between the appearance of scars or injuries and sex. The road mortality index for snakes was taken to be the number of snakes killed per day per kilometre of road (Tucker, 1995).

RESULTS

One hundred and four snakes were marked and additional 18 dead individuals were collected. In the cases of mortality that could be attributed to human action in the research area, the vast

Sex/age group	Cause of death	SVL (cm)
j	DOR	15.6
j	DOR	17
j	DOR	18.7
j	DOR	19
j	DOR	22
j	DOR	25
j	DOR	27.5
j	DOR	28
m	DOR	31
m	DOR	38.5
m	DOR	43
?	DOR	>50
m	DOR	54
m	Human activity (intentional)	57
f	Plugged eggs	59
f	Choked on fish	63
f	DOR	71
?	Animal predator	Tail and vertebrae fragment

Table 1. Causes of mortality in Grass snakes (*Natrix natrix*) from 'Stawy Milickie' reserve. DOR - dead on road, j - juvenile, m - male, f - female.

majority were road deaths heavily skewed towards small snakes (Tab. 1). The road mortality index in the investigated population was 0.27 snakes/km/day.

Most scars and injuries were visible in the region of the tail (11 individuals; fig. 1) and head (5 individuals). Only two individuals had injuries in other areas of the body.

No statistically significant difference between the sexes was observed in the appearance of scars and other injuries (p = 0.5426). Amongst those snakes, which had survived the attack of a predator, only one was a juvenile (25.8 cm). The remaining individuals were at least 48 cm long (Table 2).

DISCUSSION

On the basis of research carried out in Illinois, Tucker (1995) stated that the road mortality rate of snakes was 0.198 snakes/km/day. He suggested that such high mortality resulted from the floods, which at that time covered lower lying land and forced snakes to migrate. The road mortality rate I observed was even higher and amounted to 48,6 snakes/km/year on the assumption that the snakes are active for 180 days per year (6 months). This estimate is approximately twice the figure of 22.5 snakes/km/year reported by Rosen & Lowe (1994) and still could be an underestimate because some snakes were certainly removed from the road by predators or people before I found them (see Rosen & Lowe, 1994 for discussion of this issue).

The home ranges of Grass snakes are relatively large and can cover up to 30 ha (Madsen, 1984) and daily a snake can cover distances of up to 230 m (Nagy & Korsós, 1998). Thus, snakes migrating in search of food, a mate, or a place to lay eggs, often have to cross the roads running through their home range, which exposes them to the danger of death due to a road accident. Although there is relatively little traffic on the roads running through the nature reserve, the deaths of many Grass snakes are caused by road accidents. It may seem paradoxical, but it may be the case that more snakes die on roads where there is very little traffic. Possibly this is due to the fact that reptiles naturally steer clear of roads with heavy traffic, or that snake populations living near busy roads have significantly decreased. Moreover, snakes that are startled in open terrain sometimes do not flee at all, but remain fixed to the spot or take up a threatening pose (Borczyk, unpublished). In open areas, such as a road, snakes are visible to avian and other predators. The less they move the more cryptic they are, but the longer they are on the road, the higher the probability that they will be killed by vehicles. A common explanation of why snakes stop on the roads is thermoregulation (e.g. Rosen & Lowe, 1994), but the issue seems to be more complex (Shine *et al.*, 2004).

Forman & Alexander (1998) stated that at present far more vertebrates are killed by road accidents than by purposeful means (hunting, population control). They argue that mortality caused by road accidents may not have a significant influence on the populations of common species at a global level. They give the

Sex/age group	Injuries	SVL (cm)
j	Scars on whole body	25.8
m	Scars on head	48
m	Scars on head	50
m	Scars on head	53
m	Broken tail	54
m	Scars on tail and spine; deformed tail	55
m	Wound around the cloaca; broken tail	55.5
m	Scars on tail	55.7
m	Scars on belly	56.5
m	Scars on head	58.5
f	Broken tail	68
f	Wounded tail	70
f	Broken tail	73
f	Broken tail	75
f	Scars on head	75.5
f	Broken tail	75.5
f	Broken tail	77
f	Broken tail	80

Table 2. Bodily injuries of Grass snakes (*Natrix natrix*) from 'Stawy Milickie' reserve. j - juvenile, m - male, f - female.

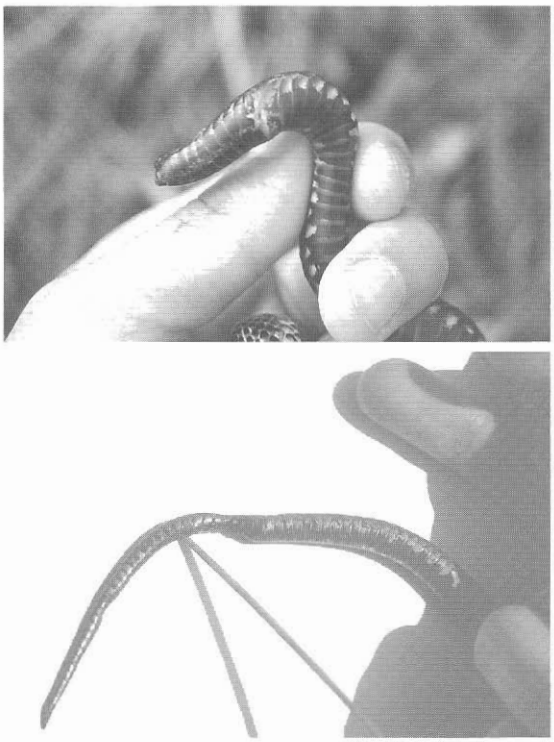

Figure 1. Examples of broken and deformed tails of Grass snakes (*Natrix natrix*) from 'Stawy Milickie' reserve.

example of the Sparrow (*Passer domesticus*), which is one of the most common victims of road accidents in the British Isles, but the population shows no sign of decreasing. This may be explained by a high birth rate, which compensates for mortality on the roads. New generations of birds migrate and inhabit the areas in which there is a high mortality rate. Mortality on the roads can have a significant impact on a population at a local level. This is an important observation, especially in the case of snakes, whose ability to migrate is far inferior to, for example, that of a bird. Thus the local effect on snakes can more readily translate into a global effect, unlike the case for vagile animals such a birds.

In their studies on the mortality of snakes, Bonnet *et al.* (1999) observed a significant relationship between the time of year and the sex/age group killed by road accidents. The most susceptible to such accidents are migrating individuals (individuals that have just hatched, males searching for females, and females looking for somewhere to lay eggs), while subadults are less likely to die in a road accident, since they do not roam to the same degree. These facts are important in relation to the local population, since females about to lay eggs are often victims of road accidents (Bonnet *et al.*, 1999). It has been observed that the population investigated has two mating seasons, and eggs are laid over a very long period (Borczyk, unpublished). Combat between males has been observed in May (Borczyk, 2004) and at the end of August (verbal communication from employees of a fish farm). Gravid females, which are just about to lay eggs, have been observed from June to the end of August, so there is less seasonality to their road mortality.

Snakes occasionally eat prey items that are too large and subsequently die (e.g. Pauly & Benard, 2002; this study). Previous examples of this

phenomenon involving Grass snakes are Gajewski (2000) who found a snake that had burst while swallowing a large Marsh frog (*Rana arvalis*) and Nagy (2001) who found snakes, whose oesophagus or lower section of the digestive system was punctured, due to swallowing an item of prey.

Also, infection or an egg of particularly large size may lead to the plugging of eggs in a female (Messonier, 1996). This may lead to a female being unable to lay her eggs. Infection and/or a prolonged pregnancy can lead to debilitation of a female and, as a result, its death.

It is difficult to estimate the impact of predator pressure on snake populations. During the present study I found only one small snake with scars suggesting that it survived a predator attack. Fitch (2003) found that females fall victims to predators more often than males. Mushinsky & Miller (1993) concluded that a higher wound rate in larger snakes suggests that they are either attacked more often or survive attempted predation better than smaller individuals. However, it can reflect the fact that older snakes live longer and therefore are subject to injuries for a longer time.

The negative effect of roads on snake population is two-fold. First, the high road mortality directly reduces the number of living and reproducing snakes. Second, habitat fragmentation by network of roads exerts a significant, negative effect on movements and mate location by snakes (Shine *et al.* 2004). There is clearly a need for more detailed studies of the impact of roads on the mobility and population dynamics of snakes, especially on the dispersal of young snakes, as well as on the strategies of conservation of snake populations that are affected by the expanding road network.

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