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CONSERVATION THREATS TO DICE SNAKES (*NATRIX TESSELLATA*) IN GOLEM GRAD ISLAND (FYR OF MACEDONIA)

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***Abstract.*—Most conservation efforts are channeled toward highly endangered species. However, snake populations decline rapidly worldwide, and many species that are currently classified as not threatened (e.g. LC - least concern, IUCN Red List) may well rapidly fall into the threatened categories. Yet, common species attract little attention. The principle, that it is more efficient to prevent disasters than to cure effects, is not taken into account. Dice Snakes (*Natrix tessellata*) offer a typical example of this situation. This species is one of the most widespread and polymorphic snake of the planet. Very large populations occur in the Balkans. On Golem Grad Island (the single island of FYR of Macedonia), a remarkable population of Dice Snakes suffers from recent assaults. Thousands of snakes are killed every year in the nets set by poachers, notably gravid females, raising population viability concerns. Protecting Dice Snakes, other reptiles (e.g. tortoises, vipers, and lizards) and the whole eco-system of Golem Grad Island would require moderate efforts: application of official rules, summer attendance, delivery of official permits to local people (including fishermen), and controlling tourism. In this paper, we addressed a central issue: does illegal fishing represent a potential threat to Dice Snakes? Our data suggest that recent increase of illegal fishing correlates with population decline.**

Key Words.—Balkan Peninsula; conservation; mortality; poaching; tourism

INTRODUCTION

A limited number of flagship organisms, essentially vertebrates and notably birds and mammals, attract the attention of media and attract most conservation efforts (Clark and May 2002; Seddon et al. 2005; Ballouard et al. 2011; McClenachan et al. 2012). Consequently, regarding neglected taxa like snakes for instance, only few highly endangered species benefited from practical (sometimes successful) conservation programs (Daltry et al. 2001; Kingsbury and Attum 2009; Read et al. 2011). However, common species should not be neglected under the obvious principle that it is more efficient to prevent disasters rather than to cure their effects (reviewed by Gaston and Fuller 2008). Overall, although protecting healthy populations of common species should be a priority, taxonomic bias for endothermic vertebrates and for nearly extinct species represents a discouraging challenge to mobilize conservation efforts toward not-yet threatened animals. This is especially true regarding unpopular organisms such as snakes (Seigel and Mullin 2009). For instance, millions of snakes are killed for disputable reasons (e.g. luxury leather industry or recreational purposes; Fitzgerald and Painter 2000; Brooks et al. 2010) without triggering public concerns or substantial conservation actions. Moreover, large populations of common snake species represent important components in many ecosystems (Beaupre and Douglas 2009).

Growing evidence suggests that an increasing number of snake populations (maybe most) are declining worldwide (Hibbitts et al. 2009; Santos and Llorente 2009; Reading et al. 2010; Godley and Moler 2013; Goiran and Shine 2013). This negative trend mirrors the worrying conservation status of reptiles, with more than 20% of the species being under imminent extinction risk (Böhm et al. 2013), and more generally reflects the failure of international conventions (e.g. Convention on Biological Diversity, CBD) to slow down the erosion of biodiversity (Moyle and Williams 1990; Perfecto et al. 1997). Thus, there is an urgent need to shift away from a narrow conservation policy focused on few iconic or nearly extinct species, and instead allocate important conservation efforts towards common organisms.

In the current study, we identified serious threats to a population of a common snake species: the amphibious Dice Snake (*Natrix tessellata*). Dice Snakes are distributed over a very large geographic area (Bannikow et al. 1977; Gruschwitz et al. 1999). This species exhibits considerable phenotypic variation; each population displays unique morphological, behavioral, and physiological characteristics (e. g. Mebert 2011;

Ajtić et al. 2013; Brischoux and Kornilev 2014). Although extremely large populations have been observed (e.g. Carlsson et al. 2011; Ajtić et al. 2013), information regarding population status is anecdotal (Luiselli et al. 2007; Ajtić et al. 2013).

We studied such a remarkable population in Golem Grad Island, a small island of the Galičica National Park of Macedonia (Former Yugoslavian Republic; FYR). The absolute number of snakes per hectare is among the highest documented: an estimated tens of thousands of sedentary piscivorous snakes live on < 20 ha (Ajtić et al. 2013). Golem Grad Island is a strictly protected area, tourism is severely restricted, and fire, hunting, and fishing are prohibited. Unfortunately, field observations (2007–2013) reveal a different situation: due to recent inability of law enforcement (border police and rangers of the National Park Galičica) to patrol the region, many tourists visit the island freely, fires are regularly lighted, and illegal hunting and fishing are very frequent (Sterijovski et al. 2011). Lack of control is a potential conservation threat for the island and populations, so we report on the impact of fish poaching on snake population and we list other threats. Although, huge numbers of snakes live on the island, suggesting that mortality caused by poachers is marginal or could be tolerated, the population status of Dice Snakes is actually fragile. Preliminary data suggest that the number of snakes drowned in illegal nets is massive (Sterijovski et al. 2011; Ajtić et al. 2013). Our goal was to determine if Dice Snakes are declining on Golem Grad Island and if they are, to identify the most likely cause of possible decline. This represents the first steps to raise public concern, to convince authorities, and hopefully to set up practical, simple, and efficient long-term conservation actions.

MATERIAL AND METHODS

We studied Dice Snakes on Golem Grad Island (GGI), which is located in Prespa Lake (18 ha; N 40°52'; E 20°59') within the Galičica National Park in the Former Yugoslav Republic (FYR) of Macedonia. It has been classified as a strictly protected area in 1988. The fact that it is situated near the tri-junction frontier of FYR of Macedonia (1.2 km south-west from the island), Greece, and Albania provides the opportunity for people (tourists and poachers) from all three countries to access (mostly illegally) the island.

The island of Golem Grad is recognized as an unique ecosystem due to the abundance of numerous rare plant and fungi species and a high density of reptile and bird species (Melovski 1998). Vegetation has not been managed for more than two centuries, resulting in a climax forest where most of the trees, *Juniperus excelsa*, are taller than 10 m. The lack of domestic and feral mammals (e.g. cats, dogs, rats, goats) that can cause major damage to the native fauna and European island ecosystems (Loss et al. 2013) likely explains the marked abundance of many species, notably predators belonging to various taxa: centipedes, snakes, otters, and raptors occur in large numbers for instance. The herpetofauna of GGI is remarkable. This small island is inhabited by dense populations of Dice Snakes, Nose-horned Vipers (*Vipera ammodytes*), and Hermann's Tortoises (*Testudo hermanni*) that are of particular interest for behavioral and ecological studies (Ajtić et al. 2013; Djordjević et al. 2013; Golubović et al. 2013; Arsovski et al. 2014).

From 2008 to 2013, we visited the study site each spring and summer (except in 2013), and occasionally in autumn (total 13 field trips). On average, the duration of each field survey was of 10 d and 1–12 people participated in each survey (Table 1). The total field effort was of 875 person-days. Most snakes we used in the analyses were captured and permanently marked using the classical scale-clipping (plus superficial burning) method (Ajtić et al. 2013). We palpated, measured body size and mass, and carefully described each snake (see Ajtić et al. 2013 for details). Processing each snake required approximately 15 min. We assessed the relationship between consecutive field trips and snake searching success (number of snakes searched, captured, and processed/day/people) using Spearman's Rank Correlation ($\alpha = 0.05$).

We estimated the impact of illegal hunting on Dice Snakes using the information provided by police

TABLE 1. Summary of the field effort (capture/mark/recapture studies) to monitor reptiles on Golem Grad Island, in Prespa Lake within the Galičica National Park in the Former Yugoslavian Republic of Macedonia.

Year	Season	No. of people	No. of days	Searching effort (person-days)
2008	Spring	4	10	40
	Summer	3	8	24
2009	Spring	6	16	96
	Summer	7	15	105
2010	Spring	4	10	40
	Summer	6	20	120
	Fall	3	3	9
2011	Spring	8	12	96
	Summer	12	22	264
2012	Spring	5	10	50
	Summer	2	4	8
	Fall	1	3	3
2013	Spring	4	5	20
Total		65	138	875

officers, official reports of the State Inspectorate, as well as using our own counting efforts. During a single random survey performed at night in early August 2011, police collected 50 illegal nets. They estimated that the maximum number of nets set per night was close to this value, and provided an estimate ranging between 30 and 40 nets per night. Each net measured 50 m long with 2.5 cm mesh. In each net, police found 10–30 dead snakes (and many fish). They also estimated that the nets were set around GGI every 2–3 nights on average, from mid of June to the end of July. Two years later (22 May 2013), police collected 238 fishing nets: 10 nets were directly taken from the water and were full of fish and some nets contained 205 kg of fish (e.g. *Cyrpinus carpio, Barbus prespensis*). On average, in each net, the poachers collected 10–15 kg of Belvica (*Alburnus belvica*) a relatively small endemic species. These data enabled us to estimate the amount of fish collected during the main Belvica fish-poaching period, which coincides exactly with the main foraging season in Dice Snakes (Ajtić et al. 2013).

To crudely estimate the impact of fish poaching on dice snakes, we used various combinations of the main parameters above, and calculated possible total numbers of snakes killed per year. We set the range of variation of the main parameters as follow: poaching season 15, 30 or 45 d; poaching frequency 1 d/week, 3 d/week, or every 3 d; number of nets set per night 5, 10, 15, 20, 30 or 40 nets; number of snakes drowned per net 5, 10, 15 or 20. We used these settings to take into account variations of the poaching pressure due to changing weather conditions; for instance, likely poachers work in large numbers only under very favorable conditions (e.g., no wind).

TABLE 2. Summary of captures and recaptures of Dice Snakes (*Natrix tessellata*) on Golem Grad Island, Prespa Lake, in the Former Yugoslavian Republic of Macedonia. Note that recaptures included snakes recaptured both within (i.e., recently marked snakes) and among session (snakes marked during previous sessions).

Year	Season	No. of snakes	Recaptures	% of recaptures
2008	Spring	361	1	0.28%
	Summer	241	2	0.83%
2009	Spring	643	6	0.94%
	Summer	519	23	4.43%
2010	Spring	764	29	4.98%
	Summer	1,281	151	11.79%
	Fall	41	2	4.88%
2011	Spring	684	66	9.78%
	Summer	1,252	233	18.41%
2012	Spring	388	64	16.49%
	Summer	18	2	6.06%
	Fall	56	0	0.00%
2013	Spring	81	13	16.05%
Total		6,329	592	

RESULTS

We captured 6,921 Dice Snakes on GGI: 6,329 captures and 592 recaptures. We fully processed snakes at capture and recapture (e.g. measurements, palpation, color description). Although population size could not be accurately estimated, the very high number of snakes processed revealed that a very large population of snakes inhabits GGI (Table 2).

Considering a main poaching period of 45 days (mid of June - end of July), around 5,500 kg of Belvica fish were taken from the waters surrounding GGI during the main period of Belvica fish poaching. In June 2010, we counted 49 Dice Snakes drowned in two nets set near the shore from late afternoon until the next morning (Fig. 1). We found 32 adult males and 17 adult females, including nine gravid females in the nets. On average, each gravid female carried nine well developed eggs.

Given our assumptions, we estimate that 2,440 ± 2,764 (SD) snakes are killed every year. However, the range of incertitude is very wide, ranging from 54 to 18,000 snakes killed per year (95% confidence interval: 2,526–3,053). Approximately 18% of the drowned snakes were gravid females. Thus we estimated that on average 439 ± 498 of gravid females are killed each year (range 10–3,240 females). Each female was carrying nine eggs on average, which leads to an additional loss of 3,954 ± 4,478 eggs per year (range 87–29,160). Using the mean body mass of Dice Snakes (0.15 kg;

FIGURE 1. Dice Snakes (*Natrix tessellata*), both sexes and three color morphs, found drowned in fishing net illegally set on the near shore of Golem Grad Island, Prespa Lake, in the Former Yugoslavian Republic of Macedonia in June 2010. (Photographed by Rastko Ajtić).

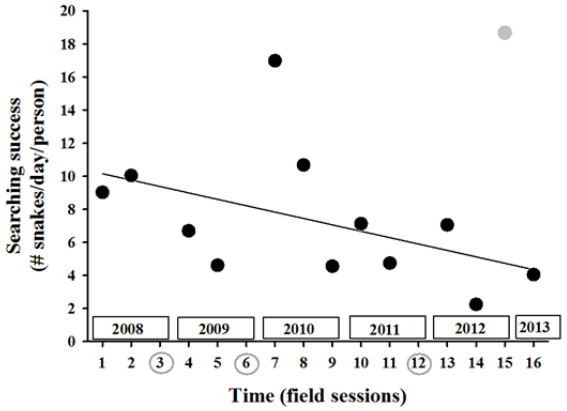

FIGURE 2. Relationship between time (session number, n = 13 from spring 2008 to spring 2013, see Table 1) and snake searching success. In autumn, most potential field sessions were not conducted and are indicated with grey circles on the X-axis. Note that one fall-session with a very low field effort (i.e., snakes were not fully processed but simply weighted and counted) was discarded (autumn 2012, grey circle).

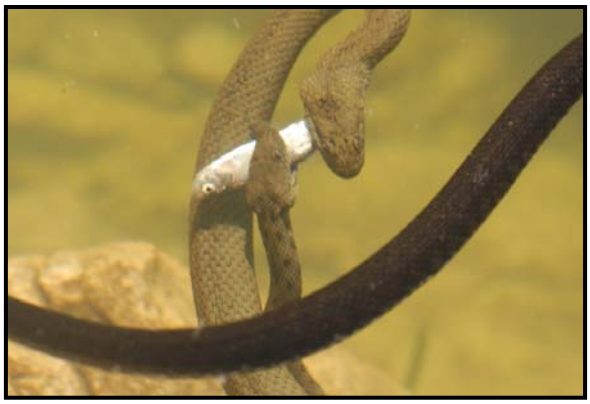

FIGURE 3. Klepto-foraging between two Dice Snakes (*Natrix tessellata*) at Golem Grad Island, Prespa Lake, in the Former Yugoslavian Republic of Macedonia. One snake caught a Belvica fish (top, larger grey snake) whereas a second snake (bottom, smaller dice-pattern snake) attempts to steal the prey. (Photographed by Xavier Bonnet).

unpubl. data), we estimated that 366 ± 415 kg of snakes are destroyed each year. We found a negative correlation between searching success and successive field trips (r_s = -0.59, P < 0.05; Fig. 2).

DISCUSSION

At the beginning of the mark/recapture study, our capacity to process snakes was the main limiting factor; we could catch hundreds of snakes in a short period of time (e.g., about 100 snakes for one person in a half an hour search time). Considering broad field efforts, the number of snakes that we captured, measured, and marked increased rapidly over time: on average, we collected about 1,100 snakes per year (ranging from approximately 100 to 2,300). In summer 2011, however, despite greater than twice the number of person days in the field, we only caught about the same number of snakes that we caught the year before. In fact, capturing even 100 animals per day required a considerable search effort. The total number of snakes processed reflected searching success, and was less limited by our capacity to process them.

Our results suggest that the impact of illegal fishing on Dice Snakes around GGI is important. The high variability of snakes drowned in the nets that we estimated are not the best way to determine the effect of poaching because this range corresponds to extreme combinations of all four factors set at their minimal or maximal levels during the whole poaching season. Using averages provides more realistic values, and indicates that thousands (about 2,500) of adult snakes likely are drowned in the nets during summers of low Police attendance, and that thousands of eggs of snakes are lost. Indeed, since 2011, poachers regularly deploy an intensive network of nets to capture Belvica fish. Golem Grad Island is easily accessible because the mean distance from Albanian and Macedonian harbors to GGI is 4.3 ± 0.7 km. Illegal fishing concentrates on the near shore because Belvica shelter in the narrow area of partly submerged boulders that surrounds GGI. Because Dice Snakes from GGI feed predominately on Belvica (Ajtić et al. 2013), the local concentration of Belvica may well explain the high numbers of resident Dice Snakes and certainly justifies the attractiveness of the area for poachers. In addition, snakes holding a fish in their mouth are frequently pursued by other snakes (Fig. 3); klepto-foraging is common in GGI and we found that roughly 10% of the snakes use this strategy when Belvica concentrate near the shore. We believe that fish trapped in the nets represent appealing prey, explaining the very high number of drowned individuals in the nets primarily designed to catch Belvica.

Consequently, the impact of poaching on Belvica and Dice Snakes is intensive, highly localized, and it increased suddenly in 2011 due to logistical difficulties faced by the Macedonian police to patrol the area. The destruction of thousands of snakes every year represents a serious threat to the population of the Dice Snakes. The low number of recaptures relative to the total number of individuals captured per season precluded performing robust analyses to estimate population size. The total number of snakes inhabiting GGI was estimated to more than 10,000 individuals in 2008–2010 (Ajtić et al. 2013); therefore an estimated 24% (95% confidence interval: 25–31%) of the population may have been destroyed during the last years of heavy poaching. This proportion might be lower considering that it is likely that > 10,000 snakes inhabited GGI

before 2011. Whatever the case, a high proportion of the Dice Snake population has been taken by the poachers since 2011. Furthermore, the impact of illegal fishing around GGI may have an influence on the entire population of Dice Snakes in the Prespa Lake region. In spring 2012, we inspected the three other islands of the lake (Agios Achilleos and Vidronisi in Greece and Mal Grad in Albania) and none of them sheltered dense or large population of Dice Snakes as observed on GGI. We note that no snakes marked on GGI were later captured on any of the three other islands of the lake, or in the shore populations of the mainland, suggesting that migrations from Golem to other sites, if any, are limited. Thus, there is little option for inter-population compensation if the colony of GGI is severely impacted.

In addition to the direct effect of poaching, indirect threats should be considered. Over-fishing may cause a depletion of the main prey consumed by Dice Snakes and by other predators (e.g. cormorants, otters). Dice Snakes represent an important food source for various birds (diurnal and nocturnal raptors, herons), otters, and vipers, that all feed regularly or intensively on Dice Snakes (Ajtić et al. 2013). The collapse of Dice Snakes may well perturb the trophic relationships and the population dynamics of different species. Finally, many tourists (transported by fishermen or poachers) freely and illegally visit GGI. In the absence of official guides, they impact the wildlife by killing snakes and illegally collecting tortoises and sometimes they light fires (forest fires were a major hazard in July 2012). Possible impacts of tourism will increase in the near future. For instance a major project for the development of tourism in the Prespa Lake was signed between the Macedonian government and the Portuguese company Aquapura International (SeeNews. 2007. Portuguese Aquapura Invests 50M€ in Hotel and Spa Centre in Macedonia. Available from http://wire.seenews.com/news/portuguese-aquapura-invests-50-mln-euro-in-hotel-and-spa-centre-in-macedonia-217972. [Accessed 15 July 2014]). We do not know if and how this project will be achieved, but the Macedonian Tourism Office is promoting GGI as a major tourist site (Macedonian Tourism Office. 2014. Lake Prespa. Available from http://makedonskibiser.com.mk/index.php?option=com_content&view=article&id=601%3A2009-11-06-16-43-18&catid=142%3A2009-08-22-23-37-48&Itemid=393&lang=en. [Accessed 25 November 2014]).

Overall, although accurate size estimates of Dice Snake or Belvica fish populations are not available, the crude calculations we performed are supported by a large data set and by the long term monitoring of the study site. Regardless of the accuracy of our estimates, illegal fishing and tourism should be better regulated before irreversible damages occur to a remarkable and prosperous population of Dice Snakes and to a whole ecosystem that shelters very dense populations of various species, notably reptiles. Paradoxically, the tri-junction frontier between the FYR of Macedonia, Greece, and Albania situated only 1.2 km south-west of GGI is poorly attended by authorities. Thus, illegal fishing is rapidly developing and large numbers of people visit GGI without official permit and without risk of sanction. Clearly, official regulations are not respected and consequently a very large snake population of Europe is in danger. Unfortunately, the conservation status of the Dice Snake (Least Concern; Agasyan et al. 2014) is not particularly helpful to launch conservation actions. A practical solution would be to involve local fishermen and students. Official permits should be delivered to selected people to organize boat transport and visits on GGI. Fees from these permits could provide an important income. Appropriate publicity may attract sufficient (albeit, limited) numbers of visitors to see the unique and fascinating reptilian fauna of the island. Providing unambiguous scientific information regarding the extraordinary ecological value of not-yet threatened reptilian species, and about major threats to them, represents the first step to convince authorities and to set up such practical conservation actions.

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