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ORIGINAL ARTICLE

Contribution of citizen science to improve knowledge on marine biodiversity in the Gulf Region



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Abstract Monitoring marine biodiversity is costly and practical solutions have to be implemented to identify species and their preferred habitats, particularly in this era of rapid global change. Citizen science has proven to be effective and with high potential for monitoring efforts, and has been extensively applied to biodiversity. We have used the citizen science approach to engage the general

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Public perception;
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public and stakeholders to contribute improving the current knowledge of sea snake biodiversity in Qatar and the Gulf Region. Logistic regression analysis using demographic data from interview surveys conducted in Qatar has indicated that the people having seen more sea snakes are older than 30 years and are Qatari citizens and/or fishermen from India.

Of the ten species of sea snakes listed in the literature to be present in the Gulf Region, most of them have been reported for Qatar, Bahrain, United Arab Emirates and Saudi Arabia. However, the number of species present is often assumed based on their occurrence within the Arabian Gulf rather than on actual captures and appropriate identification. The creation of marine reference biological scientific collections to properly identify the species and make accurate biodiversity inventories is an urgent priority for the countries in the Gulf region. To this end, contributions by stakeholders and the general public for this study have proven to be very useful. However a larger networking with local and international scientists and stakeholders is still needed to adequately survey the country's current biodiversity, identify research priorities and eventually provide the scientific input needed to assist biodiversity management related to renewable resource management and marine conservation in the Arabian Gulf Region.

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1. Introduction

Sea snake species are a diverse group with more than 60 species described that are often abundant in coral-reef ecosystems (Rasmussen et al., 2011; Rezaie-Atagholipour et al., 2016). They are considered ecological indicators of the health status of coral reefs (Brischoux et al., 2009) where they play an important role as both predators and prey (Brischoux and Bonnet, 2008). In recent decades, sea snake populations have been under threat due climate change, coastal development and water pollution (Bonnet, 2012; D'Anastasi et al., 2016). They also get entangled in the nets laid by trawlers and are susceptible to unintentional excessive catch as fishing byproduct (Courtney et al., 2010; Van Cao et al., 2014). Apart of this, sea snake venom is very important to the medicine market and their populations are highly affected by trade. All factors together may lead to local extinction as sea snake populations are highly localised (Singh, 2016).

Sea snake assemblages have been reported to be in dramatic decline in the Indo-Pacific region (Fry et al., 2001; Goiran and Shine, 2013). However, information about the status of sea snake assemblages from the Arabian Gulf, is still scarce (Heatwole, 1999).

Biodiversity field surveys are very expensive and time-consuming, thus new approaches for data collection and analysis have been developed in the last decades, including citizen science (Edgar et al., 2016; Gelcich et al., 2014). Citizen science has a high potential for biodiversity monitoring studies, and it has been extensively used by bird-watchers worldwide (Bennun et al., 2004) and also for terrestrial biodiversity (Smart et al., 2005). In the marine realm, citizen science has mainly focused on iconic animals inhabiting accessible coastal environments such as cetaceans (Scott and Parsons, 2004) or corals (Branchini et al., 2015a,b), but has also included other marine species (Scott and Parsons, 2004; Luksenburg and Parsons, 2014). In this study we have integrated the citizen science approach by conducting interview surveys and by engaging stakeholders to produce better-informed and context-based baseline biodiversity information about sea snakes in Qatar.

2. Methods

2.1. Interview surveys

Interviews were conducted following recommendations for best practice (White et al., 2005; Windle and Rolfe, 2011). Between January and May 2013, 655 interviews were conducted in 8 different ports and coastal areas of Qatar (Fig. 1), and between January to July 2016, 73 people were interviewed in Doha and in the northern area of Dukhan (Al Reem Biosphere Reserve). A questionnaire linked to photos of the 10 sea snake species likely occurring in the Gulf Region was used to know the response from people. During the interviews we asked the following questions:

1. Have you seen some of these snakes in Qatar? Please point the species looking at the photos.
2. Where did you see the snakes? When people did not know the location, we asked if snakes where seen offshore or along the coast.
3. How many years have you been living in Qatar?
4. What is your country of origin?

During the interviews we also included socio-demographic information of the respondents (e.g., Nielsen, 2011; Berrens et al., 2003; Canavari et al., 2005; Luksenburg and Parsons, 2014). We considered the gender (male, female) and the age group by eye, as people often were not comfortable responding about their age (> 30 years as adult, < 30 as young and < 15 as children. Young and children were pooled in the analyses due to small sample size for children). We also included information about the social sector of the people interviewed, including (a) fisherman (people inside fishing boats or in the port repairing the fishing nets), (b) sport (people practicing fishing, scuba diving, spear fishing, sailing, recreational boats and yachts), (c) general public (people walking along the coast line and staff from Ministries, petrol companies, universities and other institutions).

The interviews conducted in 2016 were all done to adult men from the general public without considering additional

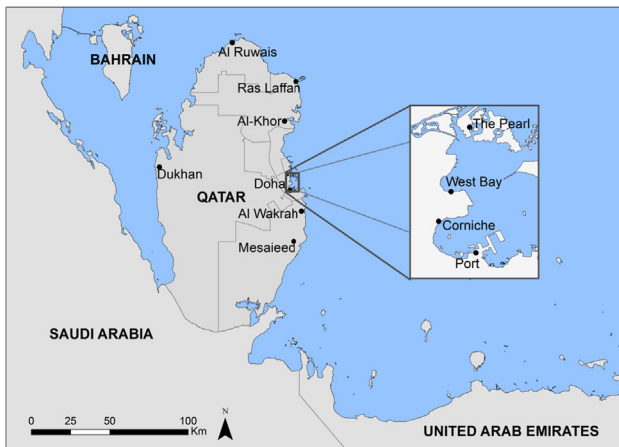


Figure 1 Map of Qatar showing the Gulf countries involved in this study and the zones where the interviews were conducted in Qatar in 2013.

demographic parameters. They were only asked to identify the snakes that they saw in the photos, and the location in Qatar.

We conducted face-to-face interview surveys in all cases. The questionnaire was in English, but when possible it was translated by locals into Arabic or Hindu (the second most spoken language in Qatar after Arabic).

Different team members conducted the surveys, but care was taken to ensure that the people interviewed were approached in the same manner. Each survey was prefaced with an explanation of the purpose and importance of the study, and lasted from 15 to 30 min depending on the subject's level of understanding and also on their willingness to provide more details of their observations.

The information from reports belonging to Ministries and petrol companies was obtained as a result of the close collaboration between scientists and stakeholders.

We also collected additional scattered information from people that voluntarily told us the location where they saw sea snakes during the excursions to the beach or diving activities.

2.2. Statistical methods

We used logistic regression analysis to determine the best predictors of whether or not a person had seen at least one snake species in Qatar. Not enough women were sampled to test for an effect of gender on the probability of seeing a snake. The independent variables considered were: (1) The age of the person – scored as young or adult, (2) the social sector (type), (3) the length of time living in Qatar (months). We tested each variable separately and also fitted a model that included all variables. Analyses were performed with the IBM SPSS Statistics Version 23.

2.3. Snake species names

The scientific names of sea snakes indicated in the publications that we have cited in this study follow different nomenclatures, such as Reptile Data Base (RDB), World Register of Marine Species (WORM), or recent taxonomic studies (Sanders

et al., 2013; Rezaie-Atagholipour et al., 2016). In this paper (texts and tables) we have always used the names of the snakes indicated in the Reptile Data Base to keep constancy and try to reduce confusion among the readers.

3. Results

3.1. Interview results

Most interviewed people were males 92% (600 of 655). The majorities were adults older than 30 years (64%), others were 15–30 years old (36%), and only 9 children younger than 15 years were interviewed (Table 1). Because so few children were present in the sample, they were merged with those 15–30 years of age into a category termed “young” ($N = 181$ or 27.6%) for purposes of logistic regression analyses comparing them with “adults” ($N = 474$ or 72.4%) (see below). With respect to social sector, 32.5% were fishermen, 15.4% were sports people, and 52.1% were general public.

The people interviewed were from 36 different countries indicating the large variety of cultures that are mixed in Qatar (Fig. 2). However the majority were from India (202 of 655, 31%) and Qatar (133 of 655, 20%). Most people interviewed were based in Qatar for one or two years (285 of 655, 44%), or all their lives (Qatari nationals: 140 of 655, 21%).

In 2013 only 16% ($n = 102$ of 655) of interviewed people in Qatar have seen marine snakes (Table 2). Most observations have been conducted offshore (89%) at traditional fishing areas around islands or in coral reefs, while coastal records were limited to mangroves, ports, beaches and marinas (11%). Most people have seen only one snake species (60 of 102, 59%), while two different species were seen by 25 people, 3 species by 15 people, and 4 species by 2 people.

We used logistic regression analysis to determine which independent variables were statistically significant predictors of whether or not the people had seen at least one snake species. Models that included zone as a predictor did not converge.

Most people who reported snakes from the general public were Qatari citizens (40%) and fishermen from India (30%) (Fig. 3). Adults saw more snakes (87%) than young (young and children pooled) (13%).

Univariate models show that all three predictors were statistically significant in separate models (Age: $P = 0.0005$ [positive effect], Social sector: $P = 0.0138$, and Time living in Qatar: $P \ll 0.0001$ [positive effect]). In a combined model, all three were again significant, and the direction of effects were the same as in the single-variable models (age $P = 0.0067$ [positive effect], type $P \ll 0.0001$, months $P \ll 0.0001$ [positive effect]) (Table 3).

Results from interviews conducted in 2016 show that the majority of adult males from the general public (70%, $n = 51$ of 73) had seen marine snakes in Qatar.

The available information regarding the areas where sea snakes have been seen by the public, indicates that sea snakes of some species are present all around Qatar and in the border of the neighbouring Gulf countries during recent times (2013–2017) (Fig. 4). Larger numbers in the circles of Fig. 4 do not indicate that more snakes are present in those areas; the numbers correspond to the number of persons in Qatar that reported having seen snakes in each particular zone, either in the coast, coral reefs or offshore near the areas. Future studies

Table 1 Number of persons interviewed (Total sample = 655) in eight coastal localities of Qatar. It is indicated the category of social group (fishermen, sport and public) and age (Child: < 15 years old, Young: 15–30 years old, and Adult: > 30 years old).

Social group	Age group	Males								Females				
		Doha Corniche	Doha Port	Doha Pearl	Doha West Bay	Al-Khor	Al-Ruwais	Al-Wakrah	Dukhan	Doha Corniche	Doha Port	Doha Pearl	Doha West Bay	Dukhan
Fishermen	Young	0	7	0	0	32	14	20	0	0	0	0	0	0
	Adult	5	46	0	0	43	20	26	0	0	0	0	0	0
Sport	Young	6	0	26	3	0	0	0	0	0	0	0	1	0
	Adult	8	1	9	40	0	0	0	0	1	0	0	6	0
Public	Child	3	0	0	0	0	0	0	0	6	0	0	0	0
	Young	69	17	2	5	7	0	0	4	23	0	0	0	2
	Adult	31	4	0	70	16	19	25	22	10	0	0	1	5
Total		122	75	37	118	98	53	71	26	40	0	0	8	7

should explore which are the species present in different zones and which is their relative abundance.

3.2. Sea snake biodiversity in Qatar

Based on photograph sightings the people confirmed having seen 10 and 9 sea snake species during the interviews conducted in 2013 and 2016 respectively. In 2016, *Hydrophis viperinus* was not reported for Qatar. The snakes more frequently reported by the people in 2013 were *Hydrophis curtus* (18% of the observations), *H. cyanocinctus* (13%) and *H. spiralis* (12%). The snakes more frequently reported by the people in 2016 were *Hydrophis lapemoides* (20% of the observations), *Hydrophis platurus* (16%) and *H. spiralis* (12%). However, we have to consider the information from the public with caution because it is very difficult to distinguish the sea snake species that have similar dorsal pattern, and most probably they have been mistaken in some cases.

The Qatar National Biodiversity Report includes three sea snakes species (*H. platurus*, *H. cyanocinctus* and *H. spiralis*) (SCERN, 2004) (Table 4). One internal report of Qatar Petroleum includes three sea snake species (defined as “types”) for Ras Laffan (NE Qatar), and indicates *H. platurus* as the least common species (2% of the observations, 9 of 385), followed by *Hydrophis* “type A” (11%, 43 of 385) and *Hydrophis* “type B” as the most common (86%, 33 of 385) (Tayab et al., 2002). Other Qatar Petroleum report also for Ras Laffan includes the presence of four species in Qatar (*Hydrophis lapemoides*, *H. ornatus*, *H. curtus*, *H. platurus*) (Takcas, 2013) (Table 4).

Four sea snakes species (*Hydrophis spiralis*, *Hydrophis schistosus*, *H. cyanocinctus*, *H. platurus*) were collected on a commercial trawler to be deposited in the Qatar Aquarium, where photographs were taken (Ahmed, 2002). The species could be used as reliable records from Qatar, though identifications need to be checked since not all photos are clear for key identification. Gillespie (2015) reports the presence of six species in Qatar (Table 4); however, the source of the observations appears to come from literature records and the general public.

4. Discussion

The public knowledge and perception have proven to be beneficial worldwide for scientific research and to enhance conser-

vation and management efforts. Accordingly it is becoming more frequent to engage society in efforts to tackle marine conservation challenges (López et al., 2003; Scott and Parsons, 2004; Luksenburg and Parsons, 2014; Jefferson et al., 2015). Citizen science has proven to be effective and has been extensively applied to many other disciplines including air pollution and public health (Jiang et al., 2015; Wang et al., 2015), food security (Canavari et al., 2005), economics and politics (Berrens et al., 2003).

In the present study, scientists from multiple countries and institutions have joined efforts to explore the presence of marine snake species in the Gulf Region (Qatar, Bahrain, UAE and Saudi Arabia) based on a literature review and the compilation of unpublished information. We have also involved the general public through interview surveys, thus allowing stakeholders to contribute to the progress of biodiversity knowledge in Qatar and the Arabian Gulf.

4.1. Interviews

The choice of survey mode for research has long been debated in the literature (Maguire, 2009), and appropriate survey collection method and design of the questionnaire require careful consideration to improve success and reduce bias (Mitchell and Carson, 1989; Windle and Rolfe, 2011). Different interview approaches are commonly used and compared including internet/paper (Windle and Rolfe, 2011), phone/email/presential (Maguire, 2009), face-to-face/web (Nielsen, 2011) and email/paper (Shih and Fan, 2009). Internet surveys are becoming a popular method because collection times are faster and the cost lower than other collection techniques (e.g., paper-based survey) (Windle and Rolfe, 2011).

We used the same interview method of face-to-face in both years. During a pilot experience in 2013, the email or drop-off/pick-up collection technique did not work in Qatar, since the majority of people did not respond to the emails nor completed the forms. More efforts are needed to encourage people in the Gulf to actively participate in surveys not subjected to face-to-face interactions in order to reduce time and efforts getting results. However, low response rates for surveys that do not include face-to-face interactions have also been observed in other regions (Windle and Rolfe, 2011). Overall, the responses of the interviews have shown that mainly adult fishermen (the

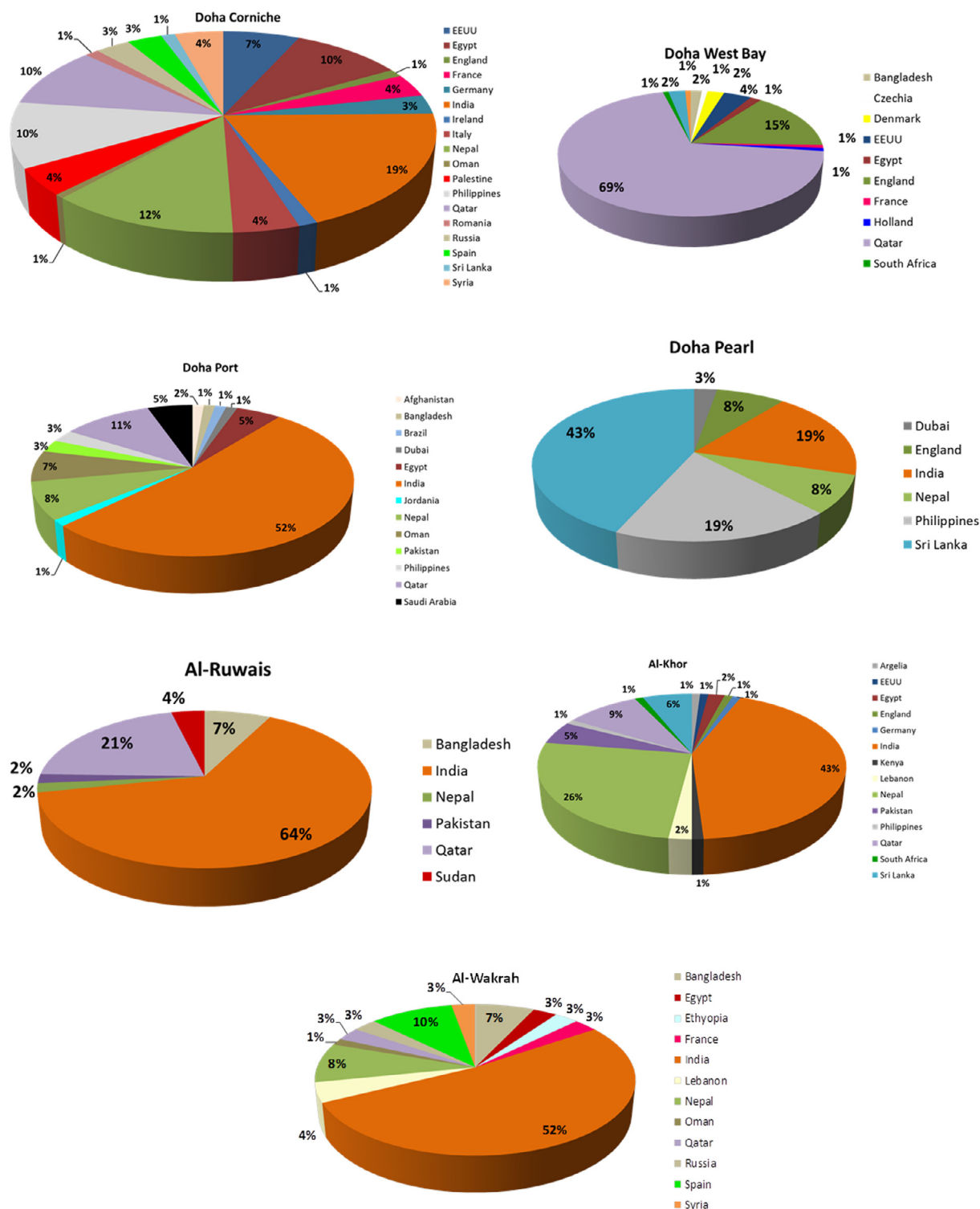


Figure 2 Percentage of surveyed people according to their country of origin. Different nationalities are represented for each different zone where interviews were done in 2013.

majority from India) and adult Qatari citizens saw more snakes than other people. A higher proportion of adult respondents in comparison to young has been reported elsewhere (Windle and Rolfe, 2011). This agrees with the fact that experienced local people or those who are well established in the

country for longer periods have a better knowledge about the local biodiversity. Other studies have also demonstrated differences in the level of species knowledge between residents and tourists, with more residents being aware of the marine biodiversity of the area than the tourists (Luksenburg and

Table 2 Number of persons interviewed ($n = 102$ of 655) that have reported to see sea snakes somewhere in Qatar. The localities in this table show the zones where the people were interviewed, but not the areas where the snakes were seen.

Social group	Age group	Doha Corniche	Doha Port	Doha Pearl	Doha West Bay	Al-Khor	Al-Ruwais	Al-Wakrah	Dukhan
Fishermen	Young	0	0	0	0	7	1	3	0
	Adult	0	16	0	0	8	4	4	0
Sport	Young	0	0	1	0	0	0	0	0
	Adult	1	0	1	17	0	0	0	0
Public	Young	0	1	0	0	0	0	0	0
	Adult	1	2	0	21	2	11	1	0
<i>N^o people observed snakes</i>		2	19	2	38	17	16	8	0
<i>N^o people interviewed</i>		162	75	37	126	98	53	71	33

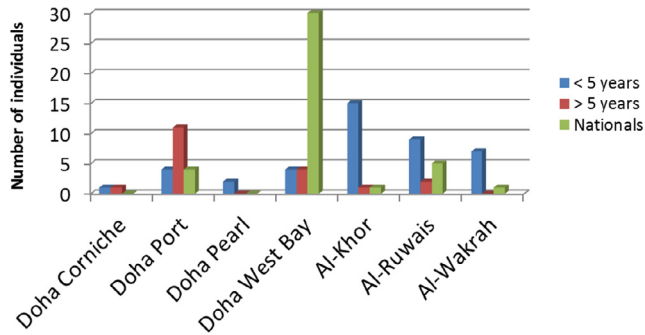


Figure 3 Number of surveyed people in 2013 that have seen sea snakes in Qatar according to the time period living in Qatar (< 5 years, > 5 years) or Qatari Nationals.

Parsons, 2014). However, a different trend could be also found.

4.2. Sea snake biodiversity in Qatar: Stakeholder’s involvement

The information we obtained from interview surveys suggests that a large variety of sea snake species of the family

Hydrophilidae are currently present in the waters around Qatar. Based on photograph sightings the people in Qatar confirm having seen the 10 species that are likely to occur in the Gulf Region. However, we have to consider this information with caution because it is very difficult to distinguish sea snake species having similar dorsal patterns, and the species may have been misidentified in many cases. Based on interviews the most frequently seen snakes are those with black and white stripes. In recent years the people have perceived some decrease in the number of species (what they call “different types”), and also in the relative abundance of snakes (*pers. coms.* from people interviewed).

In Qatar, previous studies indicate that the contribution of petroleum companies can be highly beneficial to increase the biodiversity knowledge of sea snakes (Takcas, 2013) and to implement conservation actions. For example, in Ras Laffan industrial city (NE, Qatar) (Fig. 1) sea snakes get trapped in the baskets from seawater intake systems. The snakes are collected and released far away from the industrial area as part of the conservation program to protect sea snake biodiversity in Qatar (Tayab et al., 2002). In Ras Laffan 99% of the snakes are spotted in the water treatment facility (Jackie Wessels, *pers com*). In Mesaieed industrial city (SE Qatar) the water intake and treatment systems are different than in Ras Laffan and it is not so easy to see or collect sea snakes (Jackie Wessels, *pers*

Table 3 Results of logistic regression analyses predicting whether or not a person had seen at least one snake. The results are shown for each variable tested separately and including all three variables. $N = 655$ for all models. It is indicated the standard error (S.E.), degrees of freedom (d.f.), the probability (P) and the statistics associated to the logistic regression analysis.

Independent Variable(s)	B	S.E.	Wald	d.f.	P	Exp(B)
Age	1.081	0.311	12.057	1	0.0005	2.946
Constant	-2.559	0.288	79.017	1	$\ll 0.0001$	
Type			8.565	2	0.0138	
Type 1	0.088	0.307	0.082	1	0.7748	1.092
Type 2	-0.585	0.306	3.644	1	0.0563	0.557
Constant	-1.462	0.255	32.984	1	$\ll 0.0001$	0.232
Months	0.002	< 0.001	36.743	1	$\ll 0.0001$	1.002
Constant	-2.202	0.152	210.734	1	$\ll 0.0001$	0.111
Age	0.882	0.325	7.357	1	0.0067	2.415
Type			32.200	2	$\ll 0.0001$	
Type 1	0.471	0.346	1.858	1	0.1729	1.602
Type 2	-1.408	0.372	14.356	1	0.0002	0.245
Months	0.004	0.001	45.835	1	$\ll 0.0001$	1.004
Constant	-2.750	0.398	47.789	1	$\ll 0.0001$	0.064

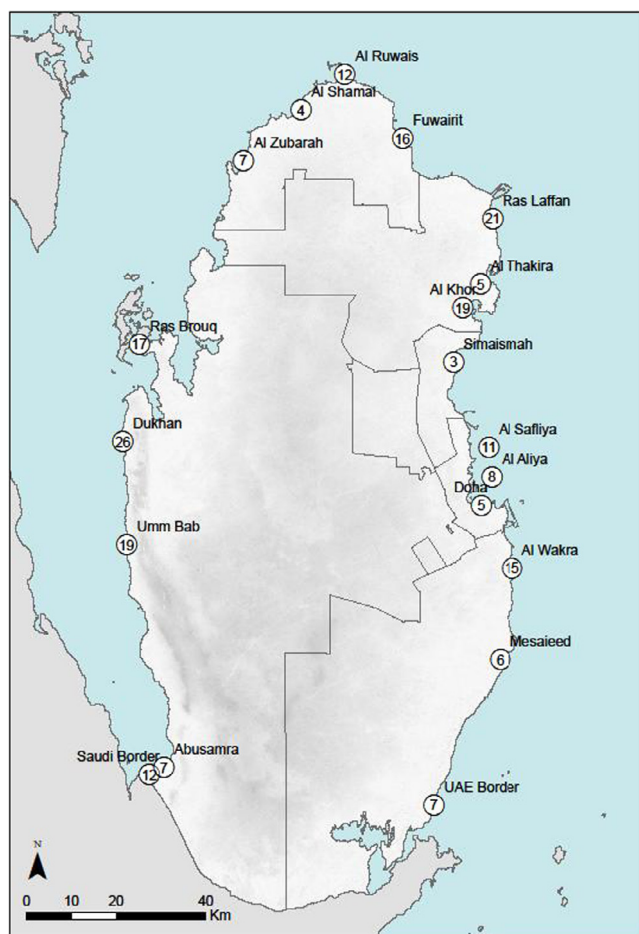


Figure 4 Locations around Qatar where sea snakes have been seen by people between 2013 and 2017. The numbers in the circles correspond to the number of persons in Qatar that reported having seen snakes in each particular zone, either in the coast, coral reefs or offshore in each particular area.

com). However, the people have seen sea snakes along the beach in Mesaieed.

In the coastal area of Dukhan industrial city (West Qatar) where sea snakes are quite common, 3 to 4 species (what locals call “types”) have been reported by divers to coexist during 2007–2010. Many artificial reefs have been created since 2013 (Qatar Petroleum internal reports, Qatar Al-Rayan Arabic TV documentary Program 2014 (https://www.youtube.com/watch?v=LXlpeSua_VY&feature=youtu.be)). The reefs have been progressively colonized by several marine species and sea snakes of different species are frequently seen in the rocky areas (Mohd Humaid and several divers, *pers. com*). One of the reefs is called “Snake Alley” by sport divers because of the large congregation of snakes that concentrate there (Gillespie, 2015, Qatar Petroleum and divers, *pers. com*). However, the species *Hydrophis platurus* (easy to recognise for its yellow and black colour) that was frequently seen in large numbers from 2007, has not been reported by divers in recent years (Mohd Humaid, *pers. com*).

The Qatar Ministry of the Environment has created large artificial reefs in the area of Mesaieed (SE Qatar) (Fig. 1), and the people and divers frequently observe sea snakes in the reefs and offshore in that area (unpublished Ministry internal reports and divers *pers.coms*).

Observations since 2014 by marine scientists from Qatar University indicate that all snake species observed are those with the white and black strep pattern (Giraldes, *pers.com*). Marine expeditions consist of about ten hours per month in the oyster beds and coral reefs of the eastern offshore of Qatar (Marine economical zone), and snakes are usually seen on the soft bottom searching for food (Giraldes, *pers.com*). Because diving research activities are conducted during the day (7 am – 2 pm), the detection of sea snake species with nocturnal activity may be difficult.

Local people and tourists have reported the presence of dead sea snakes along the coast line, ports and beaches of different areas of Qatar during different years, including Ras Brouq and Al Reem (from 2014 to 2016), Al Aliya and Al

Table 4 Sea snake species reported (published, and present study) to be present in the Arabian Gulf and separately for Qatar, Saudi Arabia, United Arab Emirates (UAE) and Bahrain. The scientific name of the species corresponds to the Reptile Data Base. The numbers correspond to the references below. It is shown the IUCN criteria of the Red List of Threatened Species for each sea snake species assessed.

Common name	IUCN criteria	Scientific name (Reptile Data Base)	Arabian Gulf	Saudi Arabia	UAE	Bahrain	Qatar
Arabian Gulf sea snake	LC: Least concern	<i>Hydrophis lapemoides</i>	1	16,17	8, 17, 20	16,17	17,18, 13,14,15
Annulated sea snake	LC: Least concern	<i>Hydrophis cyanocinctus</i>	2	16,17	8, 17	10, 17	17, 12,13,14,15,19
Yellow sea snake	LC: Least concern	<i>Hydrophis spiralis</i>	3	16,17	8, 17	16,17	17, 12,13,14,15,19
Ornate reef sea snake	LC: Least concern	<i>Hydrophis ornatus</i>	2	16,17	8	16,17	17,18,13,14,15
Beaked sea snake	LC: Least concern	<i>Hydrophis schistosus</i>	5	16,17	8, 17		19,14,15
Shaw’s sea snake	LC: Least concern	<i>Hydrophis curtus</i>	2	16,17	8, 17, 20	16,17	17,18,13,14,15
Viperine sea snake	LC: Least concern	<i>Hydrophis viperinus</i>	7	16,17	8, 16,17	17	17,14
Stoke’s sea snake	LC: Least concern	<i>Hydrophis stokesii</i>	4		9		14,15
Yellow-bellied sea snake	LC: Least concern	<i>Hydrophis platurus</i>	6	16,17	8, 16,17, 20	10, 17	17,18,11,13,14,15,19
Slender sea snake	LC: Least concern	<i>Hydrophis gracilis</i>	2	16,17	8, 16,17	16,17	17,14,15

1 Rasmussen et al., 2010a; 2 Rasmussen et al., 2011; 3 Rasmussen et al., 2010c; 4 Sanders et al., 2010; 5 Kharin and Czeblukov, 2009, 6 Guinea et al., 2010; 7 Rasmussen et al., 2010b; 8 Gardner, 2013; 9 Sanders et al., 2010; 10 Alkhuzai, 2015; 11 Tayab et al., 2002; 12 SCERN, 2004; 13 Gillespie, 2015; 14 People perception from interviews 2013; 15 People perception from interviews 2016; 16 Gasperetti, 1988; 17 Egan, 2007; 18 Takcas, 2013; 19 Ahmed, 2002; 20 Soorae et al., 2006.

Safliya islands in the eastern coast of Qatar near Doha (from 2013 to 2015, and before), Al Shamal (2014–2015) and Halul island (in different years not specified).

The engagement of stakeholders and the general public in environmental programs has proved successful elsewhere (Durham et al., 2014; Camp and Fraser, 2012), and much closer collaborations between scientists and stakeholders should include having access to all specimens captured for the proper identification of the species and also to help creating reference scientific museum collections. Citizen science has to be combined with direct observations and captures in situ to make reliable comprehensive and up-to-date biodiversity inventories (e.g., López et al., 2003; Roelfsema et al., 2016).

Gasperetti (1988) does not list a single record of any snake species from Qatar, but has many records from almost every species from Bahrain and Saudi Arabia, most of them deposited in the Natural History Museum in London. Egan (2007) lists 8 species for Qatar but mainly by extrapolating point distribution data from his distribution maps (*Hydrophis cyanocinctus*, *Hydrophis lapemoides*, *Hydrophis ornatus*, *Hydrophis spiralis*, *Lapemis curtus*, *Microcephalophis gracilis*, *Pelamis platura*, and *Praescutata viperina*). Therefore, the records of these species need to be confirmed.

For *Hydrophis schistosa*, Gasperetti (1988) lists two records from the Gulf Region (no precise locality data available) that were first reported in Smith (1926) and Corkill (1932). The samples are deposited in the Natural History Museum (London) and in the College of Agriculture (Baghdad) respectively. According to Egan (2007), Arabian Gulf records are doubtful for this species (“Gulf of Oman and probably the Arabian Gulf”).

The species *Hydrophis stokesii* is also assumed to be present within the Arabian Gulf, including UAE waters (Sanders et al., 2010). However, unconfirmed records seem to exist within the Gulf. Gasperetti (1988) lists *Hydrophis stokesii* only from the Makran Coast (Gulf of Oman in Iran), while Egan (2007) lists its distribution for Pakistan and India, and explains that it represents a vagrant in Arabian waters. Until further evidence becomes available, it should not be considered as occurring in Qatar or the Gulf Region. If ever recorded in some of the Gulf countries it is most probably an individual without a reproducing population in the Gulf.

4.3. Sea snake biodiversity in Bahrain

In Bahrain seven species of sea snakes have been reported as present (Table 2) based on published information (Gasperetti, 1988; Egan, 2007). However, the most recent biodiversity study only includes two species (*Hydrophis cyanocinctus* and *Hydrophis plaurus*) (Alkhuzai, 2015). In recent years, few observations have been recorded around the main island of Bahrain, and most of the sea snakes observations are recorded around Hawar Islands (Hani Badr, Directorate of Fisheries in Bahrain, pers. com.). Hawar Islands were declared nationally as a wildlife sanctuary in 1996, and internationally as a Ramsar site (convention on wetlands of international importance) in 1997. These islands provide undisturbed habitats for a variety of marine flora, fauna and avifauna including sea snakes (Naser, 2014). Little work has been done to study the sea snakes of Bahrain and it is urgent to assess their distribution and ecology in the country.

4.4. Sea snake biodiversity in United Arab Emirates (UAE)

The ten species of sea snakes (Table 2) are assumed to be present in UAE, but only nine within UAE waters based on their occurrence within the Arabian Gulf (Sanders et al., 2010; Gardner, 2013). These species are recorded as present in major works on UAE marine fauna (e.g. Gasperetti, 1988; Miller et al., 2004; Egan, 2007; Soorae et al., 2010; Gardner, 2013). However, only five species have been recorded based on direct surveys (Miller et al., 2004; Soorae et al., 2006), including *Hydrophis curtus*, *Hydrophis lapemoides*, *Hydrophis cyanocinctus*, *Hydrophis plaurus*, and *Praescutata viperina*. The most abundant species based on preliminary surveys are *H. lapemoides* and *H. cyanocinctus* followed by *H. plaurus* (Miller et al., 2004). Miller et al. (2004) also reported that there are a few hundred records of sea snakes, but these are not documented in an easily accessible form.

The species *Hydrophis stokesii* is assumed to be present within the Arabian Gulf, including UAE waters by the recent red listing authorities (Sanders et al., 2010). However, no confirmed records seem to exist within the Arabian Gulf as indicated above for Qatar. Very little work has been done to assess or study the sea snakes of UAE, and there is no mention of sea snakes in the 5th National Biodiversity Report (in Arabic) conducted in 2014 (UAE-CBD, 2014). There is therefore an urgent need to assess the distribution and ecology of sea snakes in UAE.

4.5. Sea snake biodiversity in Saudi Arabia

In Saudi Arabia nine species of sea snakes have been previously reported (Table 2). The sources of the records are Gasperetti (1988), Egan (2007), and also underwater sightings and photographs (Fareed Krupp, personal observations between 1991 and 2011).

5. Conclusions

The results of this study clearly demonstrate that very little work has been done to assess or study sea snakes in different countries of the Gulf, and there is common agreement among different countries about the urgent need (1) to assess the distribution, ecology and threats to sea snakes in the Gulf Region, and (2) to create marine reference biological scientific collections in Qatar and in the Gulf region to properly identify the species, make accurate biodiversity inventories and assist biodiversity management. See also Giraldez et al. (2015) for a similar claim in Qatar. The value of museum collections for research and society has been shown worldwide (review in Suarez and Tsutsui, 2004). Scientific collections are essential for the natural history heritage of the Gulf countries.

Contributions by the general public and stakeholders has proven to be very useful for this study and a larger networking with local and international scientists and stakeholders is still needed to adequately survey the country's biodiversity, identify research priorities and eventually provide the scientific input needed for renewable resource management and environmental conservation.

Conflict of interest

The authors have no conflict of interest.

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