

Uninvited guests: an overview of introduced vertebrate species in Iran

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Abstract

An introduced species is one that enters and occupies a habitat where it does not naturally occur. We have reviewed articles and media sources to shed light on the introduced vertebrate species (hereafter IVS) of Iran. Here, we present a list of IVS in Iran which have the potential to become invasive and are the ones that can harm biodiversity. We aggregated information on their approximate range in the country, origin, probable means of introduction, as well as conservation status based on the IUCN Red List of Threatened Species. Based on the results of this study, 63 such species were recognized as introduced. Human population size in each province was a correlate of the number of introduced species. We suggest that this correlation exists because human demand for exotic species as pets or livestock may result in the release of invasive species into the wild. Further investigations on the root causes of their emergence, their range in Iran, and their ecological interactions are urgently needed. Finally, we propose educating the public, and government authorities about IVS in order to encourage better management and prevent future introductions. We recommend that species with a high level of invasiveness should be targeted for eradication.

Keywords: Introduced species, Iranian vertebrates, invasive Species, invasion ecology, management

Introduction

Introduced species are species that have been transported to areas beyond their natural range (Richardson, et al., 2000, Macdonald and Willis, 2013, Simberloff, 2010). When they settle and establish a sustainable population by producing offspring and having detrimental effects on ecosystems and native species, they are considered invasive (Lymbery et al., 2014). Introduced species, with the potential of becoming invasive, are considered one of the main threats to biodiversity (Clout & Williams, 2009, Diamond, 1989, Simberloff, 2010). The introduction of species by people most likely began with hunters introducing dogs (Clout & Williams, 2009).

Introduced species will take time to settle in an ecosystem and create a self-sustaining population. This is known as “lag time”, and can vary from one species and ecosystem to another (Woodward & Quinn, 2011, Simberloff, 2010). Species introductions may occur intentionally, incidentally, or by a mixture of these factors, through various means (Woodward & Quinn, 2011), including direct assistance of humans (e.g., Trade or Tourism, Clout & Williams, 2009) or indirectly by humans (e.g. climate change, Macdonald and Willis, 2013). Introduced species can affect native fauna through direct predation, hybridization, competition, and/or disease (Macdonald and Willis, 2013, McHugh et al. 2019). They can disrupt ecosystems by changing the relationship between native predators and their prey (Feit et al., 2018). The negative impacts of invasive species are well addressed (Letnic et al., 2009, Naderi et al. 2020) but introduced species can be neutral or even have beneficial effects in some cases (Macdonald and Willis, 2013).

There have been sporadic studies regarding introduced species in Iran, mostly dealing with species-specific range modeling (Farashi et al. 2011, 2013; Moradi & Rastegar-Pouyani 2013; Esmaeili et al., 2014; Farashi & Shariati Najafabadi, 2015; Farashi & Naderi, 2017; Farashi & Shariati Najafabadi, 2017; Esmaeili et al., 2018) but no comprehensive list of the species that have been introduced exists to date. Difficulties in planning studies regarding the impact of invasive species mean few such studies exist (Feit et al., 2018). The purpose of this study was to provide a comprehensive list of the alien species that have been introduced to Iran, their country of origin, and their distribution as a precursor to the development of appropriate management strategies on how to deal with them. More specifically, we evaluated this hypothesis that there is a correlation between the area of each province, population size, population density, the number of international borders of each province with the number of invasive species. The list we provide is the first and the only list available identifying introduced vertebrate species in Iran. Due to the high number of

species and insufficient data, it is possible that not all introduced species are listed, including those that remain undiscovered.

Material and methods

We listed known introduced vertebrate species by reviewing published articles concerning invasive species in Iran. We gained further information through reports from locals and experts, directly or via social media. In addition, we interviewed national wildlife experts of each class and asked them to review the list for each vertebrate class to ensure species were not missed or falsely added. No conclusions were made on the level of these species' invasiveness, which is defined as their success in colonizing an area and their subsequent malicious impacts (Mooney et al., 2005; Macdonald and Willis, 2013; Luque et al., 2014). We cover both species from other countries and species within the country that are introduced to different provinces outside of their natural range. For mammalian species, we recorded species with established populations within Iran, as well as failed introductions. We limited the list of introduced fishes to those present in the inland waters of Iran. In our tabulation, we differentiated between range expansions in which humans are not directly involved and introduction which is a direct result of human involvement. We included species on the list irrespective of whether they have established a sustainable population or not. No differentiation on species existing as a sustainable population or those that are limited to only a few individuals was made, as the data regarding many species was insufficient. Finally, we checked our list with the global invasive species database (ISSG).

Scientific articles

In order to collect information regarding introduced species of Iran, we searched the following keywords for each class ($n = 5$) in the Google search engine both in English and Farsi, for example, Introduced mammals of Iran. We also used invasive terms in order not to miss any study regarding introduced species (Invasive mammals of Iran).

Social media

In this study, we monitored Instagram as our source for social media since it is widely used in the country. While surfacing through our professional Instagram pages we noticed there are posts reporting introduced species in Iran both from experts in the field and the general public. By observing this we decided to use the data as a source to complete our IVS list. In order to find more users with suitable information for our study we search the Instagram platform with the hashtag (#) tool, we used hashtags for all five classes, as an example, these two hashtags were used,

#invasive_species_iran and #introduced_species_iran. Also, Farsi hashtags were searched too. In the species lists the following information is provided:

1) The origin of the introduced species; 2) Their ranking in the IUCN Red List of Threatened Species (From Least Concern to Critically Endangered); 3) Intent of introduction: “Intentional” describes species that were deliberately released by people, such as in the case of unwanted pets. Conversely, “Unintentional” are species that were brought into an area for a specific purpose but were released accidentally, such as livestock or escapees. 4) The locations (province) they are recorded in in Iran. For those species whose specific locations are known, we gave the name of the place. However, the only information available for some species is the general region to which they were introduced to. Some records did not provide specific locations, but there was evidence of their presence in a general location; 5) Time of introduction where applicable.

Attributes of Iranian provinces

We collated data on attributes of Iranian provinces that we hypothesized to be correlated to the number of invasive species present (Table 1). Attributes assessed were province area, human population size, human population density, and the number of international borders of each province. Data on Province attributes were obtained from the statistical center of Iran (www.amar.org, 2019).

Table 1. The number of invasive species in each province of Iran and attributes of Iranian Provinces was hypothesized to be correlates of the number of invasive species established.

Province	Introduced Species(n)	Area (km ²)	Population (persons)	Population density (Persons per km ²)	Bordering countries (n)
Alborz	11	5833	2712400	465.0	0
Ardebil	5	17800	1270420	71.3	1
Boushehr	6	22743	1163400	51.1	0
Chahar Mahal Bakhtiari	3	16332	947763	58.0	0
East Azerbaijan	7	45650	3909652	85.6	2
Fars	5	122608	2530696	20.6	0
Gilan	21	14042	2530696	180.2	1
Golestan	11	20195	1868819	92.5	1
Hamedan	3	19368	1738234	89.7	0
Hormozgan	8	70669	1776415	25.1	0
Ilam	3	20133	580158	28.8	1
Isfahan	5	107029	5120850	47.8	0
Kerman	5	183285	3164718	17.2	0

Kermanshah	3	24998	1952434	78.1	1
Khouzestan	13	64055	4710509	73.5	0
Kohgiluyeh & Boyer-Ahmad	3	15504	713052	45.9	0
Kordestan	3	29137	1603011	55.0	1
Lorestan	3	28294	1760649	62.2	0
Markazi	5	29130	1429475	49.0	0
Mazandaran	15	23701	3283582	138.5	0
North Khorasan	4	28434	863092	30.3	1
Qazvin	4	15549	1273761	81.9	0
Qom	7	11526	1292283	112.1	0
Razavi Khorasan	8	118884	6434501	54.1	2
Semnan	4	97491	702360	7.2	0
Sistan & Baluchestan	9	180726	2775014	15.3	2
South Khorasan	4	151913	768898	5.0	1
Tehran	19	18814	13267637	705.2	0
West Azarbaijan	8	37437	3265219	87.2	2
Yazd	7	76469	1138533	14.8	0
Zanjan	3	21773	1057461	48.5	0

Statistical analyses

We conducted Pearson correlation using IBM SPSS Statistics 23.0. (IBM Corp, 2015) to investigate hypothesized drivers of the number of invasive species established in each province of Iran.

Results

The number of species

Results of this study show a total of 63 IVS are found across the country, with the distribution shown in Figure 1. Three out of 63 records (4.7%), were failed introductions. These failed introductions were all mammals; African lion (*Panthera leo*), Chital (*Axis axis*), and Scimitar oryx (*Oryx dammah*), that were released as a result of zoos or breeding facility surplus (H. Ziaie, unpubl. data) for which written documents were missed.

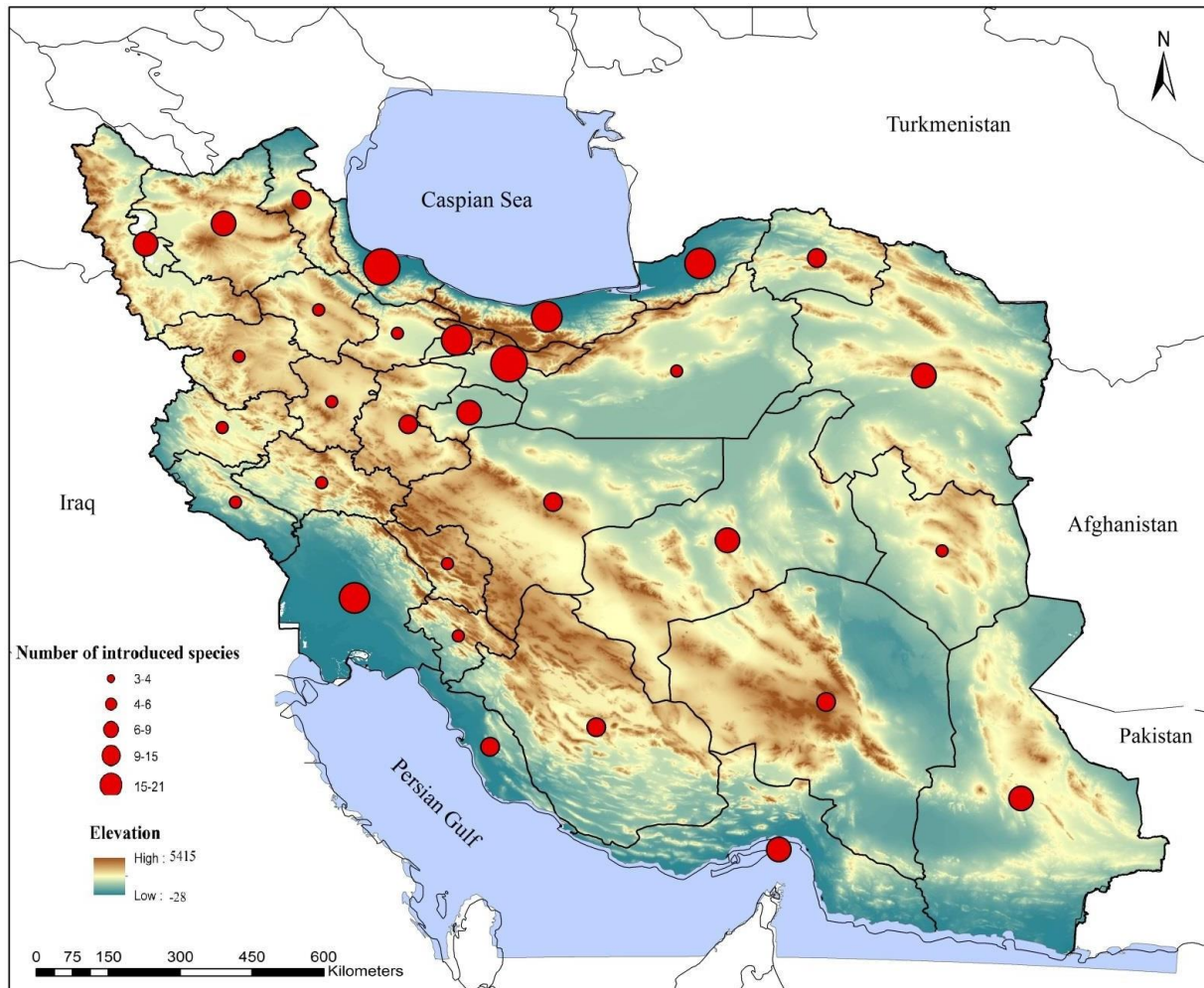


Figure 1. Map of Iran depicting provinces and the number of introduced species present in each province.

Fishes (“Class” = Pisces) have the highest number of introduced species, half of IVS, ($n = 29$) and reptiles have the lowest ($n = 4$). It should be noted that no introduced amphibians had been recorded in Iran at the time that this review was conducted. Birds and mammals have 6 and 18 introduced species, respectively (Fig 2). The most frequent IUCN red list ranking for IVS is; least concern ($n = 34$) followed by Vulnerable ($n = 6$), Near threatened ($n = 3$), Data deficient ($n = 2$), Critically endangered ($n = 1$), and Extinct in the wild ($n = 1$). 15 cases were not evaluated, mostly consisting of domestic animals. The intent of each introduction was assessed based on available evidence. Most introductions were found to be intentional ($n = 41$, 65.07%), 19 introductions were classified as unintentional and two cases appeared to be a combination of these factors (Unknown).

We found records of introduced species from all provinces of Iran ($n = 32$). The highest number of recordings is from Gilan, a northern bordering province ($n = 21$), followed by Tehran ($n = 20$).

Central provinces possess the lowest number of IVS (e.g. Hamedan, Zanjan, Chahar Mahal Bakhtiyari, Kohgiluyeh va Boyer-Ahmad, Kermanshah, Lorestan, Kordestan, and Ilam with 3 records each). Six of the recorded species were native to Iran but had undergone transfer between provinces to a novel area within the borders of the country. However, the majority of records were introductions from outside the country. All fish records were introduced from outside of the country. Among introduced species, 42 were introduced within the border of the country and 20 were introduced from foreign countries. For more details, please refer to Table S1.

Scientific articles

Few studies have directly addressed the subjects of invasive species or introduced species of Iran. Previous studies have concerned invasive fish (Esmaili et al. 2014) and introduced reptiles and amphibians (Safaei-Mahroo et al. 2015; Afroosheh et al. 2010; Moradi & Rastegar-Pouyani, 2015; Rastegar-Pouyani et al. 2015). There is no literature that we are aware of concerning introduced mammals and birds in Iran.

Social media

No search results were found for any English hashtags on Instagram. However, by searching hashtags in Farsi a total of 100 posts were discovered regarding invasive and introduced species in Iran. Most species that were discovered on Instagram such as Red-eared Slider, Chinese Soft-Shell Turtle, and Redbelly tilapia were already on our list from other different sources. The posts regarding these species confirm their presence of them in the country. A total of 7 species were added to the list from Instagram posts and personal communications with 3 Instagram users. The results mostly consist of birds, such as Zebra Finch, Budgerigar, Black Swan, Indian Pitta, Scaly-breasted Munia, and Betta Fish. It should be noted that these sightings were discussed with experts and were investigated for validation.

There were moderate correlations between the number of invasive species established and human population size and human population density, respectively (Table 1). The land area of provinces and the number of borders shared with neighboring countries were poor correlates of the number of invasive species established (Table 2).

Table 2. Pearson correlations between the number of invasive species established in provinces of Iran with each Province's area, human population, human population density, and the number of international borders (n = 32 in all cases).

Province attribute	Species
Area	-0.083
Population	0.611**
Density	0.629**
Borders	0.060
Number of bordering countries	0.086
**P=0.01	

Among our list, 10 species exist within the top 100 most destructive invasive species of the world (Lowe et al. 2000; Table 3).

Table 3. Species within our list are among the 100 top world worst alien species (Lowe et al. 2000).

Fish	Reptiles	Mammals
Trout (<i>Salmo trutta</i>)	Red-eared Slider (<i>Trachemys scripta</i>)	The domestic goat (<i>Capra hircus</i>)
Common Carp (<i>Cyprinus carpio</i>)	-----	Black Rat (<i>Rattus rattus</i>)
Largemouth Bass (<i>Micropterus salmoides</i>)	-----	Rabbit (<i>Oryctolagus cuniculus</i>)
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	-----	-----

Discussion

In this review, we provide a list of vertebrate species which have been introduced to Iran from other parts of the world or were translocated from other parts of Iran. Nowadays social media plays an important role in scientific communications as well as in citizen science (Nanni et al., 2020). Further investigation is needed to determine which of these species may be acting as invasive species (Macdonald and Willis, 2013). Here, we provide no recommendations for the elimination of the listed species due to data insufficiency. Some introduced species may have no effects or even have beneficial effects, on ecosystems (Simberloff & Von Holle, 1999). However, other species may have devastating effects on their recipient ecosystems due to their generalist life-history strategies and the strong interactions they have with native species (Ikeda et al. 2004, Messing & Wright, 2006, Pearson et al. 2015, Anderson et al., 2019). We hypothesized that species are more likely to be introduced from provinces that have borders with neighboring countries but there was no relationship between them ($\chi^2= 11.613$, p-value = 0.3). Instead, we found that there was a positive correlation between human population size and the number of invasive species in each

province. We suggest that this correlation exists because human demand for exotic species as pets or livestock may result in the release of invasive species into the wild. Our results were consistent with Sharma et al., (2010). Their results showed that the density of invasive species increased significantly with human-population density, total geographic area, GDP, and human development index. In another study Spear et al., (2013) showed that Human population density near National parks was a significant and strong predictor of the number of invasive species.

Introduced invasive species management

Controlling invasive species over a spatial scale and extended periods of time is a fundamental and challenging problem (Büyükahtakın et al., 2018). Each invasive species shows distinct population dynamics, such as varying growth and dispersal rates, and has different impacts on the ecosystem (Büyükahtakın et al., 2018). Management of invasive species involves prevention, surveillance, and control strategies (Büyükahtakın et al., 2018). The primary and best strategy to battle introduced species is the prevention of their importation (Büyükahtakın et al., 2018). Social networks can facilitate the trade of invasive species (Sardari et al., 2022). Governmental and non-governmental agencies should invest in public education and awareness toward the illegal invasive trade to restrict the demand of capturing wildlife for the pet trade (Sardari et al., 2022). One of the key pathways for IVS to enter a country is through the pet trade. As evidence of this, all the introduced reptile species, five of the introduced mammal species (e.g. *Rhesus macaque*), and six of the bird species (e.g. Rose-ringed parakeet) were introduced to Iran via the pet trade. Once escaped pets have established populations in the wild, population control programs have generally failed to eradicate those (Schlaepfer et al., 2005). Belts and roads pose a significant risk of increasing illegal wildlife trade and entering introduced vertebrate species (Farhadinia et al., 2019). In this regard, Identifying and managing the main routes of unintentional species introduction should be a priority. As a preventative measure, we recommend that regulations should be enforced to prevent the trade of exotic pets into the country, especially from bordering countries. Similarly, we recommend that the illegal trade in markets and pet shops of species that are part of the illegal pet trade should be stopped. Furthermore, we recommend that introduced species that are not under human control or living in the wild should be captured and transferred to zoos, or if not possible, euthanized humanely. Special facilities in urban parks or zoos can be devoted to this task in case of abandoned pets. Given the high number of intentional introductions, we surmise that education and law enforcement are of utmost importance (Sardari et al., 2022). Finally, we urge that programs

are undertaken to educate the population about the harmful effects that releasing non-native species, including frequently released species such as pets and fishes, can have on ecosystems and the economy. In many landscapes, free-ranging dogs (FRDs) are considered invasive species (Home et al., 2018; Nayeri et al., 2022). FRDs are a unique type of invasive species because of their especially strong bond with people (Miller et al. 2014; Nagasawa et al. 2015). Dogs are commonly held as pets and many people consider them their kin, beings that deserve equality and protection (Blouin, 2013). Consequently, many people feed FRDs and often inadvertently contribute to their population growth (Nayeri et al., 2022). Regular and continuous vaccination of FRDs through the cooperation of the relevant organizations, waste management, training programs for herders and owners, and enhanced law enforcement focusing on the restriction of the movements of free-ranging dogs could be used to reduce the presence of FRDs near Protected areas and urban ecosystem (Nayeri et al., 2022).

Conclusion

We identified 63 species as introduced vertebrate species in Iran. A wide array of methods is used to manage introduced vertebrates in some parts of the world such as the United States. Unfortunately, no study has been conducted on the management of invasive species in Iran. In this research, we report all invasive species in Iran. The introduction of invasive species to Iran should be regulated and controlled by the decision-makers such as the Iran Department of Environment and Ministry of Agriculture-Jahad and Fisheries.

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