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Review Article

Alien Vertebrates in Romania – A Review

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Abstract: We provide an updated review regarding the presence of alien vertebrates in Romania (i.e., fish, reptiles, birds, and mammals), taking into consideration both published data and a selection of international, regional and national public online databases. The literature review resulted in a preliminary checklist of 51 alien vertebrates in Romania, of which 41 were validated. The review of international and regional databases resulted in a preliminary checklist of 116 alien vertebrates, of which only 44 were validated after a quality check. The review of the national online databases resulted in a list of seven alien bird species in Romania, all of them valid. The final list contains 46 alien vertebrate species for Romania, of which 17 are established, and 29 are considered casual. Fish are the most abundant group (29 species) representing 63% of all vertebrate species, followed by mammals (eight species), birds (seven species), and reptiles (two species).

Key words: Checklist, alien species, fish, reptiles, birds, mammals.

Introduction

Human-driven biotic invasions are one of the most important direct drivers of biodiversity loss and ecosystem service changes worldwide (Bellard et al. 2016, Doherty et al. 2016, Walsh et al. 2016), second only to the direct destruction of habitats. There are currently more than 14,000 alien species recorded in Europe (EASIN, https://easin.jrc.ec.europa.eu/) with more than half originating from outside of the EU territories (Roy et al. 2019), and the number of occurrences is rapidly increasing due to new invasions and also the intensification of research on this topic (Seebens et al. 2017). Invasive alien species cause annual damages in the European Union that amount to at least €12 billion (Kettunen et al. 2009). While for other human-mediated impacts, there are clear and widely accepted indicators, the development and application of a set of internationally agreed indicators to assess the status of biological invasions is still ongoing (Wilson et al. 2018).

Invasion science, as a new discipline, is riddled with uncertainties, which is why national- and regional-scale measures to prevent or control alien species have done little to slow the increase in the extent of invasions and the magnitude of impacts (Latombe et al. 2019). It is assumed that the first uncertainty that any management action faces is the confirmation of the presence of an alien species in a region or country. Therefore, the updated national/regional checklists provide useful information both for policymakers and the general public (Nentwig et al. 2018).

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A first preliminary assessment of the presence of alien species in Romania has identified 982 alien species, of which 65 are freshwater, marine, and terrestrial vertebrates (Anastasiu et al. 2016). However, the assessment does not include online databases, nor do the authors provide a validated checklist of species and their status. To fill a knowledge gap and contribute to the implementation of the EU regulations on invasive alien species in Romania, we provide here an updated and comprehensive checklist of alien vertebrates reported in Romania as a result of an extensive review of scientific literature and the most relevant public online databases.

Materials and Methods

Literature review

We used Web of Science and Google Scholar databases (accessed on 20th June 2019) and created search queries with combinations of keywords ('alien species', 'invasive species', 'Romania', 'vertebrate', 'fish', 'amphibia', 'reptile', 'bird', 'mammal'), both in English and Romanian, with no restriction for timespan. Furthermore, we reviewed publications not indexed by the scientific search engines (grey literature). We searched published abstracts, scientific articles, books, book chapters, conference proceedings, doctoral theses, and scientific/official reports. We also reviewed published literature available as hard copies only, which was mostly the case for old publications in Romanian.

Review of online databases

We reviewed the available data on alien vertebrate species in Romania from seven public online databases (accessed on 20th June 2019): three international databases – Invasive Species Compendium (CABI), Global Invasive Species Database (IUCN GSID), and A Global Information System on Fishes (FishBase), as well as two regional – European Alien Species Information Network (EASIN) and Delivering Alien Invasive Species Inventories for Europe (DAISIE), and two national databases – ORNITODATA and Birding Romania. The international and regional databases were considered relevant for the purpose of our study since they also include data from smaller online national repositories, citizen science projects, and smartphone applications (e.g., iNaturalist, Invasive Alien Species Europe app). The Romanian online databases are, to the best of our knowledge, the only public databases available for Romanian vertebrates at the time of this review. We performed specific search queries within each of these databases, using filters that allowed us to extract only datasets regarding alien vertebrates recorded in Romania.

Data validation

The quality check of the resulted data was performed based on the authors' knowledge. We first verified if the reported species were indeed alien to Romania. We did not consider hybrids or subspecies of native species in our study. We excluded: (i) species present only in captivity and domesticated species, (ii) species reported based only on fossil records, (iii) species with uncertain origin (or cryptogenic, *sensu* Carlton 1996), (iv) data with untraceable source, and (v) species with improbable presence in Romania. Since there is a lack of consensus in the scientific literature regarding the terminology relevant to invasion ecology that includes qualities open to subjective interpretation (Colautti & MacIsaac 2004), we used the classification and terminology following Blackburn et al. (2011). Thus, we referred to casual as introduced species that are surviving in the new habitat but are not spreading, and to established as alien species that are reproducing and spreading, with some becoming invasive.

Results

The literature search (Web of Science, Google Scholar, and hardcopy literature) resulted in a list of 153 relevant publications which covered the period 1947–2018, as follows: 122 scientific articles, 17 books, two book chapters, six conference proceedings, three doctoral theses, and three reports (Annex 1). The literature review resulted in a preliminary checklist of 51 alien vertebrates in Romania, of which 41 were validated. The review of international and regional online databases resulted in a preliminary checklist of 116 alien vertebrates, of which only 44 were validated after a quality check. The review of the national online databases resulted in a list of seven alien bird species in Romania. These records were considered valid since the data reported in these databases are already curated by professional ornithologists with vast expertise in their field.

The international and regional databases included most erroneous records, with 42% of the records referring to species native in Romania. Apart from these, we discarded records of species present only in some form of captivity (zoos, aquaria) or domesticated, doubtful records (e.g., species with improbable presence in Romania,

Table 1. Checklist of alien vertebrates in Romania based on review of scientific literature and online databases. Species recorded from citizen science are marked with an asterisk (*). Alien species assessed among the worst in Europe by Nentwig et al. (2018) are marked with (#) followed by the corresponding ranking. The presence of species of European Union Concern is checked following the Commission Implementing Regulation (EU) 2019/1262 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern.

No	Species name	Group	Alien status	Species of EU concern (EU 2019)
1	*Aix galericulata**	Birds	casual	
2	*Aix sponsa**	Birds	casual	
3	*Alopochen aegyptiaca*	Birds	casual	yes
4	*Anser indicus*	Birds	casual	
5	*Branta canadensis* (#1)	Birds	casual	
6	*Phasianus colchicus*	Birds	established	
7	*Psittacula krameri** (#67)	Birds	casual	
8	*Ameiurus melas*	Fish	established	
9	*Ameiurus nebulosus*	Fish	established	
10	*Carassius auratus* (#20)	Fish	casual	
11	*Carassius gibelio*	Fish	established	
12	*Clarias gariepinus*	Fish	casual	
13	*Clarias ngamensis*	Fish	casual	
14	*Coregonus albula*	Fish	casual	
15	*Coregonus lavaretus*	Fish	casual	
16	*Coregonus peled*	Fish	casual	
17	*Ctenopharyngodon idella* (#65)	Fish	established	
18	*Gambusia holbrooki* (#80)	Fish	established	
19	*Hypophthalmichthys molitrix*	Fish	established	
20	*Hypophthalmichthys nobilis*	Fish	established	
21	*Ictalurus punctatus*	Fish	casual	
22	*Ictiobus bubalus*	Fish	casual	
23	*Ictiobus cyprinellus*	Fish	casual	
24	*Ictiobus niger*	Fish	casual	
25	*Lepomis gibbosus*	Fish	established	yes
26	*Megalobrama terminalis*	Fish	casual	
27	*Micropterus salmoides**	Fish	casual	
28	*Mylopharyngodon piceus*	Fish	casual	
29	*Oncorhynchus mykiss* (#60)	Fish	casual	
30	*Parabramis pekinensis*	Fish	casual	
31	*Perccottus glenii*	Fish	established	yes
32	*Planiliza haematocheila*	Fish	casual	
33	*Poecilia reticulata* (#76)	Fish	casual	
34	*Polyodon spathula*	Fish	casual	
35	*Pseudorasbora parva* (#59)	Fish	established	yes
36	*Salvelinus fontinalis*	Fish	established	
37	*Dama dama*	Mammals	established	
38	*Myocastor coypus* (#17)	Mammals	casual	yes
39	*Neovison vison* (#19)	Mammals	casual	
40	*Nyctereutes procyonoides* (#66)	Mammals	established	yes
41	*Ondatra zibethicus* (#4)	Mammals	established	yes
42	*Oryctolagus cuniculus*	Mammals	casual	
43	*Rattus norvegicus* (#2)	Mammals	established	
44	*Rattus rattus*	Mammals	established	
45	*Podarcis siculus**	Reptiles	casual	
46	*Trachemys scripta*	Reptiles	casual	yes

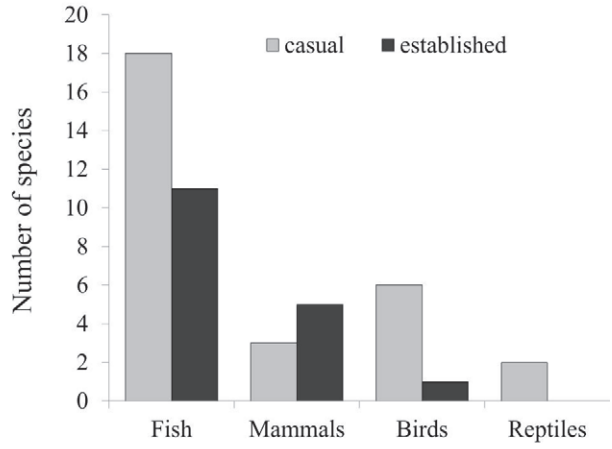

Fig. 1. Alien vertebrates in Romania according to their establishment status.

erroneous identification/ taxonomic confusion, and source not indicated), cryptogenic species, and fossil records. Exotic fish reported both in the literature and international databases, which can survive only in thermal water bodies, were also excluded. We provide in Annex 2 a list of the species and subspecies excluded after the quality check and a justification for their exclusion from the final checklist of alien vertebrates in Romania.

The checklist of alien vertebrates in Romania after data validation resulted in 46 alien species (Table 1). Of these, 41 species were recorded both in the scientific literature and online databases, while five species were recorded only in online databases, through citizen science. Based on the available published information, 17 of the alien species were considered established, with self-sustaining populations in the wild, while the rest of the species (29) were considered casual aliens since no evidence regarding their reproductive success in the wild was found in the published literature (Fig. 1).

Discussion

We report 46 alien vertebrate species for Romania, of which 17 are established, and 29 are considered casual. Fish are the most abundant group representing 63% of all vertebrate species. There are only two reptile species recorded in the country and no alien amphibian species. Among the 149 alien species ranked as the worst aliens in Europe by Nentwig et al. (2018), 40 (27%) are vertebrates, and our checklist includes 13 of them (representing 28%). Of the 66 species of European Union concern, eight are present in Romania, of which five (three fish and two mammals) have already become established in natural ecosystems (Table 1).

Our study showed that scientific literature provides more reliable data regarding the alien vertebrates in Romania, while international online databases contain numerous errors and require supplementary efforts for data validation. For example, 53 native species and subspecies were erroneously recorded as aliens to Romania. Also, some domestic species were included in the list as aliens, although there are no established wild populations (e.g., sheep, cattle, water buffalo). A special category is represented by tropical aquarium fish species that are sometimes released in the wild, but they can only survive in thermal water bodies. This is a common situation in urban areas, with many exotic species surviving in thermal water bodies, but not presenting any risk of spread (Weiperth et al. 2015). While public databases provide multiple applications for decision-makers, scientists, and the general public, stricter quality check and control of the data is required to avoid these biases.

The revised checklist of alien species has some limitations in the sense that it does not include citizen science data from other potential sources, such as social media and personal blogs. Citizen science is in its incipient stages in Romania, and while some efficient tools are available (e.g., iNaturalist, GBIF, IAS Europe app), a significant amount of biodiversity records, including alien species, from well-intended citizen scientists may remain inaccessible or difficult to access for conservation managers, scientists and policymakers. Besides data accessibility, data validation is essential in data management of online databases. Not all online databases allow public access to readily available datasets and/or provide information regarding the validation process of the input data. We decided not to consider these sources of information (i.e., social media, personal blogs) since their verification and validation by our group of experts would have been time consuming and well beyond the scope of this paper.

The alien vertebrate species present in Romania were mainly introduced intentionally either for fur farming (e.g., the American mink *N. vison*), hunting (e.g., the fallow deer *D. dama* and the pheasant *P. colchicus*), fishing (e.g., Asian carp, the rainbow trout *O. mykiss*), or pet trade (e.g., the rose-ringed parakeet *P. krameri*, the pond slider *T. scripta*). Only a few of them were introduced accidentally, e.g., the two species of rats (*R. norvegicus* and *R. rattus*) introduced in historical times, which are now widespread and have a high impact on native species, economy and human health.

Since the number of alien species worldwide is rapidly increasing with no sign of saturation

(Seebens et al. 2017), and in some cases so is their rate of spread (Roques et al. 2016) and impacts (Tittensor et al. 2014), our list of alien vertebrate species in Romania will require constant updating and impact evaluation.

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Annex 1. List of reviewed literature and online databases.

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Annex 2. Records of species and subspecies reported in the reviewed literature and online databases, which were not considered as valid, following data quality check.

No	Species name	Taxonomic group	Justification for exclusion
1	*Hyla arborea*	amphibians	native
2	*Lissotriton vulgaris meridionalis*	amphibians	subspecies of a native species with the source not found; improbable presence, doubtful record
3	*Anas platyrhynchos*	birds	native
4	*Anser anser*	birds	native
5	*Aquila chrysaetos*	birds	native
6	*Athene noctua*	birds	native
7	*Columba livia*	birds	native
8	*Cygnus olor*	birds	native
9	*Passer hispaniolensis*	birds	native
10	*Streptopelia decaocto*	birds	native
11	*Tadorna ferruginea*	birds	native
12	*Tyto alba*	birds	native
13	*Alburnus alburnus*	fish	native
14	*Aspius aspius*	fish	native
15	*Barbus meridionalis*	fish	refers to preserved specimens which later proved to be *B. petenyi*, which is a native species; see Bănărescu (1964) and Kotlik et al. (2002)
16	*Barbus peloponnesius*	fish	refers to preserved specimens which later proved to be *B. petenyi*, which is a native species; see Bănărescu (1964) and Kotlik et al. (2002)
17	*Benthophilus stellatus*	fish	native
18	*Betta splendens*	fish	can survive only in thermal waterbodies
19	*Carassius carassius*	fish	native
20	*Clupeonella cultriventris*	fish	native
21	*Coregonus maraena*	fish	source not found; improbable presence, doubtful record. Possibly confusion with *C. lavaretus maraenoides*
22	*Cyprinus carpio*	fish	native; see Zhou et al. 2003 and Xu et al. 2014
23	*Cyprinus carpio haematopterus*	fish	subspecies of a native species
24	*Cyprinus carpio var koi*	fish	ornamental variety of a native species
25	*Esox lucius*	fish	native
26	*Gambusia affinis*	fish	error; *G. holbrooki* was introduced in Romania; see Bănărescu 1964
27	*Gymnocephalus cernuus*	fish	native
28	*Huso huso*	fish	native
29	*Huso huso x Acipenser ruthenus*	fish	native
30	*Leucaspius delineatus*	fish	native
31	*Leuciscus idus*	fish	native
32	*Leuciscus leuciscus*	fish	native
33	*Macropodus opercularis*	fish	can survive only in thermal waterbodies
34	*Neogobius fluviatilis*	fish	native
35	*Neogobius gymnotrachelus*	fish	native
36	*Neogobius kessleri*	fish	native
37	*Neogobius melanostomus*	fish	native
38	*Oreochromis mossambicus*	fish	source not found; improbable presence, doubtful record
39	*Perca fluviatilis*	fish	native
40	*Percarina demidoffii*	fish	native
41	*Pethia conchonius*	fish	can survive only in thermal waterbodies
42	*Pethia ticto*	fish	can survive only in thermal waterbodies

No	Species name	Taxonomic group	Justification for exclusion
43	*Phoxinus phoxinus*	fish	native
44	*Poecilia sphenops*	fish	can survive only in thermal waterbodies
45	*Proterorhinus marmoratus*	fish	native
46	*Proterorhinus semilunaris*	fish	native
47	*Rhodeus sericeus*	fish	native
48	*Rutilus rutilus*	fish	native
49	*Salmo trutta*	fish	native
50	*Sander lucioperca*	fish	native
51	*Scardinius erythrophthalmus*	fish	native
52	*Silurus glanis*	fish	native
53	*Sparus aurata*	fish	native
54	*Squalius cephalus*	fish	native
55	*Telestes souffia*	fish	native
56	*Tinca tinca*	fish	native
57	*Trichopodus trichopterus*	fish	can survive only in thermal waterbodies
58	*Xiphophorus hellerii*	fish	can survive only in thermal waterbodies
59	*Xiphophorus maculatus*	fish	can survive only in thermal waterbodies
60	*Bos taurus*	mammals	domestic/captivity
61	*Bubalus bubalis*	mammals	domestic/captivity
62	*Capra ibex*	mammals	cannot be considered alien since fossil remains were found in Peștera cu Oase (cave), Romania. See Quilès et al. (2006)
63	*Cervus elaphus*	mammals	native
64	*Crocidura suaveolens*	mammals	native
65	*Delphinapterus leucas*	mammals	error; possibly part of a museum collection; source not found
66	*Erinaceus concolor*	mammals	probably refers to *E. romanicus*; confusion due to taxonomic re-evaluations
67	*Erinaceus europaeus*	mammals	probably refers to *E. romanicus*; confusion due to taxonomic re-evaluations
68	*Lepus europaeus*	mammals	native
69	*Lepus timidus*	mammals	source not found; improbable presence, doubtful record
70	*Macaca sylvanus*	mammals	probably recorded from captivity; source not found
71	*Microtus oeconomus*	mammals	source not found; probably recorded from Pleistocene fossils found in Romania; see Petculescu & Ştiucă (2008)
72	*Mus musculus*	mammals	cryptogenic
73	*Mustela erminea*	mammals	native
74	*Ovis aries*	mammals	domestic
75	*Ovis aries musimon*	mammals	subspecies of a domesticated species; uncertain origin; see Antone (2013)
76	*Procyon lotor*	mammals	source not found; probably recorded from captivity
77	*Rangifer tarandus*	mammals	source not found; probably recorded from captivity or Pleistocene fossils found in Romania; see Petculescu & Ştiucă (2008)
78	*Rupicapra rupicapra*	mammals	native
79	*Sus scrofa*	mammals	native
80	*Vulpes lagopus*	mammals	fossil record
81	*Podarcis muralis maculiventris*	reptiles	subspecies of a native species
82	*Zamenis situla*	reptiles	source not found; probably recorded from captivity or museum collection; might be in reference to Fuhn & Vancea (1961) citing Kiritzescu (1930), regarding a misidentified specimen from an old collection of Natural History Museum