

Review articles

Alien species of parasites – some questions concerning terminology

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ABSTRACT. The article deals with some terms proposed by the proper institutions of the Council of Europe for describing the phenomenon of invasion of living organisms into new habitats. As these terms were elaborated mainly from the point of view of free living creatures, the goal of the authors was to discuss the possibility to adapt them for parasites species. Several propositions of resolving some difficulties have been presented¹.

Key words: terminology, alien species of parasites, Bern Convention, colonization of new habitats, expansion, invasion, IUNC guidelines for prevention of biodiversity

Since the 1970's, the invasion of alien parasites species into new geographic areas and ecosystems has been one of the greatest ecological and economic problems of many European countries. This is why several institutions – both national and international – are trying to find any remedy to reduce the fatal consequences of this enormously increasing phenomenon. In 1979, the Council of Europe presented and accepted during its meeting in Bern the document: **The Convention on the conservation of European wildlife and natural habitats** (the so called “Bern Convention”) [1]. This is the schedule of activities which should be performed by governments which ratified this convention. In 2000, during its 51st meeting in Switzerland, the IUNC (International Union for Conservation of Nature) approved the document prepared by the group of specialists (SSC Invasive Species Specialists group): **IUNC guidelines for the prevention of biodiversity loss by alien invasive species** [2].

In this document, the strong emphasis has been stressed on the necessity of international cooperation, uniformity of methods, and

terminology standardization. Another important document “**European strategy on invasive alien species**” [3], published in 2004, has been directed mainly to the governments of European countries which ratified the Bern Convention.

In Poland, which ratified the Bern Convention in 1996, the faunistic studies on the phenomenon of alien species introduction and their impact on the natural ecosystems and national economy were carried out since 1999 in the Institute of Nature Conservation, Polish Academy of Sciences in Kraków and then also in other scientific institutions. The results of these different studies published in original articles, have been summarized by several authors in the book **Alien species in fauna of Poland** [4] published in 2011 by the mentioned Institute. It comprises very interesting information on alien species brought to Poland – mainly free living, but also some parasitic ones.

Though the problem of alien parasites has been noticed by Polish parasitologists and becomes more and more often the object of their studies, the recommendations of the Bern Convention remain rather unknown. That is why we recommend to our

¹The more detailed abstract of this article has been published under the same title in *Annals of Parasitology* 2013, 59, supplement. Abstracts of the XXIII Congress of the Polish Parasitological Society: 7.

colleagues not only to search for the information about the animals which are the hosts of parasites studied, but also to familiarize themselves with some chapters of the above mentioned book dealing with general problems, such as: Introduction [5], Methods and terminology [6], Final comments [7], Recommendations [8].

The goal of this article is to discuss whether the terms recommended in the mentioned documents can be used also in relation to the species of parasites. It seems to us that due to the specific, and often differentiated mode of life, not all terms employed mainly by ecologists in relation to free living organisms can be used in relation to parasites (*nota bene*, some of them are already criticized by ecologists). The base for our discussion are the terms and their definitions presented in the mentioned book: **Alien species in fauna of Poland** in the chapter: **Methods and Terminology** [6] and cited *in extenso* in this article².

The terms defined the species based on its origin

“Native, indigenous, autochthonous species (Gatunek rodzimy) – the species (or subspecies) occurring in the limits of its natural and potentially dispersive range – when it lives or can live without human care” [6].

“Alien, non-native, non indigenous, foreign, exotic species (Gatunek obcy, obcego pochodzenia, nierodzimym, introdukowany, wprowadzony, egzotyczny) – the species or lower taxon transmitted intentionally or brought accidentally outside its natural range (past or present); it includes any part, gametes, seeds, eggs which allow them to survive and subsequently reproduce. It does not, however, concern the species which widened its natural ranges spontaneously, even if it is connected with the modification of environment and landscape neither those that appear in large numbers whether irregularly or in short time intervals”[6].

“Cryptogenic species (Gatunek kryptogeniczny) – according to Carlton (1996) this is a species not evidently native or alien, and its expansion or invasion may be a result of either natural or antropogenic reasons”[6].

Comments. Several ecologists emphasize that there are some problems with classifying species established in Europe in ancient times as native or

alien. For example Kołodziejczyk et al. [9] mention that in Europe all species of flora and fauna appeared in various eras after last glaciations, and some of them not for the first time (recolonization). They consider that in definition of native and alien species “*lack of time points*” from each these two categories could be recognized.

In many cases we also do not know which species living currently in Poland are foreign, and which are the product of evolution of their alien ancestors. In relation to most free living organisms, it is possible to reconstruct their history on the basis of fossil traces – the time of appearing in given areas and the tracks of their expansions. But this is rather impossible in relation to parasites, as they very rarely leave their traces. These are mainly the shells of helminth eggs found during archeological studies on ancient human habitats or cemeteries and mummies. In some cases the analysis of the hosts circle of given parasite species can be useful, but not always. We try to speculate about the origin of parasitic helminths of carp (*Cyprinus carpio*) – the fish introduced in the Middle Ages to many European countries from the Ponto-Caspian region. Today in Poland 30 species of helminths are recorded in this fish: 16 Monogenea, 2 Digenea, 6 Cestoda, 1 Nematoda and 5 Acanthocephala [10]. Among them, two species of Cestoda, namely *Khawia sinensis* and *Bothriocephalus acheilognathi* are introduced; they were brought to Europe during the second half of the 20th century – the first in wild carp (*Cyprinus carpio haematopterus*), the second in white amur (*Ctenopharyngodon idella*) and they colonized carp already in Europe. One species of Digenea and seven Monogenea occur only in carp, which might suggest that they were brought with this fish species. The remaining species have greater circle of hosts, mainly native fish species. All these parasites occur in many Asiatic and European countries (Palearctic range); some of them also occur in North America (Holarctic range). It is possible that they came with carp from the East and colonized some native host species. But other scenarios are also possible: carp in new areas was colonized by native parasites, or carp is not the primary host of these parasites as they might shift spontaneously from East to West in other fish species, colonizing not only new areas but also new hosts. Perhaps all these scenarios were realized. We can search for some indications analyzing the data on frequency of occurrence (intensity and

² It is our translation of a Polish text. Since the recommended terms should be used in Polish articles and documents we provide their Polish version in parentheses.

prevalence) as well as pathogeny in given host species.

There are also some problems with the parasites recorded in the migrating host, especially in birds which realize the seasonal migrations. In Poland, 14 species of Digenea, three species of Cestoda [11,12], four Nematoda [13], one Acanthocephala and two Acari were recorded exclusively in birds during spring or autumn migration, while four Digenea, five Cestoda and four Nematoda in birds wintering on the west Baltic Sea-shore [11,13–15]. It is very probable that the parasites found in migrating birds are colonizers, for some of them the area of their provenience can be even defined. Most of them are not able to colonize neither resting nor nesting areas. However, wintering birds may have some parasites recruited in the nesting area and some acquired in the wintering locality. In these cases, some data on their biology may be helpful to define their origin, e.g., life cycle, longevity of developmental stages, and, most importantly, geographical range of given species, but our knowledge of this issue is generally very poor. Unlike for free living organisms, the study of parasites barely developed after World War II. Only scarce data exist from 19th to the beginning of 20th century. Nowadays in many countries the knowledge of parasitic fauna is still enriched; new parasites are recorded, and details of their range are still added.

Considering all these difficulties and limitations, we present the following propositions for discussion.

In relation to established species, we submit two arbitrary resolutions.

1. To establish time point: all species of parasites recorded in Poland before the year 1945, and for which the alien provenience has not been documented, should be defined as native species.

2. To define all parasite species for which alien provenience has not been documented (independently from time of their recording) as cryptogenic species.

We recommend **the first resolution**, since in the most cases Poland is part of a wider natural range for a given species. Even their shift there from neighboring areas was a natural enlargement of their range.

In relation to parasites recorded only in

migrating hosts and for which provenience is not known we propose **to define them as cryptogenic species³ or to record them without any classification, but with the note that they may not represent the native fauna.**

The importation of parasites by wild animals creates one more interpretation difficulty. We believe that these parasites should be treated as alien species, even if it is the importation without human activity. Repeated brought of parasites can result in colonization of new area; these new habitats usually are not the simple enlargement of the parasite's range, but new "islands", often in great distance from the native place of given species. An example of this phenomenon is *Clinostomum complanatum*. This digenean, native to subtropical regions (Africa and southern Europe), was recorded several times in herons nesting during the summer in Poland. The establishment of this species in Poland has been confirmed by the presence of metacercariae in two fish species in an artificially-heated lake in the Konin region [16]. It is evident that in heated water, miracidia survived and were able to find suitable intermediate hosts for completing their life cycle. Similarly, the nematode *Dirofilaria repens*, was several times transmitted to Poland mainly by dogs (rarely by humans). However, in 2012, the DNA of this species was found in mosquitoes from the Warsaw region [17 and personal communications of the authors] and autochthonous cases of dirofilariosis have been also recorded [18].

The terms defined the species on the basis of the character of its invasiveness

"Invasive species, invader (Gatunek inwazyjny) – a species which in a short time and large numbers colonize new areas and habitats, and creates negative, sometimes catastrophic, effects in ecosystems and/or the economy. Invasiveness may be a trait of both native and alien species, which enlarge their range"[6].

"Invasive alien species (Gatunek obcy inwazyjny) – a species which, when introduced or brought to new areas, threatens local biodiversity and/or the economy"[6].

"Non-invasive alien species (Gatunek obcy nieinwazyjny) – an alien species, which in new localities, establishes a population with only feeble possibility for dispersion"[6].

³ It is worthy to notice that the term **cryptogenic species** may be confused with the term **cryptic species**, which identifies species that are closely related and very similar morphologically.

“Post-invasive alien species (Gatunek obcy poinwazyjny) – an alien species introduced very long ago (conventionally before 1900), which in new areas does not exhibit already any fundamental changes in its range.” [6].

Comments. In parasitology, the term “invasiveness” is used to refer to a feature of an individual host, not a species; it identifies the capacity for the establishment and development at the host level, even without the negative effects [19]. With respect to invasiveness of the parasite, it is important to note that the impact of a parasite on an ecosystem or the economy is indirect; it operates through the impact on the population or community of hosts. Under natural conditions, a parasite may induce a variety of effects. If the mortality in a host population is low, there may be no repercussions at the ecosystem level; it may be even profitable *via* elimination of weak, or more vulnerable, individuals from populations. Such parasites should be treated as non-invasive. However, when parasites cause the death of great number of their hosts, e.g., in the case of an epidemic, some host species may disappear what may produce a significant impact on the structure of a biocoenosis. With animal husbandry, the situation is different. Even low parasitic infections present some measurable economical losses in the quality of animal products; there is also much greater risk for the outbreak of an epidemic. In the conditions of husbandry, many parasites are invasive and should be the subject of eradication.

These two examples deal with interference of parasites in ecosystems or economy, but without the enlargement of their range. The colonization of new areas depends on different factors of both the parasite and its host, e.g., migration of hosts and their success in colonization new areas, relative vulnerability or susceptibility to infection by a parasite, the ability of a parasite to adapt to new conditions of external and internal environments, etc. In new hosts, parasites very often cause serious morbidity, not observed in old host-parasite relationships. New hosts also may be “the vehicle” for transfer of parasites into new localities. It should also be noted that in a given host organ, several parasite species can occur, and that they will likely compete for space and nutrients. More aggressive parasites may expel previously established species. In Poland, a harmless *Caryophyllaeus fimbiceps* in carp has been replaced by *Khawia sinensis*, an alien species that appears to be strongly pathogenic for

this fish.

Considering all these different possibilities in the development of new host-parasite relationships and interspecific relations in parasite communities, we propose to define as invasive those parasites that exhibit at least one of three following features:

1. It causes some disorder in the functioning of a natural biocoenosis or in husbandry by inducing illnesses that may cause elimination of any species from biocoenosis or serious losses in husbandry;

2. it colonizes new hosts;

3. it rapidly enlarges its range.

If we accept the year 1945 as the proposed time-point for recognizing an alien parasite species in Poland, the term *post-invasive alien species (gatunek obcy poinwazyjny)* is at the present moment not useful.

The terms related to the ways of emerging of alien species in new areas or habitats

“Introduction (Introdukcja) – Intentional or accidental movement, by human agency, of a species (or lower taxon) outside its natural range (past or present)”[6].

“Intentional introduction (introdukcja zamierzona, celowa) – the purposeful transfer of living organism/species (or lower taxon) outside its natural range”[6].

“Unintentional introduction (introdukcja niezamierzona, przypadkowa, zawleczenie) – accidental, unintended transfer of living organism/species (or lower taxon) outside its natural range”[6].

Comments. The application of any of the above terms in relation to parasites is met with several serious problems. It seems that in most cases the only proper term is “unintentional” introduction, as parasites are very rarely introduced by humans for the purpose of competing with another pest. Generally they are accidentally brought by their host, by other “vehicle” animals (phoresis), or by wind or by water (dispersive stages). In the case of transfer with the host introduced purposely by humans, it is not a strictly accidental event because one should anticipate the risk of parasite transfer. On the other hand, the terms **intentional introduction** and **unintentional introduction** evoke some reservation of biologists, as “*there is an inconsistency with their intuitive understanding. Introduction implies a conscious transfer of new*

species by humans, while brought means that the transfer is unconscious” [9].

It seems that the resolution of this dilemma will be rather difficult. We propose **not to use the term “introduction” (introdukcja)** in relation to parasites and instead **to employ the term “brought” (zawlekanie)**. In order to distinguish the alien species that colonized new territories from those which are brought repeatedly, we could adapt some terms used in biological literature [20], i.e., **established alien species (gatunki obce zdomowione)** and **casual species or non-established species (gatunki niezdomowione)**. In these two cases, the terms **established brought (zawleczenie)** and **casual brought (zawlekanie)**, respectively, could be used. In Poland, the tapeworms *Khawia sinensis*, *Bothriocephalus acheilognati* [11], and *Nippotaenia mogurndae* [21] represent established alien species, while *Leishmania* sp. [22] is currently casual alien species. The repeated casual brought of any parasite species may lead to its establishment in a new area, as it has probably happened with *Clinostomum complanatum* [16]. It is worth emphasizing that in the case of repeated brought, the meeting of the established offspring with individuals from alien populations is possible, which increases the possibility of mixing the genetic material.

Terms connected with the character of species dispersion

“Expansion (ekspansja) – there is a spontaneous enlargement of the population of given species range (in a geographic sense), usually at short distance and in small groups of individuals or, in ecological sense – colonization of new habitats and filling free living space in the limits of hitherto existing range. Expansion has rather mild meaning, but it takes a long time, and is either continuous or by stages. It may be caused by natural factors”..... “or by human activity”...”. It may occur from natural range of given species of from the place of its introduction”[6].

“Invasion (inwazja) – means a rapid colonization of new area by large number of individuals, involving great distances, and in some cases rapid growth of the population, causing either greater or smaller changes in the ecosystem and sometimes losses in economy. We understand the term invasion as an aggressive colonization of new territories from the place of introduction of

alien species or from its natural range as a result of penetrating the natural geographic or ecological barriers which earlier isolated the species or lower taxons”[6].

Comments. While the presented definitions indicate that the terms “expansion” and “invasion” can also be use in relation to parasites, some comments are necessary. First, we propose **recognizing colonization of new area, as well as colonization of new host, as capturing of new habitats.** We also propose to apply the term **“expansion” in relation to parasites that enlarge their ranges gradually (progressively) in connection to the expansion of their hosts,** while the term **“invasion” is associated with those species that induce a harmful impact on host’s health, or ecosystems** (for example the expulsion of any native host or parasite), **or cause great economic losses.** We distinguish **two categories of invasion, i.e., the term “territorial invasion” (inwazja terytorialna)** specifying the parasites **that rapidly enlarge their range,** and the term **“host invasion” (inwazja żywicielska)** to specify those **that colonize new host species.** The terms invasion and expansion are applicable to both native and alien species of parasites.

The following examples illustrate the distinction of these two terms for parasites recorded in Poland. The traits of expansiveness show some alien species of protozoans (*Apiosoma* sp.) and monogeneans (mainly *Dactylogyrus* spp.) brought by introduced fishes, and remaining on their proper hosts, while some native protozoans (*Trichodina* spp.), which succeeded in colonizing new host species manifest the traits of host invasion [23]. In alien species of parasites, territorial invasion is quite often observed. Examples include the microsporean *Cucumispora dikerogammari* [25] and *Nosema pontogammari* [26] and the monogeneans *Pseudodactylogyrus anguillae* and *P. bini* [27], the ascaridid *Baylisascaris procyonis* [28], and the hookworm *Paratenuisentis ambiguus* [29], all of which remaining in their proper host species. Very often, the territorial invasion is accompanied by host invasion that is manifested by significant pathogenicity in new hosts. This is the case of the tapeworm *Echinococcus multilocularis* recorded in new habitats and with greater prevalence [30], two nematodes *Ashworthius sidemi* and *Elaphostrongylus cervi* [31,32] brought by Cervides and captured by other ruminants, and the mite *Varroa destructor* the destructive external parasite of bees

[33]. The history of *Fasciolopsis magna* in Europe is of interest. This digenean is a native of North America, where it has been recorded in several habitats in USA and Canada. It was brought to Europe via *Cervus elaphus canadensis* or *Odocoileus virginianus* in 19th century to zoological gardens and several forests. In Europe, it colonized not only new areas, but also the other ruminants, including livestock. In Poland it was recorded only two times, in 1932 and 1955, in two habitats in the Low Silesia [34]. This focus probably still exists (Prof. Aleksander Demiaszkiewicz, pers. comm.). The comparison of haplotypes of individuals from different focuses in North America and several European countries make it clear that this parasite was brought to Europe several times from the USA and Canada [35].

Table 1 presents the data on 131 alien and 10 native species of parasites. Among the alien species, 40 (mainly Monogenea and Nematoda) certainly, and eight likely (mainly Digenea), are established in Poland. Among the species included in the group of casually brought, as many as 22 species are recorded in birds during the spring or autumn migration, as well as 13 species were recorded in birds wintering in the Polish Baltic coast. Monogeneans and nematodes prevailed among the 83 species that have a documented alien origin. From among 38 established alien species, 16 are still brought by migrating hosts. In the process of

colonization of new areas about 50% of species exhibited the traits of invasion, manifested by colonization of new hosts (host invasion) or by harm for various hosts, including humans.

There are seven species of Protozoa and three species of Acari in the group of native species that colonized new habitats. Six protozoans that manifested host invasion were transferred from carp into two introduced alien fish species bred together with carp during pond husbandry [23]; one has colonized a new cervoid species as its host [24]. As for the ticks, one species parasitizing the cervides enlarged its range rapidly (territorial invasion) [35]; the two other are bird parasites, but now attack humans [37,38]. These parasites are especially threatening for animals and humans, as they not only cause instantaneous discomfort, they also are the vectors of several virus and bacterial diseases [39].

The data gathered until now probably only touch the phenomenon of expansion of alien parasitic species in Poland. While the occurrence of new parasites in the hosts under study has been intensely studied, the information regarding their origin, as well as the stabilization of given alien species, is scarce. Finding developmental stages in intermediate hosts of given species would be a valuable indication, but the parasitological studies of invertebrates, which are the intermediate hosts of many parasites with the complex live cycle, are still rather rare.

Table 1. Characteristics of parasitic alien species and invasive native species in fauna of Poland

	Established brought	Casual brought	Expansion	Invasion			References
				territorial	host	harmfulness	
PROTOZOA							
<i>Apiosoma</i> sp.	+		+		+		[23]
<i>Chilodonella hexasticha</i>					+		[23]
<i>Ch. piscicola</i>					+		[23]
<i>Eimeria catubrina</i>					+		[39]
<i>Leishmania</i> sp.		+				+	[22]
<i>Hexamita symphysodonis</i>		+			+		[40]
<i>Plasmodium falciparum</i>		+				+	[41]
<i>Plasmodium ovale</i>		+				+	[41]
<i>Trichodina domerguei</i>					+		[23]
<i>T. mutabilis</i>					+		[23]
<i>T. nigra</i>					+		[23]
<i>T. pellucidus</i>					+		[23]
MYXOSPOREA							
<i>Sphaerospora carassi</i>	+			+	+		[23]

	Established brought	Casual brought	Expansion	Invasion			References
				territorial	host	harmfulness	
MICROSPOREA							
<i>Cucumispora dikerogammari</i>	+	+		+		+	[25]
<i>Nosema ceranae</i>	+			+	+	+	[42]
<i>N. pontogammari</i>	+	+		+		+	[26]
<i>Thelohana</i> sp.	+	+		+		+	[25]
MONOGENEA							
<i>Cleidodiscus monticelli</i>	+		+				[43]
<i>Cleidodiscus pricei</i>	+		+				[43]
<i>Dactylogyrus aristichthys</i>	+		+				[23]
<i>D. hypophthalmi</i>	+		+				[23]
<i>D. lamellatus</i>	+		+				[23]
<i>D. nobilis</i>	+		+				[23]
<i>D. suchengtai</i>	+		+				[23]
<i>Gyrodactylus fairporti</i>	+		+				[44]
<i>G. perccotti</i>	+		+				[45]
<i>G. proterorhini</i>	+		+				[46]
<i>G. turnbuli</i>	+		+				[47]
<i>Paradiplozoon marinae</i>	+	+					[23]
<i>Pseudodactylogyrus anguillae</i>	+	+		+			[27]
<i>P. bini</i>	+	+		+			[27]
<i>Mymarothecium viatorum</i>		+					[48]
<i>Sciadiclecithrum variabilum</i>	+?	+	+?				[41]
<i>Thaparocleidus caecus</i>		+					[49]
DIGENEA							
<i>Apatemon somateriae</i>		+? ⁴					[50]
<i>Aporocotyle simplex</i>		+					[51]
<i>Brachylaima arcuata</i>		+?					[52]
<i>B. mesostoma</i>		+?					[52]
<i>Cardiocephaloides longicollis</i>		+?					[53]
<i>Clinostomum complanatum</i>	+?	+	+?				[16]
<i>Cyclocoelum polonicum</i>		+?					[52]
<i>Diplostomum pusillum</i>		+?					[54]
<i>Echinochasmus spinosus</i> met.		+?	+	+?	+?		[55]
<i>Euamphimerus pancreaticus</i>		+?					[56]
<i>Euclinostomum heterostomum</i>	+?	+	+?				[16]
<i>Fascioloides magna</i>	+	+		+	+	+	[34]
<i>Heterophyes heterophyes</i>		+					[57]
<i>Holostefanus curonensis</i>		+?					[58]
<i>H. luehei</i> met.	+?	+	+?		+?		[55]
<i>Lutztrema monenteron</i>		+?					[52]
<i>Meiogymnophalus minutus</i>		+					[50]
<i>Michajlovia migrata</i>		+?					[52]
<i>Moesia microsoma</i>		+?					[59]
<i>M. pavlowskii</i>		+?					[59]
<i>M. sittae</i>		+?					[59]
<i>Nephromonorchis lari</i>		+					[60]
<i>Parafasciolopsis fasciolaemorpha</i>	+	+		+	+	+	[61]
<i>Pegosomum spinifer</i>		+					[57]

⁴Point of interrogation in the column “Casual brought” means that this species recorded exclusively in migrating or wintering birds might be of native provenience, while that in the columns “Established brought”, “Expansion” or “Territorial invasion” means that it might be already established, but it is not sure.

	Established brought	Casual brought	Expansion	Invasion			References
				territorial	host	harmfulness	
<i>Psilotornus confertus</i>		+?					[62]
<i>Typodelphys immer</i>		+?					[12]
CESTODA							
<i>Bothriocephalus acheilognathi</i>	+			+	+	+	[23]
<i>Dicranotaenia mergi</i>		+?					[63]
<i>D. synsacculata</i>		+?					[15]
<i>Dubuninolepis rostellatus</i>		+ ?					[64]
<i>Echinococcus multilocularis</i>	+			+		+	[30]
<i>Emberizotaenia raymondi</i>		+?					[65]
<i>Flamingolepis liguloides</i>		+					[66]
<i>F. megalorchis</i>		+					[66]
<i>Gynandrotaenia stammeri</i>		+					[66]
<i>Khawia sinensis</i>	+			+	+	+	[23]
<i>Lacistorhynchus tenuis</i>		+					[67]
<i>Microsomacanthus oidemiae</i>		+?					[68]
<i>M. tuvensis</i>		+?					[69]
<i>Nippotaenia mogurndae</i>	+	+?	+				[21]
<i>Retinometra pittalugai</i>		+ ?					[14]
NEMATODA							
<i>Ancylostoma brasiliensis</i>		+			+	+	[70]
<i>A. duodenale</i>		+					[10]
<i>Anguillicola crassus</i>	+			+	+	+	[71]
<i>Angusticaecum holopterum</i>		+		+			[72]
<i>Aonchotheca mustellorum</i>		+		+			[73]
<i>A. puttori</i>		+		+			[73]
<i>Ascaridia platyceri</i>		+		+			[74]
<i>Ashworthius sidemi</i>	+	+		+	+	+	[30]
<i>Baylisascaris procyonis</i>	+	+	+				[28]
<i>Bourgelatia diducta</i>		+					[75]
<i>Cyathostoma microspiculum</i>	+?	+	+?				[76]
<i>Dentostomella translucida</i>		+					[77]
<i>Dicheilonema ciconiae</i>		+					[57]
<i>Diplotrriaena ozouxi</i>		+?					[13]
<i>Dirofilaria immitis</i>	+?	+		+?		+	[78]
<i>D. repens</i>	+	+		+	+	+	[79]
<i>Echinuria hypognatha</i>		+					[80]
<i>Elaphostrongylus alces</i>		+					[81]
<i>Elaphostrongylus cervi</i>	+	+	+		+	+	[31]
<i>Ichthyouris bursata</i>		+					[82]
<i>Necator americanus</i>		+					[83]
<i>Nematodirus battus</i>		+					[84]
<i>Oesophagostomum blanchardi</i>		+					[85]
<i>O. quadrispiculatum</i>		+					[75]
<i>Oxyspirura chabaudi</i>		+?					[86]
<i>Paracuaria tridentata</i>		+?					[87]
<i>Placoconus lotoris</i>	+	+		+			[88]
<i>Retinometra pittalugai</i>		+?					[14]
<i>Stegophorus stellaepolaris</i>		+?					[87]

	Established brought	Casual brought	Expansion	Invasion			References
				territorial	host	harmfulness	
<i>Splendidofilaria mavis</i>		+?					[89]
<i>Streptocara formosensis</i>		+?					[90]
<i>Strongyloides myopotami</i>		+					[91]
<i>S. procyonis</i>	+	+		+			[27]
<i>S. stercoralis</i>		+					[70]
<i>Tachygonetria lobata</i>		+					[72]
<i>T. robusta</i>		+					[72]
<i>Trichuris myocastoris</i>	+	+		+			[91]
<i>Viguera euryoptera</i>		+?		+			[13]
ACANTHOCEPHALA							
<i>Andracantha phalacrocoraxis</i>		+					[92]
<i>Paratenuisentis ambiguus</i>	+	+		+	+		[29]
<i>Southwellina hispida</i>		+?					[93]
ARTHROPODA: CRUSTACEA: Copepoda							
<i>Basanistes huchonis</i>		+					[94]
ARTHROPODA: CRUSTACEA: Isopoda							
<i>Arystone minima</i>		+					[40]
ARTHROPODA: ACARI: Ixodida							
<i>Amblyomma exornatum</i>		+				+	[95]
<i>A. flavomaculatum</i>		+				+	[95]
<i>A. latum</i>		+				+	[95]
<i>A. nutalli</i>		+				+	[95]
<i>A. quadricavum</i>		+				+	[95]
<i>A. sphaenodonti</i>		+				+	[96]
<i>A. transversale</i>		+				+	[95]
<i>A. varanensis</i>		+				+	[95]
<i>Argas polonicus</i>					+	+	[37]
<i>A. reflexus</i>					+	+	[38]
<i>Dermacentor marginatus</i>		+				+	[97]
<i>D. reticulatus</i>	+	+		+		+	[36]
<i>Hyalomma aegyptium</i>		+				+	[97]
<i>H. marginatum</i>		+				+	[38]
<i>Ixodes eldaricus</i>		+				+	[97]
<i>I. festai</i>		+				+	[97]
<i>Rhipicephalus rossicus</i>		+				+	[97]
<i>R. sanguineus</i>	+	+	+			+	[98]
ARTHROPODA: ACARI: Mesostigmata							
<i>Varroa destructor</i>	+		+	+	+	+	[33]
ARTHROPODA: INSECTA: Diptera							
<i>Cordylobia rhodaini</i>		+				+	[99]
<i>Dermatobia hominis</i>		+				+	[99]
ANNELIDA: HIRUDINEA							
<i>Acipenserobdella volgensis</i>	+			+	+	+	[100]

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