ON THE TERMINOLOGY USED IN PLANT INVASION STUDIES

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Abstract

An attempt to clarify the meaning of terms used in studies on plant invasions is presented. An alien species is understood as one which reached the area as a consequence of the activities of neolithic or post-neolithic man or of his domestic animals. There are at least 14 terms used to describe the alien status of a species. Of the 1172 studies analysed, 60.6% give an indication in their title that the paper is focused upon plant invasions and their proportion has been increasing over time. The term 'invasive' has been used most frequently (37.1% of studies that indicate focus on invasions) and its use increased dramatically in the mid-eighties. Some terms which have ambiguous meaning if related to plant invasions are still widely used (*e.g.*, weed, 22.9%). Most papers do not give explicite definitions of the terms used. Comparison of some definitions of the term 'invasive' (including 'invasion' and 'invader') has shown that some of them do not consider aliens established in man-made habitats and some have applied the term to native species. It is proposed to use the term 'invasive' for an alien whose distribution and/or abundance in the area is increasing, *i.e.*, for the one that can be considered as a successful alien. For a native species increasing its range, 'expanding' appears to be a convenient term. Comparison of European classification of man-accompanying plants with the present terminology used in plant invasion studies is given and difficulties associated with deciding about a species' native *vs.* alien status are discussed.

Introduction

Plant invasions are receiving more and more attention and in the last few years as a conservative estimate at least hundred new studies have appeared annually (Pyšek 1995). Although the first attempts to classify man-accompanying plants go back to as early as the second half of the last century (De Candolle 1855; Ascherson 1883), it is the recent burst of studies on plant invasions which brought about some attempts to clarify the terminology being used in the field (Prach and Wade 1992; Binggeli 1994; Rejmánek 1995). Plants occurring in the region where they are not native have been termed aliens, invaders, exotics, introduced, translocated, neophytes, adventive, weeds, newcomers, naturalized, colonizers, non-native, non-indigeneous, and immigrants. In many studies, these terms are being used without precise definitions, sometimes freely synonymized throughout a paper. Furthermore, some terms have been questioned recently as having anthropocentric implications (Barber 1987; Garthwaite 1993; see discussion in Binggeli 1994). Moreover, as pointed out by Binggeli (1994), only a few terms are truly needed.

In this paper, I will briefly discuss criteria for distinguishing between a species' native and alien status, provide a quantitative insight into how frequently the particular terms have been used and investigate in detail how the term 'invasive' is being interpreted by people involved in studies on plant invasions. For the purpose of the present paper, plant invasion studies are considered as those that deal with any aspect of the biology and ecology of an alien species in an area of its secondary distribution, *i.e.*, in an area to which it is not native.

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Alien *versus* native species status

To distinguish between the native and alien status of a species is the first problem one must face when studying plant invasions (Sukopp 1972; Heywood 1989; Pyšek *et al.* 1995). Ecologists and invasion biologists, especially when analysing whole floras, are largely dependent on taxonomists and on data available in local floras. Although most floras make an attempt to consider whether the species is native or introduced, the decisions are often based on inappropriate criteria (uncritical acceptance of earlier opinions, misinterpretation of fossil records) or essentially intuititive grounds, often biased by irrelevant emotional views (Webb 1985). Webb (1985) has proposed eight useful criteria for deciding about native status of which, however, only fossil records (see *e.g.*, Byrne and McAndrews 1975; Betancourt *et al.* 1984) and historical evidence can prove the status (the former one the native, the latter the alien, but neither can prove the reverse) whereas the others (habitat, geographical distribution, ease of known naturalization elsewhere, genetic diversity, reproductive pattern, and supposed means of introduction) can only provide an indication. The problem has been also discussed by Preston (1986) and Smith (1986).

The view has been generally accepted and used as a basic criterion that a species can only be regarded as native to a given area if its occurrence is independent of human activities. However, another important limitation must be added: those species which arrived before the beginning of the neolithic period (ca. 5-6000 years B.C.) should be also considered as native, even if introduced by man. Until that time, man was a part of Nature and his influence on species dispersal was equivalent to that of animals (Webb 1985). Also to the frequently used criterion that native species are those that evolved *in situ* two important points should be added. First, if a species occurred in the area before or during the last Ice Age, it was not under present conditions as the climate was different from today (Webb 1985). Species that became extinct during the last glacial and were reintroduced by man, cannot therefore be regarded as native (Kowarik 1995). Second, the species which arrived in the area in recent times by means independent of human activity, should be also regarded as native (Webb 1985). The latter point implies an interesting theoretical problem: what if a plant species is dispersed into an area in which it has never occurred by a wild living animal which is an alien to that area? Clearly, activities of domestic animals must be included into human activities in a broad sense (see Webb 1985). Following strictly the definition, such a species must be treated as an alien since had it not been for the activity of humans, it would never have reached the area under question.

Comparison of classification systems

More than a century of effort put into the classification of man-accompanying plants by European botanists has yielded a number of classification systems (De Candolle 1855; Ascherson 1883; Rikli 1903; Thellung 1922; Schroeder 1969; Holub and Jirásek 1967; Kornas 1990). These are mostly based on *(1)* time of immigration of a species into the region, *(2)* the means of introduction by humans, *i.e.*, intentionally or unintentionally, and *(3)* degree of its naturalization, *i.e.*, its ability to become established under local conditions (see discussion in Trepl 1990). Some of these systems are rather complicated and have led to the creation of an extensive jargon

(Binggeli 1994). Their complexity is probably the main reason why they did not come into wider use. Some of them (*e.g.*, Kornas 1990), by defining a number of categories often based on vague criteria, impose a number of practical problems that emerge if one is trying to use them, *e.g.*, how to distinguish seminatural and natural habitats or when is an alien already permanently established and when not.

Clearly, the use of these systems has been mostly restricted to continental (or even central) Europe and they have never reached a wide attention in Anglosaxon countries where the plant invasions are most intensively studied (Pyšek 1995). Table 1 represents an attempt to relate the classification system proposed by Holub and Jirásek (1967), in my opinion one of the most carefully elaborated, to the meaning of terms used worldwide in the contemporary literature on plant invasions. The main difference appears to be that species introduced before 1500 are usually not the subject of studies on plant invasions and as such they are often being deliberately dismissed (see *e.g.*, Weeda 1987; Pyšek *et al.* 1995). There are two reasons for that. The first reflects the difficulties associated with deciding about their alien or native status (many authors tend to treat these species as equivalent to natives, see Webb 1985) and the impossibility to follow their introduction into the area. The second is that, being a field with important practical implication, invasion ecology is simply not much concerned with these species because they usually neither cause management problems nor eliminate local flora or change ecosystem properties.

Terms used in studies on plant invasions

To obtain an insight into the use of various terms relating to a species alien status, 1172 papers dealing with various aspects of plant invasions worldwide (except those focused exclusively upon control) were analysed. The database used does not cover all the studies published on the topic but may be considered as a reasonably repre-

Table 1. Comparison of the phytogeographical terminology proposed for classification of human-accompanying plants (Holub and Jirásek 1967) with the meaning (as suggested in the present paper) of terms presently used in studies on plant invasions. Natural vegetation includes also semi-natural vegetation types (*i.e.*, those close to the natural ones); 'not considered' means that the category is usually not a subject of studies on plant invasions.

Term	Definition	Meaning
A. Apophytes[1]	native species occurring in man-made habitats	native
B. Anthropophytes	species introduced by man	
I. Hemerophytes	introduced intentionally[2]	
II. Xenophytes	introduced unintentionally[2]	
1. Archaeophytes	introduced before 1500	not considered alien
2. Neophytes	introduced after 1500	
a. Ephemerophytes	temporary occurrence, only in man-made habitats	not invasive
b. Epekophytes	established in man-made habitats	invasive in man-made habitats
c. Neoindigenophytes[3]	penetrating to natural habitats	invasive in natural habitats

[1]English transcription of terms which have been introduced in German is given.
[2]While no terms are being used in plant invasion studies to distinguish between these two categories, Frank and McCoy (1990) do so for animal invasions. Among non-native species (which they term 'adventive'), they proposed to distinguish those introduced deliberately by man (termed 'introduced') from those that arrived from elsewhere by their own volition (termed 'immigrants').
[3]Corresponds to the term 'agriophytes' *sensu* Schroeder 1969 which is also being frequently used (see *e.g.*, Lohmeyer and Sukopp 1992).

sentative sample.

First, I analysed how was that the study deals with alien species reflected in its title (Fig. 1a). Of the total number of studies, 475 (40.5%) explicitly used some of the terms to describe the alien status and 486 (41.5%) gave the name of the species studied in the title which may also be considered, at least in some cases, as an indication of the focus upon alien flora. Only 211 studies (18.0%) gave no indication, neither by using any of the terms nor by giving the species name. Undoubtedly, explicit formulation of the focus of the study improves the communication between people working in the field. However, to recognize a study on invasion only by the name of the species studied, the area to which the study is related must be indicated as well and one must know that the species under question is alien to that area. If we dismiss those rather ambiguous terms such as 'weed', we are left with 564 studies (48.1%) more or less clearly indicating by the title that they deal with alien species.

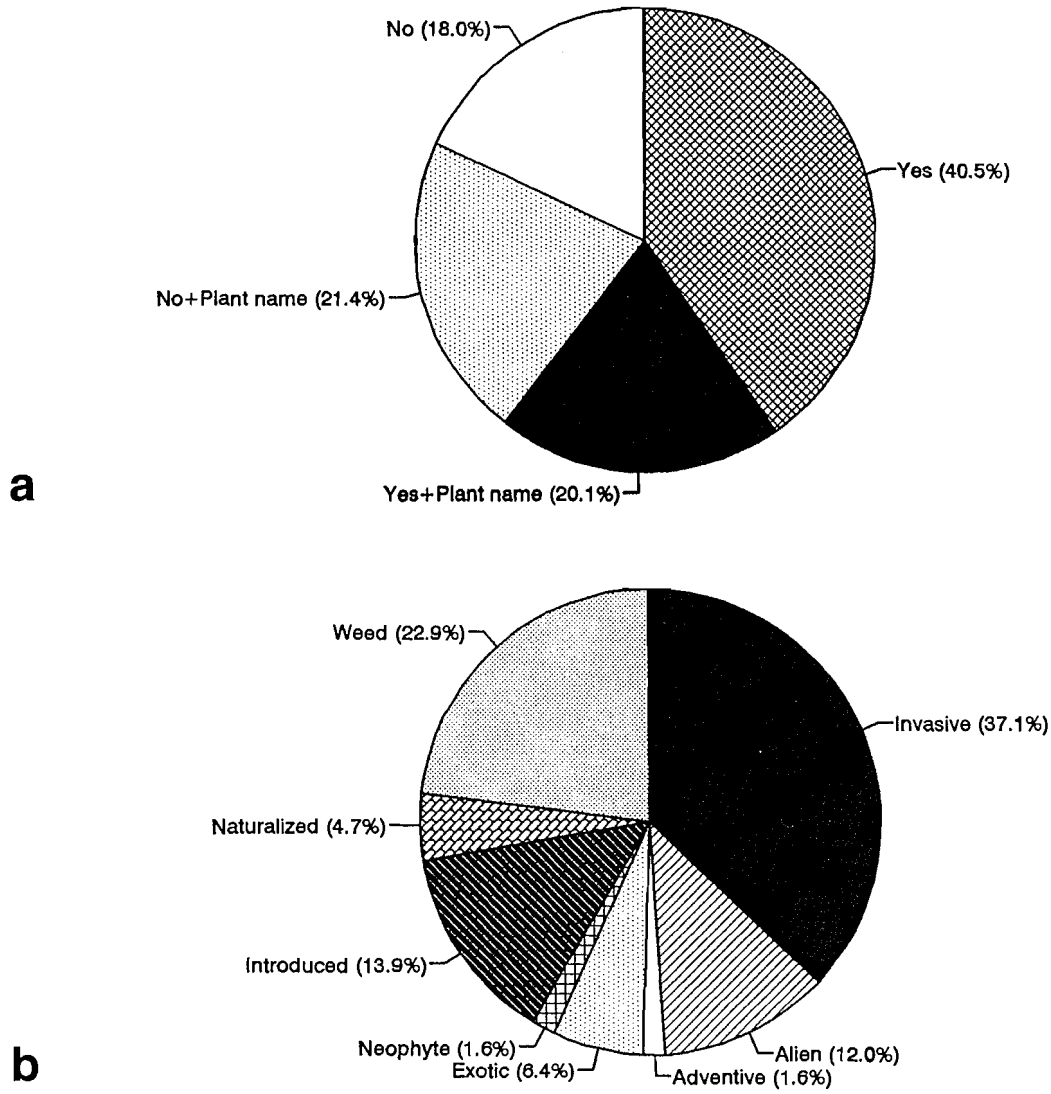

Fig. 1. (a) Analysis of 1172 studies showing whether the fact that they deal with plant invasions is reflected in their title (Yes - a term describing alien status is used in the title, No - no indication is given) or whether the name of the species studied is given or not. *(b)* Frequency of use of particular terms shown for those studies the focus of which is indicated by their title (n=710). Modifications of the terms (*e.g.*, invader, invasion, introduction, naturalization) were also considered.

One must bear in mind, that only titles were analysed here; had the keywords been included, the number would probably increase, but it is the title which is often used as a basis for a reader's decision whether to be interested in the paper or not. Hence, the present analysis can be taken as reasonably showing the potential for communication, *e.g.*, via some abstracting journals, databases or by scanning the references in papers.

There is a consistent increase in the proportion of papers indicating a focus on invasions from the beginning of the eighties (Fig. 2). This can be partly related to the increasing awareness among workers that the status of the species they study is an important aspect of their work.

Fig. 1b shows how frequently the particular terms are used. Of the total number of studies in which the status was indicated (710), there were 124 (17.5%) whose title contained more than one term (*i.e.*, invasive alien, introduced weed, naturalized exotic *etc.*). The terms* 'invasive' (309), 'weed' (191) and 'introduced' (116) were used most frequently. There is also a noticeable difference in temporal trends in using particular terms (Fig. 3a). An increase in the cumulative number of papers in whose titles the term was used appears to be be fairly constant for all but 'invasive', the use of which accelerated remarkably in the mid eighties (Fig. 3a, b). This was probably caused by the launch of the international SCOPE project on biological invasions in 1982 (Drake *et al.* 1989). The term 'weed' has been widely used since the beginning of the period analysed (Fig. 3a) but its proportional contribution is decreasing on the long-term scale (Fig. 3b).

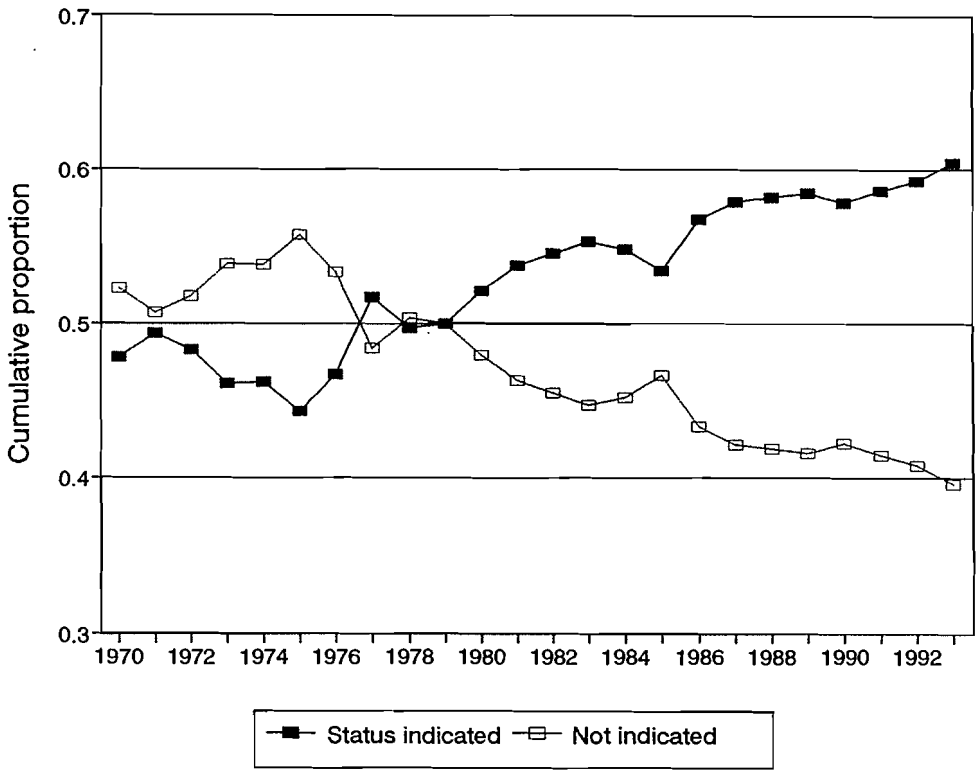

Fig. 2. Temporal trends in the proportion of studies with the focus on plant invasions *(a)* indicated and *(b)* not indicated by their title. Cumulative proportions are shown.

*In the present paper, when speaking about particular terms, terms with the same origin are also considered, *i.e.*, the number of records given for 'invasive' also includes 'invader' or 'invasion'; similarly for the other terms analysed, *e.g.*, 'introduction', 'naturalization'.

The term 'weed' is probably the best example of a term that is rather confusing when related to plant invasion studies as it refers to the anthropocentric viewpoint (Rejmánek 1995). It has been repeatedly pointed out that the term weed implies an

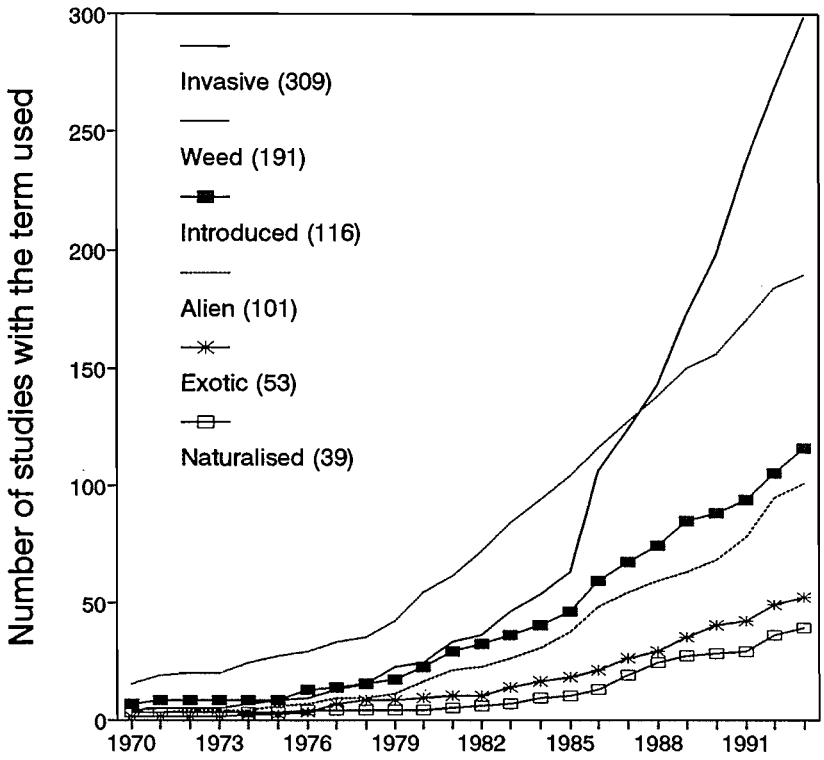

Fig. 3a. Increase in the cumulative number of studies using particular terms in their titles. The graph shows the situation up to 1993; total number of studies up to present (*i.e.*, those that were published in the first half of 1994) is given in parenthesis.

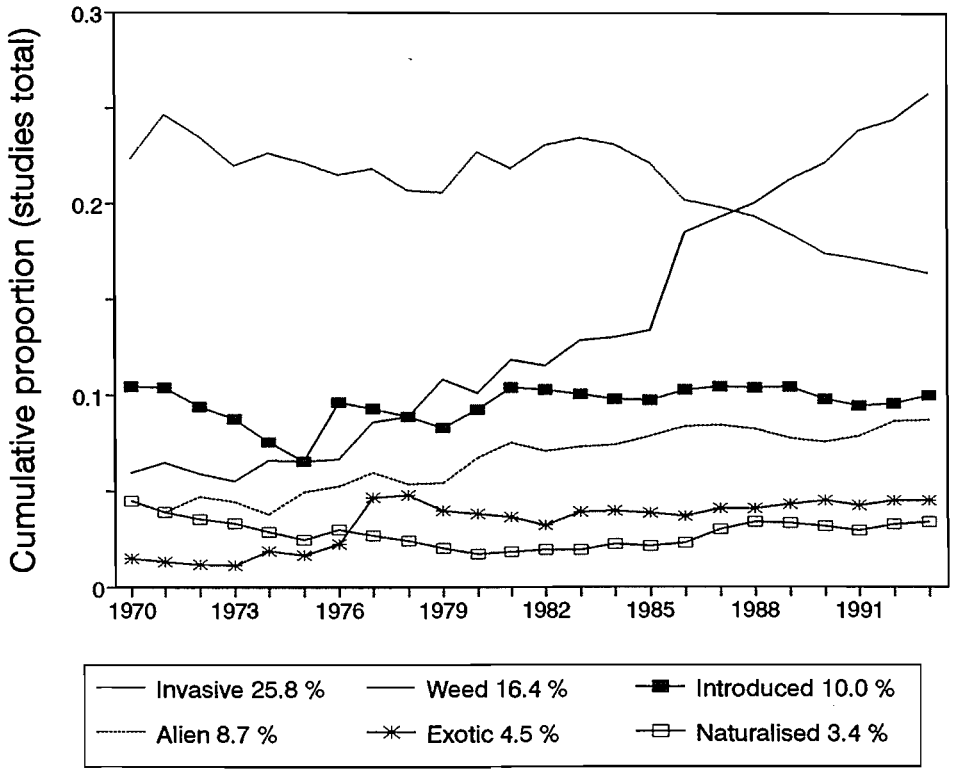

Fig. 3b. Changes in the cumulative contribution of particular terms to the total number of studies analysed (n=1172). Percentage contribution of particular terms is given.

interference with objectives and requirements of people (Binggeli 1994; Rejmánek 1995). Although the biological invasions are not the sole domain of biogeography, it is the biogeographical viewpoint from which the terminology should stem. As pointed out by Roy (1990) " ... the process of invasion brings an organism to an environment in which it did not evolve ... it is this evolutionary aspect which is unique to invaders and not implied by the concept of weeds, colonists or successional species."

How is the term 'invasive' being understood?

The term 'invasive' is not being used only in a strictly biogeographical sense, *i.e.*, referring to alien species. I have analysed the entries that appeared in Ecological Abstracts between 1987-1992 (excluding animal invasions) and found that out of 98, there were 14 cases (14.3%) of use in a different sense. Generally, the term is being used in *(a)* ecological papers, including both theoretical and field studies, to describe colonization of a community by a newly arrived species (*e.g.*, Sloan Wilson and Turelli 1986; Van Hulst 1987; Silvertown *et al.* 1994) or in *(b)* palaeontological studies referring to species migrations (*e.g.*, Davis 1987; Bennett 1987; Coope 1987). The former case also regards an interesting history of *Dittrichia viscosa*, a species native to the Mediterranean basin where it has been recently extending its geographical range by entering man-made habitats (Wacquant 1990).

Surprisingly, not many definitions of invasion or invaders are available and in the majority of studies, the term is used without explicit definition. To see how the term 'invasive' is being understood, I compared several definitions recently published in the literature with 5 theoretical situations: *(1)* a native species that is not increasing (*i.e.*, its geographical range is not extending and/or its abundance in the area under question is not increasing), *(2)* increasing native species, *(3)* not increasing alien species, *(4)* alien species increasing in man-made habitats, and *(5)* alien species increasing in natural habitats (Table 2). All the definitions in Table 2 match the category of an increasing alien. However, some of them do not include an alien increasing in man-made habitats and some also match other situations. If the logical sense of particular definitions is strictly followed, out of the total of 13, 7 do not exclude native species; of these 4 explicitly by definition (Nos. 3,5,8,9, *i.e.*, those that adopt an ecological rather than biogeographical view) and 3 (Nos. 2,6,7) by not taking into account the possibility of recent introduction independent of human activities. Three definitions (Nos. 2,8,13) do not exclude non-increasing aliens (*i.e.*, group 3) and two exclude aliens increasing in man-made habitats (Nos. 1,4; the latter, however, purposely, as it applies to nature reserves). The remaining three (Nos. 10, 11, 12) consider as an invasive species an alien established in the wild in the area of introduction regardless of the habitat, which is the meaning in which, I suggest, the term should be used.

Even if the term 'invader' is used in biogeographical sense, the main problem associated with definitions given in Table 2 remains the spatial scale implied by various terms. There is a mention of 'area', 'geographical area', 'geographical range', 'region' or 'territory', mostly without an indication of how these terms are understood. Obviously, no definition of an invasive species would be absolutely satisfactory; however, a reasonable consensus about its meaning would be most useful.

Table 2. Comparison of some definitions of the term 'invasive' ('invader', 'invasion') in literature and their interpretation with respect to possible situations. 'Native' and 'alien' without specification mean any native or any alien species. When assessing the meaning, the terms 'spreading', 'extending range', 'colonizing' were assumed to indicate a species' invasion success, as opposite to 'entering' or 'occurring' which need not to be related to a successful alien but may also include the one that has failed to establish. Natural habitats also include semi-natural ones.

Author	Definition	Matches the situation				
		Native	Increasing native	Alien	Alien increasing in	
					man-made habitats	semi-natural habitats
1. Stirton 1979	(invaders) are alien plants that invade and oust native vegetation	No	No	No	No	Yes
2. Mack 1985	(invader) any taxon entering a territory in which it has never occurred before, regardless of circumstances (even if it fails to establish)	Yes	Yes	Yes	Yes	Yes
3. Joenje 1987	(invasion) the influx of numerous individuals of a species or the sudden increase of a founder population in an area	No	Yes	No	Yes	Yes
4. Macdonald *et al.* 1989	(invasive) the introduced species capable of establishing self-sustaining populations in area of natural or seminatural vegetation*	No	No	No	No	Yes
5. Mooney and Drake 1989	(invader) when it colonizes and persists in an ecosystem in which it has never been before	No	Yes	No	Yes	Yes
6. Di Castri 1990	(invader) a species which, most usually transported inadvertedly or intentionally by man, colonizes and spreads into new territories some distance from its home territory	No	Yes	No	Yes	Yes
7. Roy 1990	(invasion) the entering of a species into a territory in which it has never before occurred, followed by an extension of the range of that species	No	Yes	No	Yes	Yes
8. Gouyon 1990	(invader) it occurs in a kind of habitat where it was not present before and/or the number of its individuals in a place it was before is abnormally increasing	Yes	Yes	Yes	Yes	Yes
9. Le Floch *et al.* 1990	(invading) species having an expanding status either in terms of geographical area or in terms of increasing frequency and density	No	Yes	No	Yes	Yes
10. Prach and Wade 1992	(invasion) rapid increase of an alien species in a region	No	No	No	Yes	Yes
11. Rejmánek 1995	(invaders) are spreading into areas where they are not native	No	No	No	Yes	Yes
12. Binggeli 1994	(invasive) the establishment of self-regenerating, usually expanding, populations of an introduced species in a free-living state in the wild	No	No	No	Yes	Yes
13. Kowarik 1995	(invasion) the whole process of range extension of an alien species ... including its very beginning	No	No	Yes	Yes	Yes

*Applies to nature reserves.

In fact, the strict separation of the term 'alien' from 'invasive alien' is difficult. I understand the term 'invasive' as describing an alien which has become successful in the area into which it was introduced (some definitions mention as an important feature that the species is creating self-regenerating populations and is capable of

further spread without direct support of humans, see *e.g.,* Binggeli 1994). Theoretically, an alien species can be considered as becoming invasive when it enters the exponential phase of spread. However, the studies measuring the rate of invasion in quantitative terms are rather rare (Connolly 1977; Trepl 1984; Trewick and Wade 1986; Pyšek and Prach 1993; Perrins *et al.* 1993) and this information is certainly not available for the vast majority of plant invasions. There is evidence in the literature database analysed in the present paper that at least some authors explicitly distinguish between 'alien' and 'invasive alien': 68 studies (*i.e.,* 9.6% of those which indicate the status) speak about 'invasive' alien (exotic, introduced, adventive, neophyte) species. These cases suggest the view that not every alien must be necessarily invasive. However, if we take into account the difficulties associated with deciding what is 'successfully established' and when, using the term 'invasive' as synonymous to 'alien' (*e.g.,* Mack 1985; Kowarik 1995) seems unavoidable and acceptable.

Conclusions - Suggestions of terminology

For the purpose of the vast majority of studies, we need to describe four basic situations with respect to a species' status (whether it is native or alien to the area) and the dynamics of its behaviour (whether it is spreading or not). There is no need to create another set of definitions since the terms needed have been properly defined elsewhere. Here are the definitions from the available literature and the suggested meaning of the terms:

- *Native* (indigenous) species is one which evolved in the area or which arrived there by one means or another before the beginning of the neolithic period or which arrived there since that time by a method entirely independent of human activity (Webb 1985);
- *Alien* (introduced, exotic, adventive) species is one which reached the area as a consequence of the activities of neolithic or post-neolithic man or of his domestic animals (Webb 1985);
- *Invasive* (naturalized) species is an alien the distribution and/or abundance of which in the wild is in the process of increasing regardless of habitat (see *e.g.,* Prach and Wade 1992; Binggeli 1994).

To avoid confusion, we also need a term describing the range extension and/or increase in abundance of a species native to the region (*e.g.,* the above mentioned example of *Dittrichia viscosa,* see Wacquant 1990). Here I refer to the terminology proposed by Prach and Wade (1992) who term a native species exhibiting such behaviour as *expanding* rather than invading.

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