

#### 4 On the numerous concepts in invasion biology

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11 Received 26 May 2005; accepted in revised form 11 July 2005

12 *Key words:* alien, concepts, exotic, indigenous, introduced, invasion, invasive, native, pest

#### 13 Abstract

14 The study of biological invasions has triggered the production of a diversity of concepts. The terminology  
15 has, however, often been applied inconsistently and inaccurately. This article lists and assesses the most  
16 commonly used terms and concepts in invasion ecology. In each case the most coherent definition and use is  
17 suggested.


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21 ...very many (probably several hundred) square  
22 miles are covered with one mass of these prickly  
23 plants, and are impenetrable by man or beast.  
24 Over the undulating plains, where these great beds  
25 occur, nothing else can live. Charles Darwin "The  
26 voyage of the beagle" 1839

#### 27 Introduction

28 Over the last two centuries, the phenomenon of  
29 biological invasions has been elevated from an  
30 unavoidable, but not very serious, spin-off of hu-  
31 man activities, to a serious encroachment on eco-  
32 logical integrity. The historical expansion of the  
33 relevance of invasion biology, and the associated  
34 trend towards homogenization and reduction of  
35 global biodiversity has even justified publication  
36 of an entire scientific journal devoted to this topic  
37 (*Biological Invasions*). This expansion has also  
38 triggered the production of a diversity of concepts.  
39 A number of authors have pointed out that  
40 the terminology related to non-native species has

often been applied inconsistently (Pyšek 1995; 41  
Mack 1996; Schwartz 1996; Bullock 1997, Rich- 42  
ardson et al. 2000; CBD 2001; Marco et al. 2002; 43  
Kowarik 2003). This has led to confusion in 44  
defining biological invasions. A common goal 45  
should be to reach conceptual agreement not 46  
only in the scientific literature, but also in how to 47  
interpret conservation treaties and laws in order 48  
to make sensible management priorities 49  
(Richardson et al. 2000; CBD 2001; Marco et al. 50  
2002). The lack of clear definitions has also been 51  
identified as a contributing factor behind the 52  
slow progress made in invasion ecology over the 53  
past 40 years (Davis and Thompson 2000). In 54  
fact, the scientific literature on invasion ecology 55  
seems to be particularly well endowed with syn- 56  
onyms. Moreover, the terms used are often value 57  
laden and associative, for example when organ- 58  
isms are termed pests, weeds, or emerging 59  
diseases (e.g. Moore 1999; Hayes and Sliwa 60  
2003). Words and expressions coined by various 61  
stakeholder groups have added further to the 62  
confusion. 63

	Journal : <b>BINV</b>	Dispatch : <b>28-7-2005</b>	Pages : <b>16</b>
	CMS No. : <b>DO00020710</b>	<input checked="" type="checkbox"/> LE	<input type="checkbox"/> TYPESET
	MS Code : <b>BINV 246R1</b>	<input checked="" type="checkbox"/> CP	<input checked="" type="checkbox"/> DISK

64 Terms and concepts always contain and imply  
 65 more than the definitions provided by dictionar-  
 66 ies, or the scientific literature. Interpretations and  
 67 symbolic meanings follow all terms, differing be-  
 68 tween scientific schools or cultural contexts, and  
 69 evolving over time. Nevertheless, terms and con-  
 70 cepts represent the basis for communication of  
 71 knowledge and understanding. It is therefore  
 72 worth nearly every effort to reach for precise def-  
 73 initions, and also to follow a stringent line of  
 74 consistent use.

75 Although attempts have been made to clarify  
 76 the terms related to alien species (ex. Mühlenbach  
 77 1979; Pyšek 1995; Williamson and Fitter 1996;  
 78 Richardson et al. 2000; Davis and Thompson  
 79 2000; Daehler 2001) invasion ecology is still bur-  
 80 dened by inaccurate use of concepts. In this article  
 81 we list and assess the most commonly used terms  
 82 and concepts in invasion ecology. In each case the  
 83 most coherent definition and use is suggested.

84 **Approach**

85 A literature study was conducted recording defi-  
 86 nitions of terms and concepts related to biological  
 87 invasions and non-native organisms. Biological  
 88 dictionaries, international treaties, and publica-

tions in scientific journals were examined. As far 89  
 as possible, the primary source of the definitions 90  
 was identified. The focus has been on relatively 91  
 recent literature (past 30 years) and on English 92  
 language literature to avoid confusion due to 93  
 translation. Emphasis was put on terms that are 94  
 not specific to any particular taxonomic group. 95

**Results and discussion 96**

*Overview 97*

The field of invasion biology has expanded 98  
 beyond the ‘classical biology’ that concerns 99  
 organisms within their natural distribution 100  
 (Figure 1). The discipline of invasion biology 101  
 deals with traits of introduced non-native species, 102  
 their ability to spread, their interactions with each 103  
 other and with native species in receiving 104  
 ecosystems Table 1. 105

We selected 145 definitions related to invasion 106  
 biology and non-native organisms (Appendix 107  
 A.1). Out of these definitions, 102 were general 108  
 and 43 were specific to taxonomic or other 109  
 groups. The taxonomic groups listed in the defi- 110  
 nitions are plants (31), animals (15), pests (6), 111

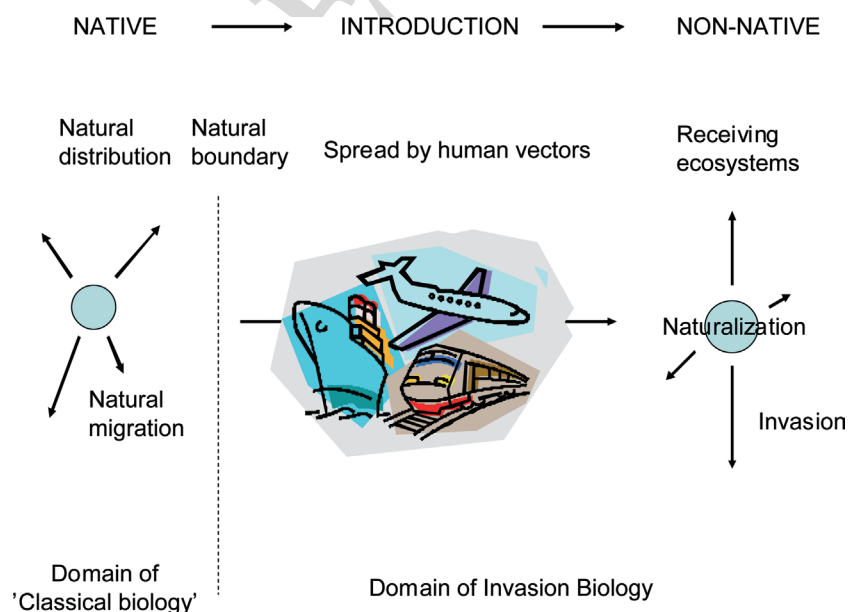


Figure 1. Schematic overview over the domains and main elements of ‘Classical biology’ vs ‘Invasion biology’.

Table 1. Proposed definitions of terms.

Term	Proposed definition
Native/indigenous/original	An organism occurring within its natural past or present range and dispersal potential (organisms whose dispersal is independent of human intervention) <sup>a</sup>
Endemic	Organism restricted to a specified region or locality <sup>b</sup>
Non-native/alien/adventive/exotic/ foreign/introduced/non-indigenous/novel	An organism occurring outside its natural past or present range and dispersal potential including any parts of the organism that might survive and subsequently reproduce (organisms whose dispersal is caused by human action) <sup>c</sup>
Introduction	Direct or indirect movement by human agency, of an organism from its native past or present range to a range outside its distribution potential <sup>d</sup>
Transfer/translocation/transplantation	Human mediated movement of an organism within its past or present range and dispersal potential <sup>e</sup>
Immigrant	An organism that moves into a community or region where it was previously not found <sup>f</sup>
Escape	Non-native organism, or part of organism that might survive and subsequently reproduce, originally domesticated, now found in the wild <sup>g</sup>
Feral	Native organism, or part of organism that might survive and subsequently reproduce, originally domesticated but now reverted to its original wild state <sup>h</sup>
Transient/casual	Native or non-native organisms that may occur and reproduce occasionally in an area, but do not form self-replacing populations and rely on repeated introductions for their persistence <sup>i</sup>
Established	Native or non-native organism that has obtained a self-sustaining population in an area it previously did not occur
Naturalized	A non-native organism that has obtained a self-sustaining population <sup>j</sup>
Re-introduced	Organism intentionally released into a part of former range from which it had become extirpated or extinct <sup>k</sup>
Re-established	Re-colonization and establishment of an organism in a part of former range from which it had become extirpated or extinct
Re-stocking	Release of an organism into an area in which it is already present to supplement the population <sup>l</sup>
Invasive	Alien organisms that have established in a new area and are expanding their range <sup>m</sup>
Pest	Organisms considered harmful to human activities <sup>n</sup>
Weed	Plants growing in areas where they are not wanted <sup>o</sup>
Environmental weeds	Non-native plant taxa invading natural vegetation affecting native biodiversity and/ or ecosystem functioning <sup>p</sup>
Transformers	Organisms that change the character, condition, form or nature of a natural ecosystem over a substantial area <sup>q</sup>
Physical ecosystem engineer	Organisms that directly or indirectly control the availability of resources to other organisms by causing physical state changes in abiotic or biotic materials <sup>r</sup>

<sup>a</sup>Modified from IUCN 2000; <sup>b</sup>Modified from IUCN 2000; <sup>c</sup>Modified from IUCN 2000 and Sutin 2000; <sup>d</sup>Modified from ICES 1995, FAO 1996 and IUCN 1995; <sup>e</sup>Morris 1992; <sup>f</sup>Modified from Godman and Payne 1996, IUCN 2000; <sup>g</sup>Modified from Morris 1992 and Bullock et al. 1997; <sup>h</sup>Modified from Richardson et al. 2000; <sup>i</sup>Modified from UKINC 1979, Mack 1996, Bullock et al. 1997, Les and Mehrhoff 1999, Lawrence 2000, Manchester and Bullock 2000 and Richardson et al. 2000; <sup>k</sup>Modified from WWF 1976, IUCN 1987, IUCN 1995 and Bullock et al. 1997; <sup>l</sup>Modified from WWF 1976 and IUCN 1987; <sup>m</sup>Modified from Binggei 1994 and Mack 2000; <sup>n</sup>Modified from Morris 1992; <sup>o</sup>Modified from Richardson et al. 2000; <sup>p</sup>Randall 1996; <sup>q</sup>Wells et al. 1986; <sup>r</sup>Jones et al. 1997.



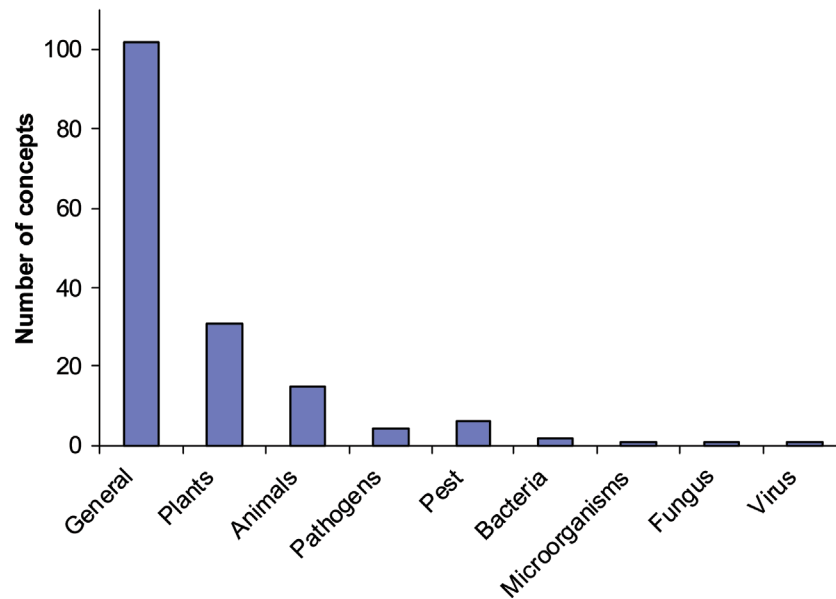


Figure 2. Number of general and specific definitions of non-native organisms found in literature.

112 pathogens (4), bacteria (2) and fungus, micro-  
 113 organisms and virus (1) (Figure 2). 11 of the defi-  
 114 nitions list more than one group.

#### 115 *Suggested terms of use*

##### 116 *Native/indigenous/original*

117 Out of ten definitions, three refer to the organ-  
 118 ism's distribution in relation to its dispersal abil-  
 119 ity and three to presence previous to a defined  
 120 time period. Six definitions classify indigenous  
 121 species as those whose present distribution is  
 122 independent of humans, while three only refer to  
 123 undefined criteria such as 'occurring naturally'.

124 Since natural communities are dynamic and  
 125 continuously expand or retract their spatial dis-  
 126 tribution, it may in practice be difficult to distin-  
 127 guish native species (existing in an area due to  
 128 their own means of dispersal) from those that  
 129 have been introduced through human interven-  
 130 tions. Classification of a species being native or  
 131 alien has often been based on a variety of crite-  
 132 ria, including emotional views, misinterpretations  
 133 of fossil records, intuitive arguments, and uncriti-  
 134 cal acceptance of earlier classification (Webb  
 135 1985).

136 Webb (1985) suggested that those species that  
 137 arrived before the beginning of the Neolithic

period (about 7–8000 years BP) should be con-  
 sidered native species. Before the introduction of  
 farming and animal husbandry, humans were an  
 agent of dispersal equivalent to that of other ani-  
 mals. Other authors consider as native those spe-  
 cies that have been present in prehistoric times,  
 or since the last glaciation (about 14000 BP)  
 (Binggeli 1994; NCC 1990 as in Bullock et al.  
 1997; Manchester and Bullock 2000). Les and  
 Mehrhoff (1999) applied case specific definitions  
 when looking at impacts of plant introductions  
 subsequent to European settlement in New Eng-  
 land. They defined indigenous species as those  
 occurring in southern New England prior to  
 1496 AD, when the first European explorer came  
 to the region. Problems of using specific tempo-  
 ral criteria include human-aided dispersal of  
 organisms prior to the proposed dates and the  
 lack of data to determine actual historical status  
 (Schwartz 1996).

Common to all these definitions is the recog-  
 nition that at some point in the past, humans  
 no longer acted as natural dispersal agents, but  
 became the driving force reshuffling species  
 beyond their dispersal limitations. Although the  
 definitions vary, and even if the practical deter-  
 mination of the native status of a specific species  
 can be problematic, the meaning of the terms

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166	denoting naturally occurring species does not	213
167	appear to be controversial. Native species are	214
168	those whose distribution is independent of hu-	215
169	mans.	216
170	<i>Endemic</i>	217
171	Endemic is a more restricted term, denoting a	218
172	species that occurs only in a restricted region	219
173	(eight of eight definitions). The geographic scale	220
174	of 'restricted area' will obviously influence the	221
175	degree to which an endemic species differs from a	222
176	native species.	223
177	<i>Non-native/alien/adventive/exotic/foreign/non-</i>	
178	<i>indigenous/novel</i>	
179	We were able to identify 20 definitions of	224
180	non-native organisms. Morris (1992) defines the	225
181	term 'exotic' merely with reference to synonyms	226
182	('foreign' and 'not native'). Three of the defini-	227
183	tions refer to absence of the organism prior to a	228
184	certain time period, 13 to the distribution of the	229
185	organism being human mediated, two to the imp-	230
186	act of the organism in the new area, and four to	231
187	the extent that the species has established	232
188	self-reproducing populations. The two last factors	233
189	are better covered by other terms related to non-	234
190	native species. A definition based on IUCN	235
191	(2000) is preferred, referring to the presence of an	236
192	organism outside its dispersal potential. From	237
193	this it is followed that non-native organisms are	238
194	those whose distribution has been mitigated by	239
195	humans. The term 'adventive' is not commonly	240
196	used, with only three, non-conclusive definitions	241
197	found in literature (Morris 1992; Bingelli 1994;	242
198	Lawrence 2000). We suggest the term as a	243
199	synonym to terms describing non-native species.	244
200	Manchester and Bullock (2000) separate	245
201	organisms whose dispersal has been mediated by	246
202	humans (non-native, alien, non-indigenous) and	247
203	those translocated independent of human activity	248
204	(exotic). In our opinion 'translocated' implies an	249
205	external agent, and we would recommend that	250
206	the term 'immigrant' is better suited to denote	251
207	organisms that become established in a new area	252
208	independent of human introductions, i.e. through	253
209	their own migratory abilities.	254
210	Davis and Thompson (2000) discourage the	255
211	use of terms like 'alien' and 'exotic' as their con-	256
212	notations could indicate that these species are	257
	governed by different ecological processes than	258
	natural immigrants. However, the terms do not	259
	refer to the ecological processes, but rather that	260
	there is an anthropogenic action that, directly or	
	indirectly, causes the appearance of the non-na-	
	tive species. Moreover, we agree with Daehler	
	(2001) that terms used in ecology not necessarily	
	need to match their common English definition.	
	The important factor is that they capture the	
	ecological concept, and are given a precise	
	definition.	
	<i>Introduction/introduced</i>	
	The terms 'introduction' and 'introduced' were in	
	17 out of 20 cases defined as non-native organ-	
	isms intentionally or accidentally transferred by	
	human agency. While 'introduction' is an act,	
	'introduced species' is a synonym to non-native	
	species as indicated by four of the references	
	(Bingelly 1994; ICES 1995; FAO 1996; Sutinen	
	2000).	
	Out of the 20 definitions, three include the	
	degree of establishment. IPPC (1997) and FAO	
	(2000) define introduction as 'the entry of a pest	
	leading to its establishment'. Establishment, or	
	naturalization, does not necessarily follow the	
	introduction of an organism. In fact, in most	
	cases of introduction, the species does <i>not</i> estab-	
	lish self-reproducing populations (Williamson	
	1996). Furthermore, the word 'pest' is highly	
	subjective and not only applicable to non-native	
	organisms (but see below). Williamson and Fitter	
	(1996) define 'introduced' as being synonymous	
	to 'feral' and 'casual'. However, these terms have	
	other meanings, as described below.	
	Introductions act on regional to continental	
	scales, when barriers between native and new	
	ranges are crossed (Kowarik 2003). In addition	
	to 'introduction', Kowarik (2003) uses the	
	expression 'secondary releases' when species are	
	moved within the new range. The criteria for	
	using 'secondary release' instead of 'introduction'	
	may be somewhat arbitrary, but under certain	
	conditions this may be a useful distinction. A	
	relevant example is the introduction of the	
	North American signal crayfish ( <i>Pasifastacus</i>	
	<i>leniusculus</i> ) to Europe (Italy) in the 1860s. To	
	compensate for over-harvesting of the native	
	crayfish species ( <i>Astacus astacus</i> and others),	

261	signal crayfish from introduced stocks in Italy	meaning of terms, degree of establishment should	306
262	and elsewhere subsequently became subject to	be specified using separate terms.	307
263	secondary releases in ever new freshwater sys-		
264	tems over most of Europe (Sandlund and Bon-		
265	gard 2000).		
266	<i>Transferred/translocated/transplanted</i>	<i>Transient/casual</i>	308
267	Organisms that have been moved by humans	Species that do not form self-sustaining popula-	309
268	within their present ranges have been referred to	tions may generally be termed transient or cas-	310
269	as 'transferred species' (ICES 1995; FAO 1996).	ual. Thus, the terms may apply to both native	311
270	Translocation has been defined as movement of	species in marginal non-permanent populations,	312
271	an organism from one place to another (Bullock	to immigrant species occurring somewhere for a	313
272	et al. 1997 based on NCC 1990; Lawrence 2000),	limited period of time, and to non-native species	314
273	and as movement within the organism's range	whose persistence rely on repeated introductions.	315
274	(IUCN 1995). A transplanted organism has also	The latter group may be referred to as 'transient	316
275	been defined in terms of being moved from one	non-native' or 'casual non-native' (Mack 1996;	317
276	place to another (Morris 1992), as well as being	Richardson et al. 2000). We would recommend	318
277	transported and released within its present range	that the terms 'transient' and 'casual' may be	319
278	(ICES 1995). The definitions of translocated and	used for all the three situations above, but al-	320
279	transplanted are few and not very precise. We	ways together with a qualifying term like, e.g.,	321
280	propose that the terms 'transferred', 'translocat-	'non-native'.	322
281	ed' and 'transplanted' should be used to describe		
282	human mediated movement of species within	<i>Naturalized/established</i>	323
283	their native range, whereas 'introduced' should	Both terms refer to organisms that have estab-	324
284	be used when species are moved beyond their	lished a self-sustaining population.	325
285	natural range and dispersal potential.	All of the ten definitions found in literature	326
286	<i>Immigrant</i>	specify that a naturalized species is novel to the	327
287	Lawrence (2000) defines immigrant species as	region. 'Naturalized' should be used to describe	328
288	those that migrate into an ecosystem, or are	non-native organisms that have established as self	329
289	introduced by humans. The latter situation is	sustaining populations. Thus, naturalization is	330
290	covered by 'introduced species', and 'immigrant	the outcome of an establishment process of non-	331
291	species' should be reserved to cover species that	native organisms (Holmes and Stroud 1995).	332
292	move into a new area without the aid of humans.	Allaby (1998) defines a naturalized species as a	333
293	<i>Escaped/feral (for domesticated species)</i>	non-native that has invaded a native community,	334
294	Escaped organisms have been defined as plants	while Mack (1996) and Richardson et al. (2000)	335
295	or animals originally domesticated that are found	stress that the occurrence of a naturalized organ-	336
296	in the wild. While the definitions of 'escape' do	ism may not develop into an invasion. The latter	337
297	not refer to the origin of the organism, three out	use is recommended as it reduces overlap	338
298	of five definitions of 'feral' specify that the	between a weaker term, 'naturalized' and a stron-	339
299	organisms have reverted to their wild state. We	ger term, 'invasion'. Holmes and Stroud (1995)	340
300	suggest that 'escape' should refer to non-native,	suggest further specifications of naturalization	341
301	while 'feral' should refer to native organisms that	according to whether the species was originally	342
302	following escape or release from domestication	domesticated, non-domestic naturally occurring,	343
303	now live in the wild. The degree of establishment	or non-native.	344
304	is included in some of the definitions of escaped	'Established' has been used to refer solely to	345
305	and feral organisms. To prevent overlapping of	pest organisms (three out of six definitions), one	346
		refer to organisms deliberately transferred from	347
		one area to another (non-native) while two defini-	348
		tions do not specify. We suggest that 'established'	349
		should be used as a general ecological term refer-	350
		ring to both native and non-native organisms	351
		that have obtained self-sustaining populations.	352

353 *Re-introduction/re-establishment/re-stocking*  
 354 The term 're-introduced' is defined as the inten-  
 355 tional release of organisms into a part of their  
 356 former natural range (six out of six definitions).  
 357 Holmes and Stroud (1995), however, claim that  
 358 re-introduction implies that the species was intro-  
 359 duced in the first place and suggest 're-estab-  
 360 lished' as a more precise term. We suggest that  
 361 're-introduced' should be used to mean introduc-  
 362 tion of organisms into a part of former natural  
 363 range from where it has been extirpated.  
 364 'Re-established' should mean that the species  
 365 itself manages to re-colonize a former area; and  
 366 that 're-stocking' should cover releases of organ-  
 367 isms to supplement wild populations already  
 368 present (four out of four definitions), like, e.g.,  
 369 the common practice when fish species for recre-  
 370 ational purposes are re-stocked into localities  
 371 where the harvest is above a sustainable level.

### 372 *Invasion/invasive*

373 An invasion is a colonization process, but it is  
 374 distinguished from succession ('a natural change  
 375 in the structure and species composition of a  
 376 community' (Chapman and Reiss 1999)) by being  
 377 restricted to describe the spread of a non-native  
 378 organism. 'Invasion' can be used synonymously  
 379 to 'secondary spread'.

380 In the literature, 'invasive' has largely been used  
 381 to deal with alien or non-native species (Pyšek  
 382 1995; Richardson et al. 2000). Invasive organisms  
 383 have established and are expanding their range in  
 384 an area where they previously did not occur. Out  
 385 of 14 references, 11 specify that invasive organ-  
 386 isms are non-native, and eight that the invasion  
 387 has a negative effect on the native community.  
 388 Eight references specify that invasive organisms  
 389 expand their range. We suggest that the word  
 390 'invasive' should be used to refer only to non-na-  
 391 tive organisms that expand their range on their  
 392 own accord. This makes it relevant to define and  
 393 specify invasive traits, such as the ability to  
 394 spread, strong competitive ability, etc. Any organ-  
 395 ism entering a new area will have an effect on their  
 396 new community. The consequences of invasions  
 397 and how they are perceived should, however, not  
 398 be included in the definition of 'invasive', but  
 399 rather be expressed by other terms (see below).

400 Pyšek (1995) suggests that invasive species  
 401 should be used as synonymous to alien, due to

difficulties related to, and a general lack of, stud- 402  
 ies documenting spread of aliens. Regardless of 403  
 this (somewhat peculiar) argument, he suggests to 404  
 define invasive as aliens whose abundance is 405  
 increasing. Furthermore, he suggests that 'inva- 406  
 sive' is synonymous to 'naturalized'. As argued 407  
 above, a naturalized species need not become 408  
 invasive. 409

Richardson et al. (2000) define the invasive 410  
 status of plants according to rate of spread 411  
 (>100 m in <50 years for taxa spreading by 412  
 seeds and other propagules, >6 m per 3 years 413  
 for taxa spreading by roots, rhizomes, stolons, or 414  
 creeping stems). Although these criteria are fairly 415  
 arbitrary, they can be useful in practice when 416  
 defining the invasive status within a comparable 417  
 group of plants. These criteria are obviously not 418  
 appropriate for all taxa as the potential rate and 419  
 degree of spread differ significantly between 420  
 organisms. Defining measurable criteria of inva- 421  
 sive status must therefore be seen in relation to 422  
 the potential growth and rate of spread of the 423  
 organism concerned. The distinction between 424  
 non-invasive and invasive can, however, be 425  
 imprecise, as spread is partly a function of time 426  
 since establishment, which is often unknown 427  
 (Kolar and Lodge 2001). 428

The term 'invasive' is now generally accepted 429  
 in international management activities relating to 430  
 this issue as an environmental problem, as the 431  
 expression 'invasive alien species (IAS) is gener- 432  
 ally used by both the Convention on Biological 433  
 Diversity (CBD; <http://www.biodiv.org>), the Glo- 434  
 bal Invasive Species Programme (GISP; [http://](http://www.gisp.org) 435  
[www.gisp.org](http://www.gisp.org)), and by IUCN's Invasive Species 436  
 Specialist Group (<http://www.issg.org>). 437

### *Pest/weed /harmful-, nuisance-species/problem 438* *plants/biological pollutants 439*

Some authors claim that introduced species may 440  
 not have significant impact on the native ecosys- 441  
 tem (Mooney and Hobbs 2000; FAO 2003). Con- 442  
 sidering all the possible direct and indirect 443  
 interactions in an ecosystem, it is hard to see that 444  
 a novel organism will not have any effect at all on 445  
 the new system. But effects clearly range from 446  
 barely detectable to large scale alterations with 447  
 displacement or loss of biodiversity, reduction in 448  
 economic value, etc. The assessment of negative 449  
 effects is always determined by the focus and scale 450

451 of study as well as social and economic conse-  
452 quences. This is further complicated by the often  
453 diverging values of interest groups. Furthermore,  
454 the perception of the non-native organism may  
455 change over time (Starfinger et al. 2003). The  
456 evaluation of the effects of non-native organisms  
457 has triggered the use of terms such as 'pest', or  
458 'weed'. Other less common terms include 'harmful  
459 species', 'nuisance species', 'problem plants' and  
460 'biological pollutants'.

461 'Pest' and 'weed' are subjective terms describ-  
462 ing any organism regarded as harmful/having  
463 negative effects. Pests have been defined as  
464 organisms being unpleasant to humans (seven  
465 out of 12 definitions), detrimental to plants,  
466 plant products or crops (eight out of 12 defini-  
467 tions), harmful to animals (one out of 12 defini-  
468 tions), and to the environment in general (one  
469 out of 12 definitions).

470 Three out of 12 definitions of "pest" describe  
471 animals as pests, three of 12 describe plants as  
472 pests, and seven of 12 concern organisms in gen-  
473 eral as pests. We suggest a definition that includes  
474 organisms that are invasive, and directly or indi-  
475 rectly have a negative effect on humans or are  
476 perceived as unwanted in terms of economy,  
477 health, or environment. This definition is non-  
478 exclusive when it comes to taxonomic reference  
479 and is in accordance with the majority of the defi-  
480 nitions, stressing the impact on human well being.  
481 'Weeds' refer specifically to undesirable plants (all  
482 five definitions). Only Godman and Payne (1996)  
483 restrict weeds to be plants growing in cultivated  
484 areas. Rather than restricting the definition to  
485 anthropogenically altered areas, one might specify  
486 the habitat where a specific organism is undesir-  
487 able. The terms 'pest' and 'weed' may be applied  
488 both to non-native and native organisms.

489 The definition of pest has been criticized for  
490 being socio-economically based and therefore  
491 having a tenuous ecological meaning. The terms  
492 'pest' and 'weed' are based on societal or socio-  
493 economic values and we suggest that their use  
494 should be followed by a more detailed descrip-  
495 tion of what kind of pest an organism represent,  
496 and for whom. For example, for local farmers an  
497 introduced or native plant or insect may become  
498 a pest requiring a certain management response,  
499 including costs and benefits.

*Transformer/ecosystem engineer/environmental* 500  
*weeds* 501

502 Terms only describing ecological processes include  
503 'transformers', 'ecosystem engineers' and 'envi-  
504 ronmental weeds'. 'Transformers' are organisms  
505 that change the character, condition, form or nat-  
506 ure of ecosystems over a substantial area relative  
507 to the extent of that ecosystem (Wells et al. 1986).  
508 Organisms controlling the availability of resources  
509 to other organisms by causing physical state chan-  
510 ges are referred to as 'Physical ecosystem engi-  
511 neers' (Jones et al. 1997). Although used in the  
512 context of non-native organisms (Wells et al.  
513 1986; Crooks 2002), the terms are not specifically  
514 defined to be restricted to non-native organ-  
515 isms. 'Environmental weeds' are specified to be  
516 non-native plants affecting biodiversity and/or  
517 ecosystem functioning (Humphries et al 1991 as in  
518 Randall 1996). All three terms describe organisms  
519 that have clear ecosystem impacts and therefore  
520 should receive extra attention.

## 521 Conclusion

522 The growing scientific field of invasion biology  
523 has suffered from its often confusing use of terms.  
524 Synonyms have been too many, many terms have  
525 not been properly defined, and the use of terms  
526 and concepts has not been consistent. Further, the  
527 definitions of terms have been related to specific  
528 taxonomic groups, most often plants. This may  
529 have created more taxonomic barriers (e.g. plants  
530 vs animals) than necessary between invasion biol-  
531 ogists and thus reduced valuable communication.  
532 When discussing biological invasions in general  
533 terms, it is important to use terms that include all  
534 types of organisms rather than more specific  
535 terms. The generality (or specificity) of the knowl-  
536 edge should be reflected in the generality (or speci-  
537 ficity) of the concepts.

538 Conceptual confusion, value laden terms, and  
539 taxonomy-based barriers within the field of inva-  
540 sion biology are all unnecessary and will lead to  
541 a reduced generality of the conclusions drawn.  
542 We encourage all invasion biologists to tighten  
543 up their use of terms and concepts for a common  
544 goal of clarity, and also to be explicit in defining  
545 their terms and concepts.



546 **Appendix A**547 *Appendix A.1.* Overview of the 145 selected concepts and definitions as used in the literature, sorted to 10 main categories.

Term	Definition	Reference
Indigenous	Describes an organism growing naturally in the area, rather than one that has been introduced	Godman and Payne 1986
Indigenous species	A native species which is not necessarily restricted in its distribution to a particular lake, drainage system or biogeographical region. A species which naturally occur in southern Africa as well as in other parts of Africa is therefore indigenous to southern Africa but not endemic to that region	Moor and Bruton 1988
Indigenous	Belonging to the locality/native/not imported	Lawrence 2000
Indigenous, native, original	Native to or occurring naturally in a particular area	Morris 1992
Indigenous, native	Species naturally occurring in an area since prehistorical time	Binggeli 1994
Indigenous, native	Species that occurs naturally in an area, and therefore one that has not been introduced by humans either accidentally or intentionally	Allaby 1998
Indigenous, native	Species, subspecies, or lower taxon, occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans)	IUCN 2000
Indigenous, native	Species or race that occurs naturally in an area, i.e. whose dispersal has occurred independently of deliberate human translocation (generally a species or race thought to have occurred in an area since before the Neolithic)	Manchester and Bullock 2000
Native	A species or race which occurs naturally in an area...whose dispersal has occurred independently of human activity. Usually organism thought to have occurred since prehistoric times	Bullock et al. 1997
Native	Animals and plants which originate in a district or area in which they live	Lawrence 2000
Endemic	Peculiar to and characteristic of locality or region	Allred and Clements 1949
Endemic species	Species restricted to a specified region or locality	UN 1997
Endemic species	Pest or pathogen limited to a certain region or occurring continuously in a given region	Godman and Payne 1986
Endemic species	A species that is restricted in its distribution to a particular lake, drainage system or biogeographical region	Moor and Bruton 1988
Endemic	Of or relating to a native species or population occurring under highly restricted conditions due to the presence of a unique environmental factor that limits its distribution	Morris 1992
Endemic	A species, race or other taxon that is restricted to a particular country or region	Bullock et al. 1997
Endemism	The situation in which a species or other taxonomic group is restricted to a particular geographic region, owing to factors such as isolation or response to soil or climatic conditions	Allaby 1998
Endemic	Restricted to a certain region or part of region	Lawrence 2000
Adventive	An organism artificially or accidentally introduced into an environment where it is not native	Morris 1992
Adventive, invasive, naturalized, neophyte	The establishment of self-regenerating, usually expanding, populations of an introduced species in a free-living state in the wild	Binggeli 1994
Adventive	Organism in a new habitat but not completely established there/non-native	Lawrence 2000
Alien, introduced, exotic	Deliberate or accidental release of a species into an area in which it has not occurred in historical times	Binggeli 1994
Alien	Plant species thought to have been introduced by humans but now more or less naturalized	Lawrence 2000
Alien	Plants or animals, bacteria or fungi, that are foreign to the area they are in and frequently out of harmony with their environment	GBWMP-SA 2004

## Appendix A.1. Continued.

Term	Definition	Reference
Alien	An introduced species from outside the boundaries of southern Africa	Moor and Bruton 1988
Alien, exotic	An introduced species	UKINC 1979
Alien, non-native, non-indigenous, foreign, exotic species	Species, subspecies, or lower taxon occurring outside its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce	IUCN 2000
Alien, non-indigenous, non-native, exotic	Species or race that does not occur naturally in an area, i.e. it has not previously occurred there, or its dispersal into the area has been mediated by humans. Usually assumed that species that have colonized since the Neolithic are non-native.	Manchester and Bullock 2000
Alien, exotic, non-native, non-indigenous plants	Plant taxa in a given area whose presence is due to intentional or accidental introduction as a result of human activity	Richardson et al. 2000
Alien, introduced, exotic, non-indigenous species	A species that has been transported by human activity, intentional or accidental, into a region where it does not naturally occur	Sutinen, J.G. 2000.
Exotic	Of foreign origin; not native to the region in which it is found	Morris 1992
Exotic	Not native to a particular country, ecosystem or ecoarea (applied to organisms intentionally or accidentally introduced as a result of human activities)	ISPM 1996
Exotic species	Species not native to a particular area which may pose a risk to endemic species.	UN 1997
Exotic	Foreign plant or animal which has not acclimatized or naturalized	Lawrence 2000
Exotic, non-indigenous, introduced species	Any species intentionally or accidentally transported and released by humans into an environment outside its present range	ICES 1995
Non-indigenous	Those species that did not occur geographically within a particularly defined region prior to some predetermined period	Les and Mehrhoff 1999
Non-indigenous, exotic, introduced species	Any species intentionally or accidentally transported and released by humans into an environment outside its present range	FAO 1996
Non-native	A species or race that does not occur naturally in an area, i.e. it has never occurred there or its dispersal into the area has been mediated by humans.	Bullock et al. 1997
Introduced species	Non-indigenous species/exotic species. Any species intentionally or accidentally transported and released by humans into an environment outside its present range	ICES 1994
Introduced species	Any species intentionally or accidentally transported and released by humans into an environment outside its present range	FAO 1996
Introduced	Plants and animals not native to the country and thought to have been brought in by humans	Lawrence 2000
Introduced species	Any (non-indigenous) species intentionally or accidentally transported and released by humans into an environment beyond its present range	FAO 2004
Introduced, alien, exotic	Deliberate or accidental release of a species into an area in which it has not occurred in historical times	Binggeli 1994
Introduced, exotic, non-indigenous species	Any species intentionally or accidentally transported and released by humans into an environment outside its present range	ICES 1995
Introduced, feral, casual	Found outside control or captivity as a potentially self-sustaining population	Williamson and Fitter 1996
Introduced, alien, exotic, non-indigenous species	A species that has been transported by human activity, intentional or accidental, into a region where it does not naturally occur	Sutinen, J.G. 2000.
Introduction	Release of animals of a species into an area in which it has not occurred	WWF 1976
Introduction	The deliberate or accidental release of animals or plants of a species or race into an area in which it has not occurred in historical times; or, a species or race so released	UKINC 1979

## Appendix A.1. Continued.

Term	Definition	Reference
Introduction	Intentional or accidental dispersal by human agency of a living organism outside its historically known native range	IUCN 1987
Introduction	The entry of a pest into a country or area where it does not occur	FAO 1990
Introduction	The deliberate or accidental release of living organisms into the wild in areas where that kind of organism does not occur naturally, and has not occurred since the last glaciation (or during historic time)	NCC 1990 as in Bullock et al. 1997
Introduction	The deliberate or accidental release of an organism (s) into the wild to areas (e.g. country, region, site, etc.) where the species or race is not native. Applies also to the release of GMOs into the wild	Bullock et al. 1997
Introduction	The entry of a pest resulting in its establishment	IPPC 1997
Introduction	Movement, by human agency, of a species, subspecies or lower taxon (including any part, gametes or propagule that might survive and subsequently reproduce) outside its natural range (past or present). The movement can be either within a country or between countries	IUCN 2000
Introduction	Deliberate or accidental release by human agency of an organism into the wild by humans in areas where the species or race is not native	Manchester and Bullock 2000
Introduction	Plant that has been transported by humans across a major geographic barrier	Richardson et al. 2000
Introduction	The entry of a pest resulting in its establishment	FAO 2002
Introduced species	A species which has been distributed intentionally or unintentionally by man to areas beyond its native range of distribution	Moor and Bruton 1988
Transferred, transplanted species	Any species intentionally or accidentally transported and released within its present range	ICES 1995
Transferred, transplanted species	Any species intentionally or accidentally transported and released by humans into an environment within its present range	FAO 1996
Translocation	Movement of living organisms from one area with free release in another	IUCN 1987
Translocation	Deliberate and mediated movement of wild individuals or populations from one part of their range to another	IUCN 1995
Translocation	General term for the transfer by human agency of any organism(s) from one place to another	Bullock et al. 1997
Translocation	Movement or removal to a different place or habitat	Lawrence 2000
Translocated indigenous species	A species naturally found within southern Africa but which has been translocated either intentionally or unintentionally by man into catchments in which it was not naturally distributed	Moor and Bruton 1988
Transplanted	To remove a plant from one place and put it in another	Godman and Payne 1986
Transplant	To transfer a growing plant from one place to another	Morris 1992
Immigrant	An organism that moves into a community or region where it was previously not found	Morris 1992
Immigrant species	Species that migrate into an ecosystem or are introduced accidentally or deliberately by humans	Lawrence 2000
Escape	Plant originally cultivated, found growing wild	Godman and Payne 1986
Escape	A usually cultivated plant growing wild in fields or by roadsides, generally surviving but not well naturalized	Morris 1992
Escape	Plant or animal originally domesticated and now established in the wild	Lawrence 2000
Escaping	Transition from imported to introduced	Williamson and Fitter 1996
Feral	Having escaped from a state of domestication and reverted to the original wild or untamed state/existing naturally in nature; not cultivated or domesticated	Morris 1992

## Appendix A.1. Continued.

Term	Definition	Reference
Feral	An organism (or its descendants) that has been kept in domestication, captivity (animals) or cultivation (plants) but which, after escape or release, now lives in the wild state	Bullock et al. 1997
Feral	Applied to a wild or undomesticated organism. Applied to wild strains of an otherwise domesticated species or to an organism that has reverted to a wild condition following escape from captivity	Allaby 1998
Feral	Wild, or escaped from domestication and reverted to wild state	Lawrence 2000
Feral	An organism (or its descendants) that has been kept in domestication, captivity (animals) or cultivation (plants) but which, following escape or release, not lives in the wild state. Populations are not necessarily self-maintaining	Manchester and Bullock 2000
Casual alien plants	Alien plants that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence (includes taxa labelled in the literature as wirfs, transients, occasional escapes and persisting after cultivation)	Richardson et al. 2000
Casual	Non-native plant which has been introduced but has not yet become established as a wild plant, although occurring uncultivated	Lawrence 2000
Transient	Alien species that leave no persistent descendants	Mack 1996
Established	(Of organisms) to make a place a permanent home for oneself/ to make strong, secure or permanent	Godman and Payne 1986
Established	An introduced species which has established self-sustaining populations in areas of natural or semi-natural vegetation or habitat	Moor and Bruton 1988
Established	An introduced pest, present in a country or area, multiplying and expected to continue	FAO 1990
Established	Organism with a self-sustaining population, naturalized	Williamson and Fitter 1996
Establishment	The formation of a self-sustaining population of the translocated species, race or GMO, i.e. some of the organisms survive to produce offspring	Bullock 1997
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry	IPPC 1997
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry	FAO 2002
Naturalization	The establishment of self-regenerating populations of an introduced species or race in a free-living state in the wild	UKINC 1979
Naturalized	An introduced species which has established self-sustaining populations in areas of natural or semi-natural vegetation or habitat	Moor and Bruton 1988
Naturalized	Alien species whose descendants have become permanent members of the local flora (may not develop into an invasion)	Mack 1996
Naturalized	A non-native species or race which, after escape or release, has become established in the wild in self-maintained populations	Bullock et al. 1997
Naturalized	Species that was originally imported from another country but now behaves like a native in that it maintains itself without further human intervention and has invaded native communities	Allaby 1998
Naturalized	Species capable of reproducing and persisting in a nonindigenous region	Les and Mehrhoff 1999
Naturalized	Alien species that have become successfully established	Lawrence 2000
Naturalized	Non-native species or race that, following escape or release, has become established in the wild in self-maintaining populations	Manchester and Bullock 2000

## Appendix A.1. Continued.

Term	Definition	Reference
Naturalized plants	Alien plants that reproduce consistently (cf. casual alien plants) and sustain populations over many life cycles without direct intervention by humans (or in spite of human intervention); they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, semi-natural or human-made ecosystems	Richardson et al. 2000
Naturalized, invasive, neophyte, adventive	The establishment of self-regenerating, usually expanding, populations of an introduced species in a free-living state in the wild	Binggeli 1994
Naturalized- feral	Domesticated species gone wild	Holmes and Stroud 1995
Naturalized- introduction	Established species which would not occur without introduction by man	Holmes and Stroud 1995
Naturalized- re-establishment	A successful re-establishment of a species in areas of former occurrence	Holmes and Stroud 1995
Naturalized- establishment	Establishment of a species which occurs but does not breed naturally in a given area e.g. a migrant, passage migrant or winter visitor	Holmes and Stroud 1995
Re-introduction	Release of animals of a species into an area in which it was indigenous until exterminated as a consequence of human activities	WWF 1976
Re-introduction	The deliberate or accidental release of a species or a race into an area in which it was indigenous in historical times; or, a species or race so released	UKINC 1979
Re-introduction	Intentional movement of an organism into a part of its native range from which it has disappeared or become extirpated in historic times as a result of human activities or natural catastrophe	IUCN 1987
Re-introduction	The deliberate or accidental release of a living organism into the wild in areas where that kind of organism was indigenous in historic times but is no longer present	NCC 1990 as in Bullock et al 1997
Re-introduction	An attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct	IUCN 1995
Re-introduction	The deliberate or accidental release of living organism(s) into the wild in areas (e.g. country, region, site, etc.) where the species or race was native but has become extinct	Bullock et al. 1997
Re-stocking	Release of animals of a species into an area in which it is already present	WWF 1976
Re-stocking	The deliberate or accidental release of a species or race into an area in which it is already present	UKINC 1979
Re-stocking	Movement of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat	IUCN 1987
Re-stocking	The release of a living organism into the wild into an area where it is already present	NCC 1990 as in Bullock et al. 1997.
Re-stocking	A distinct form of supplementation that is undertaken for amenity purposes	Bullock et al. 1997
Invasion	The movement of plants from one area to another, and their colonization in the latter; it is analysed into migration (the actual movement), ecesis (establishment), and competition	Allred and Clements 1949
Invasive species	An alien or translocated indigenous species which, after introduction, has spread unaided into untransformed ecosystems and may be responsible for causing an imbalance there	Moor and Bruton 1988
Invader	A species that moves into and colonizes a new community	Morris 1992
Invasive, naturalized, neophyte, adventive	The establishment of self-regenerating, usually expanding, populations of an introduced species in a free-living state in the wild	Binggeli 1994

## Appendix A.1. Continued.

Term	Definition	Reference
Plant invasion	Proliferation and persistence of a species in a new range such that it has detrimental consequences (abiotic and/or biotic). This persistence is not dependent on deliberate human intervention.	Mack 1996
Invasive species	Nonindigenous species capable of establishing and spreading significantly within natural communities	Les and Mehrhoff 1999
Plant invasion	Occur when a species expands into a new range intentionally or unintentionally due to human activities and is accompanied by adverse economic, ecological or other effects	Sher and Hyatt 1999
Plant invasion	Establishment, massive proliferation and spread of species in a new range, often far removed from their native range	Mack 2000
Invader	Biotic invaders are species that establish a new range in which they proliferate, spread and persist to the detriment of the environment	Mack et al. 2000
Invasive plants	Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants (approximate scales: >100 m per <50 years for taxa spreading by seeds and other propagules; >6 m per 3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems), and thus have the potential to spread over a considerable area	Richardson et al. 2000
Invasion	Range expansions over large spatial scales	Talley and Levin 2001
Invasive	Establishing in and replacing natural habitats	Simberloff et al. 2002
Invasive alien species	Species introduced deliberately or unintentionally outside their natural habitats where they have the ability to establish themselves, invade, out compete natives and take over the new environments	CBD 2004
Invasive aliens	Foreign species which get out of control and spread rapidly in a new environment, competing with, and often crowding out or wiping out the indigenous species which belong there	GBWMP-SA 2004
Pest	Any of the animals eating or destroying crops. All species detrimental to man	Godman and Payne 1986
Pest species	A species which has a major negative impact on the environment and does not have any desirable attributes	Moor and Bruton 1988
Pest (= plant pest)	Any form of plant or animal life, or any pathogenic agent, injurious or potentially injurious to plant or plant products	FAO 1990
Pest	Subjective term describing any organism that is regarded as harmful, irritating, or offensive to humans, either directly or indirectly through its effect on animals and plants	Morris 1992
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent, injurious to plants or plant products	ISPM 1996
Pest	Organism with a negative economic effect	Williamson and Fitter 1996
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products	IPPC 1997
Pest	Species, viruses, bacteria and other micro-organisms considered harmful to the health of human beings, crops and other living organisms	UN 1997
Pest	An animal that competes with humans by consuming or damaging food, fibre, or other materials intended for human consumption or use. Many such species are harmless or ecologically beneficial, others are harmless until their populations increase rapidly in response to a virtually unlimited (to them) resource	Allaby 1998
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products	FAO 2002
Weed	An undesirable wild plant adapted to live and reproduce rapidly under conditions of cultivation or pasture	Godman and Payne 1986
Weed, pest	Any plant, either native or introduced, interfering with the objectives or requirements of people	Binggeli 1994
Weed	A plant in the wrong place	Allaby 1998

## Appendix A.1. Continued.

Term	Definition	Reference
Weed	Plants that interfere with management or appreciation of natural resources (growing where they are perceived as undesirable). Can include non-indigenous or indigenous species.	Les and Mehrhoff 1999
Weeds, plant pests, harmful species, problem plants	Plants (not necessarily alien) that grow in sites where they are not wanted and which usually have detectable economic or environmental effects	Richardson et al. 2000
Transformers	Species that change the character, condition, form or nature of a natural ecosystem over a substantial area	Wells et al. 1986
Physical ecosystem engineer	Organisms that directly or indirectly control the availability of resources to other organisms by causing physical state changes in abiotic or biotic materials	Jones et al. 1997
Environmental weeds	Alien plant taxa invading natural vegetation affecting native biodiversity and/or ecosystem functioning	Randall 1996

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