

Review

A uniform terminology on bioinvasions: a chimera or an operative tool?

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Abstract

A consensual set of definitions regarding bioinvasions is essential in order to facilitate discourse among the science, policy and management communities dealing with the issue. Considering both the mode of entry and the extent of the impact of an alien species into a new environment, a set of key terms is proposed as an operative tool for marine scientists.

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1. Introduction

The study of biological invasions in the marine environment has grown over the past three decades, as it has been widely perceived that the littoral and infra-littoral biota in many regions had undergone rapid and profound changes caused by the advent of synanthropic alien species (Carlton, 1996; Ruiz et al., 1997; Galil, 2000; Occhipinti-Ambrogi and Savini, 2003). The expanding study of marine bioinvasions resulted in a surfeit of specialized terms, liable to misapplication and error. A computerized search of the 'Zoological Record' and the 'Aquatic Sciences and Fisheries Abstracts' databases disclosed the most common terms used to describe species translocated due to human activities (Fig. 1). The terms employed vary among scientific disciplines, linguistic and national borders, or are applied in different ways, and frequently constitute

synonyms, partial synonyms and neologisms that hinder communication.

In this paper we examine the terms used to describe the translocated species; highlight some problems with the current usage of these terms, and propose a set of clear and brief definitions, using a transparent framework, for terms needed by students, researchers, and policy and management personnel interested or concerned about invasions in the marine environment.

2. Methods

Definitions of 'adventive', 'alien', 'allochthonous', 'exotic', 'naturalized', were sought in various biological dictionaries. The titles, key words and abstracts of the articles published in the journal 'Biological Invasions' (1999–2004) were combed for terms denoting transport of organisms through human action. A computerized search of a database of research papers in the aquatic and marine sciences 'Aquatic Sciences and Fisheries Abstracts (ASFA) (1978–2004), was conducted for publications with the words 'alien', 'exotic', 'invasive',

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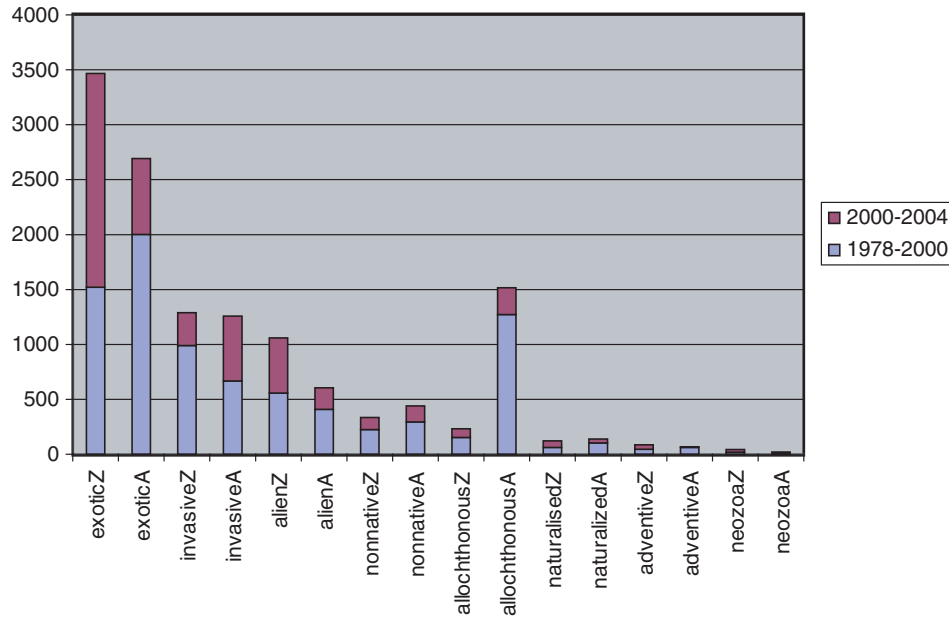


Fig. 1. Number of various bioinvasion terms used in the title, key words and abstracts of articles as cited in ‘Zoological Record’ (Z) and ‘Aquatic Sciences and Fisheries Abstracts’ (A) from 1978 to 2004.

‘*introduced*’ in the title or abstract. After removing inappropriate usages and duplications, our database comprises over 1000 publications. In addition, some of the more widely cited websites of international organizations, or of government agencies dealing with invasions were consulted.

3. Results

The terms ‘*adventive*’, ‘*alien*’, ‘*allochthonous*’, ‘*exotic*’, ‘*naturalized*’, in the biological dictionaries consulted (Appendix A), are not used by the authors in the same way, leaving us with vague and occasionally overlapping definitions. The authors differ in their perceptions concerning human activity in translocating an organism, and in defining the organism’s ‘persistence’. So that ‘*alien*’ (fide Lincoln et al., 1998) is defined solely by its geographic range, but human agency is invoked in other definitions: either moved ‘from its natural range by humans or other agents’ (fide Martin and Hines, 2000), or “Believed on good evidence to have been introduced by man” (fide Walker, 1989; Lawrence, 1995). Walker (1989) and Lawrence (1995) define ‘*adventive*’ as “[n]ot permanently established”, whereas Lincoln et al. (1998) stipulate “an organism transported into a new habitat, whether by natural means or by the agency of man”, but do not mention perpetuation. Similarly, ‘*allochthonous*’ “is usually a transient member of the community” (fide Martin and Hines, 2000), but only a “[s]pecies that has originated elsewhere” (fide Lawrence, 1995). An ‘*exotic*’ is defined simply as “non-native” (Walker, 1989), or considered “introduced” thus implying human

activity (Allaby, 1994, 1999; Lincoln et al., 1998), or marked as “brought in by man”, but not “acclimatized or naturalized” (Lawrence, 1995). A ‘*naturalized*’ species is defined as “alien species that has become successfully established” (Lawrence, 1995; Lincoln et al., 1998); though other authors maintain it has to invade native communities (Allaby, 1994; Walker, 1989; Martin and Hines, 2000, and see Richardson et al., 2000).

The six research papers dealing with the human-mediated movement of species published in the inaugural issue of ‘Biological Invasions’ employ nine different terms—‘*casual*’, ‘*exotic*’, ‘*imported*’, ‘*introduced*’, ‘*invader*’, ‘*invasive*’, ‘*naturalized*’, ‘*non-indigenous*’, ‘*pest*’—to describe the translocated species. Frequently, authors use two terms interchangeably: ‘*non-indigenous*’ and ‘*invader*’ (Parker et al., 1999); ‘*non-indigenous*’ and ‘*introduced*’ (Simberloff and Von Holle, 1999); ‘*introduced*’ and ‘*exotic*’ (Marchetti, 1999); ‘*non-indigenous*’ and ‘*exotic*’ (Smith et al., 1999); ‘*exotic*’ and ‘*imported*’ (Smith et al., 1999). Such usages persist in later issues as well, and again authors use terms interchangeably: ‘*alien*’ and ‘*exotic*’ (Kotani, 2004); ‘*exotic*’ and ‘*non-native*’ (Ayres et al., 2004); ‘*exotic*’ and ‘*non-indigenous*’ (Delibes et al., 2004).

In the ASFA abstracts examined we discerned similar ambiguities brought about by the lack of widely accepted terms to describe the status of alien organisms. Promiscuous usage of misconstrued terms is unfortunately of common occurrence: ‘*alien*’, ‘*allochthonous*’, ‘*exotic*’, and ‘*introduced*’ have been used as synonyms, as well as ‘*introduction*’ and ‘*invasion*’ (see Faasse and Moorsel, 2003). Yet, certain frequently used terms have several commonly established interpretations.

- A. A translocated organism, unqualified by its persistence or extent of range ('**Alien**', see Occhipinti-Ambrogi and Savini, 2003; Matern et al., 2002; '**Exotic**', see Avault, 2004; Wijnhoven et al., 2003; Galil et al., 2002).
- B. A translocated organism that reproduces and sustains a population in its new environment ('**Alien**', see Moyle et al., 2003; Mori and Vacchi, 2002; Breton et al., 2002; '**Exotic**', see Torchin et al., 2003; Hamabata and Kobayashi, 2002; Bennett et al., 2002).
- C. A translocated organism that spreads extensively ('**Alien**', see Piazzini and Cinelli, 2003; Kawai et al., 2002; Sebastien et al., 2002; '**Exotic**', see Vasarhelyi and Thomas, 2003; Stepien et al., 2002; Zofkova et al., 2002; Zanatta et al., 2002).
- D. An intentionally translocated organism ('**Introduced**' see Levavi-Sivan et al., 2004; Szalontai et al., 2003).
- E. An unintentionally translocated organism ('**Introduced**' see Work et al., 2003; Audenaert et al., 2003; Piazzini and Cinelli, 2003).

The definitions used by national and international bodies promoting bioinvasion management are largely derived from the scientific literature and prove the difficulty of employing scientific concepts for practical purposes (Appendix B).

We propose a set of definitions (Appendix C) regarding bioinvasions with the aim of providing an operative tool to facilitate discourse among the science, policy and management communities dealing with the issue.

4. Discussion

The concept of native species and their natural ranges and, *inter alia*, of alien species, is largely dependent on the scientific knowledge of the biota within a certain geographic region. In the Mediterranean Sea, for instance, extensive biological surveys were conducted since the beginning of the 20th century, allowing a reasonable measure of confidence in separating the alien from the native biota in the better known taxa, for other regions different 'baseline' dates may be appropriate.

In defining the terms (Appendix C) we deliberately made a distinction between the scale and impact of the alien populations on the native ecosystem, and their mode of entry. From our studies of alien organisms in the Mediterranean Sea, we have noted that some are known only from chance collections of non-breeding individuals, other from breeding populations that remain for decades in low numbers, whereas in some cases we have witnessed rapid population growth and high impact upon the ecosystem and risk to humans. Accordingly we have ordered our definitions in a nested hierarchy of increasing order of the alien's population spread and perceived impact. We are aware that the distinctions

are circumscribed in large part by our ignorance. A large, conspicuous species occurring along a frequently sampled coast, where taxonomic expertise is readily available will be noted earlier than a small, obscure species present in a rarely examined habitat.

As to mode of entry, we distinguish between introduction, which is wholly derived from human actions, and range expansion, which can result from natural phenomena or from both natural and human-induced environmental changes. Introduction is further divided into primary and secondary introduction and each of these can be intentional or unintentional. Secondary introduction could also result naturally. Moreover, the dynamics of invasion and of research progress mean that organisms may be recognised as conforming to different categories in different spatial and temporal settings.

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Appendix A. Translocated species—definitions in biological dictionaries, 1989–2000

Walker, P.M.B., 1989. **Chambers' Biology Dictionary**. Chambers & Cambridge. 324 pp.

Adventive—Not permanently established in a given habitat or area.

Alien—Believed on good evidence to have been introduced by man and now more or less naturalized.

Exotic—Not native, endemic.

Naturalized—Introduced from another region but growing, reproducing and maintaining itself in competition with the native vegetation.

Allaby, M., 1994. **The concise Oxford Dictionary of Ecology**. Oxford University Press, Oxford. 415 pp.

Allochthonous—Not indigenous, acquired. Applied to material which did not originate in its present position.

Exotic species—An introduced, non-native species.

Naturalized—Applied to a 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.

Lawrence, E., 1995. **Henderson's Dictionary of Biological Terms**. 11th Edition. J. Wiley, New York. 693 pp.

Adventive—Not native, organism in a new habitat but not completely established there.

Alien—Plant species thought to have been introduced by man but now more or less naturalized.

Allochthonous—Species that has originated elsewhere, exotic; not aboriginal.

Exotic—A foreign plant or animal which has not acclimatized or naturalized. Introduced plants and animals not native to the country and thought to have been brought in by man.

Naturalized—alien species that have become successfully established.

Lincoln, R., G. Boxshall, P. Clark, 1998. A Dictionary of Ecology, Evolution and Systematics. 2nd Edition. Cambridge University Press, Cambridge. 361 pp.

Adventive—Not native; an organism transported into a new habitat, whether by natural means or by the agency of man.

Alien—Non-native, a species occurring in an area to which it is not native.

Allochthonous—Exogenous, originating outside and transported into a given system or area; non-native, xenogenous, ectogenous.

Exotic—Non-native, alien, foreign; an organism or species that has been introduced into an area.

Naturalized—Used of an alien or introduced species that has become successfully established.

Allaby, M., 1999. Oxford Dictionary of Zoology, 2nd Edition. Oxford University Press, Oxford. 597 pp.

Allochthonous—Pertaining to an individual or object which originates somewhere other than the place where it is found.

Exotic species—Introduced, non-native species.

Martin E., R.S. Hines, 2000. Oxford Dictionary of Biology. 4th Edition. Oxford University Press, Oxford. 641 pp.

Alien (exotic)—A species or organism that is not native to a locality, having been moved there from its natural range by humans or other agents. An **alien** that establishes a self sustaining wild population is described as **naturalized**, whereas one that depends on continual introduction is termed a **casual**.

Allochthonous—Describing an organism that originates from a place other than that in which it is found. The organism is usually a transient member of the community.

Appendix B. Translocated Species—definitions of governmental and international organizations

IUCN—The World Conservation Union, 2000. Species Survival Commission (SSC). Guidelines For The Pre-

vention Of Biodiversity Loss Caused By Alien Invasive Species Prepared by the SSC Invasive Species Specialist Group. Approved by the 51st Meeting of the IUCN Council, Gland Switzerland, February 2000. <http://iucn.org/themes/ssc/pubs/policy/invasivesEng.htm> and

IUCN—The World Conservation Union, 2002. Policy Recommendations Papers for Sixth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP6). The Hague, Netherlands, 7–19 April 2002. <http://www.iucn.org/themes/pbia/wl/docs/biodiversity/cop6/invasives.doc>

Alien species (non-native, non-indigenous, foreign, exotic): a species, subspecies, or lower taxon occurring outside of 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.

Alien invasive species: an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Introduction: the 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). This movement can be either within a country or between countries.

Intentional introduction: an introduction made deliberately by humans, involving the purposeful movement of a species outside of its natural range and dispersal potential. (Such introductions may be authorised or unauthorised.)

Unintentional introduction: an unintended introduction made as a result of a species utilising humans or human delivery systems as vectors for dispersal outside its natural range.

UNEP—United Nations Environmental Program, WCMC—World Conservation Monitoring Centre, 2004. Glossary of Biodiversity Terms. <http://www.unep-wcmc.org/reception/glossary>

Native species: plants, animal, fungi, and microorganisms that occur naturally in a given area or region.

Alien species: a species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities (also known as an exotic or introduced species).

Exotic species: an organism that exists in the free state in an area but is not native to that area. Also refers to animals from outside the country in which they are held in captive or free-ranging populations.

ICES—International Council for the Exploration of the Sea, 2003. Code of Practice on the Introduction and Transfer of Marine Organisms. <http://www.ices.dk/reports/general/2003/codemarineintroductions2003.pdf>

Indigenous (native) species: a species or lower taxon living within its natural range (past or present) including the area which it can reach and occupy using its natural dispersal systems. (modified after CBD, GISP).

Introduced species (non-indigenous species, exotic species): any species transported intentionally or accidentally by a human-mediated vector into aquatic habitats outside its native range. Note: Secondary introductions can be transported by human-mediated or natural vectors.

Transferred species (transplanted species): any species intentionally or accidentally transported and released within areas of established populations and continuing genetic flow where it occurs.

EPA—United States Environmental Protection Agency, 2001. <http://www.epa.gov/gmpo/nonindig.html>
Aquatic nuisance species, Annual Report, 2001. <http://www.epa.gov/gmpo/2001annualreportfinal.pdf>

Non-indigenous species: any individual, group, or population of a species, or other viable biological material, that is intentionally or unintentionally moved by human activities, beyond its natural range or natural zone of potential dispersal, including moves from one continent or country into another and moves within a country or region; includes all domesticated and feral species, and all hybrids except for naturally occurring crosses between indigenous species. Synonyms: alien, immigrant, introduced, and non-native.

Invasive species: a species that threatens the diversity or abundance of native species; the ecological stability of infested ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and/or human health. Synonyms: harmful, injurious, invader, noxious, nuisance, pest, and weed.

Established: a species with one or more successfully reproducing or breeding (i.e., permanent) populations in an open ecosystem, which are unlikely to be eliminated by man or natural causes. Synonym: naturalized.

CSIROOnline—Website of the Australian Commonwealth Scientific and Industrial Research Organization, 2004. <http://www.csiro.au/index.asp?type=blank&id=GlobalAidRiskManagement>

APEC—Asia-Pacific Economic Cooperation, MRC WG Marine Resource Conservation Working Group, 2002. Development of a regional risk management framework for ACEC Economies for use in the control

and prevention of introduced marine pests. http://www.marine.csiro.au/crimp/reports/APEC_Report.pdf

Indigenous or native: species that would be present without human interventions.

Non-indigenous, alien, exotic, introduced or adventive: species that have been transported by human activities—intentionally or unintentionally—into a region in which they did not occur in historical time and are now reproducing in the wild.

Invasive: an alien species that becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Introduction or translocation: the human assisted movement of an animal to an area outside its natural range.

Intentional introduction: the knowing import or introduction of non-indigenous species into, or transplant through, an area or ecosystem where it was not previously established.

Unintentional introduction: an introduction of non-indigenous species that occurs as a result of activities other than purposeful or intentional introduction of the species involved, such as the transport of non-indigenous species in ballast or in water used to transport fish, molluscs or crustaceans for aquaculture or other purpose. Involved is the release, often unknowingly, of non-indigenous organisms without any specific purpose.

FAO—Food and Agriculture Organisation, 2002. **Multilingual Glossary Forest Genetic Resources.** **FAO Forestry Department and the IUFRO (International Union of Forest Research Organizations) SilvaVoc Terminology Project, 2002.** <http://iufro.ffp.csiro.au/iufro/silvavoc/glossary/index.html>

Native species: plants, animals, fungi, and microorganisms that occur naturally in a given area or region.

Introduced species: an established species not native to the ecosystem, region or country. See also alien species exotic species.

Alien species: a species occurring in an area outside its historically known natural range as a result of intentional or accidental dispersal by human activities. Also known as introduced species.

Exotic species: a species which is not native to the region in which it occurs. See also alien species introduced species.

Appendix C. Terms and definitions

NATIVE: an organism occurring within its known or consensual range (as documented in scientific publications). Synonymous with: autochthonous, indigenous.

ALIEN: an organism, inclusive of parts, gametes or propagules that may survive and subsequently reproduce, occurring outside of its known or consensual

range (as documented in scientific publications). An alien may be further characterized as ‘established alien’, ‘invasive alien’, ‘noxious alien’, in increasing order of population expansion and impact. Synonymous or partially synonymous with: adventive, allochthonous, colonist, exotic, foreign, immigrant, introduced, invader, invasive, neozoan, neozoon, non-indigenous, non-native, translocated.

CLASSIFICATION BY SCALE AND IMPACT

An alien may be further characterized as ‘unestablished alien’, ‘established alien’, ‘invasive alien’ and ‘noxious alien’, in increasing order of population expansion and impact.

UNESTABLISHED ALIEN: an alien lacking self-maintaining populations outside its natural range, either because it were unable so far to settle, or is too newly arrived.

ESTABLISHED ALIEN: an alien that is reproducing in the wild and has established a durable population outside its natural range.

INVASIVE ALIEN: an alien whose population has undergone an exponential growth stage and is rapidly extending its range.

NOXIOUS ALIEN: an alien that poses a risk to the well-being of humans. Synonymous with: nuisance, weed, pest.

CLASSIFICATION BY MODE OF ENTRY

SPREADING ALIEN: an alien that has extended its range as a result of changing environmental conditions (e.g. temperature, current regime), or by chance events, such as the attachment to drifting objects and phoresy.

INTRODUCED ALIEN: an alien occurring outside its native range as a consequence of intentional or unintentional human action.

SECONDARY INTRODUCTION: the dispersal of an alien beyond its primary location of introduction; secondary introduction could be intentional, unintentional, or by natural means.

INTENTIONAL INTRODUCTION: the deliberate transfer of alien organisms (may be combined with a vector, i.e. intentional *mariculture* introduction).

UNINTENTIONAL INTRODUCTION: the inadvertent or accidental transfer of alien organisms (may be combined with a vector, i.e. unintentional *shipping* introduction, unintentional *mariculture* introduction).

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