



## Recommendations on standardizing lists of marine alien species: Lessons from the Mediterranean Sea



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### ABSTRACT

Analyses of marine alien species based on national/regional datasets are of paramount importance for the success of regulation on the prevention and management of invasive alien species. Yet in the extant data systems the criteria for the inclusion of records are seldom explicit, and frequently inconsistent in their definitions, spatial and temporal frames and comprehensiveness. Agreed-upon uniform guiding principles, based on solid and transparent scientific criteria, are therefore required in order to provide policy makers with validated and comparable data. Following a meta-analysis on the records of marine alien species in the Mediterranean Sea, we recommend a judicious approach to compiling the data. Here, three categories of uncertainty were identified: species' taxonomic identification, species' actual occurrence in the area, and its status as an alien. In proposing guiding principles to standardize such datasets, we aim to encourage discourse on logical, standardized and transparent criteria to substantiate records of alien species.

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### 1. Introduction

European regulatory instruments concerning the issue of invasive alien species, such as the Strategy on Invasive Species (EC, 2008a), the Marine Strategy Framework Directive (EC, 2008b), the Biodiversity Strategy (EC, 2011), and the Regulation on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (EU, 2014) rely on national and regional inventories of alien species. The data on the temporal and spatial history, abundance, pathway/vector, impacts and biological traits of alien species contained in inventories are essential for developing effective policies for prevention and control (Hulme and Weser, 2011; Gatto et al., 2013; Ojaveer et al., 2014a). Up-to-date and accurate data are particularly relevant for the “horizon scanning” initiatives, where new potentially invasive alien species, which are not yet established within a region, are suggested and prioritized (Groom et al., 2015). Furthermore, inventories of alien species are important to encourage public awareness about the subject and to establish priorities of investment in research (Rocha et al., 2013).

Since inventories of alien species have scientific, political, commercial and social relevance, their accuracy and reliability is a crucial concern. However, inventorying is affected by issues of access to and interpretation of information, such as: (i) data on alien species is gleaned from a wide range of sources (i.e., peer-reviewed articles, books, conference publications, administrative reports, taxonomic monographs, and,

increasingly, web-based sources), which often involve extended temporal frames and multiple languages (e.g., biodiversity records in the Mediterranean Sea date back to the XVI century and most were published in local languages, from Arabic and Catalan to Serbo-Croatian and Turkish); (ii) the process of data entry is subject to errors such as ignored synonymies, misidentifications and similar errors in knowledge and its acquisition (McGeoch et al., 2012); (iii) alien species diversity is largely underestimated due to a “shifting baseline syndrome” (Clavero, 2014): early introduced species may have been overlooked and assumed to be part of the native ecosystem; (iv) knowledge of the native range of species is inadequate (i.e. cryptogenic species), resulting in the subjective interpretation of their alien status (Rocha et al., 2013).

Inventories of alien species are therefore affected by uncertainty and subjectivity. In order to minimize errors, McGeoch et al. (2012) suggested a “documented evidence approach”, i.e., based exclusively on peer-reviewed literature, avoiding records of species not subject to the rigorous scientific review process, such as derived from web forums, newspapers and handbooks. Yet, it is recognized that records in peer-reviewed journals are not exempt from errors, and some journals have failed to adopt best-practice rules (Bello et al., 2014). The documented evidence approach may result in the underestimation of the number and spread of alien species (McGeoch et al., 2012), as relevant data may be obtained by ‘citizen science’ (Azzurro et al., 2013). We foresee an increase of citizens' sourced records, as more data are expected to originate in monitoring and early warning programmes involving ‘citizen science’ (Thiel et al., 2014; Lehtiniemi et al., 2015). Initiatives such as ‘Invasive Tracers’ (<http://www.mikedelaney.org/user/index.htm>), ‘Jellyrisk’ (<http://jellyrisk.eu>), ‘Clodia’ (<http://chioggia.scienze>

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unipd.it/DB/segnalazioni.html), and ‘Seawatchers’ (<http://www.observadoresdelmar.es>), provide relevant data on alien species (Delaney et al., 2008; Boero et al., 2009; Azzurro et al., 2013; Piraino et al., 2014). The increasing usage of mobile communications technology is expected to further expand non-traditional observational data.

Within this rapidly changing context, inventories and their sources should be carefully scrutinized for transparency of the criteria used and the rigor of the data validation process. While it is acknowledged that the process of producing inventories of alien species in a given geographical area is inevitably fraught with pitfalls and inaccuracies, recognizing the causes for uncertain classifications is an important first step to deal with them and identify solutions (McGeoch et al., 2012).

The goals of this paper are to provide a logical framework for identifying types of uncertainty that might affect records of marine alien species, and suggest guiding principles for a “standard” for compiling inventories of marine alien species. Scientifically validated inventories should comprise only carefully screened records that are unequivocally valid.

Our case-study is the Mediterranean Sea, the most invaded marine region in the world (Galil, 2007a; Galil et al., 2014), for which several inventories of alien species have become available in recent years, spanning over a century of scientific studies (Galil and Goren, 2014).

## 2. Methods

The definition of alien species adopted hereby is the one provided by the European Environmental Agency (2012): «An alien species is an organism introduced outside its natural past or present distribution range by human agency, either directly or indirectly. This definition implies an active movement facilitated by humans through a number of different pathways, and covers both intentional and unintentional movements of species».

Our study area, the Mediterranean Sea, is here considered as a single region, where indigenous species, as well as Atlantic species, may expand their range without human agency. Following the definition above, such species as expanded their range are not considered alien species. However, alien species which underwent secondary spread without human agency are still considered alien species.

The on-line databases of marine alien species in the Mediterranean region examined were the Atlases of Exotic Species in the Mediterranean ([www.CIESM.org/atlas/](http://www.CIESM.org/atlas/)); the European online databases, i.e. DAISIE (Delivering Alien Invasive Species In Europe, [www.europe-aliens.org/aboutDAISIE](http://www.europe-aliens.org/aboutDAISIE)), AquaNIS (<http://www.corpi.ku.lt/databases/index.php/aquanis>), and EASIN (The European Alien Species Information Network, <http://easin.jrc.ec.europa.eu/>). In addition, we examined published inventories: Mediterranean-wide lists (Streftaris et al., 2005; Zenetos et al., 2005; Galil, 2008, 2009; Zenetos et al., 2010, 2012; Katsanevakis et al., 2014), as well as national lists of EU member states (Sciberras and Schembri, 2007; Katsanevakis et al., 2009; Zenetos et al., 2009; Occhipinti-Ambrogi et al., 2011; Pečarić et al., 2013; Evans et al., 2015; GSA-SIBM, 2015), non-EU states (Galil, 2007b; Çinar et al., 2011; Beqiraj et al., 2012), regional/local lists (Orlando-Bonaca, 2001; Verlaque, 2001; Gravili et al., 2010; Bazairi et al., 2013; Cecere et al., 2015; Dorgham and Hamdy, 2015; Marchini et al., 2015) and taxon-specific lists (Tsiamis et al., 2008; Izquierdo-Muñoz et al., 2009; Bilecenoglu, 2010; Orsi-Relini, 2009; Antit et al., 2011; Galil, 2011; Halim and Rizkalla, 2011; Kapiris et al., 2012; Ateş et al., 2013; Bitar, 2014; Galil and Goren, 2014).

Data on marine alien species listed in these inventories were cross-compared, in order to highlight inconsistent records and species. These inconsistencies were carefully considered: their data sources were checked and the underlying interpretations of “introduced alien species” were compared with the definition provided by the European Environmental Agency (2012). Uncertain records, i.e., unsupported by unequivocal evidence or not fitting the definition (above), were carefully examined in order to classify the type of uncertainty (see below). For cases of missing or unclear information, the authors of the records, and/or independent experts of the taxonomic group were contacted. While

preparing recommendations for guiding principles for inventories of marine alien species, we assembled examples of types of uncertainty that might affect records of marine alien species. Hence, this exercise allowed for the establishment of criteria to identify these uncertain records and suggest the motivations for their inclusion or removal from the associated inventories.

## 3. Results

Numerous inconsistencies were observed among inventories of marine alien species in the Mediterranean Sea, providing examples of three main types of record uncertainty: A. taxonomic identity; B. “alien” status; and C. occurrence.

### A. Uncertain taxonomic identity

The record of a supposed “alien” may prove a misidentification of another “alien” species or of a native species. For poorly known taxa (e.g. small-sized taxa, taxa with cryptic habits, and morphologically similar taxa), one should apply at least one of the following criteria for proper taxonomic validation of the species:

- comparisons with scientific reference material, preferably type material, performed by a taxonomic expert;
- examination of specimens by a taxonomic expert;
- molecular analysis, especially for morphologically indistinguishable taxa which may consist of biologically, ecologically and genetically distinct species (species complex), e.g. the *Falkenbergia* stage of *Asparagopsis* (Andreakis et al., 2007), or the scyphozoan *Cassiopeia* (Holland et al., 2004).

Uncertain records requiring additional evidence before inclusion in inventories comprise:

- records of species whose identification is uncertain: use of identification qualifiers, e.g. *Oenone* cf. *fulgida* (Cyprus: Çinar, 2005), *Mesanthura* cf. *romulea* (Italy: Lorenti et al., 2009); species confused with native congeners, e.g. *Corymorpha annulata* (Kramp, 1928) (Croatia: Schuchert, 2010), *Grateloupia minima* P.L. Crouan & H.M. Crouan (France, Italy: Cecere et al., 2011); records based on morphological identification for species or taxonomic units requiring molecular validation, e.g. lineage 2 of *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon (Albania: Katsanevakis et al., 2011);
- taxa with unresolved taxonomic status, e.g. *Aurelia* spp. (Adriatic Sea: Ramšak et al., 2012), *Serpula* spp. (Israel, Egypt: Ben-Eliahu and Ten Hove, 2011), *Cymadusa filosa* Savigny, 1816 (several Mediterranean countries: Peart, 2004), *Polydora cornuta* Bosc, 1802 (Greece, Turkey: Rice et al., 2008) and *Scorpidinipora costulata* (Canu & Bassler, 1929) (Lebanon: Harmelin et al., 2012);
- records of species lacking appropriate description, and/or accessible voucher specimens, species only mentioned in conference abstracts, handbooks, faunal inventories or floristic lists, e.g. *Apanthura sandalensis* Stebbing, 1900 (Israel, Lybia: Negoescu, 1980, 1981); *Sabia conica* (Schumacher, 1817) (Italy: Giannuzzi-Savelli et al., 1997).

### B. Uncertain “alien” status

Following the definition provided by the European Environmental Agency (2012) (see above), the unequivocal designation of a species as “alien” requires knowledge on its native range and likely pathway of introduction. Uncertain records requiring additional evidence before inclusion in inventories include:

- cryptogenic species sensu Carlton (1996) — species of unknown native origin and therefore impossible to designate as either aliens or non-aliens anywhere:
  - species distributed in wide apart regions and unknown biogeographical history, e.g. *Paraprionospio coora* Wilson, 1990 (Turkey: Yokoyama et al., 2010);

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