Biological Conservation xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Making non-indigenous species information systems practical for management and useful for research: An aquatic perspective

Sergej Olenin [a,*], Aleksas Narščius [a], Dan Minchin [a,b], Matej David [c], Bella Galil [d], Stephan Gollasch [e], Agnese Marchini [f], Anna Occhipinti-Ambrogi [f], Henn Ojaveer [g], Anastasija Zaiko [a]

[a] Coastal Research and Planning Institute, Klaipeda University, Klaipeda, Lithuania
[b] Marine Organism Investigations, Ballina, Killaloe, Co Clare, Ireland
[c] David Consult, Izola, Slovenia
[d] Israel Oceanographic and Limnological Research, Haifa, Israel
[e] GoConsult, Hamburg, Germany
[f] Department of Earth and Environmental Sciences, University of Pavia, Pavia, Italy
[g] Estonian Marine Institute, University of Tartu, Pärnu, Estonia

ARTICLE INFO

Article history:
Received 21 November 2012
Received in revised form 25 July 2013
Accepted 28 July 2013
Available online xxxx

Keywords:
Introduced species
Large Marine Ecosystems
Information sharing
Database
Bioinvasion management

ABSTRACT

Biological invasions attract increasing attention from scientists, policy makers and various management authorities. Consequently, the knowledge-base on non-indigenous species (NIS) continuously expands and so the number and availability of web resources on NIS rises. Currently there are more than 250 websites on NIS, ranging from global to regional and national. Many of these databases began as inventories of NIS, but evolved to include information on NIS origin, introduction history, pathways, vectors, and more. The databases have been used increasingly for scientific analyzes, though key information needs for bioinvasion management and research are only partially met. In this account we describe an advanced information system dealing with aquatic NIS introduced to marine, brackish and coastal freshwater environments of Europe and adjacent regions (AquaNIS). AquaNIS differs substantially from existing NIS information sources in its organizational principles, structure, functionality, and output potential for end-users, e.g., managing aquaculture or ship's ballast water. The system is designed to assemble, store and disseminate comprehensive data on NIS, and assist the evaluation of the progress made towards achieving management goals. With the coming into force of the EU Marine Strategy Framework Directive and similar legislation addressing the problem of biological invasions, the availability of advanced, scientifically validated and up-to-date information support on NIS is essential for aquatic ecosystem assessment and management. Key issues related to electronic information systems, such as data management principles and long-term database maintenance, are discussed.

1. Introduction

As biological invasions attract increasing attention from scientists, policy makers, management authorities and the wider public, the number and availability of electronic resources on non-indigenous species (NIS) rises. Currently there are more than 250 websites on NIS worldwide (GISIN, 2013). The geographical scope of these information resources varies from global (e.g., GISD, 2013) to regional (e.g., Baltic Sea Alien Species Database, 2013; CIESM, 2013) and national (e.g., Mastitsky et al., 2012; S.I.B.M. Allochthonous Species Group, 2013; Nehring, 2013). Many of these databases began as inventories of NIS, but evolved to include keys for NIS identification, donor and origin regions, introduction histories, pathways, vectors, etc.

NIS databases are increasingly being used for research. During the last decade information derived from these on-line sources was used in the peer-reviewed literature to: (a) aid the compilation of NIS lists for specific areas (e.g., Gollasch and Nehring, 2006; Zaiko et al., 2007; Galil, 2009a, 2012; Westphal et al., 2008; Occhipinti-Ambrogi et al., 2011), (b) prioritize the most impacting NIS (e.g., Cambray, 2003; Olenina et al., 2010; Savini et al., 2010), (c) identify, quantify and summarize the ecological impacts of specific taxa or functional groups (e.g., Butchart, 2008; Vilà et al., 2009; Occhipinti-Ambrogi and Galil, 2010; Kuebbing et al., 2013), (d) define the major pathways and vectors responsible for NIS introductions (e.g., Gollasch, 2006; Hulme et al., 2008; Marchini et al., 2008; Minchin et al., 2009; Savini et al., 2008, 2010; Galil, 2012), (e) analyze species traits and ecological preferences (e.g., Prinzing et al., 2002;

* Corresponding author. Tel.: +370 686 13984; fax: +370 46 398845.
E-mail address: sergej@corpi.ku.lt (S. Olenin).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.07.040

Paavola et al., 2005; Strayer, 2010), (f) assess the risks posed by NIS species on economies and ecosystem services (e.g., Occhipinti-Ambrogi, 2000; Baker et al., 2005; Campbell et al., 2008; Diederik et al., 2011), (g) assess the risk of certain NIS introduction vectors (e.g., Gollasch et al., 2011), and (h) provide recommendations for management measures (e.g., Casal, 2006; Olenin et al., 2011; Wilgen et al., 2012). However, we also found that information is often cross referenced, shared and recited by various databases.

Most NIS databases are based on summarized secondary data, which is of limited use for managers and policy makers. Some databases, lacking rigorous scientific validation procedures, may contain, on occasion, inaccurate or erroneous data. Very few on-line sources contain substantiated data concerning NIS impacts, though legislators and environmental managers are mainly interested in NIS populations that have significant impacts on the environment, quality of life, economy and/or human health (Olenin et al., 2011). The deficiencies and contradictions among online NIS information resources hamper and handicap NIS risk assessments, prioritization of management options and implementation of invasive species policies (Gollasch et al., 2007; David and Gollasch, 2008; Hulme and Weser, 2011). It is widely acknowledged that scientifically validated, continuously updated and maintained databases are the most reliable source for information on NIS status, their population dynamics, ecology and thereby serve as a strong basis for undertaking control measures (Genovesi, 2001). In order to be effective, information must be placed within the context and organized in a manner that is both logical and standardized (Simpson et al., 2006). Data management issues and long-term maintenance are both fundamental to providing an effective, pragmatic and accurate tool.

Here we describe an online information system on aquatic NIS introduced to marine, brackish and coastal freshwater environments of Europe and neighboring regions (AquaNIS) with one regional sea component (Baltic Sea) already opened for the wider public. AquaNIS inherited and incorporated multiple NIS data collections from earlier projects and initiatives to which the co-authors contributed, acknowledged in the Credits section of AquaNIS (www.corpi.ku.lt/databases/aquanis).

2. AquaNIS concept and implementation

An important feature of AquaNIS is its flexible, easily extendible structure, where new data blocks and functional modules may be added as necessary. Presently data are organized in four interrelated data blocks: "Introduction event", "Species", "Geography" and "Impacts" (Fig. 1). Data within blocks are grouped according to attributes, e.g., Development trait, Pathways and vectors.

2.1. "Introduction event" data block

The basic data entry in AquaNIS is an introduction event record, documenting a species introduction into a recipient region (Fig. 1). Here, the recipient region is a country and/or a country sub-area within a Large Marine Ecosystem (LME) or LME sub-region. The date of the first record indicates when a species presence was noticed in a region, according to different levels of certainty (year, decade or century). In AquaNIS only the first record of a NIS arrival to a recipient region is recorded. For example, if a NIS arrives to the recipient region "Italy-Adriatic Sea" this is recorded as an introduction event (see Section 2.3). The same species arrived to another recipient region within the same country, "Italy-Western Mediterranean", would be counted as another introduction event. So far, multiple arrivals of the same species into the same recipient region are not recorded, but may be remarked upon in the comment boxes provided. To address certain management requirements, e.g., ballast water management related risk assessment, an even more detailed occurrence of NIS can be documented in AquaNIS to the level of ports and port vicinities.

Species status refers to either a species being non-indigenous or cryptogenic (CS). In AquaNIS the following definitions are being used:

- Non-indigenous species (synonyms: alien, exotic, introduced, non-native): a species, subspecies or lower taxa introduced intentionally or accidentally by a human-mediated vector outside its natural range (past or present) and outside its natural dispersal potential (Occhipinti-Ambrogi and Galil, 2004; Olenin et al., 2010).
- Cryptogenic species: a species, which cannot be reliably demonstrated as being either non-indigenous or indigenous (sensu Carlton, 1996).

In each case information on the population status is provided and classified according to three levels of certainty: low, moderate (Table 1) and high. The latter is applied if a species' population status has been assessed using BINPAS (Bioinvasion Impact/Biopollu-

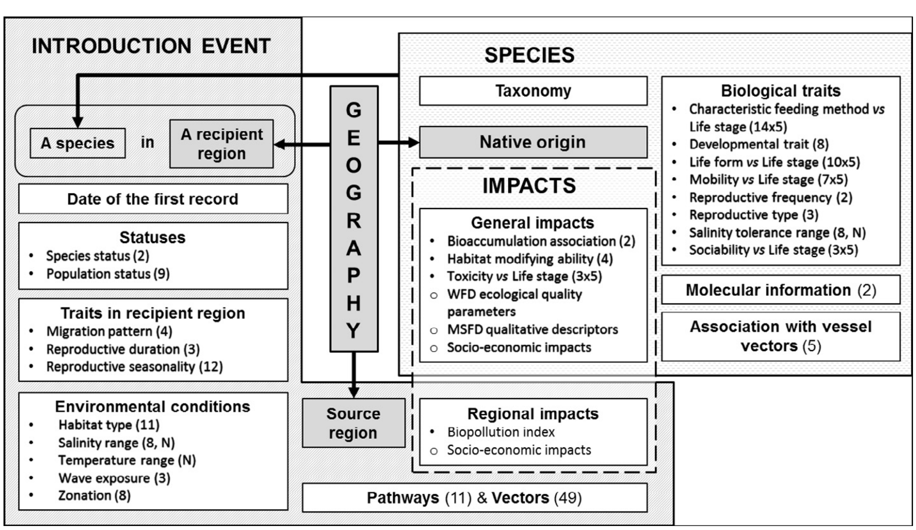

Fig. 1. Present structure of AquaNIS: two main (Introduction events and Species), one supporting (Geography) and one composite (Impacts) data blocks and attributes within them. Numbers in parentheses indicate how many predefined values are covered by each attribute; "*N*" means that numerical values are entered; "*x*" indicates a matrix of possible choices. Attributes indicated by open bullet points are under development.

Please cite this article in press as: Olenin, S., et al. Making non-indigenous species information systems practical for management and useful for research: An aquatic perspective. Biol. Conserv. (2013), http://dx.doi.org/10.1016/j.biocon.2013.07.040