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ScienceDirect
Marine Pollution Bulletin 55 (2007) 379–394
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Assessment of biopollution in aquatic ecosystems

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Abstract

The introduction of alien species (AS) in marine environments is a factor of disturbance that can be viewed as a pollution agent. Using basic information on abundance and distribution of alien species, we developed an index that classifies AS impacts on native species, communities, habitats and ecosystem functioning. This method can be used to evaluate impact at five different levels of biopollution, fitting within the existing schemes for water quality assessment. Both spatial and temporal comparisons are possible. The assessments may also be used to evaluate management performance where avoidance measures were necessary and assist in preventing further unwanted introductions. Such assessments made for the same areas over time provide opportunities for measuring change in biopollution. We have tested the method using four different well-studied areas within the Baltic Sea (brackish to freshwater environments) for two different times, 20 years apart. Further developments of the scheme may be needed to cover some specific cases and taxonomic groups according to their life history.

Keywords: Xenodiversity; Biological pollution; Community; Habitat; Ecosystem; Alien species

1. Introduction

The term ''biological pollutants'' has been used recently to discuss the problems caused by alien aquatic species (AS) (e.g. Boudouresque and Verlaque, 2002). An alien species (synonyms: non-native, non-indigenous, exotic, introduced) was defined as a species intentionally or unintentionally introduced by humans outside its past or present natural range and dispersal potential (based on IUCN, 1999; for recent reviews of alien species terminology see, e.g. Occhipinti-Ambrogi and Galil, 2004; Colautti and MacIsaac, 2004). Natural shifts in distribution range (e.g. due to climatic change or dispersal by ocean currents) do not qualify a species as an alien. An alien species is considered to be invasive if its ''population has undergone an exponential growth stage and is rapidly extending its range'' (Occhipinti-Ambrogi and Galil, 2004) or its ''introduction does or is likely to cause economic or environmental harm or harm to human health (IUCN, 1999)''.

Structural and functional diversity caused by alien species (or xenodiversity, *sensu* Leppäkoski and Olenin, 2000) have an effect on various levels of biological organisation: genetic, population, community and habitat/ecosystem (Reise et al., 2006). These ''effects of introduced, invasive species sufficient to disturb an individual (internal biological pollution by parasites or pathogens), a population (by genetic change) or a community (by increasing or decreasing the species complement); including the production of adverse economic consequences'' were defined as biological pollution (biopollution) (Elliott, 2003).

Often the impact of alien species may be interpreted as decline in ecological quality resulting from changes in biological, chemical and physical properties of aquatic ecosystems. These changes include (but are not confined to): elimination or extinction of sensitive and/or rare species; alteration of native communities; algal blooms; modification of substrate conditions and the shore zones; alteration of oxygen and nutrient content, pH and transparency of

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doi:10.1016/j.marpolbul.2007.01.010

water; accumulation of synthetic pollutants, etc. Thus, the definition of biopollution may be widened to include impacts on the structural components (both biotic and abiotic) and functioning of the invaded ecosystems (Text Box 1).

Text Box 1. Definition of biological pollution (modified from Elliott, 2003)

The impacts of alien invasive species sufficient to disturb ecological quality by effects on:

- an individual (internal biological pollution by parasites or pathogens),
- a population (by genetic change, i.e. hybridisation),
- a community (by structural shift),
- a habitat (by modification of physical–chemical conditions),
- an ecosystem (by alteration of energy and organic material flow).

The biological and ecological effects of biopollution may also cause adverse economic consequences.

The literature on AS impacts continues to expand world-wide, yet there is currently no method to assess biopollution in different ecosystems affected by xenodiversity. For instance, the concept of ecological quality indicators has been examined in relation to the European Water Framework Directive (WFD Directive, 2000/60/EC) which aims to improve (or maintain good status of) the water quality of rivers, lakes, transitional, coastal waters (e.g. Rolauffs et al., 2004; Borja et al., 2006). Although in WFD there is no explicit mention of AS and their potential impact on quality of surface waters, in the instructive Guidance Document (2003) the introduction of AS is given as an example of biological pressure and impact.

The aim of the present study was to elaborate an assessment method enabling comparison of different aquatic ecosystems according to the level of biopollution reflecting the magnitude of impacts of AS. We used numerous published accounts to analyze the distribution and abundance ranges of AS; we related these ranges with impacts of AS on native community structure, habitat traits and ecosystem functioning and constructed the biopollution assessment method based on the relation between the abundance/distribution ranges and the level of impacts.

2. Development of the biopollution assessment method

2.1. Assessment concept

According to Carlton (2002) all alien species have impact following their arrival; however, these impacts are not always possible to measure for practical reasons. The effect of biopollution cannot be deduced simply from alien to native species ratios. Compared to the almost 30,000 listed in the register of European marine species (Costello et al., 2001), the share of aliens is 2%, or 2.5% when taxonomic groups not covered consistently are left out (Reise et al., 2006). Numerically these numbers may seem low, but this comparative assessment does not take into account the contribution of AS to the total community biomass or abundance. For example, in the eastern Gulf of Finland (Baltic Sea), the accumulated plankton and benthic xenodiversity accounts only for 5% of all recorded mesozooplankton and bottom macrofauna species yet this alien component makes up ~96% of the total biomass within the community (Orlova et al., 2006).

The abundance, distribution range and the magnitude of AS impact can vary over time. We postulate that AS produce measurable effects on a local community and ecosystem only after attaining a particular level of abundance and when occupying a sufficiently large area. It is clear that at the largest level of population expansion an invader has greater impact than close to the time of arrival or subsequent adjustment (*sensu* Reise et al., 2006). Consequently, the relative abundance of an alien species, the range of its spread and magnitude of impact(s) should be considered when assessing biopollution.

Precise measurement and comparison of impacts within and/or between different ecosystems is difficult to achieve when data available from one region may not exist for another. To overcome this difficulty we propose a scale involving five levels of biopollution. These levels correspond to different ranges of abundance and extent of the distribution of AS which are related to the magnitude of their impacts. Thus, the prerequisite for the assessment is the data on the abundance and distribution range of AS. To assess the magnitude of impacts we consider separately the following categories:

- Community – the changes caused in native species composition and abundance, including shifts in type-specific communities.
- Habitat – the character of habitat modification.
- Ecosystem – the impact on ecosystem processes and functioning.

The magnitude of the impacts for these three categories is usually interrelated: the higher the level of habitat modification caused by AS the larger is the change to the structure of the native community and the more likely the performance of the ecosystem is altered. Dividing the impacts into three separate groups facilitates an assessment and helps to evaluate a level of biopollution even where there is a limited knowledge of impacts.

In each impact category, the scale involves five levels ranging from no impact (no measurable impact) to massive impact (Sections 2.3–2.5). We combined the abundance and distribution ranges of AS with the levels of impact