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BIOPOLLUTION: A USEFUL CONCEPT TO ADDRESS BIOLOGICAL MARINE INVASIONS IN A SUSTAINABLE WAY?

BIOPOLLUTION: UN CONCETTO UTILE PER UN APPROCCIO SOSTENIBILE ALLA TEMATICA DELLE INVASIONI BIOLOGICHE IN MARE?

Abstract - *The term biopollution has been used to refer to the adverse effects of the introduction of non-indigenous species (NIS), with the intention of following the methods of detection, categorization and measurement already adopted for allelochemicals. Data on NIS are accumulating evidence of the extent and impact of species introduction, but require greater standardization of terminology and wider consensus on metrics. The need to define and measure the detrimental effects of NIS may find useful guidance from analogous ecotoxicological studies. For example, the IUCN standard "Environment Impact Classification for Alien Taxa" (EICAT) deserves to be re-examined in the light of the increasing scientific knowledge; the ALien Biotic IndEX (ALEX) index, which has also been used in Italy, needs further generalisation. Treating the introduction of NIS similarly to other types of pollution could facilitate the preparation of intervention plans starting with the appropriate monitoring methods: the possible beneficial effects of introduced species should not weaken the attention that must be maintained towards this threat to ecosystems.*

Keywords: *allochthonous species, biological invasions, biosecurity, impact, Mediterranean Sea, non-indigenous species*

Introduction – Sustainability implies environmental security, economic well-being and just development. The invasion of non-indigenous (NIS) or allochthonous marine species, which is a consequence of economic development and ever-increasing trade exchanges between countries worldwide, results in environmental threats, economic losses and calls for for supranational governance. Managing the introduction of non-indigenous species has some analogies with strategies put in place to combat anthropogenic toxic and pollutant substances (Elliot, 2003; Olenin *et al.*, 2007). Analogies and differences with traditional pollution schemes (Tab. 1) involve definitions of the disturbances induced by external agents introduced by human activities and the phenology of the consequences at all biological levels of the individual, species, population and community. This has been largely incorporated in various international conventions and documents (ICES, 2005; EU, 2014; CBD, 2023). It should be noted, however, that a number of recent papers have challenged an a priori negative perception by focusing on the beneficial consequences that may result from the introduction of NIS (Giangrande *et al.*, 2020; Kourantidou *et al.*, 2022; Sax *et al.*, 2022). Therefore, this paper will update the review published a few years ago (Occhipinti-Ambrogi, 2021) and will speculate on the usefulness of maintaining a precautionary attitude in tackling the ever increasing wave of new introductions at sea that are causing profound changes in the Mediterranean Sea.

Tab. 1 – Analogies and differences in chemical and biological pollution
Analogie e differenze tra l'inquinamento chimico e biologico.

Category	Chemical pollution	Biopollution
Terminology	Contamination	Introduction
Terminology	Xenochemical	Xenobiotic
Terminology	Exogenous	Alien
Fenology	Mortality	Extinction
Fenology	Exposure	Pathways
Effects	Disturbance	Deterioration
Effects	Toxicity	Nuisance
Effects	Modification	Alteration

The current situation of biopollution studies – Olenin *et al.* (2024) propose a distinction between biological contamination - as the human-induced addition of NIS in a new environment regardless of whether these species cause any measurable harmful effects to the natural environment and human welfare – and biological pollution - the detrimental impacts caused by invasive alien species. In order to adequately evaluate all the aspects of sustainability, the positive aspects of the introduction of NIS should be taken into account, considering the perspective of ethical and value-laden arguments (Vimercati, 2020). In any case, the bibliography on the impacts caused by invasive species, albeit rapidly growing, is far from describing all the implications of the interactions between introduced species and natural and human systems, both in the ecological domain - e.g., the well known cases of *Mnemiopsis leidyi* A. Agassiz, 1865 (Ghabooli *et al.*, 2013; Piccardi *et al.*, 2024) and *Caulerpa* spp. (Piazzi *et al.*, 2016; Mannino *et al.*, 2021) in the Mediterranean – in the economic sense (Diagne *et al.*, 2021; Haubrock *et al.*, 2022) and in the human health context (Ulman *et al.*, 2024). With the aim of evaluating and assessing impacts, monitoring standards have been proposed (e.g., the SERC protocol used in Italy by the group of the University of Pavia – Tamburini *et al.*, 2021) and indexes employed to describe the level of biopollution (e.g., the ALEX index, employed in the Mediterranean to quantify the impact on benthic communities – Piazzi *et al.*, 2024), in clear analogy of what has been developed for the chemical pollution case. A standardized methodology to examine impacts by individual introduced species (in any of the ecological domains) has been developed by the SSC of the IUCN in three volumes dealing with the Environmental Impact Classification for Alien Taxa (EICAT: Kumschick *et al.*, 2020), the Socio-Economic Impact Classification for Alien Taxa (SEICAT: Probert *et al.*, 2023) and finally EICAT+, which uses five semiquantitative scenarios to categorize the magnitude of positive impacts, and describes the underlying mechanisms (Vimercati *et al.*, 2022). Once the incurred (or incumbent) impact has been assessed, managers are asked to evaluate and prioritize the actions to be taken in order to minimize the effects. In the marine domain prevention measures are most often preferred, as eradication and removal techniques have limited effectiveness and are only being used on an experimental scale (e.g., Cheng *et al.*, 2022; Huseyinoglu *et al.*, 2024). Management efforts are guided by risk evaluation tools, among which the AS – ISK (Aquatic Species Invasiveness Screening Kit) is very popular. It has been developed by CEFAS (UK) starting from a sequence used to evaluate the risk of the introduction of non-native fish (Copp *et al.*, 2016). It

consists of 69 questions about the biogeography and biology of the examined taxon. To date AS-ISK has been employed in 120 areas of the world to evaluate 819 species in 15 groups of animals and plants (Vilizzi *et al.*, 2022).

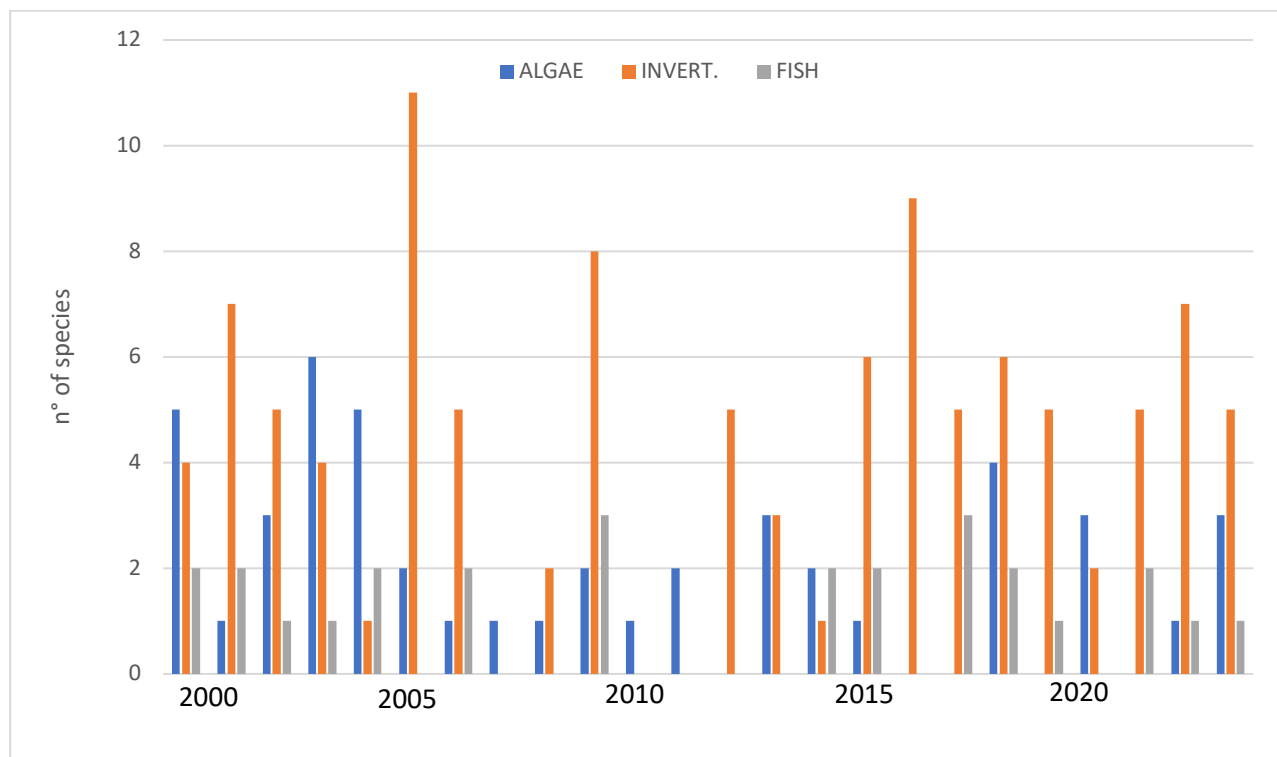


Fig. 1 – First sightings of NIS in Italy recorded in the annual National Reports prepared by the SIBM Allochthonous Group from 2000 to 2023.

Prime segnalazioni di specie non indigene in Italia, dalle registrazioni del National Report preparato dal Gruppo Alloctoni della SIBM dal 2000 al 2023.

The Italian contribution to biopollution studies – Italian marine biologists have contributed a considerable amount of information and knowledge, taking advantage of the geographical position of the Italian peninsula at the crossroads between the eastern and western basins of the Mediterranean Sea. In fact, most of the introduced species, have arrived through the Suez canal and have colonized the Levantine Basin, eventually spreading towards the West, favoured by the progressive warming of the whole basin. The Italian Society of Marine Biology (SIBM) has been instrumental in promoting the development of marine invasions studies, starting from the end of the 20th century. In particular, the Allochthonous Species Group has been set up in 1999, at the initiative of the then President, prof. Giulio Relini, and since then it has gathered a number of specialists, dedicated to the different taxonomic groups. The active participation in the international arena started with the ICSEM, (International Commission for the Study of the Mediterranean) and the UNEP Specially Protected Areas Regional Activity Centre (RAC-SPA) for the Mediterranean. A unique opportunity has been the voluntary participation of the SIBM Allochthonous Group (with an observer status) in the annual meetings of the ICES Working Group for Introductions and Transfer of Marine Organisms (WGITMO). Every year, from 2000 to the present, the SIBM has prepared a National Report (analogous to those presented by the full members of the WGITMO) and participated in the discussion, generating a strong interest in the comparison of the

Mediterranean and North Atlantic situations. The Italian National Report (NR), together with information from a legislative and organisational point of view, listed the new sightings of NIS along the Italian coasts, together with a review of papers and seminars dealing with established species and, in general, the biology and ecology of introduced species. The number of new introduced species has been increasing over the years (Fig. 1). The current number (March 2024) of introduced species known from the Italian seas is 255. The list of species is available on the SIBM website (<https://www.sibm.it/index.php?p=documenti>), the species data are also collected into the international database AquaNIS (Olenin *et al.*, 2014), managed by the WIGTMO. The database is open to the public and the data can be freely downloaded in Excel format for further processing. The contributions of numerous members of the SIBM (and other research specialists) have been acknowledged in each of the NRs, and the number of papers published has continued to increase year after year (Fig. 2).

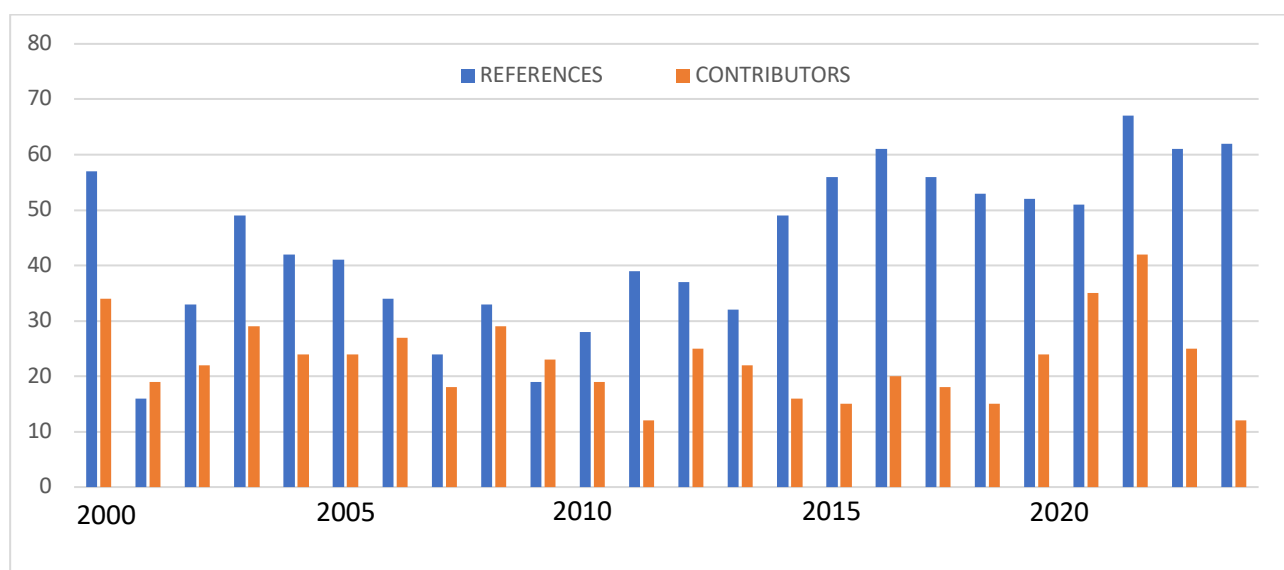


Fig. 2 – Number of references published annually on NIS in Italy as reported in the annual National Reports prepared by the SIBM Allochthonous Group from 2000 to 2023 and number of contributors providing information to the Group.

Lavori pubblicati sulle specie non indigene in Italia elencati nei National Report preparati dal Gruppo Alloctoni della SIBM, dal 2000 al 2023 e numero dei colleghi che hanno fornito informazioni al Gruppo.

Conclusions – The need for a consistent and reliable flow of information from the scientific community (in our case from the marine biologists) emerges clearly from the previous notes, if the aggravating problem of biological invasions has to be managed in order to ensure a sustainable development based on the marine environment. Rotter *et al.* (2020) propose an innovative approach to the management of biological pollution, the so-called 8s model (Recognize, Reduce, Replace, Reuse, Recycle, Recover/Restore, Remove, and Regulate). The analogies with the schemes developed since many years to face the marine pollution problems are evident, together with some peculiar aspects of transfer of the non-indigenous species. It is clear that marine scientists must seek a common understanding, starting with terminology, if they are to assist decision makers and operators in the difficult task of ensuring the protection of marine resources (Soto *et al.*, 2024). Comprehensive and long-term studies that incorporate a range of

measures of environmental drivers and ecosystem response are crucial to better understanding the cumulative, community/ecosystem-scale changes associated with biological invasions (Zaiko *et al.*, 2024).

The continuing accumulation of allochthonous species in the marine biological communities, with a particular reference to the Mediterranean Sea, and thus to our coasts, is a complex and multifaceted process with inherent consequences in several aspects. Reise *et al.* (2023), while supporting increasing efforts against introductions to avoid risk, observe that, in some cases, once species are integrated, they can improve the environment. In my opinion the common, a priori condemnation attitude against “non-natives” or “aliens” should be critically reconsidered. However, the recognition of possible beneficial effects should not overshadow the evidence that the proportional contributions of species to communities is changing over time in areas under high bioinvasion pressure. This fact alters the original ecological equilibrium and leads to consequences that can be disruptive for the environment, economy and social life.

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