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MARINE BIOINVASIONS
The Sovereign Base Areas of Akrotiri and Dhekelia, British Overseas Territory, Cyprus

Synopsis: A recent ‘horizon scanning’ exercise identified 16 invasive alien species (IAS) in Cyprus coastal waters considered to pose a potential threat. Many intentionally and unintentionally marine species introduced to the Levantine Basin, Mediterranean Sea, have been documented to displace or reduce native species, alter community structure and food webs, change ecosystem functioning and the consequent provision of goods and services. Once established, they are unlikely to be contained or controlled and their impacts are irreversible. The major vectors are vessels, culture, trade, and the Suez Canal. The management ineffectiveness of marine protected areas under high bioinvasion load is highlighted and the impact of rising temperatures on marine bioinvasions is considered. Management options, as well as policy, legislation and regulatory actions are briefly introduced.

INTRODUCTION

The introduction of non-native species into the Levant Basin, Mediterranean Sea, is considered to be among the main direct drivers of biodiversity change, exacerbated as it is by climate change, pollution, habitat loss and other human-induced disturbances. Some edible marine non-native species, intentionally and unintentionally introduced into the Levant Basin, comprise nowadays commercially important crops. Yet, many unintentionally introduced species have been documented to displace or reduce native species, alter community structure and food webs, change ecosystem functioning and the consequent provision of goods and services. Once established, they are unlikely to be contained or controlled and their impacts are irreversible. As introduction vectors and the receiving environment determine the introduced taxa, their geographical origin and the role of propagule pressure, changes to shipping routes and magnitude, recreational boating habits, mariculture and aquarium trade economics, and maritime canals, the non-native propagule pressure has been increasing inexorably while undergoing constant change (Galil et al. 2019).

Less accessible than terrestrial and inland water environments, the extent and impacts of marine introductions have long remained obscure, leading to underestimations of their scale over both time and space. Only recently have marine non-native species been recognized as a major threat in Cyprus, where the Sovereign Base Areas of Akrotiri and Dhekelia constitute a British Overseas Territory. (Peyton et al. 2019).

VECTORS AND IMPACTS

Vessels

The dispersal and introduction of marine animals and plants on (as biofouling organisms), and inside (in solid or water ballast) vessels are often challenging to reconstruct. Vessels (both commercial and recreational) and their fouling communities are a high-risk vector for both
primary introductions and secondary spread of marine non-native species, owing to their ubiquity, spatial distribution, travel patterns and fluid connectivity between higher- and lower-risk areas. Some of the most widespread, non-native species with dire ecological and economic impacts have been transported by both commercial and recreational vessel fouling. Cypriot marinas (Karpaz, Famagusta) proved inundated with IAS: Amathia verticillata, one of the most ubiquitous fouling bryozoans, occurring in many ports and marinas and capable of forming massive colonies, as well as Celleporaria vermiciformis and Parasmittina egyptiaca; the ascidians Clavelina oblonga, Microcosmus exasperates, Phallusia nigra and Symplegma brakenhielmi; the crustaceans Ampithoe bizsei and Charybdis (Gonioinfradens) giardi), Mesanthura cf. romulea, Paracerceis sculpta and the sponge Paraleucilla magna – all newly recorded from Cyprus (Gewing et al. 2016, Gerovasileiou et al. 2017, Ulman et al. 2017).

Among the species introduced in Ballast water to Cyprus we count one of the most highly invasive and calamitous species. The introduction with ballast water of the carnivorous North American comb jelly Mnemiopsis leidyi into the Black Sea in the 1980s is associated with major ecosystem collapses and severe adverse socio-economic effects. Blooms of the comb jelly were recorded in Larnaca and Limassol (Fyttis et al. 2015).

Culture and trade in live organisms – intentional, unintentional, illegal

The intentional transplantation of non-native edible marine species occurred partly in response to increased demand for seafood and to stock failures of native species.

Illegal, unreported and unregulated (IUU) movement of non-native species may result in introduction of marine species. The western Atlantic brown shrimp, Penaeus aztecus, has been previously recorded from several locations in the Levant Basin, though not from Cyprus. It is likely that the sudden, near concurrent records of from distant locations within the Mediterranean Sea (Egypt to France), result from IUU introductions, as several of the records were collected in the vicinity of fish and shellfish farms.

The number of marine fish species in the aquarium trade has increased greatly in recent decades. The high numbers of species and individuals traded are mirrored in a recent uptick of records of species found in the wild attributed to this vector. The brightly colored blue tang, Acanthurus coeruleus, common in the aquarium trade, were documented in the wild in several locations off Cyprus, including Akrotiri (Langeneck et al. 2012, 2015).

The Suez Canal

By forming ‘bridge of water’ and altering shipping routes, the Suez Canal has provided marine biota with new opportunities for dispersal by natural means as well as by shipping. Although until the 1960s the sea-level Suez Canal retained a salinity barrier in the hypersaline Bitter Lakes, successive enlargements of the canal nullified the barrier's efficacy. The Canal’s increased depth and volume (from 1962 to 2014 its depth increased from 15.5 to 24 m and cross sectional area from 1800 to 5200 m²), provided an extraordinarily successful pathway for introductions. Many of the 135 marine multicellular non-native species (including the majority of fish, crustaceans and molluscs) recorded in Cypriot waters have entered the Mediterranean through the Canal.
Human Health

A small number of marine IAS engender human health impacts. Some non-native venomous and poisonous species have drawn the attention of scientists, managers, media and public for their conspicuous human health impacts. Human health hazards of IAS are expected to worsen, benefitting from climate change and the greatly enlarged Suez Canal (Galil, 2018).

Several have been identified from the coastal waters of Cyprus:

The striped eel catfish *Plotosus lineatus* - one of the most dangerous venomous fishes known, causing fatal envenomations.

The lionfish *Pterois miles* - Envenomation produces intense pain and swelling which may continue for several hours, depending upon the amount of venom.

The two species of rabbitfish, *Siganus rivulatus* and *S. luridus* - Their venom is not life-threatening to adult humans, but causes severe pain.

The silverstripe blausop, *Lagocephalus sceleratus* - Tetradotoxin, a potent neurotoxin that inhibits voltage-gated sodium channels, is present in gonads, gastrointestinal tract, liver, muscle and skin of puffer fish. It is one of the most potent, nonprotein poisons known. Occasionally fatal.

The long-spined urchin *Diadema setosum* - its brittle spines may inflict deep penetrating wounds and break off easily to become embedded in the tissue, the venom is mild and may cause inflammation, swelling, and acute pain.

The nomadic jellyfish *Rhopilema nomadica* – envenomation is followed by severe pain, swelling, itching, urticaria and marked discoulouration. Severe anaphylactic reaction may occur.

The feathery stinging hydroid *Macrorhynchia philippina* - a brush with its nematocyst-laden branches may cause a mild stinging sensation, but a more extensive contact results in a burning sensation. Victims generally develop pinpoint lesions, blotchy red rash, blisters and raised itchy weals, which may last up to ten days.

Reversing conservation – bioinvasions and marine protected areas

Marine protected areas (MPAs) are created to attempt to conserve natural diversity of native species in their habitats and provide some measure of insurance against environmental degradation or management uncertainty. The prevailing theory holds that MPAs, owing to (in some regions) their high species diversity and putative abundance of indigenous predators, competitors, and parasites, are resistant to bioinvasions. Lately, their conservation effectiveness in regions overrun by non-native species has been questioned.

Like in the Caribbean and the Gulf of Mexico, large populations of the Indo-Pacific lionfish have been documented in protected areas in Cyprus. The lionfish, *Pterois miles*, which entered through the Suez Canal, has been reported in great numbers from MPAs, where they prey on juvenile fishes, hampering stock recovery of key economically and ecologically important species. In fact, some Red Sea species are the most conspicuous denizens in MPAs along the eastern Mediterranean, having displaced and replaced native species, undoing marine conservation efforts. These MPAs may ironically in fact serve as ‘seed banks’
inducing ‘spill-over effect’ to adjacent areas, as well as hubs for secondary spread. It is questionable whether MPAs, or even networks of MPAs, can conserve the indigenous biota under high bioinvasion load unless non-native species management is explicitly embedded in marine spatial planning that addresses introductions with robust long-term management measures.

**Rising temperatures and marine bioinvasions**

As a result of global climate change, seawater is generally warming. For some of the most successful thermophilic introductions into the Mediterranean Sea the initiation of the explosive population growth coincided with the recent rise. Experimental studies have also demonstrated that under rising temperatures, the survival, growth, and fecundity of some recent introductions are higher than co-occurring native species, thus enabling the former to expand into regions in which they previously could not survive and reproduce. It is likely the abrupt increase in populations of thermophilic non-native species in Cypriot waters in recent decades resulted from climate change.

The projected continuation of climatic warming may facilitate and amplify the risk of introductions through the disruption of recipient communities and habitats where resident species become increasingly poorly adapted to the warming environment, alteration of organisms pools to include species better adapted and more competitive under the new conditions, and shifts in vectors and pathways that alter human-mediated connectivity. Global warming will thus contribute to increasing the range and area of habitats that are suitable for non-native species originating from warmer regions (or capable of adapting to or tolerating higher water temperatures), and thus transforming local and regional ecosystems. Given the present evidence, climatic warming will add to other drivers of ocean change – including water pollution and overfishing – to potentially enhance non-native abundances, ranges, and thus impacts.

**Management: prevention, eradication, control**

Vector management is the most effective strategy for preventing translocation, and thereby reducing introduction and spread of marine non-native biota. Lack of effective control on propagule transfer by the major vectors (shipping and boating, culture activities, trade, and canals, as reviewed above), reduces management to frequently futile eradication and control efforts.

Culling, labor-intensive and costly, has become the preferred strategy in an attempt to reduce the density of the invasive lionfish (see above). Culling may temporarily reduce lionfish in shallow reefs, but their effectiveness in terms of long-term reduction of lionfish abundance is drastically undercut by high rates of recruitment and presence of populations beyond diving depths – lionfish in Cyprus were recorded at depths of 90-150 m (Jimenez et al. 2019). Management of marine non-native species which spread beyond their site of introduction is increasingly viewed as unfeasible and unsustainable in the long term. Prevention through the cessation, reduction, or restriction of introduction pathways and vectors is the overwhelmingly preferred option.

**Policy, legislation and regulatory actions – non-native and invasive species**
Policy, legislation and regulatory actions are dilatory, reactive, and fragmentary, often following disastrous and costly NIS outbreaks.

While Guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships’ ballast water and sediment discharges were established in 1991, and the legally binding instrument ‘International Convention for the Control and Management of Ships’ Ballast Water and Sediments’ (BWMC) was adopted in 2004 by the International Maritime Organisation (IMO), it entered into force only in 2017. A key aspect of this is that "entered into force" means that steps must now be undertaken by the shipping industry, in the years and decades to come, to reduce the number of living organisms in ballast water – not that such reduction was achieved in 2017. ‘Guidelines for the control and management of ships’ biofouling to minimize the transfer of invasive aquatic species’ were recently developed by the IMO, and efforts to develop legislation to regulate biofouling are also underway.

The European Union (EU) has a substantial body of environmental laws. The EU Marine Strategy Framework Directive aims to protect the marine environment by achieving ‘Good Environmental Status’ in European Seas by 2020. It comprises an explicit regulatory objective “Descriptor 2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.” Another legally binding instrument, the EU Regulation on the prevention and management of the introduction and spread of invasive alien species, entered into force in 2015. This approach, centered on already widespread established species, is unlikely to succeed in marine ecosystems.

Regulatory policies and instruments to manage introductions have been reactive and slow to evolve, attempting to address only a subset of vectors and factors that drive invasions. Major global and regional introduction vectors such as biofouling, culture and trade in live organisms, and maritime canals, still lack legally binding, timely implemented, and strictly monitored instruments. A robust and vigorous commitment for a regionally coordinated, integrative multi-vector management approach, will be both essential and obligatory to achieve increased protection of Cyprus marine biota.

Glossary

Ballast: water used to maintain stability and trim and thus safe operating conditions in ships. Biofouling: the accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. Bioinvasion/bioinvasive: refers to non-native organisms moved by human agency and established in a new region, which may lead to harm to biodiversity, ecosystem functioning, socio-economic values and human health; also known as introduced, non-native, non-indigenous, alien, or exotic species. Native: an organism indigenous or endemic to a region. Primary introduction: the initial site of successful establishment of a non-native species in a new region. Secondary introduction/dispersal: the spread of non-native species from the primary site of introduction, by either human-mediated or by non-human means, to new sites. Vector (introduction vector): a means of introducing organisms, intentionally or unintentionally, from one region to another (e.g., vessels, mariculture, trade, canals).

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