Marine Pollution Bulletin 136 (2018) 477–480

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Marine introduced species in Australia, where to from here? A personal perspective from a practising taxonomist

Pat Hutchings

Australian Museum Sydney, Australia
Department of Biological Sciences, Macquarie University, North Ryde, NSW 2109, Australia

ARTICLE INFO

Keywords:
Marine introduced species
Taxonomic identification
Pest species
Ballast water
Hull fouling

ABSTRACT

While introduced marine species have been arriving in Australia for centuries, it was the advent of container shipping and the discharge of ballast water into Australian ports that highlighted the problem. A summary is provided of how Australia responded to this challenge and continues to. More recently there has been an acceptance that hull fouling is also an important vector of introductions. A major problem in Australia is distinguishing introduced species from as yet undescribed native species. This is a particular problem in northern Australia where the native fauna is poorly documented. Despite the economic and environmental threats posed by introduced species, the impetus to undertake expensive comprehensive surveys has declined and attention is now focusing on targeted surveys especially of known marine pest species and molecular data to identify introductions. Ongoing research is still needed to monitor other species identified as being introduced and their potential to become pests.

Australia is a major exporter of raw materials. With the advent of bulk carriers in the late 1960s, these dedicated ships arrived in Australian ports empty but fully loaded with ballast water for vessel trim, stability, and manoeuvrability. As raw materials such as iron ore, coal, bauxite, wheat etc. were loaded onto ships in Australian ports, ballast water from overseas ports was discharged. Data up to 1992, data indicated that 58 million tonnes of foreign ballast water was discharged into Australian waters annually (Hutchings, 1992). Cope et al. (2015) based on modelling of shipping data from 1999 to 2012, showed that the volume of ballast water discharged had more than doubled during this period with the majority associated with bulk carrier traffic and certainly this will have increased since 2012. The shipping data they used consisted of 184,249 records of individual voyages to Australian ports made by 20,325 vessels between 1999 and early 2013, and they also documented which ports received the most and from where (Cope et al., 2015, plus Supplementary data).

Below is a brief summary of how authorities in Australia became aware of the increased risks of introduced species from ballast water becoming established in our ports and potentially becoming 'pest' species (Friese, 1973; Medcov, 1975; Medcov and Wolf, 1975). While marine species have always been translocated around the world as hull fouling organisms or attached to drift algae (see Pollard and Hutchings, 1990a, 1990b, for Australian examples), the advent of bulk carriers and discharge of foreign ballast water increased the risk of such introductions. It was not only the sheer volume of ballast water which was being discharged into ports but also the reduced shipping time between ports allowing a wider range of organisms to survive shipping and establish populations.

Concern within the Australian fishing industry prompted the then New South Wales Department of Fisheries, now the Department of Primary Industry, to survey the ballast water from Japanese ships arriving at several Australian ports. This survey confirmed that live organisms were present in ballast water and that they could survive discharge from the ship into the port (Williams et al., 1988) including Twofold Bay on the south coast of New South Wales (37°05′S, 149°54′E). At that time Twofold Bay received ballast water on a regular basis from northern Japan as part of woodchip export operations (Williams et al., 1988). Twofold Bay has been an important port since the later 1880's for a range of products, so non-native species could have been introduced earlier by hull fouling (Matthews, 1947). However, no survey of the Bay had ever been undertaken. As a result of the pressure from commercial fishers at Twofold Bay, the Fisheries Industry Research Trust initiated a survey of the bay through the Australian Museum (Hutchings et al., 1989). The Bay is large, with a surface area of 30.7 km^2 and an average depth of 10.9 m (Hutchings et al., 1989). Sampling was carried out on both soft and hard substrates along the coast and in creeks leading into the bay typical of estuarine environments around the world. Such conditions were likely to facilitate

E-mail address: pat.hutchings@austmus.gov.au.

https://doi.org/10.1016/j.marpolbul.2018.09.047
Received 29 July 2018; Received in revised form 20 September 2018; Accepted 25 September 2018

survival and establishment of any larvae discharged via ballast water. Seven introduced species were found in the Bay. At the same time as the Twofold Bay survey was undertaken, other studies confirmed that ballast water introductions were a world-wide phenomenon (Carlton, 1987).

While these studies were interesting, little more would have been done, except for the finding that toxic and non-toxic dinoflagellates occurred in ballast water and subsequent discovery of non-native dinoflagellates in Australian harbour waters and sediments (Hallegraeff, 1993, 1998; Hallegraeff and Bolch, 1991; Hallegraeff et al., 1991). Some of these can cause paralytic shellfish poisoning (Hallegraeff et al., 1988), which was of major concern as they have the ability to produce resistant resting cysts which can be readily transported by ballast water and retain their viability. In addition to threats to human health, blooms of these dinoflagellates can cause aquaculture facilities to be closed with significant economic costs.

The realization that toxic dinoflagellates could be introduced via ballast water led to a major survey of ballast water within ballast tanks of inbound ships. Sixty-five percent of samples also contained sediment of which 50% contained dinoflagellate cysts. Of these, 5% contained cysts of toxic dinoflagellates (Hallegraeff and Bolch, 1991, 1992). One ship arriving in Eden, Twofold Bay was estimated to contain 300 million cysts of toxic dinoflagellates (*Alexandrium catenella* and *A. tamarense*) and the cysts could be germinated in the laboratory. Subsequently it was found that the ship had taken onboard ballast water in Japan during a dinoflagellate bloom (often referred to as a red tide).

The above studies together increasing pressure from the aquaculture lobby led in 1989, to the Bureau of Rural Resources within the Federal Department of Primary Industries and Energy to establish a Scientific Working Group on Ballast water. The charter of this Scientific Working Group was to develop control methods and management options to reduce risk of introductions of introduced species. The group included scientists, representatives of the shipping and aquaculture industries, the Australian Quarantine and Inspection Service (AQIS now Biosecurity within Department of Agriculture and Water Resources), and representatives of various other Federal and State agencies. One project was to test the efficacy of reballasting at sea, as well as the feasibility of storing the discharged ballast water in land tanks where it could be treated (Rigby and Hallegraeff, 1994). However, given the volume of ballast water being discharged into Australian ports (58 million tonnes discharged annually (Hutchings, 1992)) this was never going to be a feasible option. Reballasting at sea is also problematic given the need to maintain the stability of the ships and cannot occur during rough seas. Evidence of reballasting relies upon logbooks which indicate the co-ordinates as to where this occurred. This led to AQIS introducing voluntary ballast water quarantine guidelines in 1990 and since 2001 Australia has had ballast water management for international shipping. It also has ratified the BWM Convention adopted by the International Maritime Organisation (IMO) which requires vessels travelling both internationally and domestically to manage their ballast water since September 2017. For more details regarding modelling of ballast water discharge and invasion risks, where ballast water is discharged and areas where no ballast water can be discharged see Cope et al. (2015) and http://www.marinepests.gov.au/national-system/Pages/National-System-history.aspx.

The Scientific working group highlighted the need to document the fauna of Australian ports and identify any introduced species already present. In response to this, the Centre for Research on Introduced Marine Pests (CRIMP) was established in 1994, by the CSIRO Division of Marine Research, to undertake these surveys. Initially CRIMP undertook the surveys (Hewitt and Martin, 2001), but subsequently a wide range of government and non-government agencies were contracted by Port Authorities to supplement CRIMP's work. In recognition that many agencies were undertaking such surveys, a standard set of protocols were developed to ensure consistency in sampling (Campbell et al., 2007), These protocols have been adopted by several countries and included the type of habitats to be sampled, largely based on those identified by Hutchings et al. (1989) as habitats most likely to be colonized by non-native species. The protocols focused surveys on taxa included on the NIMPUS schedule of target introduced pest species www.marinepests.gov.au/nimpis and those species which are known or likely to have been introduced into Australia (Hayes et al., 2005).

Such monitoring surveys were considered to be integral to the effective management of new arrivals of exotic species for the following reasons: (1) they provided a detection system for target pest species, facilitating the opportunity for their eradication before proliferation and spread; (2) establish a baseline of native and exotic biodiversity, against which future arrivals may be assessed; (3) assess invasion patterns relative to abiotic and biotic factors; and to (4) provide information on impacts of invasions. To assess whether these port surveys of Australian ports achieved these goals, Bishop and Hutchings (2011) analysed 46 available reports from these port surveys and found some major problems with the identification of the collected samples. In over half of the reports, the groups in which taxa were not identified to species exceeded 50%. Priority was given to families and genera containing the national target species, largely due to time constraints, budgets but also because of the failure to utilize the existing taxonomic expertise available in Australia, and often relying upon para-taxonomists. This highlighted the low priority given to ensuring that the correct taxonomic identification of material collected. These priorities raise the possibility that new exotic species, previously unknown to have invaded a region, could go undetected. Also by focusing on exotics already known in an area can be counter-productive because many of them have already established self-sustaining populations, which are difficult to eradicate or control. Another failure in many of these surveys was to act as baseline studies for future studies. Bishop and Hutchings (2011) suggest that in hindsight it would have been better to have strategically selected a few ports based on their vulnerability or proximity to vulnerable habitats and to sample comprehensively. Such comprehensive sampling has been used in Port Phillip Bay to document the bay's invasion history over 150 years (Hewitt et al., 2004).

CRIMP was subsequently closed down by CSIRO and all their collections were distributed to the relevant state museums. In part this was due to the high cost of the initial port surveys (see costs quoted by Campbell et al., 2007) and little support for follow up surveys by the relevant ports. However, this program was a missed opportunity to develop comprehensive faunal lists for the majority of Australian international ports, and certainly they will never be repeated again. In hindsight museums and herbariums should have been included in the planning and implementation of these surveys to ensure a much higher level of identification of the biota and ensuring that reference collections were always deposited in the relevant state museum.

All the ports surveys highlighted the cost and time of identifying the port fauna and the lack of taxonomic expertise in many groups of marine invertebrates difficult to distinguishing between introduced species and undescribed native species (Hutchings et al., 2002; Bishop and Hutchings, 2011; Sun et al., 2016, 2017). The difficulty is compounded by the fact that many introduced species belong to genera with at least one native species within the genus in Australia making it difficult for non-specialists to distinguish between of native and introduced species. Distinction between even closely related introduced and native species is important given that they may play very different roles in ecological communities (see Bishop and Peterson, 2006 for an example of the different roles played by oysters of the genus *Crassostrea*). Contributing to the problems of port surveys is that many of the harbours surveyed had never been sampled previously for benthic invertebrates. This was especially true of ports in northern areas of Australia and highlighted the limited taxonomic expertise available in Australia (for more details see Hutchings, 2013, 2017). To rectify this situation for invasive polychaetes, Kupriyanova et al. (2016) developed a web-based guide to distinguish native and introduced polychaetes of Australia belonging to the three major families (Serpulidae, Sabellidae