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Ecotoxicological risk assessment of antifouling emissions in a cruise ship port

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ABSTRACT

Worldwide growth of cruise ship tourism is constantly increasing marine environmental contamination risks, frequently neglected by the tourism practices. Paradoxically, environmental degradation ultimately decreases the quality of resources tourism is dependent upon. Vessels antifouling-related contamination is one of the most serious threats posed upon marine ecosystems. We propose here an interdisciplinary triangulation to evaluate antifouling-pollution environmental risks within the frame of the Dubrovnik Port case study. Heavy metal environmental burden was calculated based on the cruiser ships anchoring data. Pollution impact was confirmed by three independent ecotoxicological studies conducted recently in the same area: heavy metals sediment analyses, antifouling related imposex occurrence in banded murex *Hexaplex trunculus* and biomonitoring study on Mediterranean mussel *Mytilus galloprovincialis*. Antifouling-pollution cost was estimated by applying the actual sea bottom remediation methods in order to present the monetary value of pollution prevention that could be achieved through the non-toxic antifouling strategies. Implementation of these is considered one of the prerequisites for environmentally sustainable cruise tourism.

1. Introduction

1.1. Problem description

The literature describes cruise ship-related pollution as highly intensive (Clark, 2001) and potentially hazardous to the existing tourism in visiting destinations (Klein, 2008).

Flexibility and mobility of cruise ships, in combination with the intensity of their impact, create a new and unique phenomenon in tourism, and also a problem in environmental protection (Carić, 2010). Cruiser vessels exert their negative effect on the marine environment through various different pathways and in many instances management fails to adequately prevent or absorb the environmental damage (Carić, 2010, 2011, 2012). Concerns are being raised regarding the fact that degradation of environmental quality, scenic landscapes, and destinations' attractions, do not directly affect the cruise companies, as they can simply transfer their activities elsewhere. Furthermore, many stakeholders raised concerns over environmental misconducts cruise companies were either investigated or prosecuted for (Copeland, 2008; GAC, 2000; Klein, 2008).

Antifouling emissions are one of the main marine traffic environmental impacts recognized as a threat to the coastal environmental health (Prime et al., 2006; Srinivasan and Swain, 2007; Karlsson et al., 2010). Thus, it is becoming ever more relevant to determine the extent of the antifouling contamination and its detrimental impact on the ecosystem in question in order to set the appropriate coastal management measures. Studies on this subject are needed to provide further evidence to strengthen the implementation of the Marine Strategy Framework Directive (MSFD) prepared by the Commission of the European Communities (CEC, 2008). MSFD is a European Union Integrated Maritime Policy with the aim to achieve “Good Environmental Status” (GES) in European marine waters by 2020. Eleven qualitative key descriptors are to be considered in determining GES in order to set the guidelines for adaptive environmental management in the particular marine region. These encompass, among others, different aspects of biological diversity and population health across all levels of marine food webs, and the environmental quality of habitats,

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with special attention given to the occurrence and concentration of anthropogenically introduced contaminants.

The aim of this paper is to present a survey based on a case study of antifouling biocide emission within the Dubrovnik Port (Croatia), which is used to create a straightforward Environmental Risk Assessment (ERA) framework that can enable tourism decision makers, developers and all other interested parties to prevent or diminish the antifouling environmental risk. This study also aimed to broaden the awareness and understanding of the fairly neglected environmental issue of cruise/nautical tourism by applying a simple calculation model and interdisciplinary approach in the risk assessment arena. Analyses and methods presented in the paper are, from a methodological point of view, consistent with the approaches used in environmental impact assessment practices, for which a legal framework exists in most Mediterranean countries.

2. Trends in cruise tourism

2.1. World, Mediterranean and Croatia

The modern concept of cruise tourism was developed in the USA and Canada in the mid-1960s as cruises to the Caribbean. Cruising has since significantly evolved, and although the Caribbean still remains the world's leading market for it, other seas and destinations are growing steadily. Certain projections indicated that the 20 million passengers mark might be reached soon (Dowling, 2006). The concept of further development of cruise tourism is based on large vessels (so-called 'mega cruise' ships) for over 2000 passengers. Megacorporations are dominating the cruise market: in 2006 three corporations (Carnival Corporation, Royal Caribbean Cruises, and Star Cruises Group) accounted for over 75% of bed capacities (Papatheodorou, 2006). The global cruise statistics confirm the phenomenon of huge growth and establishment of a new cruise tourism segment, as indicated by the 22 mega cruise ships commissioned in 2009 (GPW, 2009).

The Mediterranean is now the most intensive tourist region in the world, in which the role of cruise tourism is growing steadily, accounting for ~18% of the global cruise market (Institute for Tourism, 2010). A survey of basic statistical indicators for 2008 showed that there were 159 cruise ships operating in the Mediterranean, transporting approx. 4.4 million passengers, staying on board 8 days on average (GPW and BREA, 2009). Five Mediterranean ports are enlisted within the top ten cruisers' homeports in the world (Barcelona, Civitavecchia, Piraeus, Venice and Palma) picturing the significance of cruise tourism in the region (Ashcroft, 2009).

International cruises in Croatia are performed by vessels of various sizes and features, from the small, so-called 'boutique' ships (with the capacity of around 60 passengers) to the so-called mega cruise ships (with the capacity of around 3300 passengers and 1100 crewmembers). Furthermore, Croatian cruise tourism is growing significantly, as confirmed by the fact that traffic has increased almost threefold during the period from 2002 to 2012 (Table 1).

In Croatia, Dubrovnik holds the largest proportion of the activity (over 80%) and was ranked 10th in the world's list of busiest ports of call in 2008 (Ashcroft, 2009). Nevertheless, calls to other similar destinations (Split, Korčula, and Zadar), and some fifteen smaller locations along the coast and on the islands, are also becoming more frequent (Institute for Tourism, 2006).

Port authorities and tourism experts in Croatia correspondingly observed the global trend of increasing frequency of large cruise ships with even shorter stays in ports. This represents a negative trend that has also been noticed in other ports and destinations around the world, showing that passengers spend less time ashore, reducing the opportunity to spend money at a given destination, while at the same time their impact on the environment becomes more intensive (Carić, 2012; Clark, 2001). All the above mentioned further confirm the concern that cruise ships generate a new kind of mass tourism (Weaver, 2005).

Table 1
Cruise tourism intensities in the Croatia (CBS, 2002–2010; CBS, 2010; CEA, 2013).

Year	Total passengers	Total cruises	Days in Croatian waters	Average days in port
2002	225,784	307	624	2.03
2003	420,542	582	1086	1.87
2004	440,254	420	528	1.26
2005	511,417	456	658	1.44
2006	597,708	565	800	1.42
2007	694,104	628	990	1.58
2008	936,424	822	1569	1.91
2009	989,272	754	1264	1.68
2010	1,093,919	855	1625	1.90
2011	1,141,454	830	1659	2.00
2012	1,154,814	802	1486	1.85

2.2. Cruise tourism in Dubrovnik

Dubrovnik old town is listed on the UNESCO World Heritage List, and has a long tradition as an international tourist destination. The subject of this study is the assessment of the environmental impact of the cruise tourism within the main Dubrovnik Port (Gruž), which together with the adjacent Daksa anchoring site, accommodates approx. 70% of all cruise ships visiting the Dubrovnik area (Fig. 1). The remaining 30% of the cruise ships are anchored in front of the Old City Port.

In order to accommodate increasing demand by larger cruise ships the port was renewed and substantially enlarged during 2009, and now encompasses ~ 88.000 m^2 of land surface, with

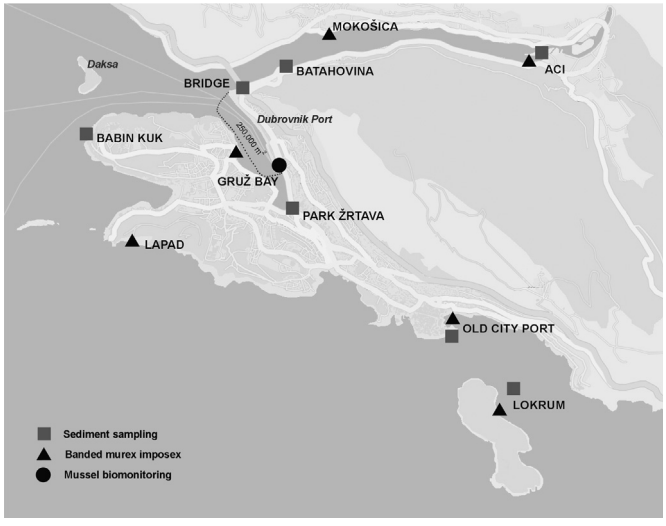

Fig. 1. Dubrovnik aquatorium with the ports and anchoring sites (Dubrovnik Port, Daksa, Old City Port). Denoted are also sites of ecotoxicological research conducted in the area: squares – sites of sediment sampling for chemical analyses, triangles – sites of investigation of imposex occurrence in banded murex *Hexaplex trunculus*, and circle – site of sampling Mediterranean mussel *Mytilus galloprovincialis* population used in the biomonitoring study. Hypothetical intervention area at the Dubrovnik Port is indicated with the dashed line, for which calculated Cu sedimentation contamination per year is 154 kg (map source: Google Earth).