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Mapping cumulative impacts on Hong Kong's pink dolphin population

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ABSTRACT

Indo-Pacific humpback dolphins have historically inhabited the northern waters off Lantau Island, Hong Kong; however their numbers have significantly decreased over the past decade, while human pressure has simultaneously increased. Based on a spatio-temporal analysis using a Geographic Information System (GIS), this study aims to assess the cumulative human impacts of local activities on this dolphin population since 1996. After introducing and discussing the multiple approaches, difficulties, and limitations to cumulative effects assessments (CEA), this paper outlines our proposed CEA methodology. Our methodology involves mapping and analysis of anthropogenic marine impacts in relation with historical dolphin distributions in the area. Local scale results show evidence of a relationship between the addition of new high-speed ferry (HSF) routes into the cumulative environment and the decrease in dolphins in a specific region known as the Brothers Islands. These results coincide with past research showing that whales and dolphins are significantly disrupted in the presence of high vessel traffic, which continues to grow in the northern waters off Lantau Island, Hong Kong and in many other places around the world.

1. Introduction

Boasting a population of more than 7 million residents, Hong Kong is one of the most developed and economically successful cities in Asia. With its rapidly expanding economy and population, this city radically highlights the conflict between development and the environment. Coastal development in particular is a major issue in Hong Kong, as it is in many places around the world, as the growing need for space drives land reclamation, resulting in increasing areas of artificial coastline. Over the last two decades approximately 12 square kilometers in western Hong Kong waters has been developed into new land (Clarke, 2013); this transformation has led to a competition for space between humans and the local marine species.

To the west of Hong Kong Island, at the mouth of the Pearl River Estuary, lies Lantau Island, whose northern and western coastlines provide a prime habitat for Hong Kong's dolphins (Fig. 1). Locally known as Chinese White Dolphins, these Indo-Pacific humpback dolphins (*Sousa chinensis*) have attracted growing concern in face of accumulating coastal impacts (Jefferson, 2000; Jefferson et al., 2009). The Whale and Dolphin Conservation Society argues that this dolphin population is "under pressure as it lives in an ever-shrinking, ever-more polluted habitat" (WDCS, n.d.). Impacts such as fishery by-catch, chemical pollution, noise pollution, vessel strikes, climate change, and prey depletion are stressors on global marine mammal populations (Parsons et al., 2007; Reeves et al., 2003; Thompson et al., 2013), and are especially marked in Hong Kong waters. Indeed, Wilson et al. (2008) have argued that no other dolphin population faces as dire a threat as those in the Pearl River Estuary. By one abundance estimate, only 61 dolphins presently remain around Lantau Island (HKCRP, 2013) while there was an estimated 158 in 2003 (HKCRP, 2012). In light of this population decline, some environmental organizations in Hong Kong have requested a proper cumulative effects assessment (CEA) to better identify and mitigate the high level of impacts these dolphins are facing (HK Dolphin Watch, 2005; Parry and Knowles, 2013).

As Hong Kong's practice of CEA has suffered from a lack of statutory guidelines, weak analytical methods, and limited spatial and temporal scope (Yang and Lam, 2001), the research in this paper attempts to establish an improved CEA methodology. This methodology has been developed to identify existing relationships

Abbreviations: HSF, High Speed Ferry; HKSAR, Hong Kong Special Administrative Region; HKDCS, Hong Kong Dolphin Conservation Society; HKCRP, Hong Kong Cetacean Research Project; DPSE, Dolphins Per Survey Effort.

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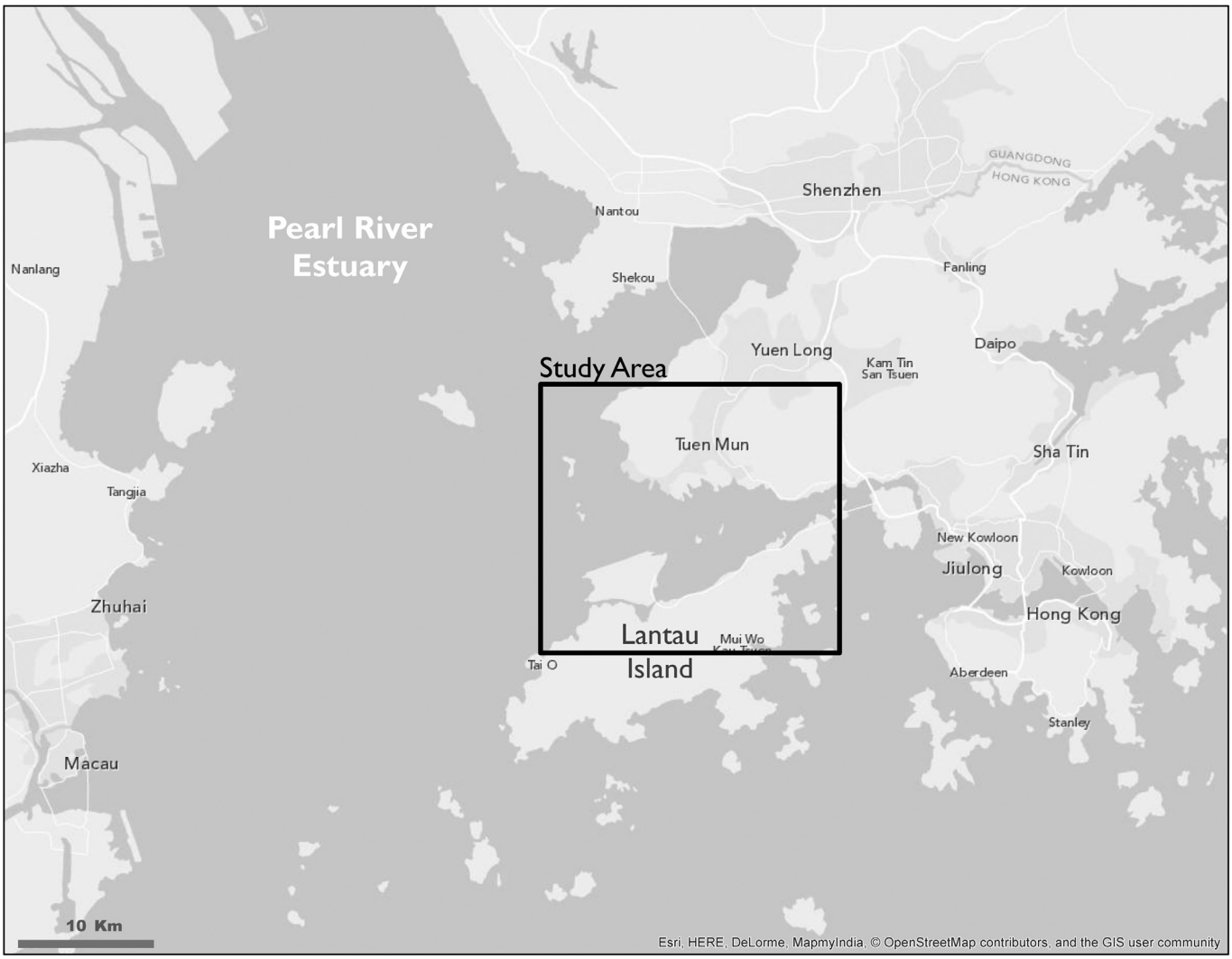

Fig. 1. Geographic location of Hong Kong and Lantau Island (Source of the base map: ESRI). The size of the study area is about 20 km^2.

between changes in dolphin population in the northern waters off Lantau Island and changes in cumulative human impacts within that same area, using a Geographic Information System (GIS). Through an extensive spatio-temporal analysis over a period of two decades, this study aims to contribute to the identification of specific human activities that have affected the distribution of Hong Kong's Indo-Pacific humpback dolphin. Beyond this specific case study, this paper provides insight into how a GIS can be applied to assess cumulative marine impacts, and can also help us revisit the way we envision the use of GIS for environmental studies.

2. Contextualization

The Indo-Pacific humpback dolphin, a coastal species whose range extends from central China throughout Southeast Asia and as far west as India (Jefferson, 2000; Jefferson and Rosenbaum, 2014), is an important species in many of its home-range countries. In Hong Kong specifically, numerous tourists come each year to see these animals for their famous vibrant pink color and friendly nature. The official mascot for Hong Kong's reunification with China, this iconic species is an integral part of Hong Kong's heritage, as well as an important member of the local marine ecosystem (Jefferson and Hung, 2004; Parry and Knowles, 2013). Although past research by Jefferson and Hung (2004) show no significant trends in Indo-Pacific humpback dolphin abundance within Hong Kong between the years 1995 and 2002, declining trends in the Hong Kong dolphins have been noticeable since then and seem related to the rapid rates of development and human activities within their habitat (HKCRP, 2012; HKCRP, 2013; Jefferson and Hung, 2004). In fact, this species has been red-listed as "Near Threatened" by the International Union for Conservation of Nature (IUCN) due to identified threats such as habitat and seabed destruction, water pollution, vessel disturbances, and accidental by-catch (IUCN, 2013). Although previous research has investigated the dolphin's ecology (Jefferson, 2000; Parsons, 1998), distribution (Jefferson, 2000; Jefferson and Hung, 2004), behaviors (Jefferson, 2000; Ng and Leung, 2003; Piwetz et al., 2012) and even their reactions to individual human disturbances (Hung, 2008; Jefferson and Hung, 2004; Jefferson et al., 2009; Sims et al., 2012), no studies have attempted to spatially investigate their response to the cumulative impacts in the area to this date.

With increasing rates of marine anthropogenic impacts the need for proper cumulative effects assessments (CEAs) is unprecedented (IPSO, 2013). Geographic Information Systems (GIS) can offer extensive functionalities for spatial investigations, and thus can contribute to the field of CEA. Combined with multi-criteria analysis, GIS can help identify certain spatio-temporal characteristics of cumulative impacts and compare them with biological and