Marine Pollution Bulletin 128 (2018) 82–88

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

The underwater acoustic environment at SGaan Kinghlas-Bowie Seamount Marine Protected Area: Characterizing vessel traffic and associated noise using satellite AIS and acoustic datasets

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A R T I C L E I N F O

Keywords:
Ocean acoustics
Vessel noise
Bowie Seamount
Marine Protected Area
Cetacean conservation

A B S T R A C T

Vessel traffic is one of the most wide-spread anthropogenic contributors to ocean noise worldwide and has the potential to alter ecosystems upon which cetaceans and other acoustically sensitive marine organisms rely. Canada's SGaan Kinghlas-Bowie Seamount Marine Protected Area (SK-B MPA) is one such area whose productive ecosystem could benefit from greater monitoring of human induced threats in order to inform management. Despite earning official designation as a Marine Protected Area under the Oceans Act in 2008, little remains known about vessel traffic in the region and the associated potential impacts on vulnerable marine species. Therefore, to increase our understanding of vessel traffic and accompanying noise at SK-B MPA, satellite AIS and acoustic data were investigated. The results of this study suggest that variations in ambient sound levels in the region are driven by near and distant shipping events, thus having implications for future management of the MPA.

1. Introduction

The marine environment has always been filled with sounds generated from natural biological and physical processes (Hildebrand, 2009). The striking increase in ocean noise levels in recent years, however, is due primarily to sound generated from anthropogenic activities (Hildebrand, 2009; Andre et al., 2011; McKenna et al., 2012). Among other human-generated sound sources, noise generated from commercial vessel traffic has become increasingly pervasive (Arveson and Vendittis, 2000; Hatch et al., 2008; McKenna et al., 2013; Erbe et al., 2014) and has raised low-frequency ambient sound levels throughout the world's oceans by as much as 12 dB (Hildebrand, 2009; Veirs et al., 2016).

Sources contributing to ambient sound in the ocean are a compilation of natural sound events (e.g. wind, precipitation, breaking waves, bio-acoustic sounds, natural seismic activity) and anthropogenic sound events (e.g. near and far seismic surveys, vessel traffic, other industrial activity) (Wenz, 1962; Hildebrand, 2009; McKenna et al., 2012). Depending on the frequency band (i.e. low: 10–500 Hz, medium: 500 Hz–25 kHz, and high: > 25 kHz), a different set of sound sources are dominant (Hildebrand, 2009). For example, sound from breaking waves and sea surface agitation is a major contributor to spectra between 500 Hz and 50 kHz, while fish sounds contribute to the lower-frequency spectra (i.e. < 500 Hz), and marine mammals together produce sounds spanning nearly all frequency bands (Southall et al., 2007; Hildebrand, 2009).

In general, commercial vessels radiate sound with peak spectral power below 200 Hz due to propeller cavitation and propulsion machinery, though sound is also radiated into higher frequencies, with considerable sound intensity concentrated up to approximately 1000 Hz (Ross, 1976; Arveson and Vendittis, 2000; Veirs et al., 2016). As larger vessels typically generate more sound at frequencies below 1000 Hz than do smaller vessels (Richardson et al., 1995; Veirs et al., 2016), the steady increase in size of individual vessels and the persistent growth of the global shipping fleet continue to raise ocean sound levels (Hildebrand, 2009; McKenna et al., 2012). The sound output of individual vessels, however, is highly variable and vessel size alone does not determine a vessel's contribution to ocean sound levels (McKenna et al., 2012). Vessel class, together with operational condition (e.g. speed), vessel maintenance, propeller design, and propulsion power are

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https://doi.org/10.1016/j.marpolbul.2018.01.014
Received 15 June 2017; Received in revised form 19 December 2017; Accepted 6 January 2018

major factors that define a vessel's sound output (McKenna et al., 2013; Veirs et al., 2016). Short of vessel design and operation changing, it is projected that vessel-generated sound in the ocean will continue to rise as the demands of global trade are met (Hildebrand, 2009; McKenna et al., 2012). Such a trend in rising ocean noise levels may become further exacerbated by the effects of climate change as ocean acidification results in decreased sound absorption, thus allowing sound to propagate over greater distances (Hester et al., 2008; Hildebrand, 2009).

For the purpose of this work, we define 'noise' as anthropogenic sound that interferes with the biological activities of the receiver. As is evident in the growing body of literature on the potential effects of underwater noise on cetaceans, fish, and marine invertebrates, there is concern regarding the extent to which organisms exposed to noise sources may be impacted (Southall et al., 2007; Andre et al., 2011; Holt et al., 2013; Hawkins and Popper, 2016). Cetaceans, in particular, rely on sound for virtually all critical life functions (i.e. communication, navigation, detection of prey, reproduction, and in some cases, detection and avoidance of predators) (Holt et al., 2013) and may lose the ability to carry out these functions effectively in the presence of noise. Despite efforts to quantify the level and extent of noise exposure required to induce auditory injury (i.e. temporary and permanent hearing loss) and auditory disturbance (i.e. masking of biologically important information and behavioral changes that lead to decreased fitness) (Southall et al., 2007; NMFS, 2016), the long-term consequences of noise exposure to cetaceans and other marine life remains poorly understood (Au and Hastings, 2010; NMFS, 2016; Hawkins and Popper, 2016).

In taking a precautionary approach to minimize noise exposure to vulnerable cetaceans and other marine species (Oceans Act, 1996; Dolman, 2007), it is therefore imperative that acoustic baseline data be acquired for areas that support rich biological communities and are susceptible to increased noise-generating activities such as vessel traffic (Davies et al., 2011; DFO, 2015). By gaining a better understanding of the acoustic baseline in biologically significant areas, conservation objectives may be more appropriately defined and robust management plans developed.

1.1. Study site

Canada's SG̲aan K̲inghlas – Bowie Seamount Marine Protected Area (SK-B MPA) is one such area whose rare ecosystem could benefit from greater monitoring of human-induced threats in order to inform management (Davies et al., 2011; DFO, 2015). Recognized for its unique oceanographic conditions and high biological productivity (Glazer, 2013), Bowie Seamount, together with adjacent Hodgkins and Davidson seamounts, received official designation as Canada's seventh Marine Protected Area (MPA) under the Oceans Act in 2008 (Davies et al., 2011; Hoyt, 2011). This 6131 km^2 area is considered one of Canada's most sacred marine ecosystems by the neighboring Haida people, and by the broader scientific community and general public. Located 180 km off shore of Haida Gwaii, British Columbia, the submarine volcano ranges from approximately 3000 m at its deepest depth, to just 24 m below the ocean surface (Dower and Fee, 1999; Davies et al., 2011) (Fig. 1) (Glazer, 2013). The great biodiversity here can be attributed largely to the nutrient-rich waters that result from ocean currents interacting with the Seamount, combined with its summit falling within the phototrophic zone, thus supporting both coastal as well as deep sea-dwelling species (Davies et al., 2011; DFO, 2011).

Among the diverse array of marine invertebrates, 50+ taxa of fish, and numerous migratory bird species supported by Bowie Seamount, are a variety of marine mammal species, of which many are listed under Canada's Species at Risk Act (SARA) (Canessa et al., 2003; Davies et al., 2011; DFO, 2011). Of note, cetacean vocalizations confirmed in the present dataset include Killer whale (*Orcinus orca*), Blue whale (*Balaenoptera musculus*), Humpback whale (*Megaptera novaeangliae*), Fin whale (*Balaenoptera physalus*), Sperm whale (*Physeter catodon*), Baird's Beaked whale (*Berardius bairdii*), and Pacific White-sided dolphin (*Lagenorhynchus obliquidens*) (Pilkington and Ford, 2016).

1.2. Management of SK-B MPA

Given the many cetacean and other marine species known to frequent SK-B MPA, a greater understanding of stressors associated with human activity is needed. What is currently known about the MPA and surrounding region is based on few historical surveys (Dower and Fee, 1999; McDaniel et al., 2003; Canessa et al., 2003) and more recent studies on rockfish habitat (Siegle et al., 2013). In reviewing descriptions of the MPA's environmental and socio-economic components, the need to collect baseline data on vessel traffic and associated noise is reiterated throughout several key management documents (Canessa et al., 2003; Davies et al., 2011; DFO, 2011, 2015). This lack of baseline data can be attributed, in part, to the offshore location of SK-B MPA. Additionally, despite past studies having looked at managing the *physical* interaction between transiting vessels and cetaceans (Vanderlaan et al., 2008, 2009; Reeves et al., 2012; Allen, 2014), the issue of managing exposure of cetaceans and other marine organisms to vessel noise specifically is fraught with technical, logistical, legal and even ethical challenges (Erbe et al., 2014; Merchant et al., 2014; Williams et al., 2015). Collection of baseline data through acoustic and remote sensing technologies is thus a logical starting point in seeking to understand and manage noise from anthropogenic sources at SK-B MPA (Ford et al., 2010).

As part of a broader project to characterize the contribution of vessel noise to the overall sound levels along Canada's coasts, the present study aimed to increase the current understanding of vessel traffic patterns and associated noise at SK-B MPA by means of analyzing data from satellite Automated Identification System (AIS) and underwater acoustic recordings. With one of the primary objectives being to reduce potential noise-related impacts on cetaceans, the authors hope to gain insight into whether the region would benefit from stricter management of the acoustic environment. It is also expected that the baseline data provided herein may support the SK-B MPA Management Board (i.e. DFO and Council of Haida Nation) in completing a robust and appropriate management plan for the MPA.

2. Methods

In seeking to characterize the contribution of vessel noise to the underwater acoustic environment at SK-B MPA, both acoustic and satellite AIS datasets from the region were analyzed. Acoustic data collected via autonomous recorders deployed at SK-B MPA were provided by Fisheries and Oceans Canada (DFO) and processed using PAMLab acoustic analysis software developed by JASCO Applied Sciences. Concurrent satellite AIS data were obtained by exactEarth Ltd. The acoustic datasets were processed (both automatically and manually) to determine the contribution of vessel-generated noise to the underwater acoustic environment, and the satellite AIS track data were used to determine spatial and temporal attributes of vessel presence in the region. The two datasets were then compared to validate vessel presence, and for assessment of the acoustic contribution of individual vessels to the ambient sound field. To capture potential seasonal variability, one representative summer month (August 2011) and one representative winter month (February 2012) were selected for detailed analysis.

2.1. Acoustic data analysis

Acoustic data were collected at Bowie Seamount using an Autonomous Underwater Recorder for Acoustic Listening (AURAL-M2, Multi-Electronique Inc.) with a HTI96 hydrophone (High Tech, Inc.) deployed by DFO's Cetacean Research Program. The data discussed herein were collected during one physical deployment which included