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Catch me if you can: Comparing ballast water sampling skids to traditional net sampling

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ABSTRACT

With the recent ratification of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, it will soon be necessary to assess ships for compliance with ballast water discharge standards. Sampling skids that allow the efficient collection of ballast water samples in a compact space have been developed for this purpose. We ran 22 trials on board the RV Meteor from June 4–15, 2015 to evaluate the performance of three ballast water sampling devices (traditional plankton net, Triton sampling skid, SGS sampling skid) for three organism size classes: ≥ 50 μm, ≥ 10 μm to < 50 μm, and < 10 μm. Natural sea water was run through the ballast water system and untreated samples were collected using paired sampling devices. Collected samples were analyzed in parallel by multiple analysts using several different analytic methods to quantify organism concentrations. To determine whether there were differences in the number of viable organisms collected across sampling devices, results were standardized and statistically treated to filter out other sources of variability, resulting in an outcome variable representing the mean difference in measurements that can be attributed to sampling devices. These results were tested for significance using pairwise Tukey contrasts. Differences in organism concentrations were found in 50% of comparisons between sampling skids and the plankton net for ≥ 50 μm, and ≥ 10 μm to < 50 μm size classes, with net samples containing either higher or lower densities. There were no differences for < 10 μm organisms. Future work will be required to explicitly examine the potential effects of flow velocity, sampling duration, sampled volume, and organism concentrations on sampling device performance.

1. Introduction

Ballast water is one of the most prominent vectors for the transfer of marine non-indigenous species (Verling et al., 2005). In order to minimize potential harm, the International Maritime Organization (IMO) adopted the Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004 (IMO, 2004). The convention, which restricts permissible discharge concentrations for viable organisms in specified size classes and for indicator microbes through Regulation D-2, will enter into force in September 2017 (IMO, 2016). As such, port state control regulators must prepare to monitor ships' compliance with these discharge standards. Any compliance monitoring activities based on biological sampling will necessarily include protocols for sample collection and sample analysis, and multiple technologies for both are currently in development and testing phases (Gollasch et al., 2003; IMO, 2008; IMO, 2013; Gollasch and David, 2015).

Traditionally, ballast water sampling during shipboard type approval testing has been conducted using an open collection system with plankton nets. Samples are collected using in-line, "L" shaped sampling probes (i.e. pitot tubes) installed in the vessel's ballast water piping. Ballast water is pressure-fed through tubing and into a conical plankton net with 35 μm mesh (50 μm in diagonal) within a wetted sample tub, and the sample retained in the net is collected for analysis of organisms in the ≥50 μm size class. In general, 350–3000 L of water is concentrated for assessment of ≥50 μm size organisms at low concentration (US Coast Guard, 2010; Briski et al., 2014), so it is necessary to dispose of 'waste' water (i.e. water that was filtered through the net). 'Waste' water can, for example, be returned to the ballast system downstream via a return port or drain valve (Briski et al., 2014), sent overboard, or deposited into the bilge. For organisms ≥10 μm to <50 μm (hereafter, 10–50 μm size class), a composite sample totalling ~5 L is taken by

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collecting ~400 mL of water from the sample tubing (either before or after water passes through the plankton net) every two to 5 min during the entire sampling duration (e.g. Gollasch and David, 2011; GSI, 2011; Briski et al., 2014).

More recently, shipboard collection systems (i.e. sampling skids) have been developed that enable filtration and collection of large volumes of water in a small space and, optionally, the ability to directly return filtered 'waste' water into the ship's ballast water pipe (known as a closed loop system). Again, the sampling skid connects to the ship's ballast system using an in-line, "L" shaped sampling probe and the sampled ballast water flows through a filter housing with a filter sized according to Regulation D-2 (size 50 μm in diagonal/diameter). Large size organisms (≥50 μm) are collected inside the filter assembly, and a diverter after the filter housing equipped with a ball valve allows for obtaining water samples as single, small volume samples or continuous drip samples to assess small size organisms (10–50 μm). For both types of collection systems and both size classes, the flexible nature of the integument of many organisms (and the nylon mesh, for plankton nets), may lead to some error in the division of these samples (i.e. error in the separation of plankton ≥50 μm from those <50 μm).

Shipboard collection systems provide operational advantages versus traditional plankton net collection protocols because their compact size allows for them to be permanently installed or stored on ships to enable inspectors to collect a sample for compliance monitoring without carrying sampling equipment on board. Further, the potential to use skids in the closed configuration can provide a significant operational advantage by circumventing the need to dispose of waste water generated during sample collection. This may enable samples to be collected more efficiently and provide a significant time savings. However, in order to maintain a small footprint, sampling skids concentrate organisms using a much smaller filtration surface area than plankton nets. Traditional plankton nets have a large filtration surface area that minimizes stress on organisms during collection. The smaller filtration surface area offered by sampling skids could subject collected organisms to greater pressures. It is therefore important to assess if the use of compact shipboard sampling skids will impact the viability of collected organisms in advance of their use in enforcement scenarios.

In this paper, we evaluate whether sampling skids provide equivalent samples to traditional plankton net collection methodology. We acknowledge that traditional plankton nets may be imperfect (i.e. error in the separation of plankton; negative impacts on plankton viability), but use them as a logical baseline comparison since they represent the current standard. We focus on two sampling skids: the SGS Ballast Water Sampler (BWS) 1 (hereafter, SGS skid), and the Triton NP 6007 TG 18 (hereafter, Triton skid), used in both open and closed loop configurations. Since the skids have different specifications, we also compare the skids to each other.

Our experiments were conducted on board the research vessel 'Meteor' in transit from Mindelo, Cape Verde, to Hamburg Germany. Owing to the installation of multiple in-line sampling and return ports, the RV Meteor presented a rare opportunity to collect paired samples simultaneously during ballast water uptake using different sampling technologies. This experimental design provides an advantage over previous efforts to assess sampling skid and plankton net comparability in sequence (e.g. First et al., 2012), since there are known differences between organism concentrations at varying time points of a discharge event (First et al., 2013). Samples were analyzed in parallel by multiple analytic tools to quantify the concentration of viable organisms (hereafter, organism concentration) in samples. Any observed differences may be attributed to mortality during collection or differential pressure regimes causing concentration differences between the sample and the main ballast pipe. Sample representativeness was not examined herein. Due to natural variation in plankton communities during the voyage, devices were tested across a wide range of plankton concentrations. Results provide information on the equivalence of different sampling methodologies and thereby support efforts to establish compliance monitoring protocols which will be needed upon the entry into force of the Convention for the Control and Management of Ships' Ballast Water and Sediments.

2. Methods

2.1. Test vessel and experimental design

The ballast water system onboard the RV Meteor is comprised of DN100 galvanized steel pipes (diameter 100 mm) and an uncompensated piston pump with a maximum capacity of 65 m^3/h. An Optimarin OBS80 ballast water management system (BWMS) is also installed; the BWMS was not operated for this study, but the sampling points associated with the BWMS were used. Fig. 1 gives a schematic overview of the BWMS with sampling points and valves that can be used to produce different flow paths through the ship's ballast system; the arrowed pathway details the route of the sea water during our trials. A total of 22 trials were run with sampling devices positioned at sample point A and sample point C. Each is equipped with an "L" shaped sampling probe facing upstream as recommended by the IMO Guidelines for Ballast Water Sampling (IMO, 2008). A return probe, supplied by SGS, was installed at point D with the opening facing downstream. All sample probes were DN25. When possible, sampling devices were rotated between sampling points during testing. Since the closed filter skid

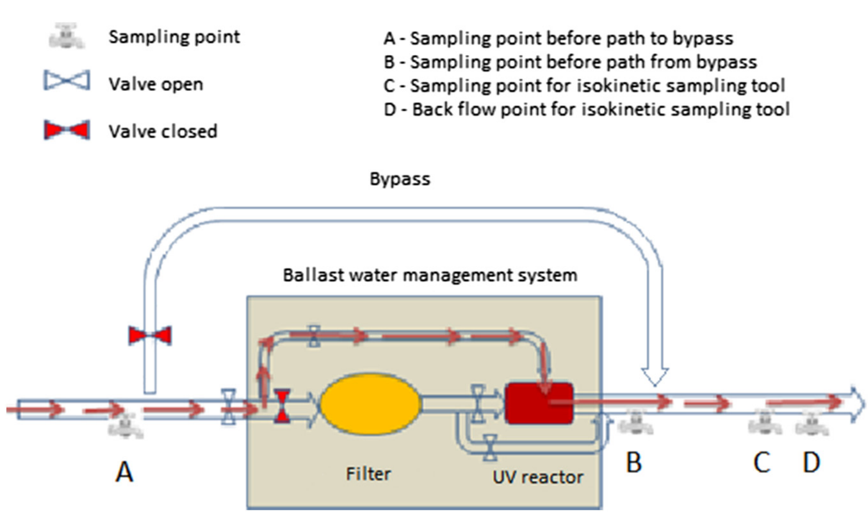

Fig. 1. Schematic view of the BWMS with sampling points at position (A), (B), (C) and (D).