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Spatial and temporal variation of intertidal nematodes in the northern Gulf of Mexico after the *Deepwater Horizon* oil spill

Pamela M. Brannock [a, *, 1], Jyotsna Sharma [b], Holly M. Bik [c, d], W. Kelley Thomas [c], Kenneth M. Halanych [a, **]

[a] Department of Biological Science, Auburn University, 101 Rouse Life Science Building, Auburn, AL 36849, USA
[b] Department of Biology, University of Texas at San Antonio, TX 78249, USA
[c] Hubbard Center for Genome Studies, University of New Hampshire, 35 Colovos Rd, Durham, NH 03824, USA
[d] Department of Nematology, University of California, Riverside, CA 92521, USA

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ABSTRACT

Nematodes are an abundant and diverse interstitial component of sedimentary habitats that have been reported to serve as important bioindicators. Though the 2010 *Deepwater Horizon* (*DWH*) disaster occurred 60 km offshore in the Gulf of Mexico (GOM) at a depth of 1525 m, oil rose to the surface and washed ashore, subjecting large segments of coastline in the northern GOM to contamination. Previous metabarcoding work shows intertidal nematode communities were negatively affected by the oil spill. Here we examine the subsequent recovery of nematode community structure at five sites along the Alabama coast over a two-year period. The latter part of the study (July 2011–July 2012) also included an examination of nematode vertical distribution in intertidal sediments. Results showed nematode composition within this region was more influenced by sample locality than time and depth. The five sampling sites were characterized by distinct nematode assemblages that varied by sampling dates. Nematode diversity decreased four months after the oil spill but increased after one year, returning to previous levels at all sites except Bayfront Park (BP). There was no significant difference among nematode assemblages in reference to vertical distribution. Although the composition of nematode assemblages changed, the feeding guilds they represented were not significantly different even though some variation was noted. Data from morphological observations integrated with metabarcoding data indicated similar spatial variation in nematode distribution patterns, indicating the potential of using these faster approaches to examine overall disturbance impact trends within communities. Heterogeneity of microhabitats in the intertidal zone indicates that future sampling and fine-scale studies of nematodes are needed to examine such anthropogenic effects.

1. Introduction

Nematodes are important constituents of intertidal communities (Warwick, 1976; Blome, 1983; Sharma and Webster, 1983; Nicholas, 2001; Gingold et al., 2010), and their distribution in intertidal habitats can be affected by environmental gradients of sediment granulometry, salinity, and temperature (Gingold et al., 2010). In addition, hydrodynamic and physical features that influence wave and tidal action can generate different microhabitats, such as sandbars and runnels (Maria et al., 2013), thereby affecting horizontal and vertical distributions of nematodes (Brustolin et al., 2013). Free-living nematodes are abundant and ubiquitous with short life cycles (5 days-1 year) and rapid turnover (Heip et al., 1985). As primary and secondary consumers, nematodes respond to physical, chemical, and biological properties of their food. They demonstrate a rapid response to anthropogenic disturbances such as oil spills, radiation leakage, and large amounts of total suspended solids and thus are important bioindicators (Vincx and Heip, 1991; Danovaro et al., 2009).

Ecosystem health in the northern Gulf of Mexico (nGOM) was of great concern after the explosion of the *Deepwater Horizon* (*DWH*)

* Corresponding author.
** Corresponding author.
E-mail addresses: pamela.m.brannock@gmail.com (P.M. Brannock), ken@auburn.edu (K.M. Halanych).
[1] Present Address: Department of Biology, Rollins College, 1000 Holt Avenue, Winter Park, FL, 32789, USA.

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offshore oil platform on April 20, 2010. Even though this disaster occurred 60 km offshore at a depth of 1525 m, immediate attention was focused on the impact of the spill to coastal regions (Newton et al., 2013). Studies of the effect of the oil spill on intertidal to deep-sea benthos have demonstrated a decrease in abundance and diversity of meiofauna (Bik et al., 2012; Montagna et al., 2013; Landers et al., 2014; Baguley et al., 2015). As oil moved towards eastern nGOM coastline by wind and currents, it washed onto beaches and coastal regions in Alabama from early June 2010 until about mid-July 2011 (Graham et al., 2010; Hayworth et al., 2011) and continued to have an effect on the marine environment for some time (MacDonald et al., 2014). The Shoreline Cleanup Assessment Technique (SCAT) program surveys revealed that the Alabama GOM coast, including Dauphin Island, experienced heavy oiling from the *DWH* oil spill during a portion of their survey (Michel et al., 2013). Although Michel et al. (2013) reported no oil observed in Mobile Bay regions especially near Bayfront Park (BP) and Belleair Blvd (BB), satellite images of oil slicks in Mobile Bay were observed (e.g. http://response.restoration.noaa.gov/about/media/mapping-fallout-deepwater-horizon-oil-spill-developing-one-tool-bring-unity-response.htm), which are consistent with eye-witness accounts. By May 2011 oil conditions in this geographic region decreased to light or trace levels and further decreased to trace or no oil observed conditions in May 2012 (Michel et al., 2013).

Bik et al. (2012). noted a dramatic shift in intertidal meiofaunal communities along portions of the Alabama coast from a metazoan dominated community composition prior to the spill to one dominated by fungal taxa after. Subsequently, Brannock et al. (2014). reported the large portion of fungal taxa had disappeared from these locations by July 2011 and the community returned to one dominated by metazoans. Both studies (Bik et al., 2012; Brannock et al., 2014) utilized metabarcoding high-throughput sequencing approaches to examine the meiofaunal community composition. Use of metabarcoding technology to explore the composition of meiofaunal communities is less developed compared to protist and prokaryotic systems, but holds great promise and potential (Bik, 2014; Brannock and Halanych, 2015).

Previous studies examining effects of oil spills on coastal meiofaunal communities have found that oil pollution has mixed effects on nematode communities (Boucher, 1985; Danovaro, 2000; Burgess et al., 2005). Differences in the response of nematodes to hydrocarbon pollutants may be attributed to the heterogenous sedimentary environment and tolerance of some nematodes to pollutants (Giere, 1979). Studies note that nematodes are more resilient than other meiofauna taxa (Boucher, 1985), whereas other studies indicate abundance and diversity of nematodes may decrease immediately after exposure to oil contaminants, although they recover rapidly in comparison to other meiofauna (Danovaro et al., 1995; Danovaro, 2000). Only a few long-term studies have examined recovery of nematode communities following oil exposure (Giere, 1979; Gourbault, 1987; Danovaro et al., 1995), as baseline data before an oil spill disturbance is often not available. Although there are taxonomic studies of intertidal nematodes in the GOM (summarized in Hope, 2009), to date there is only one study on the ecology of intertidal nematodes from this geographic region (King, 1962).

Herein we examine spatial, temporal, and vertical distribution patterns of intertidal nematode communities along the Alabama coast and within western Mobile Bay based on morphological taxonomic methods. The main objectives of this study were to (1) examine spatial, temporal, and vertical distributions in nematode community composition within five Alabama intertidal locations, (2) explore the functional diversity as determined by nematode feeding groups within these locations, (3) compare nematode diversity within communities pre- and post *DWH* oil spill, (4) examine the pattern of recovery of nematode assemblages over time after the oil spill, and (5) briefly compare morphological and metabarcoding approaches in examining nematode communities.

2. Material and methods

2.1. Study sites

Samples were collected at five Alabama intertidal sites (Fig. 1, Table 1). Two collection sites were located within Mobile Bay (Bayfront Park: BP and BelleAir Boulevard: BB) and three sites along Dauphin Island (Ryan Court: RC, Shellfish Lab: SL, and Cadillac Avenue: CA) (Fig. 1, Table 1). BP, BB, and CA are more sheltered locations found within in low energy "Bay" type habitats, whereas RC and SL are more exposed GOM-facing beaches. These were the same sampling locations utilized by Bik et al. (2012), Williams (2013), and Brannock et al. (2014). Pre-spill sediment samples were collected in May 2010. This is after the *Deepwater Horizon* (*DWH*) oil spill commenced but prior to any oil exposure to the coast of Alabama, which did not occur until June 2010 (Graham et al., 2010; Hayworth et al., 2011). Choice of location for sample site was dictated in no small part by the ability to reach localities that were not closed off by authorities as they prepared for oil to reach the shoreline. Post-spill sediment samples were collected in September 2010 (Bik et al., 2012), March 2011 (Bik, unpublished data), and bi-monthly from July 2011–July 2012 (Brannock et al., 2014). Sediment granulometry and organic composition for a subset of the samples used in the current study have been reported previously (Williams, 2013).

2.2. Sample collection

For nematode morphological analysis, two 4-cm diameter and 10-cm depth sediment cores per collection site were taken during

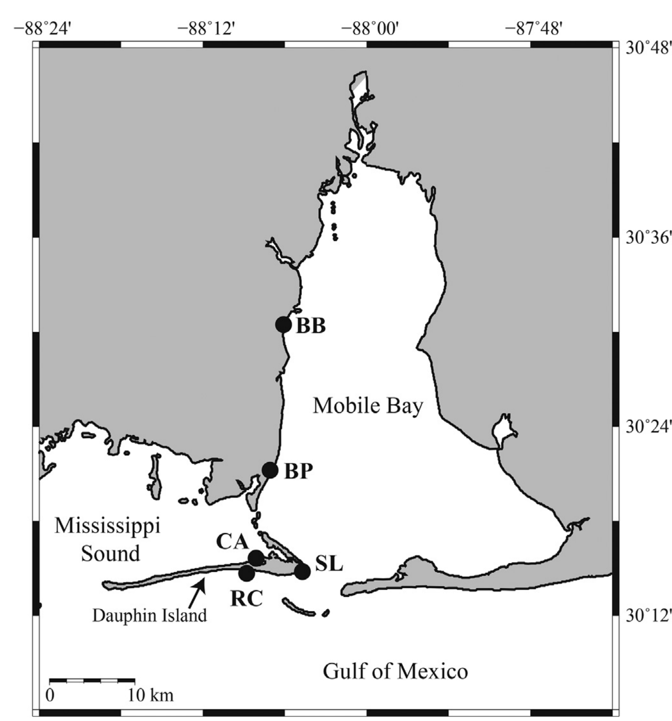

Fig. 1. Geographic representation of sampling locations within Mobile Bay and along Dauphin Island, Alabama. Site abbreviations and GPS coordinates are provided in Table 1.