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Population structure of *Abyssorchomene abyssorum* (Stebbing, 1888) (Amphipoda: Lysianassoidea), a scavenging amphipod from the Mid-Atlantic Ridge in the vicinity of the Charlie-Gibbs Fracture Zone

Grant A. Duffy*, Tammy Horton, Martin Sheader, Michael H. Thurston

National Oceanography Centre Southampton, University of Southampton Waterfront Campus, European Way, Southampton, SO14 3 ZH, UK

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ABSTRACT

This study focussed on the common and ubiquitous scavenging amphipod *Abyssorchomene abyssorum* collected from a section of the Mid-Atlantic Ridge with one pair of sampling areas at 49°N and the other at 54°N, north and south of the Charlie Gibbs Fracture Zone (CGFZ) and east and west of the ridge, at a water depth of 2500 m. Baited-trap samples of necrophagous amphipods were collected during three research expeditions on the RRS *James Cook* in 2007, 2009, and 2010, allowing for direct comparisons to be made amongst populations of *A. abyssorum* at the four sample areas. Random subsamples of 200 individuals from nine trap samples were sexed, dissected, and measured.

Males, females, and juveniles were found in all samples but no ovigerous females were identified. The finding of sexually mature mid-sized females, variability of oocyte size with body size, and presence of mature females with 'empty' ovaries, suggest that *A. abyssorum* is capable of having multiple broods in a lifetime. This reproductive strategy is beneficial to a scavenging organism living under a variable and unpredictable nutrient regime, allowing for a rapid reproductive response to advantageous conditions. Females north and south of the CGFZ fall into distinct cohorts with different distributional parameters. The total body lengths of female cohorts south of the CGFZ were consistently larger than those in the north. This is likely due to increased nutrient availability at the southern sampling areas.

Males were significantly smaller than females and possessed longer, more articulate antennae. Longer antennae are thought to facilitate mate-searching by males. Estimates of the maximum brood size ranged from 36–78 offspring with actual brood size expected to be at the lower end of this scale. This places the estimated brood size of *A. abyssorum* in a similar range to that of other scavenging amphipods of comparable size. The juvenile:non-juvenile ratio differed north and south of the CGFZ with significantly more juveniles in the north. Possible reasons for this difference are discussed.

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1. Introduction

Through their role in recycling organic carbon from large food-falls, scavenging organisms, and in particular scavenging amphipods, are a vital component of secondary production cycles that support numerous deep-sea ecosystems (Stockton and DeLaca, 1982; Christiansen and Diel-Christiansen, 1993; Britton and Morton, 1994; Payne and Moore, 2006). In spite of this, our understanding of the ecology of these organisms remains poor. A concerted effort in the field has furthered our understanding of deep-sea scavenging amphipods and their distribution at the community level (e.g. Thurston, 1990; Jamieson et al., 2011; Duffy et al., 2012; Horton et al., 2013), but few studies have examined the factors affecting population structure and distribution of deep-sea scavenging amphipods.

Numerous population studies have been carried out on shallow water amphipods (see Sainte-Marie, 1991, for a comprehensive review of pre-1990 literature; Arndt and Beuchel, 2006; Nygård et al., 2009). The study of deep-sea populations is, however, largely limited to the giant amphipods *Eurythenes gryllus* Lichtenstein 1822 (Ingram and Hessler, 1987; Premke et al., 2006) and *Alicella gigantea* Chevreux, 1899 (Barnard and Ingram, 1986), and species inhabiting hydrothermal vent (Sheader et al., 2000, 2004; Sheader and Van Dover, 2007), submarine canyon (Kaïm-Malka, 2003, 2004, 2005), and trench environments (Thurston et al., 2002; Blankenship et al., 2006). Without detracting from the importance of these studies, *E. gryllus* is rarely the most abundant species in deep-sea scavenging communities, and vent, canyon, and trench environments account for a very small part of the deep-sea by area.

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* Corresponding author. Tel.: +44 2380 596358.
E-mail addresses: g.duffy@noc.soton.ac.uk (G.A. Duffy), tammy.horton@noc.ac.uk (T. Horton), martin.sheader@noc.soton.ac.uk (M. Sheader), mhth@noc.ac.uk (M.H. Thurston).

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Mid-ocean ridges, on the other hand, represent a large area of the deep-sea benthic habitat, yet they have been poorly studied beyond their hydrothermal vent systems.

The Mid-Atlantic Ridge (MAR) bisects the Atlantic Ocean and accounts for 45.7% (3 704 404 km^2) of seabed in lower bathyal (800–3500 m) depths in the North Atlantic (Priede et al., 2013). Prior to the commencement of the MARECO and ECOMAR projects very little was known of the ecosystems of this environment. Following 19 research expeditions, involving partners from 17 countries, our understanding has progressed substantially.

The ECOMAR project provided a unique opportunity to study deep-sea scavenging amphipod communities at a single depth (~2500 m) across four geographically separated sampling areas at the MAR over a four-year period. Distinct scavenging amphipod assemblages were found at each sampling area with significant differences north and south of the Charlie-Gibbs Fracture Zone (CGFZ; Horton et al., 2013). All samples were dominated by the lysianassoid amphipod *Abyssorchomene abyssorum* Stebbing, 1888. The presence of this species in high abundances at all sampling areas provided the opportunity to study these organisms at the population level.

Abyssorchomene abyssorum, like all other scavenging amphipods, has a limited dispersive ability, obligate brooding, and direct development; yet evidence suggests it has a wide-ranging, cosmopolitan distribution (Barnard and Karaman, 1991; Thurston 1990). An in-depth analysis of the populations of *A. abyssorum* inhabiting the MAR, including observations of sexual characteristics, will provide vital information concerning the life history of this species and will help us to understand its success in the deep sea. Sampling across four distinct areas at a constant depth allows for direct comparisons to be made amongst these populations. Analysing how populations vary between sampling areas may facilitate the identification of the environmental factors responsible for population-level variation amongst sampling areas.

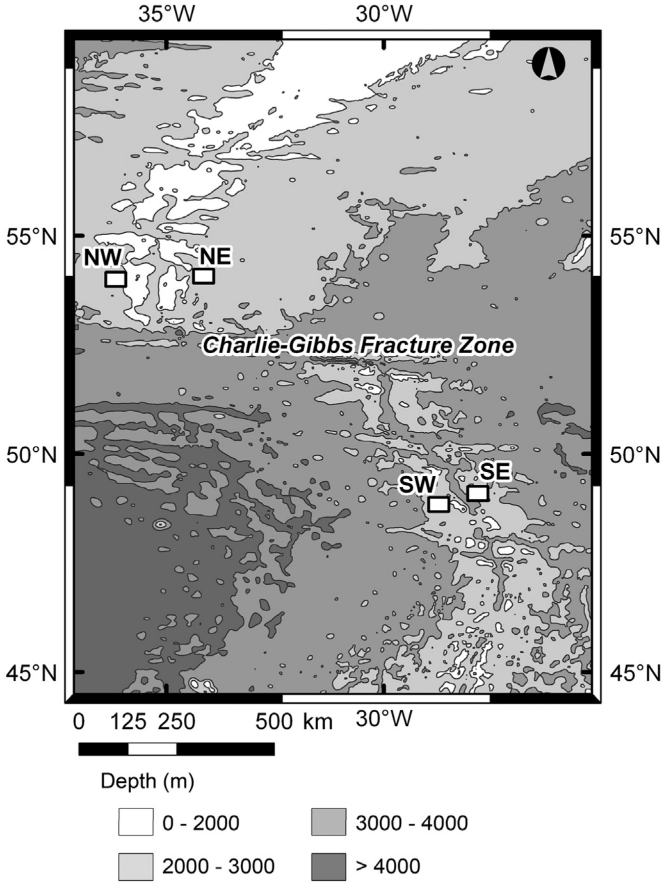

Fig. 1. Bathymetric map of study area coloured by water depth. Sampling areas highlighted by white boxes.

2. Materials and methods

2.1. Sample collection

Four ECOMAR sampling areas were studied (Fig. 1) during research expeditions in the boreal summers of 2007, 2009, and 2010 (RRS *James Cook* expeditions JC011, JC037, and JC048 respectively). Amphipods were collected using baited traps attached to free-fall landers. The lander design and trap arrangement varied across years (see Horton et al., 2013, for further discussion) however the basic trap design was consistent. A funnelled entrance led to the bait of a whole mackerel (*Scomber scombrus*), either in a meshed off section of the trap or wrapped in muslin cloth. Soak time varied (from 13–101 h) as a result of weather conditions and operational constraints. For this reason samples were selected such that the effects of variable soak time were minimised with particularly long deployments excluded in favour of shorter deployments at the same sampling area where possible (Table 1).

Due to operational constraints the southwest sampling area was only sampled in 2010 and the southeast area was sampled during two years (2009, 2010). Both northern areas were sampled successfully on all three expeditions. The contents of the traps were fixed in either 100% ethanol or 4% buffered formaldehyde–saline solution. Formalin-fixed material was subsequently transferred to 80% industrial methylated spirit. Samples were sorted to species level (Horton et al., 2013) with the *A. abyssorum* component of selected samples used for population analysis in this study.

2.2. Data collection

Every individual was assigned a unique identification number and 200 individuals were randomly selected from each sample using a random number generator. Selected individuals were dissected and measured under a stereo-dissecting microscope. Specimens were preserved in a variety of postures and many were damaged, making it difficult or impossible to accurately measure total body length for all individuals. Previous studies have resolved this problem by measuring an individual body-part as a proxy for total body length. A range of proxies have been used previously, including coxal plate 4 diagonal length (Chapelle, 1995; Blankenship et al., 2006), pereonite 1 dorsal length, (Thurston et al., 2002; Nygård et al. 2009), the length of the dorsal margin of pleonite 1 (Sheader et al., 2004; Sheader and Van Dover, 2007), dorsal margin length of pleonite 3 (Sheader et al., 2000). In this study coxal plate 4 was used as a proxy for total body length.

The total body length (distance along the dorsal margin between the anterior margin of the head and the tip of the telson) of all intact individuals from sample JC048/032 was measured. This was performed using a digital graphics tablet and HTML-assisted Measuring System (HaMS) calibrated using a stage graticule of known length. Use of HaMS permitted accurate measurement of a curved line. These data were subsequently correlated to the diagonal linear measure of coxal plate 4 (as in Chapelle, 1995), which were made using a stage graticule. Estimation of total body length for all remaining specimens was possible using the coxal plate 4 measurement as a proxy.

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