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Nighttime vertical distribution and regional species composition of eel larvae in the western Sargasso Sea

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HIGHLIGHTS

- Vertical and horizontal distributions of leptocephalus larvae were investigated.
- >47 species collected by MOC-10 at 5 western Sargasso Sea stations.
- Differences in species distributions and vertical distributions were observed.
- Thermocline depth may influence nighttime vertical distributions.

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ABSTRACT

Eel larvae, called leptocephali, are widespread throughout the surface layer of tropical and subtropical oceans, but their ecology is poorly understood and few studies have examined their vertical distributions. The species composition and vertical distribution of leptocephali was studied in the western Sargasso Sea using a 10 m^2 mouth-opening MOCNESS-10 trawl system with multiple nets that sampled 4 discrete depth ranges at 5 night stations extending from the northern Florida Current (FC) to near the northern Bahamas in July–August 1993. Nets mostly fished in the upper 200 m (max. depth 600 m), and collected 469 leptocephali of >47 species from 11 families (size range: 20–260 mm). *Anguilla* leptocephali (32–53 mm) were caught at each station at depths from 0–30 m to 40–70 m, with only one individual collected at 90–120 m. Some marine eel taxa had different vertical distributions and their species composition varied geographically. The congrid *Rhynchoconger flavus* and nettastomatid *Hoplunnis macrura* were only abundant along the western side of the FC in the north at 50–100 m depths. *Ariosoma selenops* leptocephali and a richer assemblage of species were present near the eastern edge of the FC, with the majority caught at 0–50 m. Farther south in the recirculation region east of the FC, >33 species were collected, with *Anguilla rostrata*, congrids, chlopsids, moringuids, ophichthids, and muraenids being most abundant at 0–30 m, but nemichthyids and derichthyids were most abundant at 30–60 m. Similar depth ranges were observed at the southern stations, and no leptocephali were collected in the 400–600 m depth range. These data indicate there is variability in the fine-scale vertical distributions of leptocephali within the upper 100 m at night and that few of these larvae are present in deeper layers offshore.

1. Introduction

Leptocephali are a unique type of transparent fish larvae that are present worldwide primarily in tropical and subtropical ocean regions, but little is known about their behavior and ecology (Smith, 1989a; Miller, 2009). They reach larger sizes (∼60 to >300 mm) than most fish larvae, which may enable them to more frequently avoid standard sized plankton nets or even avoid large nets during the day or possibly to some degree at night (Castonguay and McCleave, 1987a; Miller and McCleave, 1994; Miller et al., 2006a, 2013a). Some studies have examined the geographic distributions or species composition of leptocephali in several parts of the world using large plankton nets fished at night (e.g. McCleave, 1993; Miller et al., 2006a,b; Miller and McCleave, 2007; Ross et al., 2007), but there have been only a few studies on the vertical distributions of leptocephali.

Studies on the vertical distributions of leptocephali in the open ocean have found that they are generally present only in upper 100 m at night and that some taxa move to deeper depths during the day as reviewed by Miller (2009). The most extensive

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study on the vertical distribution of leptocephali was conducted in the Sargasso Sea by Castonguay and McCleave (1987a) using a 2-m ring net during surveys in the winter/spring and summer/fall. That study found evidence that leptocephali of some species vertically migrate from the upper 100 m at night to as deep as about 300 m during the day. Other studies with small mouth-opening gear (Schoth and Tesch, 1984; Otake et al., 1998) or open nets fished horizontally at specific depths (Tesch, 1980; Kajihara et al., 1988) have all generally found similar patterns of leptocephali being most abundant in the upper 100 m at night, or at deeper depths during the day. Therefore it is likely that many species of leptocephali perform a daily pattern of vertical migration, similar to many fish larvae, mesopelagic fishes, and invertebrates (Lampert, 1989; Huebert et al., 2011). Leptocephali may swim to deeper depths >300 m along continental shelves (Tesch, 1980; Ross et al., 2007; Miller, 2009), possibly as they prepare for recruitment to coastal areas. The behavioral aspects of the vertical distribution of leptocephali are not well-understood yet though, because detailed data about their vertical distributions have only been collected in a few areas.

Their biology and ecology are also not well understood. Leptocephali differ from other fish larvae not only in their large size, but also in their feeding ecology and physiology (Pfeiler, 1999; Bishop et al., 2000; Miller, 2009). They appear to feed on particulate organic matter (POM) such as marine snow or discarded appendicularian houses (Otake et al., 1993; Mochioka and Iwamizu, 1996; Miller et al., 2011, 2013b) and not on zooplankton like most fish larvae. Marine snow can contain a wide range of materials including bacteria, cyanobacteria, protozoans, discarded appendicularian houses, and various colonizing small organisms (Alldredge and Silver, 1988; Shanks and Walters, 1997; Kiørboe, 2000). Food contents are most visible in leptocephalus intestines when they are collected during the day (Miller et al., 2011), but when they feed and the depths at which they feed are not known. Their general vertical distributions directly overlap with the highest concentrations of marine snow and POM in the open ocean that are often in the upper 200 m (Hebel and Karl, 2001; Pilskaln et al., 2005). Because leptocephali feed on POM, it may be important to understand more about their role in the ocean carbon cycle in which POM is an important component (Miller, 2009).

More information is available about the horizontal distribution of leptocephali than their vertical distribution, because of surveys that have been conducted to study the offshore spawning areas of anguillid eels. The southern part of the Sargasso Sea is the spawning area of the American eel, *Anguilla rostrata*, and the European eel, *Anguilla anguilla*, so extensive collections have been made there (see McCleave, 1993; Miller et al., 2015), and all the other species of leptocephali have also been studied there (Miller, 1995; Miller and McCleave, 1994). The American conger eel, *Conger oceanicus*, also appears to spawn in the southwestern Sargasso Sea (McCleave and Miller, 1994), and the mesopelagic eels of the Nemichthyidae, Serrivomeridae and Eurypharyngidae (Miller and McCleave, 1994; Wippelhauser et al., 1996) and Derichthyidae (Castonguay and McCleave, 1987b) spawn offshore in the Sargasso Sea.

Several studies have also reported on the species composition of leptocephali in the Florida Current (FC) and southern Sargasso Sea region. The assemblages of leptocephali of the shallow-water eel families of the Congridae, Chlopsidae, Moringuidae, Muraenidae, and Ophichthidae were examined in the FC in February as part of a larger study (Miller, 1995) and the distribution of anguillid leptocephali in the Florida Current in August was studied (Kleckner and McCleave, 1982). Some data on the collection depths of congrid leptocephali in the FC have also been reported (Miller, 2009). Other collections were made along the western edge of the FC and over the shelf (Ross et al., 2007) and across the FC in the western end of a long transect of stations across the southwest Sargasso Sea in October (Miller and McCleave, 2007). There have been no studies of leptocephali at different latitudes in the complex recirculation region just to the east of the FC though. Leptocephali have long larval durations of several months to possibly up to a year or more, so their distributions reflect regional current patterns (reviewed by Miller, 2009).

This study examined the distribution of leptocephali from both vertical and horizontal perspectives and in comparison to the general hydrographic structure of the western Sargasso Sea and FC. The species composition, size, and vertical distributions of leptocephali were examined using discrete depth samples collected by a large midwater trawl with multiple opening and closing nets. Data from single deployments of the trawl at 5 stations ranging from the northern part of the FC to the Antilles Current region just east of Abaco Island of the northern Bahamas were used to examine the nighttime vertical distributions of leptocephali and their geographic species compositions in relation to the oceanographic features of the region.

2. Materials and methods

2.1. Oceanographic structure of the western Sargasso Sea region

The present study included 2 stations located approximately on each side of the FC at about 32°N, 1 station in the western Sargasso Sea, and 2 stations near the northern Bahamas in the Antilles Current area (Fig. 1). This is a dynamic oceanic region because the powerful FC flows northward and then northeast along the edge of the continental shelf of the South Atlantic Bight. The FC extends from the Straits of Florida to Cape Hatteras and is the southern part of the Gulf Stream, which is the western boundary current of the North Atlantic subtropical gyre (Schott et al., 1988; Schmitz and McCartney, 1993). The flow of the FC is narrow and very strong with velocities reaching about 180 cm/s (Leaman et al., 1987; Meinen et al., 2010). There are typically fewer meanders in this current before it flows past Cape Hatteras, but there are frequently eddies or intrusions of water from the FC into the western Sargasso Sea (Vukovich and Crissman, 1978; Cornillon et al., 1986) as can be seen in the sea surface temperature (SST) images of Fig. 1. The FC usually turns slightly to the east just south of Cape Fear as it flows northeast towards Cape Hatteras as a result of the current being deflected by the bottom topographic feature referred to as the "Charleston bump" (Bane and Dewar, 1988, Fig. 1(C)).

Another mechanism that causes mixing of water in the western Sargasso Sea is that Gulf Stream cold core rings can move southwest in the region (Richardson, 1980). Because of these factors as well as the temperature fronts that form in the Sargasso Sea from the fall to spring (Eriksen et al., 1991), the oceanographic structure, eddies, and current patterns can be highly variable as has been observed by oceanographic surveys (Amos et al., 1971; Ingham, 1975; Gunn and Watts, 1982) and drifter tracks (Reverdin et al., 2003).

The region east of the northern Bahamas typically has northwest current flow that is referred to as the Antilles Current. This flow is strongest just off the Abaco Islands and extends 50 km or more offshore throughout most of the year, and may be strongest in August and September (Hacker et al., 1996; Johns et al., 2008). This flow may also sometimes be part of a large circulation cell in the southwestern edge of the Sargasso Sea (Stommel et al., 1978; Gunn and Watts, 1982; Olson et al., 1984).

The present study was conducted from the FC southward to the northern Bahamas in late July and early August of 1993 while the ship was in transit back to port. Because no hydrographic data are available from the 5 stations of this study, three temperature sections were plotted from temperature profile data obtained from the World Oceanographic Database to evaluate the hydrographic