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Nocturnal planktonic assemblages of amphipods vary due to the presence of coastal aquaculture cages

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ABSTRACT

Nocturnal pelagic swimming is common in the daily activity of peracarids in marine ecosystems. Fish farming facilities in coastal areas constitute an optimal artificial habitat for invertebrates such as amphipods, which can reach high abundance and biomass in fouling communities. Additionally, fish farms may modify the local oceanographic conditions and the distribution of pelagic communities. The aim of this study was to determine if nocturnal abundance and species composition of planktonic amphipod assemblages are affected by fish farm structures, using light traps as collecting method. A total of 809 amphipods belonging to 21 species were captured in farm areas, compared to 42 individuals and 11 species captured in control areas. The most important species contributing to the dissimilarity between farms and controls were the pelagic hyperiid *Lestrigonus schizogeneios*, the fouling inhabitants *Ericthonius punctatus*, *Jassa marmorata*, *Stenothoe* sp. and *Caprella equilibra*, and the soft-bottom gammarids *Periculodes aequimanus* and *Urothoe pulchella*. The great concentrations of planktonic amphipods at fish farm facilities is a result of the input of individuals from fouling communities attached to aquaculture facilities, along with the potential retention there of hyperiids normally present in the water column and migrant amphipods from soft sediments. Therefore, in addition to the effects of aquaculture on benthic communities, the presence of fish farms induces major changes in planktonic assemblages of invertebrates such as amphipods.

1. Introduction

Nocturnal pelagic swimming is common in the daily activity of many invertebrate organisms in marine ecosystems (Alldredge and King, 1985). A large number of species with a typical diurnal benthic life form part of the zooplankton community at night due to their diel vertical migrations (Watkin, 1939; Armonies, 1988; Kringel et al., 2003). Amphipods, one of the most abundant groups in benthic habitats (Thomas, 1993), characteristically represent this migratory behaviour, ascending from the seabed into the water column and thus frequently appearing during night hours in the pelagic system as members of the zooplankton community (Williams and Bynum, 1972; Macquart-Moulin, 1984; Kaartvedt, 1986). Moreover, holoplanktonic amphipods, the hyperiids, swim up from deeper layers during dark hours towards near-surface waters (Laval, 1980; Pai et al., 2010). Amphipods are an important link in the food web, since they are primary productivity consumers but also predators of larvae and adult organisms at the same time that they constitute a preferential food of small crustacean, polychaetes and many fish species (Bellan-Santini et al., 1998).

Nocturnal movements could have various ecological purposes for these species: to feed in more productive areas, to avoid competition or predation, to promote the colonisation of new habitats, to mate, or to find hosts in the case of parasitoid hyperiids (Mills, 1967; Laval, 1980; Alldredge and King, 1985; Conlan, 1991; Sanchez-Jerez et al., 1999). These migrations can range in extent from centimetres to hundreds of metres (Sanchez-Jerez et al., 1999), increasing the biomass of amphipods in the zooplankton, principally near the surface at night (Watkin, 1939). The driving factors behind these migrations are apparently changes in light intensity such as sunset or sunrise or new and full moon, and also chemical cues (e.g. predator exudates) or food concentration (Ringelberg, 1995). In fact, a relationship between vertical migration patterns of amphipods and the lunar cycle has been detected in several studies (Alldredge and King, 1980; Mcquart-Moulin et al., 1984; Drolet and Barbeau, 2009). All these factors may act as

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environmental triggers, stimulating circadian rhythms in amphipods (Alldredge and King, 1980).

The distribution of pelagic communities may be affected by the modification of marine currents due to the introduction of coastal infrastructures. Following the global trend, Mediterranean aquaculture production is increasing in coastal areas, floating sea-cages being the main method. Indeed, more than 20,000 floating cages are situated within 10 km offshore along the entire Mediterranean coast (Trujillo et al., 2012). Aquaculture facilities are generally moored at a particular position, remaining there for decades. Their structural framework consists of surface collars, mooring ropes, nets and buoys and modifies the local oceanographic conditions by the reduction in currents speed and subsequent particle retention (Plew et al., 2005; Klebert et al., 2013). Coastal species transported by sea currents rapidly colonise these structures and fouling communities dominated by algae, hydroids or mussels are normally found on fish farm facilities (Sarà et al., 2007; Fitridge et al., 2012). Fish farms constitute an optimal habitat for amphipods, appearing in high abundance and biomass associated with such adherent communities (Green and Grizzle, 2007; Fernandez-Gonzalez and Sanchez-Jerez, 2014). Fish farming also provoke changes in benthic amphipod assemblages, because of its negative effects on the seabed such as silting, increased oxygen demand, anoxic sediment generation and toxic gases (Wu, 1995; Borja, 2002). These derive mainly from organic enrichment due to surplus fish feed and waste products (Gowen and Bradbury, 1987; Kalantzi and Karakassis, 2006). Indeed, benthic amphipods below the cages have shown lower abundances and biodiversity in comparison with control areas (Fernandez-Gonzalez et al., 2013).

Because of the ecological importance of amphipods as a key faunal component of food webs in coastal ecosystems and the scarce information about the potential effects of coastal infrastructures on their abundance and behaviour, we carried out a study with the general aim of identifying the influence of fish farms on planktonic amphipods. However, the use of traditional zooplankton sampling methods, such as trawls with plankton nets is often unsuitable in farming areas given their complex floating structure. In contrast, despite being primarily used to collect fish larvae (Kissick, 1993; Hernandez and Shaw, 2003; Félix-Hackradt et al., 2013), light traps have proved an excellent means of collecting small crustaceans like amphipods, isopods, cumaceans or decapod larvae (Jones, 1971; Fincham, 1974; Michel et al., 2010; Tor et al., 2010). Therefore, the main objective of this study was to determine if nocturnal abundances and species composition of amphipods with different habitat preferences (pelagic, fouling and soft-bottom inhabitants), are affected by fish farm structures. For this purpose we previously tested: (1) the catchability of nocturnal swimming amphipods using light traps in farming and control areas to detect potential biases due to sampling method, and (2) the variability caused by environmental variables that may also explain behavioural traits of amphipods as those related to the lunar cycle.

2. Materials and methods

2.1. Study area and sampling effort

This study was carried out in coastal waters of Guardamar del Segura (Alicante, Spain: 38° 5′ 7.45″ N; 0° 35′ 51.40″ W) from 12 June to 10 October 2012, which correspond to warm period in the Western Mediterranean. Sampling was conducted at two fish farms – producing sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) – and two control areas – at least 2 km away from the nearest fish farm – on 16 arbitrarily chosen nights. All four localities are located 3–4 km offshore at depths ranging from 23 to 30 m. Each farm consisted of 18 rings with a diameter of 19 m or 25 m and cage nets reached depths from 12 to 15 m. Changes in abundances and species composition of amphipods in the plankton population were investigated by sampling farm and control areas with light traps. Four traps were built with identical design and light source to allow simultaneous sampling of two replicates within one farm and two at one control area each sampling night (Fig. 1A).

Light trap design was a modification of that employed by Floyd et al. (1984) and Kissick (1993), which consisted of a plexiglass collection chamber measuring 40 × 40 × 40 cm, with eight panels forming four funnel-shaped entrances 3 mm wide. The light source was a hand diving-torch (Led Lenser D14, 150 lumen) coupled to a white plastic container which produced a diffuse point of illumination.

The traps were suspended from a buoy which in turn was anchored to the sea-bottom in such a way that there was approximately 20 m to the sea bottom and a 4 m water column above the trap (Fig. 1B). They were deployed after sunset for approximately 1 h, recording deployment and retrieval times to the nearest minute, and their contents were then removed. Six retrievals were made each sampling night, considering each one as one replicate. Traps were recovered by slowly raising them to allow the filtration of the chamber content through the 250 μm-mesh bottom of the collection cup. Material retained was preserved in 4% formalin seawater solution.

Light traps were combined with plankton hauls, allowing the effectiveness and selectivity of the light traps to be tested. A conical plankton net 0.6 m in diameter and 250 μm-mesh was connected to a flowmeter (model 2030 General Oceanics), and towed at a depth of 1 m–5 m for four minutes at low speed (3 knots). Four double-oblique plankton hauls were taken each sampling night in order to cover a similar depth as light traps. At the end of each trawl, the net was washed down with seawater and the retained material was also preserved in 4% formalin seawater solution.

In the laboratory, amphipods were sorted, identified to species level whenever possible and counted. Moreover, individuals were classified according to sex and life history stage: males, females, brooding females and juveniles. Sexual dimorphism was used to distinguish males and females adults by the size and shape of the gnathopods and the presence of oostegites or penial papillae. Females with eggs or juveniles in the brood pouch were termed brooding females. Small amphipods that could not be clearly identified as adult males or females were considered juveniles. Each species was assigned to its habitat of origin (i.e. pelagic, fouling or soft-bottom) based on their ecology (Vinogradov et al., 1996; Bellan-Santini et al., 1998) and published literature from the same study area (Fernandez-Gonzalez et al., 2013; Fernandez-Gonzalez and Sanchez-Jerez, 2014).

The environmental variables taken into account were: Temperature (Temp, °C), Days of lunar month (DLM), Moon illumination (MI, %), Time to moonrise (TM, h), Time since sunset (TS, h), Time between sunset and moonrise (TSM, h), Time from the nearest high tide (HT, h) and Cloud cover (CC, %). The exact rising and setting times for the Moon and the Sun and the percentage of moon illumination were taken from http://www.timeanddate.com/.

2.2. Data analysis

Light trap samples were standardised to a catch per unit effort (CPUE) of amphipods per h and plankton net samples to the number of amphipods collected per 100 m^3. Light trap selectivity was estimated according to the formula: $E = (r_i - p_i)/(r_i + p_i)$, based on Ivlev's index (E; Ivlev 1961), where r_i is the percentage of the species i in the trap and p_i the percentage of the species i in the environment (plankton tows). This index varies from −1.0 to +1.0, where positive values indicate selectivity and negative values avoidance.