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Hiding and feeding in floating seaweed: Floating seaweed clumps as possible refuges or feeding grounds for fishes

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Abstract

Floating seaweed is considered to be an important habitat for juvenile fishes due to the provision of food, shelter, a visual orientation point and passive transport. The importance of the presence of the highly dynamical seaweed clumps from the North Sea to juvenile neustonic fishes was investigated by analysing both neuston samples (without seaweed) and seaweed samples concerning fish community structure, and length-frequency distributions and feeding habits of five associated fish species. While the neustonic fish community was mainly seasonally structured, the seaweed-associated fish community was more complex: the response of the associated fish species to environmental variables was species specific and probably influenced by species interactions, resulting in a large multivariate distance between the samples dominated by *Chelon labrosus* and the samples dominated by *Cyclopterus lumpus*, *Trachurus trachurus* and *Ciliata mustela*. The results of the stomach analysis confirmed that *C. lumpus* is a weedpatch specialist that has a close spatial affinity with the seaweed and feeds intensively on the seaweed-associated invertebrate fauna. Similarly, *C. mustela* juveniles also fed on the seaweed fauna, but in a more opportunistic way. The shape of the size-frequency distribution suggested enhanced growth when associated with floating seaweed. *Chelon labrosus* and *T. trachurus* juveniles were generally large in seaweed samples, but large individuals were also encountered in the neuston. The proportion of associated invertebrate fauna in their diet was of minor importance, compared to the proportions in *C. lumpus*. Individuals of *Syngnathus rostellatus* mainly fed on planktonic invertebrates but had a discontinuous size-frequency distribution, suggesting that some of the syngnathids were carried with the seaweed upon detachment and stayed associated. Floating seaweeds can therefore be regarded as ephemeral habitats shared between several fish species (mainly juveniles) that use them for different reasons and with varying intensity.

Keywords: juvenile fish; floating seaweed; refuge; North Sea

1. Introduction

A wide variety of fish taxa throughout the world's oceans have a natural tendency to aggregate beneath or associate with floating structures such as plastic debris, floating seaweeds, pieces of wood, jellyfish, fish aggregation devices (FADs) and animal remains (e.g. Safran and Omori, 1990; Davenport and Rees, 1993; Moser et al., 1998; Masuda and Tsukamoto, 2000; Castro et al., 2001; Thiel and Gutow, 2005a,b). Generally, the fish community is found to be more diverse below floating seaweeds than below other floating items (Fedoryako, 1989). According to Kingsford (1995), the increased diversity in the presence of floating seaweeds compared to the surrounding water column can be attributed to the substantial increase in habitat complexity of the pelagic environment.

Many authors have already attempted to classify fish based on the spatial and temporal relation between the fishes and the floating object. Castro et al. (2001) distinguished 'associated' fishes (circulate around the structure and do not show any dependence) and 'aggregating' fishes (live close to the floating object and depend on it). Dooley (1972) separated coincidentally associated fishes with rare occurrence, moderately associated fishes, seasonally occurring fishes, and closely

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associated fishes. Hirosaki (1960 – in Thiel and Gutow, 2005b), proposed a classification in: (1) fishes that stay within the branches of the algae; (2) fishes that remain underneath the floating patch; and (3) fishes that swim around the patch with close association; and Gooding and Magnuson (1967) discerned transients (no response to and no contact with the floating object), visitors (response but no contact) and residents (response and contact). Although different classifications have been used in literature, they all distinguish groups based on the dependency of the fishes to the floating object and are therefore relatively comparable and applicable in new studies.

Floating seaweed is considered to be an important habitat for juvenile fish. Masuda and Tsukamoto (2000) found that the onset of the association behaviour already starts at an early stage in some fish species (at 12 mm TL for *Pseudocaranx dentex*) and is probably triggered by visual and mechanical stimuli. The advantages of associating with floating seaweeds are numerous (reviewed in Castro et al., 2001): (1) the benefits of living in the shade in relation to predators and detection of prey (Kingsford, 1992); (2) the presence of abundant food sources like smaller fish, associated macrofauna or the seaweed itself (Wright, 1989; Safran and Omori, 1990; Davenport and Rees, 1993); (3) the shelter from piscivorous fish and birds (Wright, 1989; Kokita and Omori, 1998); (4) the potential for passive transport (Dooley, 1972); (5) the meeting point function for the formation and maintenance of schools or for spawning (Masuda and Tsukamoto, 2000); (6) the substitution of the seabed for non-pelagic fish; and (7) the function of floating objects as cleaning stations (Gooding and Magnuson, 1967). Accordingly, aggregative and associative behaviour of juvenile fish can be the expression of convergent behaviours resulting from different motivations (Castro et al., 2001).

Different studies indicate that the association between most fish species and floating seaweeds is of a temporary nature, particularly in the juvenile stages (e.g. Davenport and Rees, 1993; Castro et al., 2001; Ingólfsson and Kristjánsson, 2002). Furthermore, Shaffer et al. (1995) described that the function of floating seaweed with regard to juvenile fish may change seasonally. Juvenile *Sebastes diploproa*, for example, finds refuge from predators in spring and summer, whereas in autumn, the seaweed increasingly serves as a prey habitat. Several studies reported higher fish densities in summer months, probably due to the increased availability of floating seaweed in that period (Kingsford, 1992; Thiel and Gutow, 2005b). Next to temporal variation, variations in the size of floating seaweed patches strongly influence the densities and species composition of the associated ichthyofauna (Hunter and Mitchell, 1967; Dooley, 1972; Moser et al., 1998; Nelson, 2003). Because effects of seaweed species composition, distance to shore and raft age (increased epibiont load) have already been reported for rafting invertebrates (Fine, 1970; Ingólfsson, 2000; Castro et al., 2001; Ólafsson et al., 2001; Thiel and Gutow, 2005b; Vandendriessche et al., 2006b), these factors are also likely to apply to rafting fish.

Although research about the importance of association behaviour is very important from the perspective of fisheries ecology, very little information is available concerning the relation between fishes and the highly dynamical floating seaweed clumps found in the North Sea. Therefore, the present study aims to investigate the species composition and association behaviour of fishes associated with floating seaweeds. To this end, we identified neustonic fishes with a tendency to associate with floating objects, and investigated the variability within the fish community. For each of the associated fish species, the underlying motivation for association behaviour (food, shelter or other) was investigated.

2. Material and methods

2.1. Sampling

Based on literature (e.g. Dooley, 1972; Ingólfsson, 1995; Cho et al., 2001) and personal experience, a neuston net and a dip net were found to be the most effective net types for sampling neustonic (not associated with floating objects) and seaweed-associated juvenile fish communities, respectively. This approach, however, was expected to result in variations concerning net efficiency, and therefore in differences concerning the fish species and sizes caught. In the present study, we took into account the variation in net efficiency by analysing the quantitative data from the two sampling methods separately.

2.1.1. Neuston net samplings

A year-round survey of the neuston (monthly samplings) was carried out in the Belgian part of the North Sea (BPNS) (6 sampling stations, Fig. 1) in the period July 2003–June 2004. Samples were taken with a rectangular net (2 m × 1 m, 1 mm mesh), of which only the lower half was immersed, thereby sampling the upper 0.5 m of the water column. After a tow of 15 min (average filtered volume: 2623 m^3, average speed: 1.5 knots), the net was emptied and rinsed, while the contents were preserved in formalin solution. All fishes were first anaesthetised in a benzocaine (Ethyl amino-4-benzoate)-water solution to prevent regurgitation of the stomach contents.

2.1.2. Dip net samplings

Seaweed samplings were conducted from October 2002 to September 2004 in the BPNS. The RV 'Zeeleeuw' was used to collect patches of floating seaweed using a 40 cm diameter dip net with 300 μm mesh, ensuring that the captured fish had a spatial affinity with the seaweed. During the sampling period, 249 seaweed samples from 60 sampling sites (Fig. 1) were collected along with their associated macro-invertebrates and fish fauna. Three control samples (i.e. surface water samples without seaweeds) were taken at each sampling site. The size of the seaweed samples was dictated by the diameter of the sampling net used. In the field, all fishes were anaesthetised in a benzocaine – water solution and preserved in formalin solution together with the rest of the associated fauna.

Sampling intensity was not equal over the seasons because bad weather often prevented the search for floating seaweeds (especially in the period October–January). For successful samplings, the mean number of sampling points (and hence