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Interspecific Comparison of Deep-sea Fish Locomotion Behaviour and Habitat Selection

by

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Abstract

Fishing effort and success strongly depend on the behaviour and habitat preferences of target species. In order to compare the locomotion behaviour and habitat selection of demersal deep-sea fishes we studied video sequences from dives performed with the French manned submersibles "Cyana" and "Nautile" at depths between 400 and 2000 m in the Bay of Biscay, NE Atlantic. Several behavioural parameters and habitat association patterns were quantitatively compared. In addition to the frequently occurring roundnose grenadier (*Coryphaenoides rupestris*), orange roughy (*Hoplostethus atlanticus*), and northern cutthroat eel (*Synaphobranchus kaupi*), the less abundant teleosts and several chondrichthyans were considered, too. These included, among others, *Bathypterois* sp., *Galeus melastomus*, *Helicolenus dactylopterus*, *Lepidion eques*, *Molva molva*, *Neocyttus helgae*, and *Phycis blennoides*. The behavioural analyses revealed clear differences among species or higher taxa in disturbance response, activity level, locomotion mode, or degree of attachment to the bottom. Furthermore, depth-related variations in locomotion behaviour and species-specific preferences for habitat types with distinct bottom structure and hydrological conditions were found. Our data suggest that deep-sea fishes respond behaviourally diverse, flexible, and choosy to the environmental conditions encountered in slope waters. These results provide new information on resource partitioning patterns and life-history and foraging strategies in deep-sea fishes. Implications for fisheries in slope waters are shortly discussed.

Introduction

Fisheries in the deep sea are still based on scarce information only regarding the small-scale spatial distribution and vulnerability of target species. Studies of habitat preferences and behaviour of deep-sea fishes should fill such gaps of knowledge and thus contribute to the development of a sustainable fisheries management. This presentation provides preliminary data on interspecific differences in habitat selection and locomotion behaviour of deep-sea fishes based on studies with manned submersibles. Quantitative statistical analyses of fish behaviour were carried out based on video tracks recorded during transects performed close to slope bottoms in the Bay of Biscay, NE Atlantic. The following questions were asked: (1) Do deep-sea fishes show differential distribution patterns at small spatial scale? This question deals with the problem of scale, which is one of the major challenges in deep-sea fisheries. (2) Are fish distribution patterns related to species-specific differences in locomotion behaviour and habitat selection? This question emphasizes the species-specific or "individualistic" component of deep-sea fish assemblages (e.g., Uiblein, 1966; Uiblein *et al.*, 1996; Merrett and Haedrich,1997; Wienerroither, 2001). Species may differ significantly from each other in their response to ecological conditions in the respective habitats. This may lead to local dominance of some species in distinct areas such as, for instance, seamounts, where orange roughy *Hoplostethus atlanticus* have been found to form dense aggregations (Koslow, 1997).

Material and Methods

Between 1996 and 1998 a total of 41 dives were carried out with the French submersibles “Cyana” and “Nautile” in the Bay of Biscay, NE Atlantic, within the two cruises “OBSERVHAL 96” and “OBSERVHAL 98” (Latrouite 1999). Most dives were aimed at tagging fishes for ageing purposes or observations of epipelagic or shelf-dwelling fishes. Five dives performed with “Nautile” during the second project as linear transects over slope bottom (Fig.1) at depths between 422 and 1848 m were used for the present investigation. The identification of taxa and quantitative behavioural analyses were based on the video recordings made with two cameras. The spoken comments of pilot and accompanying scientist facilitated species identification. Data on environmental conditions including depth, temperature, current velocity and current temporal variability, slope inclination, and bottom structure allowed to distinguish among different habitats (Uiblein *et al*., submitted).

For the behavioural analysis, the following categorical variables were studied: activity level (inactive, active, or arrival after prior disturbance), locomotion behaviour (inactive with no locomotion, station holding, drifting, and forward movement), position in water column (attached to, slightly above, well, or far above bottom), and flight response (no, far distance, or short distance flight response).

The multivariate matrix of taxonomic, behavioural, and ecological variables was studied using Multiple Correspondence Analysis (MCA) in order to investigate the association among the modalities of these categorical data. The four behavioural variables (see above) were set as active variables to define a "behavioural space". The additional variables (taxon, dive, habitat, depth zone, slope inclination, current velocity, current temporal variability) were set as illustrative in order to investigate their distribution in this space. Among the fishes studied, 63 were arriving already disturbed in the field of the camera and hence were excluded from this analysis. When some major feature could be observed and identified, the individuals displaying this combination of behavioural patterns were set as illustrative in order to better investigate the remaining individuals.

To determine the effect of each variable separately, the percentage of occurrence of each modality in each of the more abundant taxa (n>13) was graphically displayed and univariate analyses using G-test of independency were performed.

Results

A total of 1658 fishes belonging to 27 taxa and 18 species were encountered during the five dives. Of a dense aggregation of orange roughy in one habitat only a subsample was studied resulting in a total of 1362 fishes analysed.

Among the nine habitats, which could be distinguished by one or several environmental factors, clear differences in fish density and species composition occurred. Most of these variations were not related to depth. Particular high densities were found in two habitats of intermediate depths, which showed a numerical dominance of either northern cutthroat eel *Synaphobranchus kaupi* or orange roughy and roundnose grenadier *Coryphaenoides rupestris*.

The preliminary results of this study in progress (Uiblein *et al*., in preparation) based on Multiple Correspondence Analysis (MCA) are as follows: in the MCA along axis 1 individuals being attached to the bottom and/or inactive could be distinguished from all others (group 1, Fig.2a). Along axis 2 individuals showing drifting behaviour were separated from all others (group 2, Fig. 2a) and along the third axis station holding individuals were opposed to those moving actively forward. The setting of those individuals belonging to taxa with striking behavioural differences (= that were clearly distinguished along the axes) as illustrative elements allowed a further classification of the behavioural patterns of other taxa. At this stage, 1123 individuals remained in the analysis. The variable “activity level” was set as illustrative, too, because more than 95% of the individuals had the same modality for this variable. By this method four additional groups could be identified (Figure 2b).

For selected taxa with higher number of specimens univariate analyses were carried out to further identify interspecific differences in habitat selection and behaviour. This included the following species or genera: *S. kaupi*, *Notacanthus* sp., *Mora moro, Lepidion eques, Phycis blennoides, Molva molva*, *C. rupestris*, *Neocyttus helgae*, *Helicolenus dactylopterus, H. atlanticus*, *Galeus melastomus* and *Bathypterois* sp. Among these 12 species significant differences in at least one of the behavioural or habitat variables were found. Among four taxa showing relatively low activity level and less locomotion behaviour two (*H. dactylopterus*, *Bathypterois* sp.) were mainly attached to the bottom. The shark *G. melastomus* and the orange roughy were found more often slightly above the bottom and showed also station holding or forward movement. Among the other more active taxa, the four station holders *M. moro*, *L. eques*, *P. blennoides*, and *M. molva* could be identified. Two of them, M. *moro* and *M. molva*, are more attached to the bottom. *P. blennoides* showed the highest disturbance response during encounter with the submarine. The remaining taxa *S. kaupi*, *Notacanthus* sp., *C. rupestris*, and *N. helgae* showed more forward movement and a relatively high rate of drifting and were also encountered in a more elevated position above the bottom. Further differences among this group, but also among other taxa occur in habitat characteristics, in particular with respect to slope inclination or steepness (basin with no inclination, low, or high slope inclination), bottom type (soft, soft mixed with hard, or hard and highly structured bottom), current velocity (absent or very low, low, moderate, or moderate to high and high current), or current temporal variability (constant and no variation, moderate, or high variability). Two taxa *S. kaupi* and *Notacanthus* sp. were rather similar with respect to behavioural and habitat characteristics. This is however at least partly due to the rather wide distrbution among habitats and high behavioural flexibility found in S. kaupi (Uiblein et al. submitted and see below).

Interestingly, in some species like *S. kaupi*, behavioural variations among different habitats were found, too. This species occurred in a wide range of habitats and obviously adjusted to different ecological conditions with high flexibility. These findings were further substantiated by the analysis of swimming speed in this deep-sea eel species (Uiblein et al. submitted). Another indication of flexible adjustment to different habitat conditions is the occurrence of a large aggregation of orange roughy in the basin of a canyon where currents were very low or even completely absent (Lorance et al. submitted). In this habitat orange roughy was behaviourally inactive and could be approached by the submersible at rather short distances. This indicates to the function of this habitat as an area used for metabolic relaxation between foraging trips into the surrounding more turbulent areas where orange roughy usually forages (cf. Koslow 1997).

Discussion

In continuation of earlier studies of the submersible dives carried out during the cruises "OBSERVHAL 96" and "OBSERVHAL 98" (Latrouite, 1999; Lorance *et al*., 2000, Lorance *et al*., submitted, Uiblein *et al*., submitted) the present analysis of interspecific differences in spatial distribution and locomotion behaviour of deep-sea fishes demonstrates how these organisms adapt to ecological variation at small spatial scale. Such small-scale studies bear considerable importance for deep-sea fisheries, too, as they allow an *in situ* monitoring of the availability and vulnerability of target species. This data is necessary for the development of adequate fisheries methods and sustainable management strategies.

The present findings also emphasize the importance of regarding each deep-sea fish species as highly individualistic in behaviour and habitat choice which deserves more consideration in future community-oriented studies. Apart from such species-specific patterns, evidence for marked behavioural flexibility is provided. Such adaptive plasticity may allow proper adjustment to the rather heterogeneous and dynamic environmental conditions along the Gulf of Biscay continental slope.

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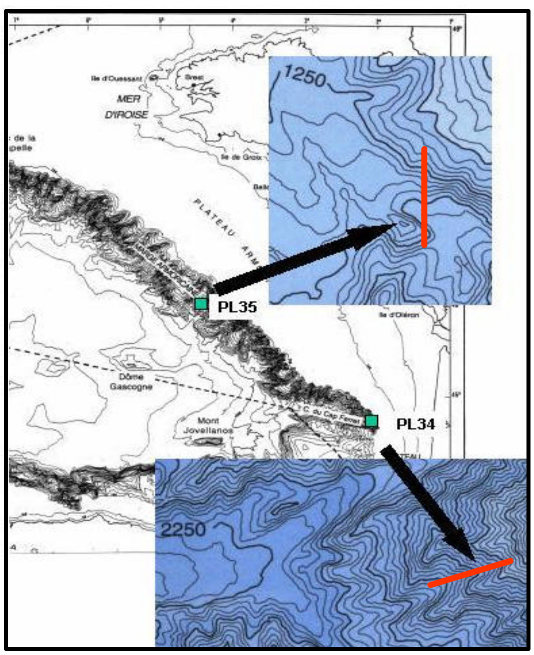

Fig.1. Example of two dives (nr. 34 and 35) with transects along the slope bottom of the Bay of Biscay, NE Atlantic, which were carried out during the OBSERVHAL 98 study and used for the present analysis.

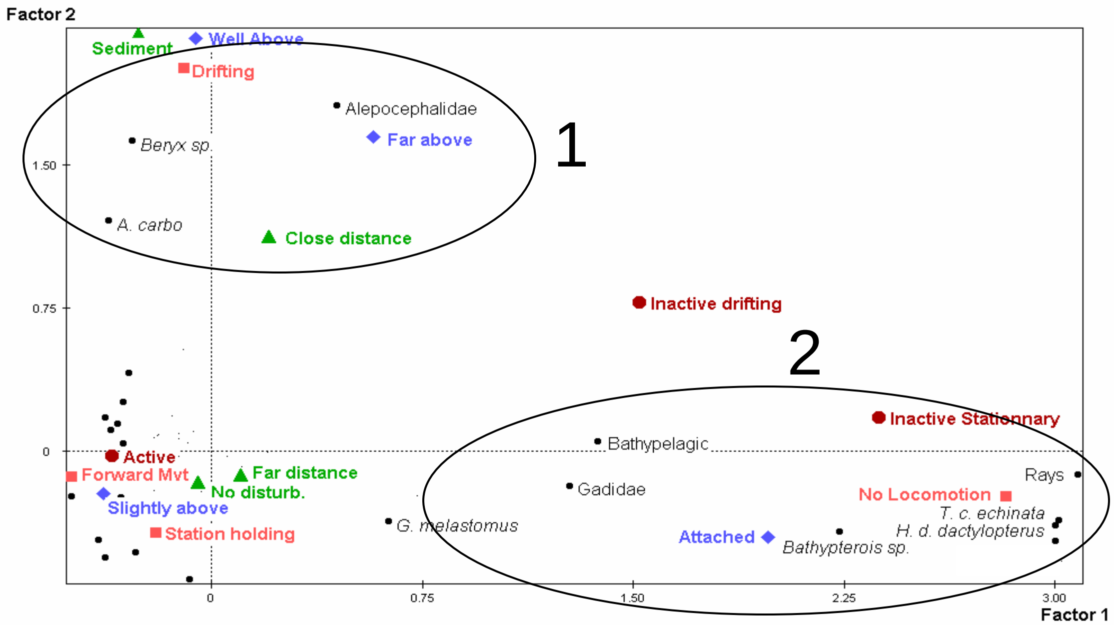

Fig. 2a. Results of Multiple Correspondence Analysis (MCA), first working step (see text). Names and positions of species and higher taxa in the "behavioural space" are indicated.

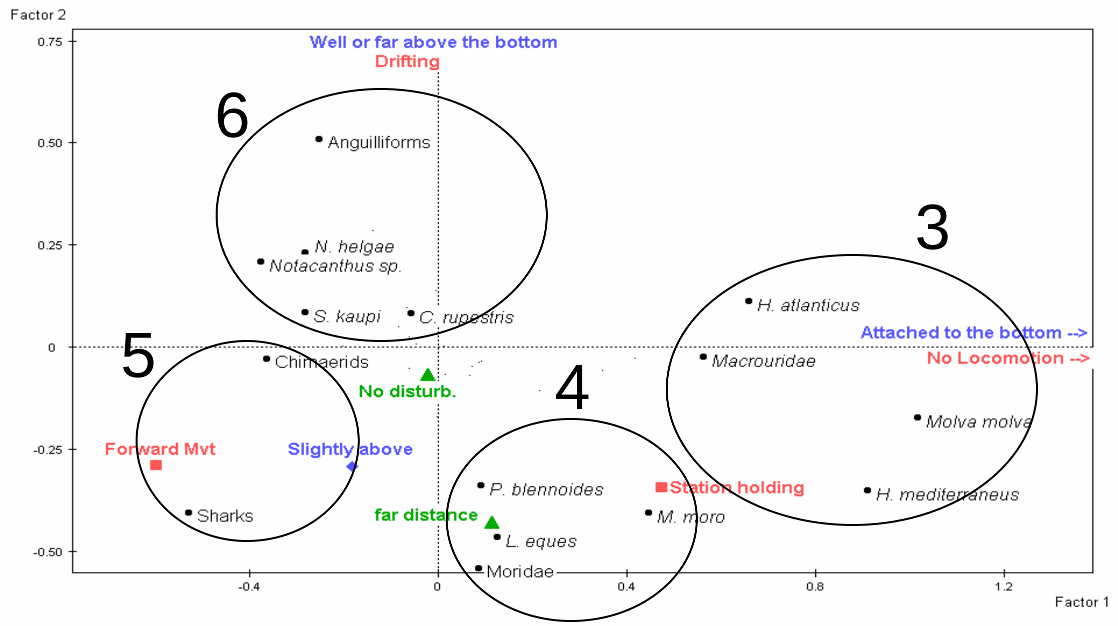

Fig. 2b. Results of Multiple Correspondence Analysis (MCA), second working step (see text). Names and positions of species and higher taxa in the "behavioural space" are indicated.