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Habitat selection in whiting

C. J. L. Atkinson, M. Bergmann and M. J. Kaiser*

School of Ocean Sciences, University of Wales-Bangor, Menai Bridge, Anglesey, LL59 5AB, U.K.

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Given a choice of habitats in a laboratory experiment, whiting *Merlangius merlangus* preferentially spent most time over sand, then gravel and least time over a habitat with emergent structures. The introduction of a predator stimulus increased the preference for the sand habitat for large whiting, whereas small whiting had an increased preference for the habitat with emergent structures.

Key words: habitat selection; ontogeny; whiting.

Fisheries managers have tended to focus their attempts to conserve stocks of exploited species to single species management. There is now, however, a much greater appreciation of the need to consider wider ecosystem effects of fishing on the marine environment and the potential influence of these effects on populations at higher trophic levels (Gislason *et al.*, 2000). The effects of towed bottom-fishing gears on sea bed habitats have been studied in detail over the last two decades and consistently demonstrate that such fishing practices reduce habitat complexity in areas of intensive fishing activity (Jennings & Kaiser, 1998; Auster & Langton, 1999). Habitat complexity has been shown to have important consequences for the survival of juvenile and young (+1 and +2 year group) stages of commercial species such as cod, *Gadus morhua* L. (Gotceitas & Brown, 1993; Walters & Juanes, 1993), and bedforms (*e.g.* sand wave habitat) provide cover for ambush predators such as silver hake *Merluccius bilinearis* (Mitchill) (Auster *et al.*, 2003). There is now greater emphasis on the need to manage both the effects of fishing on the target population and the direct consequences of those activities on habitats that may also affect survival and recruitment (Benaka, 1999). Thus, it is important to understand the characteristics of sea bed habitats that may be important for the survival of demersal fishes.

Whiting *Merlangius merlangus* (L.), are an important 'pressure' stock in the waters of northern Europe and with the demise of larger body-sized species are important predators at the higher trophic levels within their marine ecosystem. Despite a reduction in fishing mortality the stocks have declined over the past

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*Author to whom correspondence should be addressed. Tel.: +44 (0) 1248 383 751; fax: +44 (0) 1248 716 367; email: m.j.kaiser@bangor.ac.uk

20 years below the proposed precautionary levels as a result of overfishing and heavy discarding of juveniles in prawn fisheries (DEFRA, 2000). Although many aspects of the biology of whiting are well known, to date, no studies have investigated the ontogenetic change in seabed habitat use by whiting although it is known that some whiting are predominantly demersal as opposed to pelagic feeders (Pedersen, 2000). In the present study, the habitat preferences of adult whiting (20–26 cm total length, L_T) with and without the stimulus of a predator stimulus (a shadow passing over an experimental tank) were examined.

Whiting were caught on rod-and-line to minimize body damage and maintained in 60 × 60 × 90 cm opaque tanks under a 12L : 12D light regime and fed lugworm *Arenicola marina* L. and squid *Loligo* spp. every 2 days. Fish were held in groups of five individuals (two groups of small and two groups of large individuals) in each of four tanks, with a constant flow-through of sea water at ambient temperature. Within-size groups, fish were randomnly assigned to each group. Fish were fed 24 h prior to conducting any habitat choice trials. Habitat choice trials were undertaken in a 1·5 m diameter × 1 m deep grey circular tank housed in a room with blackened walls and ceiling with illumination provided overhead from fluorescent strip lights. The bottom of the tank was divided into three equally sized areas which intersected at the centre of the tank. Thus all three habitats were adjacent to each other, hence no bias could be introduced with respect to the proximity of one habitat to another. Each of these areas was completely covered with either sand, gravel (1–3 cm diameter particle size) or mixed sediments with emergent imitation foliose bryozoans, *Flustra foliosa* L. made from plastic sheet attached to a buried anchor substratum (emergent biota). Imitation bryozoans were used as live material and may contain cryptic prey that would have attracted fish to the cryptic habitat to feed and, thereby, would have confounded the experiment. These bryozoans represent some of the most prominent emergent fauna observed on the seabed in the Irish Sea and they provide shelter from seabed currents for juvenile gadoids (M.J. Kaiser, pers. obs.). Prior to experimentation, each group of fish was moved to a holding tank adjacent to the experimental tank. Behavioural observations began 24 h after fish had been transferred from the holding tank into the experimental tank. Direct observations of the number of fish observed over each substratum were made from behind an opaque screen through a small observation panel such that the fish were unable to see the observer. Fish were deemed to have selected a habitat when the entire body was observed directly over one of the habitats. The first experiment examined the habitat selection of each group of five fish separately with no external stimulus. Observations were made every minute during fifteen 30 min periods spread evenly during the day between 0900 and 1700 hours over a 72 h period. These data were expressed as the mean ($n = 15$) of the total number of fish observed over each substratum during a 30 min period. Of a total of 1800 records of fish habitat selection, only 1215 could be assigned as positive habitat selection (*i.e.* the entire body of the fish over one habitat). The second experiment examined the response separately of each group of fish to the passing of a shadow across the tank effected by a remotely released board that swung above the tank from one side to the other thereby momentarily casting a shadow across the tank. The shadow was designed to represent the stimulus perceived when a mammalian, avian or piscine predator would pass over a school of whiting. Each group of fish was observed immediately after and 1 and 2 min after the shadow was caste across the tank. This trial was repeated eight times with each group of fish with a period of 1 h between each run to prevent habituation. These data were expressed as the mean ($n = 8$) of the total number of fish observed over each substratum during the three observation time intervals (immediately after, 1 and 2 min after exposure to the predator stimulus). Thus the sampling effort after exposure to the predator stimulus is lower than for the observations made in the absence of a predator stimulus. All results were analysed using a two-way ANOVA testing for differences in the response of large and small fish (group factor) to different substrata (sand, gravel and emergent biota) after testing that the data were normally distributed ($A^2 = 0{\cdot}75$, $P = 0{\cdot}06$) and square root transforming the data to meet the assumptions of equal variance (Barlett's test statistic $= 1{\cdot}09$, $P = 0{\cdot}58$). Tukey-Kramer multiple comparison tests were performed when appropriate.

In the absence of any external stimulus all groups of fish spent most time over the sand habitat followed by the gravel habitat and spent least time over the habitat with emergent bryozoans (Fig. 1). There were no significant differences

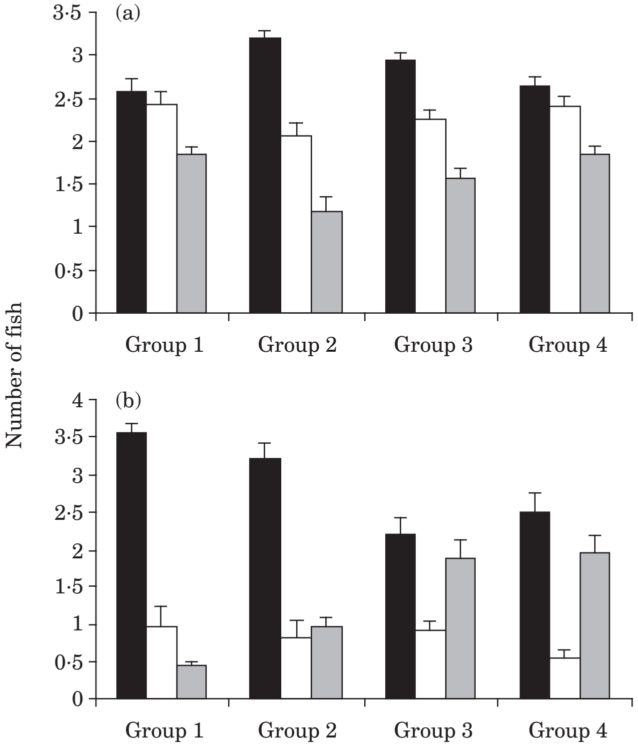

FIG. 1. Mean ± S.E. total number of fish over each substratum type (■, sand; □, gravel; ▨, emergent bryozoans) (a) 30 min^{-1} without any external stimulus ($n = 15$) and (b) during three consecutive 1 min observation periods after the introduction of a predator stimulus ($n = 8$). Mean ± S.E. total length: group 1, 23·6 ± 0·5 cm and group 2, 26·9 ± 0·7 cm (large fish); group 3, 20·4 ± 1·0 and group 4, 20·9 ± 1·9 cm (small fish).

between groups of small and large fish and there was no significant interaction term (Fig. 1 and Table I). Observations of fish over different substrata did not vary with the time of day when the observation was made (one-way ANOVA, d.f. = 4 and 88, $P = 0{\cdot}99$). The introduction of an external stimulus increased the strength of habitat selection made by the large fish and changed the choice made by small fish (Fig. 1). Small fish decreased their relative preference for the sand substratum and a similar number were observed within the habitat with emergent bryozoans, while gravel remained the least preferred substratum (Table I; all comparisons, Tukey-Kramer, $P < 0{\cdot}05$). For large fish, the introduction of the shadow stimulus increased their relative preference for the sand substratum and eliminated the preference for gravel over the habitat with emergent bryozoans.

Previous studies of habitat choice in gadoids have tended to focus on juvenile cod that demonstrate strong selection for complex habitats especially in the presence of a predation threat (Keats *et al.*, 1987; Gotceitas *et al.*, 1995; Fraser *et al.*, 1996; Gregory & Anderson, 1997). The emphasis of research on cod no doubt stems from its commercial and ecological importance and the over-exploited status of many stocks in the northern Atlantic, but this has perhaps diverted research effort away from habitat use by other species. In addition, behavioural studies have tended to concentrate on juvenile fishes that are easier to manipulate in aquaria, although *in situ* studies of silver hake have revealed the manner in which these fish conceal themselves in the troughs between sand waves where they can ambush prey as they move off the ridge of the sand wave (Auster *et al.*, 1997, 2003; Langton *et al.*, 1995). In the present study, smaller whiting were clearly attracted to complex habitats in response to a shadow stimulus passing across the tank while they preferred the least complex habitat (sand) under normal conditions. The larger whiting, however, exhibited a greater tendency to seek the featureless sand habitat in strong preference to either the gravel or complex habitat when the shadow stimulus was introduced.

TABLE I. Summary table of ANOVA for each of the habitat choice experiments, without and with an external stimulus. Habitat type (substratum) and fish group (small or large fish) are fixed factors

	d.f.	SS	*F*	*P*
Habitat choice with no external stimulus				
Group	1	0·106	0·106	0·74
Substratum	2	28·31	14·15	0·004
Group × substratum	2	0·345	0·172	0·83
Error	6	5·26		
Total	11	34·02		
Habitat choice with external stimulus				
Group	1	0·0001	0·00	0·98
Substratum	2	9·20	89·46	0·0001
Group × substratum	2	2·54	24·76	0·0001
Error	6	0·31		
Total	11	12·05		

This preference for sand may be linked to the aggregative behaviour of whiting that occur in large schools in the water column where they undertake diel migrations between the seabed and midwater to feed at different times of the day (Bromley *et al.*, 1997). Thus, schooling may be a more important threat avoidance mechanism than the use of shelter when fish reach a certain body-size. Furthermore, the dorsal colouration of whiting is a uniform dull brown that would give the best camouflage against a uniform background as provided by the sand habitat. Fishery survey data indicate that adult whting are captured over a wide variety of benthic habitats including mud, gravels and sandy substrata (pers. obs.). In this context, it may be noteworthy that whiting are known to switch diet with an increase in size from feeding primarily on crustaceans to piscivory and that this shift is most pronounced within the 21 cm (North Sea; Jones, 1954), 22 cm (Irish Sea; Nagabhushanam, 1964) or the 25 cm size-class (North Sea; A.P. Robb, M.A. Bell, J. MacMillan & J.R.G. Hislop, pers. comm.) groups. This size-dependent prey preference may also reflect in the behaviour of different size-classes as was found in the present study, which record the different behavourial responses to the same stimuli in fish that varied in mean body size by only 6 cm, and indicates that small and large whiting have different habitat preferences in response to a predator threat.

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