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Spatio-temporal variations in gillnet catch rates in the vicinity of North Sea oil platforms

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Use of decommissioned North Sea oil platforms as artificial reefs may provide an alternative to their being removed. Three fishing experiments with gillnet fleets lasting 3–5 days and using different mesh sizes were conducted in the vicinity of two platforms to study their potential as sites for commercial fishing. In each case, five fleets were set in a star-shaped pattern centred around the platform and running up to a distance 1400 m. Catches consisted mainly of cod (*Gadus morhua*) and saithe (*Pollachius virens*), and in one case also of ling (*Molva molva*). In two experiments, catch rates of nets set within a distance of 110–165 m of the platform were three to four times higher than those of nets set at greater distances. In the third experiment, the highest catches were taken 150–300 m from the platform, also by a factor of four compared to catches taken at greater distances. However, patterns differed among species, areas, and seasons. Catch rates varied considerably between fishing days, and in only one experiment did catch rates (specifically of ling) decline consistently throughout the fishing period, suggesting gradual depletion. Although the study provided evidence of pronounced aggregations of fish close to the platforms, responses are complex and results are inconclusive regarding species-specific temporal and spatial patterns.

Keywords: artificial reef, catch rates, gadoids, gillnets, North Sea, oil platform.

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Introduction

A large number of oil wells in the North Sea will soon have been exploited beyond their profitable level, and 14 out of 29 platforms on the Ekofisk field will have to be decommissioned. These platforms might be turned into artificial reefs as an alternative to being removed and brought ashore. The decision by the authorities on the future use of redundant rigs should be based on a thorough understanding of the consequences of the different options. To assess the potential use of decommissioned oil rigs as artificial reefs in commercial fishing, knowledge of the spatio-temporal variations in catch rates obtained in the vicinity of these rigs is needed.

Several studies have demonstrated that fish aggregate around both natural and artificial reefs (Bohnsack and Sutherland, 1985; Stanley and Wilson, 1991). Artificial reefs have been deployed in many areas to enhance local fisheries (Seaman and Sprague, 1991; Grove *et al.*, 1994). In the Gulf of Mexico, commercial and recreational fishermen use both active and decommissioned oil rigs as valuable fishing sites (Stanley and Wilson, 1990). Studies on fish aggregation and distribution in the vicinity of oil rigs in the North Sea are scarce (but see Olsen and Valdemarsen, 1977; Valdemarsen, 1979), and findings from studies in other areas cannot be applied directly to the North Sea situation because areas differ in both physical (e.g. temperature, depth, size, and rig design) and biological (e.g. species composition, ecosystem structure) aspects.

Fishing experiments were conducted with gillnets in the vicinity of two North Sea platforms, one partially decommissioned and one operational, to study their potential as sites for commercial fishing. They were selected to obtain information from sites that differed with respect to depth, bottom topography, rig design (steel jacket versus concrete), and species composition. The experiments were designed to provide quantitative

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data on fish abundance at different distances from the rigs, seasonal variations in fish abundance, and the effect of continued fishing for several days on catch rates.

Material and methods

The experiments were conducted at the Albuskjell 2/4 F and Gullfaks C oil platforms located in the central and northern North Sea, respectively (see Figure 1 in Jørgensen *et al.*, 2002). Fishing was carried out at Albuskjell during two periods (13–16 May and 6–10 September 1998), and at Gullfaks in one period (18–20 May 1998). The Albuskjell platform sits on a steel jacket (Figure 1a), has been partially decommissioned since 1990, and is located on flat, muddy and sandy bottom at 70-m depth. Gullfaks (Figure 1b) is a fully operational concrete platform located on a slope with mud, sand, and stones at a depth of 200–230 m.

Commercial gillnetters were chartered for the fishing experiments. Monofilament gillnets of mesh sizes from 132 to 180 mm were used to target species most likely to occur in the two areas and of a wide size range (cod (*Gadus morhua*), ling (*Molva molva*), and saithe (*Pollachius virens*)). In the two May trials, five fleets of 50 gillnets (each 27.5 m long) were used, which had the following mesh sizes: 132 and 140 mm (alternating nets), 148 mm (two fleets), 156 and 168 mm (alternating nets), and 180 mm. In the September trial, five fleets of 11–13 gillnets (each 75 m long) were used, two with 140 mm and three with 163 mm mesh sizes. Experimental designs in the May and September trials differed because the two vessels chartered were rigging their gear differently.

The five fleets of gillnets were set daily (with one exception when only four were set) between 16:00 and 23:00 h in a star-shaped pattern around the platforms (Figure 2) and hauled the following day between 8:00 and 14:00 h. Starting positions were as close to the platform as the skipper could go for safety reasons and some fleets were set along the platform before bending off to obtain maximum information from this area. The fleets of gillnets stretched out to a distance of 1375 m in the May trials and to 975 m in September.

For statistical analysis of spatial effects, catch rates (May: kg per two nets; September: kg per net) were compared between regions of increasing distance from the platform. The distance increment (i.e. the width of each region) in May and September corresponded to the length of two gillnets (55 m) and one gillnet (75 m), respectively. Nets were regarded as having fished within a certain region if >50% of the net was set within its boundaries. Catches were pooled and numbers and total weight by species were recorded for every second net in the May trials and for each net separately in September. Also, all individual fish were measured (total length).

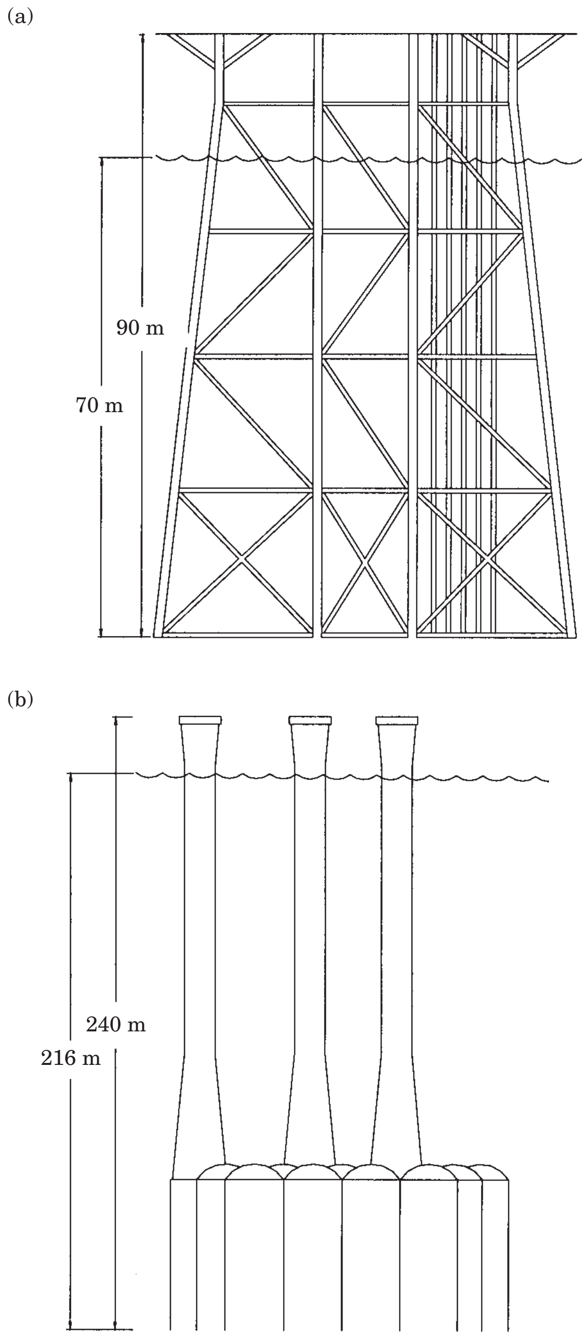

Figure 1. The constructions of (a) the steel jacket of Albuskjell 2/4 F and (b) the concrete legs of Gullfaks C.

Current speed was recorded on a current meter suspended 1.8 m above the seabed. These measurements showed a higher mean current speed at Gullfaks than at Albuskjell (12.7 and 8.7 cm s^{-1}, respectively). At Gullfaks, catch rates of the last nets closest to the rig were lower than those of the second last nets. Stewart

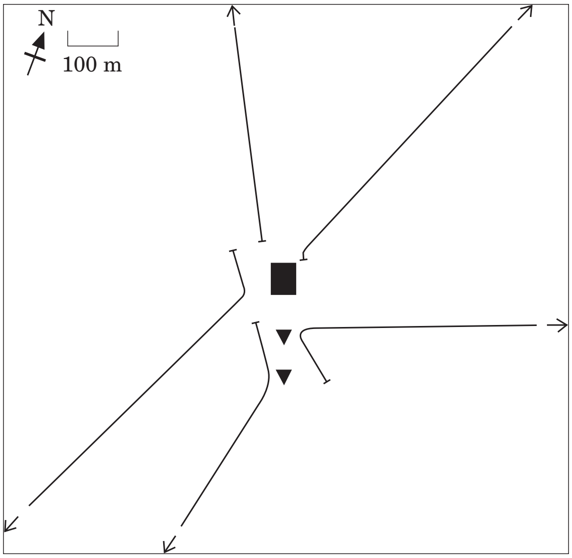

Figure 2. Typical setting positions of gillnet fleets around the platforms.

Table 1. Total catches (kg) of the main species taken at Albuskjell 2/4 F during 13–16 May and 6–10 September, and at Gullfaks C during 18–20 May 1998.

Species	Albuskjell May	Albuskjell September	Gullfaks May
Cod	2075	8462	1232
Ling	21	7	3886
Saithe	734	380	2716
Total	2844	8889	7850

(1988) showed that headline height of bottom-set gillnets is affected by current speed and skipper B. Rundereim of MS "Røyrbuen" experienced that this effect may be more pronounced for the net at the fleet end. End nets at Gullfaks were therefore excluded from the analyses.

Results

The most abundant species in the catches taken at Albuskjell was cod, while catches at Gullfaks consisted mainly of ling, saithe, and cod (Table 1). The total catch at Albuskjell in May was low compared to catches at Gullfaks and at Albuskjell in September.

All trials demonstrated that catch rates were affected by the distance between the position of the gillnet and the platform (Figure 3; one-way ANOVA, $p<0.05$). Catches were highest close to the platform and declined with distance. This trend was not an artefact of the curved shape of some fleets close to the platform because catch rates of nets set in a curve and those set in a straight line were not significantly different (Albuskjell – May: 8.2 and 6.6 kg; Gullfaks: 23.2 and 21.8 kg; Albuskjell – September: 38.8 and 38.7 kg, respectively; t-tests).

At Albuskjell in May, only nets within a distance of 110 m from the platform showed elevated catch rates (three times higher than those of nets set at greater distances), and catch rates (species combined) of the 0–55 m nets were twice as high as those of the 55–110 m nets (Figure 3a). Catch rates at Gullfaks were sufficiently high to allow separation by species. The pattern for ling was remarkably similar to the pattern observed at Albuskjell in May: gillnets set closer to the platform than 165 m gave catch rates four times as high as those set at greater distances, and catch rates of nets set in the region closest to the platform (55–110 m) were about twice as high as those of the next two nets (110–165 m) (Figure 3c). Catch rates of cod (although low) and saithe did not show any effect of distance from the platform.

Catch rates at Albuskjell in September showed a different pattern compared to both May trials. The highest catch rates were taken in the third and fourth nets (150–300 m), and decreased gradually at greater distances from the platform (Figure 3b). Catch rates also decreased towards the platform, but these differences were not significant.

Daily variations in mean catch rates were large (Figure 4). For the two trials conducted at Albuskjell, there was no significant decrease over the fishing period (one-way ANOVA), although the lowest catch rates were observed during the last fishing day. At Gullfaks, catch rates dropped significantly over the 3-day period ($p<0.05$).

Cod caught in the two regions closest to the Albuskjell platform were significantly smaller during both sampling periods than those caught in the three to five outermost regions (two-sample t-test; Table 2). Ling at Gullfaks showed the same tendency, but the difference was not significant.

Discussion

Fishing experiments aimed at studying spatial variations in catch rates in the vicinity of oil rigs require the use of passive fishing gears because active gears are difficult to operate near rigs (Soldal *et al.*, 2002). A preliminary trial with longlines and pots conducted at Albuskjell in May had yielded very low catch rates, and therefore we used gillnets here. Gillnets are highly size-selective, and conclusions can be drawn only on the abundance and distribution of fish in the size range efficiently caught in the nets used. We employed mesh sizes commonly used in commercial fishing because we were primarily interested in marketable fish.

In interpreting the results, we assumed a linear relationship between catch rates and fish abundance. We

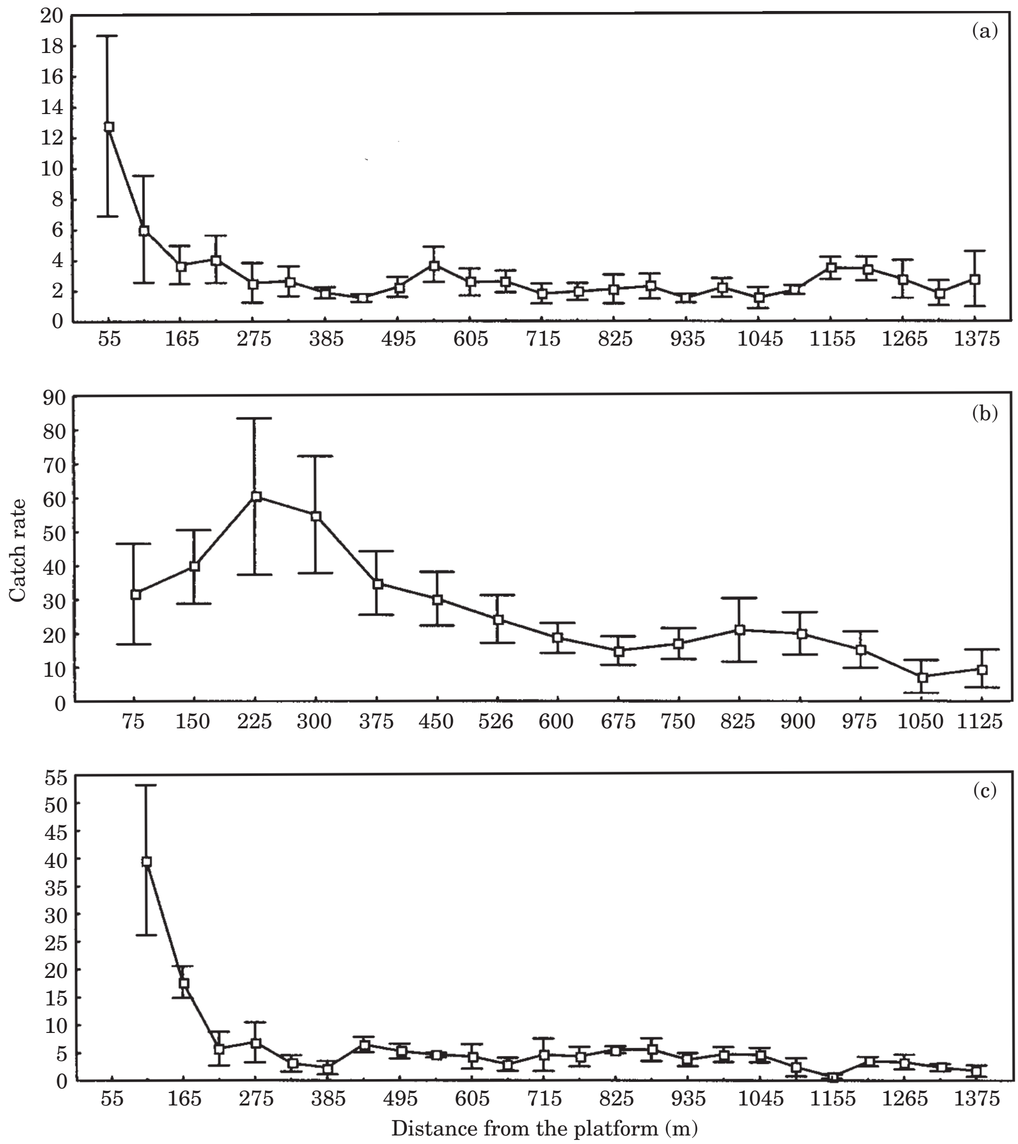

Figure 3. Mean catch rate (bars: s.e.) of gillnets in relation to distance from the platform: (a) Albuskjell 2/4 F in May (cod and saithe: kg per two nets); (b) Albuskjell 2/4 F in September (mainly cod: kg per net); and (c) Gullfaks C in May (ling: kg per two nets).

found no evidence that catch rates were affected by the curve in the gillnets set closest to the platform, and gear saturation seems unlikely because catch rates were relatively low. According to Meth (1970), gear saturation might occur if catch rates exceed 58 fish per gillnet, a figure that was seldom reached (Figure 3). However, abundance close to the platform may have been underestimated because of the higher fishing effort in this area and potential effects of depletion. Nevertheless, catch rates increased rapidly close to the platforms, indicating a pronounced increase in fish abundance. However, the effects differed among species, areas, and seasons.

Increased abundance of fish around oil platforms has been demonstrated in the Gulf of Mexico (Stanley and Wilson, 1990, 1997) and in the North Sea (Olsen and Valdemarsen, 1977; Valdemarsen, 1979). Lower risk of predation, higher prey densities, and shelter from the current have been suggested as possible explanations of the tendency for fish to congregate at artificial reefs (Bohnsack *et al.*, 1991; Spanier, 1996). The latter two factors seem more important in this case, because the catches were dominated by large gadoids that may prey directly or indirectly on organisms known to colonize rigs (Olsgard and Gray, 1995), and at least cod have

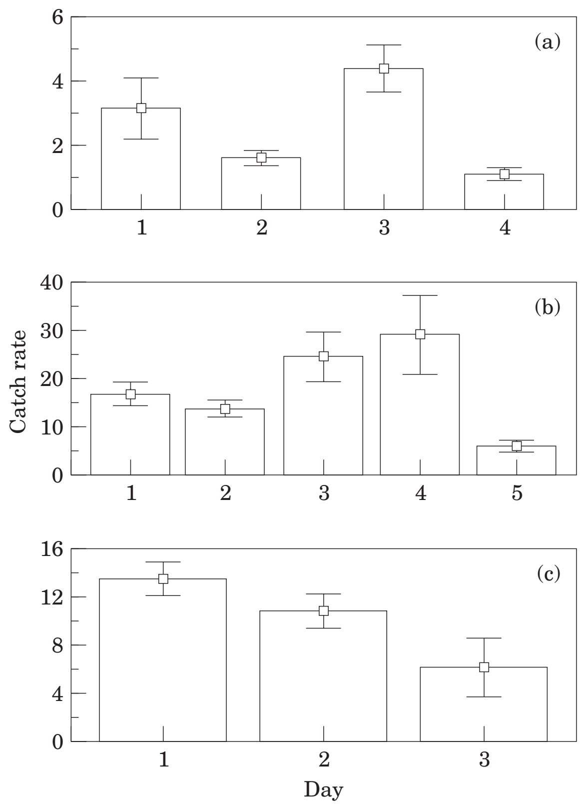

Figure 4. Mean catch rates (bars: s.e.) of target species during successive days at (a) Albuskjell 2/4 F in May (kg per two nets), (b) Albuskjell 2/4 F in September (kg per net), and (c) Gullfaks C in May (kg per two nets).

Table 2. Mean length (cm) of cod and ling caught in the two regions closest (close) to and the three to five regions furthest (far) from Albuskjell 2/4 F in May and September and from Gullfaks C in May (in parentheses: standard deviation and number of fish measured).

Region	Cod, Albuskjell May	Cod, Albuskjell September	Ling, Gullfaks May
Close	64.2 (8.0, 144)	64.4 (18.0, 271)	99.5 (13.8, 99)
Far	69.4 (9.0, 69)	73.0 (14.1, 324)	102.2 (10.8, 107)
p, t-test	<0.05	<0.05	n.s.

been observed to maintain position by heading upstream close to a platform leg (Løkkeborg *et al.*, 1989). There are few known predators of large cod (Pálsson, 1994), and ling are also regarded as top predators (Bergstad, 1991).

The higher abundance of fish at Albuskjell in September than in May may be due to seasonal differences in behaviour. The difference in experimental design between May and September trials may have affected the result, but cannot explain the threefold increase in total catch in September. The higher abundance in September was associated with a peak at 150–300 m distance from the platform and increased densities over a much larger area than in May. When more fish aggregate at an artificial reef, the advantages of staying close to the reef may decrease, which might explain the dispersal over a wider area. However, the harsher weather conditions in September also may have made it more difficult for the fish to maintain their position close to the steel jacket. Indeed, fishermen have experienced that fish disperse further off platforms in bad weather (B. Rundereim, pers. comm.). However, it cannot be ruled out that the lower catches nearer the platform are caused by depletion owing to the higher gillnet density.

At Gullfaks, only ling was concentrated around the platform, while cod and saithe were evenly distributed. These species-specific differences suggest that cod and saithe may avoid areas of high densities of ling. In addition, tracking studies have shown differences in space utilization between ling and cod, where ling spent most of its time in a relatively small core area within its home range, while cod utilized its home range more evenly (Løkkeborg *et al.*, 2000). These different patterns were explained by interspecific differences in prey choice, with cod taking a high proportion of stationary prey that may become depleted when feeding is restricted to a small area, whereas ling may meet its food requirements by attacking larger and more mobile prey (Bergstad, 1991) passing through the core area. Likewise, Sarno *et al.* (1994) showed that saithe roam more widely around a reef than pollack (*Pollachius pollachius*), and they explained this difference by diversification in feeding strategies.

The differences in bottom topography in the areas around the two platforms, as well as their designs, may have affected the results for individual species. A uniform, flat bottom such as around Albuskjell may result in stronger aggregation of widely roaming species such as cod and saithe than the sloping and more diverse substrate around Gullfaks. Furthermore, steel jackets have more complex structures than a concrete platform, and may thus form a more attractive reef (Pickering and Whitmarsh, 1997), as supported by underwater camera observations showing aggregations of cod at Albuskjell (Løkkeborg *et al.*, 1989; Soldal *et al.*, 2002).

The differences in temporal depletion as indicated by declining catch rates after fishing first started may also be explained by species-specific differences in space utilization. The more stationary ling (Løkkeborg *et al.*, 2000) are likely only slowly to recolonize an area that has been intensively fished. In contrast, wide-ranging cod and saithe may recolonize an artificial reef faster. Colonization of new reefs may occur within hours after they have been deployed (Shulman, 1985). However, catch data often show large variations (Gulland, 1983), and the effects of continuous fishing for several days may be masked by variations in catch rates owing to a variety of factors including, for instance, environmental conditions, fish activity, setting time, and sheer luck.

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