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Rigs-to-reefs in the North Sea: hydroacoustic quantification of fish in the vicinity of a "semi-cold" platform

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We describe an experiment intended to estimate the extent to which decommissioned platforms in the North Sea attract fish. The work was carried out at a "semi-cold" platform in the Norwegian Sector between May and September 1998. Hydroacoustic quantification and trawling carried out by a research vessel running transects from the platform out to a distance of five nautical miles did not demonstrate higher concentrations of fish near the platform. However, for practical and security reasons the vessel was not permitted to operate closer than 50–100 m to the platform. To measure concentrations of fish close to the sides of the jacket, acoustic transducers were hung from three sides of the platform. Large differences in fish density were observed, depending on the side of the platform concerned, time of day, and season. During daytime, mackerel were schooling around the platform, while demersal fish tended to be found under the platform and close to the bottom. At night, the demersal fish spread throughout the water column in such a way that their distribution was suitable for acoustic biomass estimation. Estimated densities of cod and saithe were 0.13, 0.27, and 0.24 kg m^{-2} in May, July, and September, respectively, with corresponding biomass estimates at the platform of 7, 14, and 108 t. An additional 2.3 and 1.2 t of mackerel was present in July and September, respectively.

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Introduction

Since oil production on the Norwegian continental shelf started in 1971, the petroleum industry has greatly increased in economic importance. Today, the largest fields have all passed their peak production and the output is declining. Some smaller fields have ended production or are in the process of being closed down. In the course of 1998, 14 platforms in the Ekofisk field were shut down. The closure plan for Ekofisk was submitted to the Norwegian Ministry of Petroleum and Energy in autumn 1999. The plan included an evaluation of a number of disposal options for each individual platform. Several studies were launched to provide the best background information about the options selected.

The experiments described here formed part of a study intended to estimate the extent to which decommissioned oil platforms attract fish. As has been done successfully in the Gulf of Mexico (Gurney, 1992), this was used as input to the decision process concerning whether North Sea platform jackets could be used as artificial reefs. The rigs-to-reefs concept has not yet been adopted in the North Sea, and efforts put into quantifying aggregations of fish around rigs in this area have been limited.

Fish abundance at natural and artificial reefs has usually been quantified by means of diving techniques (Bortone *et al.*, 1989), but harsh weather conditions and greater depths make this method less suitable in the North Sea. We therefore developed hydroacoustic techniques similar to those previously used by Thorne (1994)

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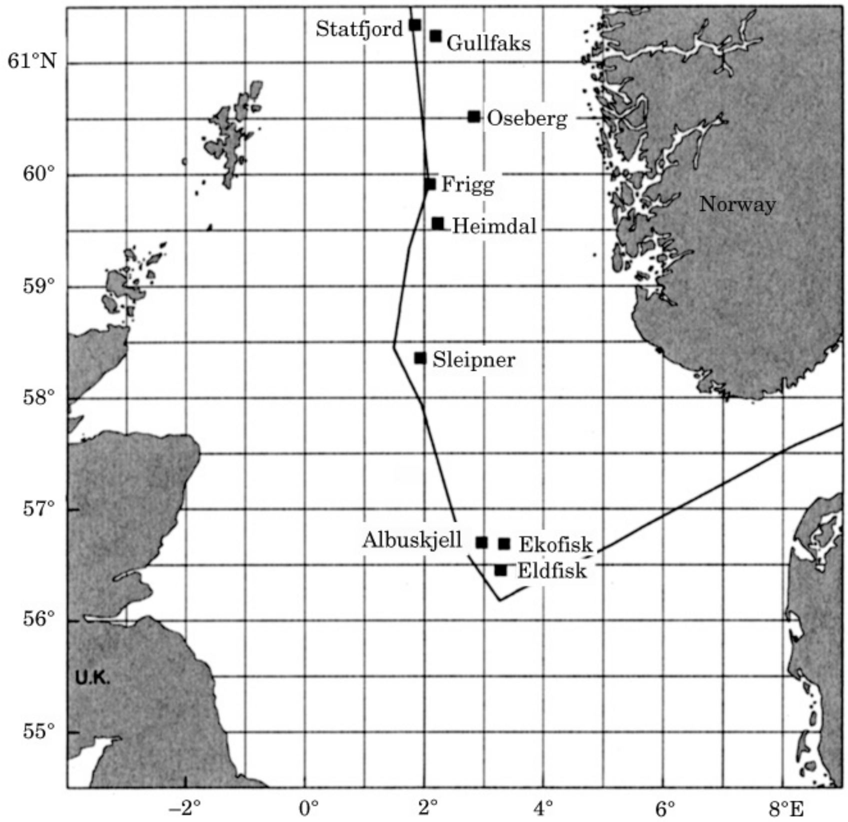

Figure 1. Location of the experimental platform, Albuskjell 2/4F, in the Ekofisk field in the North Sea.

and Stanley and Wilson (1996, 1997) to estimate fish abundance at a decommissioned platform.

Materials and methods

Experimental area

The study was performed near the Albuskjell 2/4 F platform on the Ekofisk field in the Norwegian Sector of the North Sea (Figure 1). The platform is "semi-cold", i.e. production was shut down in 1990 and has remained unmanned since, except for occasional maintenance. There is neither noise nor discharge of food waste or sewage, but the platform is still illuminated at night. It stands on a steel jacket weighing 7320 t and measuring 50 × 65 m at the base, forming an open grid structure between the bottom and the surface (Figure 2). The seabed is flat and homogeneous with sand and clay at a depth of 70 m.

Research-vessel samples

The RV "Michael Sars" (overall length 45.7 m, GRT 493, 1500 hp) was used from 11 to 25 May 1998 for acoustic quantification of fish and trawling experiments around the platform. It was equipped with a hull-mounted split-beam transducer (38 kHz) and a SIMRAD EK500 echosounder connected to the Bergen Echo Integrator System (Knudsen, 1990). Acoustic measurements were made along transects, with the platform at the centre and out to a distance of five nautical miles (Figure 3). The vessel passed as close to the platform as safety permitted, i.e. 50–100 m. Four acoustic surveys were performed, two during daylight hours and two at night.

Fish abundance was estimated using standard hydroacoustic methods (MacLennan and Simmonds, 1991). In interpreting the acoustic data, the water column was divided into a bottom channel (from the seabed up to 10 m) and a pelagic channel. In the bottom channel, echo integrator values were split among cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), whiting (*Merlangius merlangus*), herring (*Clupea harengus*), and other demersal fish according to the appearance of the echo recordings and the species composition in trawl catches. In the pelagic channel, the integrator values were split among plankton, saithe, and pelagic fish on the basis of the echo

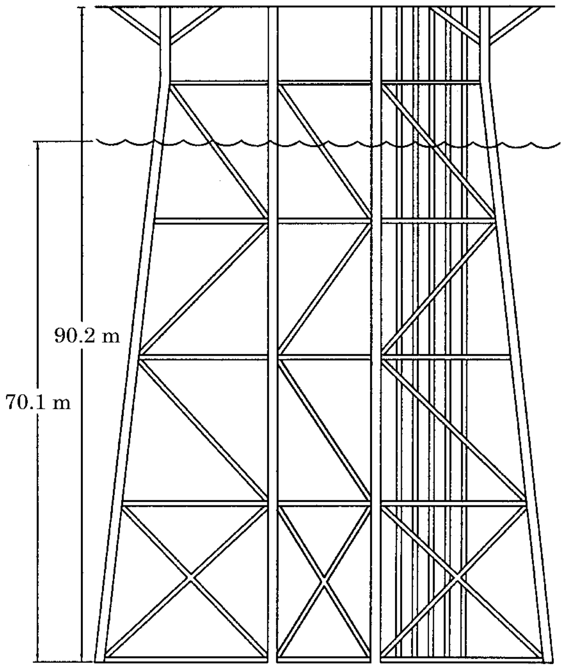

Figure 2. The steel jacket of Albuskjell 2/4F.

recordings only. This was done for each 0.1 nautical mile (185.2 m) along the survey transects.

To identify species and size distributions of fish observed in the bottom channel, as well as to compare catches taken at different distances from the platform, a Campelen 1800 bottom-sampling trawl (80 mm stretched mesh size in the codend) rigged with rockhopper gear and Waco trawl doors (2 × 3 m, 1400 kg) was used. Trawl hauls were made parallel to the survey tracks at three different distances from the platform (Figure 3) from as close to the platform as possible to five nautical miles out. In total, 47 hauls were made at a towing speed of 1.5 ms^{-1} and with a duration of 15 min.

For each species identified, a GLM analysis (General Linear Models, SAS Institute Inc. 1989) was carried out to test for differences in acoustic fish density at different distances from the platform. The model used was

$$\gamma_{ijk}=\mu+\alpha_i+\beta_j+s+\varepsilon_{ijk} \quad (1)$$

where y was the measured S_A-value (acoustic density) for species A, μ was the expected value of y, α was the effect of distance from the platform, β was the effect of time of day (light or dark), s represented first- and second-order interaction effects, and ε was a random error term. An identical model was used to test for a distance effect on catch rates, where y was the total catch (in kg) of the species concerned.

Platform samples

Underwater video observations (UTV) of fish concentrated under the platform were made in July and September by lowering a high-sensitivity camera (Osprey SIT) with a pan and tilt head from the platform deck to the bottom.

Acoustic quantifications from the platform were carried out during three periods: 11–25 May, 8–10 July, and 1–11 September 1998. Three 120 kHz split-beam transducers (Simrad ES120-7/G) were lowered to a depth of 6–8 m to the north, east, and west sides of the platform (Figure 4). The three transducers were sequentially connected to an echosounder (Simrad EK500) via a multiplexer (Simrad MP500). The number of transmissions in each sequence was 10, with a 2-s interval between each transmission, giving 10 transmissions from each transducer every minute, day and night. Data were stored on tape for subsequent interpretation using the Bergen Echo Integrator as described above. To achieve comparable integrator values among transducers, each was calibrated separately according to standard procedures (Foote *et al.*, 1987).

Acoustic values were split among species mainly on the basis of the appearance of the echo recordings, but in addition UTV observations and information on the species composition in gillnet catches obtained in a simultaneous fishing experiment (Løkkeborg *et al.*, 2002) were used. Cod and saithe were mixed close to the bottom, and because their size distributions were similar, they were treated as one species category (cod/saithe). The integrator values were also split among herring, mackerel, and plankton. Mackerel were observed throughout the observation periods in July and September, but not in May. Only cod/saithe and mackerel were observed frequently enough to make a significant contribution to the analyses.

The acoustic backscattering cross-section of individual fish, $\langle\sigma\rangle$, is the average contribution of each fish to the integrator value (McLennan and Simmonds, 1991), and is used to convert the acoustic density of fish to absolute fish density according to Urich (1975):

$$\varsigma=4\pi\ 10^{0.1TS} \quad (2)$$

The length-dependent average target strength (TS) is known for a number of species (Foote, 1987): for codfish, TS=20 logL − 68 (dB), and for mackerel TS=20 logL − 77 (dB).

The transducers hung from the platform yielded three spot measurements of fish density close to the platform. To obtain an overall estimate of the amount of fish close to the platform, the average of the night values from the three transducers was used, assuming uniform fish distribution in the area covered by the platform and out to a certain distance. The determination of this distance

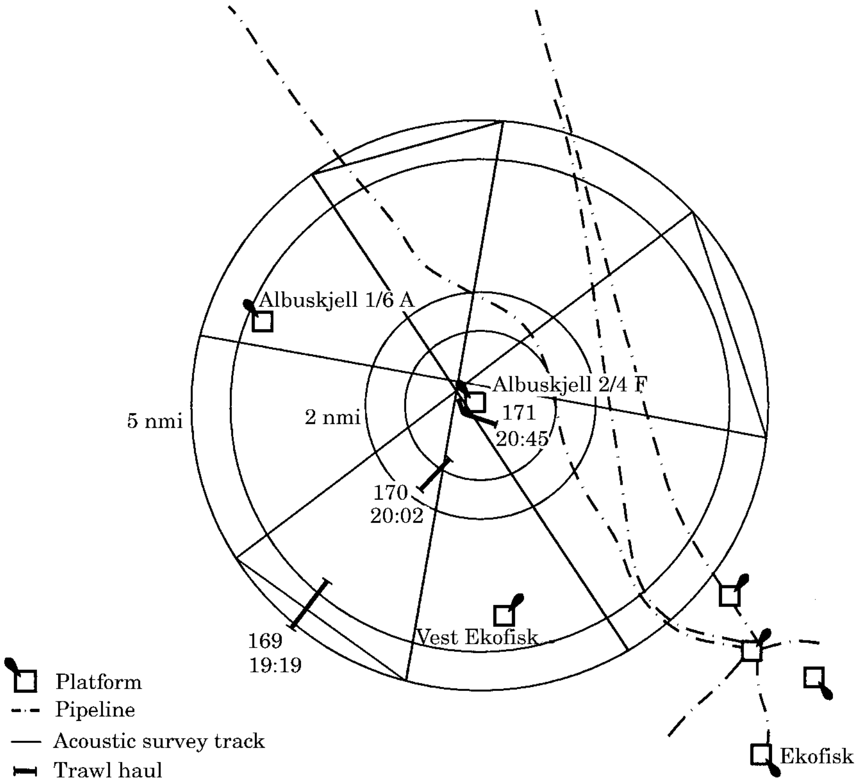

Figure 3. Acoustic survey tracks (unbroken lines running through the centre of the circle) and one subset of trawl hauls taken at three different distances from the platform.

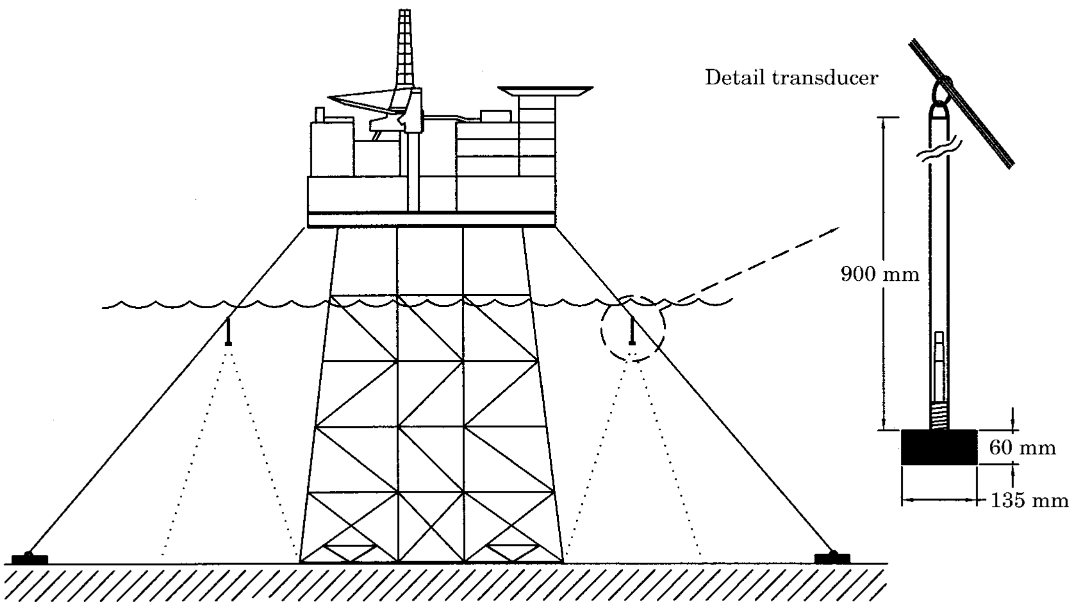

Figure 4. Rigging of acoustic transducers at the platform. The transducers were lowered along a rope anchored to the bottom at one end and secured to the platform at the other.

Table 1. Average size of trawl catches (N: number of fish; W: weight in kg) taken by RV "Michael Sars" at three different distances from the platform.

	Haddock		Saithe		Cod	
	N	W ± s.d.	N	W	N	W ± s.d.
Near platform	10	3.3 ± 2.5	1	0.6	10.7	10.7 ± 8.8
1.25–2 nm distance	39.2	9.5 ± 10.2	—		12.6	5.8 ± 3.7
4.25–5 nm distance	72.2	17.9 ± 15.9	1	2.9	15.7	6.8 ± 4.7

Table 2. Total number (N) and average individual lengths (L in cm) of cod and haddock caught by trawl at three different distances from the platform.

	Cod		Haddock	
	N	L ± s.d.	N	L ± s.d.
Near platform	139	43.8 ± 14.3*	121	31.4 ± 6.0
1.25–2 nm distance	164	31.8 ± 11.0	509	28.9 ± 4.2
4.25–5 nm distance	204	33.1 ± 11.8	886	28.8 ± 4.9

*Significantly larger than other groups ($p<0.01$).

was not straightforward, as no direct measurements were made. On the basis of the spatial distribution of the gillnet catch rates in the simultaneous fishing experiment (Løkkeborg *et al.*, 2002), we assumed uniform fish density out to a distance of 50 m, and of half this density from 50–100 m. In September, however, increased gillnet catches were obtained out to a distance of 300 m from the platform. For September, therefore, we have made two estimates, one assuming the same fish distribution as in May and July, and the other assuming a uniform fish distribution out to 300 m from the platform.

Results

Research-vessel samples

Acoustic density on the Ekofisk field was generally low during the period when the experiments were carried out, and GLM analyses did not show any increase in fish density close to the platform. However, the analyses showed significant differences in the amount of fish according to time of day. More cod, saithe, and plankton were registered during the day than at night.

Species composition in the trawl catches was dominated by cod, haddock, and saithe, followed by several species of flatfish [long rough dab (*Hippoglossoides platessoides*), lemon sole (*Microstomus kitt*), and plaice (*Pleuronectes platessa*)]. The average catches of the three most abundant species at different distances from the platform (Table 1) indicate significantly less haddock close to the platform than further off. No significant differences were found in the catches of cod, although there was a tendency in the direction of larger catches in weight close to the platform. Cod caught close to the platform were indeed on average larger than those caught further off (Table 2).

Platform samples

In May, the acoustic recordings were dominated by cod/saithe. In July and September, cod/saithe made up the largest fraction of the fish biomass recorded close to the bottom, while shoals of mackerel were seen circling around the platform at a depth of about 30 m. Although cod/saithe was treated as a single category in the analyses, the appearance of the echo traces indicated that saithe were most frequent in May, while cod dominated in July and September. The highest fish densities were found close to and up to 10 m from the bottom. Fish densities varied widely with time of day and side of the platform, with significantly higher acoustic values being recorded at night and on the east side of the platform (Figure 5). Target strength measurements showed that cod/saithe were within the length range of 60–90 cm.

Underwater video observations in July and September showed demersal fish, particularly cod, very close to the platform legs near or at the sea bottom during the day, where they could not be measured acoustically. At night, however, the fish rose from the bottom and spread throughout the water column. To estimate fish density, therefore, we used the average night values of the acoustic recordings. This gave fish densities of 0.13, 0.27, and 0.24 kg m^{-2} in May, July, and September, respectively. The total amount of cod/saithe close to the platform was estimated at 6.8, 14, and 12 t, respectively. For September, the alternative estimate based on the wider distribution observed produced a total estimate of 108 t. Both UTV and acoustic recordings showed that

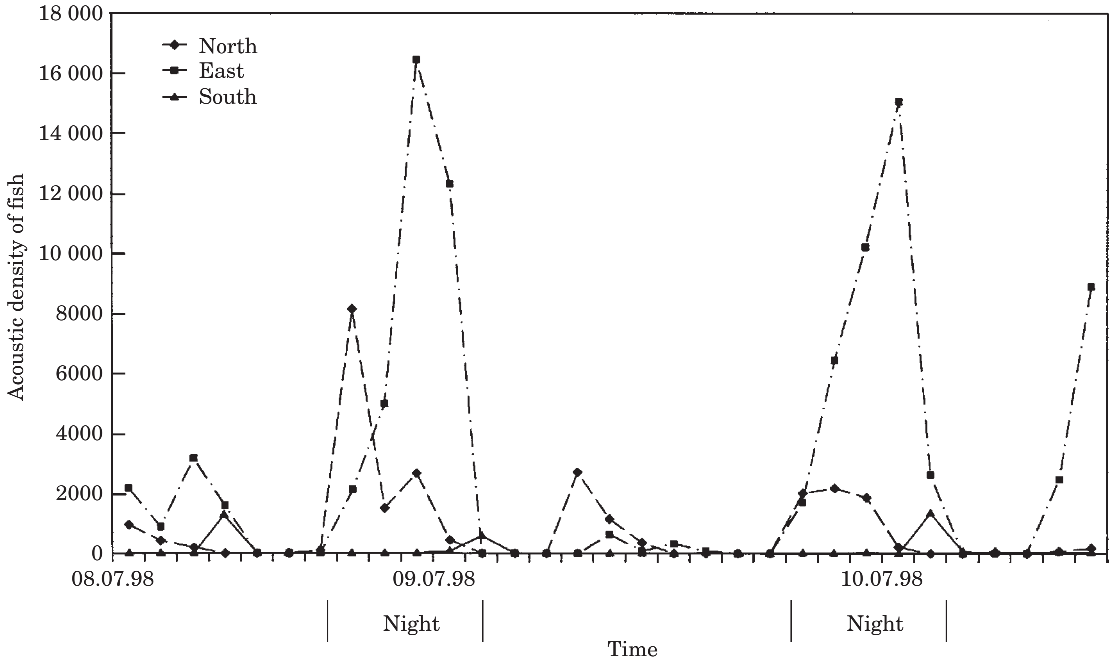

Figure 5. Measured acoustic density (S_A) of cod/saithe on the northern, eastern, and southern sides of the platform in July. Measurement interval corresponds to a period of 1 h 30 min.

mackerel were more evenly distributed throughout the day, and that they were not as closely linked to the jacket structure as cod and saithe. The estimated mackerel densities were therefore based on the average acoustic density over the entire experimental period in July and September, giving a biomass of 2.3 and 1.2 t, respectively.

Discussion

Trawl hauls and vessel-based hydroacoustics did not reveal any increase in fish density close to the platform, while the acoustic measurements from the platform showed a large amount of fish present close to the structure. The research vessel could not operate safely closer than 50–100 m to the platform, and this may not have been close enough to reveal the fish concentrations associated with the platform. Fishing experiments with gillnets during the same periods (Løkkeborg *et al.*, this volume) yielded significantly higher catch rates in nets standing close to the platform, also suggesting that platforms do attract fish. These observations are in accordance with the results of earlier fishing experiments performed at Ekofisk (Olsen and Valdemarsen, 1977; Valdemarsen, 1979). Also, observations from routine video inspections of pipelines and jackets showed that large amounts of fish may gather around underwater structures, and that they are closely associated with the structures themselves (Cripps and Abel, 1995).

Two distinct communities dominated the area around the platform studied: pelagic fish, mainly mackerel, schooled at a depth of about 30 m, while large predators, cod and to a lesser degree saithe, aggregated close to the structure. Similar observations have been made at a platform offshore Cameroon (Gerlotto *et al.*, 1989). Bohnsack *et al.* (1994) have previously shown that larger reefs, like our platform, comprise larger but fewer individuals than smaller reefs. This has been attributed to competitive advantages of larger individuals and predation. We observed that average size of cod caught by trawl close to the platform was larger and catches of haddock were lower than further away from the structure, possibly because smaller cod and haddock were eaten or scared off by the large fish inhabiting the reef.

Fish density varied considerably according to time of day and horizontal location relative to the platform. The highest density was found at night, when the fish spread throughout the water column in a way that made them more accessible to acoustic detection. A similar behaviour pattern has been observed in other species (Gerlotto *et al.*, 1989; Thorne *et al.*, 1989; Thorne, 1994). As has been reported by Stanley and Wilson (1997), fish densities also varied considerably from one side of the platform to another. This may be due to prevailing water currents making one side more favourable for foraging, or offering shelter from the currents.

Most attempts to quantify fish stocks near natural or artificial reefs have used visual techniques (diving, UTV) (Bortone *et al*., 1989), although some have also used hydroacoustic techniques similar to the one used here (Thorne *et al*., 1989; Stanley and Wilson, 1996, 1997). Stanley and Wilson (1997) measured fish abundance by using four acoustic transducers hung from each of the four sides of a platform and also assumed fish densities measured by the transducers close to the platform to be valid for the area under the platform.

To obtain an estimate of the total biomass of fish at a platform site, the area over which the fish are (evenly) distributed must be known. We have no accurate measurements of the distribution area, but only indications obtained from research vessel transects and fishing experiments, which led us to assume that the fish were evenly distributed out to a distance of 50–100 m from the platform in May and July, and out to 300 m in September. However, these distances are based on indications only and are highly uncertain. Stanley and Wilson (1997) measured the distribution area by using a horizontally oriented acoustic transducer and observed an increase in fish density only 16–20 m off the platform in the Gulf of Mexico. Based on routine video inspections of pipelines and jackets in the North Sea, Cripps and Aabel (1995) reported a sharp drop in fish density at a distance of 50–100 m from the platforms.

Overall, we conclude that decommissioned platforms in the North Sea might be used effectively as artificial reefs. They do attract fish, particularly cod and saithe, to an extent that the profitability of fishing operations might be enhanced, at least for a limited number of vessels.

Acknowledgements

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