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Fisheries

Different behaviour of North and Irish Sea cod

Cod (*Gadus morhua*) are bottom-living, predatory fish of considerable commercial importance¹, but surprisingly little is known of what cod do for most of their time because it is difficult and costly to study the behaviour of fish at sea^{2,3}. Here we use electronic data-storage tags to investigate the behaviour of cod in the North Sea and in the Irish Sea and find that there are marked differences in the activity of fish in the two regions. This difference could be explained by dissimilar foraging ecology and may have implications for the future management of severely depleted cod stocks.

Evidence from acoustic⁴ and fishing⁵ surveys can be used to infer variations in behaviour patterns between different cod stocks, but behavioural data have never been collected simultaneously from individual fish from different stocks over timescales appropriate to fisheries management⁶. In March–April 1999, we tagged 78 cod (each over 50 cm long) with electronic data-storage devices: 58 were in the southern North Sea and 20 in the central Irish Sea. Twenty-two tags have so far been returned from fish caught in the North Sea, providing over 1,500 days of data, and four have been returned from the Irish Sea (over 750 days of data).

By using the depth record to estimate a cod's activity, we found that Irish Sea cod were extremely active at all times (dark regions in Fig. 1a), showing no discernible evidence of diurnal or seasonal patterns. North Sea cod were also very active during April and May, but in June all fish still at liberty (8 fish) showed a marked reduction in vertical movement, and in July they spent much or all of their time on the sea floor. Fish still free in August and September (5 fish) became active at night, and during October and November (2 fish) they returned to activity levels seen in the previous April and May (Fig. 1a). In a follow-up experiment in 2000, we monitored the position of North Sea cod implanted with

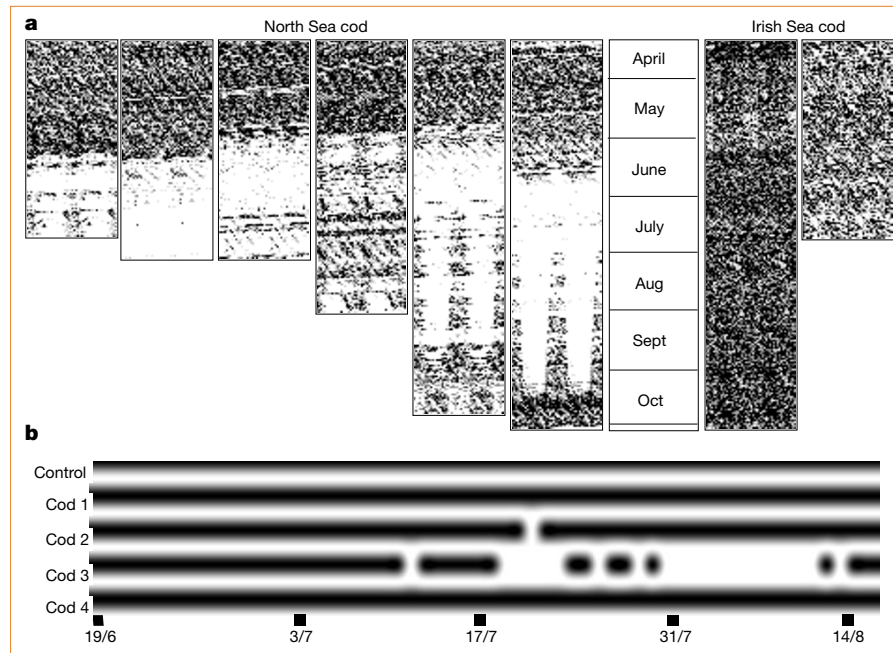


Figure 1 Cod behaviour in the North Sea and Irish Sea. **a**, Activity between April and November 1999. Active and inactive states of each individual were determined from the depth (measured every 10 min) record of its tag (Lotek Marine Technologies LTD100). When an individual was 'inactive' on the seabed, its tag recorded only the smooth changes in pressure resulting from the rise and fall of the tide. Individuals were classed as 'active' when vertical movements were more rapid or irregular than could be accounted for by the tide alone. For each hour of the day, summed hourly activity held a value between zero (white; inactive) and six (black; most active). Each fish's activity record is shown as a double-plot actogram, with data in 48-h periods along the x-axis and days of the year along the y-axis. **b**, Residence on summer feeding grounds in the North Sea in 2000. A moored listening station continuously monitored the presence (bars) or absence (no bar) of four individuals implanted with individually coded acoustic tags. The listening station had a detection range of 500 m. The control tag was located within 200 m of the listening station for the duration of the experiment.

individually coded acoustic tags and demonstrated that their range of movement during the summer months (mid-June to mid-August) was less than 1 km (Fig. 1b).

The technology is not yet available to measure the feeding behaviour of fish directly in the field. However, our results indicate that North Sea cod reduce their foraging movements during the summer months. This observation challenges the explicit assumptions of multispecies management models⁷ that cod are active and forage over substantial geographical areas. By contrast, Irish Sea cod appear to be active throughout the spring and summer. We propose that these differences in activity could be behavioural responses to variations in the distribution and abundance of prey species between sea basins, an idea we intend to test by using a tag equipped with a feeding sensor to investigate the feeding dynamics of free-ranging cod.

Low spawning-stock biomass, increased seawater temperatures and high fishing rates have put North Sea and Irish Sea cod stocks under great pressure^{8,9}. Special technical conservation measures designed to provide protection for cod have been specified in recovery plans announced in 2000 for the Irish Sea¹⁰ and recently for the North Sea¹¹. A significant component of these plans involves closing particular areas of sea to fishing for short periods of time.

Our findings show that the activity of cod varies through the year, and that seasonal patterns of activity differ between stocks. To our knowledge, this is the first time that the activity patterns of cod from different stocks have been described over extended periods at such a fine temporal and spatial scale. This understanding will improve our ability to predict the effectiveness of fisheries management by closed areas in different regions.

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