

Electronic data storage tags (DSTs) were used to reveal the temperatures experienced by cod (*Gadus morhua*) tagged in the southern and northern North Sea. Our initial findings reveal that individuals did not adjust their behaviour in order to maintain a constant mean temperature but instead appeared to follow the seasonal trends in environmental temperature.

## Introduction & Methods

Fish vary their behaviour in response to changes in environmental and biological conditions and it has long been known that the recruitment and distribution of cod stocks may be influenced by temperature. We tagged cod with electronic data storage tags (DSTs, LTD\_1200\_100 Lotek) programmed to record water temperature ( $-4$  to  $23^{\circ}\text{C} \pm 0.03^{\circ}\text{C}$ ) every ten minutes. Tagged cod were released off Lowestoft (southern North Sea) and off the Shetland Isles (northern North Sea) between 1999 and 2003. We present the temperature records collected over 4000 days from 22 individuals and compare the temperature experience of cod in the southern and northern North Sea.

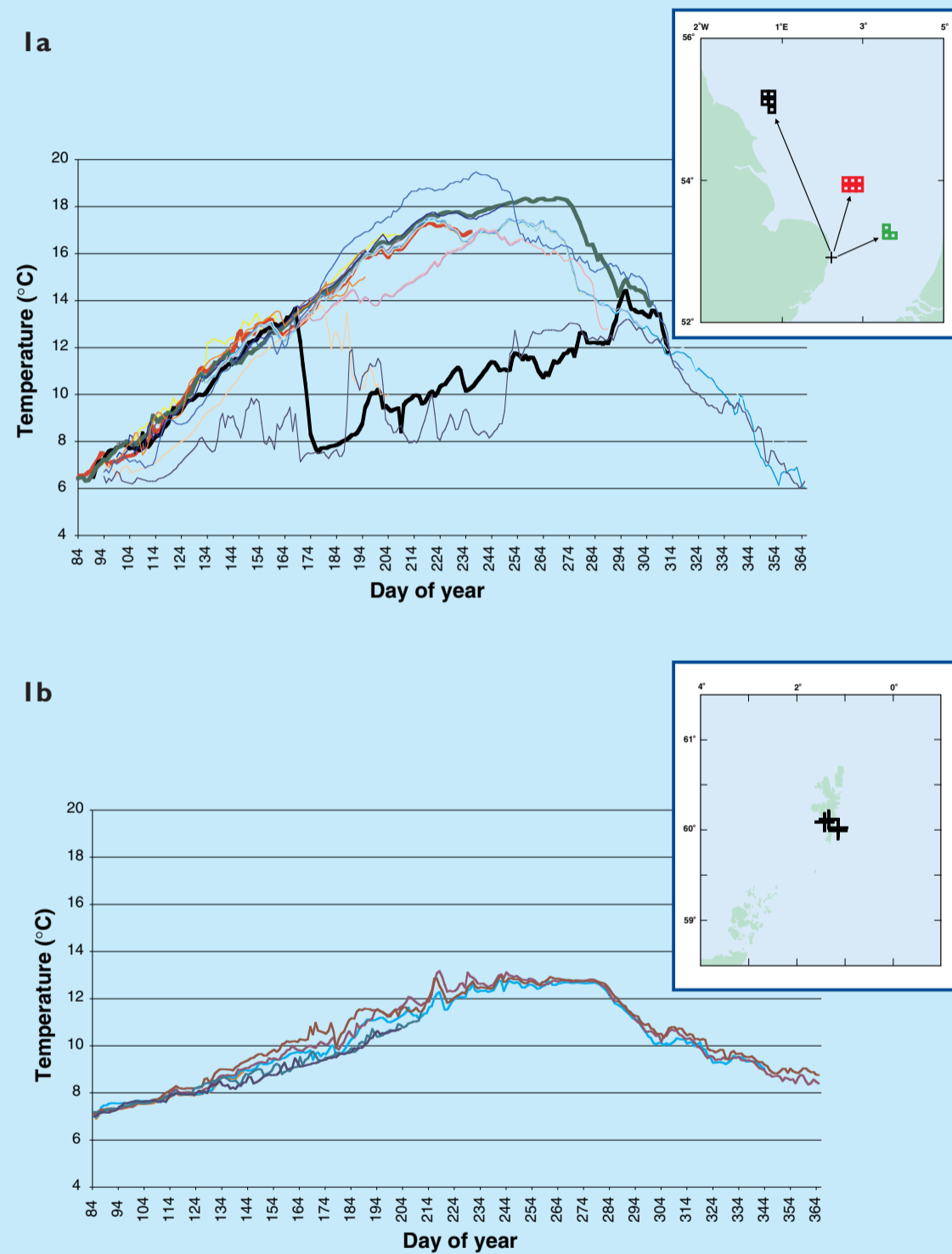


Figure 1: The daily mean temperature experienced by cod in (a): the southern and (b): the northern North Sea. The map inserts show the release positions and the summer distribution of three southern individuals.

Comparisons of the daily mean temperature (Figure 1), show that cod in the southern North Sea experienced a much wider mean temperature range ( $6.4^{\circ}\text{C} - 16.2^{\circ}\text{C}$  compared to  $7.0^{\circ}\text{C} - 12.9^{\circ}\text{C}$ ) and higher mean temperatures whilst at liberty, particularly during the summer months (Days 150 – 250). Both sets of fish reached a maximum temperature peak at a similar time (Day 221 in the southern North Sea and Day 218 in the northern North Sea) but the temperature experienced was much higher in the south ( $16.0^{\circ}\text{C}$  compared to  $12.7^{\circ}\text{C}$ ). Three individuals that were released together in the southern North Sea (Figure 1(a)), appeared to migrate along a similar thermal path until day 168 (17th June 1999, temperature  $13.6^{\circ}\text{C}$ ). The three temperature records then diverged and the fish were later geolocated at different locations in the North Sea (See Figure 1 (a) insert maps). In general though, the temperature records from the majority of individuals appear to have followed seasonal trends in environmental temperature.

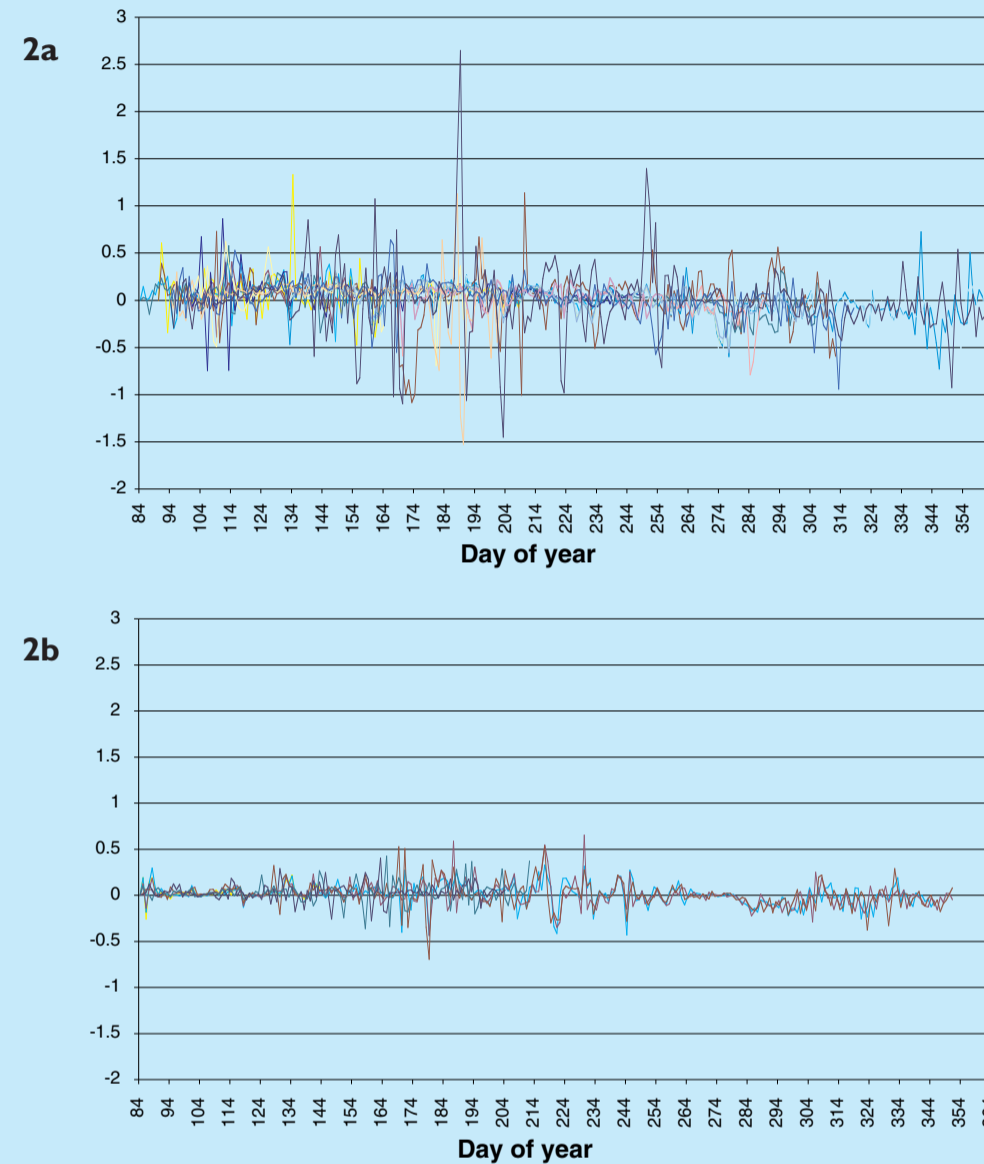


Figure 2: The differences in daily mean temperature in (a): the southern and (b): the northern North Sea.

Increases in daily mean temperature were often followed by decreases and vice versa (Figure 2). However, while this could be interpreted as a behavioural mechanism to maintain an equilibrium temperature, a statistical runs test showed that 19 out of 22 fish had significantly fewer such patterns than expected ( $p$ -value  $< 0.05$ ).



Cod (*Gadus morhua*)

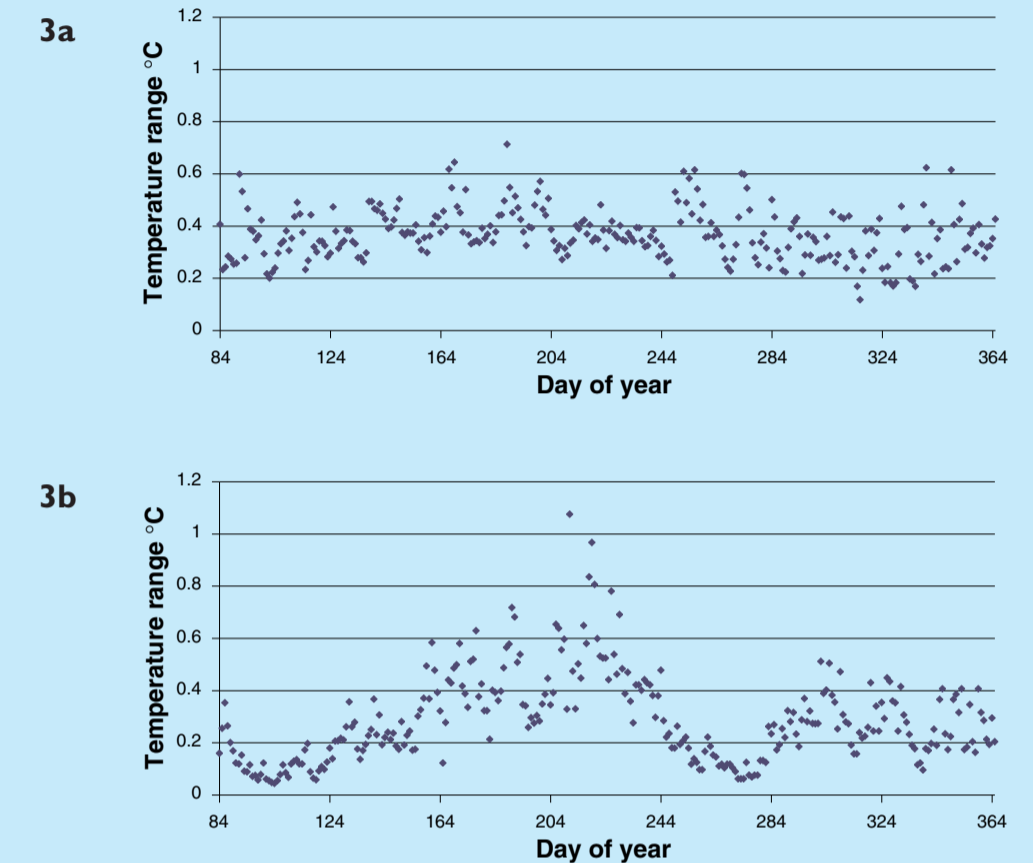


Figure 3: The daily mean temperature range experienced by cod in (a): the southern and (b): the northern North Sea.

Figure 3 shows that the spread of the mean temperature range was similar for cod in both the southern and northern North Sea (range  $0.2 - 0.6^{\circ}\text{C}$ ). However, the amplitude of the range experienced by cod in the southern North Sea was more consistent throughout the year and did not show the seasonal variations experienced by cod in the northern North Sea, which appeared to have the lowest amplitude around days 100 and 275 (spring and autumn).

Cod in the southern North Sea experienced the lowest amplitude of range between days 200 – 250 (Figure 3(a)). Previous work has shown that these fish show a decrease in activity at this time and spend the summer months predominantly on the seabed. In contrast, cod in the northern North Sea (Figure 3(b)) at this time show the highest range of amplitude.

## Conclusions

- Cod in the southern North Sea experienced much higher mean temperatures than cod in the northern North Sea throughout the year.
- Individuals showed no evidence of regulating their temperature by behavioural means though at least three of the southern North Sea fish appear to have chosen different thermal and migratory pathways to the others (Figure 1(a)).
- The daily temperature range experienced by cod in the southern North Sea was more consistent throughout the year and did not show the cyclical seasonal pattern experienced by cod in the northern North Sea.
- Future work will be to look at the temperature experience of more individuals by position and time, to use finer scale environmental data to compare the DST temperature with that of the environment, and, in particular, to identify the spatial distribution of the thermocline in the North Sea.