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Movements, migrations and space use of fish in the North Sea in relation to offshore wind farms

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Summary

Important commercial fish species like plaice, cod and thornback rays have complex movement patterns characterised by seasonal migrations and distinct habitat preferences. A key knowledge gap for assessing the impact of marine renewable energy developments is how large-scale marine wind turbine arrays will affect fish migrations and space use because no large-scale, long-term 'before-and-after' study has been conducted to assess this prospect directly. Wind turbine arrays constructed across migratory routes or in essential habitat may lead to displacement of fish into sub-optimal habitats where they may either not be accessible to existing fishing fleets, or into areas that are more intensively exploited. We present an analysis of a unique set (>400) of electronic tag records collected from plaice (217), cod (96) and thornback rays (117) between 1993 and the late 2000s in southern North Sea areas that were free of large-scale wind farms at that time. The depth time series data have been analysed using a tidal geolocation method imbedded in a hidden Markov model (HMM) to reconstruct migration pathways and determine space use in relation to areas now occupied by Round 1 and 2 wind farms, and prior to development of large Round 3 sites. This analysis provides information that can be used, inter alia, for designing statistically robust "post construction" studies to establish if and how windfarms have affected the migration pathways and patterns of space use for these species and how these in turn may impact fishery capture rates.

Introduction

The EU Renewables Directive of 2009 requires that by 2020 20% of the energy consumed within the EU is obtained from renewable sources. As of October 2010, 3.16 GW of offshore wind power capacity was operational, mainly in Northern Europe, with more than 16 GW of additional capacity to be installed in the next few years. Globally, offshore wind power capacity is expected to be 75 GW worldwide by 2020. A key knowledge gap is how large-scale wind turbine installations affect long-distance migration and space use patterns of fish, and, consequently, how these effects may contribute to changes in fishery capture rates. It is possible that turbine arrays constructed across migratory routes or in essential habitat used by fish for feeding or spawning lead to displacement of fish into suboptimal habitats, where they may be either not accessible to existing fishing fleets, or may occur in more intensively exploited areas. However, currently, there has been no large-scale 'before-and-after' study assessing this prospect directly over the time scale of years. We used telemetry data collected in the late 1990s and early 2000's to assess the overlap between windfarm development sites and the space use of three species of demersal fish.

Materials and Methods

We tagged European plaice (*Platessa platessa*), Atlantic cod (*Gadus morhua*) and thornback ray (*Raja clavata*) caught in the North Sea with archival electronic tags programmed to record depth and temperature data every 10 minutes. Daily estimates of geographic location were made using a geolocation method that used tidal range data, and depth as inputs. Data on the location and size of current and future windfarm arrays were used to assess spatial overlap between the occupied area of individuals and groups of fish. Probabilistic measures were developed to assess the potential impact of windfarm arrays at different times of year.

Results and Discussion

We tagged 2430 fish between 1993 and 2006 (Figure 1). In total, 217 recoveries were achieved from plaice, 96 from cod and 117 from thornback ray, comprising more than 58,000 days of data. Space use of individuals related to their stock of origin. Plaice tagged in the western or southern North Sea used tidal streams to migrate between spawning and feeding areas in the eastern English Channel and the Dogger Bank, while those tagged in the eastern North Sea used the German Bight and the Great Fisher Bank. Cod tagged in the southern North Sea were either resident or moved north to occupy deep water north of the Dogger Bank. Thornback rays tended to remain in the Thames Estuary, where they were tagged, but made migrations out into the wider North Sea and into the English Channel. Spatial overlap between fish populations and proposed or active windfarms varied between seasons, with probability reaching a maximum of 0.65 during the winter months when individuals were migrating to spawning grounds. Our measures of tag return rate, time at liberty & power analysis of space-use allows us to identify best future releases sites in relation to wind-farm (or other) locations. These data also enable us to estimate the scale, cost and likely success of future tag release studies needed to assess impact of offshore industrial development.

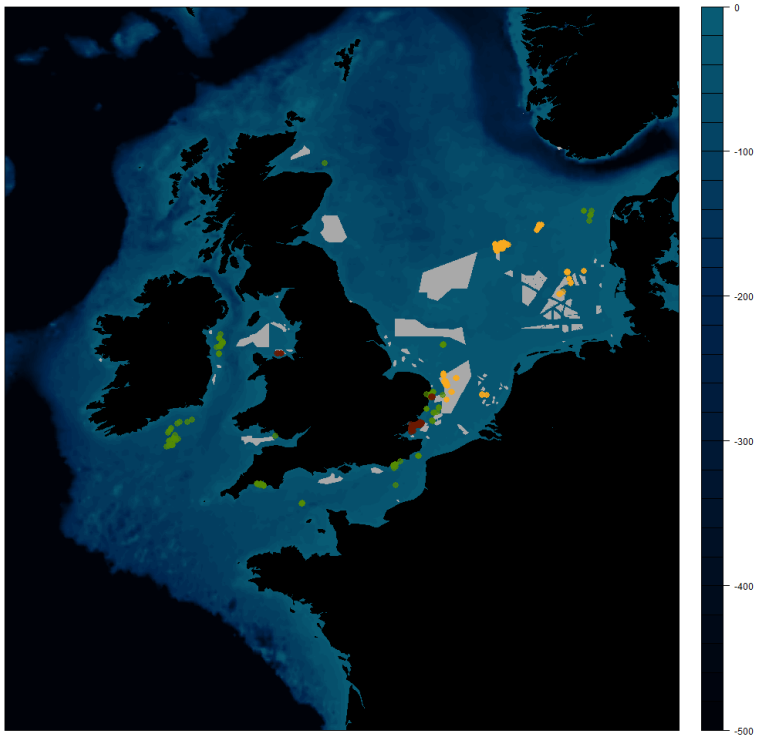

Figure. 1 Planned and operational windfarm areas (grey) in relation to release locations of Atlantic cod (green), thornback ray (red) and European plaice (yellow).