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A detailed characterisation the spawning distribution of Blue Whiting

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Summary
We provide here the strongest evidence to date supporting the existence of two independent Blue Whiting (*Micromesistius poutassou* Risso, 1827) stocks in the North Atlantic. In spite of extensive data collected in conjunction with the fishery and management of this species, the population structure of Blue Whiting is poorly understood. In particular, genetic, otolith and drift modelling studies point towards the existence of two stocks, but observations of adult distributions point towards a single stock. A paradox therefore arises in attempting to reconcile these two pieces of information. Here we analyse 1100 observations of Blue Whiting larvae from the Continuous Plankton Recorder (CPR) from 1948-2005 using modern statistical techniques. We show a clear separation between a Northern spawning component, in the Rockall trough, and a Southern one, in the Porcupine Seabight. We further show a difference in the timing of spawning between these components of at least a month, and statistically significant differences in interannual variability. The results, taken with previous studies, therefore support the two-stock hypothesis. Furthermore, we resolve the spawning paradox by showing that the acoustic observations cited in support of the single-component model are not capable of resolving both stocks, as they occur too late in the year and do not extend sufficiently far south to cover the southern component.

Introduction
Blue whiting (*Micromesistius poutassou* Risso, 1827) is a small pelagic planktivorous gadoid that is found throughout the Northeast Atlantic. The first scientific reports date back more than a century and the species has been the subject of a large commercial fishery since the late 1970s, and of fisheries surveys, a formal stock assessment and agreed management regimes since the early 1980s. In 2004, it was the third largest marine fishery in the world and comprised 80% of the landings in the Farore islands: the population has however since collapsed and recent scientific advice recommended the closure of the fishery altogether. Yet, in spite of the relative importance of this fish population, and the wealth of information and studies that normally are associated with an assessed species, there are still important gaps in our understanding.

One major knowledge gap is the population structure. A long-running line of argument suggests that the population consists of two separate populations: one northerly population spawning to the west of Great Britain and the Outer-Hebrides and a second southerly population spawning around Porcupine bank. This hypothesis is supported by genetic studies, otolith growth studies, morphometric and meristic studies, and oceanographic circulation modelling. However, acoustic observations of adults on the spawning ground suggest one large agglomeration, with no separation into components. Furthermore, the stock is managed as a single stock: the most recent ICES advice even goes so far as to deny the possibility of two stocks, stating "*...there is no scientific evidence in support of multiple stocks with distinct spawning locations or timings.*"

In this work, we investigate the spatial and temporal distribution of Blue whiting larvae observations from the Continuous Plankton Recorder (CPR). In particular, we hope to gain a comprehensive overview of the spawning distribution with the benefit of modern statistical modelling techniques.

Materials and Methods

CPR blue whiting larval observations covering the area to the west of the British Isles from 1948-2005 were obtained upon request from SAHFOS. Both presence and confirmed absence observations were incorporated in the data set analysed. Observations were modelled using a Generalised Additive Model (GAM) incorporating interactions between longitude, latitude, and day of year, with day/night and year as additional terms.

Results

The fitted models were demonstrated to have extremely high quality fits to the observations, with an AUC of 0.97 for the best model. Models incorporating component-dependent effects were shown to be statistically superior to those without them.

Two centres of high-spawning density were clearly apparent in the fitted models (Figure 1). One centre occurs over the Rockall trough, whilst the other appears in the Porcupine Seabight. These centres also differ in the timing of spawning by a month, and show statistically different interannual variability. We therefore conclude that they represent two different spawning components.

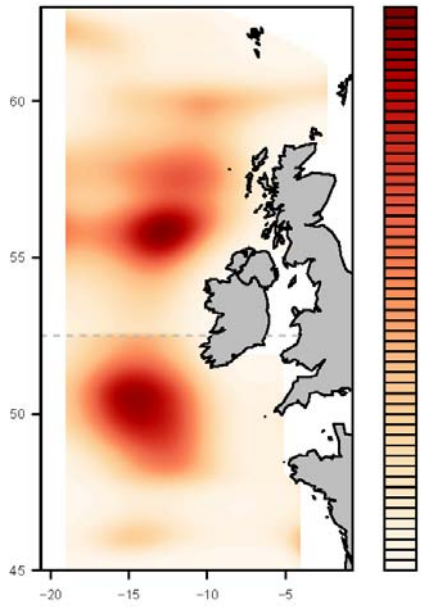

Figure 1. Annually integrated spatial larval density from the fitted model. Separate components are identified above and below the grey line at 52.5N.

Discussion

The spatial separation into two spawning components closely mirrors the results obtained elsewhere from particle tracking studies. These studies have shown a separation between the components at around 53- 55N, which agrees with the near absence of larvae observed in this region.

Importantly, these results suggest a resolution to the question of Blue whiting spawning and stock structure. The core of the problem is the supposed lack of separation of the two hypothesised populations on the spawning grounds. However, we propose that this picture is simply an artefact of survey design. For example, the most recent survey design takes place over two weeks at the very end of March and the beginning of April and stretches from 52N to 61N. Such a survey will not capture spawning in the southern component for two reasons. Firstly, it occurs too late: we show that spawning in the southern component is complete by the end of March. Secondly, it does not extend sufficiently far south: this survey stops at 52N, whereas the southern component spawns in the Porcupine Seabight, between 48 and 52N. We therefore conclude that the Blue Whiting spawning paradox is simply an observational artefact.

With the spawning paradox resolved, there is now clear evidence that the North Atlantic Blue Whiting population should be considered as two independent stocks. Previous studies based on genetic markers and otolith growth analysis has hinted at the uniqueness of the populations. In this study, we show a clear physical separation between the two spawning regions and a difference of at least a month in the timing of spawning. It would therefore seem that there is a complete case for the independence of these two populations. Improved monitoring (*e.g.* extending the survey region) and developing separate assessments for the two stocks should therefore be considered as high priorities to ensure the precautionary management of Blue Whiting in the North Atlantic.