The dangers of ignoring stock complexity in fishery management: the case of the North Sea cod

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The plight of the marine fisheries is attracting increasing attention as unsustainably high exploitation levels, exacerbated by more extreme climatic conditions, are driving stocks to the point of collapse. The North Atlantic cod (Gadus morhua), a species which until recently formed a major component of the demersal fisheries, has undergone significant declines across its range. The North Sea stock is typical of many, with a spawning stock biomass that has remained below the safe biological limit since 2000 and recruitment levels near the lowest on record. Cod within the North Sea are currently managed as a single stock, and yet mounting empirical evidence supports the existence of a metapopulation of regionally variable, genetically distinct, sub-stocks. Applying the same management strategies to multiple stocks that differ in their resilience to exploitation inevitably results in the overfishing and likely collapse of the weaker components. Indeed, recent studies have identified two North Sea spawning stocks that have undergone disproportionately large collapses with very substantial reductions in egg production. Similarly affected cod stocks in the northwest Atlantic have shown little evidence of recovery, despite fishery closures. The possible implications of ignoring substructuring within management units for biocomplexity, local adaptation and ecosystem stability are considered.

Keywords: biocomplexity; local adaptation; extirpation; fisheries management

The North Atlantic cod (Gadus morhua) has historically supported one of the largest marine fisheries, but, as with many commercially exploited species, it has undergone a significant reduction across its range in recent years, resulting in the complete closure of some of the major fishing grounds. Although there is now evidence that large, slow-growing species may undergo local extinction (extirpation) through their inclusion as by-catch (Hiddink et al. 2008), faster maturing species, such as cod, with large, weakly structured populations and a capacity for extensive migration, are thought to be more resilient to exploitation. Cod within the North Sea have typically been treated as a single panmictic population; however, mounting evidence from tagging surveys (Wright et al. 2006), molecular genetic analysis of spawning aggregations (Hutchinson et al. 2001) and otolith microchemistry (Gibb et al. 2007) supports the existence of a metapopulation of distinct spawning aggregations, with regionally varying stock dynamics (Holmes et al. 2008). Where equal fishing pressure is applied to stocks that differ significantly in biomass and resilience, there is the potential to bring about a collapse of the less productive populations.

Alarming, two recent studies indicate that several of the North Sea spawning stocks have undergone a very significant decline over the last 30 years, with a substantial reduction in egg production. Fox et al. (2008) undertook an ichthyoplankton survey of the North Sea in 2004, using genetic probes to assign gadoid eggs to their species of origin. The distribution of cod eggs closely matched the spawning grounds proposed in earlier studies (Daan 1978; Harding & Nichols 1987). However, the eggs were virtually undetectable on the previously productive spawning grounds off Flamborough Head, prompting Fox et al. (2008) to suggest that such severely depleted stocks may require ‘targeted conservation measures’. Furthermore, Holmes et al. (2008) used cod recruitment and spawning stock biomass data from the North Sea to investigate regional trends between 1993 and 2005. They concluded that the Dogger Bank and Flamborough populations may be facing commercial extinction before the rest of the North Sea shows a similar response.

These findings corroborate the results of an earlier study by Hutchinson et al. (2003) in which a temporal genetic analysis of fish caught off Flamborough Head identified a significant change in the genetic composition of the population, commensurate with a gradual loss of the original population and increased influence of low numbers of incoming migrants. The study spanned the period from 1954 to 1998, but the greatest change was seen in the 17 years prior to 1998. Harding & Nichols (1987) found high densities of eggs off Flamborough Head in their 1976 survey; however, this region has supported some of the highest exploitation levels in the North Sea since the 1970s, which undoubtedly contributed to the significantly reduced densities observed by Fox et al. (2008). As subsequently discussed, the collapse or complete loss of such a population may have important implications for the species’ genetic diversity and long-term viability, particularly where there is evidence for local adaptation. Furthermore, cod represents a key prey item and predator in the North Atlantic and, consequently, its removal is likely to have impacts across trophic levels potentially threatening ecosystem stability.

It has been argued that biocomplexity, in particular the diversity of life-history characteristics and adaptation to local variations in spawning and nursery habitat, may help fisheries to adjust to environmental change and resist the pressures of exploitation (Hilborn et al. 2003). Although it is difficult to determine the heritable component of biocomplexity, particularly in fishes that typically exhibit high phenotypic plasticity, it is now generally accepted that the erosion of genetic diversity is likely to be detrimental for a species’ long-term viability (Hoffmann & Willi 2008). Indeed,
The loss of a local cod spawning stock


