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COMMENT

Beauty is in the eye of the beholder: management of Baltic cod stock requires an ecosystem approach

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ABSTRACT: In a recent 'As We See It' article, Cardinale & Svedäng (2011; Mar Ecol Prog Ser 425:297–301) used the example of the Eastern Baltic (EB) cod stock to argue that the concept of ecosystem regime shifts, especially the potential existence of alternative stable states (or dynamic regimes), blurs the fact that human exploitation (i.e. fishing) is the strongest impact on marine ecosystems. They further concluded that single-species approaches to resource management are functioning and that ecosystem-based approaches are not necessary. We (1) argue that the recent increase in the EB cod stock is inherently uncertain, (2) discuss the critique of the regime shift concept, and (3) describe why the EB cod stock dynamics demonstrates the need for an ecosystem approach to fisheries management.

KEY WORDS: Baltic cod · Climate · Ecosystem approach · Regime shifts · Hysteresis · Uncertainty

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Uncertainty in estimating stock recovery

The article by Cardinale & Svedäng (2011) is based on the assumption that the Eastern Baltic (EB) cod stock 'has recently recovered after more than 2 decades of low biomass and productivity' (p. 297).

Gårdmark et al. (2011) assessed the EB cod stock using the fully deterministic extended survivor analysis (XSA; Shepherd 1999), and showed that the perception of the stock dynamics is crucially affected by assumptions made in the model. The change in only one assumption (e.g. changing the shrinkage setting from 0.5 to 0.75) decreased the estimated fishing mortality (F) by >50 % (Fig. 1). This changed the estimated number of recruits from slightly above-average recruitment to almost double — the highest level of recruitment in the past 2 decades.

Gårdmark et al. (2011) also used a state–space stock assessment model to evaluate the uncertainty of the assessment estimates. Given the uncertainties in the data, their results show that F was then anywhere between 0.15 and 0.61 (see confidence intervals for 2008 in Fig. 1). Correspondingly, the uncertainty in the estimated recruitment level was high, ranging from the highest recruitment in 25 years to no positive recruitment trend at all. Spawning stock biomass (SSB) ranged from a level where the reproductive capacity of the stock is assumed to be impaired, to the especially

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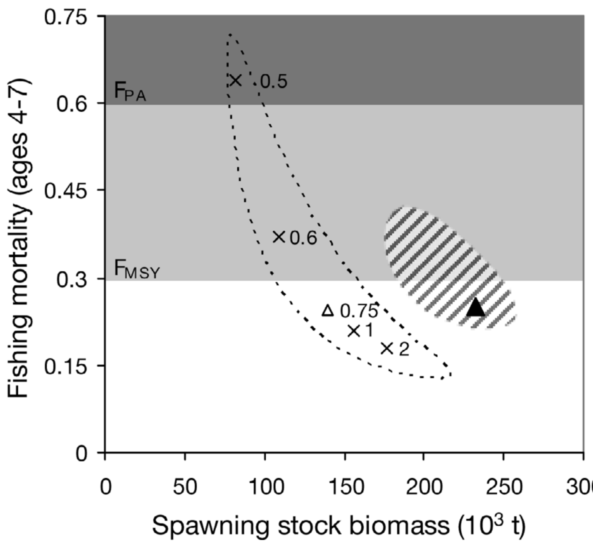

Fig. 1. Variability and uncertainty in stock assessments of Eastern Baltic cod *Gadus morhua*. Triangles show estimates of spawning stock biomass (SSB) and fishing mortality (F) from ICES (2009, 2011); ellipses show the corresponding confidence intervals in 2008 (open/dotted-line) and 2010 (filled/hatched); crosses show 2008 estimates with different shrinkage settings in the stock assessment model. Light grey: $F_{MSY} > 0.3$ (i.e. above the level resulting in maximum sustainable yield, the target of the EC management plan); dark grey: $F_{pa} > 0.6$ (i.e. the precautionary approach fishing level). After Gårdmark et al. (2011), ICES (2011)

high SSB mentioned by Cardinale & Svedäng (2011). Indeed, the latest assessment of EB cod still shows great uncertainty in SSB, ranging from 180 to 250 t (Fig. 1, Table 1).

We do not question a positive trend in the stock size of EB cod. However, we caution against too optimistic perceptions of the development of the stock, and propose a more precautionary way of thinking. Data for assessing the EB cod stock dynamics are noisy, due to catch under- and misreporting, uncertain information on discards, and national differences in sampling methodology and age determination (e.g. ICES 2009). Furthermore, the model used in stock assessment tends to overestimate stock size and underestimate fishing mortality (ICES 2011). The most recent stock assessment, despite confirming an increase in stock size, shows that recruitment and SSB were overestimated by about 20% in the year before (Table 1). In addition, the stock still suffers from other effects of unsustainable fishing pressure, such as a skewed age and size structure, i.e. too few old and large individuals, potentially affecting recruitment (Vainikka et al. 2009). Additionally, as Cardinale & Svedäng (2011) correctly describe, the spatial structure of the stock (i.e. extension of suitable spawning areas) is impaired due to hydrographic conditions, which makes a rapid stock recovery unlikely. All in all, we caution against classifying the EB cod stock as 'recovered'; we can only hope that the future will show it to be recovering.

Table 1. Confidence intervals of fishing mortality and spawning stock biomass of Eastern Baltic cod *Gadus morhua* in recent stock assessments

Assessment for year 2008	2009	2010	Source
Fishing mortality (F)			
0.15 to 0.61			ICES (2009)
0.22 to 0.40	0.17 to 0.32		ICES (2010)
0.35 to 0.59	0.27 to 0.47	0.22 to 0.39	ICES (2011)
Spawning stock biomass (SSB; 10^6 t)			
84 to 198			ICES (2009)
113 to 160	183 to 274		ICES (2010)
95 to 120	152 to 196	183 to 250	ICES (2011)

Ecosystem regime shift

Cardinale & Svedäng (2011) reviewed the literature and correctly described the Baltic ecosystem regime shift. However, they described the change in population structure of EB cod (from 3 to only 1 spawning area) due to deterioration of hydrographic conditions as a phenomenon unrelated to this ecosystem regime shift. We emphasize that the reduction in spawning habitat is a vital element in the collapse of the EB cod stock during the early 1990s, and hence it is part of the ecosystem regime shift at large. Generally, there seems to be a misunderstanding with respect to the term 'regime shift'. In describing the difference between ecosystem changes in the Öresund and those in the central Baltic, Cardinale & Svedäng (2011) made the distinction between a 'hydrographically-induced regime shift' and a fishing-induced 'trophic cascade shift'. We consider both types of reorganization to be ecosystem regime shifts that are characterized by infrequent and abrupt changes in ecosystem structure and function, and that occur at multiple trophic levels and on large geographic scales (Collie et al. 2004, de Young et al. 2004, Bakun 2005, Lees et al. 2006). More importantly, ecosystem regime shifts are often a result of multiple causes, such as climate change and overexploitation of resources, or a combination of both (Scheffer & Carpenter 2003, Lees et al. 2006). Hence, both bottom-up (climatic and/or productivity changes) and top-down (fishing) effects are part of an ecosystem regime shift.

The central Baltic Sea ecosystem regime shift occurred due to a combination of deteriorated hydrographic conditions and overexploitation (Möllmann et al. 2009). In contrast, the change in the Öresund ecosystem demonstrates how reduced fishing impact can counteract bottom-up changes and avoid collapses of top predators (Lindegren et al. 2010a). We agree with Cardinale & Svedäng (2011) concerning the crucial role of exploitation for ecosystem changes. We emphasize, however, that the changes in the Öresund demonstrate that sustainable management requires a consideration of multiple interacting stressors (e.g. Marasco et al. 2007; and see below).

Another question in relation to regime shifts is whether feedback loops help to 'lock' the ecosystem into an alternative stable state (Regime A), unless a perturbation is large enough to push the system into another state (Regime B). Hysteresis, whereby a critical threshold that triggers the shift from Regime A to B differs from the threshold at which the system shifts from Regime B back to A, characterizes many, but not all, regime shifts (Scheffer et al. 2001, Scheffer & Carpenter 2003). In other words, ecosystem regime shifts can occur without feedback loops and may sometimes be easily reversible (Collie et al. 2004). If alternative stable states exist, restoration may need drastic and costly management interventions (Scheffer et al. 2001, Suding et al. 2004).

Cardinale & Svedäng (2011, p. 300) questioned the existence of stable states in the Central Baltic Sea ecosystem regime and argued that 'the speed of the reversal' (i.e. the increase in EB cod) is 'contrary to the predictions of the regime shift theory'. We consider this a misinterpretation, as not the speed of a potential shift is crucial, but rather the magnitude of the intervention required to return to the initial state (Scheffer et al. 2001, Scheffer 2009). Assuming that the apparent recovery of EB cod is real, one could argue that the drastic reduction in fishing mortality ($F < 0.3$) to levels existing before the onset of an industrialised fishery (Fig. 2; Eero et al. 2008), and much lower than the previously suggested F_{pa} (ICES 2010), represents a drastic intervention that resulted in a rapid reversal of the regime.

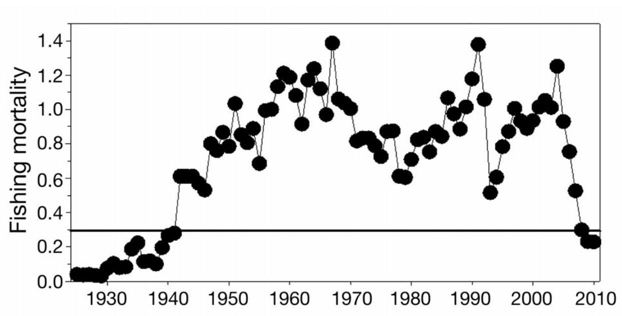

Fig. 2. Historical development fishing mortality (F) in Eastern Baltic cod *Gadus morhua* from 1925 to 2010. Horizontal line indicates F = 0.3, the target of the EC management plan (adapted from Eero et al. 2008)

Nevertheless, we argue that the existence of alternative stable states is not a prerequisite for identifying and understanding the Baltic Sea regime shift in general, and the dynamics of the EB cod stock in particular. Alternative stable states are generally difficult to demonstrate in large marine ecosystems. However, there are strong indications for alternative stable states such as feedback loops and thresholds in the Baltic Sea ecosystem (Casini et al. 2008, 2009, Möllmann et al. 2008, 2009). Although there is no conclusive proof yet of the existence of alternative stability, ignoring the possibility of alternative stable states would not be a precautionary strategy for management of marine resources. When indications for alternative stable states exist, the possibility should be accounted for and we should manage ecosystems in a way that avoids the risk of unwanted regime shifts such as a collapse of the Baltic cod stock. The regime shift theory is not an 'unclear metaphor' (Cardinale & Svedäng 2011, p. 300), rather it is a means by which we can prevent disasters such as the collapse of a fish stock.

Need for an ecosystem approach

Based on the recovery of EB cod, Cardinale & Svedäng (2011) concluded that single-species approaches to resource management are functioning and that ecosystem-based approaches are not necessary. We do not doubt the former; however we strongly disagree with Cardinale & Svedäng concerning the latter. The decline of the EB cod stock in the late 1980s/early 1990s started with changing environmental conditions and subsequent recruitment failure. The actual collapse was then caused by excessive fishing pressure (Köster et al. 2005, Eero et al. 2011). Simulations with a food-web model show that the collapse could have been avoided by adapting fishing pressure to environmental conditions and food-web interactions (Lindegren et al. 2009). Furthermore, projections with the same model show that expected climatic changes necessitate a precautionary approach and adjustment of future exploitation levels to protect the long-term existence of the stock (Fig. 3; Lindegren et al. 2010b). For example, $F = 0.3$ — which corresponds to the current EC management plan (EC 2007) and is the proposed F_{MSY} (ICES 2011) — could be too high if hydrographic conditions change (e.g. further decrease in salinity), as predicted by up-to-date climate change scenarios (BACC 2008); therefore, F would need to be reduced in the future, since cod is a marine species at its limit of distribution in the brackish waters of the Baltic Sea.

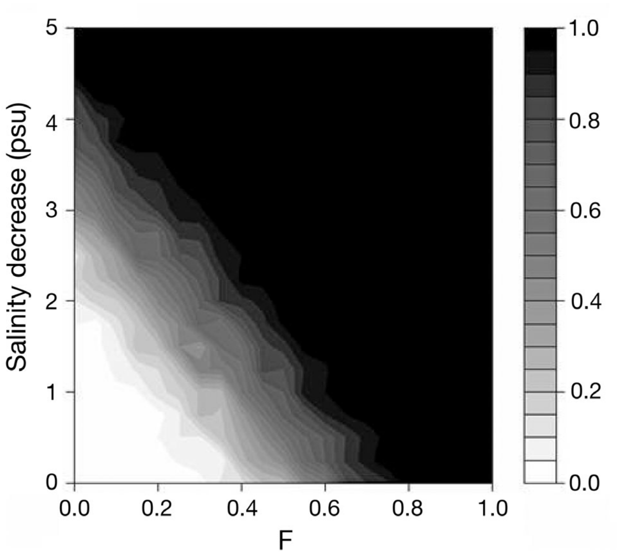

Fig. 3. Probability of a decrease of the Eastern Baltic cod stock below 'ecologically safe' levels (B_{lim} = 160 000 t), given future changes in salinity fishing mortality (F). From Lindegren et al. (2010b)

The essence of the ecosystem approach is to consider multiple impacts/stressors, to identify which factors may erode resilience and which have the capability to cause sudden change, and to manage a resource in a precautionary way, thus avoiding catastrophic reorganizations in the ecosystem. In the case of highly exploited marine ecosystems such as the Baltic Sea, this involves reducing fishing mortality, as correctly stated by Cardinale & Svedäng (2011), but fishery pressure must be adapted to ecosystem conditions, to avoid stock collapses and the need for expensive political interventions (e.g. subsidising fishermen to stay in harbour; see Cardinale & Svedäng 2011). The insight that exploited top predators need to be managed in their ecosystem context and the communication of these relationships to stakeholders and societies may also help in reducing unsustainably high exploitation levels.

Ecosystem-based management approaches, and ecosystem knowledge in general (not only in relation to regime shift theory), additionally reduce uncertainty in present day single-species approaches. Gårdmark et al. (2011) showed how strong the uncertainty is in the case of EB cod, but they also provide approaches to reduce uncertainty and they propose indicators for the state of the environment that are based on ecosystem studies. These indicators comprise stock specific biological indicators (e.g. stock structure, and predator and prey biomass), indicators of ecosystem development, and trends in the physical environment that affect EB cod recruitment. Indicator systems of this kind are fundamental for every ecosystem approach and crucially needed for sustainable resource management.

Conclusions

(1) We caution against optimistic assumptions regarding the recovery of the EB cod stock, given the large uncertainties inherent in stock assessment models and input data, the skewed age/size structure of the stock and the small extent of suitable spawning areas.

(2) We think that the regime shift concept is not an 'unclear metaphor', but rather provides new insights into ecosystem functioning and offers new approaches for ecosystem-based management.

(3) We argue that ecosystem-based approaches are crucially needed to manage the Baltic cod stock in the future.

Ecosystems are complex adaptive systems (Levin 1999). They are characterized by multiple possible outcomes and by the potential for rapid changes and ecological surprises (Doak et al. 2008, Levin & Lubchenco 2008). In order to sustainably manage living resources such as fish stocks we need to embrace this complexity. Whether simplicity or complexity are regarded as beautiful we leave to the eye of the beholder.

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