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Comment

Comment on stock assessment of eels in the Baltic by Westerberg and Wickström (2015): do we need more unknowns?

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European eel (*Anguilla anguilla*) is considered as critical endangered and even under the best circumstances it may take decades before the stock recovers. Estimation of eel escapement biomass, $B_{escapement}$, is of critical importance to evaluate management schemes and to predict the recovery potential for the eel stock. Westerberg and Wickström (2015. Stock assessment of eels in the Baltic: reconciling survey estimates to achieve quantitative analysis. ICES Journal of Marine Science, 73: 75–83) attempt to estimate potential $B_{escapement}$ based on the assumptions that all elvers at the entrance of the Baltic also migrate into the Baltic Sea and that natural mortality is low under the whole growth stage (close to 0.02 at the age of 10 years and older). As a consequence, Westerberg and Wickström estimated the present potential $B_{escapement}$ at ~10–20 000 tonnes and fishing mortality close to 0.05–0.10, while it was also suggested that other sources of anthropogenic mortality may reduce the actual escapement to unknown levels. Here we argue that these conclusions are entirely speculative and contradicted by tagging experiment and fishery data, which instead indicate a much higher fishing mortality (mortality induced by legal professional fishery) rates and a considerably smaller eel biomass.

Keywords: *Anguilla anguilla*, eel management plan, escapement biomass.

Introduction

European eel (*Anguilla anguilla*) is considered to be critically endangered (ICES, 2014; Jacoby and Gollock, 2014). An EU management plan (EU Council Regulation no. 1100/2007) has been implemented since 2007, with a long prequel, first within EIFAC (Svärdson, 1976) and thereafter at EIFAC/ICES (e.g. Moriarty and Decker, 1997). Even if recruitment has start rising, as some positive signs have been showing (ICES, 2014), the long (~10 years) time-lag between recruitment and reproduction, implies lower recruitment in the years to come before the possibly enhanced recruitment today is transformed into new, more abundant generations. It may thus take decades before a recovery of European eel may be well established (Åström and Dekker, 2007). Therefore, eel management is a long-term commitment.

To understand eel population dynamics, the level of escapement, or spawning migration from continental and coastal waters towards the ocean, remains one of the most frustrating unknowns that makes eel population dynamics particularly uncertain (e.g. Moriarty and Decker, 1997). However, as eel fishing in areas such as the Baltic Sea has continued more or less unrestricted, as neither TACs nor effort control have been enforced in any country (except for a seasonal fishing ban in Denmark) around the Baltic Sea, trend in landing and catch statistics (Andersson *et al*., 2012) support the view that a recruitment decline since the 1950s/1960s in this part of the eel distribution area (Svedäng, 1996) has indeed resulted in lower biomass of eel and reduced escapement from the Baltic Sea around 10–20 years later (Svärdson, 1976).

Estimation of eel escapement biomass

We appreciate the innovative way of reasoning introduced by Westerberg and Wickström (2015). Westerberg and Wickström (2015) make an effort in estimating the biomass of eel in the Baltic Sea, fishing mortality and recruitment by reversing the direction of regular assessments, i.e. the regular procedure is that estimates of mortality rates and landings will determine the total biomass and not vice versa. Finally, Westerberg and Wickström (2015) raise the issue concerning "anthropogenic mortality", which includes other sources of human induced mortality such as hydroelectric power turbines and leisure fishing.

This assessment is merely performed by estimating the number of 0+ and 1+ elvers (young eels) from field studies in the Öresund at the entrance to the Baltic Sea (the other Danish sounds are left out from the calculation). All these elvers are then assumed to enter the Baltic Sea and stay there for the rest of the growth phase until maturation sets in and they are transformed into migrating silver eels, which eventually leave the Baltic Sea for spawning in the Sargasso Sea. But is there any evidence that elvers and yellow eels massively abandon the Öresund and the Kattegat for the Baltic Sea? The annual landings of the yellow eel fishery on the Swedish west coast amounted >300 tonnes (cf. Svedäng, 1999) until a fishing ban was introduced lately, suggesting that settled and rather resident elvers constitute the basis for a rather dense eel stock in the Öresund and Kattegat. We suggest that settled elvers in the Danish Sounds (including the Öresund) and the Kattegat either die, stay in the brackish littoral or ascend the rivers that enter on the Swedish west coast. As the density of elvers in the rivers on the Swedish west coast is much higher than in the Baltic Sea, this suggest that migration into the rivers is a common destination for many of the eels inhabiting the brackish zone on the Swedish west coast.

Westerberg and Wickström (2015) estimated natural mortality rate per year, M, by using the model of Bevacqua *et al.* (2011), for which M is estimated to be low already at the early phase of the yellow eel stage (~0.20) and very low in the latter part (~0.02).

These two assumptions result in very high-potential biomasses as escapement approaches, due to the great number of recruits moving into the Baltic Sea and the very low M over the entire growth phase. In addition, eel stockings with transplanted glass eels from Western Europe are added to the stock, making up between 15 and 40% of the total stock number. Between 1994 and 2012, the Baltic potential $B_{\text{escapement}}$ is estimated by Westerberg and Wickström (2015) to vary from 60 000 to 15 000 tonnes. Fishing mortality rate, F, estimated in percentages (between 5 and 15%, corresponding roughly to F between 0.05 and 0.15), is entirely linked to the silver eel stage and it is estimated as the ratio between landings and the total potential $B_{\text{escapement}}$ in the Baltic Sea, although it would better have been estimated as the actual $B_{\text{escapement}}$. This ratio is then assumed by Westerberg and Wickström (2015) to be constant over time as the decline in landings follows the reduction in potential $B_{\text{escapement}}$, which in turn is a reflection of the general trend of declining recruitment of the European eel stock. Finally, Westerberg and Wickström (2015) state that the actual $B_{\text{escapement}}$ might be much smaller due to anthropogenic mortality besides F.

Migration of elvers

However, besides the lack of clarity in defining actual and potential $B_{\text{escapement}}$ by Westerberg and Wickström (2015), their major assumptions are also unsubstantiated. It is still not known whether recruitment from the Öresund (or rather all Danish sounds) into the Baltic Sea is mainly taking place by passive transportation of glass eels or by actively migrating elvers/yellow eels (cf. Svärdson, 1976). The decline in numbers of 0+ and 1+ old elvers in the Öresund at the entrance to the Baltic Sea, interpreted by Westerberg and Wickström (2015) as to be due to migration into the Baltic Sea, could just as well be related to natural mortality and migration in all directions. The whole coastal zone of the Kattegat and Skagerrak, which is brackish, is used as a nursery and feeding area for eel and only a minority of them leave marine waters for freshwater and some upstream migrating eels even return rather soon to coastal waters (Limburg *et al.*, 2003). The supposed urge of elvers in the Öresund and the entire Kattegat to show a unidirectional movement into the Baltic Sea has hence never been evidenced. The littoral part of the Öresund is just as brackish as the adjacent Baltic Sea, surface sea currents fluctuate between north-going (i.e. from the Baltic Sea) and south-going (i.e. into the Baltic Sea) with no clear direction (Stigebrandt, 1983).

Natural mortality

The life history of eel do not support the view of Westerberg and Wickström (2015) of an extremely low M already at ages 1 and 2, corresponding to $M \approx 0.2$ and $M \approx 0.05$, respectively. For instance, M might be estimated using the relationship established by Pauly (1980):

$$\log\ M = 0.0066 - 0.279\ \log\ L_\infty + 0.643\ \log\ K + 0.4634\ \log\ T, \quad (1)$$

where L_∞ is the mean asymptotic length (cm) of the population, K is the rate at which L_∞ is attained (year^{-1}), and T is the mean annual water temperature (°C). Instead, given the life-history characteristics in Westerberg and Wickström (2015), M would rather equal 0.4 for the entire yellow eel stage according to Pauly (1980), which would reduce potential $B_{\text{escapement}}$ to a much lower level than estimated by Westerberg and Wickström (2015).

Eel escapement biomass and exploitation rates

The postulated high level of potential $B_{\text{escapement}}$ still produced in the Baltic Sea also has serious implications for the coherence of the idea held by Westerberg and Wickström (2015). The eel biomass have to be much larger than the escapement biomass, as only a minor fraction is available for exploitation according to what is postulated (i.e. no fishing mortality before the silver eel migration is initiated). For the estimation of the mean total population biomass per recruit, B/R, the following equation is given by Beverton and Holt (1957):

$$\frac{B}{R} = W_{\text{inf}} \sum_{n=0}^{3} \Omega_n \mathrm{e}^{-nK(t_r - t_0)} \times \left[\left(\frac{1 - \mathrm{e}^{-(M+nK)p}}{M + nK} + \left(\frac{\mathrm{e}^{-(M+nK)p}(1 - \mathrm{e}^{-(F+M+nK)landa)}}{F + M + nK} \right) \right) \right] \quad (2)$$

According to Equation (2), if size at first catch (L_c) is set at 70, $M \approx 0.02$, and L_{inf} is set at 78 cm as in Westerberg and Wickström (2015), the proportion of the stock that is fishable is just 35% relative to the total eel biomass >25 cm. If the present potential $B_{\text{escapement}}$ is 20 000 tones, the total biomass would thus amount to ~50 000 tonnes. This represents a huge biomass that would attract predators of all kinds, such as cormorants, seals as well as fishers, potentially imposing a considerable mortality rate on the eels, i.e. M would be higher than postulated by Westerberg and Wickström (2015). Moreover, there are no empirical indications that such large biomass of eel is present in the littoral margins of the Baltic Sea. Noteworthy, Westerberg and Wickström (2015) hint at a solution to this conundrum by suggesting that this potential $B_{\text{escapement}}$ is never realized due to other anthropogenic mortality (i.e. besides F), meaning that an unknown is improved by yet another unknown.

However, no comparison is made with previous studies on exploitation rates. First, between 1941 and 1968 when recaptures of tagged fish were reliably reported by the fishers on the Swedish east coast (Ask and Erichsen, 1976), recapture rates equalled ~50%, indicating F at 0.65, i.e. much higher than the F-values given by Westerberg and Wickström (2015). Furthermore, since the landings (C) at that time equalled *c.* 6000 tonnes for the entire Baltic, the actual $B_{\text{escapement}}$ in 1970 might have been in the region of 12 500 tonnes, using Equation (2) and assuming a similar F for the entire Baltic Sea:

$$C = (1 - e^{-F})B_{\text{escapement}}. \quad (3)$$

This estimate stands in sharp contrast to the potential $B_{\text{escapement}}$ of 60 000 tonnes 20 years later in the mid-1990s, as it is estimated by Westerberg and Wickström (2015).

Second, when conspicuous archival tags were tagged externally on silver eels on the southeast coast of Sweden in 2005, and the fishers were rewarded by 40 € per retained tag or fish, the proportion of reported retained tags raised to 50% (Westerberg *et al.*, 2007). The number of reported retained tagged fish were small ($n = 16$), yet it represents an actual observation and is not based on speculations. This level of recapture rate corresponds to an actual $B_{\text{escapement}}$ in 2005 ~700 tonnes on the Swedish Baltic coast, i.e. ~4% of the $B_{\text{escapement}}$ estimate produced by Westerberg and Wickström (2015) although the Swedish coastline constitute 45% of the entire Baltic coastline.

Furthermore, Andersson *et al.* (2012) report that cpue in the Swedish east coast eel fishery has been stable over a period of 50 years, although the landings are declining. In many fisheries, cpue and F are inversely related due to concurrent, density-dependent changes in catchability (e.g. Ellis and Wang, 2007). In case of the pond fishery for migrating silver eels on the Swedish east coast, there are good reasons to believe that catchability changes with alterations in fishing effort. The pond nets are far from randomly set, as they stand more or less on a line along the east coast of Sweden, blocking the natural eel migratory route (e.g. Svedäng, 1996). When the number of pond nets decrease, the catchability will change for whose that are left. Because the effort has declined sharply over the period, we propose that F has been stable, whereas catchability has changed (i.e. increased). In other words, when the actual $B_{\text{escapement}}$ declines just as effort does, F, which is the fraction taken by the fishery, remains more or less constant. This means that actual $B_{\text{escapement}}$ has fallen sharply since the 1970s in contrast to the view of Westerberg and Wickström (2015). Indeed, the estimates on F presented in our comment suggest that F is rather similar over time.

Conclusively, the estimations of potential $B_{\text{escapement}}$ and F made by Westerberg and Wickström (2015) are unsubstantiated. Moreover, no further elaborations on anthropogenic mortality, i.e. besides F, should be based on this ground. On the other hand, the steadily decline in fishing effort on the Swedish part of the Baltic without affecting cpue (Andersson *et al.*, 2012) indicates an ongoing population decline. This crucial information that once again is highlighting the present dire status of the European eel stock.

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