ICES Journal of Marine Science
January 2009 ; Volume 66 (1) : Pages 109-121
http://dx.doi.org/10.1093/icesjms/fsn166

A model-based evaluation of Marine Protected Areas: the example of eastern Baltic cod (Gadus morhua callarias L.)

Gerd Kraus[1, *], Dominique Pelletier[2,3], Julien Dubreuil[2], Christian Möllmann[4], Hans-Harald Hinrichsen[5], Francois Bastardie[6], Youen Vermard[2] and Stéphanie Mahévas[2]

[1] National Institute of Aquatic Resources, Technical University of Denmark, Kavalergarden 6, Dk-2920 Denmark; present address: Johann Heinrich von Thünen-Institut (vTI), Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmaille 9, D-22767 Hamburg, Germany
[2] Institut Français de Recherche pour l'Exploration de la Mer, BP 21105, 44311 Nantes Cedex 03, France
[3] Campus de l'IRD, 101 Promenade Roger Laroque, Anse Vata, BP A5, 98848 Nouméa Cedex, New Caledonia
[4] Institute for Hydrobiology and Fishery Science, University of Hamburg, Olbersweg 24, D-22767 Hamburg, Germany
[5] Leibniz Institute of Marine Sciences, IFM-GEOMAR, Düsternbrooker Weg 20, D-24105 Kiel, Germany
[6] Department of Marine Fisheries, National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund Castle, DK-2920 Charlottenlund, Denmark

*: Corresponding author : Gerd Kraus, email address : gerd.kraus@vti.bund.de

Abstract:

The eastern Baltic cod stock collapsed as a consequence of climate-driven adverse hydrographic conditions and overfishing and has remained at historically low levels. Spatio-temporal fishing closures [Marine Protected Areas (MPAs)] have been implemented since 1995, to protect and restore the spawning stock. However, no signs of recovery have been observed yet, either suggesting that MPAs are an inappropriate management measure or pointing towards suboptimal closure design. We used the spatially explicit fishery simulation model ISIS-Fish to evaluate proposed and implemented fishery closures, combining an age-structured population module with a multifleet exploitation module and a management module in a single model environment. The model is parameterized based on (i) the large amount of biological knowledge available for cod and (ii) an analysis of existing spatially disaggregated fishery data. As the population dynamics of eastern Baltic cod depend strongly on the climate-driven hydrographic regime, we considered two production regimes of the stock. MPAs were only effective for stock recovery when they reduced overall fishing effort. The performance of MPAs needs to be evaluated relative to environmental regimes, especially for stocks facing strong environmental variability.

Keywords: Baltic cod, fishery management, Marine Protected Areas, model, stock recovery

1. Introduction

Implementing an Ecosystem-Based Fisheries Management (EBFM) puts forward the use of closed areas as a management tool to prevent at least parts of marine ecosystems from the adverse effects of fishing (Agardy, 1994). Beyond the preservation of biodiversity in permanently closed areas, it is often expected that closed areas will also provide direct benefits to adjacent fisheries (Murawski *et al*., 2005; Halpern and Warner, 2003). Yet, these benefits must be evidenced. Furthermore, as fisheries are dependent on the productivity of the ecosystem, and fisheries have an effect on the supporting ecosystem of the target species, the design of fisheries management measures should take account of environmental variations (e.g., Hutchings and Myers, 1994). However, most fisheries models have a limited spatial description and ignore the effects of environmental conditions on the productivity of fish stocks.
The adoption of the EBFM approach fostered the development of comprehensive models accounting for trophic interactions (e.g. Walters *et al*., 1999; Watson *et al*., 2000; Pinnegar *et al*., 2005). But the spatially-explicit description of interactions between resources and fishing activities including management options received less attention (Pelletier and Mahévas, 2005). One reason for this is that most fisheries are complex systems not only due to the diversity of the exploited resources (multi-species), but also to multiple fishing activities (multi-fleet), which hampered the development of models able to handle this complexity while not oversimplifying the system. Additional complexity arises from the fact that EBFM will not only consider a range of closure designs, but a number of other management tools, which need to be considered in simulation models. Recently, the generic and spatially explicit fishery simulation model ISIS-Fish (Mahévas and Pelletier, 2004; Pelletier and Mahévas, 2005) has been applied to a number of case studies in the North-east Atlantic and Mediterranean (see e.g. Drouineau *et al*., 2006; Pelletier et al. 2007). We used this model to evaluate the effects of spatio-temporal closures implemented in the Central Baltic Sea to support recovery of the Eastern Baltic cod stock.
Eastern Baltic cod has been depleted for several years. The spawning stock declined from an extremely high level during the early 1980s (~665.000t in 1982) to a historic low of ~65.000t in 2005, due to recruitment failure and high fishing intensity with no sign of recovery (ICES, 2007). Decreased predation pressure by the cod stock, in combination with high reproductive success and relatively low fishing mortalities, resulted in the second half of the 1990s in a drastically enlarged sprat (*Sprattus sprattus*) stock (Köster *et al*., 2003). This switch in dominance was facilitated by the fact that cod recruitment is highly dependent on environmental conditions, which mainly affect the egg and larval stages. Egg survival is determined by oxygen conditions and clupeid predation pressure in the reproduction layers (Köster *et al*., 2005), whereas larval survival is limited by availability of suitable prey, and successful settlement in suitable nursery areas is determined by larval transport (Hinrichsen *et al*., 2008; this volume).
Until 2005, exploitation of Baltic fish stocks was managed by the International Baltic Sea Fisheries Commission (IBSFC) mainly through TACs. However, landings frequently exceeded the agreed TAC's. Moreover, from 1982 to 1988 IBSFC was not able to establish a TAC resulting in an unregulated fishery (Radtke, 2003) over a period of frequent recruitment failure (Köster *et al*., 2005). In view of the rapid decline of the cod stock during the 1980's, IBSFC introduced new regulatory measures such as fishing closures, mesh size regulations and minimum landing sizes (Radtke, 2003). Two types of fishing closures were enforced to preserve the stock. In 1995, a summer ban of 4.5 months on fisheries targeting cod was implemented. Its duration was subsequently modified with a minimum duration of 2 months in 2007. Secondly, a specific spawning closure to all fisheries was put in place in a relatively small area east of the island of Bornholm with size varying over years. It was complemented in 2005 by two closed areas in the Gdansk Deep and Gotland Basin spawning grounds.
In the present paper, we evaluated the performance of past, present and proposed closures to help the stock to recover. As the population dynamics of Eastern Baltic cod is strongly dependent on the prevailing climate-driven hydrographic regime, we considered alternative production regimes of the stock. These scenarios are based on long term observations on utilisation of spawning areas, recruitment, growth, maturation, survival, and migration patterns. Hydrodynamic drift model results were used to determine suitable nursery grounds (Hinrichsen *et al*., 2008; this volume).

2. Material & methods

2.1. Model description

ISIS-Fish (Mahévas and Pelletier, 2004; Pelletier and Mahévas, 2005) is a model of fisheries dynamics based on three sub-models: a population model, an exploitation model and a management model. Each sub-model is spatially explicit and operates on a monthly time step. The model domain, i.e. the fishery region, for Eastern Baltic cod is defined by the main distribution area of the stock ranging from latitude 54° to 59° North and from longitude 14° East to 24° East (Figure 1; Bagge *et al*., 1994). The fishery region is overlaid with a regular grid of spatial resolution 0.25 deg. lat. and 0.5 deg. long., corresponding to a quarter of an ICES statistical rectangle. The spatial resolution of the grid was chosen to match the dynamics of the processes to be described and the precision of the information available for parameterizing the model. Within the fishery region, zones were independently defined for each population area (spawning grounds, nursery areas, feeding grounds), each fishing activity and each management measure. Seasons (i.e., sets of successive months) were also defined for each population group (age classes), each fishing activity and each management measure. Within each zone and season, fishing effort and population abundance are assumed to be homogeneously distributed. Seasonal migrations between population zones are considered and zone-specific catchability depends on seasons. The exploitation model calculates the standardised effort per fishing activity affecting the population in each zone and month. In ISIS-Fish, fishing units are not individually identified but grouped into fleets described by métiers and strategies. A métier is characterised by a combination of gear, target species, zone and season. Fishing effort is standardized between gears, and a selectivity model is defined for each combination of gear and species, with a parameter that can possibly be modified through management measures, e.g. mesh size. Vessels that practise a similar sequence of métiers during the year constitute a fishing strategy that is characterised by a seasonal allocation of fishing effort between métiers. The management model describes the management scenario considered, its impact on the fishing activity in particular due to fisher's response to management. At each time step the model calculates changes in the distribution of fishing effort among métiers of a strategy and generates the corresponding catch and abundance estimates for each zone. Further detail and the equations are given in Pelletier and Mahévas (2005).

2.2. Population model

2.2.1. Zones

Eastern Baltic cod traditionally utilize three well separated spawning grounds in the Bornholm Basin (BB), the Gdansk Deep (GD) and Gotland Basin (GB). Spawning grounds were delineated from the long-term average distribution pattern of the youngest egg stage (Bagge *et al*., 1994; Hinrichsen *et al*., 2007) and were defined as zones in the model (Figure 1a).
Two scenarios were considered in the model corresponding to distinct climate and thus stock productivity regimes. The first is a 'good environmental scenario', where hydrographic conditions (i.e, inflow of oxygen-rich waters) favour cod reproduction and all three spawning grounds produce viable offspring (Figure 1a). The second is a 'bad environmental scenario', where hydrographic conditions are adverse for cod reproduction and recruitment. In this case, the easternmost spawning ground, i.e. GB, is not utilised due to oxygen depletion in the spawning layers (MacKenzie *et al*., 2000). Feeding areas were assigned to each of the three spawning grounds and defined as slope regions of the deep spawning basins (Figure 1b). Nursery areas were defined based on long term simulations (1974-2003) with a hydrodynamic model developed by Lehmann (1995). Virtual cod larvae were used as Lagrangian drifters to simulate potential settlement areas (Hinrichsen *et al*., 2008, this volume). In the population model, for each spawning ground, corresponding nursery areas were defined as model cells where the average settling probability of juveniles from the spawning ground was higher than 10% (Figure 1c).

2.2.2. Migrations

Migration from feeding areas to spawning grounds is age-specific and lasts from February until May (Tomkiewicz and Köster, 1999). After spawning all age groups gradually migrate from July to September to the feeding areas that are closest to their spawning grounds. We assumed no differences between age groups in the timing of the migration from the spawning areas to feeding areas (Tomkiewicz and Köster, 1999). Immature age 2 recruits were assumed to migrate from their nurseries to the nearest feeding area in one shot in September. A conceptual model of the Eastern Baltic cod life cycle is provided in Figure 2.

In the ‘good scenario’, migrations happen only within a region (GB, GD, BB; see Figure 1), i.e., between corresponding nursery-, feeding- and spawning areas. In the ‘bad scenario’, the GB spawning ground is not utilised, but may produce recruits as a result of easterly larval drift from GD and BB spawning areas. As no detailed information on migration of these recruits is available, we assumed immature age 2 recruits from the GB nursery area to migrate first to their corresponding GB feeding ground. Upon maturation they were evenly distributed between BB and GD spawning grounds. The spawning migration of the adult stock and mature age 2 recruits from BB and GD feeding grounds was parameterised based on observed and scenario specific distribution patterns from the ICES Baltic International Trawl Survey database. Two thirds of these specimens distribute to the BB spawning ground and one third to the GD spawning ground.

2.2.3. Population parameters

The cod population was structured into 7 classes from age 2 to 8. All fish older than 8 years were accumulated in the last class. Von Bertalanffy growth curves were defined for each environmental scenario based on observed, length converted weight-at-age data. Similarly, mean weight–at-age for each environmental scenario was obtained by fitting exponential weight-at-age curves. Natural mortality was assumed to be 0.2 for all age classes. Spawning stock biomass (SSB) was calculated from stock numbers and scenario- and area-specific observed maturity ogives. Total SSB was summed over all population areas and fed into a common, but scenario-specific Beverton-Holt stock-recruit relationship. The resulting total abundance of immature age 2 recruits was redistributed between the three nursery areas using observed and scenario specific distribution patterns from the ICES Baltic International Trawl Survey database. Detailed information on population parameters and related references are given in Table 1.

2.3. Exploitation model

On average 83% of the cod catches are taken by Poland, Sweden, Denmark, Germany and Latvia, with ICES Subdivisions 25 and 26 being the most intensively fished areas in the Central Baltic Sea. The main fisheries for cod in the Eastern Baltic use demersal trawls, pelagic trawls and gillnets, representing more than 99% of total catch (ICES, 2007).

The exploitation model was parameterised from logbook data from the five countries mentioned above. Data include catch and effort (in days at sea) for years 1995 to 2005. Fishing by other countries in the Central Baltic Sea amounts to 13% of the total fishing effort and was accounted for by increasing the effort proportionally among fleets represented in the model.

Data were available per month, ICES statistical rectangle, vessel size group, gear type and country. Three vessel size groups were considered: <12m, 12-24m, >24m. An average trip duration was assigned to each of these groups, and three main gears were considered, namely trawl, gillnet and “other gears”, the latter mainly comprising longlines. Selectivity curves for the main gears (trawls and gillnets) were taken from R. Nielsen (pers. comm.; Table 2). For “other gears”, an average selectivity curve was computed from the previous two gears, as no specific data on selectivity were available. The standardisation factor of a gear F_{std} quantifies the ratio in overall catch between each gear and a reference gear (i.e. the difference in efficiency between gears). Standardisation factors were estimated for each gear by fitting a Generalized Linear Model (GLM) to log-book Catch Per Unit Effort (CPUE) data. The model is loglinear with factors gear, month and zone, including an interaction between month and zone. For a given gear, the

standardization factor F_{std} was estimated as the back-transformed gear effect of the model. It was equal to 1.71 for trawl and to 1.16 for "other gears" using gill net as reference gear.
As the only target species in the model was cod, metiers were defined based on fishing zones, gears used and fishing seasons for that species. In total 23 metiers and 19 corresponding fishing zones were identified (see Appendix table). A fishing zone was defined as a group of contiguous statistical rectangles comprising at least around 80% of the fishing effort of that métier.
In the case of a single target species in the model, the target factor F_{target} depicts differences in fishing efficiency between metiers, including fisher's savoir-fair. F_{target} was calculated by fitting a GLM to logbook CPUE, while taking into account the standardisation factor F_{std} calculated above. The model is a loglinear model of CPUE/F_{std} with factors vessel size group, month and zone. F_{target} was estimated as the back-transformed vessel size group effect of the model. Using small vessels as the reference vessel size group, F_{target} was equal to 1.44 for medium-size vessels and 1.72 for large-size vessels. Finally, strategies were defined from the monthly allocation of effort (log-book data) between the different metiers practised by a set of vessels (small, medium and large).
Catchability in ISIS-Fish is defined as the probability that a fish present in a specific zone during a season is caught by a standardised effort unit from a non-selective vessel (Pelletier and Mahévas, 2005). Catchability coefficients were fitted by calibrating the model against total quarterly catches over an arbitrarily chosen period of two years (2002-2003; Figure 3). Calibration was based on the simplex method (Walters *et al.,* 1991). As cod form dense pre-spawning and spawning aggregations, relatively larger catchability coefficients were assigned to months corresponding to the presence of spawners on the spawning grounds. For simplicity, age effects were ignored and only two catchability coefficients were estimated for spawning and non spawning fish (respectively 8.04×10^{-6} and 1.17×10^{-5}).

2.4. Management model

Management options considered in the model comprised the exclusion of fishing effort at different temporal and spatial scales. When a metier was partly affected by a closure, its fishing effort was assumed to redistribute among the cells of its fishing area located outside of the closure. When the entire fishing area of a metier fell into the closed area, the effort of that metier was set to zero.
Four scenarios were simulated over periods of 20 years, each under favourable and unfavourable conditions for cod reproduction (Table 3). The first set of simulations considered no closures using initial stock sizes for 2005, i.e., the most recent year where an area-disaggregated multi-species stock assessment (MSVPA) was available providing the required area specific initial stock sizes for the model (ICES, 2005). However, as ICES (2007) estimated the reported landings to be on average 40% lower than the true landings during most recent years and about 10% of the total catch being discarded, simulations were run with and without correction for misreporting and discarding. In order to avoid using two different model calibrations, the correction was done by proportionally increasing the effort levels of all fleets until the landings increased by 50%. In the following the scenarios without closures, but corrected for misreporting and discarding will be referred to as "baseline scenarios".
Secondly, the effects of a single, small spawning closure in the Bornholm basin in combination with a closed season were simulated based on the IBSFC management plan for 1995 (Table 3; Figures 4a, d). For this scenario (further on denoted as "1995 scenario") initial stock sizes from area-disaggregated MSVPA for 1994 were used (ICES, 2005). The third set of simulations comprised three small spawning closures plus a closed season based on the management plan proposed by the EU Commission for 2007, where the 10% reduction in days at sea included in the management plan was accounted for by extending the closed season (Table 4; Figures 4b, d). Lastly, two large, year-round spawning ground closures in the Bornholm Basin and Gdansk Deep were considered (Table 3; Figure 4c). For the latter two scenarios (denoted as "2007 scenario" and "large spawning closure scenario" in the following) the most recent area-specific MSVPA estimates for year 2005 were used as initial stock sizes for the simulations (ICES, 2005).

3. Results

The baseline scenario did not consider closed areas or seasons, but was used to show the effect of misreporting and discarding on the dynamics of spawning stock biomass (SSB) and yield (Figures 5a-b). Note that we have chosen to display the annual average SSB rather than SSB at the start of the year, as SSB at January, 1st is strongly influenced by the strength of the recruiting year classes, whereas the annual average SSB already accounts for exploitation of the youngest recruited year class. The effect of misreporting and discarding was most dramatic under adverse environmental conditions as the annual average SSB continued to decline to levels below 50.000 tonnes (Figure 5a). Even if reported catches were the true catches, the stock would only slowly recover to a SSB of about 140.000 tonnes after 20 years of simulation, which is still below the present biomass limit reference point of 160.000 tonnes. For both scenarios, total annual yield remained relatively stable at low level, but an increasing trend was observed in the simulation with the uncorrected landings with yield reaching a maximum of ~45.000 tonnes after 20 years, which corresponded to the trend in SSB (Figure 5a).

Under favourable environmental conditions, the stock recovered irrespective of the correction for discard and misreporting (Figure 5b). Recovery appeared to be slower with the correction. The final SSB was about half the size compared to results obtained without correction. Accordingly, yield increased slower in the simulation with the correction. However, for both scenarios, total annual yield after 20 years reached the same plateau indicating a maximum catching capacity around 110.000 tonnes under the current parameterization of the model.

In a second step, we evaluated the 1995 closure scenario using 1994 area disaggregated MSVPA stock numbers as initial stock sizes (Figure 6). Under adverse environmental conditions, SSB remained relatively stable below B_{lim} at approximately 115.000 tonnes, however, with a slightly decreasing trend leading to a final total SSB of 112.000 tonnes after 20 years. After an initial drop, yield stabilized after 4 years at about 50.000 tonnes. Under favourable environmental conditions, SSB steadily increased over the simulation period and exceeded 400.000 tonnes after 20 years. Following SSB increase, yield increased to ca. 110.000 tonnes after 20 years.

Lastly, we simulated the 2007 and the large spawning closure scenarios (Table 4). These can be compared to the baseline scenario, as the simulation periods were the same. Under favourable environmental conditions, both SSB and catch substantially increased with the 2007 scenario (Figure 7a), while the consequences of the large spawning closures were similar to the baseline scenario, i.e. the latter closure scenario was ineffective in terms of both SSB and yield under favourable environmental conditions (Figure 7b). This may be explained by the fact that the majority of metiers were able to displace their effort beyond the closure boundaries and maintain similar catch levels. However, during the first ten simulation years of the large spawning closure scenario SSB was constantly a few tonnes below the baseline scenario, which may be interpreted as an effect of effort displacement into regions of higher catchability compared to the traditional fishing grounds. In the case of adverse environmental conditions, SSB under the large spawning closure scenario remained relatively stable at very low level with the final SSB after 20 years of simulation being 20.000 tonnes higher than under the baseline scenario and still much lower than Blim (Figure 7b). Similar to SSB, yield stayed stable and reached a total of 27.000 tonnes at the end of the simulation period, which was only slightly higher than the baseline scenario. With respect to the 2007 scenario, SSB doubled over the simulation from 50.000 tonnes to slightly more than 100.000 tonnes (Figure 7a). Contrary to SSB, the increase in yield from around 30.000 tonnes to 40.000 tonnes was less pronounced.

It is difficult to directly compare the 1995 with the two other closure scenarios, as they do not start from the same years nor initial stock sizes. Initial stock sizes were much lower for the 2007 and large spawning closure scenario (SSB 50.000 tonnes) than for the 1995 scenario (SSB 147.000 tonnes). At the end of their respective simulation periods, however, the SSB levels reached in the 2007 and 1995 scenarios were similar, respectively above 400.000 tonnes (favourable conditions) and around 110.000 tonnes (unfavourable conditions) (Figures 6, 7a). This seems to indicate a stabilization of the dynamics of the population, which can be expected given the assumption of a Beverton-Holt stock-recruit function. Accordingly, catch levelled off between 123.000 tonnes (1995 scenario) and 113.000 tonnes (2007 scenario) under favourable

environmental conditions, which is only a minor deviation from the baseline scenario (110.000 tonnes), indicating that the population was fully exploited.
None of the scenarios investigated allowed the stock to recover even to B_{lim} level under unfavourable conditions. In contrast, under favourable conditions B_{pa} was reached after 9 years with the 1995 scenario, after 13 years under the 2007 scenario and after 18 years under large spawning closures (Figures 6, 7a,b). Note that this latter result was also obtained in the baseline scenario without closures (Figure 5b).
In order to disentangle the effects of small and large spawning closures as well as closed seasons, an additional simulation was conducted with only the three small spawning closures of the 2007 scenario being implemented, i.e. leaving aside the closed season of that scenario. In this exercise, we only considered adverse environmental conditions as favourable environmental conditions led to stock recovery irrespective of closed areas or seasons. The SSB trajectory over the 20 year simulation period showed no effect of the small spawning closures as results were similar to the baseline scenario (Figure 8). The large spawning closure scenario in comparison moderately differed from the baseline SSB stabilising the stock. A positive SSB development could be observed when the full 2007 scenario including the seasonal closure was implemented (Figure 8).

Discussion

The primary management measures for demersal stocks in the Baltic Sea are TAC's. These are accompanied by an extensive array of technical measures, including seasonal closures, closed areas, additional restrictions of days at sea to be allocated individually by the member states, minimum landing sizes and regulations concerning codend mesh configuration (ICES, 2007). Consequently, a detailed evaluation of the separate effects of each of the management measures on the stock and fishery was hardly possible. Contrary to Drouineau *et al*. (2006) who applied ISIS-Fish to the hake and Nephrops fishery in the Bay of Biscay we did not attempt to disentangle the effects of several measures jointly implemented, but rather chose to evaluate specific closure scenarios either already implemented or proposed.
The ISIS-Fish model of the Baltic cod fishery is the first application of the model to a fish population with a comprehensive amount of biological and ecological knowledge. Based on the available biological time series data and output from a coupled bio-physical model for Eastern Baltic cod (Hinrichsen *et al*., 2008; this volume), we were able to construct and parameterise the population model for two contrasting environmental regimes, which enabled us studying the effects of different management options under varying environmental forcing conditions.
In contrast to short term stock predictions, medium term stock projections as conducted in the present study heavily depend on the recruitment model (Gislason, 1993). Most of the processes determining year class strength as well as growth, maturation and survival during the adult life are reasonably well understood for eastern Baltic cod. A main driver of recruitment variability is the thickness and oxygen content of the reproduction volume for cod eggs affecting egg survival (MacKenzie *et al*., 2000; Nissling *et al*., 1994; Köster *et al*., 2003, 2005). These two variables are affected by the frequency and intensity of inflow events of oxygen rich water masses from the western Baltic and North Sea, which in turn are determined by regional atmospheric forcing and long term climate fluctuations (Matthäus and Franck, 1992; Mohrholz *et al*., 2006). It is mainly the limited long term predictability of the regional climate and related changes in the hydrographic conditions that impair realistic recruitment predictions and thus projections of future population development of Baltic cod. Consequently, we considered Beverton-Holt recruitment models fitted to periods characterised by distinct environmental regimes to account for differences in stock productivity during favourable and adverse environmental conditions. Similar to recruitment, environment-dependent growth, maturation, spawning and migration functions were also parameterized based on available data sets (ICES, 2005; 2007; STORE, 2002) and implemented into the population model. As we explored two extreme environmental regimes between most conditions will range it can be expected that our two scenarios would also represent the upper and lower extremes of population development. The difference in population sizes thus may serve as a valid indicator of model sensitivity to these biological hypotheses.

These differences in population size and yield between the two environmental scenarios were by far larger than the effects of the discard and misreporting correction as well as the influence of the applied management scenario. A similar strong environmental signal on population abundance and yield was revealed in earlier studies (Röckmann et al. 2007; ICES, 2005). However, these studies considered scenarios of fixed fishing mortalities at limited spatial resolution (i.e. ICES SDs) and were not depicting fleets.

An important error source related to the exploitation model is the high rate of misreporting in the Baltic cod fishery. Whereas discards are regularly sampled with a good coverage, misreporting leads to substantial uncertainty in total landing estimates (ICES, 2007). In recent years ICES has attempted to correct for such misreporting by applying raising factors to national catches based on the information available on misreporting for each national fleet. However, by nature this information is highly uncertain and incomplete with no information available for some nations where nonetheless misreporting is suspected to occur. Although catches used in the present study were corrected for misreporting using information provided by ICES they can at best be considered to be approximate minimum values (ICES, 2007). As a result, our simulations may provide a too optimistic picture, but as the correction for misreporting and discarding was done by increasing the effort equally throughout all metiers, model runs with and without correction provide an indication for sensitivity of the model to variations in overall exploitation levels.

Under favorable environmental conditions a simulation without closures showed a stock recovery to levels around B_{pa} after 18 years, even when the effort was increased to account for illegal landings and discarding. This indicates that the present total effort would be sustainable on the long run under such conditions. However, unfavorable conditions are known to occur frequently and future climate change is not expected to improve environmental conditions for cod reproduction in the Baltic Sea. Westerly airflows have intensified, especially during winter, contributing to higher winter temperatures, greater precipitation and reduced inflow activity (BACC, 2008). Studies of past and recent ecosystem changes have demonstrated the sensitivity of the Baltic Sea ecosystem to changing temperatures. Several effects could be related to temperature changes, in particular changes in species composition. For instance, higher temperatures during the 1990s were associated with a shift in dominance within the open sea copepod community from *Pseudocalanus acuspes* to *Acartia* spp. (Möllmann and Köster, 2000). Survival of Baltic cod larvae is strongly dependent on the occurrence of *Pseudocalanus acuspes* in their prey field (Hinrichsen *et al*., 2002). These trends are expected to continue in the future according to regional climate change scenarios (BACC, 2008). Thus, sustained periods of favorable environmental conditions for cod reproduction as considered in some of the simulations are an unlikely scenario for the future.

On the contrary, under unfavourable environmental conditions, none of the proposed or implemented closure scenarios was able to recover the stock even to B_{lim}. Such a scenario of consistently low recruitment might be overly pessimistic as even during long stagnation periods, infrequent inflows were observed (Mohrholz *et al*., 2006). These events would improve the strength of single or a few year classes and consequently the resilience of the stock against heavy exploitation.

As both population and exploitation models are subject to some uncertainty as described above, the interpretation of SSB and yield should be cautious. Still, a relative comparison of different closure regimes under otherwise constant conditions provides valuable insights into the performance of closures such as those tested here. For example, our results demonstrated that closed seasons of the entire fishing area had a much larger impact on recovery rates, final stock sizes and yield compared to regionally restricted spawning area closures. This observation is in contrast to Halliday (1988) who could not evidence positive effects when analysing seasonal closures on Georges Bank to preserve haddock. Even the “large spawning closure scenario” affecting year around about one fifth of the entire fishing area performed remarkably worse than the tested seasonal closures. Although this scenario effectively removed all effort from dense pre-spawning and spawning concentrations, the capacity of the cod fleets was obviously high enough to compensate the closure effect to a large degree by reallocating the effort into open areas maintaining high catch levels. In addition, effort may be reallocated into potentially sensitive nursery areas with additional negative population effects not accounted for in our model (Hinrichsen *et al.,* 2008, this volume).

Another possible reason for the limited impact of spawning closures might reside in the effort reallocation rule implemented in our model. We assume that only if a metier falls completely into a closure the effort is eliminated from the fishery, i.e., assuming that these metiers would leave the area and search for other distant fishing options, whereas the effort of partially affected metiers is reallocated. As the spatially restricted spawning closures in the Baltic Sea affected most metiers only partly, the largest portion of the effort is reallocated into open cells of the metiers along the boundaries of the closures as also documented by Murawski *et al*. (2005) for Georges Bank, whereas the large scale seasonal closures effectively reduced the overall fishing pressure also from potentially sensitive nursery areas (Hinrichsen *et al.,* 2008, this volume). However, the positive effects of large spawning closures may prove larger than shown here, because economic constraints like increasing travel time and fuel costs imposed to fleets in relation to the closure were not accounted for in the present model. Moreover, large year-round closures may also induce positive effects on stock structure that are beneficial for adjacent fisheries (Roberts *et al*., 2001), but are not accounted for in our model, e.g., an increase in the number of large, fecund fish.

Despite the strong and obvious influence of environmental conditions, we conclude that conditioned on model assumptions for effort reallocation, the reduction of effort and thus fishing mortality as imposed by closed seasons is more efficient at stock recovery rather than reduction of spawner disturbances through the implementation of spatially restricted spawning closures. As our model fleets are parameterised based on catch data comprehensive for the entire Baltic cod fishery we are certain that this conclusion will also hold for the existing cod fleets, i.e., catch losses imposed by closed seasons can not be fully compensated during other times of the year.

An effective, traditional management regime may thus be a viable alternative to the MPA design currently implemented in the Baltic Sea, which is well in line with other studies on the effects of MPA's on temperate, highly mobile fish species (Hilborn *et al*., 2004; Kaiser, 2005). We however have to acknowledge, that our present model ignores multi-species interactions, effects of spawning closures on protection of big, old, fecund females and possible effort re-allocation effects on sensitive nursery areas. Yet, it would be interesting to further investigate effort reallocation schemes, e.g. through the analysis of Vessel Monitoring Systems (VMS) or fishers interviews, in order to better parameterize fisher's response to MPA implementation.

Acknowledgements

The present study evaluates aspects of the Baltic cod fishery and population biology based on results from the Commission of the European Communities Specific Targeted Research Project (STREP) 513670 (PROTECT), 502516 (EFIMAS), and 022717 (UNCOVER). We are especially indebted to project participants providing data sets, to Benjamin Poussin for immediate online software support, to R. Nielsen, P. Sparre and S. Lehuta for valuable discussions while building the model, and to three referees for their fast and constructive reviews.

References

Agardy, M.T. 1994. Advances in marine conservation: The role of marine protected areas. Trends in Ecology and Evolution, 9: 267-270.

BACC. 2008. Assessment of Climate Change for the Baltic Sea basin. Springer Regional Climate Studies XXII, Heidelberg, Germany: 474 pp.

Bagge, O., Thurow, F., Steffensen, E., and Bay, J. 1994. The Baltic cod. Dana, 10: 1-29.

COM(2006) 485 final. 2006. Proposal for a Council Regulation fixing the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks applicable in the Baltic Sea for 2007. European Commission, Brussels, 5.9.2006, 26 pp.

Drouineau, H., Mahévas, S., Pelletier, D., and Beliaeff, B. 2006. Assessing the impact of different management options using ISIS-Fish: The French *Merluccius merluccius – Nephrops norvegicus* mixed fishery of the Bay of Biscay. Aquatic Living Resources, 19: 15-29.

Gislason, H. 1993. Effect of changes in recruitment levels on multispecies long-term predictions. Canadian Journal of Fisheries and Aquatic Sciences, 50: 2315-2322.

Halliday, R. G. 1988. Use of seasonal spawning area closures in the management of haddock fisheries in the Northwest Atlantic. Northwest Atlantic Fisheries Organization Scientific Council Studies, 12: 27–36.

Halpern, B.S., and R.R. Warner. 2003. Matching marine reserve function to stakeholder needs. Proceedings of the Royal Society of London Series B: Biological Sciences, 270: 1871-1878.

Hilborn, R., Stokes, K., Maguire, J-J., Smith, T., Botsford, LW., Mangel, M., Orensanz, J., *et al*. 2004. When can marine reserves improve fisheries management? Ocean Coastal Management, 47: 197-205.

Hinrichsen, H.H., Kraus, G., Böttcher, U., and Köster, F.W., 2008. Identification of Baltic cod nursery grounds as potential Marine Protected Areas using hydrodynamic modeling. ICES Journal of Marine Science: (in press).

Hinrichsen, H.H., Voss, R., Wieland, K., Köster, F.W., Andersen, K.H., and Margonski, P. 2007. Spatial and temporal heterogeneity of the cod spawning environment in the Bornholm Basin, Baltic Sea . Marine Ecology Progress Series, 345: 245-254.

Hinrichsen, H.-H., Möllmann, C., Voss, R., Köster, F.W., and Kornilovs, G. 2002. Biophysical modelling of larval Baltic cod (*Gadus morhua* L.) growth and survival. Canadian Journal of Fisheries and Aquatic Sciences, 59: 1858-1873.

Hutchings, J.A., and Myers, R. A. 1994. What Can Be Learned from the Collapse of a Renewable Resource? Atlantic Cod, *Gadus morhua*, of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences, 51: 2126-2146.

IBSFC 1994. Proceedings of the 20th Session. International Baltic Sea Fisheries Commission, Warsaw, Poland, 12-16 September 1994. 338 pp.

ICES 1999. Report of the Baltic Fisheries Assessment Working Group. ICES Document CM 1997/ACFM:15.

ICES 2005. Report of the Study Group on Multi-species Assessment in the Baltic. ICES Document CM ICES 2005/H:06.

ICES 2006. Report of the Study Group on Multi-species Assessment in the Baltic. ICES Document CM ICES 2006/BCC:07.

ICES 2007. Report of the Baltic Fisheries Assessment Working Group. ICES Document CM 2007/ACFM:15.

Kaiser M.J. 2005. Are marine protected areas a red herring or fisheries panacea? Canadian Journal of Fisheries and Aquatic Sciences, 62: 1194–1199.

Köster, F.W., Möllmann, C., Hinrichsen, H.-H., Tomkiewicz, J., Wieland, K., Kraus, G., Voss, R., *et al*. 2005. Baltic cod recruitment – the impact of climate and species interaction. ICES Journal of Marine Science, 62: 1408-1425.

Köster, F.W., Möllmann, C., Neuenfeldt, S., Vinther, M., St John, M.A., Tomkiewicz, J., Voss, R., *et al*. 2003. Fish stock development in the Central Baltic Sea (1996–2000) in relation to variability in the environment. ICES Marine Science Symposia, 219: 294-306.

Lehmann, A. 1995. A three-dimensional baroclinic eddy-resolving model of the Baltic Sea. Tellus, 47A: 1013-1031.

MacKenzie, B.R., Hinrichsen, H.-H., Plikshs, M., Wieland, K., and Zezera, A.S. 2000. Quantifying environmental heterogeneity: Habitat size necessary for successful development of cod Gadus morhua eggs in the Baltic Sea. Marine Ecology Progress Series, 193: 143-156.

Mahévas, S., and Pelletier, D. 2004. ISIS-Fish, a generic and spatially explicit simulation tool for evaluating the impact of management measures on fisheries dynamics. Ecological Modelling, 171: 65-84.

Murawski, S.A., Wigley, S.E., Fogarty, M.J., Rago, P.J., and Mountain, D.G. 2005. Effort distribution and catch patterns adjacent to temperate MPAs. ICES Journal of Marine Science, 62:1150-1167.

Matthäus, W., and Franck, H. 1992. Characteristics of major Baltic inflows – a statistical analysis. Continental Shelf Research, 12: 1375-1400.

Möllmann, C., and Köster. F.W. 2000. Food consumption by clupeids in the Central Baltic: Is there evidence for top-down control? ICES Journal of Marine Science, 56: 100-113.

Mohrholz, V., Dutz, J., and Kraus, G. 2006. The impact of exceptionally warm summer inflow events on the environmental conditions in the Bornholm Basin. Journal of Marine Systems, 60: 285-301.

Nissling, A., Kryvi, H., and Vallin, L. 1994. Variation in egg buoyancy of Baltic cod *Gadus morhua* and its implications for egg survival in prevailing conditions in the Baltic Sea. Marine Ecology Progress Series, 110: 67-74.

Pelletier D., and Mahévas, S. 2005. Spatially explicit fisheries simulation models for policy evaluation. Fish and Fisheries, 6: 1-43.

Pelletier, D., Mahévas, S., Jarraya, M., Capoulade, M., Drouineau, H., Vermard, Y. and Bastardie, F. 2007. Investigating the consequences of Marine Protected Areas upon fish populations and fisheries through ISIS-Fish, a generic simulation tool. *In* First International Marine Protected Areas Congress, 23-27 October 2005, conference proceedings: IMPAC1 2005, pp. 340-341. Ed. by J.C. Day, J. Senior, S. Monk, and W. Neal., Geelong, Victoria, Australia: http://www.impacongress.org. 665 pp.

Pinnegar, J.K., Blanchard, J.L., Mackinson, S., Scott, R.D., and Duplisea, D.E. 2005. Aggregation and removal of weak-links in food-web models: system stability and recovery from disturbance. Ecological Modelling, 184: 229-248.

Radtke, K. 2003. Evaluation of the exploitation of Eastern Baltic cod (*Gadus morhua callarias* L.) stock in 1976-1997. ICES Journal of Marine Science, 60: 1114-1122.

Röckmann, C., St. John, M.A., Schneider, U.A., and Tol, R.S.J. 2007. Testing the implications of a permanent or seasonal marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions. Fisheries Research 85: 1-13.

Roberts, C.M., Bohnsack, J.A., Gell, F., Hawkins J.P., and Goodridge, R. 2001. Effects of Marine Reserves on Adjacent Fisheries. Science, 294: 1920-1923.

STORE 2002. Environmental and fisheries influences on fish stock recruitment in the Baltic Sea. Final Progress Report to the EU Commission, FAIR 98 3959 Part 1 & 2. European Commission, Directorate General XIV Fisheries, rue de la Loi 200, 1049 Brussels, Belgium, 1216 pp.

Tomkiewicz, J., and Köster, F.W. 1999. Maturation processes and spawning time of cod in the Bornholm Basin of the Baltic Sea: preliminary results. ICES Document CM 1999/Y:25.

Tomkiewicz, J., Eriksson, M., Baranova,T., Feldman, V. and Müller H. 1997. Maturity ogives and sex ratios for Baltic cod: establishment of a database and time series. ICES Document CM 1997/CC:20.

Walters, F.H., Morgan, S.L., Parker, L.R., Deming, S.N. 1991. Sequential simplex optimization. CRC Press LLC, Florida, United States: 402pp.

Walters, C., Pauly, D., and Christensen, V. 1999. Ecospace : prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. Ecosystems, 2: 539-554.

Watson, R., Alder, J., and Walters, C. 2000. A dynamic mass-balance model for marine protected areas. Fish and Fisheries, 1: 94-98.

Tables

Table 1. Estimated population parameters used in the ISIS-Fish model.

Parameters		**Values**	**Source**
General parameters	Number of age groups	8	ICES, 2007
	Growth	von Bertalanffy: "good environment" K = 0.064, Linf = 187.55 cm and T0 = -1.086 "bad environment" K = 0.101, Linf = 145.154 cm and T0 = -0.727	ICES, 2007
	Stock recruit relationship	Beverton & Holt "good environment" Recr A2=(2.35*SSB)/(1+0.000006*SSB) "bad environment" Recr A2=(1.15*SSB)/(1+0.000005*SSB)	ICES, 2007
Age specific parameters	Natural mortality	0.2 for all age groups and scenarios	ICES, 2007
	Weight at age	"good environment" weight = - 1.3070993 + exp(0.204730*age) "bad environment" weight = - 1.3094575 + exp(0.2206051*age)	ICES, 2007
	Maturity	curve: y = a / (1+(x/x0)^b) "good environment" a=0.9943; b=-5.066; c=3.111 "bad environment" a=1.0083; b=-4.781; c=3.00151	Tomkiewicz *et al*., 1997 ICES, 2007

Table 2. Selectivity curve parameters for each gear. S1 and S2 correspond to the equation s(x)=1/(1+exp(S1-S2*x)) where x is fish length in cm.

Gear	**S1**	**S2**
Gillnets	37.99	0.92
Trawls	14.87	0.34
Others gears	26.43	0.63

Table 3. Simulated scenarios and corresponding figures, closure design, season and years of implementation, Reference is given where applicable.

Scenario	Simulation period	Simulated management measures	Reference
Baseline scenario	2006-2025	- No closures	--
1995 scenario	1995-20019	- Summerban from 15.04-31.08 for targeted cod fishing in ICES SD 25-32 -Spawning closure for all fishing activities in a small area in the Bornholm Basin from 15.05-31.08	IBSFC, 1994; reviewed in ICES, 1999
2007 scenario	2006-2025	- Spawning closures in the Bornholm Basin, Gdansk Deep and southern Gotland Basin from 15.06-30.09; passive large meshed gears allowed - Summerban from 15.06-14.09 for targeted cod fishing in ICES subdivisions 25 to 27 - 10% reduction of days at sea compared to 2006 fishing days	COM(2006) 485 final
Large spawning closure scenario	2006-2025	- Large, year around spawning closure in the Bornholm Basin and Gdansk Deep/southern Gotland Basin	--

Figures

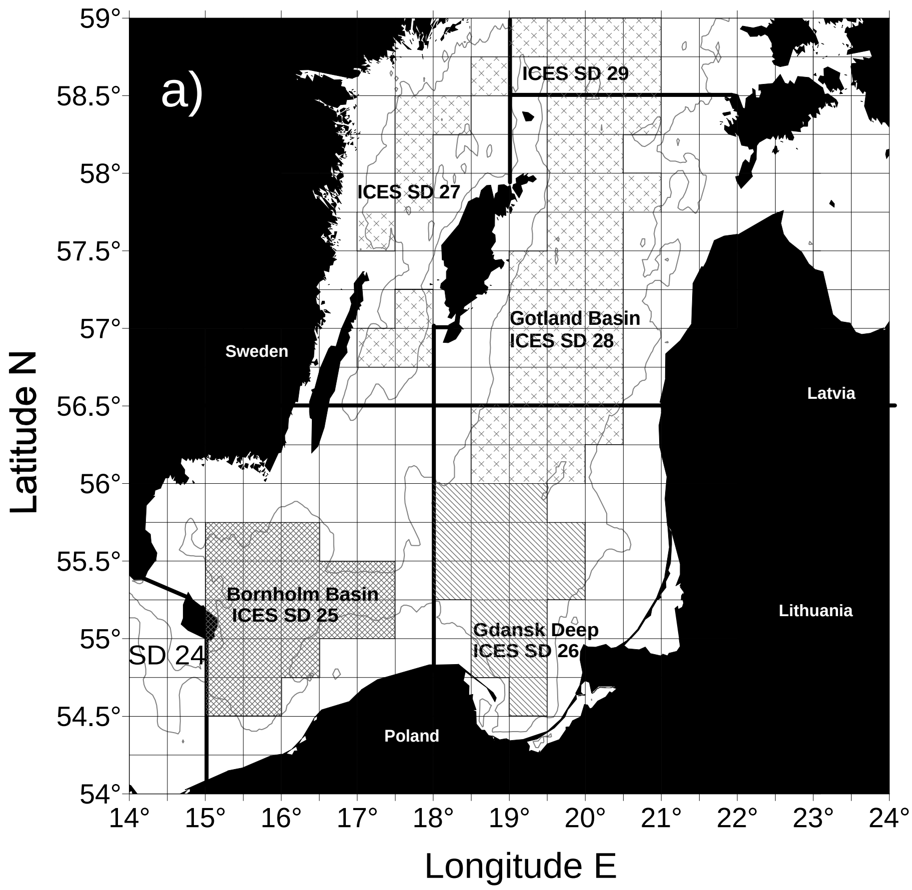
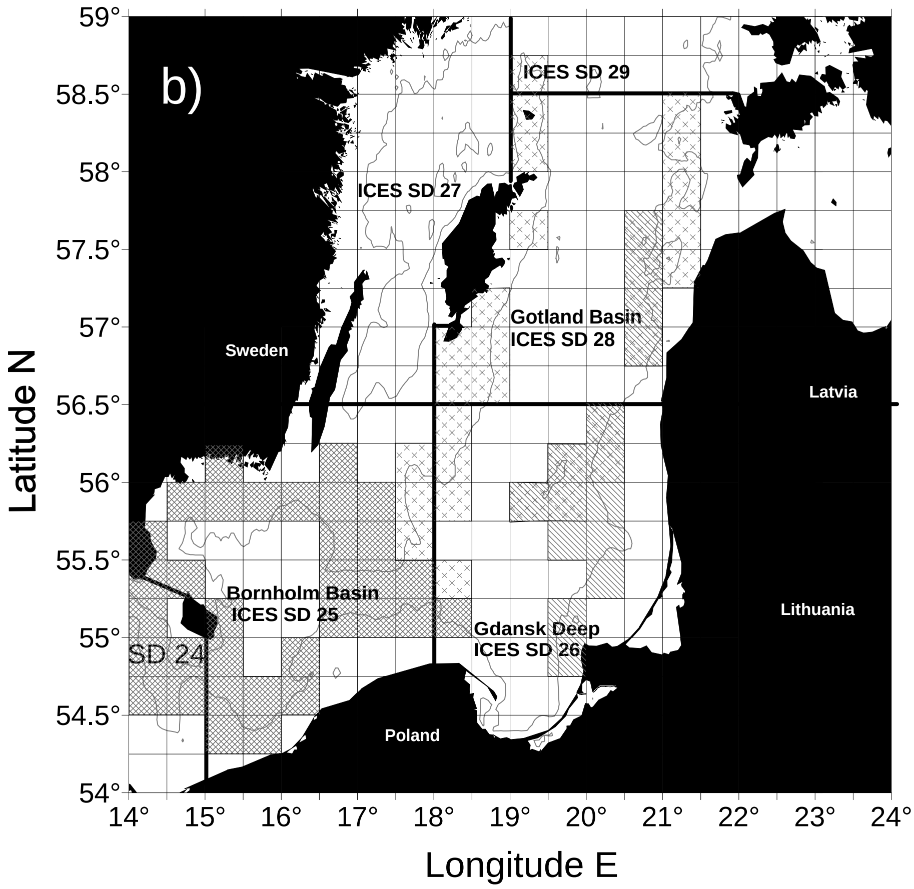


Figure 1a



b)
ICES SD 29
ICES SD 27
Gotland Basin
ICES SD 28
Sweden
Latvia
Bornholm Basin
ICES SD 25
Lithuania
Gdansk Deep
ICES SD 26
SD 24
Poland
59°
58.5°
58°
57.5°
57°
56.5°
56°
55.5°
55°
54.5°
54°
14°
15°
16°
17°
18°
19°
20°
21°
22°
23°
24°
Latitude N
Longitude E

Figure 1b

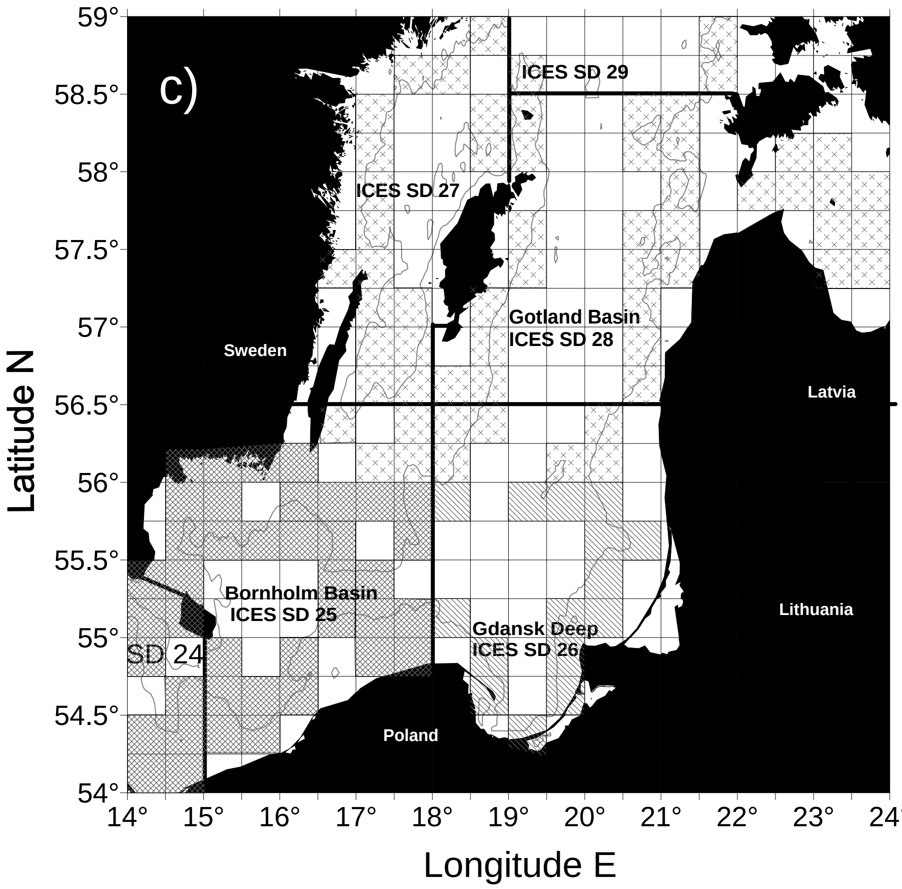


Figure 1c

Figure 1: Population zones considered in the ISIS-Fish model: a) Spawning areas, b) Feeding areas, c) Nursery areas. Population zones corresponding to the Gotland Basin stock component are indicated by a cross pattern, a diagonal crossed line pattern was assigned to zones of the Bornholm Basin stock component and diagonal line patterns to the Gdansk Deep stock component.

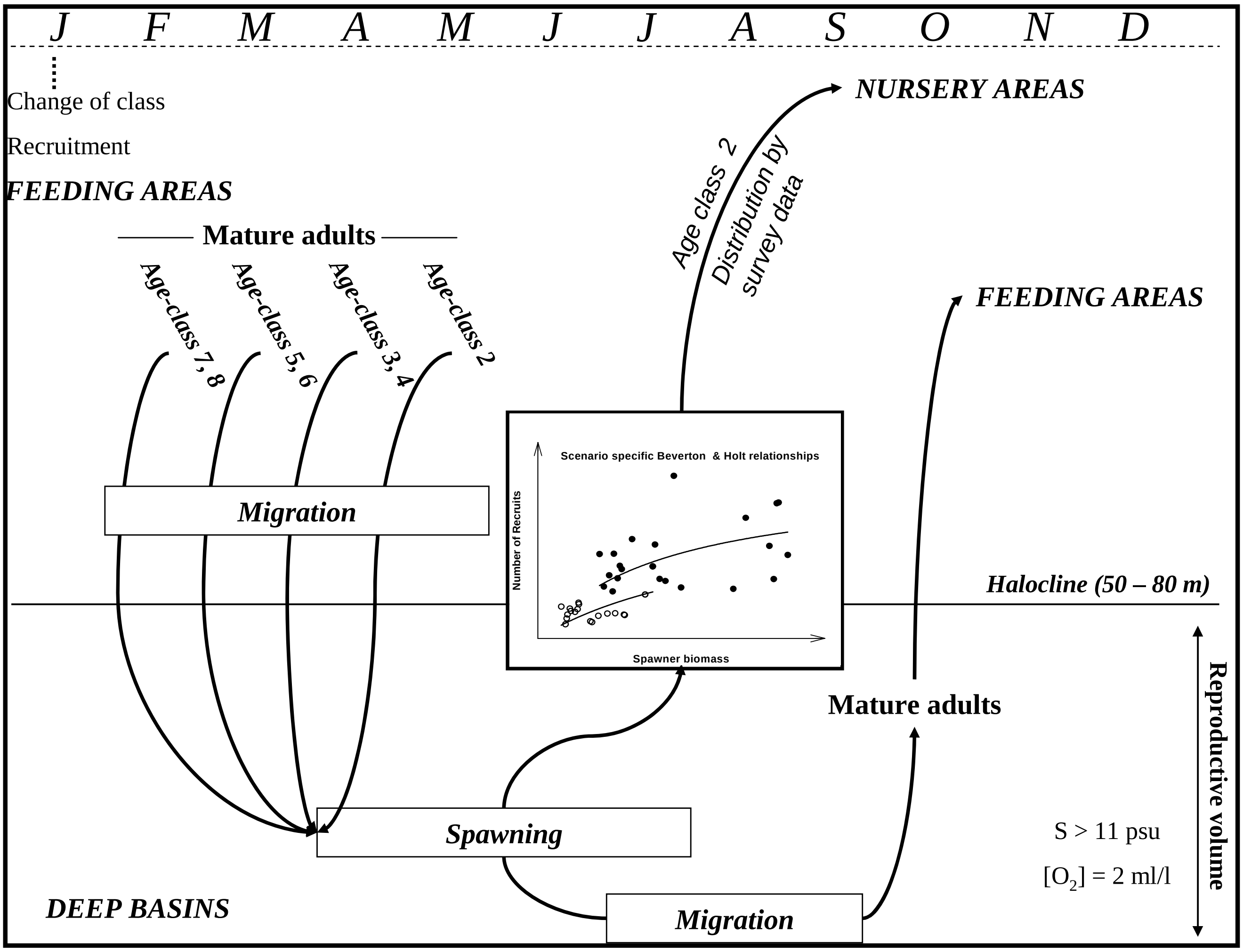


Figure 2

Figure 2. Conceptual diagram of the population model for Eastern Baltic cod including migrations. The horizontal plane visualises the seasonal development (month initials given in the top line), the vertical plane displays the depth gradient from cod spawning in the deep Baltic basins to feeding and recruiting at the shallow basin slopes and coastal regions.

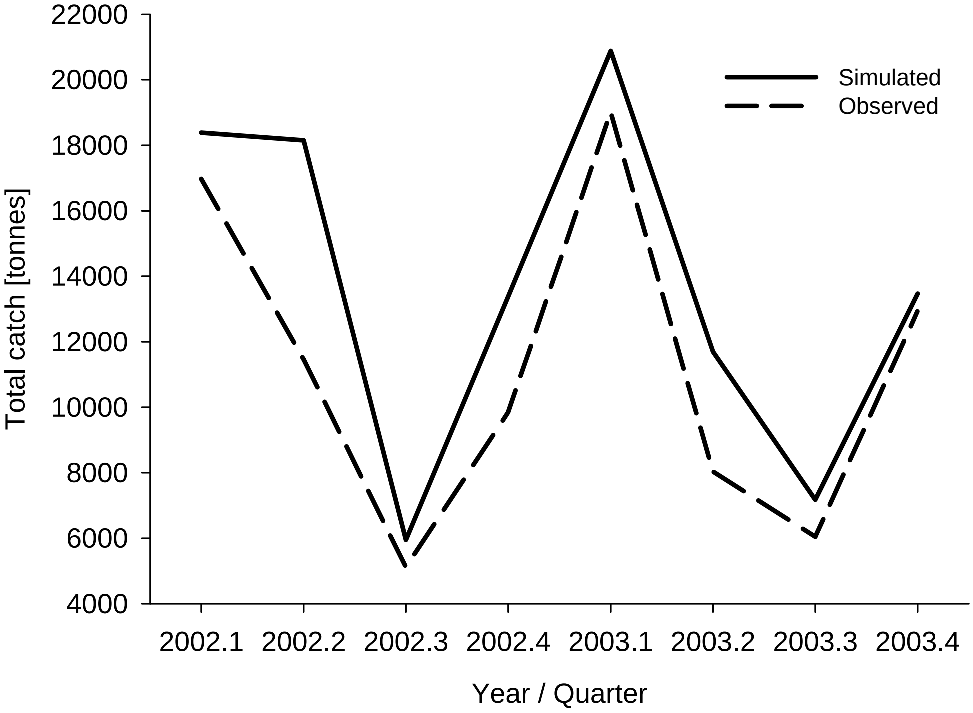


Figure 3

Figure 3. Calibrated quarterly effort pattern applied in the model (dashed line). The calibration is based on observed quarterly cod catches (solid line) for the period 2002-2003 using the simplex method to minimise differences between simulated and observed catches and estimate catchability coefficients.

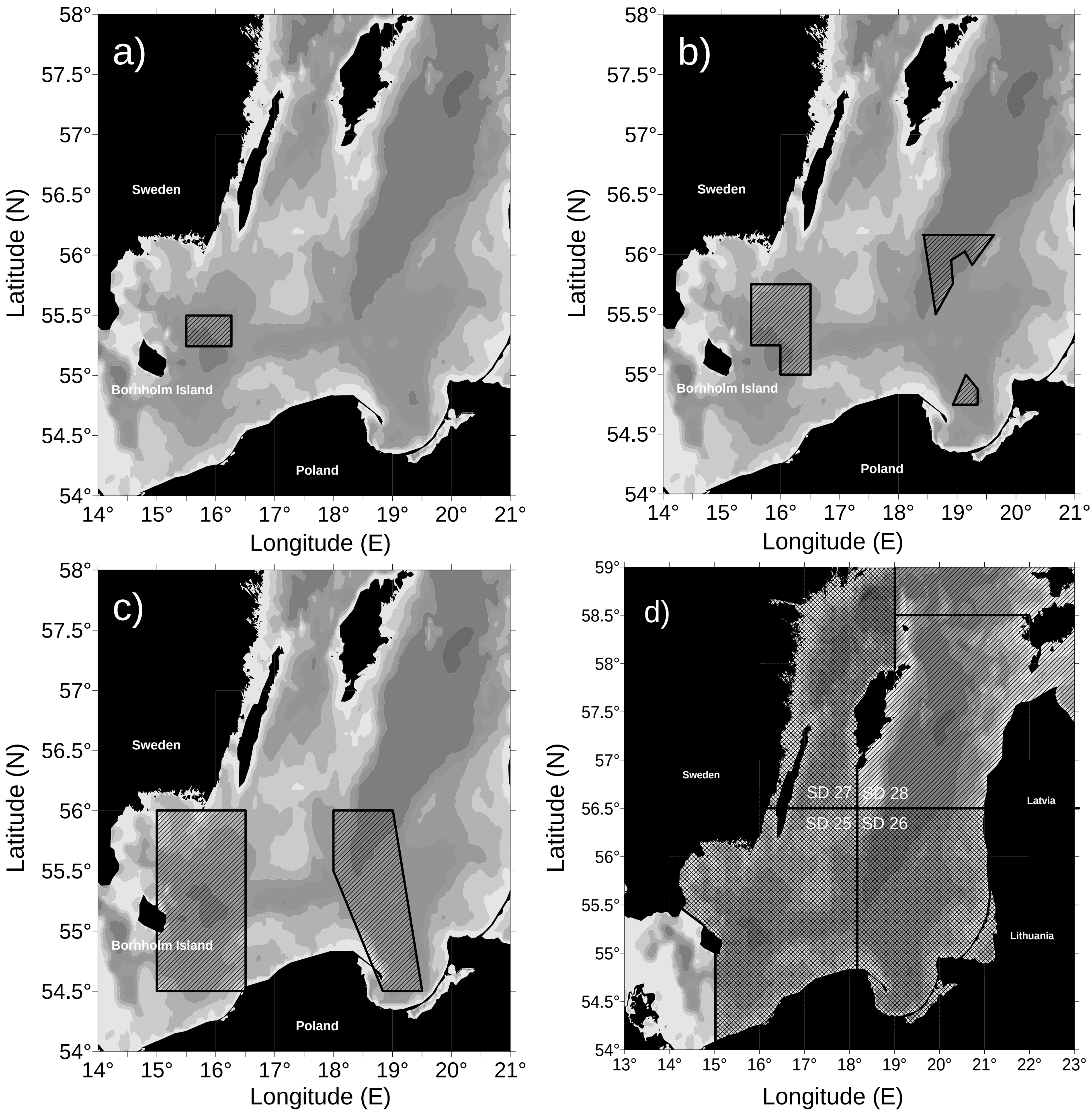


Figure 4

Figure 4. Spawning closures aimed at restoring eastern Baltic cod: a) implemented from 1995 to 2003 and used in the “1995 scenario”; b) implemented since 2004, and used in the “2007 scenario”; c) suggested by the EU Commission for 2006 and used in the “large spawning closure scenario”; d) depicts the areas of the model domain affected by the summer bans of the targeted cod fishery for the “1995 scenario” (entire Central Baltic Sea) and the “2007 scenario” (ICES Subdivisions25-27).

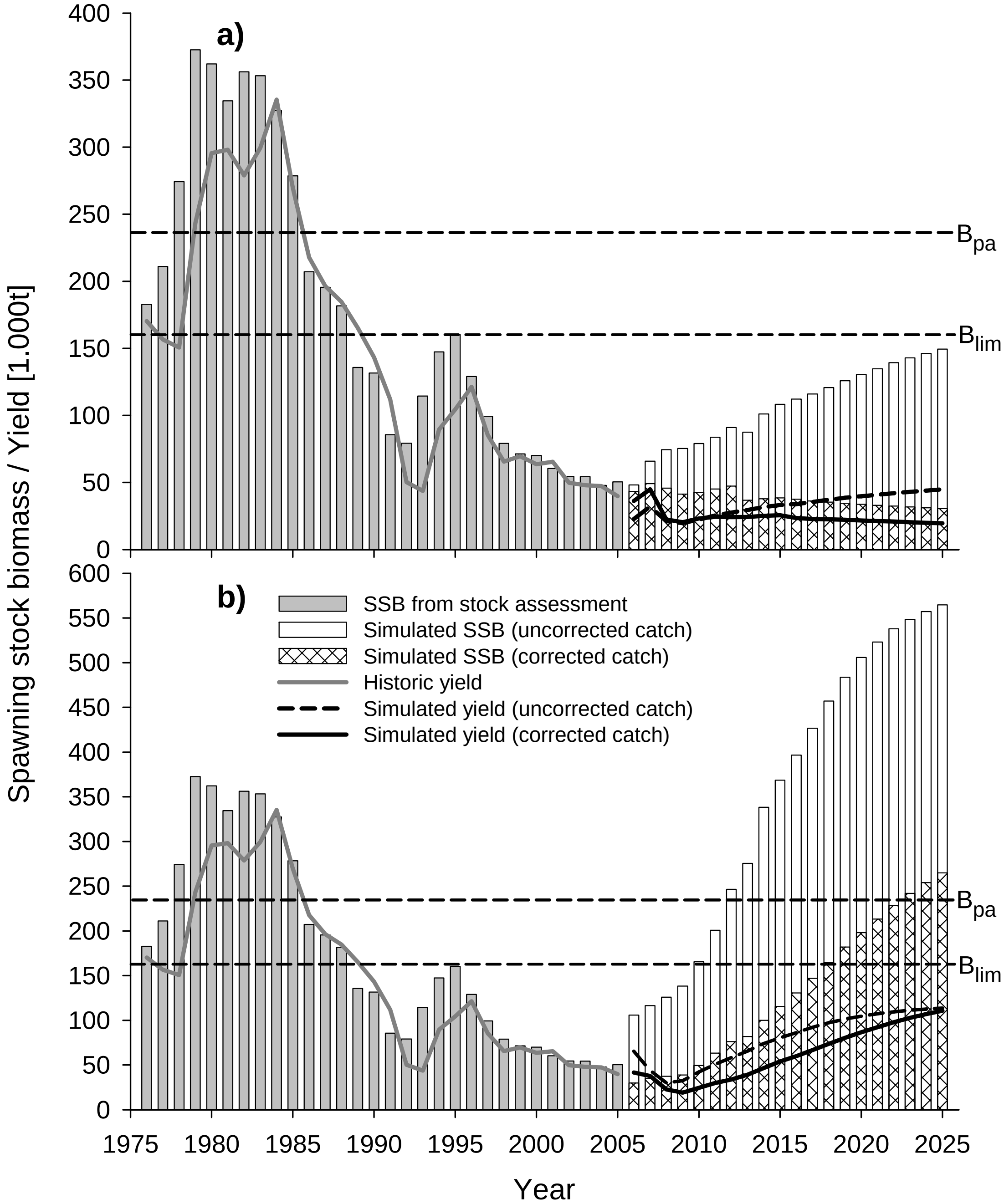


Figure 5

Figure 5. Trajectories of annual average SSB (bars) and total annual yield (lines) without fishing closures implemented. Results are shown for a) adverse and b) favourable environmental conditions. In each case, results are displayed with and without correction of reported catches for misreporting and discarding. 1976-2005 annual average SSB and total annual yield as estimated from an area-disaggregated multi-species VPA by quarter are shown in addition. The corresponding limit (B_{lim}) and precautionary (B_{pa}) reference points are displayed as horizontal lines (ICES 2007).

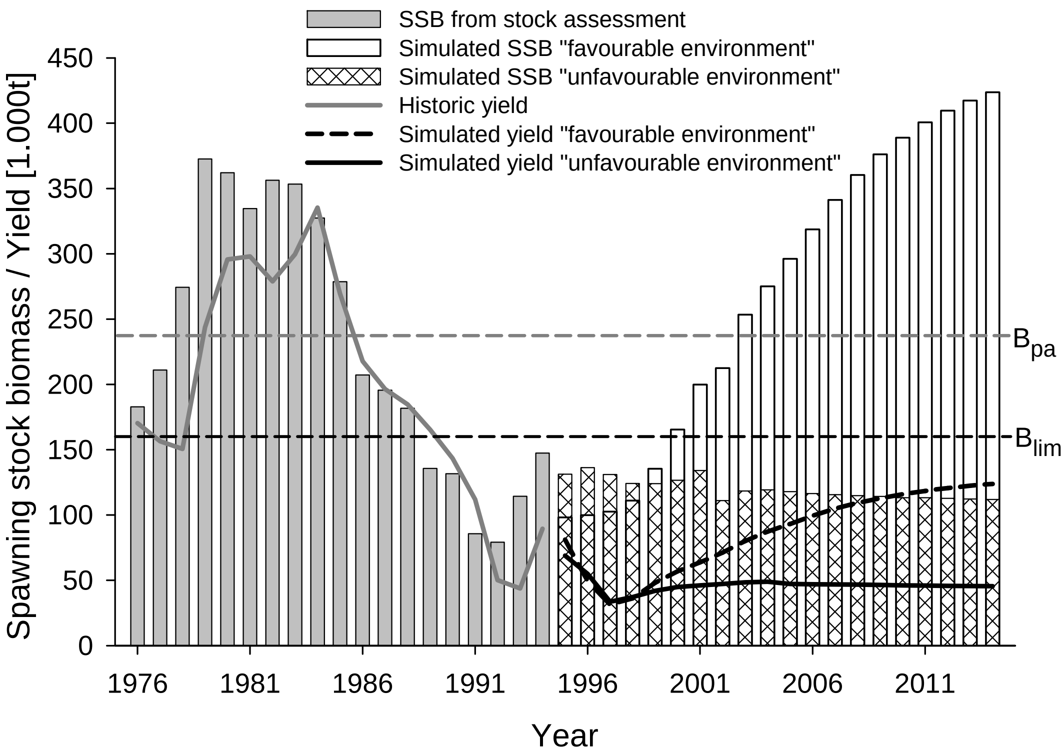


Figure 6

Figure 6. Trajectories of annual average SSB (bars) and total annual yield (lines). Simulations were run based on corrected catches, but considering the closures of the “1995 scenario”. Scenarios were simulated for adverse and favourable environmental conditions. 1976-1994 annual average SSB and total annual yield as estimated from an area-disaggregated MSVPA by quarter is shown in addition. The corresponding limit (B_{lim}) and precautionary (B_{pa}) reference points are displayed as horizontal lines (ICES 2007).

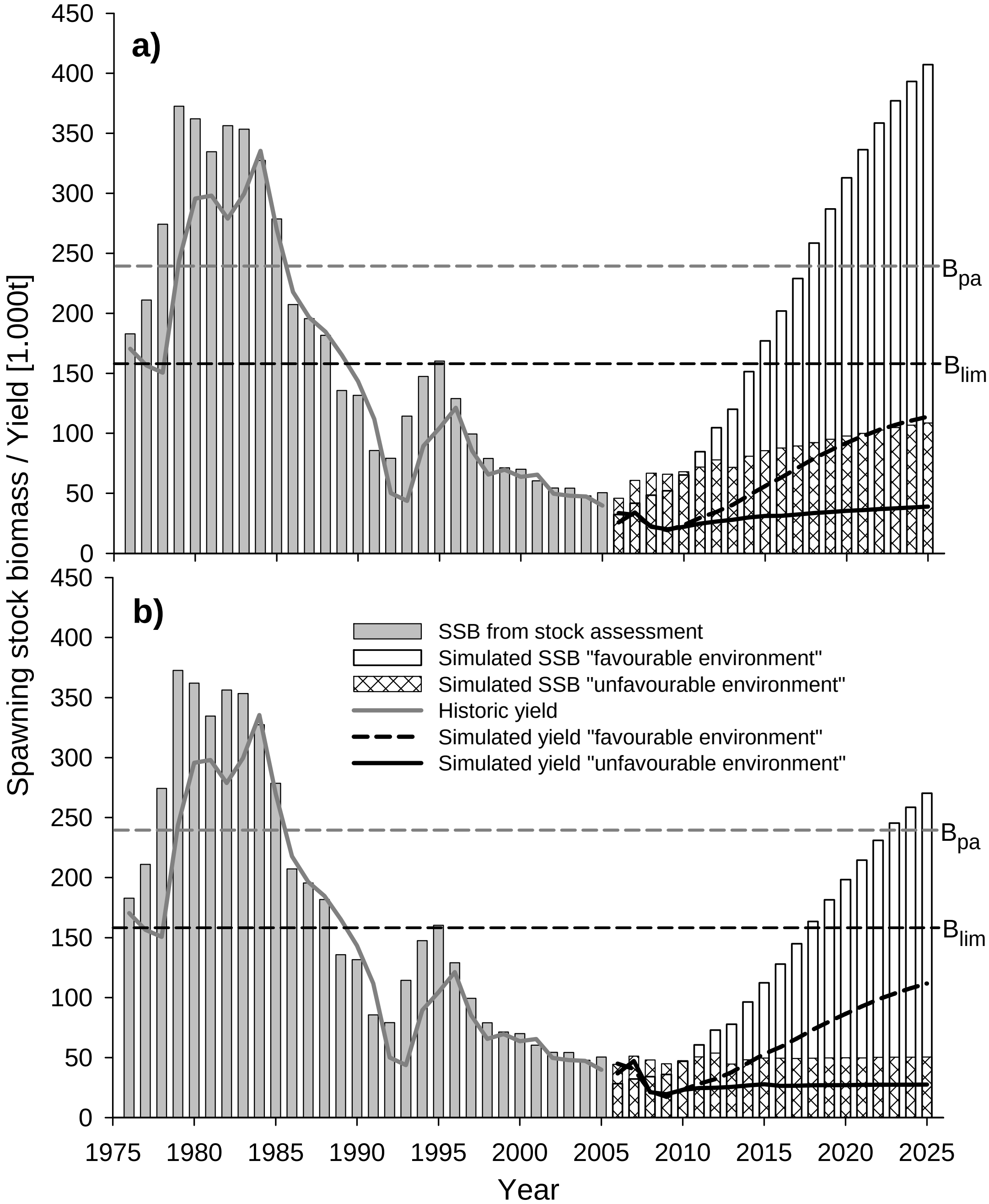


Figure 7

Figure 7. Trajectories of annual average SSB (bars) and total annual yield (lines). Simulations were run based on corrected catches, but considering the closures of a) the “2007 scenario”, and b) the “large spawning closure scenario”. In each case, scenarios were simulated for adverse and favourable environmental conditions. 1976-2005 annual average SSB and total annual yield as estimated from an area-disaggregated MSVPA by quarter are shown in addition. The corresponding limit (B_{lim}) and precautionary (B_{pa}) reference points are displayed as horizontal lines (ICES 2007).

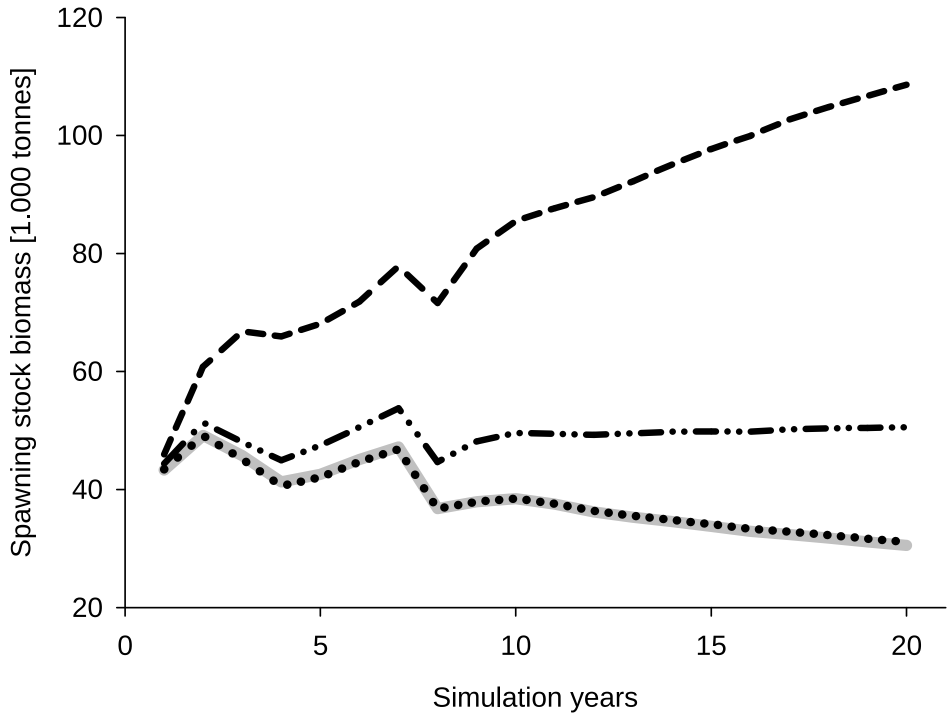


Figure 8

Figure 8. Comparison of the consequences of different closures on SSB development over 20 year simulation periods: no closures (grey line), three spawning closures of the “2007 scenario” (black dotted line),” large spawning closure scenario” (black dash and dot line) and the full “2007 scenario” including three small spawning closures plus a seasonal closures (black dashed line). Simulations were run based on corrected catches adverse environmental conditions.

Appendix Table. Gear used, vessel sizes, fishing zones (with corresponding ICES statistical rectangles) and seasons for each métier considered in the model. Seasons are labelled in months (T = Trawl; vessel sizes 1 = <12m; 2 = 12-24m; 3 = >24m).

Gear & vessel size	Métier	Fishing zone	ICES squares (% effort)	Total effort (%)	Season (months)
T – 1	Denmark1.1	Denmark1	39G5 (56.44%) 39G4(27.25%) 38G5 (16.31%)	100	J F M A J J A S O N D
T –1	Sweden1	Sweden1	40G4(33.43%) 40G5(60.54%)	93.88	J F M A S O N D
T – 2	Denmark1.2	Denmark1	39G5(41.06%) 38G5(14.27%) 39G4(23.12%)	78.49	J F M A M J J A S O N D
T – 2	Germany1	Germany1	38G4(25.81%) 39G5(19.13%) 38G5(15.46%) 40G6(11.79%) 37G4(9.56%) 39G4(8.01%) 39G6(6.79%)	96.55	J F M A M J J S O N D
T – 2	Poland 1	Poland 1	39G8(16.38%) 38G8(15.10%) 38G5 (14.48%) 39G7 (14.01%) 38G9(9.24%) 37G5(7.18%) 38G7(5.52%) 39G6(5.08%) 38G6(3.98%)	90.97	J F M A M S O N D
T – 2	Sweden 2	Sweden 2	40G4(28.85%) 40G5(20.57%) 40G6(15.55%) 39G4(15.51%)	80.48	J F M A S O N D
T – 3	Germany 2	Germany 2	40G6(26.68%) 38G5(25.84%) 39G5(25.84%) 39G6(7.87%) 38G4(5.62%)	91.45	J FM A M S O N D
T – 3	Latvia 1	Latvia 1	41G9(66.13%) 42H0(4.44%) 42G9(3.68%) 41H0(3.6%)	77.85	J F M A M S O N D
T – 3	Poland 2	Poland 2	39G8(28.9%) 39G6(13.04%) 39G7(13.04%) 40G8(13.01%) 38G5 (10.42%) 38G6(7.48%) 39G5(3.33%) 38G8 (2.62%) 38G9(2.3%) 39G9(1.98%) 40G7 (1.64%) 37G5(1.04%) 38G7(0.56%)	99.36	J F M A M S O N D
T – 3	Sweden 3	Sweden 3	40G6(33.9%) 40G4(18.43%) 40G5(14.22%) 41G7(8.27%) 41G6(5.42%) 39G6(4.97%)	85.21	J F M A S O N D
G –1	Denmark 1.3	Denmark 1	39G5(43.1%) 38G5(28.2%) 39G4(19.02%)	90.32	J F M A M J J A S O N D
G – 1	Poland 3	Poland 3	37G5(36.96%) 38G6(20.5%) 38G7(11.75%) 38G8(6.75%) 37G8(6.65%) 38G5(5.09%) 37G4 (4.23%)	91.93	J F M A M J J A S O N D

Appendix Table (continued).

Gear & vessel size	Métier	Fishing zone	ICES squares (% effort)	Total effort (%)	Season (months)
G – 1	Sweden 4	Sweden 4	40G4(31.38%) 40G5(14.07%) 41G6(8.84%) 41G5(8.65%) 39G4(7.61%) 42G6(6.92%) 43G7(4.21%) 43G6(3.25%) 41G4(2.55%) 40G6(2.34%) 41G7(2.05%) 42G7(1.83%)	93.8	J F M A M J J A S O N D
G – 2	Poland 1.2	Poland 1	39G7(23.55%) 38G6(16.54%) 39G8(13.38%) 39G6(11.91%) 38G8(8.87%) 37G5(7.72%) 38G5(6.21%) 38G7(6.03%) 38G9(0.4%)	94.21	J F M A M S O N D
G – 2	Sweden 5	Sweden 5	40G5(26,98%) 41G6(20.4%) 41G7(7.94%) 40G4(7.82%) 40G6(5.96%) 42G7(4.81%) 42G6(4.31%) 43G7(3.33%) 43G6(3.17%)	84.72	J F M A M S O N D
G – 3	Latvia 2	Latvia 2	41H0(35.4%) 40G7(12%) 41G9(10.21%) 40G6(9.45%) 41G7(8.78%) 41G8(5.48%) 42H0(4.17%)	85.49	J F M A M S O N D
G – 3	Poland 4	Poland 4	39G7(44.34%) 40G7(26.77%) 39G8(13.92%) 40G8(7.43%)	92.46	J F M A M S O N D
O – 1	Denmark 2	Denmark 2	39G4(48.53%) 38G5(24.27%) 38G4(8.04%) 39G5(6.96%)	87.8	J F M A M S O N D
O – 1	Poland 5.1	Poland 5	38G6(30.49%) 37G5(27.33%) 39G6(10.64%) 38G7(9.9%) 39G7(9.43%) 38G5(7.58%) 37G6(2.58%)	97.95	J F M A M S O N D
O – 1	Sweden 6	Sweden 6	40G4(57.97%) 41G5(15.12%) 41G4(11.85%) 40G5(9.36%)	94.3	J F M A M J J A S O N D
O – 2	Poland 5.2	Poland 5	38G6(29.89%) 39G7(23.69%) 39G6(13.41%) 37G5(10.22%) 38G7(7.04%) 38G5(6.07%) 37G6(0.6%)	90.92	J F M A M S O N D
O – 2	Sweden 7	Sweden 7	40G5(24.53%) 40G4(18.5%) 40G7(13.92%) 39G5(9.77%) 39G4(6.86%) 41G7(6.02%) 41G6(5.2%) 38G5(5.2%) 40G8(3.19%) 41G8(2.7%) 39G6(1.87%) 40G6(1.25%)	93.71	J F M A M J J A S O N D
O – 3	Latvia 3	Latvia 3	41H0(79.39%) 42H0(8.4%)	87.79	S O N D