Contents

1. SUMMARY

I provide below stochastic 5 years medium term projection outcomes of the Baltic cod stock status, i.e. the spawning stock biomass SSB and the fishing mortality *F* levels both for West and East cod stocks, together with the likely fisheries income dynamics earned out of the two Baltic cod stocks.

The effect of fishing time-area closure scenarios suggested to the STECF evaluation is assessed and quantified using the spatially-explicit DISPLACE modelling platform. This platform models the fine movement of individual fishing vessels at an hourly time step in a management strategy evaluation framework that reproduces the annual TAC management following F_{MSY} reference levels.

The Baltic Sea DISPLACE application has been already parameterized and used in a 2016 published study in ICES Journal of Marine Science. I develop here some extra scenarios adapted to the present request to STECF and implement these scenarios by reusing some previous assumptions i.e. assuming poor condition and slow growth for East cod, migration of East adult cod toward West cod areas and increased natural mortality from unknown external factors.

In short, both the cod stocks benefit from the effect of the simulated fishing closures but to a less extent for the Eastern cod and not sufficiently to reverse alone the declining trend from the ongoing low productivity regime. The early spring ICES SD 22-23-24 closure is efficient at reducing pressure on West cod but has side effect on East cod when some effort is displaced toward SD25. The vessels owning East cod quotas now focusing on this area, and also getting a larger proportion of unmarketable fish in their catches. With the early spring ICES SD 22-23-24 closure the risk for enhanced discards to impact the East cod dynamics, however, would only be possible in the absence of landing obligation (implemented in 2015), unless the fishery and decreased TACs relying on poor stock condition would incentivize for underreporting discards with higher probability compared to the situation when there is no closure in place. The ICES SD 24-25-26 summer closure appears beneficial for both fisheries on the medium term even if/because some earning losses from cod landings are expected on the short term. Polyvalent vessels might possibly compensate with catches from other stocks during that period, though, as showed for the larger vessels in the Danish case, but the overall profit is reduced.

Therefore one can recommend to apply the setting 1b (*'the fisheries closure period in subdivisions 24, 25 and 26 to be applicable from 1 July to 31 August to vessels fishing for cod'*) or 2b (closure *'in waters shallower than 20 m by vessels with a length overall up to 15 m equipped with VMS (except pair trawling) as derogation from measure indicated in paragraph 1b'*) where the simulations showed most of the benefits for the stocks and the fisheries after several years.

The present simulations assume a spatial displacement of the effort toward the remaining opened areas during the closure period, both for the Danish fleet (dynamically simulated) and the landings made by other fleets. The outcomes, however, are likely depending on the ability of the vessels to also reallocate their individual effort in time outside the period of the closure. If the vessels are not at their maximal capacity of effort deployment the protected stock surplus might vanish and the benefits nullify.

A general conclusion from these simulations is that the effect of the proposed fishing closures to the STECF evaluation is helpful but not sufficient alone to ensure the sustainable fishing and the economic viability of the two Baltic cod fisheries (especially east cod) and additional action(s) would be required for the recovery of the Baltic cod stocks. Several biological processes are likely not fully captured by a single fishing mortality F target value and any management procedure should likely be refined to account for them. Baltic cod is suffering from a row of varying and interacting causes (other than fishing) and therefore the outcomes of the simulations performed here will remain somehow speculative, since all these processes are still poorly understood and thus difficult to account for in a model.

2. BACKGROUND REQUEST AND ITS OPERATIONAL TRANSLATION

2.1 - During the October 2016 AGRIFISH Council meeting, ministers reached political agreement on quota levels in the Baltic Sea for 2017. The quota level for the western cod stock is based on the scientific advice and complies with the requirements of the Baltic multiannual management plan (Regulation (EU) No 2016/1139).
The Baltic multiannual management plan requires adopting further measures in cases when the stock is below certain conservation reference points as laid down in the plan. According to the plan such measures should be adopted with the Commission delegated act following the submission of the Joint Recommendation by the Member States concerned. The Joint Recommendation was submitted to the Commission on 11 October 2016.
The Commission should facilitate the cooperation among the Member States and ensure that measures indicated in the joint recommendations are based on the best scientific advice and shall contribute to the achievement of the objectives of the Baltic multiannual management plan.
Therefore the Commission is seeking the advice and the scientific opinion from the STECF to be provided following the Terms of Reference below.

STECF is requested to:

1. *Assess and quantify the impact of the measures to establish fisheries closure periods on the effort applied in the cod fisheries and its impact on cod stocks, as well as, to the elimination of discards by avoiding and reducing unwanted catches:*
   a. *the fisheries closure period in subdivisions 22, 23 and 24 to be applicable from 1 February to 31 March to vessels fishing for cod;*

   b. *the fisheries closure period in subdivisions 24, 25 and 26 to be applicable from 1 July to 31 August to vessels fishing for cod;*

   c. *the fisheries closure period in subdivisions 27 and 28 to be applicable from 1 July to 31 August to vessels fishing for cod.*

2. *Assess the impact of the measure to allow cod fishery in waters shallower than 20 m by vessels with a length overall up to 15 m equipped with VMS (except pair trawling) as derogation from measure indicated in paragraph 1a, 1b and 1c.*

Background documents

1. *2013-2016 ICES advices on cod stocks in the Baltic Sea.*
2. *2013-2016 ICES WGBFAS reports.*
3. *Baltfish Joint Recommendation ARES(2016)5863715 – 11/10/2016.*

2.2 - In line with this description, the baseline Baltic cod stocks DISPLACE scenario assumes management to F_{MSY} targets with a minimum biomass reference point (Btrigger) for both Baltic cod stocks, individual vessels optimizing the spatial effort allocation depending on the expected profit of the trip before leaving the harbours.

2.3 - The Baltic cod Long Term Management Plan (EC, 2007) is here replaced by the F_{MSY} approach including a Btrigger to target with a lower *F*-value (the *F* target is multiplied by the ratio of F_{MSY} to the assessed perceived *F*) when the SSB is perceived to be less than Btrigger (ICES, 2016). In 2012, the starting point of the present simulations where the Baltic cod stock situations were best known, ICES (ICES, 2013) decided to advise on TACs based on this approach, and the F_{MSY} for the Eastern Baltic Cod stock (ECOD) was recorded at 0.46 and the B_{MSY} trigger was recorded at 88,200 t. For WB cod (area based assessment for SD 22–24, including eastern cod in the area), the FMSY was 0.26, and the B_{MSY} trigger was 36 400 t. Btriggers are SSBs. Moreover, in the simulations and because the fisheries management is in a rapid transition phase from LTMP to F_{MSY} approach and landing obligation, the landing obligation is not considered to be fully implemented yet within the time horizon of the simulations we presented here, meaning the simulated discards are not counted against the simulated TAC.

2.4 - Because the current Baltic cod stocks status is uncertain provided that evidences for recent changes (including migration of adult fish from East to West) affect the biomass and abundance estimates as well as uncertainties in the estimation procedure, it has been required to look back in time to the nearest known situation (i.e. 2012) where we have the largest scientific knowledge available for both the fish and fisheries. I therefore compare management scenarios in relative terms from there. The underlying biological scenario in the stock parameterisation of the model assumes i) a stock mixing between East and West cod, some East cod size classes measured to migrate toward SD 24 (Hüssy *et al.*, 2016), ii) poor condition, taking a slower growth of 0.7 of the current Van Bertalanffy growth asymptotic size, iii) smaller weight at size for East cod (0.97), and iv) an increase of the natural mortality by 10%. These assumptions on the underlying biological operating model are aligned with the potential drivers that might explain the current poor cod status, also listed in Eero *et al.* (2015), when compared to the last accepted East cod ICES analytical assessment (ICES, 2013).

2.5 - In the simulations, 'other' landings than the Danish landings are informed from the STECF landings per ICES rectangle data collected by the STECF Effort Working Group (http://stecf.jrc.ec.europa.eu/ web/stecf/ewg1313). The 'other' landings are distributed on the model nodes that define the stock distribution area, and their spatial abundance structure per stock by ICES rectangle is preserved, unless a fishing closure applies. If a fishing closure applies, the other landings are redistributed on the remaining opened areas specific to the stock and within the same month. Hence, two levels of resolution for simulating the catches have been used because of the limitation in the input data available at the date of the present evaluation. When the individual catches are known (as it was for the Danish fleet) then the displacement account for the choices of individual fishing vessels actively looking during the closure period at the remaining opportunities in fishing grounds. When the total catches per month are the only known data (as it was the case for vessels below 12 m and for all other fleets than the Danish fleet in this specific case), these catches are displaced evenly between the remaining areas with presence of cod and during the same month.

Table 2.1: Extra scenarios (hereafter called STECF 2016 scenarios) implemented on top of the ones described in Bastardie et al., 2016. Impacted segments naming refers to Data Collection Framework classification for level 5.

Scenarios	**Fishing Closure**	**Timing of closure**	**Dynamic displacement**	**Static (spatial) displacement**	**Impacted segments**
Stecf_baseline	None				
Stecf_tor1a	ICES SD 22, 23, 24	1st of Feb to 31 of March	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF
Stecf_tor1b	ICES SD 24, 25, 26	1st of July to 31 of August	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF
Stecf_tor1c	ICES SD 27, 28	1st of July to 31 of August	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF
Stecf_tor2a	ICES SD 22, 23, 24 if vessel LOA >15m ; over 20m deep within ICES SD 22, 23, 24 otherwise	1st of Feb to 31 of March	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF
Stecf_tor2b	ICES SD 24, 25, 26 if vessel LOA >15m ; over 20m deep within SD 24, 25, 26 otherwise	1st of July to 31 of August	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF
Stecf_tor2c	ICES SD 27, 28 if vessel LOA >15m ; over 20m deep within SD 27, 28 otherwise	1st of July to 31 of August	Danish vessels > 12 m	Others	FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF

2.6 - A total of 10 stochastic runs are conducted per scenario (Table 2.1) to model the movement and discrete time catch operations of the larger Danish vessels, together with the effect of displacing the catches from smaller vessels and from other participating Baltic countries (“others”) to comply with the tested fishing closure scenarios. This number of replicates is rather low but has been constrained by the tight deadline imposed to deliver this report. Stochastic variation range from ECOD is expected to be narrower because Danish fleet creating part of the stochastic variation is only a part of the total catches here.

3. OUTCOMES OF THE EVALUATION

3.1. ToRs 1a & 2a

The fishing closure is greatly beneficial to the West cod stock level (increased SSB and low F; Figure 7.1).

There is, however, a side effect potential on the East cod from displacing catches during these months from west to the east area when vessels also own quotas on the East cod, and therefore, in interaction with the minimum landing size, creating more East cod discards on the way (Table 7.1), and finally lowering down the East stock SSB further. We note that this simulated additional increased pressure on East cod SSB during the closure period is certainly overestimated, and the earning from the landings these vessels can expect also overestimated, in case the EU landing obligation (implemented in 2015 in the Baltic Sea) is fully enforced and that the discards should therefore be counted against the TAC.

Potential for effort displacement is the result of the Danish quotas as well as the total international TAC for cod stocks not been fully utilized in recent years (e.g. 86.8 and 72.5% of Danish quotas for western and eastern cod in 2012, respectively), as vessels have been unable or unwilling to catch their quotas, thus resulting in effort reallocation in certain areas. Potential for discards is the result of cod in poor condition large enough to be caught but with body size below the minimum landing size.

Effort displacement accentuates the declining baseline trend for East cod, a trend induced by poor stock condition (i.e. stock made out of small, unmarketable fish), low growth and disappearance of larger fish (Figure 7.1), a decline that the very large decrease in TAC preconized by the F_{MSY} management is not able to correct for (Figure 7.3). The *F* is indeed more or less kept stable (at the cost of large TAC cuts) giving on the situation a somewhat misleading signal to the management.

Meanwhile the fisheries are also both less energy efficient from higher fuel use to catch fewer fish induced by the change in trip patterns and declining catch rates from poor stock status (Figure 7.4).

3.2. ToR b

Some parts of the East and West COD are protected within the two months closure and not caught later in the year (indeed, no temporal effort redistribution is assumed in the simulations, vessels being assumed to go fishing already at their maximal pace) which create a surplus of larger fish available for the following months and years (Figure 7.1) also provided decreased discard rates on both stocks (Table 7.1). The beneficial effect on West cod is because SD24 cod is now protected from fishing during the closure period while the catches still possible in SD22 do not compensate for the catches in the first years, the catch rates within this area being lower and, for west Danish fleet (the main share for West Cod TAC), the effective effort per trip also reduced.

Because accumulated cod landings are lowered (Figure 7.5), the total revenue for fishing vessels on Baltic cod is also lowered ca. by half after 5 years, at constant fish price conditions. The gross added value reduction is however limited when vessels shift for fishing upon other stocks but allocating more effort at sea and using more fuel to reach other fishing grounds (Figure 7.4) possibly even outside the Baltic Sea (therefore putting some new pressure out there). Looking at the profitability, this shift toward other stocks does actually compensate the losses from the cod fisheries (Figure 7.4 with Table 7.2, and Figure 7.5), but with unknown consequences on other stocks.

3.3. ToRs a and b

The analysis of the distributional effect of the fishing closure at the scale of individual harbours for cod (from the Danish perspective) shows that the beneficial or the detrimental effects are relatively well distributed across the harbours albeit the eastern Bornholm island harbours would appear less affected than the others (Figure 7.6) and on the contrary benefit from the closure. In the eastern Bornholm island harbours the number of vessels that are positively affected is greater than the ones negatively affected.

3.4. ToR c

The fishing closure design of ToR c is slightly affecting the West cod stock level (Figure 7.2). Results indicates that the fisheries use slightly less fuel from less number of trips but forced to do longer, less efficient trips when fishing on smaller fish (Figure 7.4 with Table 7.2). It might be speculated that this rather unexpected outcome on West Cod is a sign for a cascading effect when narrowing down the space for fishing on cod to SD25 only therefore protecting a part of the East stock and making more adult East cod migrants toward the west that sustain the west cod in SD24.

3.5. ToR 1 (abc) *vs* ToR 2 (abc)

Restricting the fishing to areas shallower than 20 meters (and only to vessels < 15m) is not significantly impacting the outcomes of the simulations (Figure 7.2 and 7.3), likely because the effort is displaced on areas outside of where the main bulks of the two fish stocks are (see Technical Annex 3 for a picture about where the Danish catches of larger vessels are usually made), therefore not able to compensate for the lost catches in the main fishing grounds restricted by the management. In consequence, there was no need to assess the derogation for pair trawling in ToR 2.

4. DISCUSSION AND RECOMMENDATIONS

4.1 - A general conclusion from these simulations is that the effect of the proposed fishing closures to STECF evaluation is helpful but not sufficient alone, all others things being equal, to ensure the sustainable fishing and the economic viability of the two Baltic cod fisheries. The proposed ToR b settings might be preferred to the ToR a, this latter likely to create side effects on the East cod (increased discards) from incentivizing effort displacement and quota fulfilment. ToR c is not really affecting the outcomes of the present simulations and the outcomes are rather uncertain given the present simulation settings might be more accurate for the Central Baltic area. ToR 1 and 2 only marginally differentiate, possibly because there is no difference to expect since the remaining opened areas are being set quite off the main bulk of the distribution of cod, or, less likely, because the present model settings are unable to capture the effect.

4.2 - Provided there is no striking difference among ToR 1 and 2, one might favour the specifications of ToR 2b that offer more flexibility to (and therefore social acceptance from) fishermen when smaller vessels are still allow to pursue fishing within the below 20 m band as they wish.

We wish to draw attention of decision makers on the facts that:

- 4.3 – The removals from the recreational fishery add uncertainties to the total removals of cod, as the recreational catches are not restricted, which is seen as of particular importance when taking action on western cod given the amount of caught fish by recreational fishing might actually be of the same order of magnitude than the commercial fishing in this area (ICES, 2016).

- 4.4 – The possible incidence of extensive 2-month closures on the fish market seasonal dynamics and the attached chain of processing industries (e.g. incidence on fish prices, incidence on amount of sales, etc.) has not been evaluated here. Fish price fluctuations in Baltic cod, however, are expected to be more influenced by externalities such as more global market price dynamics markets outside the region (e.g., Barents Sea cod). But economic benefits may also arise from better quality fish provided that fishes in poor condition are expected to be of less value as the drop in Eastern cod prices in recent years suggests.

- 4.5 – The possible incidence of a change in spatial distribution total extent of the Baltic cod along a change in the level of the total stock abundance has not been evaluated here. It might be expected that during the period of low stock size, the stock will shrink to the main part of its distribution, therefore increasing even more the pressure of fishing at the same level of effort (hyperstability effect).

- 4.6 – The possible effect of the full enforcement of the landing obligation has not been evaluated here. However, the outcome concerning the stock status from the simulations performed here might be only slightly affected provided that the catches of undersized fish would still increase even if these fish are forced to be retained on board when the small fish are counted against the TACs under the landing obligation. This is because the fleet is likely to continue fishing in an attempt to catch the larger marketable fish, not really constrained by small fish weighing less in the TACs (and less and less in poor cod stock condition). Meanwhile what could depart from the present simulations might be the economic revenue and it is expected that the economic loss will be made worse provided that the final individual catches will be made out of smaller, unmarketable fish.

- 4.7 – The scientific opinion that ecological issues in the Baltic are likely more important at present than fisheries management regarding the recovery (or lack of) for Baltic cod stocks. Hence, there is no clear evidence about the current Baltic cod situation being the result of overfishing only. The present Baltic cod stock situations certainly comes from an array of entangled causes (other than fishing), together with the failure in management to catch up in due time the underlying biological changes (see e.g. Bastardie *et al.* 2016) or includes biological process-oriented knowledge in the management procedure that are likely not fully captured by a single fishing mortality *F* target value (i.e. the so-called F_{MSY}). Baltic cod is suffering from a row of varying and interacting causes including lower growth, mixing from migration, pollution, reduction of the suitable habitat and benthic food availability from larger Baltic anoxic zones, the extend of suitable nursery areas, parasite disease, mismatch with the (sprat) prey distribution, varying egg survival success, etc. So the outcomes of the simulations performed here will remain somehow speculative, since all these processes are still poorly understood and thus difficult to account for in a model.

5. FACTS ON THE USED SCENARIO TESTING PLATFORM

5.1 - DISPLACE is an agent-based model on a per-vessel basis which is covering several fisheries and stocks for benchmarking alternative fishermen’s decision-making processes and their local knowledge when they face changes in fishery management, economic factors influencing the fishery, economic viability, and underlying stock conditions, including spatial and seasonal patterns in resource availability (informed from scientific survey data).

5.2 - DISPLACE operates with high resolution in time (e.g. hour) and space (e.g. 4 x 4 km grid). The platform is then taking a bird´s eye view from aggregating all the small (fishing) operations at sea but is still able to look at the spatial and temporal details for a good understanding of the intertwined dynamics. In that context the approach specifically evaluates whether some benefits compensate the additional (economic and ecological) costs of the effort displaced to surrounding or new areas, these benefits also constrained by the type of fishery management in place.

5.3 - DISPLACE accounts for parameters that determine fishermen’s decisions, and it offers projections of fishing effort displacements based on expected revenues and operating costs (fuel costs) and in response to assumed spatial planning measures. Simulations are based on the creation of fishing activity scenarios over a certain period of time (typically a 5-year horizon based on hourly time intervals). The operation of fishing activities in simulations is based on the actions of individual vessels in response to changes in space and time in terms of fish stock abundances and available fishing space. These individual vessels use varying type of gears with selectivity specific to the species harvested, which sometime generate discards when the caught fish is undersized (i.e. below the minimum landing size).

5.4 - DISPLACE is parameterised and operational for the Baltic fisheries, among others. The details of the method (modelling from the coupled VMS data to logbooks, from Bottom International Trawl scientific Surveys data, etc.) is given in Bastardie *et al.* 2016 and the present simulations are extra scenarios derived from the same settings (individual vessel parameterization, etc.) also described in this work. Hence, the movements of all Danish vessels that are larger than 12 m in length and that were active in 2012 in the Baltic Sea are simulated at hourly time intervals, here on a 4 by 4 km geodesic spatial grid. After each trip, simulated fishing vessels return to port and earn money from the landings in harbour where the fish prices are informed per marketable category and the gross added value is computed from the actual operating costs of the trip.

6. REFERENCES

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7. TABLES & FIGURES

Table 7.1 – Estimates of WCOD and ECOD change in discard rate of fish i.e. disc. kg/(disc. kg+land. kg) for the STECF ToR 1 and 2 scenarios compared to the simulated baseline situation.

	WCOD		ECOD	
	Average %	Confidence Int.	Average %	Confidence Int.
stecf_baseline	0	0	0	0
stecf_tor1a	-61.4	±1.4	+23.3	±3.8
stecf_tor1b	-22.8	±1.3	-62.0	±1.7
stecf_tor1c	-2.6	±0.6	+4.8	±3.7
stecf_tor2a	-55.1	±1.0	+23.6	±3.7
stecf_tor2b	-19.3	±1.0	-45.8	±2.3
stecf_tor2c	-2.2	±0.5	+4.9	±3.8

Table 7.2 – Vessel performance indicators (see Figure 7.4) for the Danish vessels involved in the Baltic cod fisheries for additional STECF scenarios expressed as percentage change (and confidence interval) compared to the baseline situation.

	Baseline	ToR a		ToR b		ToR c	
		stecf_tor1a	stecf_tor2a	stecf_tor1b	stecf_tor2b	stecf_tor1c	stecf_tor2c
Indicators	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Fishing effort	0	+26 ±1	+28 ±1	+10 ±2	+11 ±2	-2 ±2	-1 ±2
Steaming effort	0	+47 ±2	+47 ±2	+36 ±2	+36 ±2	+2 ±3	+2 ±2
Nb. of trips	0	+21 ±1	+25 ±2	+8 ±1	+13 ±2	-9 ±2	-9 ±2
Trip duration	0	+13 ±1	+9 ±1	+11 ±1	+8 ±1	+12 ±1	+12 ±1
CPUE at fishing	0	-29 ±1	-31 ±1	-46 ±1	-44 ±1	+2 ±3	+2 ±2
Tot land. WCOD	0	-6 ±3	-9 ±1	+15 ±4	+14 ±2	+7 ±3	+10 ±3
Tot land. ECOD	0	-13 ±1	-13 ±1	-64 ±1	-59 ±1	-3 ±1	-3 ±1
Tot land. OTHER	0	+10 ±5	+12 ±4	+22 ±5	+22 ±5	-8 ±5	-7 ±4
Disc. rate WCOD	0	-62 ±1	-55 ±1	-23 ±1	-19 ±1	-3 ±1	-2 ±1
Disc. rate ECOD	0	+23 ±4	+24 ±4	-62 ±2	-46 ±2	+5 ±4	+5 ±4
Net Present Value	0	-5 ±5	-3 ±6	+9 ±8	+7 ±7	-13 ±7	-14 ±6
Value Per Unit Fuel	0	-29 ±5	-28 ±6	-11 ±8	-14 ±6	-4 ±8	-5 ±8
Income inequality	0	-3 ±2	-4 ±3	-5 ±3	-6 ±2	-2 ±2	-4 ±3

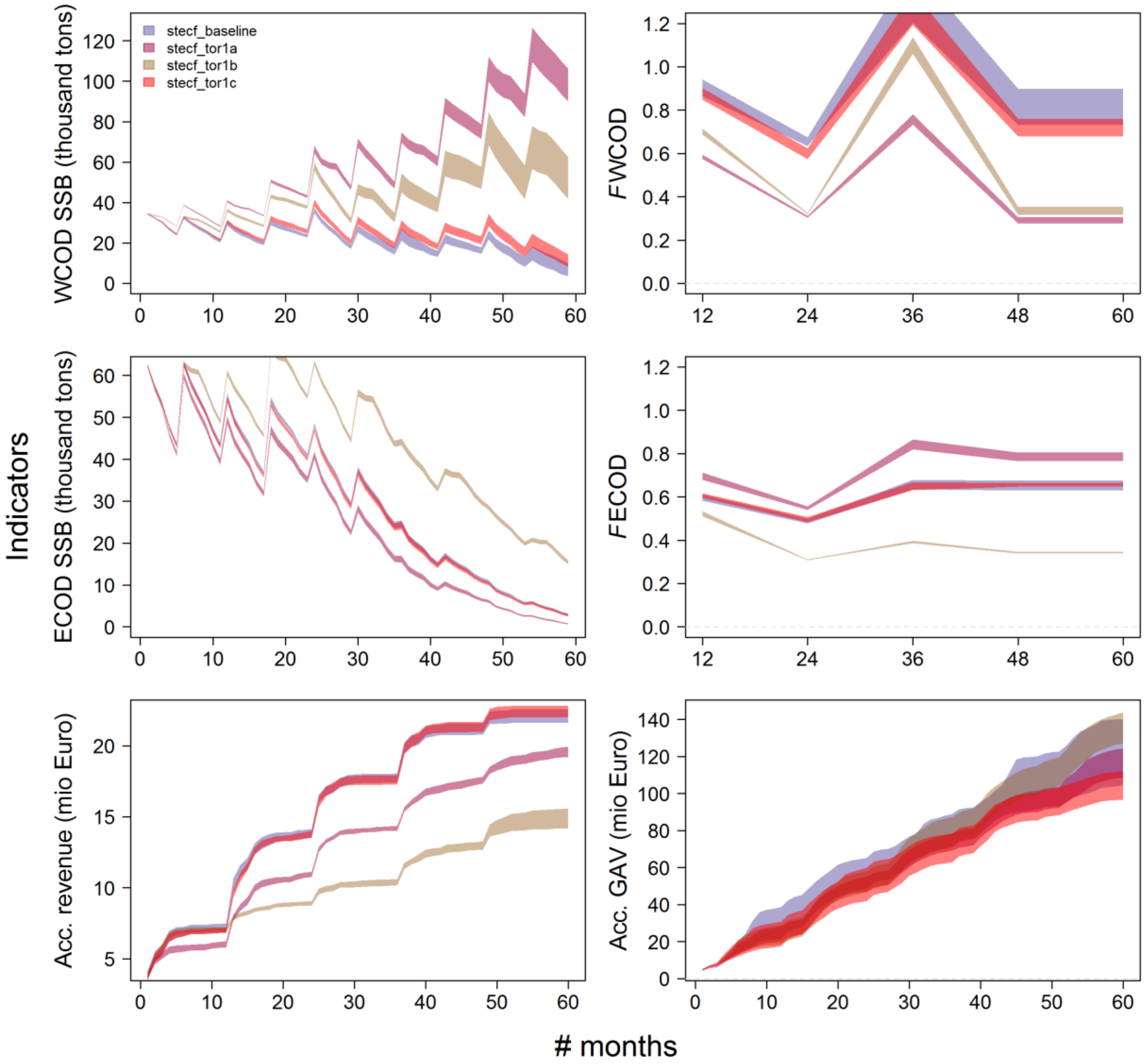


Figure 7.1 - Projected West Cod (WCOD) spawning stock biomass SSB, average fishing mortality for WCOD (i.e. $F_{3\text{-}6}$), East Cod (ECOD) SSB, average fishing mortality for ECOD (i.e. $F_{4\text{-}6}$), accumulated Danish revenue from cod only (WCOD+ECOD) landings, and accumulated Danish gross added value from all landings i.e. all other stocks included (GVA; with a 4% discount rate) over the simulation period up to the horizon time (10 stochastic replicates per scenario). This is developed according to STECF ToR 1 fishing closure scenarios and under the F_{MSY} management regimes.

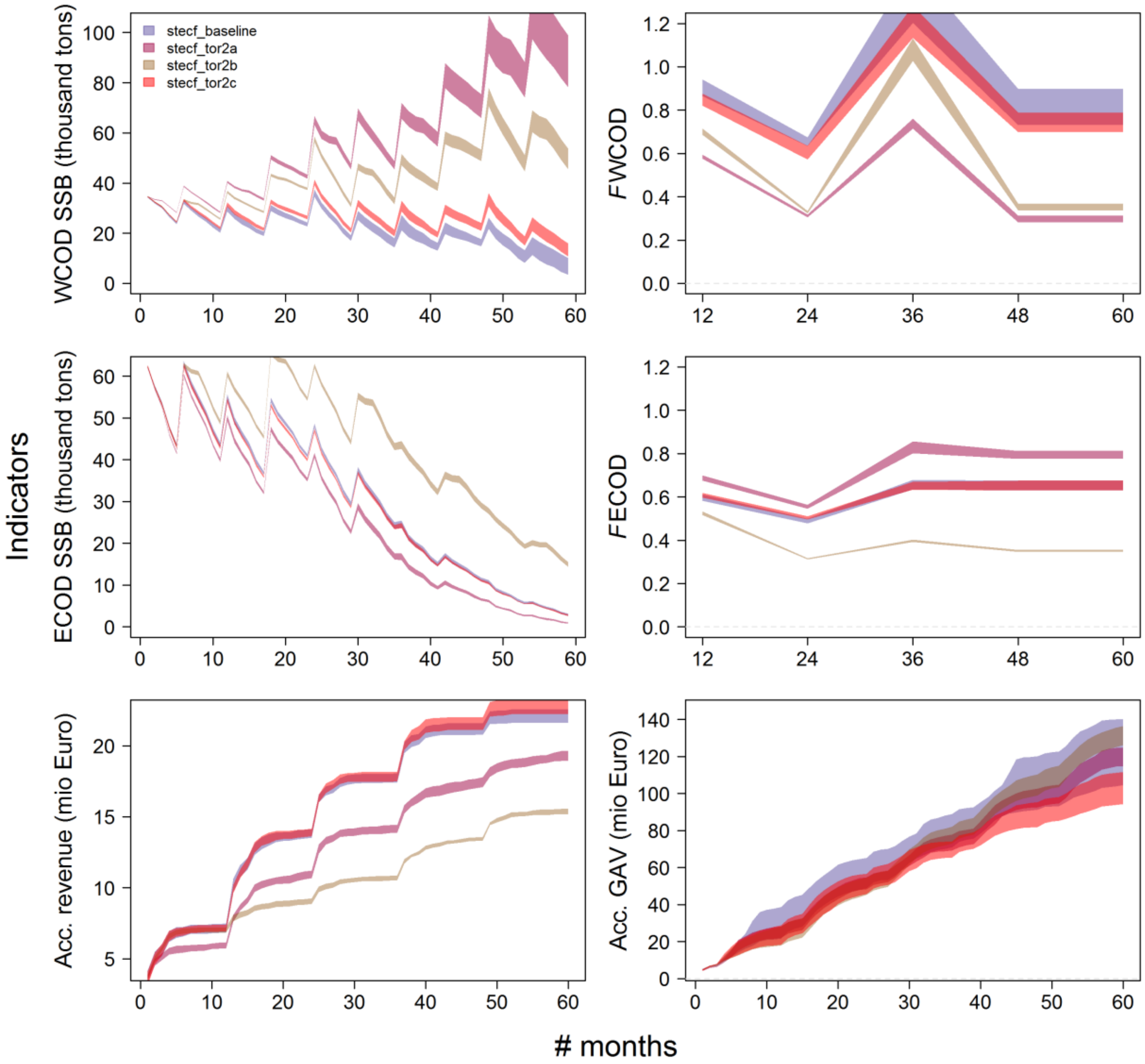


Figure 7.2 - Same as figure 1 but developed according to STECF ToR 2 fishing closure scenarios.

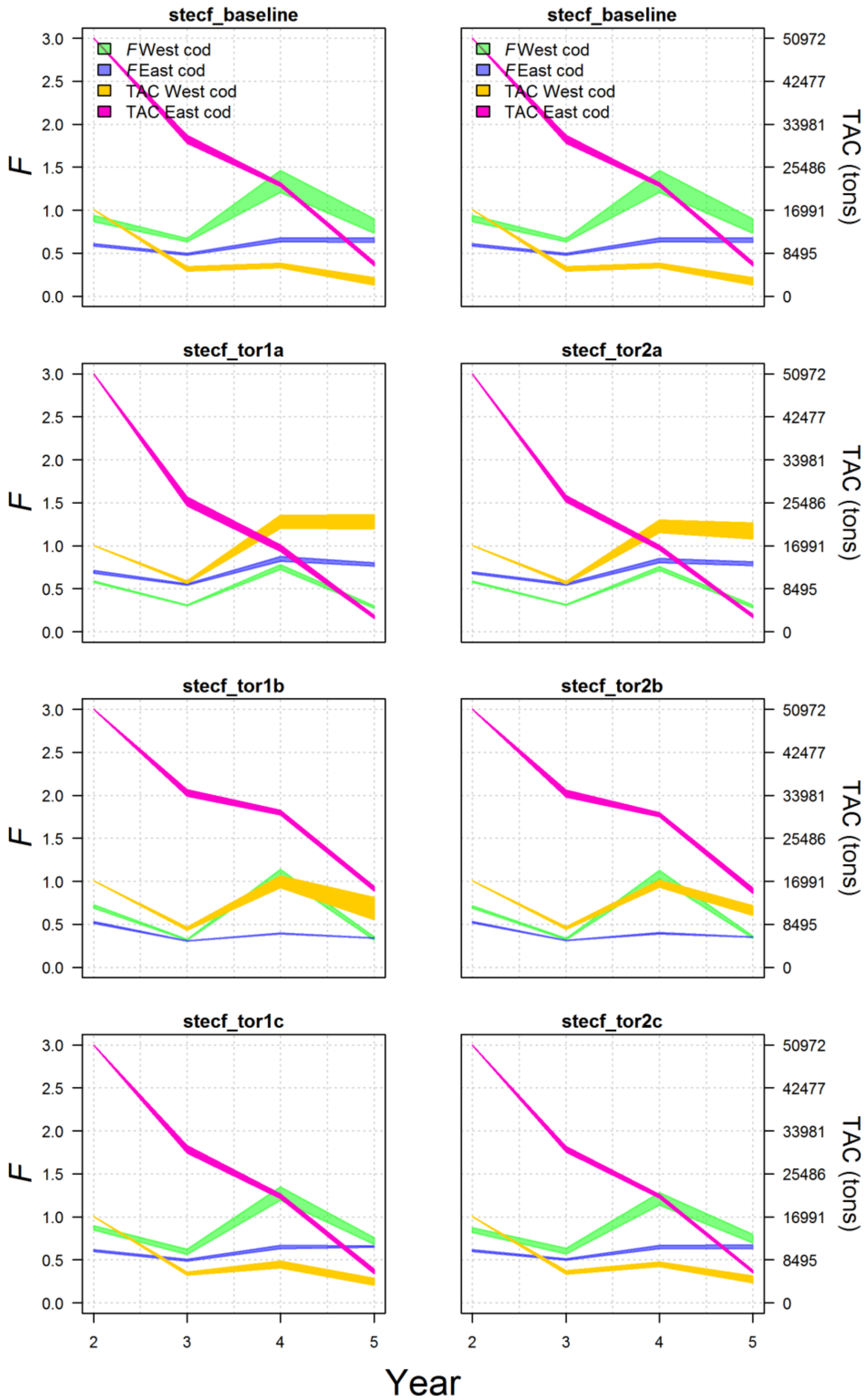


Figure 7.3 - Simulated average annual fishing mortalities per stock (Fbar) for each scenario and over the four forecasted years, and TAC (in tons) implemented according to the FMSY approach applied within the simulation for each STECF ToR scenario and over the 4 forecasted years. The 95% percentile is given from the 10 runs per scenario. The baseline plot is repeated twice just for visual convenience.

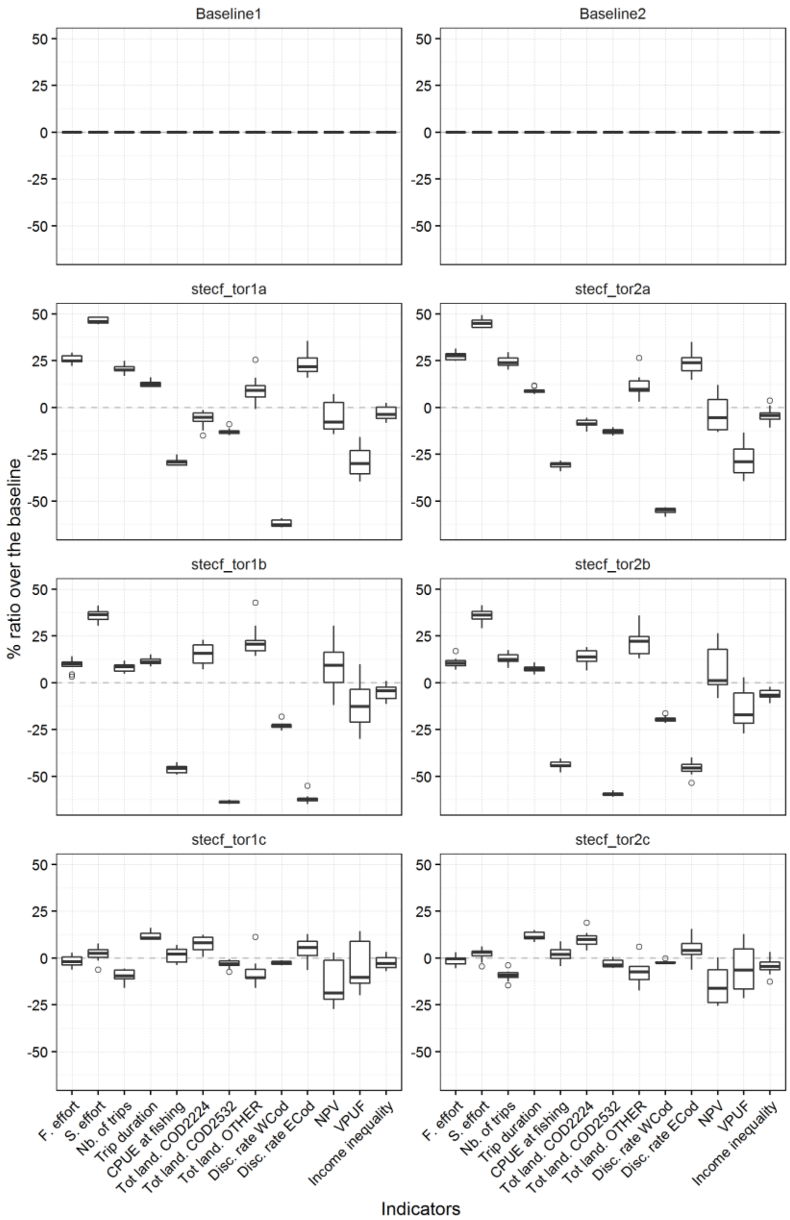


Figure 7.4 - Comparison of aggregated STECF ToR scenario outcomes (10 stochastic replicates per scenario, aggregation over the entire 5 years period) on vessel performance indicators (percent relative to the baseline) for vessels involved in BCOD fisheries. The percentages are relative to the baseline situation for Fishing efforts; Steaming efforts; The number of trips; Trip durations; CPUE for catching BCOD; Total landings for western, eastern and other stocks; Discard rates of Western and Eastern cod; Net Present Value NPVof gross added value with a 4% annual discount rate; Value Per Unit Fuel VPUF; and income inequality computed based on the Hoover Index.

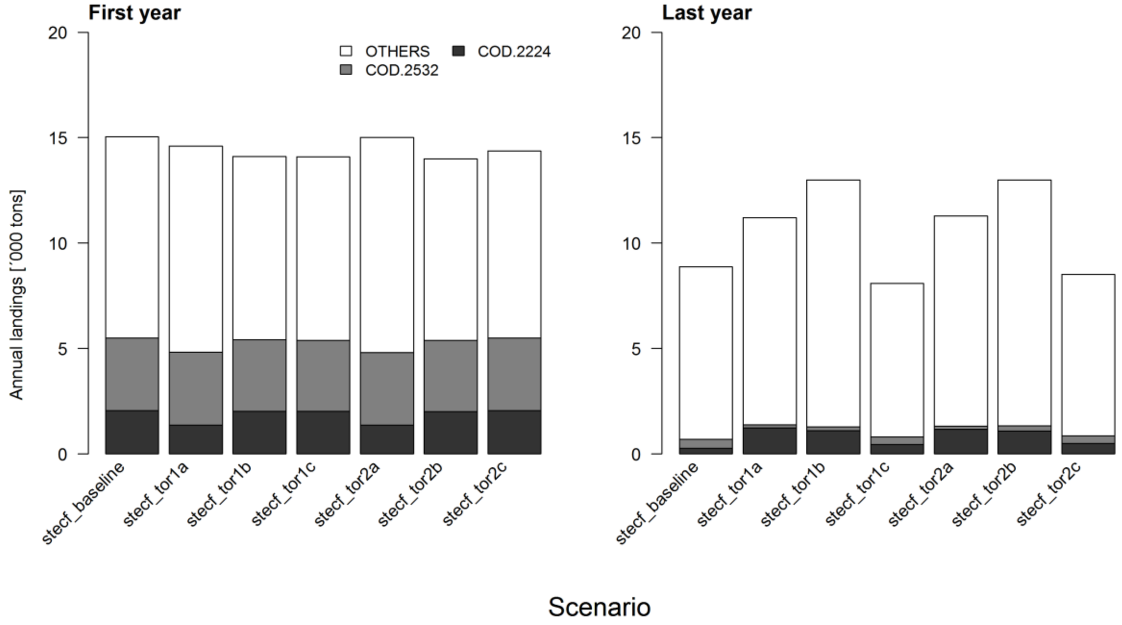


Figure 7.5 - First and last year landing composition of the simulation period per scenario (average over the 10 runs—top 15 stocks merged except for ICES SD 22–24 western cod (WCOD) and SD 25–32 eastern cod (ECOD)). Here only the Danish vessel involved in BCOD fisheries was selected. Dynamics of WCOD+ECOD stocks are explicitly simulated, but this does not prevent vessels in the model from fishing for other stocks depending on their specific catch rates.

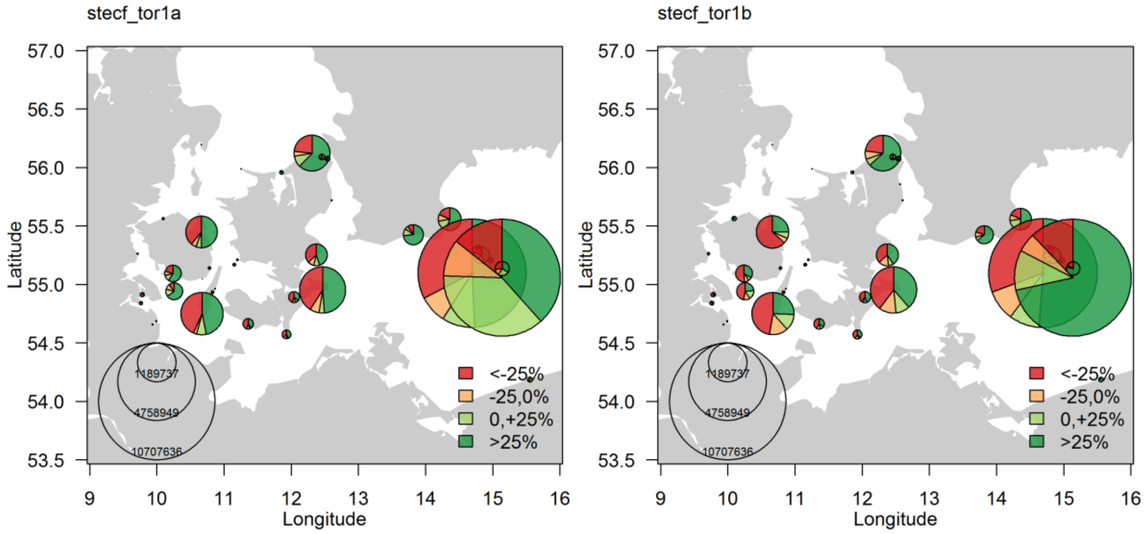


Figure 7.6 – Categorized simulated impact on revenue per selected scenario and per harbour where Danish vessels are used to land Baltic cod catches expressed as proportion of the vessels in each % class of monetary gains or losses compared to the baseline scenario. The size of the circle gives the baseline revenue from the cod landings in euros of the harbour accumulated after 5 years and was averaged over the 10 replicates.

8. Technical annex 1 – Setting the STECF scenarios in DISPLACE

ToR 1a

DISPLACE v0.9.1 procedure to set up the STECF ToR 1a scenario:

i) Start a new DISPLACE
ii) Load 'myfish' Graph 56 in Graph>Load
iii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\1_222324.shp
iv) In Graph>Add penalties from Shapefiles, adjust closed_for_fishing specifications to the scenario (i.e. months=Feb and Mar, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 1_222324.shp, vessel sizes= select all vessel sizes) and click ok
v) Save Graph (i.e. Graph 1 derived from Graph 56) in Graph>Save in DISPLACE_STECF\Graphs
vi) Load the new graph Graph 1 with 'Graph>Load'
vii) Compute the shortest paths in a shortPaths_myfish_a_graph1 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph1]
viii) Compute the shortest paths with Graph>Create short path from myfish\vesselsspe\vessels_fgrounds.dat
ix) Create a .dat scenario file stecf_tor_1a.dat from myfish baseline.dat with the option area_monthly_closure ticked
x) Quit DISPLACE or Graph> 'Clear Graph'

1b

DISPLACE v0.9.1 procedure to set up the STECF ToR 1b scenario:

i) Start a new DISPLACE
ii) Load 'myfish' Graph 56 in Graph>Load
iii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\4_24.shp and DISPLACE_STECF\Shapes\3_2526.shp
iv) In Graph>Add penalties from Shapefiles, adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF,

OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 4_24.shp and 3_2526.shp, vessel sizes= select all vessel sizes) and click ok

v) Save Graph (i.e. Graph 2) with a different name from Graph>Save in DISPLACE_STECF\Graphs

vi) Load the new graph Graph 2 with 'Graph>Load'

vii) Compute the shortest paths in a shortPaths_myfish_a_graph2 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph2]

viii) Create a .dat scenario file stecf_tor_1b.dat from myfish baseline.dat with the option area_monthly_closure ticked

ix) Quit DISPLACE or Graph> 'Clear Graph'

1c

DISPLACE v0.9.1 procedure to set up the STECF ToR 1c scenario:

x) Start a new DISPLACE

xi) Load 'myfish' Graph 56 in Graph>Load

xii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\3_2728.shp

xiii) In Graph>Add penalties from Shapefiles, adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 3_2728.shp, vessel sizes= select all vessel sizes) and click ok

xiv) Save Graph (i.e. Graph 3) with a different name from Graph>Save in DISPLACE_STECF\Graphs

xv) Load the new graph Graph 3 with 'Graph>Load'

xvi) Compute the shortest paths in a shortPaths_myfish_a_graph3 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph3]

xvii) Compute the shortest paths with Graph>Create short path from myfish\vesselsspe\vessels_fgrounds.dat

xviii) Create a .dat scenario file stecf_tor_1c.dat from myfish baseline.dat with the option area_monthly_closure ticked

xix) Quit DISPLACE or Graph> 'Clear Graph'

2a

DISPLACE v0.9.1 procedure to set up the STECF ToR 2a scenario:

i) Start a new DISPLACE

ii) Load 'myfish' Graph 56 in Graph>Load

iii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\1_222324.shp and over20m222324.shp

iv) In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Feb and Mar, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 1_222324.shp, vessel sizes= 15-18m, 18-24m, 24-40m, >40m) and click ok

v) Again, In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Feb and Mar, metiers = LEAVE EMPTY TO AVOID DUPLICATES BECAUSE over20m222324.shp is fully inside 1_222324.shp, shapes= over20m222324.shp, vessel sizes= <15m) and click ok, this will append to the previous step.

vi) Save the Graph (i.e. Graph 4) in 'Graph>Save'

vii) Load the Graph 4 again in 'Graph>Load'

viii) Compute the shortest paths in a shortPaths_myfish_a_graph4 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph4]

ix) Create a .dat scenario file stecf_tor_2a.dat inspired from myfish baseline.dat but with the DynAllocSce option 'area_monthly_closure' ticked, this option will make the closure dependent on combinations in the simulations i.e. a given vessel will be affected on locations if and only if banned metiers is TRUE and banned vessel size of this vessel is also TRUE on these locations.

xx) Quit DISPLACE or Graph> 'Clear Graph'

2b

i) Start a new DISPLACE
ii) Load 'myfish' Graph 56 in Graph>Load
iii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\2_2526.shp and 4_24.shp and over20m2526.shp over20m24.shp
iv) In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 2_2526.shp, 4_24.shp, vessel sizes= 15-18m, 18-24m, 24-40m, >40m) and click ok
v) Again, In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = LEAVE EMPTY TO AVOID DUPLICATES BECAUSE over20m2526.shp is fully inside 2_2526.shp, shapes= over20m2526.shp, over20m24.shp, vessel sizes= <15m) and click ok, this will append to the previous step.
vi) Save the Graph (i.e. Graph 5) in 'Graph>Save'
vii) Load the Graph 5 again in 'Graph>Load'
viii) Compute the shortest paths in a shortPaths_myfish_a_graph4 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph4]
ix) Create a .dat scenario file stecf_tor_2b.dat inspired from myfish baseline.dat but with the DynAllocSce option 'area_monthly_closure' ticked, this option will make the closure dependent on combinations in the simulations i.e. a given vessel will be affected on locations if and only if banned metiers is TRUE and banned vessel size of this vessel is also TRUE on these locations.
xxi) Quit DISPLACE or Graph> 'Clear Graph'

2c

i) Start a new DISPLACE
ii) Load 'myfish' Graph 56 in Graph>Load

iii) Load ArcGIS WGS84 shape files in File>import Shapefile, as many as required i.e. DISPLACE_STECF\Shapes\3_2728.shp and over20m2728.shp

iv) In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = myfish FPO_DEF, GNS_DEF, OTB_DEF, OTM_DEF, PTB_DEF, PTM_DEF, SDN_DEF, SSC_DEF, shapes= 3_2728.shp, vessel sizes= 15-18m, 18-24m, 24-40m, >40m) and click ok

v) Again, In 'Graph>Add penalties from Shapefiles', adjust closed_for_fishing specifications to the scenario (i.e. months=Jul and Aug, metiers = LEAVE EMPTY TO AVOID DUPLICATES BECAUSE over20m2728.shp is fully inside 3_2728.shp, shapes= over20m2728.shp, vessel sizes= <15m) and click ok, this will append to the previous step.

vi) Save the Graph (i.e. Graph 6) in 'Graph>Save'

vii) Load the Graph 6 again in 'Graph>Load'

viii) Compute the shortest paths in a shortPaths_myfish_a_graph4 folder placed in \DISPLACE_STECF with 'Graph>Create short paths' from myfish\vesselsspe\vesselsspe_fgrounds_quarter1.dat. [This step is optional given no penalty has been added so far so myfish shortPaths_myfish_a_graph56 can be directly re-used by copy/pasting in shortPaths_myfish_a_graph6]

ix) Create a .dat scenario file stecf_tor_2c.dat inspired from myfish baseline.dat but with the DynAllocSce option 'area_monthly_closure' ticked, this option will make the closure dependent on combinations in the simulations i.e. a given vessel will be affected on locations if and only if banned metiers is TRUE and banned vessel size of this vessel is also TRUE on these locations.

xxii) Quit DISPLACE or Graph> 'Clear Graph'

9. TECHNICAL ANNEX 2 – GIS SHAPE FILES IN DISPLACE

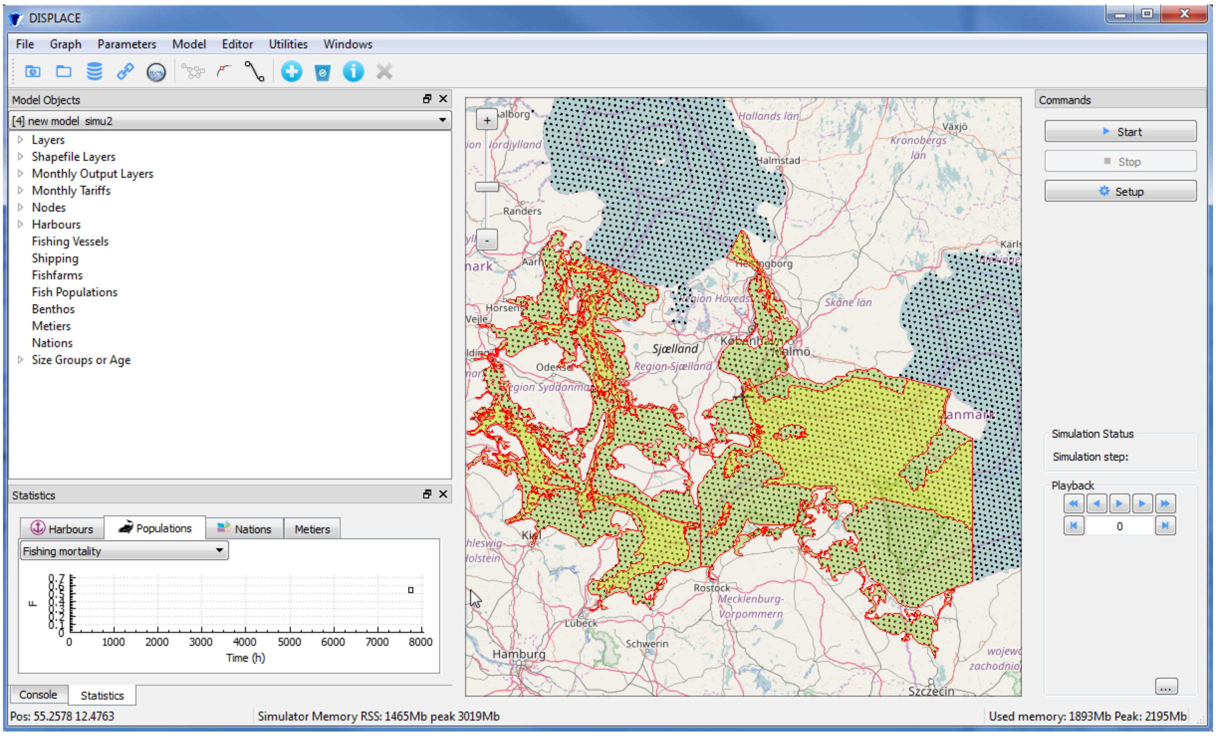


Figure: 222324.shp (soft green) and over20m_222324.shp (soft yellow)

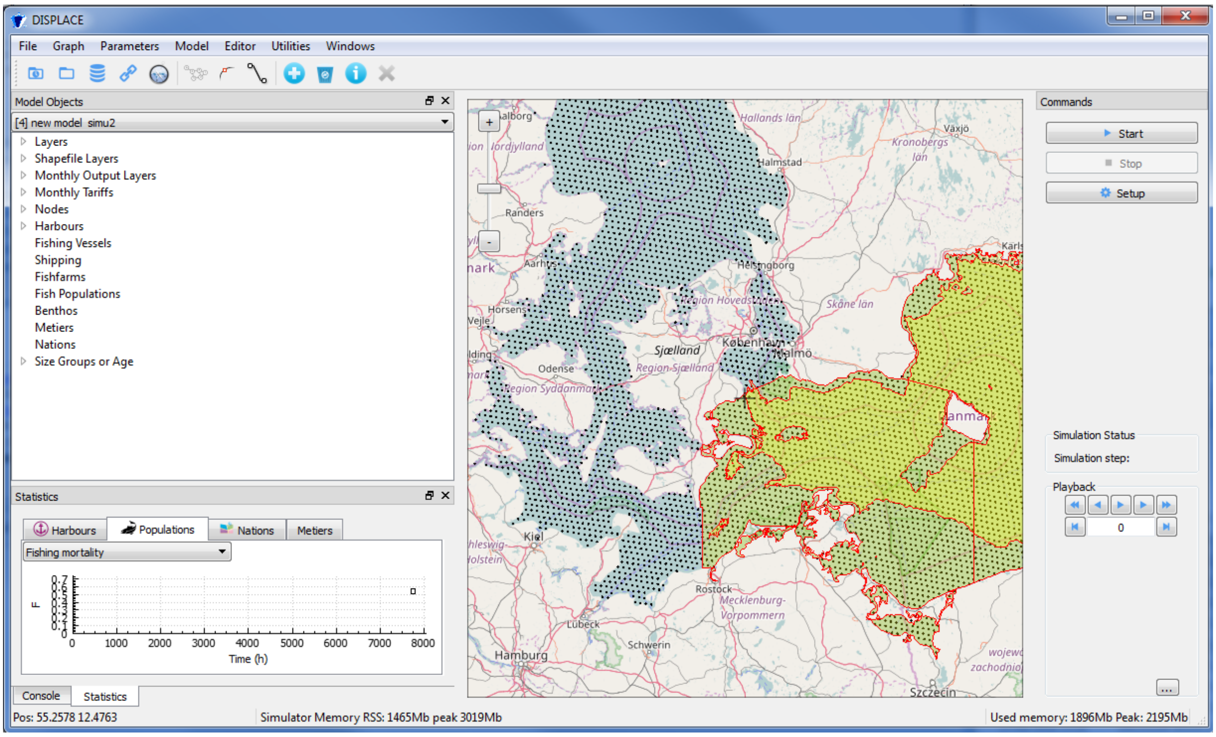


Figure: 242526.shp (soft green) and over20m_242526.shp (soft yellow)

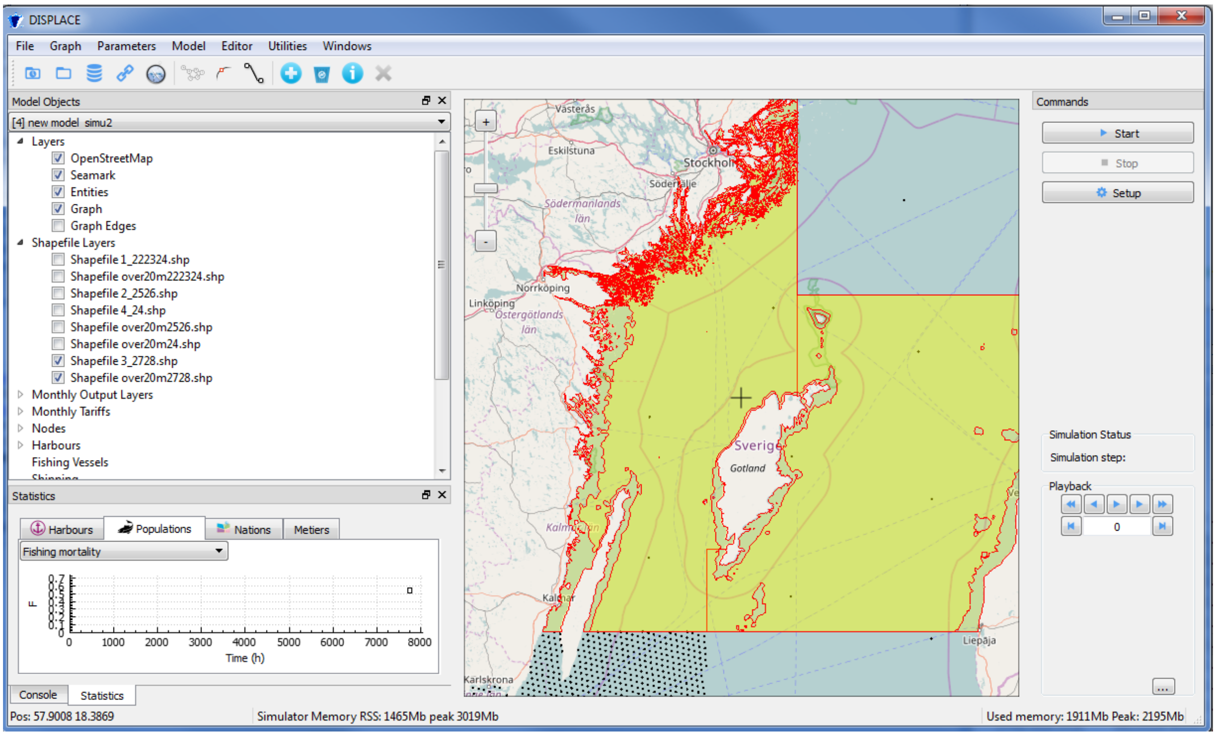
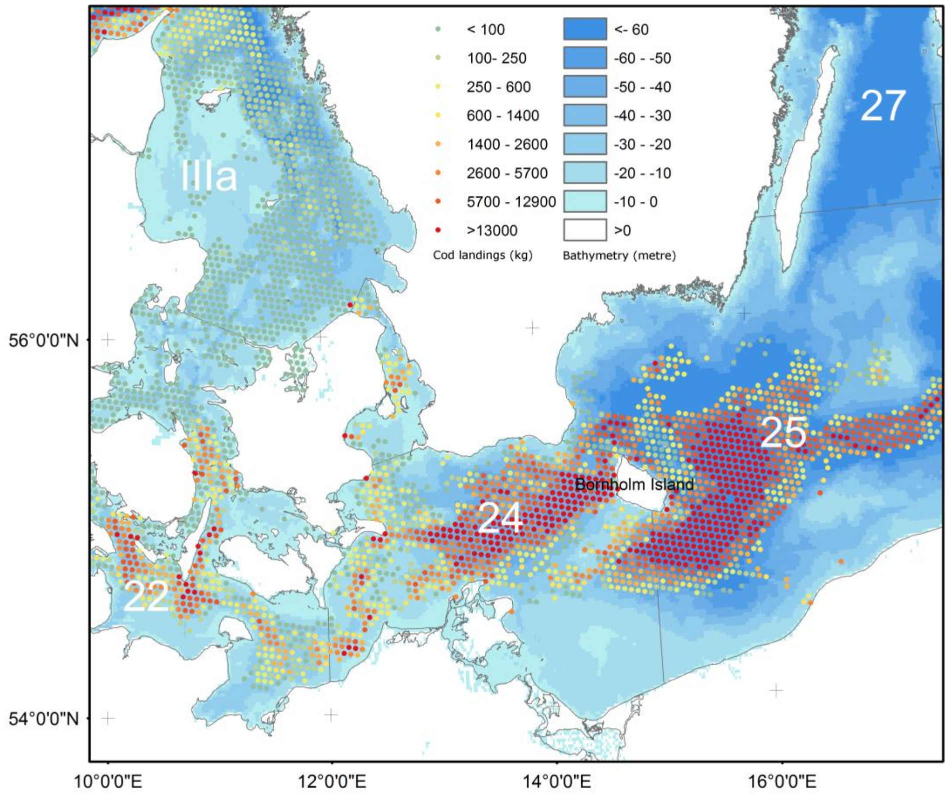


Figure: 2728.shp (soft green) and over20m_2728.shp (soft yellow)

10. TECHNICAL ANNEX 3 – ORIGIN OF DANISH COD LANDINGS



From Bastardie et al. (2016) - The Central Baltic Sea region with ICES area codings and bathymetry (in blue levels). The DISPLACE model discrete positions (underlying graph nodes; 4 by 4 km grid in IIIa, SD22-25; 100 by 100 km otherwise) are shown together with the spatial origin of the 2012 cod landings in kg (colored circles; for the selected vessels only) used for deducing area- and vessel-specific catch rates when combined with the deployed individual effort.