Potential Indicators and Reference Points for Good Environmental Status of Commercially Exploited Marine Fishes and Invertebrates in the German EEZ

Rainer Froese, Helmholtz Centre for Ocean Research GEOMAR, Düsternbrooker Weg 20, Germany, rfroese@geomar.de

Arlene Sampang, FishBase Information and Research Group FIN, Khush Hall, IRRI, Los Baños, Laguna, Philippines, a.sampang@fin.ph

Cite as: Froese, R. and A. Sampang. 2013. Potential Indicators and Reference Points for Good Environmental Status of Commercially Exploited Marine Fishes and Invertebrates in the German EEZ. World Wide Web electronic publication, available from http://oceanrep.geomar.de/22079/

Note: This version of the text [MSFD_8.pdf] replaces an earlier version [MSFD_5.pdf] of September 2013. It fixes a misalignment of proxy recruits and spawners in the data-limited stocks and adds an indication of total biomass. It also adds an analysis of commercial catch data relative to stock abundance, to improve the estimation of mortality for the data-limited stocks. The concepts, overall results and conclusions are not affected by these changes.

Abstract

Indicators and reference points for assessing the good environmental status of commercially exploited marine fishes and invertebrates are presented, using 20 stocks from the German exclusive economic zone. New estimates of length-weight relationship, von Bertalanffy growth, length at 50% and 90% maturity, age at 50% maturity, and length and age where cohort biomass is maximum are presented for each stock. Twice the stock size below which recruitment may become impaired (SSB_{pa}) is proposed as a proxy for the biomass that can produce the maximum sustainable yield, which is the lower limit reference point for stock size. A rule-based hockey stick function is presented to estimate SSB_{pa} from stock-recruitment data. The rate of natural mortality is proposed as an upper limit reference point for fishing mortality. The length where 90% of females have reached sexual maturity is proposed as a lower limit reference point for mean length of fishes in commercial catches. The length where cohort biomass is maximum and where therefore a given catch has the least impact on the age structure of the stock is recommended as target length in commercial catches. A new large fish indicator (LFIS) is developed as the ratio of large fish biomass to mature fish biomass. The corresponding upper limit reference point is the ratio of large fish that would be present with fishing mortality equal to natural mortality. Survey and catch data data are used to establish proxies for above indicators and reference points for data-poor stocks. Applying the data-poor methods to fully assessed stocks and comparing the resulting scores for good environmental status shows reasonably good agreement. Data, spread sheets and R-code used in this study are available online from http://oceanrep.geomar.de/22079/.

Introduction

Assessing the good environmental status of commercially exploited fishes and invertebrates in the national exclusive economic zone (EEZ) is a requirement for European states under the European Marine Strategy Framework Directive (MSFD 2008, COM 2010). The overarching legal framework for suitable indicators and reference points is provided by the United Nations Convention on the Law of the Sea (UNCLOS 1982), the Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea (UNFSA 1995), and the 2013 reform of the European Common Fisheries Policy (CFP). Here we explored the usefulness of several indicators for this purpose and tested them out on 21 commercial stocks that occur regularly in the Germany EEZ.

In the Northeast Atlantic, over 200 species of marine organisms are regularly found in commercial catches. Populations of these species, such as North Sea herring or the Western Baltic herring, are called stocks, and the International Council for the Exploration of the Sea (ICES) keeps catch statistics for about 200 of such stocks (ICES 2012a). However, full stock assessments, including annual estimates of recruitment, spawning stock biomass and fishing mortality, are conducted for only about 50 of these stocks.

In the following we perform a preliminary assessment of the resilience of commercially exploited marine fishes and invertebrates in the German EEZ. Typical criteria for such assessment are the size of a stock and its age structure relative to a sustainably exploited, healthy stock, and the level of exploitation relative to levels that are expected to be sustainable, with least possible impact on stock size and age structure.

We distinguish between status indicators, such as spawning stock size and age structure, and pressure indicators such as the proportion of fish killed by fishing (= fishing mortality) and the size targeted by fishers. The necessary data are readily available for the fully assessed stocks. Reasonable proxies can be derived for most of the other data-limited stocks from research survey data in combination with catch data. Note that definitions of all indicators, reference points and life history parameters are given in Appendix II.

A general challenge for indicator-based assessments is the availability of meaningful reference points. For stock status, the spawning stock biomass (SSB) is the internationally recognized indicator and the SSB that can produce the maximum sustainable yield (SSB_{msy}) is the corresponding reference point (UNCLOS 1982). For human pressure on the stock, fishing mortality (F) is the internationally recognized indicator and the F that lets a stock reach SSB_{msy} is the corresponding reference point F_{msy} (UNFSA 1995). ICES provides estimates of F_{msy} for most of the fully assessed stocks, but no estimates of SSB_{msy}. However, two other meaningful reference points are available for many stocks. The rate of natural mortality M, i.e., the mortality caused by predation, diseases, natural hazards and old age, has long been used in fisheries science as a proxy for F_{msy} (e.g. Gulland 1971, Shepherd 1981, Beddington and Cooke 1983, Clark et al. 1985, Beverton 1990) and more recently as an upper limit of F_{msy} (Patterson 1992, Thompson 1993, Walters and Martell 2002, Walters and Martell 2004, MacCall 2009, Pikitch et al. 2012). Also, the spawning stock biomass below which recruitment may become impaired (SSB_{pa}) can be estimated for many stocks, and since population dynamics theory suggests such impairment to occur at stock sizes below half of SSB_{msy}, it follows that two times SSB_{pa} is a reasonable proxy for SSB_{msy} until better estimates become available.

Obtaining an indicator and a reference point for an age structure that is indicative of a healthy stock (MSFD 2008, COM 2010) is more challenging. Here we propose to use the biomass of large fish relative to the spawning stock biomass as indicator, with a reference point derived from simulations. This new concept is explained below.

Figure 1 assumes that we follow a cohort (fish of the same stock born in the same year) through its expected life time from ages 1 to 15. Data for natural mortality and somatic growth are those of North Sea cod.

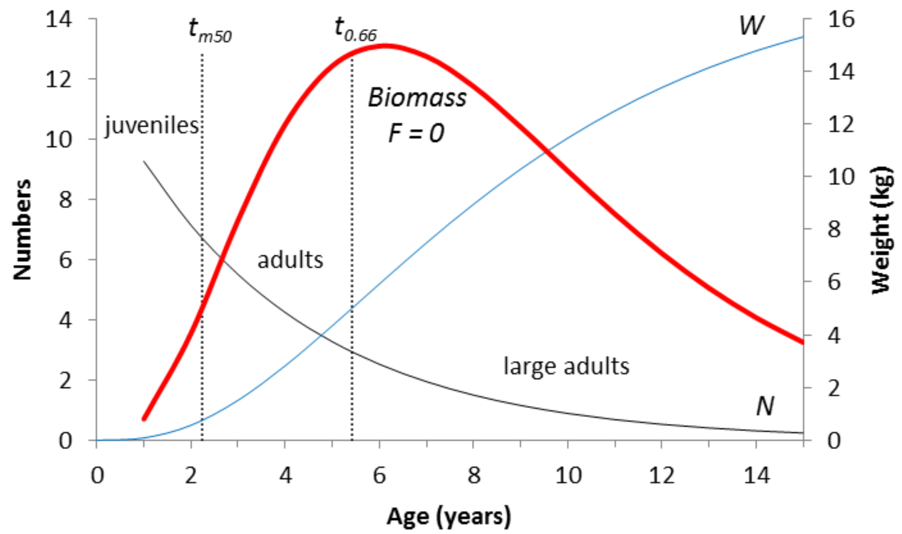

Figure 1. Conceptual drawing of decline in numbers (*N,* black curve), increase in individual body weight (*W*, blue curve), and resulting cohort biomass (red curve) over cohort age, if no fishing takes place (*F*=0). The area under the red curve as separated by the dotted vertical lines represents the biomass of juveniles (age < t_{m50}), adults (age > t_{m50}) and large adults (age > $t_{0.66}$). [NMS_Concept_5.xlsx]

In this first conceptual drawing, the number of individuals (*N*, thin black curve) declines with age only due to average natural mortality, since in this example we assumed no fishing mortality (*F*=0). Fish grow throughout their lives and thus individual body weight (*W,* thin blue curve) increases with age. The product of number of survivors times their average body weight gives the total weight or biomass of the cohort by age (bold red curve). Individuals before the age t_{m50} where 50% of the females have reached maturity are mostly juveniles, above that age they are mostly adults. The biomass of adults is the area under the red curve to the right of the vertical dotted line marked as t_{m50}. The area under the red curve to the right of the dotted line marked $t_{0.66}$ represents the biomass of large fish, longer than 66% of the average maximum length. The ratio of large fish to mature fish biomass is the large fish indicator *LFIS*. The simulation suggests that in an unexploited cod stock, 80% of the adult biomass would consist of large fish.

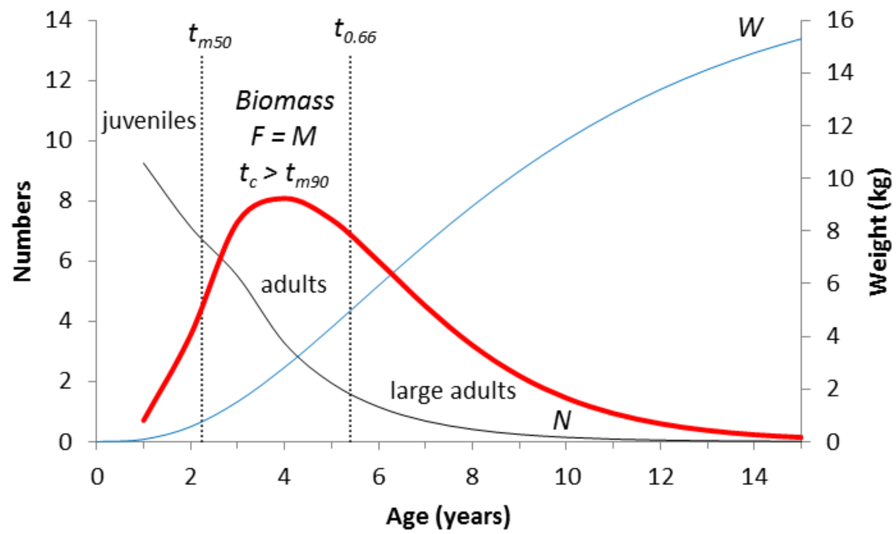

Figure 2. Same scales and concepts as shown in Figure 1, but with fishing starting at the age of t_c = 3 years, with a fishing mortality *F* equal to natural mortality *M*. [NMS_Concept_5.xlsx]

Figure 2 uses the same scales and shows the same concept as Figure 1, but with fishing from three years onward, after more than 50% of the females have reached maturity, with a fishing mortality equal to natural mortality (*F* = *M*). Overall biomass is reduced to 37% of the unexploited biomass, and the proportion of large fish is reduced to 53% of adult biomass. This last percentage varies and thus has to be calculated for every stock. It is the proposed reference point against which the observed proportion of large fish biomass can be evaluated.

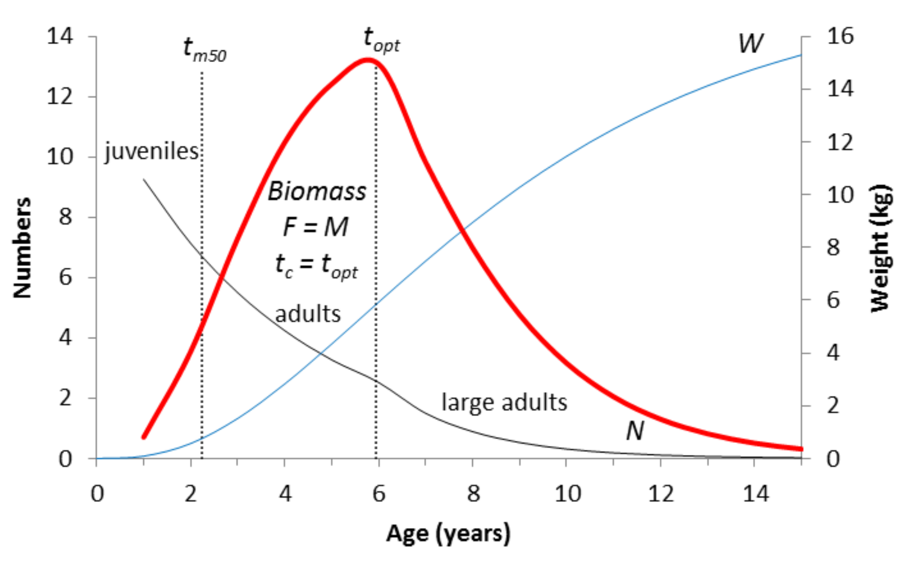

Figure 3. Same scales and concepts as in Figures 1 and 2, but here the onset of fishing is delayed until cohort biomass has reached its maximum. The same fishing mortality *F* = *M* as in Figure 2 then results in a larger overall biomass and slightly larger fishable biomass and catches. [NMS_Concept_5.xlsx]

Figure 3 shows the expected biomass from fishing with $F = M$ if fishing starts not at t_{m50} but at the age t_{opt} when cohort biomass has reached its maximum. Such fishing has the least impact on the stock and leads to considerably higher biomass of about 61% of the unexploited stock. The proportion of large fish increases to 66% of adult biomass. Despite the later onset of fishing (age 6 instead of age 3), the biomass accessible to fishing has not decreased but slightly increased due to the continuing growth of the smaller fishes. Since fishing mortality F is the fraction of the average biomass that can be taken by the fishery, slightly higher accessible biomass also means slightly higher catches. Additional benefits to the fishery may arise from better prices for larger fish and lower cost of fishing due to higher abundance and wider distribution. The age and size for the best start of fishing, L_{opt} and t_{opt}, are thus target reference points indicative of a well-managed fishery.

From above considerations it follows that the length class targeted by fishing, represented by the mean length L_{mean} in commercial catches, is a pressure indicator. This length is here evaluated against the length L_{m90} at which 90% of the females have reached maturity and against the length L_{opt} where a given catch has the least negative impact on the stock.

Two examples of applying the indicators to fully assessed stocks

For the calculation of indicators and reference points we relied on life history parameters such as length-weight relationships, growth in body length, and lengths where 50% and 90% of the females have reached maturity. With few exceptions, the respective parameters could be estimated for the selected stocks using length-weight-maturity-at-age data from 2000-2012 as provided in the DATRAS SMALK database (ICES 2013). The respective parameters are documented for every stock in Appendix I.

For the purpose of a preliminary evaluation of sustainability, resilience, and good environmental status of fully assessed stocks, the ratios between indicators and their respective limit reference points described below were applied. The ratios were arranged such that good scores are larger than 1.0, and the distance of a score to 1.0 is proportional to the distance between the indicator and its limit reference point.

Ratios between indicators and limit reference points used for scoring

***SSB / pSSB$_{msy}$*:** This is a state indicator giving the ratio of observed spawning stock biomass to the (preliminary) biomass that can produce the maximum sustainable yield. For data-limited stocks, the respective proxy values were used.

***LFIS / LFIS$_{F=M}$*:** This is a state indicator giving the proportion of large fish biomass relative to the expected value if $F = M$ and fishing starts in the year after 50% of the females have reached maturity.

F_{msy} / F*:** This is a pressure indicator giving the ratio of the rate of fishing mortality that would result in the maximum sustainable yield once the stock is rebuilt, to the actually observed rate of fishing mortality. ***F_{msy} is available for most of the fully assessed stocks.

M* / *F: This is a pressure indicator giving the ratio of the rate of natural mortality to the observed rate of fishing mortality.

L_{mean} / L_{m90}: This is a pressure indicator giving the ratio of the observed mean length in the catch to the length where 90% of the females have reached maturity.

We now show examples of the application of these indicators to two fully assessed stocks. We chose North Sea plaice because it provides an example of a stock that has recently recovered from previous overfishing, and North Sea cod as an example of a stock which continues to suffer from severe overfishing.

Figure 4 shows the rebuilding of spawning stock biomass of North Sea plaice since 2000 (red curve). The biomass crossed the threshold of the proxy spawning stock biomass that can produce the maximum sustainable yield ($pSSB_{msy}$) and would earn a score of 1.04 in 2011. The biomass of large fish (green line) has also increased, from 14% in 2000 to 39% in 2011, but is still much smaller than the 61% expected from fishing with *F* = *M* and with start of fishing at age 3, when most fish have matured, resulting in a score of 0.6.

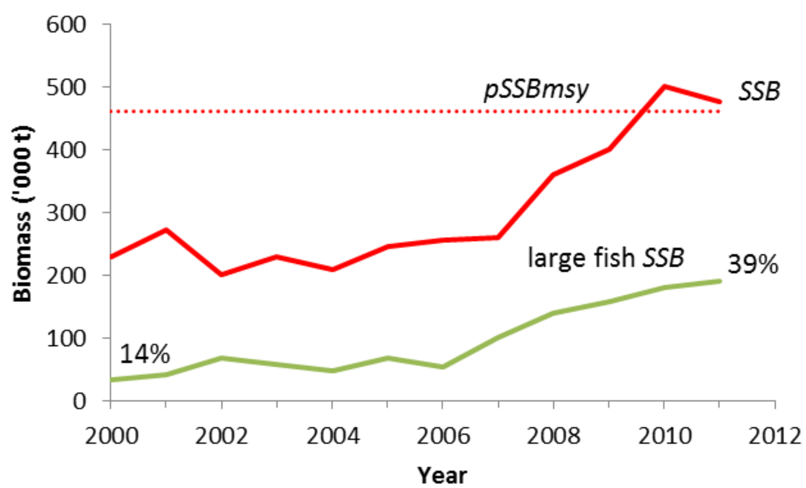

Figure 4. Status graph: Spawning stock biomass of North Sea plaice (red curve) from 2000 to 2011, with indication of the proxy biomass that could produce the maximum sustainable yield ($pSSB_{msy}$). The green line shows the biomass of large fish, representing 14% of *SSB* in 2000 and 39% in 2011. [NMS_Germany_Stocks_9.xlsx]

Figure 5 shows the decrease in fishing mortality from 2000 to 2011, which allowed for the rebuilding of spawning stock biomass shown in Figure 4. Note, however, that fishing mortality still exceeds natural mortality and that the mean length in the commercial catches is still slightly below the length where 90% of the females have reached maturity and well below the length where fishing has the least impact on size and age structure. Probably for historic reasons, ICES (2012b) uses a rather low estimate of natural mortality *M* = 0.1 for flatfish. A more realistic *M* = 0.25 would mean that *F* is about equal to *M* in

2011, which would be better in line with the official F_{msy} = 0.25 (ICES 2012b) and the observation that spawning stock biomass is above the reference point in 2011.

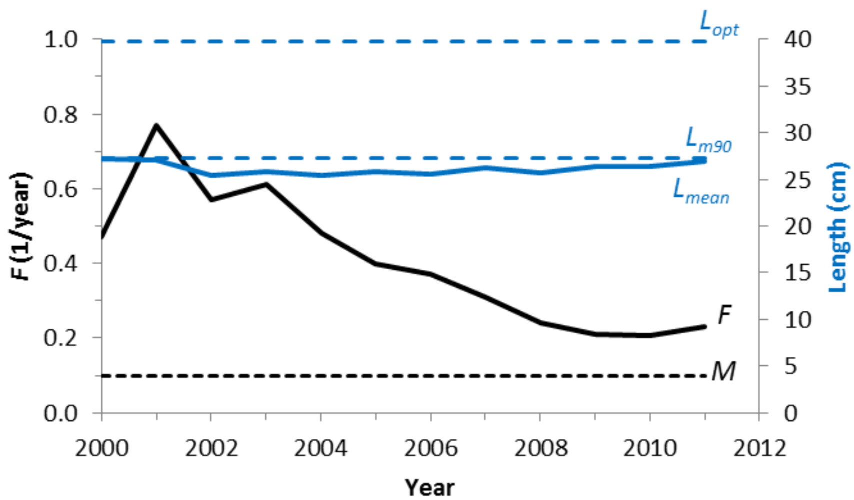

Figure 5. Pressure graph: Fishing mortality *F* (black curve) and mean length in commercial catches L_{mean} (blue curve) for North Sea plaice in 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

Figure 6 summarizes the scores obtained by North Sea plaice against the described reference points. The area above the 1.0 dashed line is indicative of sustainably managed, healthy stocks. Only spawning stock biomass reached that area in 2010, while mean length in catches was close throughout the time series. The proportion of large fish biomass is still too low and fishing mortality still too high. The *M*/*F* curve would be close to 1.0 in 2011 if *M* were 0.25 instead of 0.1. In that scenario, North Sea plaice would be well on its way to become a stock with sufficient biomass and adequate fishing pressure. The remaining tasks for an overall good assessment are for management to increase the mean length in the catch beyond L_{m90} and toward L_{opt}. Such management would lead to a larger stock size with a healthy age structure and also higher catches.

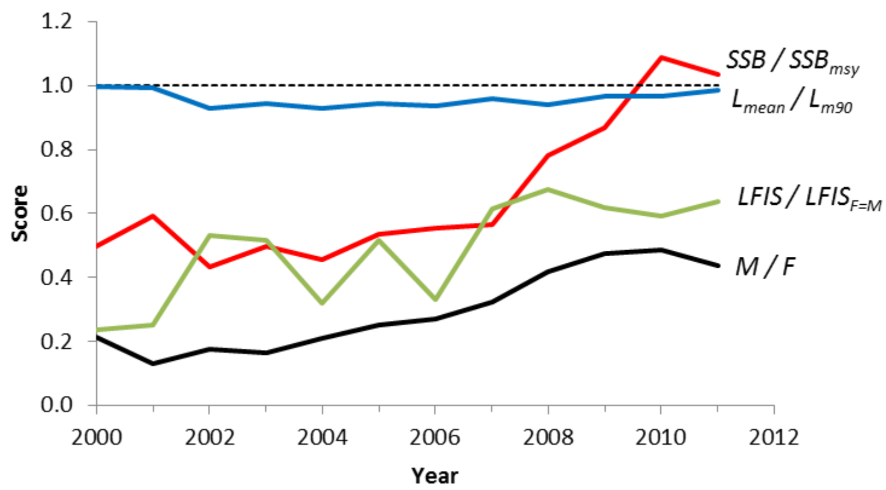

Figure 6. Score graph: Scores obtained by North Sea plaice relative to the limit reference points, for fishing mortality *M/F* (black curve), large fish biomass *LFIS/LFIS*$_{F=M}$ (green curve), mean length in catches *L*$_{mean}$/*L*$_{m90}$ (blue curve) and spawning stock biomass *SSB/SSB*$_{msy}$ (red curve). Scores above the dashed 1.0 line are indicative of sustainable fishing pressure and/or a healthy stock status. [NMS_Germany_Stocks_9.xlsx]

Figures 4-6 referred to plaice throughout the North Sea. Since the purpose of this exercise is to evaluate the status of commercial stocks in the German EEZ, we present a graph that shows the abundance in the respective ICES area, here roundfish area 6, which includes the German Bight in the southern North Sea. For Baltic stocks we use ICES subdivisions 22 & 24 which include the Baltic Sea west of Bornholm, excluding the Öresund.

Figure 7 shows a time series of average catch in numbers of plaice resulting from one hour of survey trawling with standardized gears. These catches reflect the stock abundance in the German EEZ. A good stock status would be indicated by recent abundances being at or above the overall mean, with increasing or stable trend over the last 5 years. This is the case for North Sea plaice.

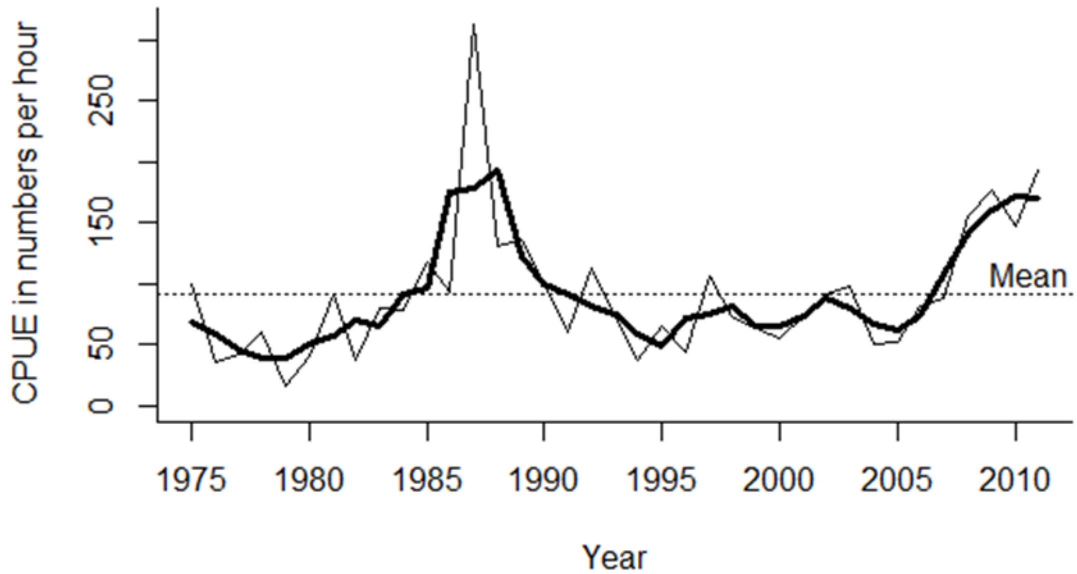

Figure 7. Average catch in numbers resulting from one hour of trawling with standardize survey gears. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catches over the time series. [CPUE_Area_24.r]

Figure 8 to Figure 11 show the respective status, pressure, score and abundance graphs for the North Sea cod. The depleted status of the stock and the continuing excessive fishing pressure are well captured by the indicators and the scores. Especially Figure 11 shows the extirpation of North Sea cod from the German EEZ, where catch in numbers declined from 150 individuals in the 1970s to 2-3 individuals in recent years.

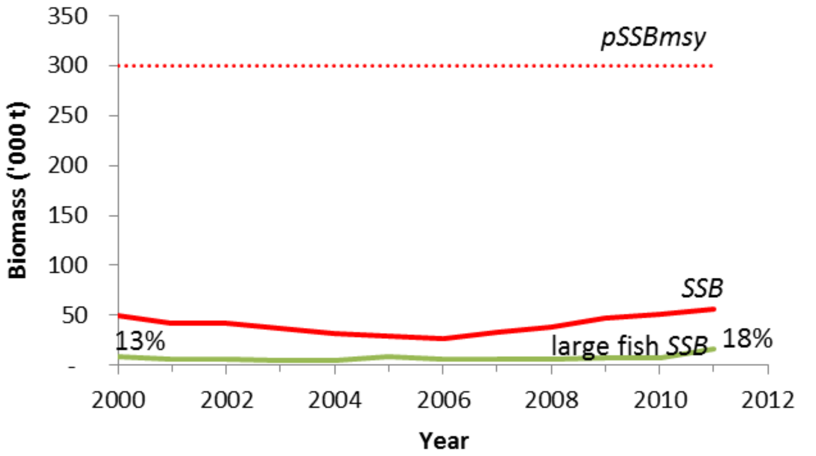

Figure 8. Status graph for North Sea cod spawning stock biomass (SSB, red curve) relative to the proxy biomass ($pSSB_{msy}$) which could produce the maximum sustainable yield. The green curve indicates the biomass of large fish, which is far below the expected percentages resulting from fishing at *F*=*M*. [NMS_Germany_Stocks_9.xlsx]

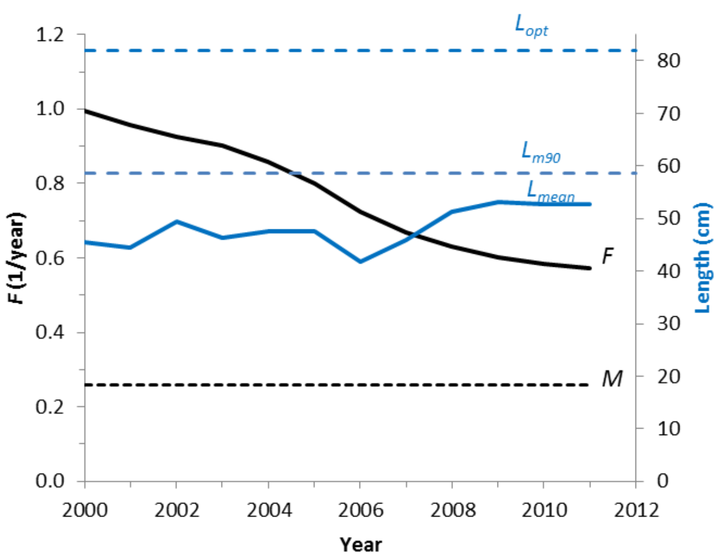

Figure 9. Pressure graph for North Sea cod, showing the fishing mortality (*F*, black curve) relative to natural mortality (*M*), and the mean length (L_{mean}, blue curve) targeted by fisheries relative to the length where 90% of the females would reach maturity (L_{m90}) or where fishing would have the least impact on the stock (L_{opt}). [NMS_Germany_Stocks_9.xlsx]

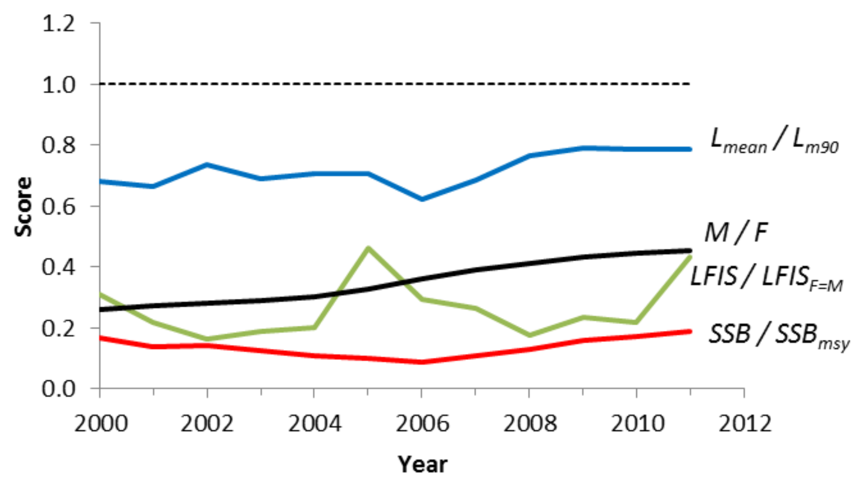

Figure 10. Score graph for North Sea cod, for fishing mortality *M/F* (black curve), large fish biomass *LFIS/LFIS$_{F=M}$* (green curve), mean length in catches *L_{mean}/L_{m90}* (blue curve) and spawning stock biomass *SSB/SSB$_{msy}$* (red curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure or a healthy stock status. [NMS_Germany_Stocks_9.xlsx]

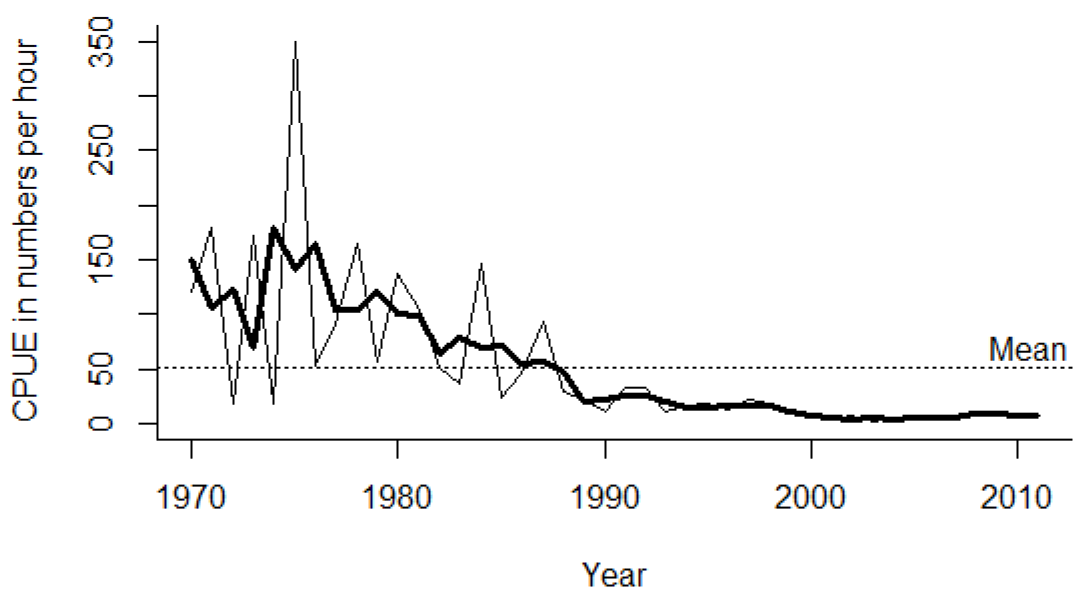

Figure 11. Average catch in numbers of North Sea cod resulting from one hour of trawling with standardized survey gears. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. Catch in numbers has declined from 150 individuals before 1975 to 2-3 individuals in recent years. [CPUE_Area_24.r]

Applying the indicators to data-limited stocks

Data-limited stocks lack assessments of fishing mortality, biomass and recruitment and thus the indicators as described above cannot be applied directly. Landings data are available for most of these stocks but may be unreliable, mainly because they do not include discards and therefore underestimate the true catches. Available data are life history data such as growth in length, length-weight relationships, and length or age at first maturity, as derived with standard models from DATRAS SMALK data (ICES 2013). Also, ICES provides catch per unit effort by length class and ICES area in the DATRAS CPUE-per-length-per-area database. Landings data can be used to estimate the ratio between catches and abundances indices from surveys, as indication of fishing pressure. From combinations of these data, proxies for fishing mortality and spawning stock size were derived.

An unexpected shortcoming of the DATRAS data was a bias towards large fish, i.e., the DATRAS data suggested higher abundance of large fish than supported by the full assessments and expected from stock status. Therefore, the large fish indicator (*LFIS*) and the mean length indicator (L_{mean}) could not be used for data-limited stocks. Instead, new proxy indicators and reference points were developed for fishing mortality and stock size, as described below.

Figure 12 shows an assessment of a data-limited stock, here the North Sea dab *Limanda limanda*. The four graphs show survey catch in numbers in the upper left panel, number of individuals younger than 1.5 years (presumed recruits) in the upper right panel, survey catch expressed as biomass of mature and large fish in the lower right panel, and annual estimates of total mortality *Z* in the lower left panel. We will discuss these graphs now in more detail.

The upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of dab caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals that are larger than the length at 50% female maturity L_{m50} = 15 cm and that are larger than the first length class that is fully retained by the gear L_v = 17 cm. This second condition is necessary because of the definition of recruits below. The dotted horizontal line indicates the overall mean of total annual catch in numbers. A first assessment suggests that abundance is increasing and in recent years above the long-term mean.

The upper right graph shows the number of youngest fish in the survey. This would normally be fish smaller than the length expected for 1.5 years of age $L_{1.5}$ = 12.6 cm, as proxy for recruits. However, this is below the length class L_v = 17 cm that is fully selected by the gear, and thus in this case all fishes with 17 cm or smaller were considered recruits in the sense that they have become vulnerable to the survey gear. The dotted line indicates the geometric mean of recruitment, see Figure 13 and method of estimation below. A first assessment suggests that recruitment has been around average in recent years.

In the lower right graph, length of fish larger than 17 cm was converted to weight and summed up to show the proxy biomass of mature fish. The black line shows the biomass of all fish in the survey. The dotted horizontal lines are proxy reference points for spawning stock biomass, see discussion of Figure 13 below. A first assessment suggests that spawning stock biomass has been within safe biological limits (above proxy SSB_{pa}) for the past two decades, and has reached the size that can produce the maximum sustainable yield (proxy SSB_{msy}) in 2010.

The lower left graph shows annual total mortality *Z* experienced over the respective previous three years, as a proxy for fishing mortality. The bold circles are three-year averages of *Z*. The blue line is exploitation rate *u* (COM 2010), i.e. the ratio between commercial catches and total survey biomass (black curve in lower right panel). Unfortunately, no reference point for *u* is available. Here, *u* has been scaled such that maximum *u* equals maximum *Z* during the survey period. The scale *u*-curve was then adjusted vertically such that the squared residuals between *Z* and scaled *u* were minimized. Since *u* can be thought of as relating catches to the average annual biomass of the stock, it becomes directly comparable *F* and *M*, with *M* as a reference point. No estimate of natural mortality exists for this stock, so a preliminary value of *M* = 0.25 is assumed, which is a compromise between the *M* = 0.1 often used by ICES for flatfish and the *M* = 1.5 *K* = 0.32 suggested by general life history theory (Jensen 1996). The dotted line then is the reference to fishing with *F* = *M*. A first assessment suggests that fishing mortality of dab is higher than the natural mortality rate.

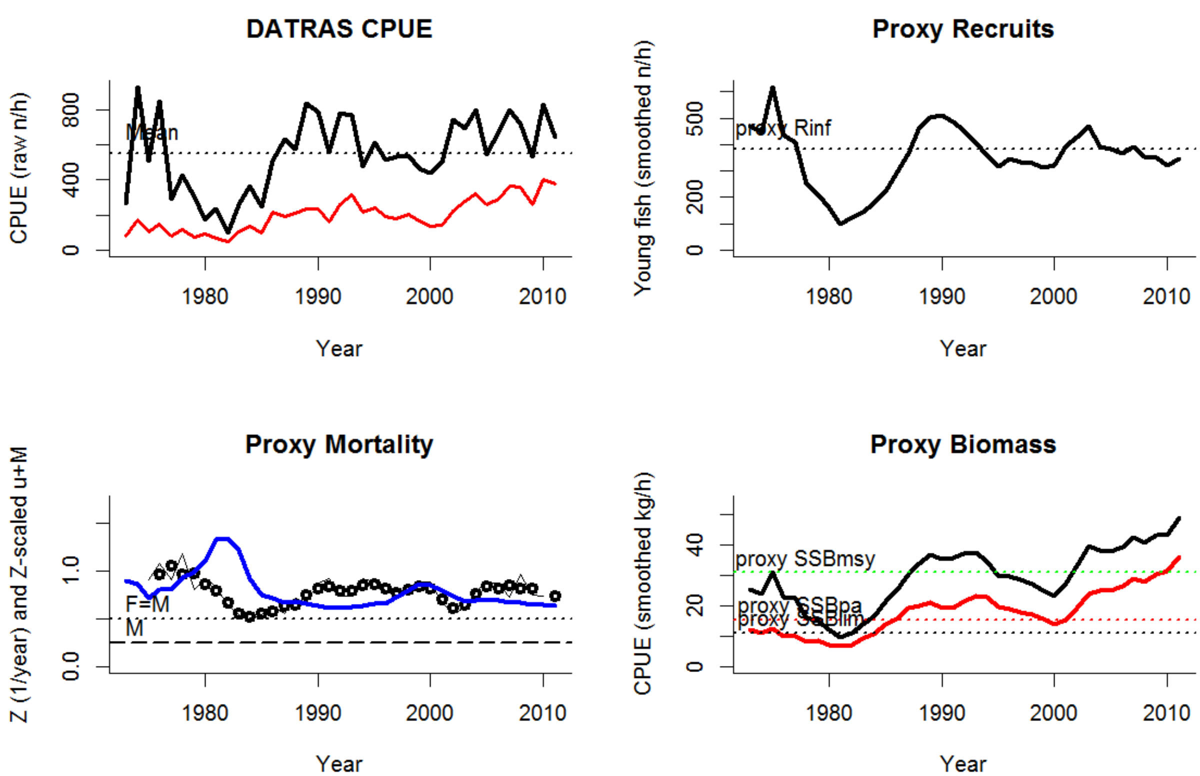

Figure 12. Evaluation of a data-limited stock, here North Sea dab. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of dab caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective

previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

Figure 13 shows a proxy stock-recruitment relationship. The biomass of mature fish in the surveys was used as proxy for *SSB* and the number of youngest fish two years later was used as proxy for number of recruits. A hockey stick was fitted by an automated procedure, where the shaft of the hockey stick represents the geometric mean number of recruits R_{inf} produced by biomasses in the upper half of the range of available *SSB* estimates, to represent average long-term recruitment at reasonably large stock sizes. The shaft is connected to the blade at the smallest biomass which resulted in a recruitment not less than the long-term average. The tip of the blade connects to the origin of the graph. The point where shaft and blade meet marks the proxy biomass SSB_{lim}, below which recruitment was reduced. The same procedure was applied to the upper 95% confidence limit of R_{inf} to obtain the precautionary borderline to potentially compromised recruitment proxy SSB_{pa}. However, if this resulted in an estimate of SSB_{pa} that was smaller than 1.4 SSB_{lim}, as in our example, then SSB_{pa} was set to 1.4 SSB_{lim}, as is often done by ICES working groups in data-limited situations. Multiplying SSB_{pa} by two gives the proxy SSB_{msy} that can produce the maximum sustainable yield, see Figure 12.

Note that no attempt was made to fit a hockey stick to the proxy data for recruits and biomass if the data were deemed unfit for the task. In these cases, either the smallest or the largest proxy biomass was set to SSB_{pa} according to the following rules: If the number of years with proxy S/R data was less than 10 (e.g. for eel), or proxy fishing mortality exceeded 3 times the natural mortality rate throughout the survey time series (e.g. for spurdog), or all catches during the survey time series were smaller than half the maximum catch on record (e.g. plaice in the Western Baltic), then the stock was deemed to be outside of safe biological limits and the highest proxy biomass was used for SSB_{pa}. Alternatively, if all proxy total mortality during the survey was below 3 *M* and all catches were above half of the overall maximum catch (e.g. in Baltic sprat), then the stock was assumed to be within safe biological limits throughout the time series and the lowest proxy biomass was used for SSB_{pa}.

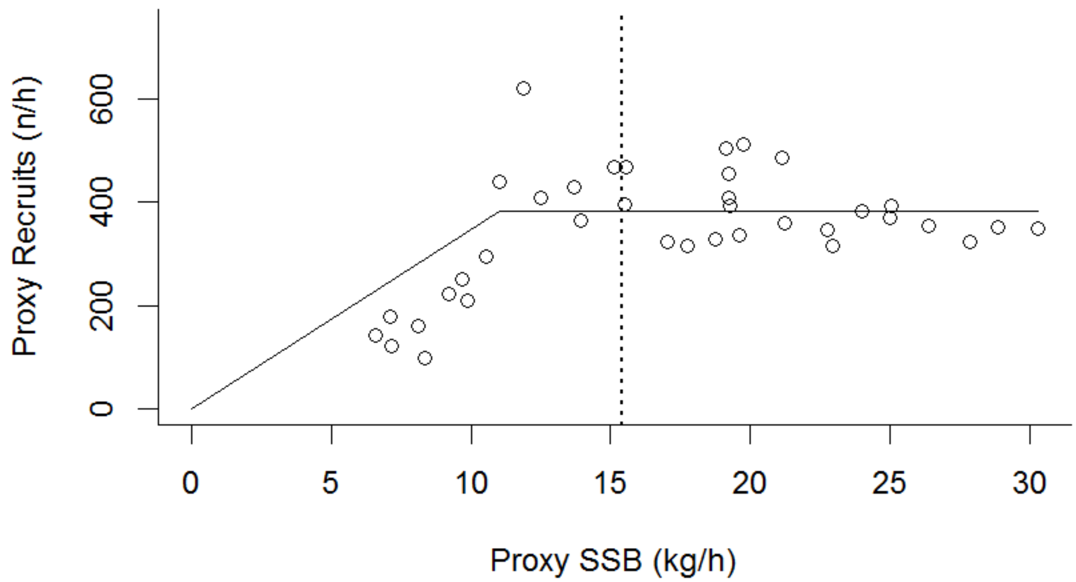

Figure 13. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

Figure 14 shows a score graph for North Sea dab, with the red curve indicating the biomass score and the black line indicating the fishing pressure score. Both scores increase slightly, with dab proxy biomass exceeding the 1.0 threshold in 2010.

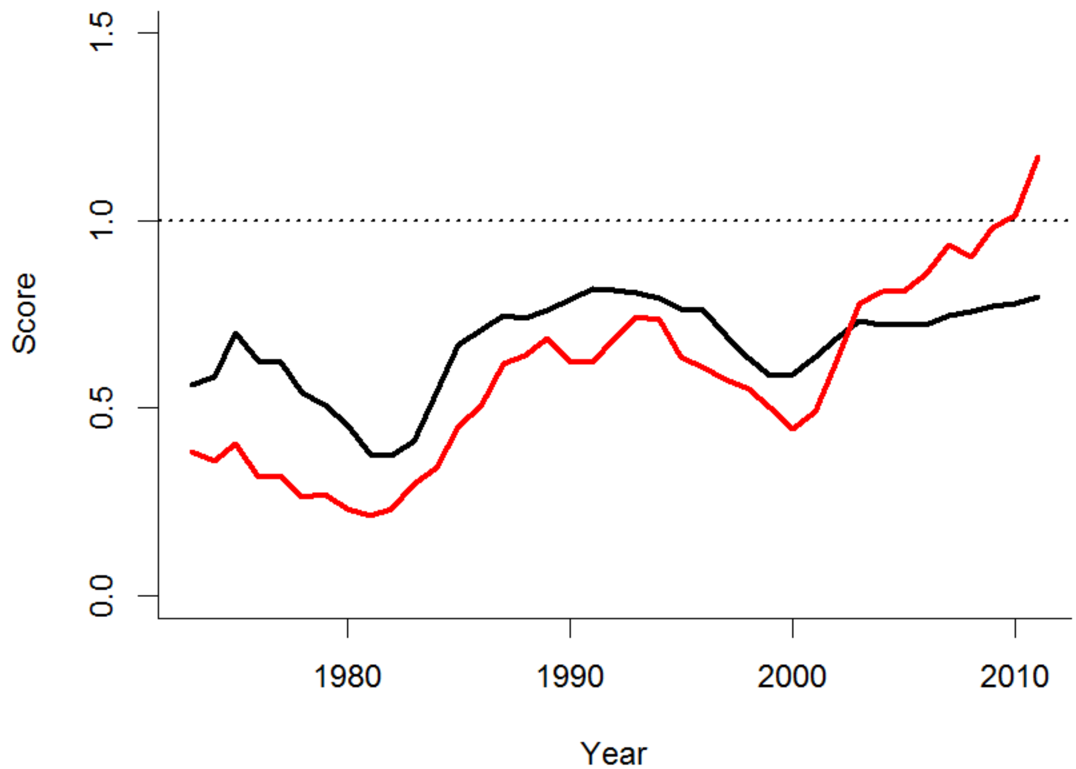

Figure 14. Score graph: Time series of preliminary scores for the data-limited North Sea dab. The red curve indicates the biomass score and the black curve indicates the mortality score. Desired scores are larger than 1.0. [CPUE_Area_24.r]

Figure 15 shows the catch in numbers resulting from one hour of survey trawling in ICES roundfish area 6, which includes the German Bight. There seem to be decadal fluctuations in abundance, with recent peaks lower than previous ones.

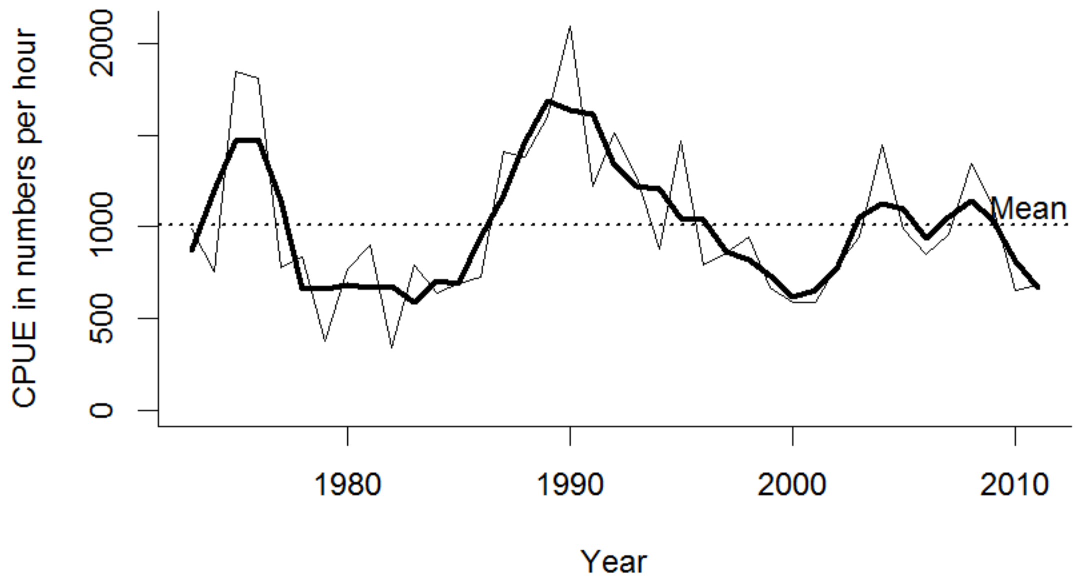

Figure 15. Average catch in numbers of North Sea dab resulting from one hour of trawling with standardized survey gears. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

Discussion of indicators, reference points and performance of proxies for data-limited stocks

With the above considerations we have derived proxy indicators with reference points for recruitment, spawning stock biomass and fishing pressure of data-limited stocks. Theoretically we could also calculate the ratio of large fish biomass to *SSB* or the mean length in the catch, however, DATRAS CPUE data overestimate the number and thus the biomass of very large specimens. This is evident from length-frequency diagrams with surprisingly large numbers of large fish, e.g. for North Sea cod, where the full stock assessment shows that large cod are actually rare (see Figure 8), but also for other stocks such as plaice or dab. The reasons for such bias can only be assumed. In depleted areas, such as the southern North Sea for North Sea cod, recruitment fails and remaining individuals are either lone survivors which grow larger as time passes, or adult immigrants from other areas. Length frequency samples from these areas will thus consist mostly of large fish. If these length-frequencies are combined with equal weight with areas where recruitment still occurs, such as in the northern North Sea, then the overall frequency will be biased towards large fish. Also, there may be a “large fish fascination” resulting in a tendency to include too many large fish when creating subsamples from a catch that is too large to be processed in total. These few more large fish result in a strong bias towards large fish when the subsample is raised to the total (ICES 2010, p.31). There may be another issue with the accounting for zero-catch hauls when estimating mean catches. Also, since L_{mean} is supposed to reflect the pressure exercised by the commercial fishery and not by the research surveys, a method would have to be developed to estimate the commercial L_{mean} from increased mortality at length visible in the survey data. In any case, the bias in DATRAS CPUE length-composition prevented the application of the *LFIS* and L_{mean} indicators in data-limited stocks.

In the following we discuss the pros and cons of the different indicators and reference points. Where appropriate, we also point out which limit and target values may be appropriate for MSY-level fishing, achievement of good environmental status, resilience against climate change, and conservation of biodiversity.

SSB / pSSB_{msy}: This state indicator is available for most fully assessed stocks in the ICES area. It shows the adult stock size relative to the size $pSSB_{msy}$ that can produce the maximum sustainable yield. The preliminary SSB_{msy} is needed because ICES so far does not provide estimates of SSB_{msy}, which is a reference point referred to in UNCLOS (1982), UNFSA (1995), MSFD (2008), Descriptors 1 and 3 in COM (2010), and in the on-going CFP reform. These laws, instruments, agreements and proposals agree that a biomass below SSB_{msy} requires rebuilding of the stock. A score above 1.0 indicates a spawning stock size above the level that can produce *MSY*. Targets of 1.3 and 1.5 have been proposed for regular and forage fish, respectively, by Froese et al. (2011). A score of 1.5 is a proposed target considered to provide good resilience against anthropogenic or environmental disturbances.

F_{msy} / F : This pressure indicator is available for most of the fully assessed stocks in the ICES area. It shows fishing mortality relative to the one that can produce the maximum sustainable yield. F_{msy} is referred to as an upper limit reference point in UNFSA (1995). MSFD (2008), Descriptors 3 in COM (2010) and the on-going CFP reform require $F <= F_{msy}$, which, in agreement with UNFSA (1995), can be interpreted as F not being allowed to exceed F_{msy}. Targets of F as 90% or 75% of F_{msy} have been proposed for regular and for forage fish, respectively, allowing stocks to fluctuate above SSB_{msy} (Froese et al. 2011). Note that for compatibility with the other scores, the ratio has been set such that $F < F_{msy}$ gives a score larger than 1.0.

***M / F*:** This pressure indicator is available for all fully assessed stocks in the ICES area, showing fishing mortality relative to natural mortality. It builds on a long held and widely agreed consensus in fisheries management that safe and sustainable fishing rates may not exceed the rate of natural mortality (e.g. Gulland 1971, Shepherd 1981, Beddington and Cooke 1983, Clark et al. 1985, Beverton 1990, Patterson 1992, Thompson 1993, Walters and Martell 2004, MacCall 2009), i.e., the fishery shall not cause more mortality than all other causes (predation, diseases, natural hazards, old age) combined. A recent study on forage fish (Pikitch et al. 2012) suggests that fishing mortality of regular fish should not exceed 75% of M and for fish like sandeel, sprat or herring, which are the main prey of a wide range of predators, fishing mortality should not exceed 50% of natural mortality. Note that for compatibility with the other scores, the ratio has been set such that $F < M$ gives a score larger than 1.0.

(2 *M*) / *Z*: This is a pressure indicator which is available for most stocks. It shows observed total mortality *Z* relative to natural mortality *M*. *Z* is a proxy for *F* for stocks for which no estimate of fishing mortality is available. Estimates of total mortality *Z* can be obtained from the decline in numbers-at-age in subsequent years in survey data. To avoid the bias in large fish numbers described above, *Z* is calculated for only three years subsequent to the length where fish are fully retained by the survey gear. The same reasoning as for the *M* / *F* indicator applies, only that *M* is multiplied by a factor of two because $Z = F + M$ and if $F = M$ then $Z = 2\,M$. A score above 1.0 then indicates that fishing mortality *F* does not exceed natural mortality *M*. This indicator is only used for data-limited stocks.

(2 M) / (*u*+*M*): This another pressure indicator based on the ratio *u* between commercial catches and mean abundance indices in a given year. There is no immediate reference point available for this *u*, the value of which depends on the vulnerability of the respective species to the survey gears. Here, *u* was related to *Z* in a two-step process: first, the range of *u*-values was adjusted to the range of *Z*-values such that max *u* became equal to max *Z*. Then, for all years with estimates of *u* and *Z*, the u-curve was shifted vertically until the squared residuals of *Z-u* were minimized. By this procedure, *u* was rescaled to *Z* and then the same reference points became applicable. Since the rescaled *u* was typically available for more years than *Z*, the ratio (2 M) / (*u*+*M*) was used for calculating the scores.

L_{mean} / L_{m90}: This is a pressure indicator available for all fully assessed stocks. It indicates the length class that is most heavily targeted by commercial fishing L_{mean} relative to the size when 90% of the females reach maturity L_{m90}. It has been formally shown that the risk of overfishing can be drastically reduced if all fish have a chance to reproduce before being caught (Myers and Mertz 1998). If a direct estimate of L_{m90} was not available, a multiplier of 1.2 was used on the more common length class L_{m50}, where 50% of the females have reached maturity. A score above 1.0 indicates that most females had a chance to reproduce at least once before being caught. The optimum landing length L_{opt} can serve as a target for L_{mean}. At the optimum landing length a given catch takes the lowest proportion of cohort biomass per length class (see Figure 3) and thus allows the stock to achieve a size and age distribution indicative of a healthy population with good resilience against anthropogenic or environmental disturbances.

$LFIS$ / $LFIS_{F=M}$: This is a state indicator available for all fully assessed stocks, giving the ratio of the observed total weight of fishes with lengths above 2/3 L_{inf} in survey data to the expected value if $F = M$. It relates to the proportion of old fish in the population, as required by Descriptors 1 and 3 of COM (2010). This indicator is based on biomass rather than number of individuals and therefore is less sensitive to fluctuations in first-time spawners, because these fish still have much lower body weight than large fish. A score above 1.0 indicates that the population has a proportion of large and old individuals that is better than the theoretical proportion that would be expected if fishing mortality was equal to natural mortality, i.e., the proportion of old fish biomass is indicative of a healthy size and age distribution.

CPUE by area: This is a state indicator, giving the annual abundance in numbers in survey catches per hour of trawling per area. For the purpose of this study we used ICES roundfish area 6 to reflect abundance in the German EEZ in the North Sea and ICES Sub-divisions 22 and 24 to reflect abundance in the western Baltic. No life history reference point is available for CPUE, and thus we present the time series for CPUE in numbers as graph with indication of the overall mean. We indicate the raw annual CPUE data and a moving average over three years, to deal with uncertainty in survey indices (ICES 2012), smooth the data and facilitate detection of trends. Since all stocks considered here have been overexploited in the past, recent CPUE values should fall above the overall mean to indicate a positive state. In cases where state indicators suggest stock sizes below SSB_{msy}, CPUE trends should be increasing. In cases where stock size is above SSB_{msy}, CPUE trends should be above the mean and more or less horizontal.

A key question is how well the indicators and reference points for data-limited stocks capture the true status of and pressure on these stocks. For this purpose, we compared scores suggested by the data-limited methods with scores based on full assessments. In Table 1, mean scores over the last 5 years for stock size and fishing pressure are compared. For spawning stock size, most scores based on proxies deviate little from the scores derived from full assessments. If we assume arbitrary 95% confidence limits around the biomass estimates of +/- 30%, then the proxy-based estimates are not significantly different, except for Baltic herring (her-3a22), where the proxy based biomass is significantly lower. Applying the same logic to fishing pressure, significant differences are only found for North Sea herring and North Sea plaice. In summary, biomass estimates were not significantly for 7 of 8 stocks (87%) and fishing pressure estimates were not significantly different in 6 of 8 (75%) of the stocks.

Table 1. Comparison of scores for stock size and fishing mortality, using averages over the last 5 years, between full assessments (SSB / $pSSB_{msy}$, M / F) and preliminary assessments based on survey data and life history parameters ($proxySSB$ / $proxySSB_{msy}$, 2M / Z).

Species	Stock	NS / BS	SSB / $pSSB_{msy}$	$proxySSB$ / $proxySSB_{msy}$	M / F	$2M$ / Z
Cod	cod-347d*	NS	0.15	0.12	0.43	0.49
	cod-2224*	BS	0.41	0.47	0.36	0.39
	cod-2532*	BS	0.26	0.40	0.68	0.87
Herring	her-47d3*	NS	0.71	1.34	3.47	0.87
	her-3a22*	BS	0.54	0.12	0.62	0.65
Plaice	ple-nsea*	NS	0.87	1.16	0.43	1.30
Sole	sol-nsea*	NS	0.44	0.26	0.28	0.51
Sprat	spr-2232*	BS	0.92	0.54	1.06	1.69

Results of preliminary stock status assessments

For the stocks listed in Table 2, full assessment details are given in Appendix I. A summary of the obtained scores is provided in Table 3. A detailed description of the life history parameters and the methods used to derive the indicators and reference points is given in Appendix II.

Table 2. English, German and scientific names of species and delineation and ICES identification code of stocks evaluated in this report. Stocks with full assessments (= time series data on *SSB* and *F* are available) are marked with an asterisk (*) in the last column.

English name	German name	Scientific name	Stock	ICES ID
Cod	Kabeljau	*Gadus morhua*	North Sea, Sub-area IV, Divison VIId & Division IIIa (Skagerrak)	cod-347d*
	Dorsch		Baltic Sea, Sub-divisions 22 to 24	cod-2224*
	Dorsch		Baltic Sea, Sub-divisions 25-32	cod-2532*
Dab	Kliesche	*Limanda limanda*	North Sea, Subarea IV and Division IIIa	dab-nsea
			Baltic Sea, Subdivisions 22–32	dab-2232
Dogfish/Spurdog	Dornhai	*Squalus acanthias*	Northeast Atlantic	spurdog
European eel	Aal	*Anguilla anguilla*	Northeast Atlantic	eel-eur
Flounder	Flunder	*Platichthys flesus*	North Sea, Division IIIa and Subarea IV	fle-nsea
			Baltic Sea, Subdivisions 22–32	fle-2232
Herring	Hering	*Clupea harengus*	North Sea, Sub-area IV, Divisions VIId & IIIa (autumn-spawners)	her-47d3*
			Baltic Sea, Sub-divisions 22-24 and Division IIIa (spring-spawners)	her-3a22*
Norway lobster	Kaisergranat	*Nephrops norvegicus*	North Sea, subarea IV	nep-IV
Plaice	Scholle	*Pleuronectes platessa*	North Sea, Sub-area IV	ple-nsea*
			Baltic, Kattegat, Belt and Sounds, subdivisions 21-23	ple-2123
			Baltic, subdivisions 24-32	ple-2432
Sole	Seezunge	*Solea solea*	North Sea, Sub-area IV	sol-nsea*
Sprat	Sprotte	*Sprattus sprattus*	North Sea, Sub-area IV	spr-nsea
			Baltic Sea, Sub-divisions 22-32	spr-2232*
Turbot	Steinbutt	*Scophthalmus maximus*	North Sea, Subarea IV and Division IIIa	tur-nsea
			Baltic Sea, Subdivisions 22-32	tur-2232

Table 3. Overview of scores obtained by the examined North Sea (NS) or Baltic (BS) stocks. An asterisk in the Stock column indicates a fully assessed stock. Note that for data-limited stocks, i.e. those without an asterisk, proxy-assessments were used and average values over recent 5 years (2007-2011) are shown. A dash means that the analysis was not applicable to data-limited stocks. NA means that not enough data were available for the analysis. See Appendix I and II for details of stock assessments. Scores above 1.0 indicate sustainable pressure or healthy stock status and are highlighted in green. Scores below 1.0 are highlighted in red. For the abundance in the German EEZ, the last column indicates whether abundance in the last 5 years was above or below the long-term mean and whether the trend in abundance was increasing, decreasing, or horizontal. See text for definition of other column headings.

Species	**Stock**	**NS / BS**	SSB / SSB_{msy}	F_{msy} / F	M / F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS / LFIS_{F=M}$	EEZ Abundance Mean	Slope
Cod	cod-347d*	NS	0.19	0.33	0.45	0.90	0.64	0.43	below	horizontal
	cod-2224*	BS	0.46	0.60	0.48	1.32	0.57	0.03	above	increasing
	cod-2532*	BS	0.33	1.05	0.84	1.08	0.60	0.25	above	increasing
Dab	dab-nsea	NS	1.01	-	0.77	-	-	-	below	decreasing
	dab-2232	BS	0.60	-	0.66	-	-	-	above	decreasing
Dogfish	spurdog	NS	0.12	-	NA	-	-	-	below	horizontal
Eel	eel-eur	NS&BS	0.20	-	NA	-	-	-	below	decreasing
Flounder	fle-nsea	NS	0.53	-	1.00	-	-	-	above	decreasing
	fle-2232	BS	0.80	-	1.13	-	-	-	above	horizontal
Herring	her-47d3*	NS	0.90	2.69	3.76	0.84	0.85	1.20	above	horizontal
	her-3a22*	BS	0.49	1.24	0.99	0.84	0.96	0.61	below	decreasing
Norway lobster	nep-IV	NS	0.42	-	1.92	-	-	-	above	decreasing
Plaice	ple-nsea*	NS	1.04	1.09	0.44	0.95	0.68	0.64	above	increasing
	ple-2123	BS	0.41		1.15	-	-	-	above	increasing
	ple-2432	BS	0.46		NA	-	-	-	above	increasing
Sole	sol-nsea*	NS	0.50	0.74	0.34	1.17	0.87	0.48	below	increasing
Sprat	spr-nsea	NS	0.92	-	NA	-	-	-	above	horizontal
	spr-2232*	BS	0.79	1.22	1.32	1.01	1.02	1.78	below	decreasing
Turbot	tur-nsea	NS	0.42	-	0.54	-	-	-	above	horizontal
	tur-2232	BS	0.58	-	NA	-	-	-	above	horizontal

Discussion of preliminary results

Table 3 shows a preliminary assessment of 20 stocks whose area of distribution overlaps with the German EEZ in the North Sea or in the Baltic Sea. With the exception of North Sea plaice and North Sea dab, all stock sizes are still below the (proxy) level that can produce *MSY*. Dogfish, North Sea cod, and eel are the most depleted stocks. North Sea sprat and North Sea herring are closest to reaching the *MSY* level in stock size.

With regard to fishing pressure, six stocks have fishing mortality rates *F* below the rate of natural mortality *M*, i.e., they will be able to increase in stock size toward the *MSY* level. In contrast, six stocks are still subject to high fishing mortality rates that prevent them from recovering. North Sea cod and Western Baltic cod suffer from the most severe overfishing relative to F_{msy}. No formal assessment of fishing pressure was possible for five stocks, although dogfish and eel are highly likely to suffer from ongoing overfishing at $F > M$.

Analysis of the mean length targeted by fishing gears relative to the length where 90% of the females have reached maturity is only possible for fully assessed stocks, where data about catch-at-age could be turned into catch-at-length. The preliminary analysis shows that in half of these stocks, fish are targeted before they had a chance to reproduce. Note that this assessment may be too positive, because in cod and plaice the length at first maturity seems to have decreased as a result of fisheries-induced selection for early maturity. Evidence of such decrease would result in a negative score under the MSFD (COM 2010).

Mean length in commercial catches relative to the length where cohort biomass is maximum and fishing impact minimum is only available for fully assessed stocks. Since this is a target reference point around which stocks are expected to fluctuate, scores above 0.8 are marked green in Table 2 and no scores are marked red. A preliminary analysis shows that in addition to sole, especially small pelagic fishes such as herring and sprat are fished close to the optimum length. In contrast, cod and plaice are still targeted at much too small sizes.

The proportion of large fish in spawning biomass is also only available for fully assessed stocks. The preliminary results suggest that, except for North Sea herring and Baltic sprat, biomass of large fish is still too small compared with the proportion expected from fishing with $F = M$ and start of fishing in the year after 50% maturity is achieved.

The analysis of abundance trends in the German EEZ shows a mixed picture. Seven stocks have current (mean of last 5 years) abundances below the long-term average and in only two of these stocks abundance is increasing. Of the 13 stocks with recent abundances above the long-term average, three show decreasing trends.

Overall, while there are signs of improvement, stock size and age structure in most stocks in the German EEZ are still unsatisfactory and require a fast decrease in fishing mortality and an increase in mean length at first capture.

Availability of data, spread sheets and R-code

The data, spreadsheets and R-code used in this study are available for download as indicated in Table 4.

Table 4. The files in this table can be downloaded from http://oceanrep.geomar.de/22079/

File name	Content
AnguillaAll.csv	DATRAS CPUE-per-length-per-area data for eel, all areas
cod-2532_2013_SR.csv	Stock-recruitment data for eastern Baltic cod
CPUE_Area_24.r	R-code for analysis of CPUE-per-length-per-area DATRAS data and creation of respective graphs
CPUE_Area_22_24_cod-balt_-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for western Baltic cod
CPUE_Area_25-29_EB-cod-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for eastern Baltic cod
CPUE_Area1-7_2012_1Q_StdSp.csv	DATRAS CPUE-per-length-per-area data for the North Sea standard species, first quarter surveys
CPUE_Area_dab_balt_-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for Baltic dab
CPUE_Area_dab_nsea-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for North Sea dab
CPUE_Area_fle-balt-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for Baltic flounder
CPUE_Area_fle_nsea-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for North Sea flounder
CPUE_Area_her-balt-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for Baltic herring
CPUE_Area_neph-nsea-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for North Sea nephrops
CPUE_Area_ple-balt-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for Baltic plaice
CPUE_Area_NS-turbot-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for North Sea turbot
CPUE_spr-balt-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for Baltic sprat
CPUE_sol-nsea-2012_1Q.csv	DATRAS CPUE-per-length-per-area data for North Sea sole
CPUE_tur-balt-2012_All.csv	DATRAS CPUE-per-length-per-area data for Baltic turbot
dab_nsea_2000-12.csv	DATRAS SMALK data for standard North Sea dab
FishDataLim.csv	Time series data of fish catch/landings
her-47d3_2000-12_3Q.csv	DATRAS SMALK data for North Sea herring
her_balt_2000-12_1Q.csv	DATRAS SMALK data for Baltic herring
NMS_Concept_5.xlsx	Simulated data behind Figures 1-3
NMS_Germany_Stocks_9.xlsx	Data, analysis and graphs for stocks with full assessments
ple_nsea_2000_12_1Q.csv	DATRAS SMALK data for North Sea plaice
Smalk_Analysis_25.r	R-code for analysis of length-weight, growth and maturity
SMALK_BITS_StdSp-2012_1Q.csv	DATRAS SMALK data for Baltic standard species
SMALK_dab_balt_2000-12_1Q.csv	DATRAS SMALK data for Baltic dab
SMALK_fle-nsea_2000-12_1Q.csv	DATRAS SMALK data for North Sea flounder
SMALK_NS_00-12_1Q_StdSp.csv	DATRAS SMALK data for standard North Sea species
SpurdogAll.csv	DATRAS CPUE-per-length-per-area data for spurdog, all areas
sol_nsea_2000-12.csv	DATRAS SMALK data for standard North Sea sole
spr-balt_2000-12_All.csv	DATRAS SMALK data for Baltic sprat
spr_nsea_2000_12_1Q.csv	DATRAS SMALK data for North Sea sprat
sr_1.r	R-code to fit a rule-based hockey stick to S-R data
tur-balt_2000-12_All.csv	DATRAS SMALK data for Baltic turbot
tur-nsea_2000-12_All.csv	DATRAS SMALK data for North Sea turbot

Acknowledgement

We acknowledge support from the German Agency for Nature Conservation (BfN) under the project "Ökosystemgerechtes Fischereimanagement in der deutschen ausschließlichen Wirtschaftszone (AWZ)." This is FIN Contribution Number 139.

References

Beverton, R. 1990. Small marine pelagic fish and the threat of fishing; are they endangered? Journal of Fish Biology 37 (Suppl. A):5-16.

Beddington, J.R. and J. Cooke. 1983. The potential yield of previously unexploited stocks. FAO Fisheries Technical Paper 242. Food and Agriculture Organization of the United Nations, Rome.

BMU, 2010. Indikatorenbericht 2010 zur Nationalen Strategie zur biologischen Vielfalt. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU). Berlin, 88 p.

Clark, C.W., A.T. Charles, J.R. Beddington and M. Mangel. 1985. Optimal capacity decisions in a developing fishery. Marine Resource Economics 2:25-54.

COM, 2010. Commission Decision of 1 September 2010 on criteria and methodology standards on good environmental status of marine waters. Official Journal of the European Union L232/14-24.

Froese, R., T.A. Branch, A. Proelß, M. Quaas, K. Sainsbury and C. Zimmermann. 2011. Generic harvest control rules for European fisheries. Fish and Fisheries 12:340-351.

Gulland, J.A. 1971. Preface. The fisheries resources of the ocean. London: Fishing News.

ICES, 2010. Manual for the International Bottom Trawl Surveys. ICES, Copenhagen, 69 p.

ICES, 2012a. ICES implementation of advice for data-limited stocks in 2012 in its 2012 advice. ICES DLS Guidance Report 2012. ICES CM 2012/ACOM 68. 42 p.

ICES, 2012b. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April - 3 May 2012, ICES Headquarters, Copenhagen. ICES CM 2012/ACOM: 13: 1346 pp. Downloaded in April 2013 from http://www.ices.dk/publications/library/Pages/default.aspx#k=wgnssk.

ICES, 2013. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53:820-822.

MacCall, A.D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. ICES Journal of Marine Science 66:2267-2271.

MSFD, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L 164/19-39.

Myers, R.A. and G. Mertz, 1998. The limits of exploitation: a precautionary approach. Ecological Applications 8(1):5165-5169.

Patterson, K. 1992. Fisheries for small pelagic species: an empirical approach to management targets Reviews in Fish Biology and Fisheries 2(4): 321–338.

Pikitch, E., P.D. Boersma, I.L. Boyd, D.O. Conover, P. Cury, T. Essington, S.S. Heppell, E.D. Houde, M. Mangel, D. Pauly, É. Plagányi, K. Sainsbury and R.S. Steneck. 2012. Little fish, big impact: managing a crucial link in ocean food webs. Lenfest Ocean Program. Washington, DC. 108 pp.

Sheperd, J.G. 1981. Cautious management of marine resources. Math. Biosci. 55:179-181.

Thompson, G.G. 1993. A proposal for a threshold stock size and maximum fishing mortality rate. p. 303-320. In S.J. Smith, J.J. Hunt, and D. Rivard (eds.) Risk evaluation and biological reference points for fisheries management. Canadian Special Publication of Fisheries and Aquatic Sciences 120, 442 p.

UNCLOS, 1982. United Nations Convention on the Law of the Sea. 1833 UNTS 3. Downloaded in April 2011 from http://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf.

UNFSA, 1995. Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982, relating to the conservation and management of straddling fish stocks and highly migratory fish stocks. 2167 UNTS 88. Downloaded in April 2011 from http://www.un.org/Depts/los/convention_agreements/texts/fish_stocks_agreement/ CONF164_37.htm

Walters C.J. and S.J.D. Martell. 2002. Stock assessment needs for sustainable fisheries management. Bulletin of marine science. 70(2): 629.

Walters C.J. and S.J.D. Martell. 2004. Fisheries ecology and management. Princeton: UK Princeton University Press.

Appendix I: Indicators and Reference Points for Selected Stocks in the German EEZ

Species: Cod, Kabeljau, *Gadus morhua*

Stock: North Sea (cod-347d), Sub-area IV, Division VIId & Division IIIa (Skagerrak), fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 0.19, F_{msy}/F 0.33, M/F 0.45, L_{mean}/L_{m90} 0.90, $LFIS/LFIS_{F=M}$ 0.43

EEZ below mean, EEZ slope horizontal

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Ref.	Comment
M (1/year)	0.26				ICES 2012a	
F_{msy} (1/year)	0.19				ICES 2012a	
SSB_{pa} (t)	150,000				ICES 2012a	
SSB_{msy}Trigger (t)	150,000				ICES 2012a	
$pSSB_{msy}$ (t)	300,000				ICES 2012a	This study
Length range (cm)	9 - 123				ICES 2013b	This study
a	0.00587	0.00575 – 0.00598	6,755	0.995	ICES 2013b	log sd=0.058
b	3.14	3.13 – 3.14			ICES 2013b	This study
L_∞ (cm)	116		6,713		ICES 2013b	This study
K (1/year)	0.208	0.205 – 0.211			ICES 2013b	This study
t_0 (years)	0.18	0.16 – 0.2			ICES 2013b	This study
L_{m50} (cm)	37.8		2,131		ICES 2013b	This study
L_{m90} (cm)	58.6				ICES 2013b	This study
L_{opt} (cm)	81.9				ICES 2013b	This study
$L_{0.66}$ (cm)	77.3				ICES 2013b	This study
t_{m50} (years)	2.1				ICES 2013b	This study
$t_{0.66}$ (years)	5.5				ICES 2013b	This study
$LFIS_{F=M}$	0.41				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*) (ICES 2012b), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	*SSB*	*F*	L_{mean}	*LFIS*	*SSB* / pSSB_{msy}	F_{msy}/F	*M/F*	L_{mean} / L_{m90}	L_{mean} / L_{opt}	*LFIS* / $LFIS_{F=M}$
2000	49,662	1.00	45.6	0.13	0.17	0.19	0.26	0.78	0.56	0.31
2001	41,731	0.96	44.5	0.09	0.14	0.20	0.27	0.76	0.54	0.22
2002	42,574	0.93	49.4	0.07	0.14	0.21	0.28	0.84	0.60	0.16
2003	36,901	0.90	46.4	0.08	0.12	0.21	0.29	0.79	0.57	0.19
2004	31,984	0.86	47.5	0.08	0.11	0.22	0.30	0.81	0.58	0.20
2005	29,762	0.80	47.5	0.19	0.10	0.24	0.33	0.81	0.58	0.46
2006	26,239	0.72	41.9	0.12	0.09	0.26	0.36	0.71	0.51	0.29
2007	32,827	0.67	46.0	0.11	0.11	0.28	0.39	0.78	0.56	0.26
2008	38,254	0.63	51.4	0.07	0.13	0.30	0.41	0.88	0.63	0.17
2009	47,193	0.60	53.2	0.10	0.16	0.32	0.43	0.91	0.65	0.23
2010	51,792	0.58	52.7	0.09	0.17	0.33	0.45	0.90	0.64	0.22
2011	56,331	0.57	52.7	0.18	0.19	0.33	0.45	0.90	0.64	0.43

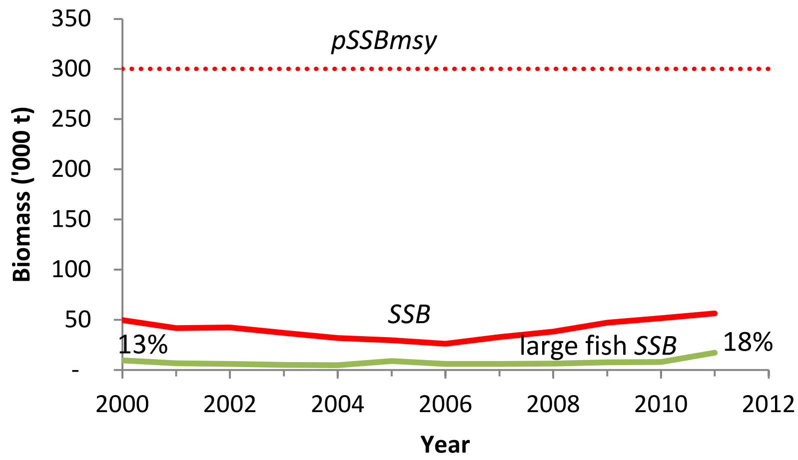

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield (*$pSSB_{msy}$*). The green line shows the biomass of large fish, representing 13% of *SSB* in 2000 and 18% in 2011. [NMS_Germany_Stocks_9.xlsx]

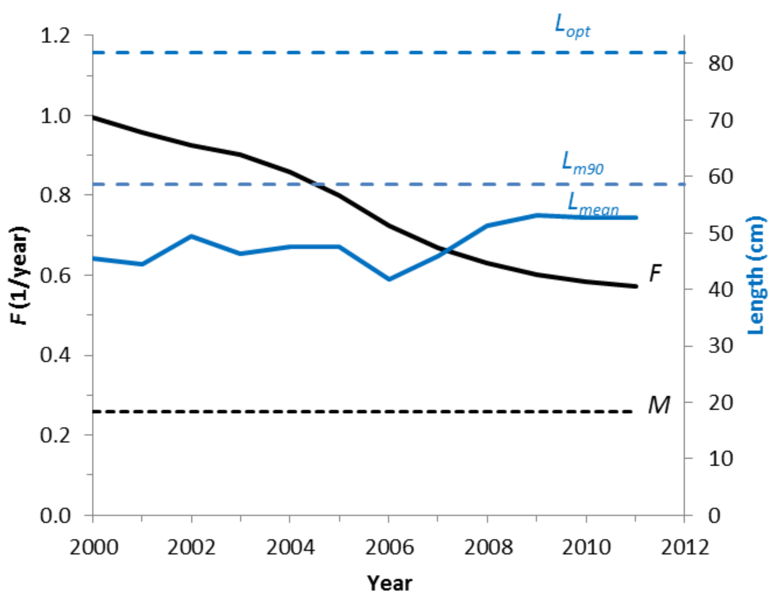

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches L_{mean}, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

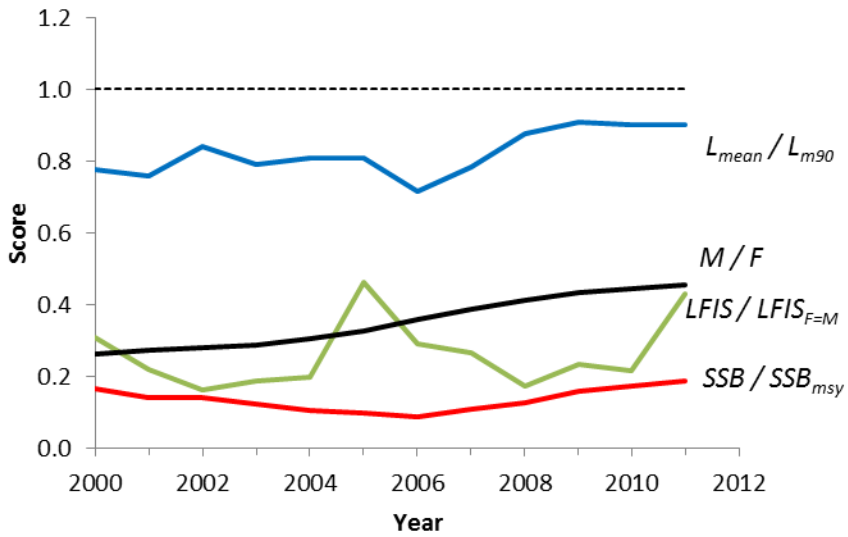

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

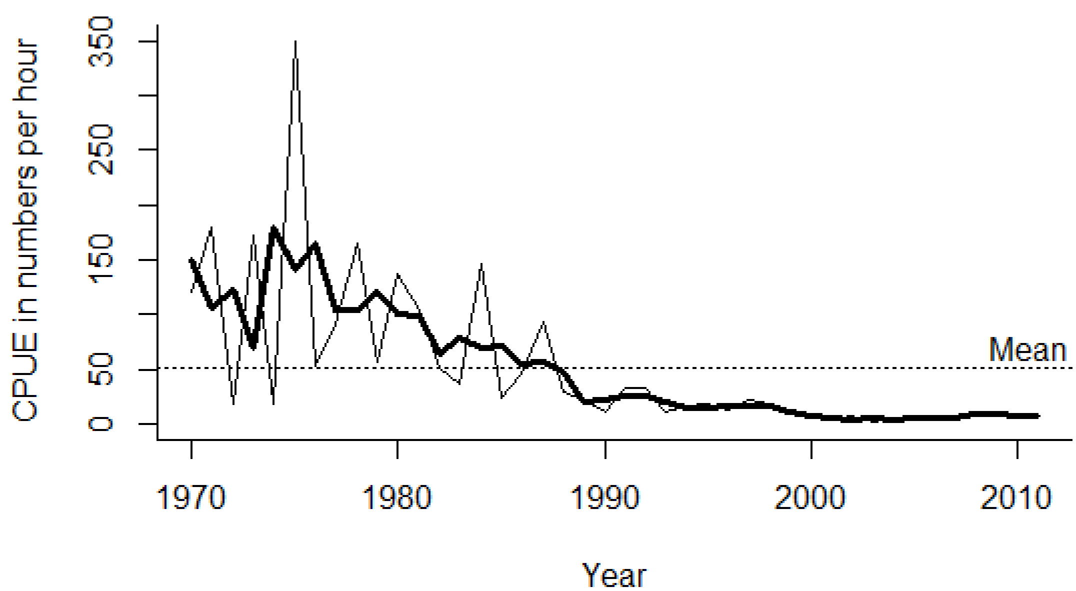

Figure 4. German EEZ abundance graph: Time series of average catch in one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. [CPUE_Area_24.r]

References

ICES, 2012a. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April - 3 May 2012, ICES Headquarters, Copenhagen. Downloaded in April 2013 from http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2012/WGNSSK/WGNSSK%202012.pdf

ICES, 2012b. Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak). http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/cod-347.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Cod, Dorsch, *Gadus morhua*

Stock: Western Baltic Sea (cod-2224), Sub-Division 22 & 24, fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 0.46, F_{msy}/F 0.60, M/F 0.48, L_{mean}/L_{m90} 1.32, $LFIS/LFIS_{F=M}$ 0.03

EEZ above mean, EEZ slope increasing

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.2				ICES 2012	
F_{msy} (1/year)	0.25				ICES 2012	
SSB_{pa} (t)	36,400				ICES 2013a	
SSB_{msy}Trigger (t)	36,400				ICES 2013a	
$pSSB_{msy}$ (t)	72,800				ICES 2013a	This study
Length range (cm)	5 - 119					This study
a	0.00669	0.00661 – 0.00677	19,139	0.994	ICES 2013b	log sd = 0.049
b	3.1	3.10 – 3.11			ICES 2013b	This study
L_∞ (cm)	119		19,040		ICES 2013b	This study
K (1/year)	0.15	0.147 – 0.150			ICES 2013b	This study
t_0 (years)	-0.16	-0.17 - -0.14			ICES 2013b	This study
L_{m50} (cm)	29		4,410		ICES 2013b	This study
L_{m90} (cm)	35.6				ICES 2013b	This study
L_{opt} (cm)	82.0				ICES 2013b	This study
$L_{0.66}$ (cm)	79.3				ICES 2013b	This study
t_{m50} (years)	1.7				ICES 2013b	This study
$t_{0.66}$ (years)	7.3				ICES 2013b	This study
$LFIS_{F=M}$	0.41				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	26,930	1.22	43.1	0.01	0.37	0.20	0.16	1.21	0.53	0.01
2001	30,303	1.24	43.9	0.01	0.42	0.20	0.16	1.23	0.54	0.01
2002	23,933	1.20	45.3	0.00	0.33	0.21	0.17	1.27	0.55	0.00
2003	27,337	1.02	43.7	0.01	0.38	0.25	0.20	1.23	0.53	0.01
2004	26,503	1.09	45.2	0.01	0.36	0.23	0.18	1.27	0.55	0.01
2005	23,790	1.06	43.6	0.01	0.33	0.24	0.19	1.22	0.53	0.01
2006	30,884	0.74	45.8	0.01	0.42	0.34	0.27	1.29	0.56	0.01
2007	35,454	0.71	46.6	0.01	0.49	0.35	0.28	1.31	0.57	0.01
2008	23,086	0.73	48.1	0.04	0.32	0.34	0.28	1.35	0.59	0.04
2009	28,339	0.60	46.0	0.04	0.39	0.41	0.33	1.29	0.56	0.04
2010	30,001	0.44	45.7	0.03	0.41	0.56	0.45	1.28	0.56	0.03
2011	33,523	0.42	46.9	0.03	0.46	0.60	0.48	1.32	0.57	0.03

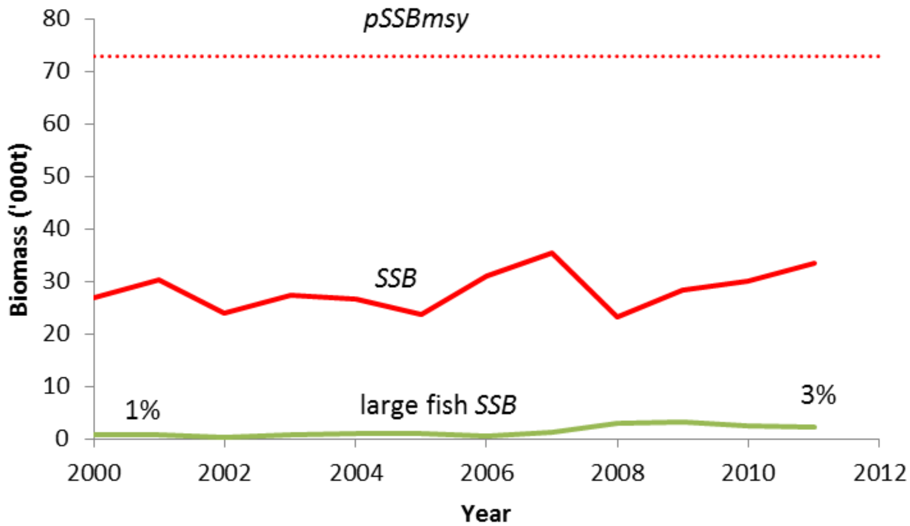

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield (*$pSSB_{msy}$*). The green line shows the biomass of large fish, representing 1% of *SSB* in 2000 and 3% in 2011. [NMS_Germany_Stocks_9.xlsx]

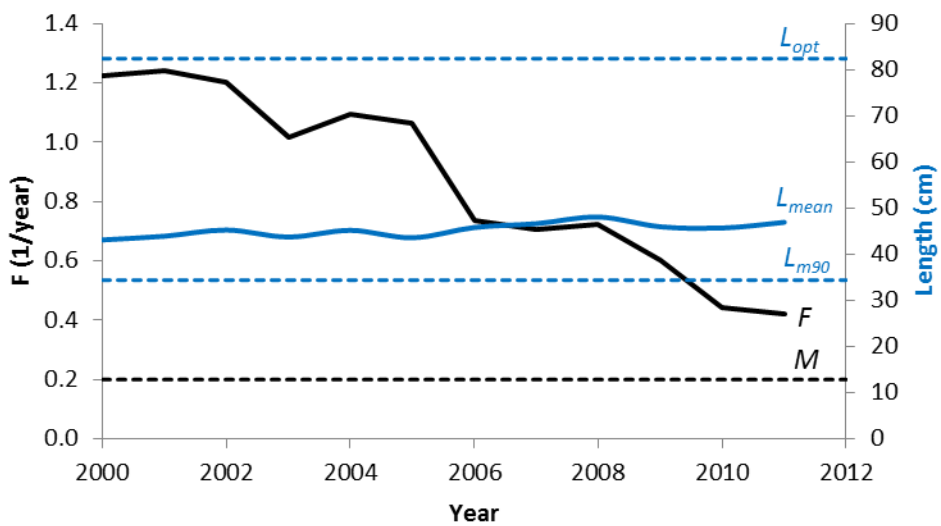

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches L_{mean}, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

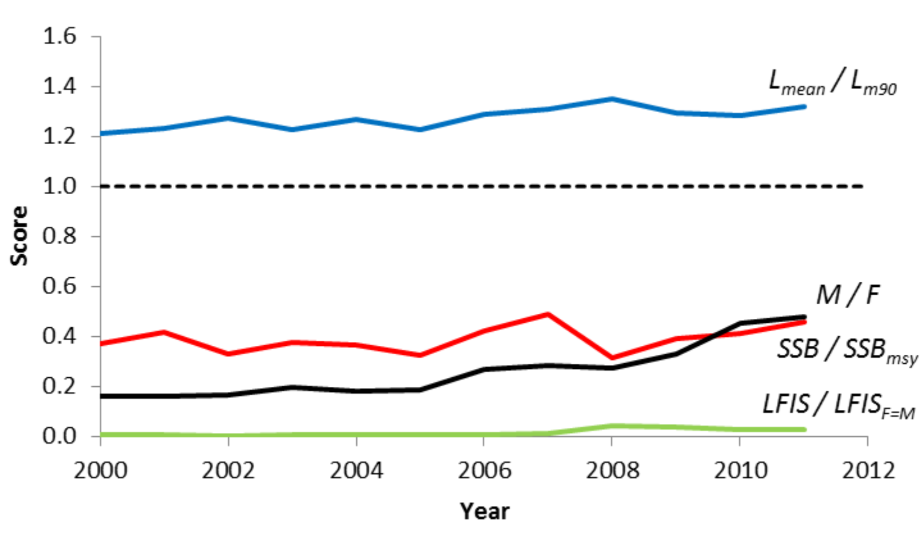

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

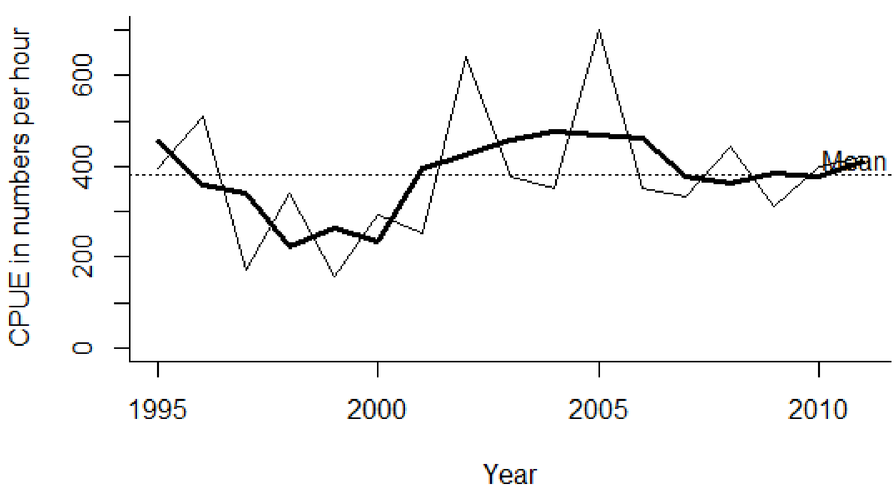

Figure 4. German EEZ abundance graph, here ICES Subdivision 22 & 24, including the German EEZ in the Baltic. The thin line shows the time series of average catch in numbers resulting from one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. The dotted line shows the mean of the time series. [CPUE_Area_24.r]

References

ICES, 2012. Cod in Subdivisions 22-24, Advice May 2012. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/cod-2224.pdf

ICES, 2013a. Cod in Subdivisions 22-24, Advice May 2013. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/cod-2224_201304100002.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx

Species: Cod, Dorsch, *Gadus morhua*

Stock: Eastern Baltic Sea (cod-2532), Sub-Division 25-32, fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 0.33, F_{msy}/F 1.05, M/F 0.84, L_{mean}/L_{m90} 1.08, $LFIS/LFIS_{F=M}$ 0.25

EEZ above mean, EEZ slope increasing

Table 1. Parameters, reference points, methods and data sources used for this stock. Note that $pSSB_{msy}$ was estimated anew from stock recruitment data, since SSB_{pa} as estimated by ICES appeared incorrect (see Fig. 1). Also, F_{msy} = 0.46 as used by ICES is higher than that of its main prey (sprat and herring), which is ecologically impossible. Therefore, F_{msy} = 0.25 from the western Baltic cod stock was used. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r_2	Data Ref.	Comment
M (1/year)	0.2				ICES 2012	
F_{msy} (1/year)	0.25 (0.46)				ICES 2012	
SSB_{pa} (t)	322,868 (88,200)				ICES 2012	
SSB_{msy}Trigger (t)	(88,200)				ICES 2012	
$pSSB_{msy}$ (t)	645,736				ICES 2013a	This study
L range (cm)	5 - 121					
a	0.00743	0.00737 – 0.00749	52,546	0.993	ICES 2013b	log sd=0.056
b	3.06	3.06 – 3.07			ICES 2013b	This study
L_∞ (cm)	115				ICES 2013b	This study
K (1/year)	0.114	0.0113 – 0.0114	51,927		ICES 2013b	This study
t_0 (years)	-0.08	-0.09 - -0.07			ICES 2013b	This study
L_{m50} (cm)	32.2		15,020		ICES 2013b	This study
L_{m90} (cm)	40.7				ICES 2013b	This study
L_{opt} (cm)	71.6				ICES 2013b	This study
$L_{0.66}$ (cm)	76.7				ICES 2013b	This study
t_{m50} (years)	2.8				ICES 2013b	This study
$t_{0.66}$ (years)	9.6				ICES 2013b	This study
$LFIS_{F=M}$	0.24				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	115,928	0.77	44.0	0.04	0.18	0.33	0.26	1.08	0.61	0.17
2001	104,229	0.88	43.9	0.01	0.16	0.29	0.23	1.08	0.61	0.06
2002	83,094	0.82	44.9	0.03	0.13	0.31	0.25	1.10	0.62	0.12
2003	80,394	0.89	44.4	0.02	0.12	0.28	0.23	1.09	0.61	0.07
2004	79,488	0.85	46.3	0.02	0.12	0.29	0.23	1.14	0.64	0.10
2005	65,577	0.84	46.4	0.02	0.10	0.30	0.24	1.14	0.64	0.07
2006	83,503	0.78	44.5	0.01	0.13	0.32	0.25	1.09	0.61	0.06
2007	101,652	0.50	45.0	0.02	0.16	0.50	0.40	1.11	0.62	0.06
2008	119,417	0.35	45.6	0.03	0.18	0.71	0.57	1.12	0.63	0.12
2009	184,040	0.26	45.5	0.04	0.29	0.96	0.77	1.12	0.63	0.15
2010	208,152	0.24	45.9	0.06	0.32	1.04	0.83	1.13	0.63	0.26
2011	211,344	0.24	43.9	0.06	0.33	1.05	0.84	1.08	0.60	0.25

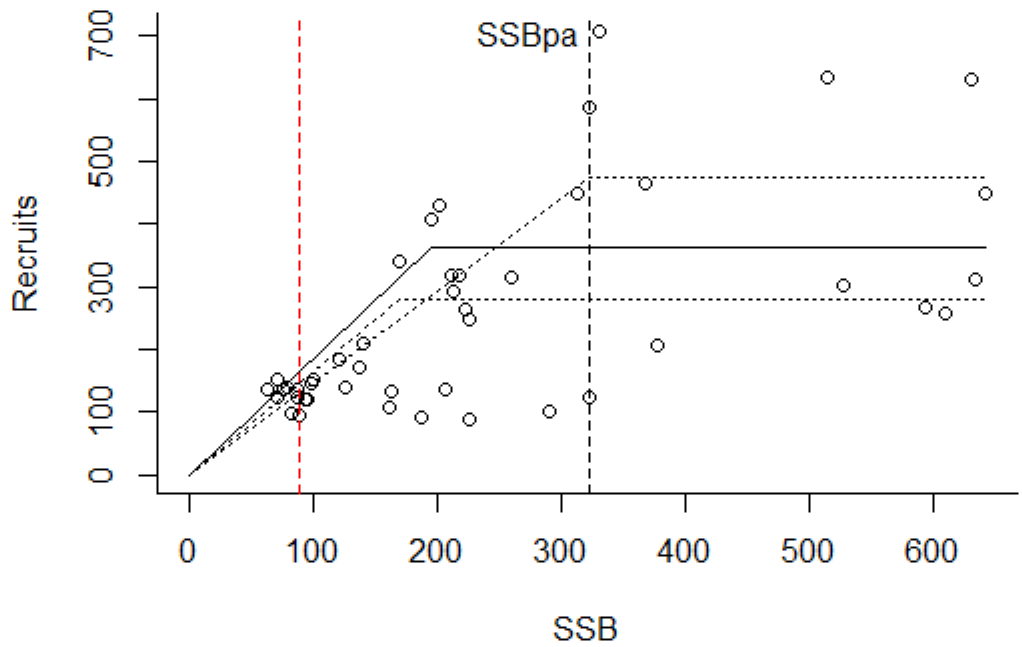

Figure 1. New analysis of stock-recruitment data, as the ICES (2012, 2013b) estimate of SSB_{pa}=88,200 tonnes (red vertical line) does not seem to represent correctly the biomass below which recruitment is reduced. The bold hockey-stick represents the new stock-recruitment relationship. The dotted horizontal lines indicate the 95% confidence limits of recruitment at large stock sizes. The black vertical dashed line indicates the new estimate of SSB_{pa}=322,868 tonnes below which recruitment may be reduced. [SR_1.r]

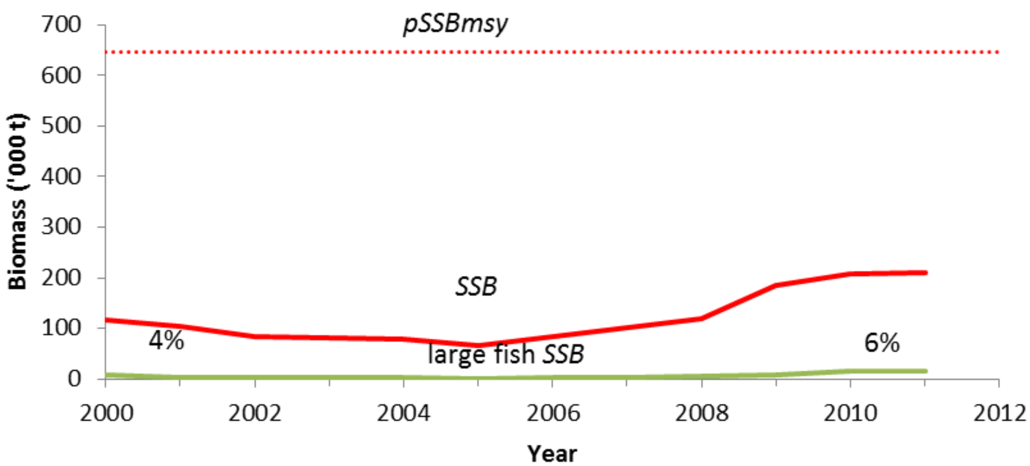

Figure 2: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield ($pSSB_{msy}$). Note that here $pSSB_{msy}$ was derived anew from stock-recruitment data as ICES' estimate of SSB_{pa} appeared incorrect. The green line shows the biomass of large fish, representing 4% of *SSB* in 2000 and 6% in 2011. [NMS_Germany_Stocks_9.xlsx]

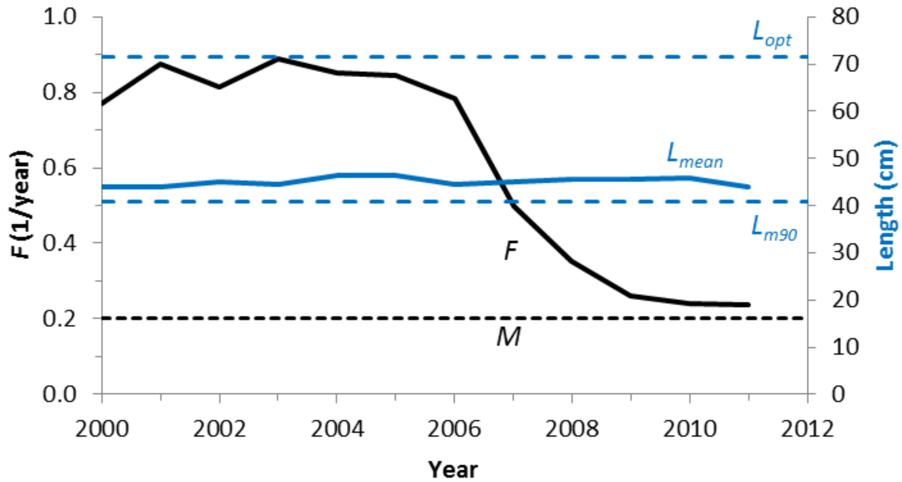

Figure 3. Pressure graph: Fishing mortality *F* and mean length in commercial catches L_{mean}, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

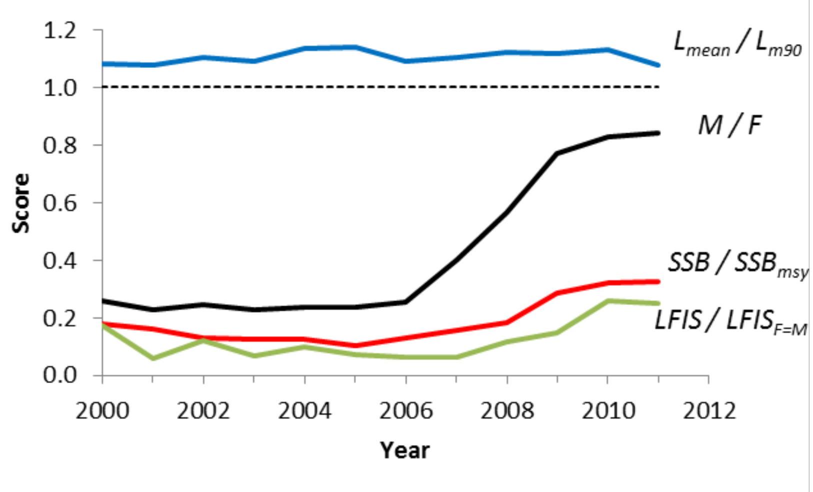

Figure 4. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). Note that here SSB_{msy} was derived anew from stock-recruitment data as ICES' estimate of SSB_{pa} appeared incorrect. [NMS_Germany_Stocks_9.xlsx]

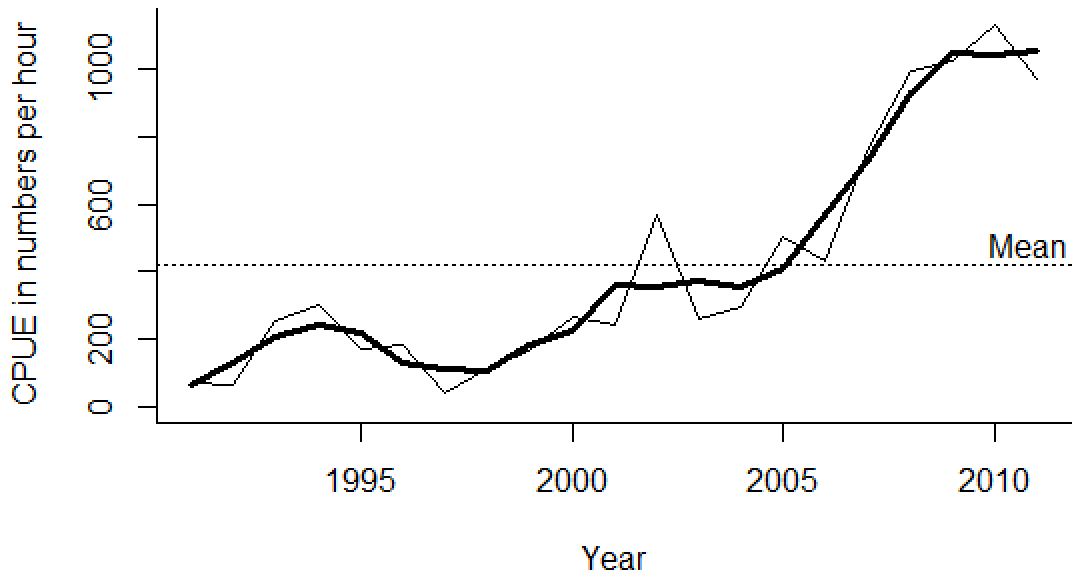

Figure 5. German EEZ abundance graph, here ICES Subdivision 25, bordering the German EEZ. The thin line shows the time series of average catch in numbers resulting from one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. [CPUE_Area_24.r]

References

ICES, 2012.Cod in Subdivisions 25-32, Advice May 2012. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/cod-2532.pdf

ICES, 2013a. Cod in Subdivisions 25-32, Advice May 2013. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/cod-2532_201304112231.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Dab, Kliesche, *Limanda limanda*

Stock: North Sea (dab-nsea), Sub-area IV, data-limited

Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 1.01, $2M/Z$ 0.77, EEZ below mean, EEZ slope decreasing

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Ref.	Comment
M (1/year)	0.25					Between 0.1 (ICES for flatfish) and 0.32 = 1.5 K
F_{msy} (1/year)	0.2					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	11				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	15.4				ICES 2013b	This study
$proxySSB_{msy}$ (kg/h)	30.9				ICES 2013b	This study
L range (cm)	10 - 33					This study
a	0.0068	0.00604 – 0.00772	462	0.981	ICES 2013b	log sd=0.0762
b	3.14	3.10 – 3.18			ICES 2013b	This study
L_∞ (cm)	33				ICES 2013b	This study
K (1/year)	0.21	0.191 – 0.223	460		ICES 2013b	This study
t_0 (years)	-0.89	-1.2 – -0.6			ICES 2013b	This study
L_{m50} (cm)	13				ICES 2013b	This study
L_{m90} (cm)	17				ICES 2013b	This study

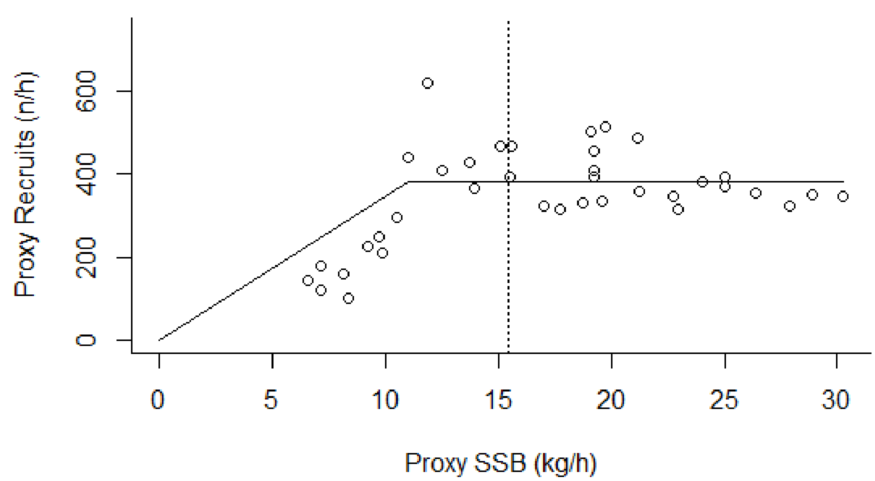

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

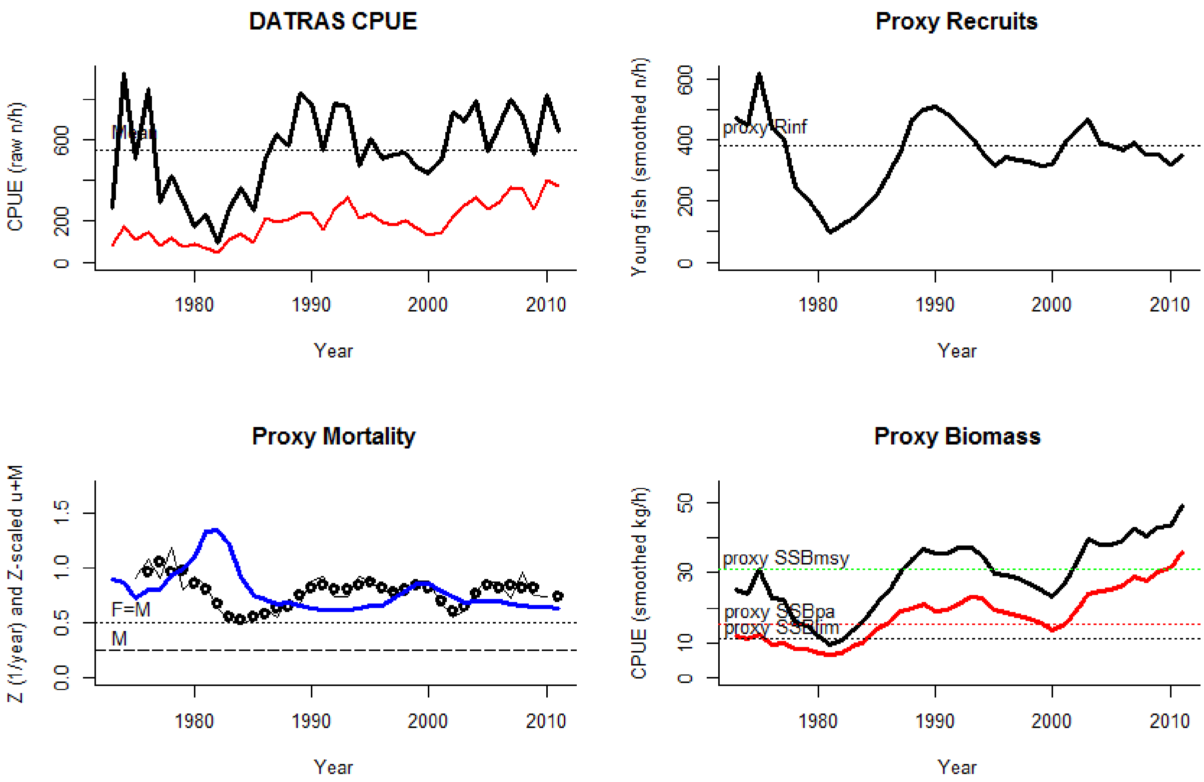

Figure 2. Evaluation of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of dab caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality Z experienced over the respective previous two years (black circles) and scaled exploitation rate u+M, both as a proxies for fishing mortality, with indication of natural mortality (M, dashed line) and total mortality if F = M (dotted line) as reference points. [CPUE_Area_24.r]

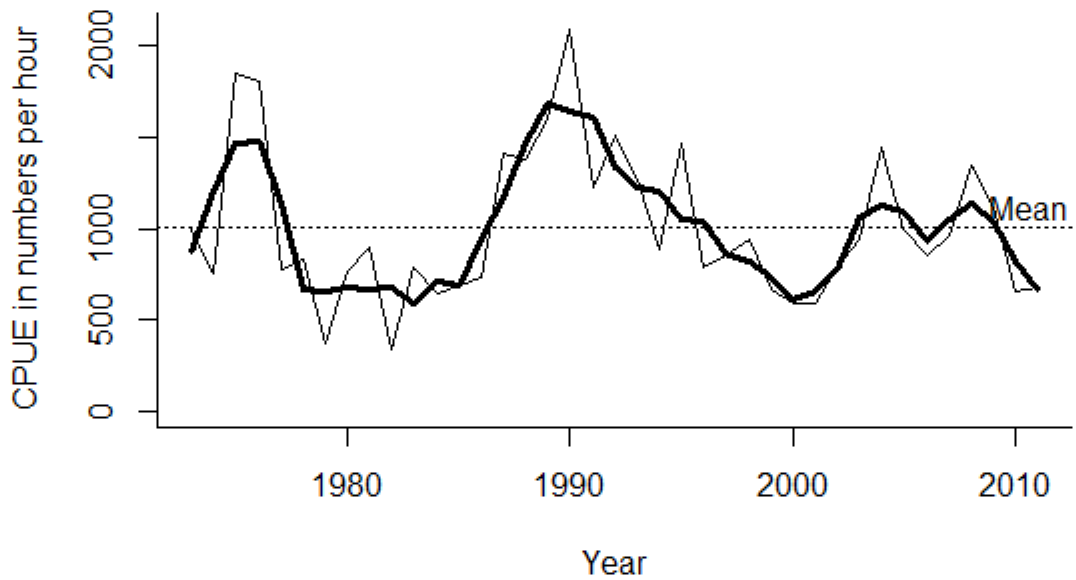

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES Subarea 6, which includes the German Bight. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Dab, Kliesche, *Limanda limanda*
Stock: Baltic Sea (dab-2232), ICES areas 22-32, data-limited
Mean Scores in 2007-11: *proxySSB/proxySSB*$_{msy}$ 0.60, 2*M*/*Z* 0.66, EEZ above mean, EEZ slope decreasing

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r2	Data Ref.	Comment
M (1/year)	0.25					Between 0.1 (ICES for flatfish) and 1.5K=0.38
F_{msy} (1/year)	0.2					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	18.7				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	26.1				ICES 2013b	This study
$proxySSB_{msy}$ (kg/h)	52.3				ICES 2013b	This study
L range (cm)	5 – 40				ICES 2013b	This study
a	0.00545	0.00527 – 0.00564	3,778	0.989	ICES 2013b	log sd=0.212
b	3.23	3.22 – 3.24			ICES 2013b	This study
L_∞ (cm)	37.7				ICES 2013b	This study
K (1/year)	0.25	0.238 – 0.254	1,333		ICES 2013b	This study
t_0 (years)	-0.4	-0.49 - -0.32			ICES 2013b	This study
L_{m50} (cm)	14.8				ICES 2013b	This study
L_{m90} (cm)	17.4				ICES 2013b	This study

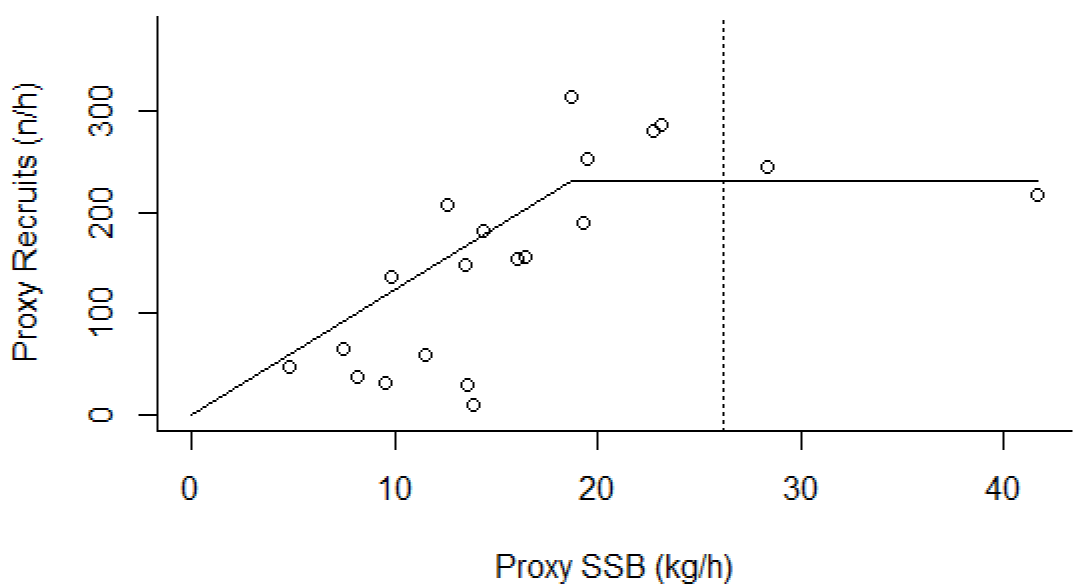

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

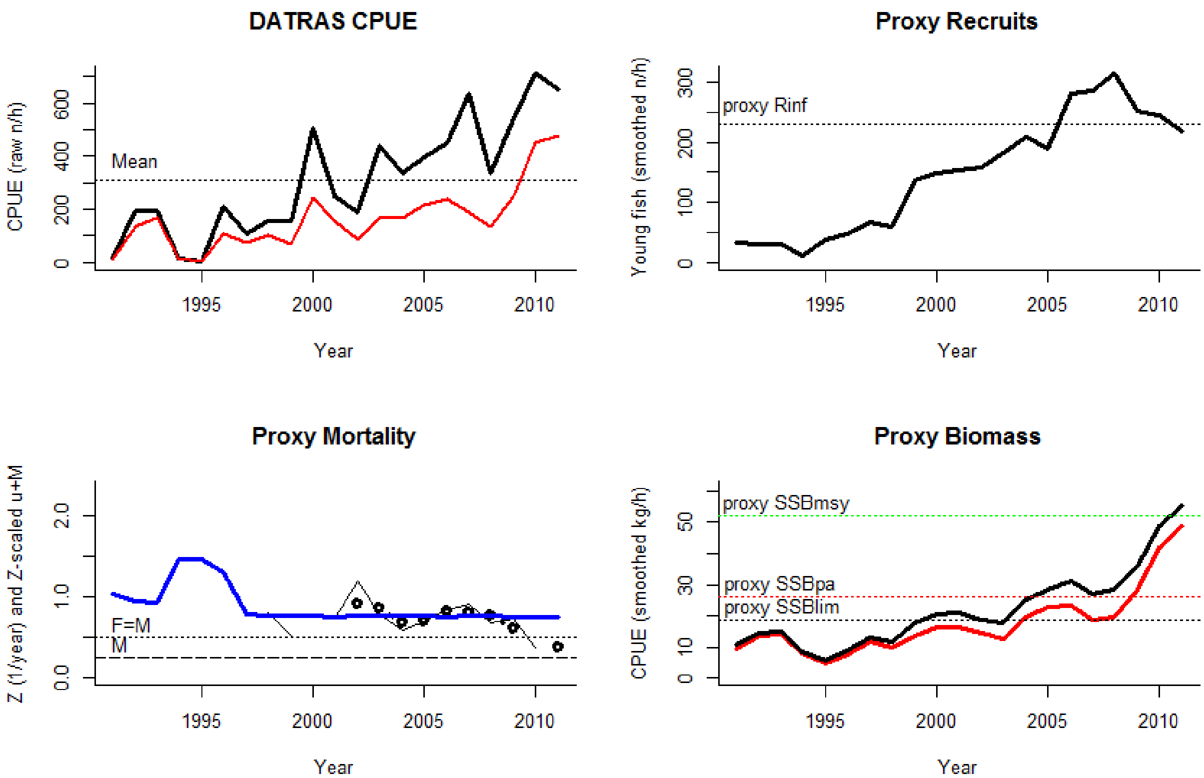

Figure 2. Evaluation of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of dab caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

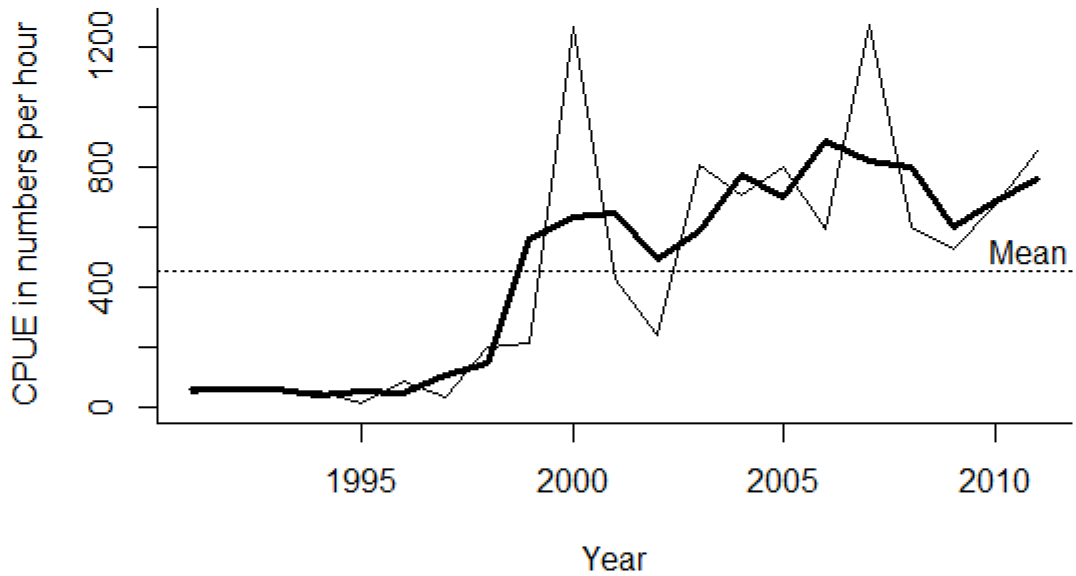

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES Subareas 22 and 24, which include the German EEZ. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Dogfish / Spurdog, Dornhai, *Squalus acanthias*
Stock: Northeast Atlantic (spurdog), data-limited
Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.12, $2M/Z$ NA, EEZ below mean, EEZ slope horizontal

Table 1. Parameters, reference points and data sources used for this stock. No SMALK data were available. [CPUE_Area_24.r]

Trait	Estimate	Data Ref.	Method	Comment
M (1/year)	0.1		Studies in FishBase	This study
F_{msy} (1/year)	0.1		$F_{msy} = M$	This study
$proxySSB_{lim}$ (kg/h)	NA	ICES 2013b		This study
$proxySSB_{pa}$ (kg/h)	14.2	ICES 2013b	Set to largest *proxySSB*	This study
$proxySSB_{msy}$ (kg/h)	28.5	ICES 2013b		This study
a	0.0032		Studies in FishBase	This study
b	3.07		Studies in FishBase	This study
L_∞ (cm)	101		Studies in FishBase	This study
K (1/year)	0.11		Studies in FishBase	This study
t_0 (years)	-3.6		Studies in FishBase	This study
L_{m50} (cm)	70		Studies in FishBase	This study
Hockey stick analysis not done, only low SSB during survey				

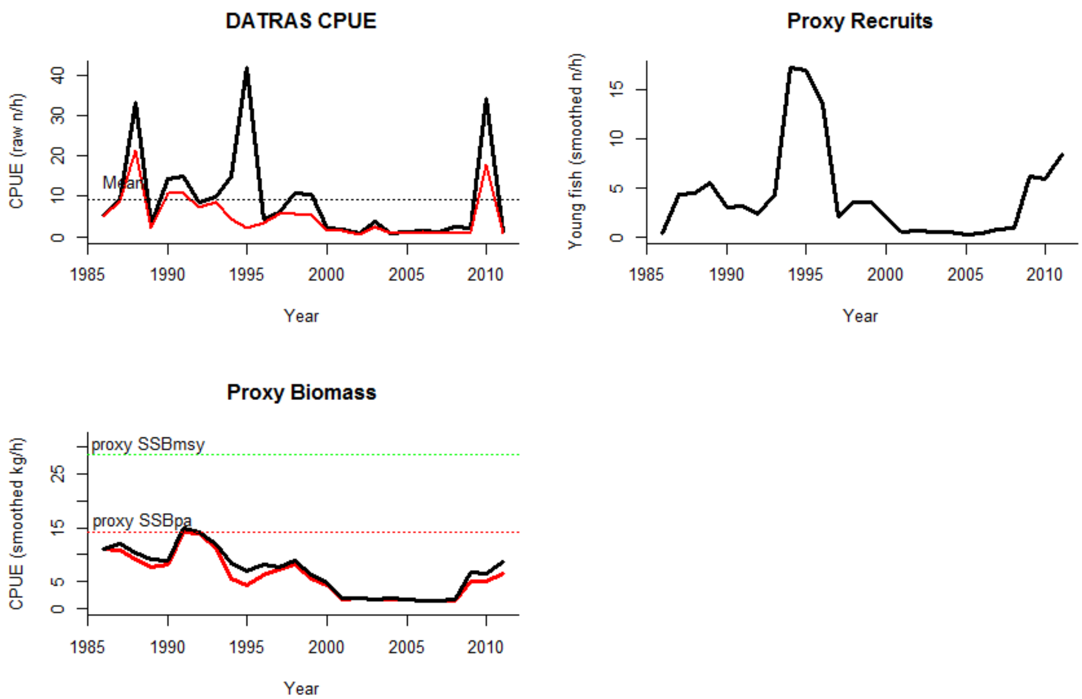

Figure 2. Evaluation of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of spurdog caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower left graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. [CPUE_Area_24.r]

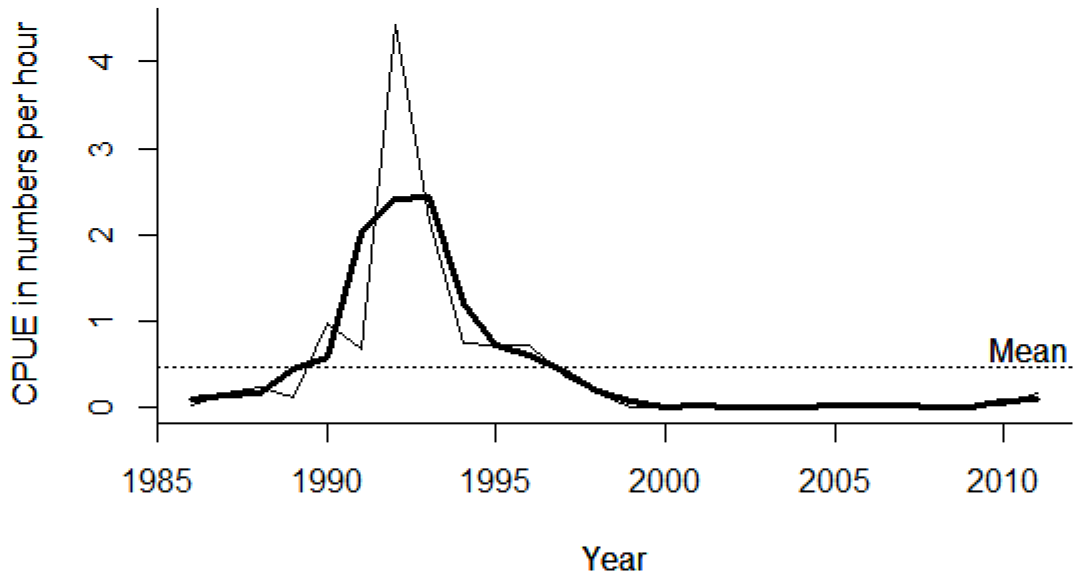

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES Subarea 6, which includes the German Bight. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Eel, Aal, *Anguilla anguilla*
Stock: Northeast Atlantic (eel-eur), data-limited

Mean Scores in 2007-11: *proxySSB/proxySSB*$_{msy}$ 0.20, 2*M*/*Z* NA**,** EEZ below mean, EEZ slope decreasing

Table 1. Parameters, reference points and data sources used for this stock. No SMALK data were available. [CPUE_Area_24.r]

Trait	Estimate	Data Ref.	Method	Comment
M (1/year)	0.2		Between 0.26 (FishBase) and 1.5 K=0.12	This study
F_{msy} (1/year)	0.2		$F_{msy} = M$	This study
$proxySSB_{lim}$ (kg/h)	NA	ICES 2013b		This study
$proxySSB_{pa}$ (kg/h)	0.18	ICES 2013b	Set to largest *proxySSB*	This study
$proxySSB_{msy}$ (kg/h)	0.35	ICES 2013b		This study
a	0.0008		Studies in FishBase	This study
b	3.2		Studies in FishBase	This study
L_∞ (cm)	83.2		Studies in FishBase	This study
K (1/year)	0.08		Studies in FishBase	This study
t_0 (years)	0.0		Studies in FishBase	This study
L_{m50} (cm)	60.0		Studies in FishBase	This study
Hockey stick analysis not done, only low SSB during survey				

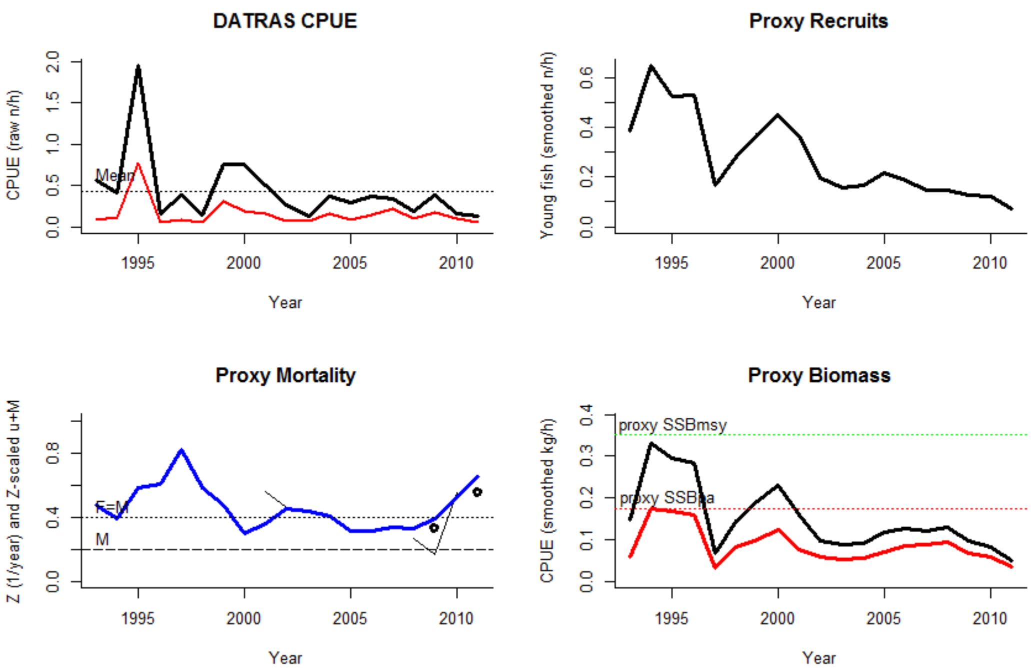

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of eel caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

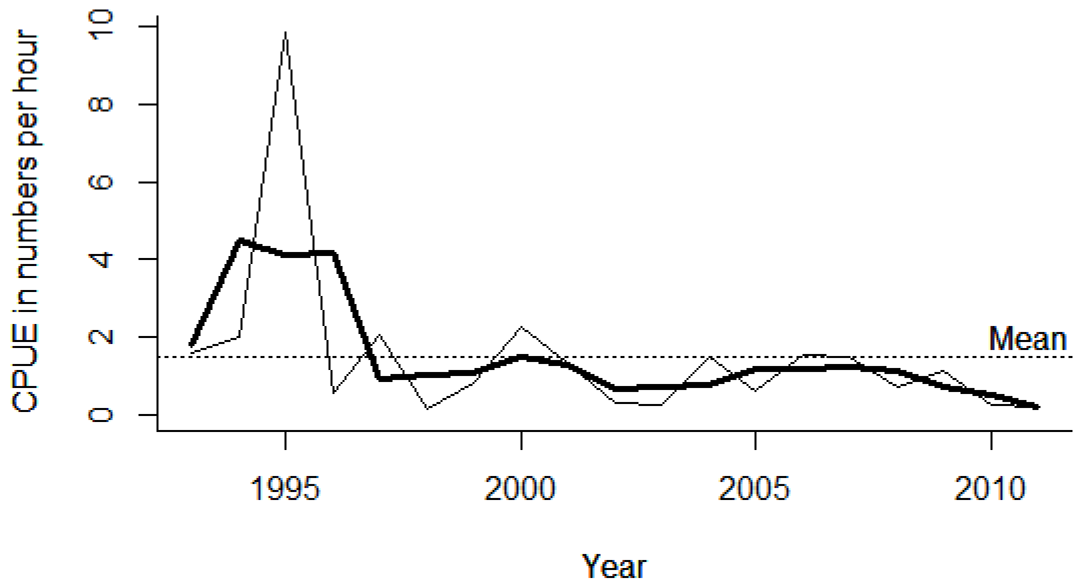

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in the German EEZ of the North Sea and the Baltic Sea. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Flounder, Flunder, *Platichthys flesus*
Stock: North Sea (fle-nsea), Sub-area IV, data-limited
Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.53, $2M/Z$ 1.0, EEZ above mean, EEZ slope decreasing

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.2					Between 0.1 (ICES for flatfish) and 1.5 K = 0.54
F_{msy} (1/year)	0.2					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	0.16				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	0.22				ICES 2013b	This study
$proxySSB_{msy}$ (kg/h)	0.44				ICES 2013b	This study
Length range (cm)	12.3 - 40.7				ICES 2013b	This study
a	0.00867	0.00438 – 0.0172	114	0.88	ICES 2013b	log sd = 0.113
b	3.06	2.86 – 3.27			ICES 2013b	This study
L_∞ (cm)	40.8		114		ICES 2013b	This study
K (1/year)	0.36	0.291 – 0.432			ICES 2013b	This study
t_0 (years)	-0.25	-0.775 – 0.274			ICES 2013b	This study
L_{m50} (cm)	21		24		ICES 2013b	This study

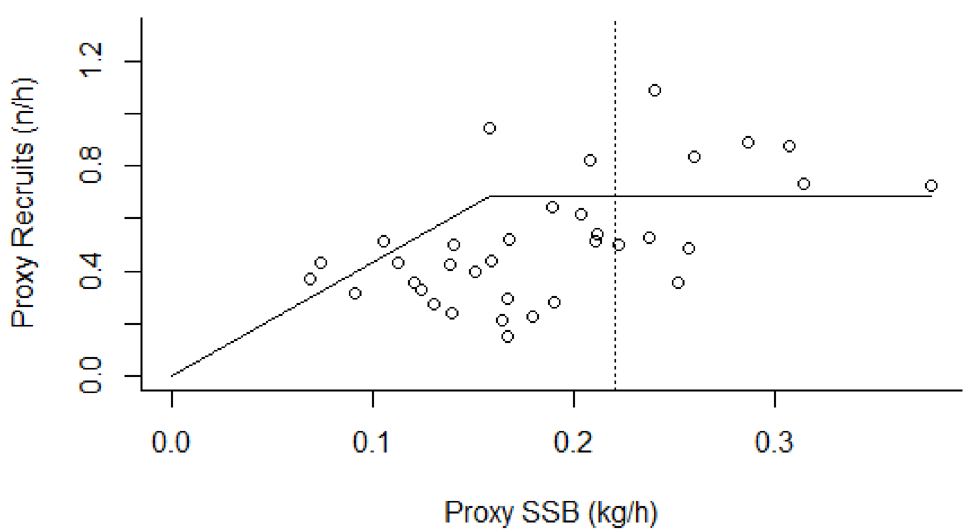

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

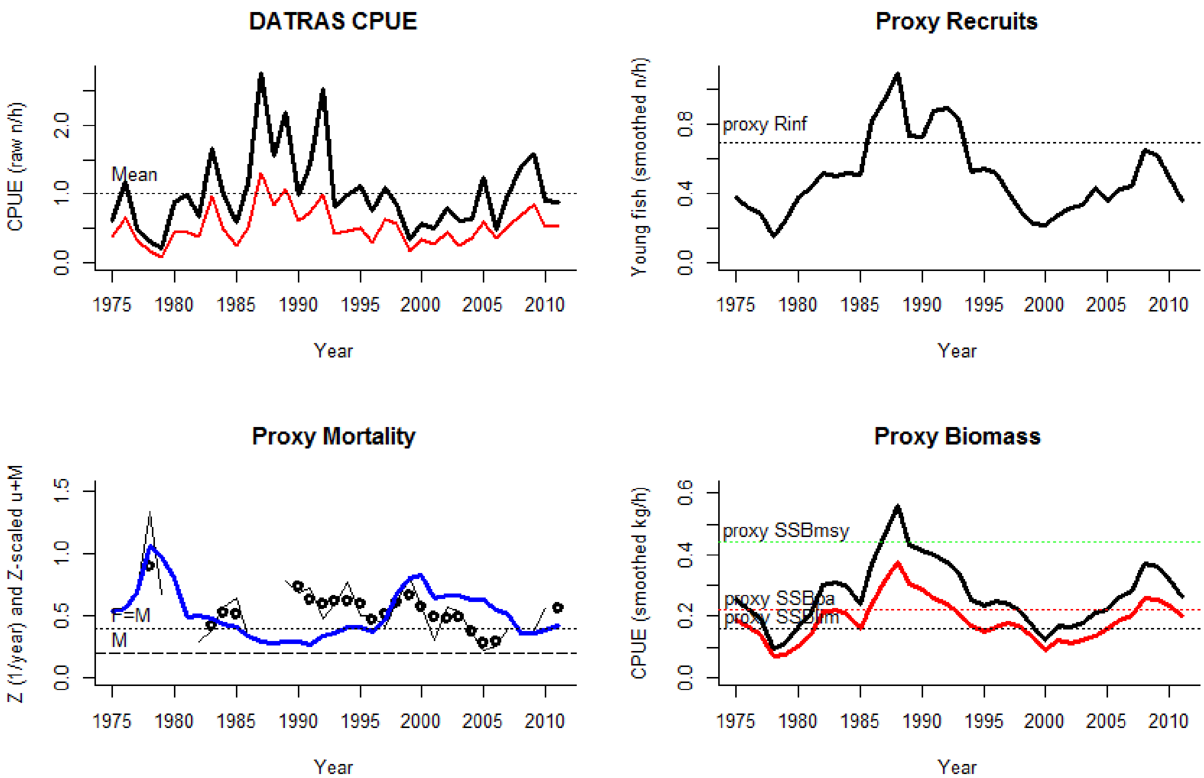

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of flounder caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

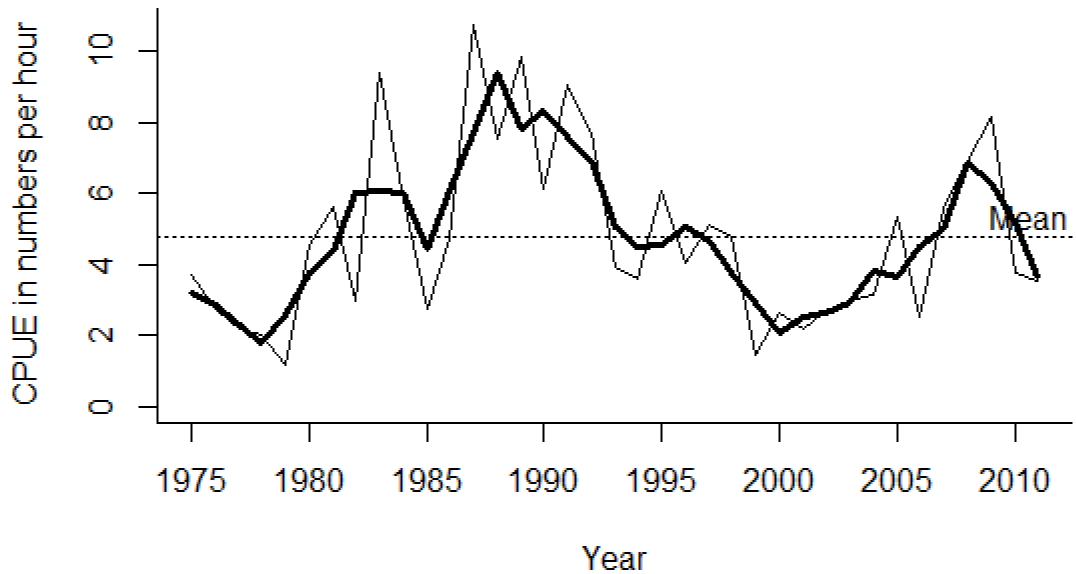

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES subarea 6 which includes the German EEZ of the North Sea. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Flounder, Flunder, *Platichthys flesus*
Stock: Baltic Sea (fle-2232), Subdivisions 22–32, data-limited
Mean Scores in 2007-11: *proxySSB/proxySSB$_{msy}$* 0.80, 2*M/Z* 1.13, EEZ above mean, EEZ slope horizontal

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r; CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.2					Between 0.1 (ICES for flatfish) and 1.5 *K* = 0.21
F_{msy} (1/year)	0.2					$F_{msy} = M$
proxySSB$_{lim}$ (kg/h)	21.7				ICES 2013b	This study
proxySSB$_{pa}$ (kg/h)	30.4				ICES 2013b	This study
proxySSB$_{msy}$ (kg/h)	60.8				ICES 2013b	This study
Length range (cm)	6 – 53				ICES 2013b	This study
a	0.00667	0.00647 – 0.00687	22,770	0.961	ICES 2013b	log sd=0.067
b	3.18	3.17 – 3.19			ICES 2013b	This study
L_∞ (cm)	48		22,724		ICES 2013b	This study
K (1/year)	0.14	0.141 – 0.145			ICES 2013b	This study
t_0 (years)	-1.6	-1.64 – -1.5			ICES 2013b	This study
L_{m50} (cm)	19.8		11,136		ICES 2013b	This study
L_{m90} (cm)	23.1				ICES 2013b	This study

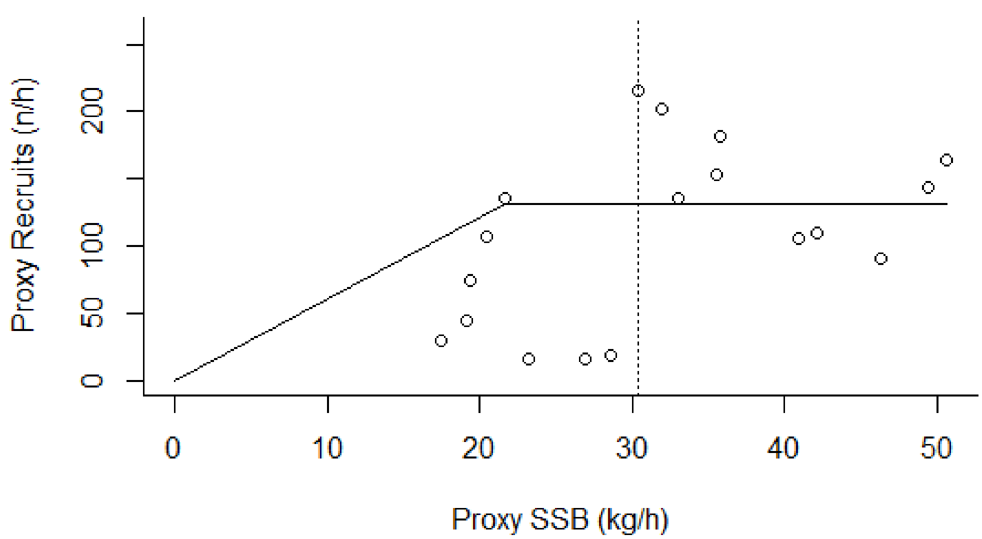

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy *SSB$_{pa}$* as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

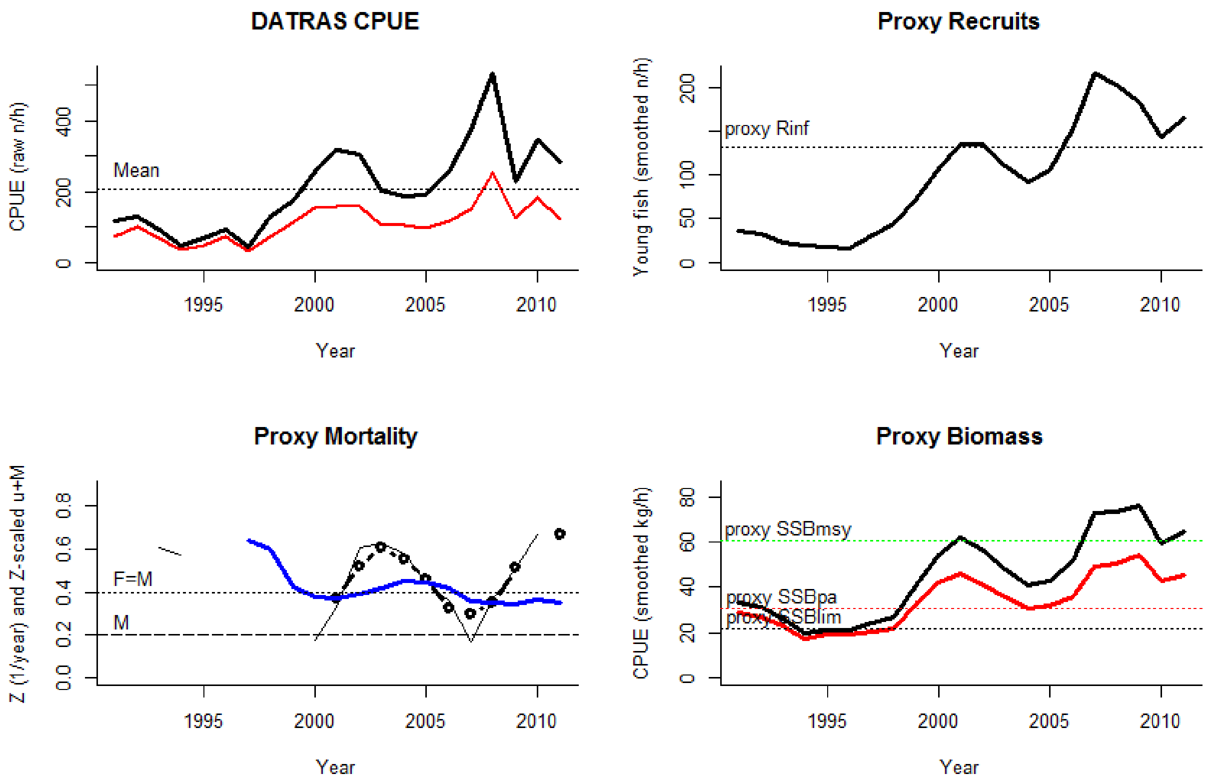

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of flounder caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

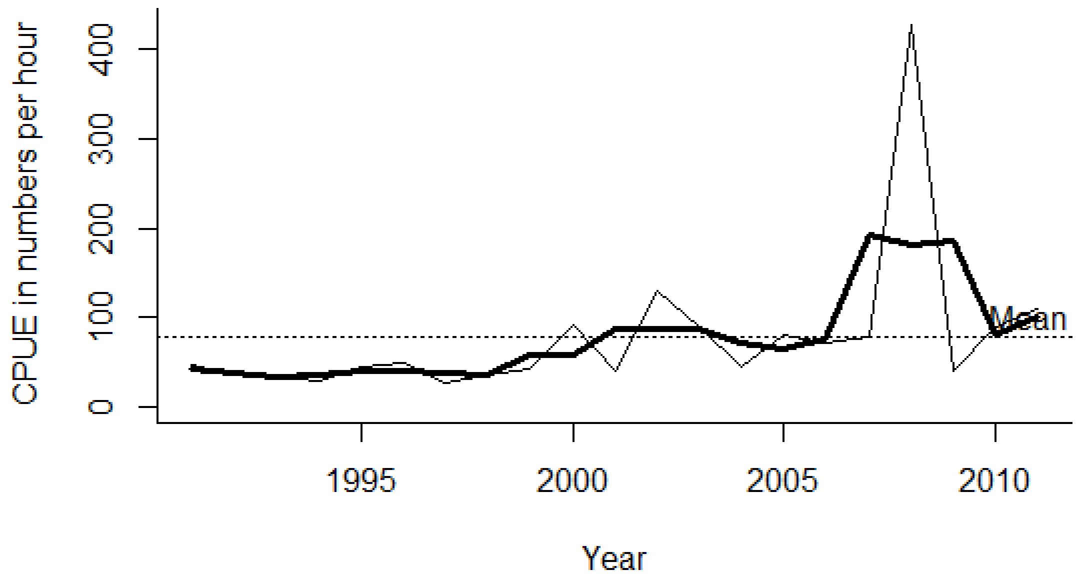

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES areas 22 and 24, which includes the German EEZ of the Baltic Sea. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Herring, Hering, *Clupea harengus*
Stock: North Sea (her-47d3), Sub-area IV, Divisions VIId & IIIa (autumn-spawners), fully assessed
Scores in 2011: $SSB/pSSB_{msy}$ 0.90, F_{msy}/F 2.69, M/F 3.76, L_{mean}/L_{m90} 0.84, $LFIS/LFIS_{F=M}$ 1.20

EEZ above mean, EEZ slope horizontal

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r_2	Data Ref.	Comment
M (1/year)	0.35				ICES 2012a	
F_{msy} (1/year)	0.25				ICES 2012a	
SSB_{pa} (t)	1,300,000				ICES 2012a	
SSB_{msy}Trigger (t)	Undefined				ICES 2012a	
$pSSB_{msy}$ (t)	2,600,000				ICES 2013b	This study
Length range (cm)	7 - 37					
a	0.00322	0.00317 – 0.00326	20,165	0.991	ICES 2013b	log sd=0.044
b	3.22	3.22 – 3.23			ICES 2013b	This study
L_∞ (cm)	35.9				ICES 2013b	This study
K (1/year)	0.348				ICES 2013b	This study
t_0 (years)	-0.447	-0.468 - -0.426			ICES 2013b	This study
L_{m50} (cm)	24.1		7,629		ICES 2013b	This study
L_{m90} (cm)	27.3				ICES 2013b	This study
L_{opt} (cm)	26.9				ICES 2013b	This study
$L_{0.66}$ (cm)	23.9				ICES 2013b	This study
t_{m50} (years)	2.73				ICES 2013b	This study
$t_{0.66}$ (years)	2.69				ICES 2013b	This study
$LFIS_{F=M}$	0.60				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*) (ICES 2012b), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	*SSB*	*F*	L_{mean}	*LFIS*	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	1,531,870	0.21	21.9	0.76	0.59	1.18	1.65	0.80	0.81	1.28
2001	2,084,418	0.19	21.3	0.48	0.80	1.34	1.87	0.78	0.79	0.81
2002	2,397,651	0.18	22.9	0.72	0.92	1.42	1.99	0.84	0.85	1.21
2003	2,455,891	0.20	24.0	0.50	0.94	1.24	1.74	0.88	0.89	0.84
2004	2,419,327	0.24	24.7	0.82	0.93	1.02	1.43	0.91	0.92	1.38
2005	2,294,441	0.26	24.4	0.88	0.88	0.96	1.35	0.90	0.91	1.47
2006	1,797,667	0.23	24.7	0.79	0.69	1.08	1.52	0.90	0.92	1.33
2007	1,444,105	0.20	24.8	0.80	0.56	1.27	1.78	0.91	0.92	1.33
2008	1,525,755	0.13	23.4	0.72	0.59	1.95	2.73	0.86	0.87	1.21
2009	1,899,308	0.08	23.0	0.67	0.73	3.29	4.61	0.84	0.86	1.13
2010	2,004,690	0.08	23.0	0.75	0.77	3.21	4.49	0.84	0.85	1.25
2011	2,343,134	0.09	23.0	0.72	0.90	2.69	3.76	0.84	0.85	1.20

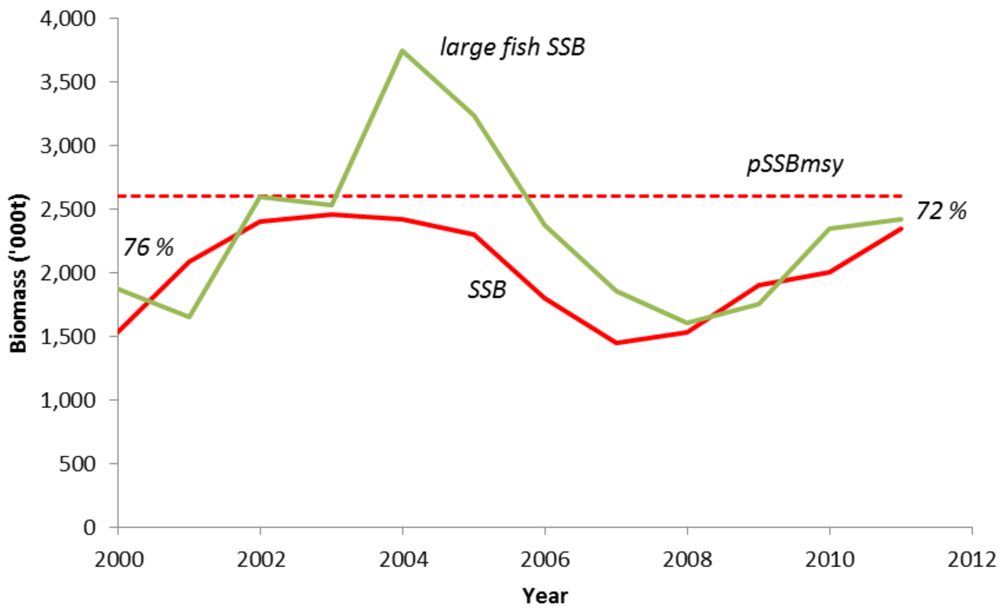

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield (*$pSSB_{msy}$*). The green line shows the biomass of large fish, representing 76% of *SSB* in 2000 and 72% in 2011. [NMS_Germany_Stocks_9.xlsx]

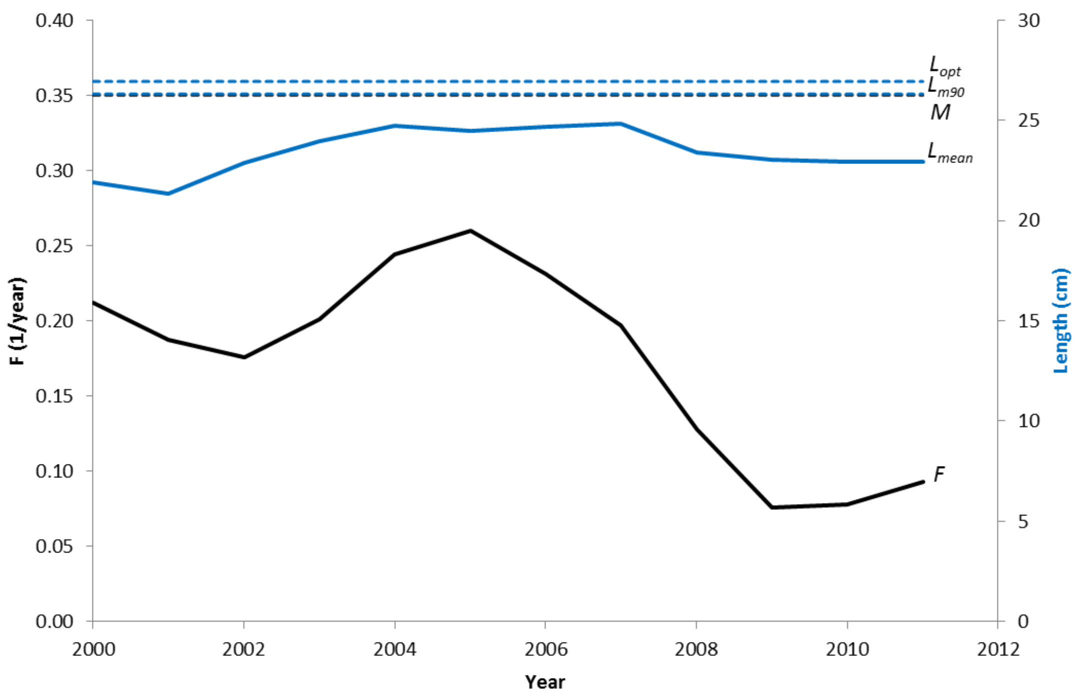

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches *L_{mean}*, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length *L_{m90}* where 90% of the females have reached sexual maturity and the length *L_{opt}* where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

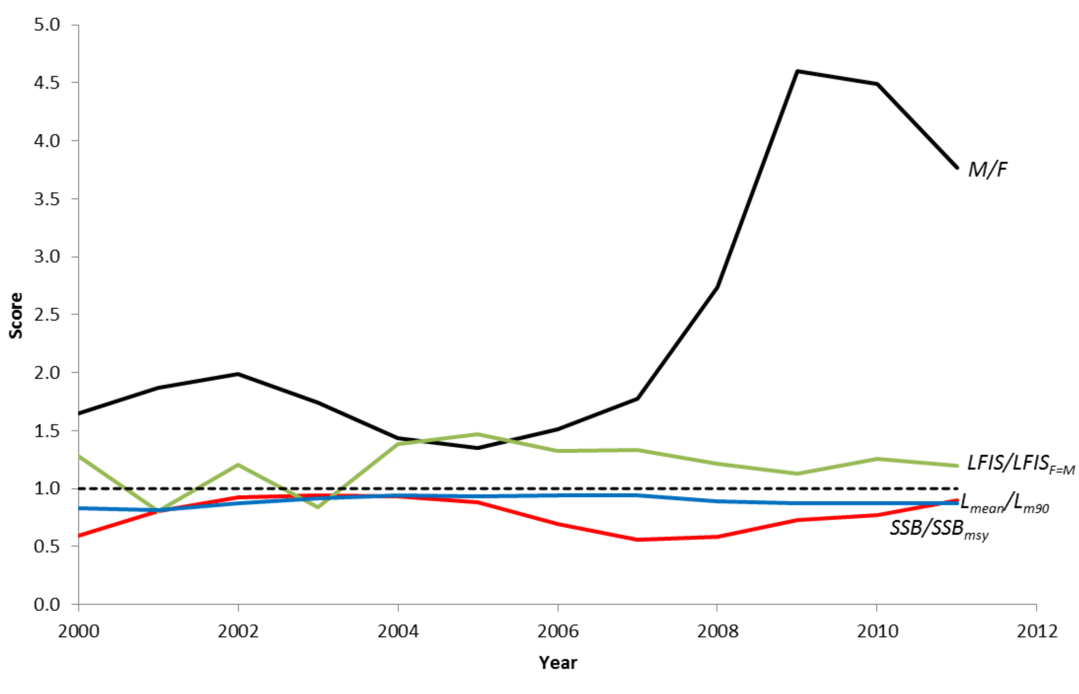

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

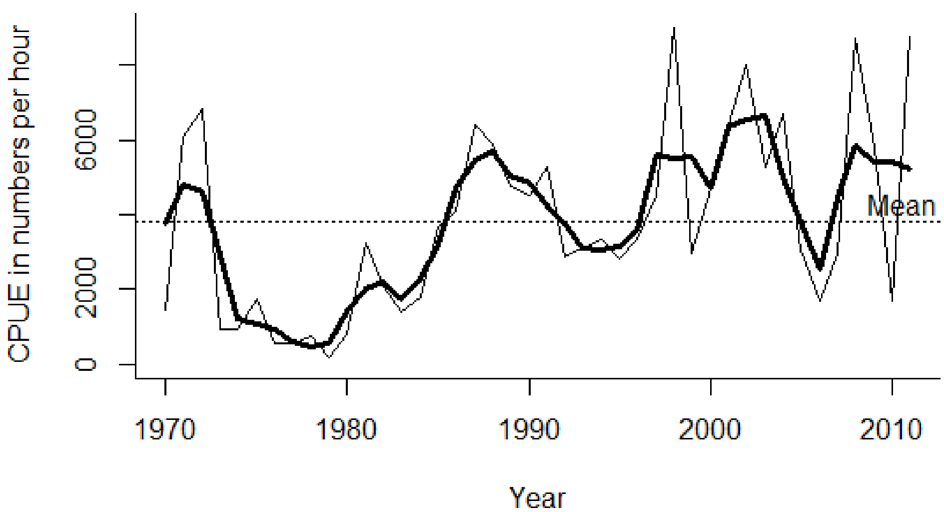

Figure 4. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES roundfish area 6, which includes the German EEZ of the North Sea. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2012a. Report of the Herring Assessment Working Group for the Area South of 62 N (HAWG), 13-22 March 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/ACOM:06 835 pp. Downloaded in April 2013 from http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2012/HAWG/HAWG%202012.pdf

ICES 2012b. Herring in Subarea IV and Divisions IIIa and VIId (North Sea autum spawners). Downloaded in April 2013 from http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/her-47d3.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx

Species: Herring, Hering, *Clupea harengus*

Stock: Western Baltic Sea (her-3a22), Sub-divisions 22-24 and Division IIIa (spring spawners), fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 0.49, F_{msy}/F 1.24, M/F 0.99, L_{mean}/L_{m90} 0.84, $LFIS/LFIS_{F=M}$ 0.61

EEZ below mean, EEZ slope decreasing

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.2				ICES 2012a	
F_{msy} (1/year)	0.25				ICES 2012a	
SSB_{pa} (t)	Undefined				ICES 2012a	
SSB_{msy}Trigger (t)	110,000				ICES 2012a	
$pSSB_{msy}$ (t)	220,000				ICES 2013b	This study
Length range (cm)	10.5 – 30.5				ICES 2013b	This study
a	0.00215	0.00199 – 0.00231	909	0.989	ICES 2013b	log sd=0.0436
b	3.35				ICES 2013b	This study
L_∞ (cm)	30		900		ICES 2013b	This study
K (1/year)	0.33	0.315 – 0.344			ICES 2013b	This study
t_0 (years)	-0.88	-0.985 - -0.782			ICES 2013b	This study
L_{m50} (cm)	22.1		185		ICES 2013b	This study
L_{m90} (cm)	28.3				ICES 2013b	This study
L_{opt} (cm)	25				ICES 2013b	This study
$L_{0.66}$ (cm)	20				ICES 2013b	This study
t_{m50} (years)	3.16				ICES 2013b	This study
$t_{0.66}$ (years)	2.45				ICES 2013b	This study
$LFIS_{F=M}$	1.2				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*) (ICES 2012b), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	140,102	0.48	20.5	0.67	0.64	0.53	0.42	0.72	0.82	0.54
2001	161,426	0.56	19.6	0.65	0.73	0.45	0.36	0.69	0.78	0.53
2002	201,125	0.41	21.4	0.77	0.91	0.61	0.48	0.76	0.86	0.63
2003	162,782	0.39	23.4	0.79	0.74	0.63	0.51	0.83	0.94	0.64
2004	168,338	0.34	21.0	0.78	0.77	0.74	0.59	0.74	0.84	0.63
2005	166,503	0.39	22.5	0.73	0.76	0.65	0.52	0.80	0.90	0.59
2006	184,317	0.49	24.7	0.81	0.84	0.51	0.41	0.87	0.99	0.65
2007	143,326	0.41	23.9	0.79	0.65	0.61	0.49	0.85	0.96	0.64
2008	123,711	0.44	24.8	0.78	0.56	0.57	0.45	0.88	1.00	0.63
2009	116,377	0.46	24.1	0.80	0.53	0.55	0.44	0.85	0.97	0.65
2010	108,427	0.27	24.8	0.78	0.49	0.93	0.74	0.88	0.99	0.63
2011	107,342	0.20	23.9	0.75	0.49	1.24	0.99	0.84	0.96	0.61

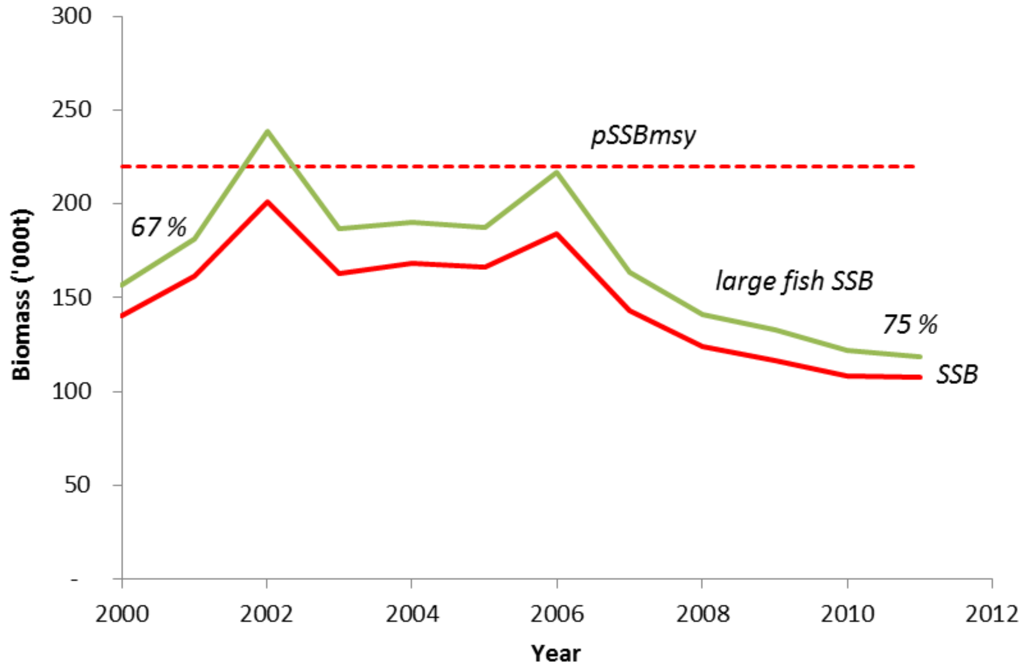

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield (*$pSSB_{msy}$*). The green line shows the biomass of large fish, representing 67% of *SSB* in 2000 and 75% in 2011. [NMS_Germany_Stocks_9.xlsx]

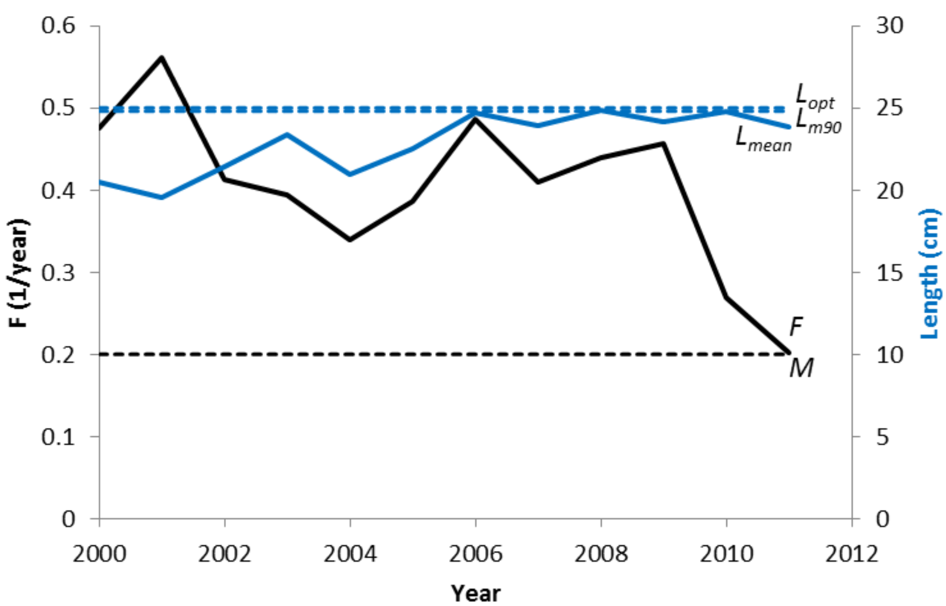

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches *L_{mean}*, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length *L_{m90}* where 90% of the females have reached sexual maturity and the length *L_{opt}* where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

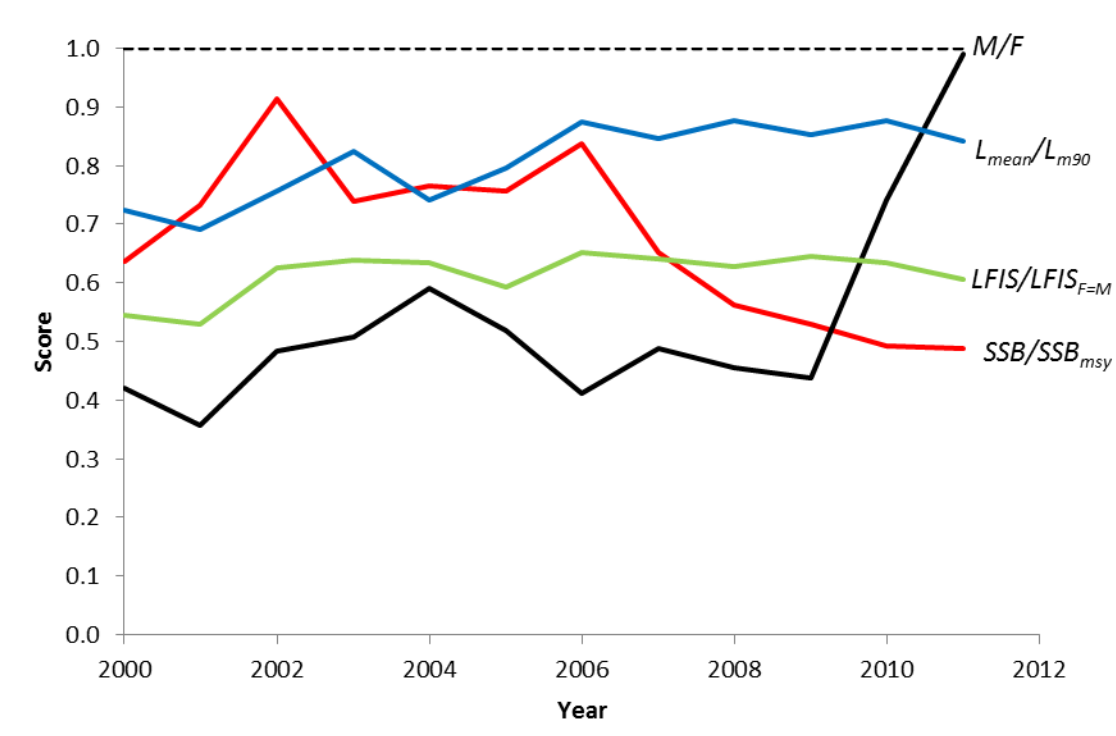

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

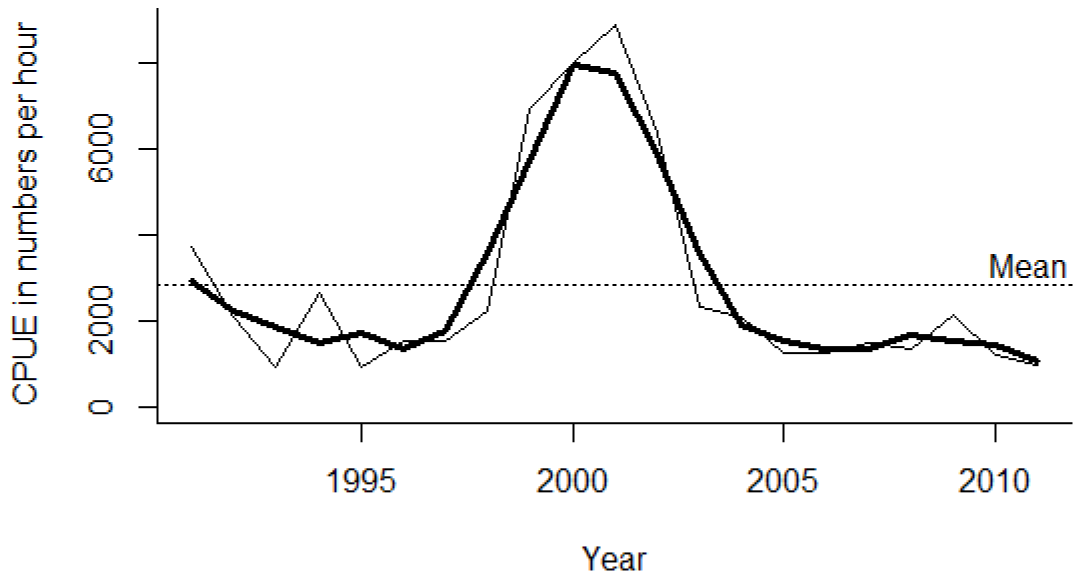

Figure 4. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES subdivisions 22 & 24, which include the German EEZ of the Baltic Sea. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2012a. Report of the Herring Assessment Working Group for the Area South of 62 N (HAWG), 13-22 March 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/ACOM:06 835 pp. Downloaded in April 2013 from http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2012/HAWG/HAWG%202012.pdf

ICES 2012b. Herring in Divisions IIIa and Subdivisions 22-24 (western Baltic spring spawners). Downloaded in April 2013 from http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/Her-3a22.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx

Species: Norway lobster, Kaisergranat, *Nephrops norvegicus*
Stock: North Sea (nep-IV), Sub-area IV, data-limited
Mean Scores in 2007-11: *proxySSB/proxySSB$_{msy}$* 0.42, 2*M*/*Z* 1.92, EEZ above mean, EEZ slope decreasing

Table 1. Parameters, reference points and data sources used for this stock. [CPUE_Area_24.r]

Trait	Estimate	Data Ref.	Method	Comment
M (1/year)	0.2		Close to 1.5 *K* = 0.15	This study
F_{msy} (1/year)	0.2		$F_{msy} = M$	This study
$proxySSB_{lim}$ (kg/h)	NA	ICES 2013b		This study
$proxySSB_{pa}$ (kg/h)	0.19	ICES 2013b	Set to largest *proxySSB*	This study
$proxySSB_{msy}$ (kg/h)	0.38	ICES 2013b		This study
a	0.58		from studies in www.SeaLifeBase.org	This study
b	3.1		from studies in www.SeaLifeBase.org	This study
L_∞ (cm)	9		from studies in www.SeaLifeBase.org	This study
K (1/year)	0.1		from studies in www.SeaLifeBase.org	This study
t_0 (years)	0		from studies in www.SeaLifeBase.org	This study
L_{m50} (cm)	3.5		from studies in www.SeaLifeBase.org	This study
Hockey stick analysis not done, only low SSB during survey				

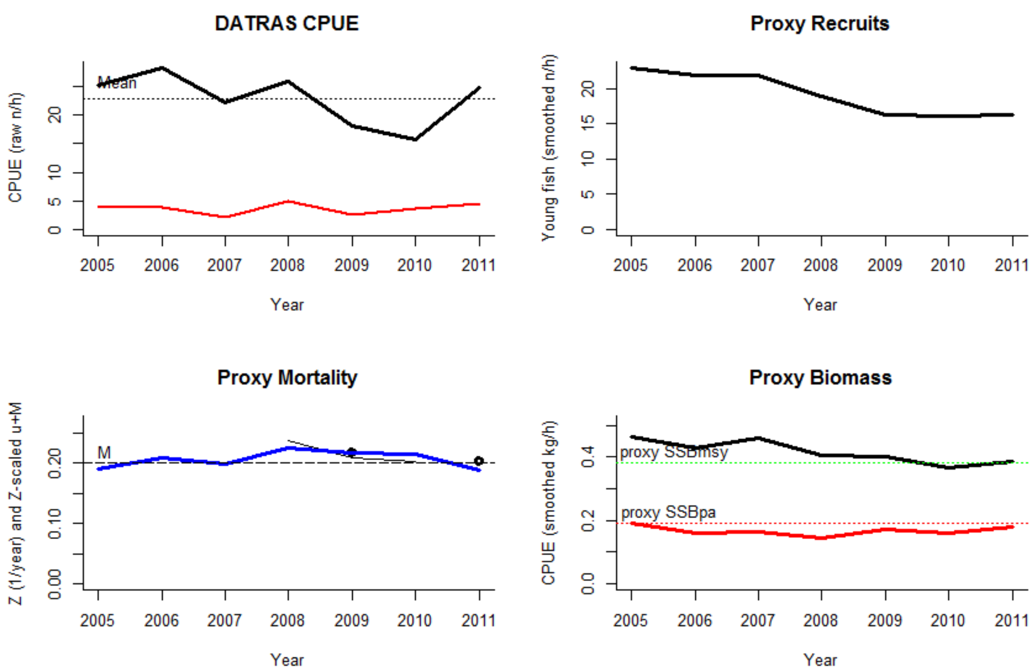

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of Norway lobster caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

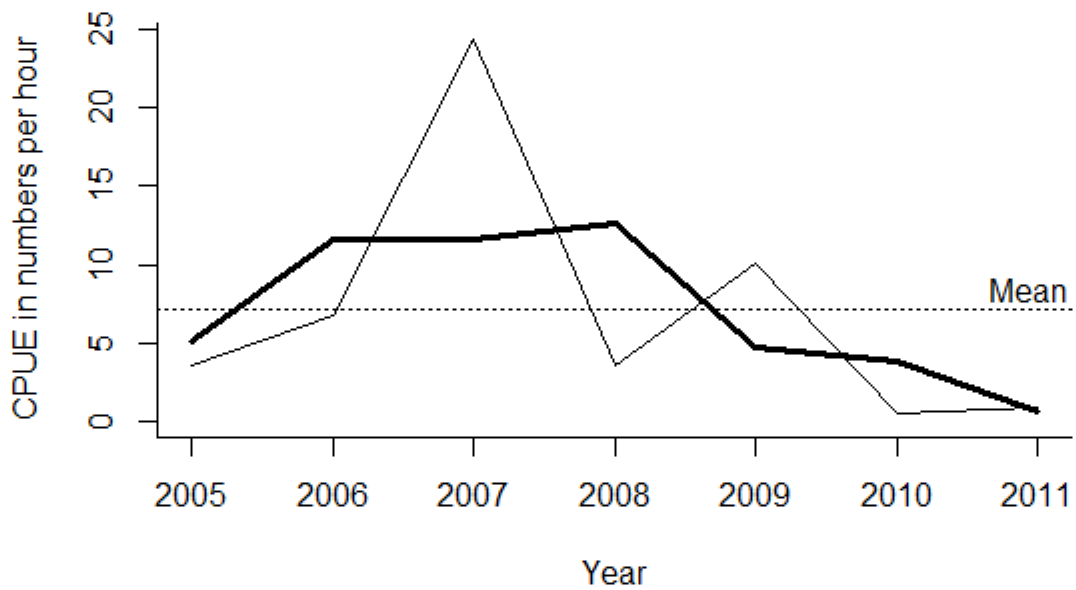

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES roundfish area 6, which includes the German Bight. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Plaice, Scholle, *Pleuronectes platessa*

Stock: North Sea (ple-nsea), Plaice in Sub-area IV, fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 1.04, F_{msy}/F 1.09, M/F 0.44, L_{mean}/L_{m90} 0.95, $LFIS/LFIS_{F=M}$ 0.64

EEZ above mean, EEZ slope increasing

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.1				ICES 2012a	
F_{msy} (1/year)	0.25				ICES 2012a	
SSB_{pa} (t)	230,000				ICES 2012a	
SSB_{msy}Trigger (t)	230,000				ICES 2012a	
$pSSB_{msy}$ (t)	460,000				ICES 2012a	
Length range (cm)	8.5 - 55				ICES 2013b	This study
a	0.0107	0.00977 – 0.0103	7,191	0.986	ICES 2013b	log sd=0.048
b	2.97				ICES 2013b	This study
L_∞ (cm)	48.0		7,153		ICES 2013b	This study
K (1/year)	0.16	0.161 – 0.167			ICES 2013b	This study
t_0 (years)	-1.0	-1.1 – -0.96			ICES 2013b	This study
L_{m50} (cm)	22.1		3,039		ICES 2013b	This study
L_{m90} (cm)	28.3				ICES 2013b	This study
L_{opt} (cm)	39.7				ICES 2013b	This study
$L_{0.66}$ (cm)	32.0				ICES 2013b	This study
t_{m50} (years)	2.9				ICES 2013b	This study
$t_{0.66}$ (years)	5.9				ICES 2013b	This study
$LFIS_{F=M}$	0.61				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	229,154	0.47	27.2	0.14	0.50	0.53	0.21	0.96	0.68	0.23
2001	271,900	0.77	27.1	0.15	0.59	0.32	0.13	0.96	0.68	0.25
2002	199,295	0.57	25.4	0.32	0.43	0.44	0.18	0.90	0.64	0.53
2003	228,558	0.61	25.8	0.31	0.50	0.41	0.16	0.91	0.65	0.52
2004	209,023	0.48	25.4	0.19	0.45	0.52	0.21	0.90	0.64	0.32
2005	245,870	0.40	25.8	0.31	0.53	0.63	0.25	0.91	0.65	0.52
2006	255,522	0.37	25.6	0.20	0.56	0.68	0.27	0.90	0.64	0.33
2007	259,832	0.31	26.2	0.37	0.56	0.81	0.32	0.93	0.66	0.62
2008	359,187	0.24	25.7	0.41	0.78	1.04	0.42	0.91	0.65	0.68
2009	400,100	0.21	26.4	0.38	0.87	1.18	0.47	0.93	0.66	0.62
2010	500,800	0.21	26.4	0.36	1.09	1.21	0.49	0.93	0.67	0.59
2011	476,100	0.23	26.9	0.39	1.04	1.09	0.44	0.95	0.68	0.64

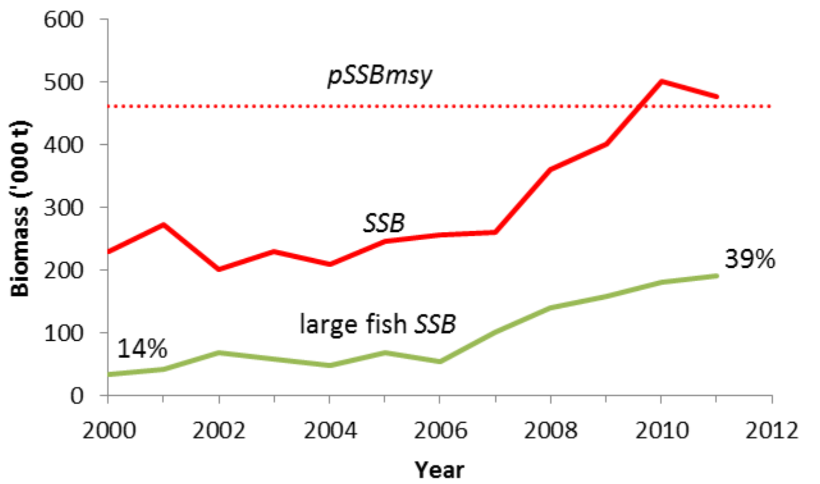

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield ($pSSB_{msy}$). The green line shows the biomass of large fish, representing 14% of *SSB* in 2000 and 39% in 2011. [NMS_Germany_Stocks_9.xlsx]

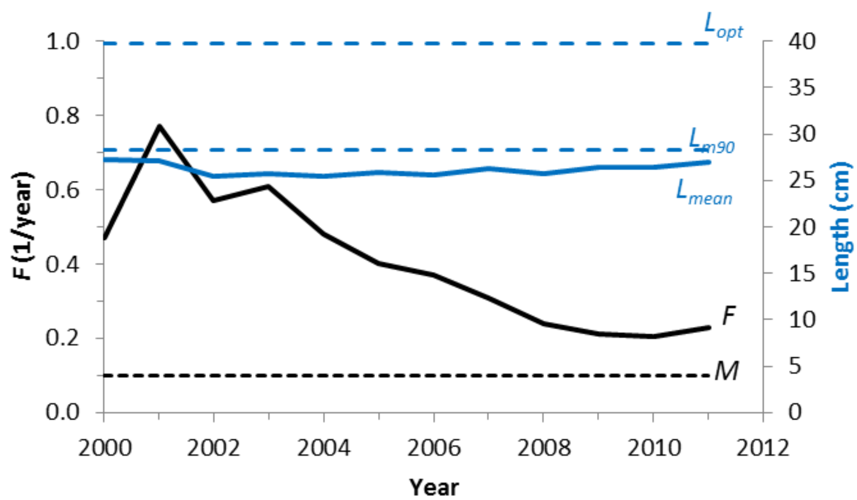

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches L_{mean}, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

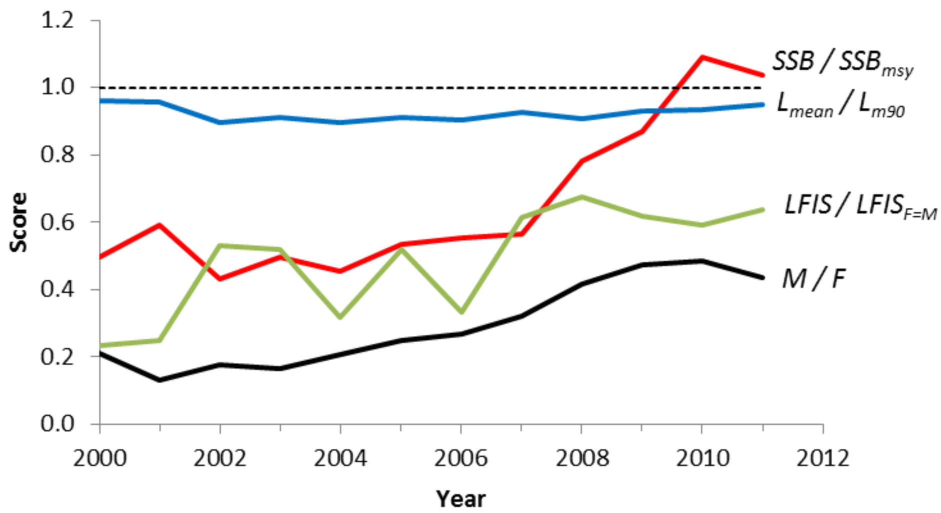

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

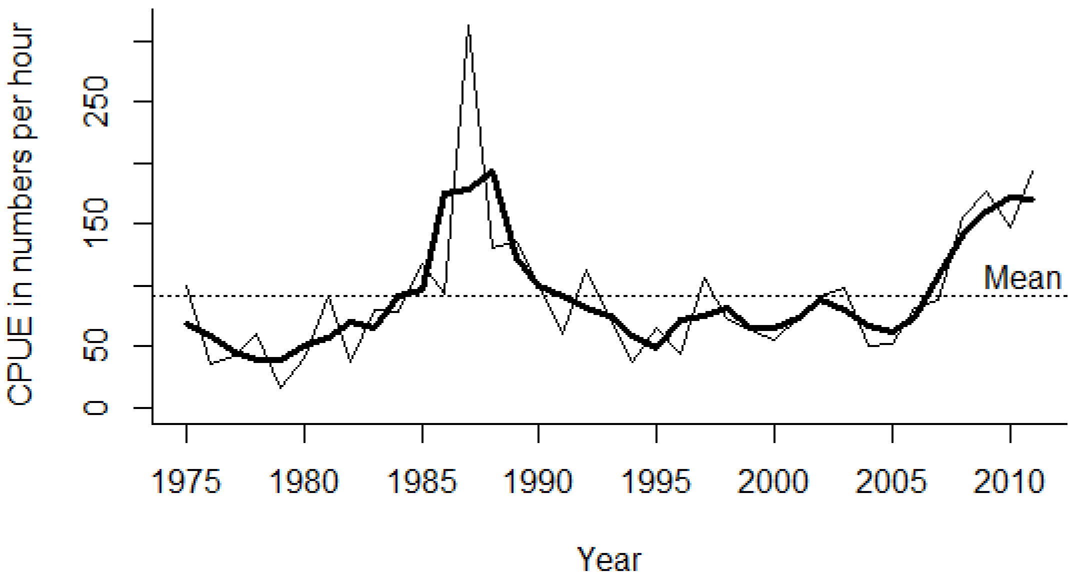

Figure 4. German EEZ abundance graph: Time series of average catch in one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. [CPUE_Area_24.r]

References

ICES, 2012a. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April - 3 May 2012, ICES Headquarters, Copenhagen. ICES CM 2012/ACOM: 13: 1346 pp. URL: http://www.ices.dk/publications/library/Pages/default.aspx#k=wgnssk (April 2013).

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Plaice, Scholle, *Pleuronectes platessa*

Stock: Kattegat, Belt and Sounds (ple-2123), semi-data-limited (F , F_{msy} and relative SSB are available)

Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.41, F_{msy}/F 0.60, $2M/Z$ 1.15, EEZ above mean, EEZ slope increasing

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.2					This study
F_{msy} (1/year)	0.25				ICES 2013a	This study
$proxySSB_{lim}$ (kg/h)	NA				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	46.1				ICES 2013b	Set to largest *proxySSB*
$proxySSB_{msy}$ (kg/h)	92.1				ICES 2013b	This study
a	0.0101	0.00975 – 0.0104	8,379	0.979	ICES 2013b	This study
b	3.0	2.99 – 3.01			ICES 2013b	This study
L_∞ (cm)	52				ICES 2013b	This study
K (1/year)	0.168	0.165 – 0.170	8,341		ICES 2013b	sd of log(L)= 0.164
t_0 (years)	-0.72	-0.76 – -0.67			ICES 2013b	This study
L_{m50} (cm)	17		289			This study
L_{m90} (cm)	17.3					
Hockey stick analysis not done, only low SSB during survey						

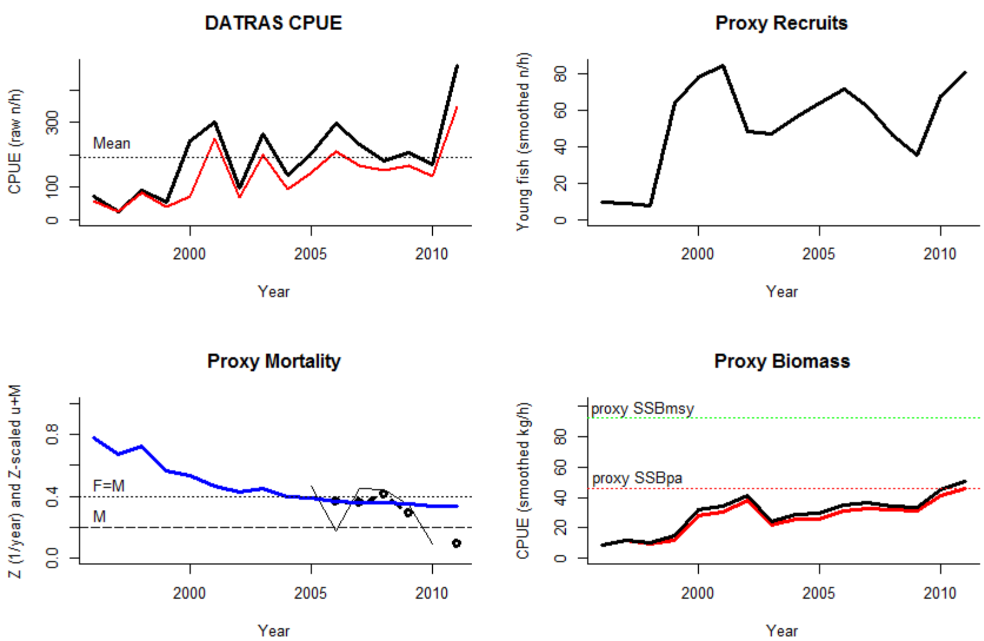

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of plaice caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F = M* (dotted line) as reference points. [CPUE_Area_24.r]

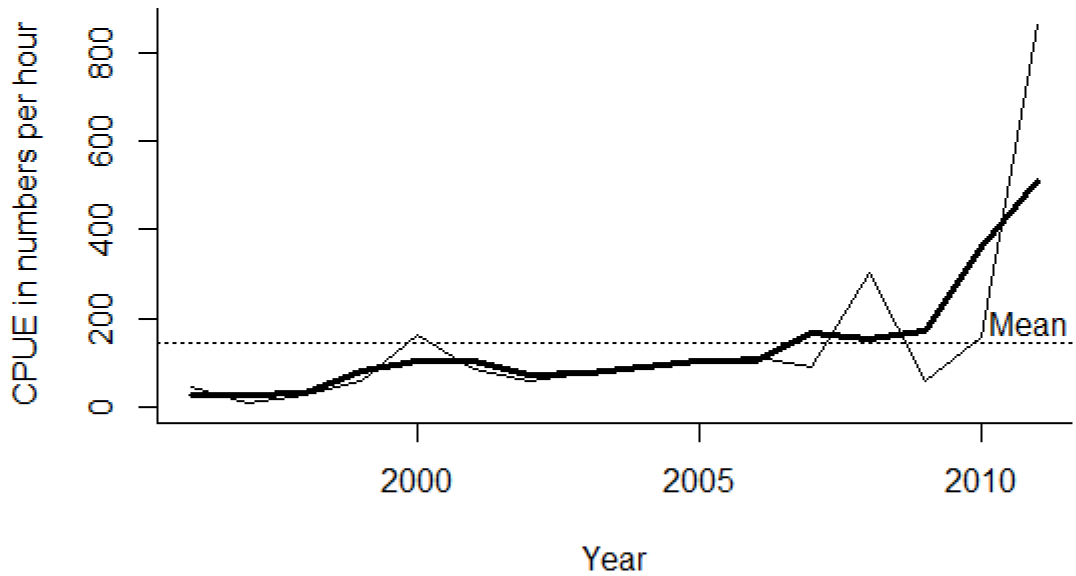

Figure 3. German EEZ abundance graph for the western Baltic Sea (subdivision 22): Time series of average catch in one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. The dotted line indicates the mean CPUE over the time series. [CPUE_Area_24.r]

References

ICES 2013a. ICES advice for Plaice in Subdivisions 21-23 (Kattegat, Belts and Sound) in May 2013, http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/ple-2123_201304142222.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Wetherall, J.A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte 4(1): 12-14

Species: Plaice, Scholle, *Pleuronectes platessa*

Stock: Baltic Sea in subdivisions 24-32 (ple-2432), data-limited, ICES 2013a

Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.46, $2M/Z$ NA, EEZ above mean, EEZ slope increasing

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% CL	n	r^2	Data Ref.	Comment
M (1/year)	0.1					NS plaice
F_{msy} (1/year)	0.1				ICES 2013a	$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	NA				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	5.22				ICES 2013b	Set to largest *proxySSB*
$proxySSB_{msy}$ (kg/h)	10.4				ICES 2013b	This study
a	0.0123	0.0117 – 0.0129	3,821	0.976	ICES 2013b	This study
b	2.94	2.92 – 2.95			ICES 2013b	This study
L_∞ (cm)	57				ICES 2013b	This study
K (1/year)	0.146	0.142 – 0.149	3,804		ICES 2013b	sd log(L)=0.128
t_0 (years)	-0.87	-0.951 – -0.793			ICES 2013b	This study
L_{m50} (cm)	20				ICES 2013b	This study
L_{m90} (cm)	23.4				ICES 2013b	This study
Hockey stick analysis not done, only low SSB during survey						

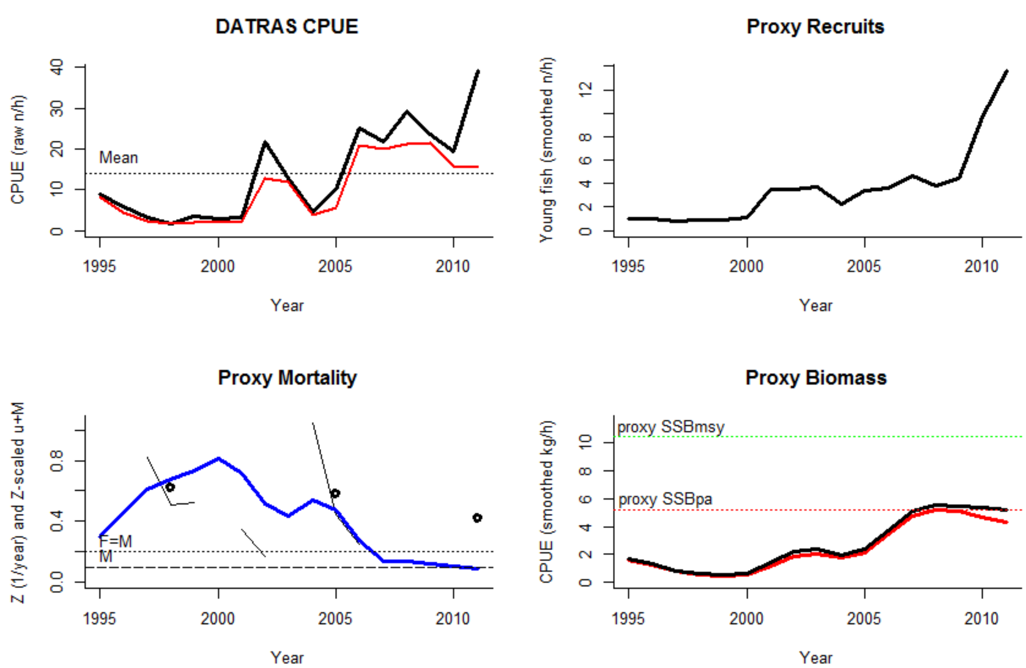

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of plaice caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F = M* (dotted line) as reference points. [CPUE_Area_24.r]

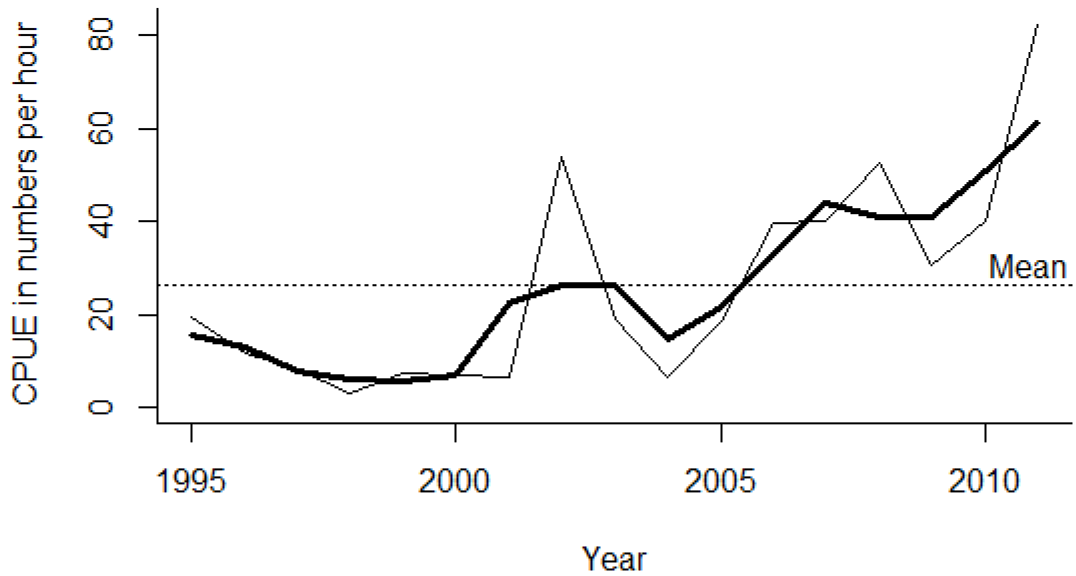

Figure 3. German EEZ abundance graph: Time series of average catch in one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. The dotted line indicates the mean CPUE over the time series. [CPUE_Area_24.r]

References

ICES 2013a. ICES advice for Plaice in Subdivisions 24-32 (Baltic Sea) in May 2013, http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/ple-2432_201304142230.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Wetherall, J.A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte 4(1): 12-14

Species: Sole, Seezunge, *Solea solea*

Stock: North Sea (sol-nsea), Sub-area IV, fully assessed

Scores in 2011: $SSB/pSSB_{msy}$ 0.50, F_{msy}/F 0.74, M/F 0.34, L_{mean}/L_{m90} 1.17, $LFIS/LFIS_{F=M}$ 0.48

EEZ below mean, EEZ slope increasing

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.1				ICES 2012a	
F_{msy} (1/year)	0.22				ICES 2012a	
SSB_{pa} (t)	35,000				ICES 2012a	
SSB_{msy}Trigger (t)	35,000				ICES 2012a	
$pSSB_{msy}$ (t)	70,000				ICES 2012a	This study
Length range (cm)	10 - 42				ICES 2013b	This study
a	0.00497	0.00418 – 0.0059	334	0.975	ICES 2013b	log sd = 0.0525
b	3.2	3.14 – 3.25			ICES 2013b	This study
L_∞ (cm)	40		333		ICES 2013b	This study
K (1/year)	0.148	0.144 – 0.152			ICES 2013b	This study
t_0 (years)	-3.0				ICES 2013b	This study
L_{m50} (cm)	18.8		173		ICES 2013b	This study
L_{m90} (cm)	24.2				ICES 2013b	This study
L_{opt} (cm)	32.7				ICES 2013b	This study
$L_{0.66}$ (cm)	26.7				ICES 2013b	This study
t_{m50} (years)	1.2				ICES 2013b	This study
$t_{0.66}$ (years)	4.3				ICES 2013b	This study
$LFIS_{F=M}$	0.59				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*) (ICES 2012b), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	38,500	0.61	28.9	0.11	0.55	0.36	0.16	1.19	0.88	0.19
2001	30,200	0.58	29.2	0.25	0.43	0.38	0.17	1.21	0.89	0.43
2002	30,800	0.58	29.2	0.25	0.44	0.38	0.17	1.21	0.89	0.41
2003	25,000	0.59	28.9	0.17	0.36	0.37	0.17	1.19	0.88	0.30
2004	37,200	0.51	28.7	0.19	0.53	0.43	0.19	1.19	0.88	0.33
2005	31,800	0.58	29.1	0.19	0.45	0.38	0.17	1.20	0.89	0.33
2006	23,700	0.46	29.5	0.39	0.34	0.48	0.22	1.22	0.90	0.66
2007	17,600	0.47	28.1	0.20	0.25	0.47	0.21	1.16	0.86	0.33
2008	35,900	0.37	29.1	0.18	0.51	0.60	0.27	1.20	0.89	0.30
2009	33,100	0.36	29.4	0.18	0.47	0.60	0.27	1.22	0.90	0.30
2010	33,500	0.36	29.4	0.38	0.48	0.62	0.28	1.22	0.90	0.64
2011	34,700	0.30	28.4	0.29	0.50	0.74	0.34	1.17	0.87	0.48

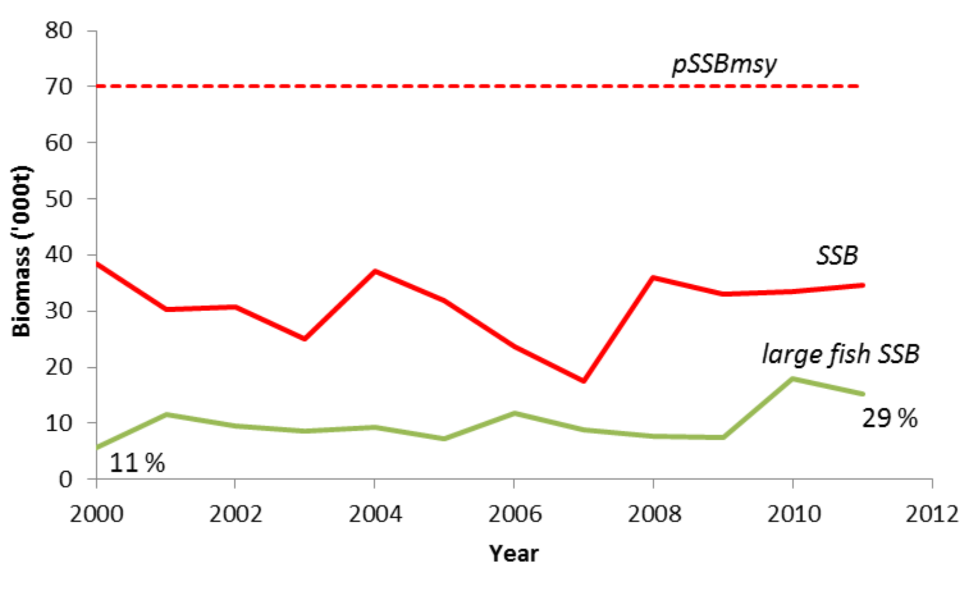

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield (*$pSSB_{msy}$*). The green line shows the biomass of large fish, representing 11% of *SSB* in 2000 and 29% in 2011. [NMS_Germany_Stocks_9.xlsx]

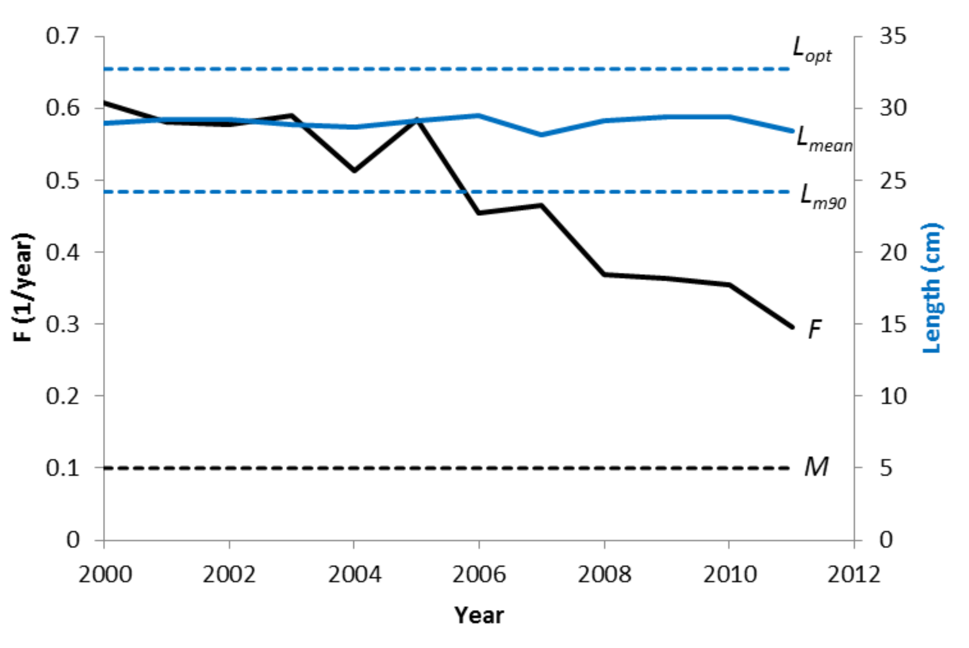

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches *L_{mean}*, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length *L_{m90}* where 90% of the females have reached sexual maturity and the length *L_{opt}* where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

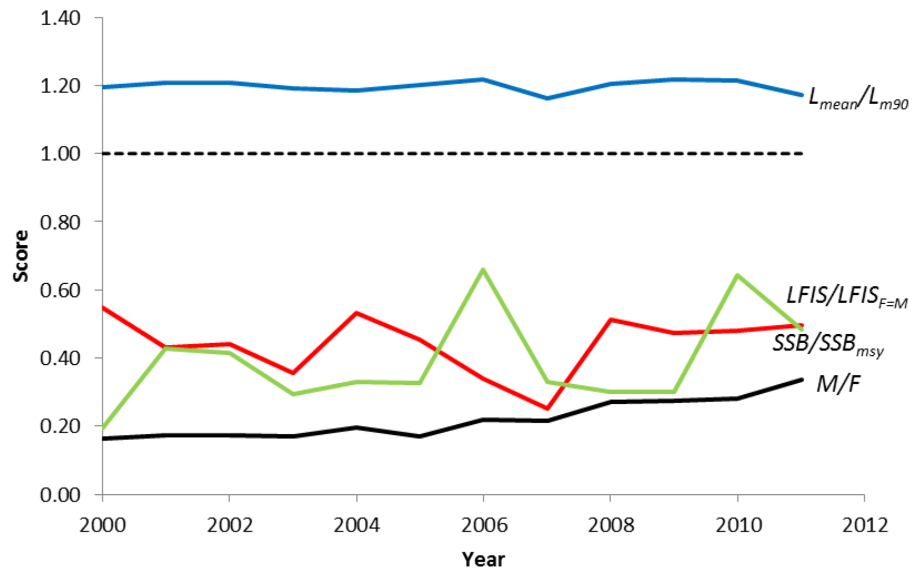

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curve s). [NMS_Germany_Stocks_9.xlsx]

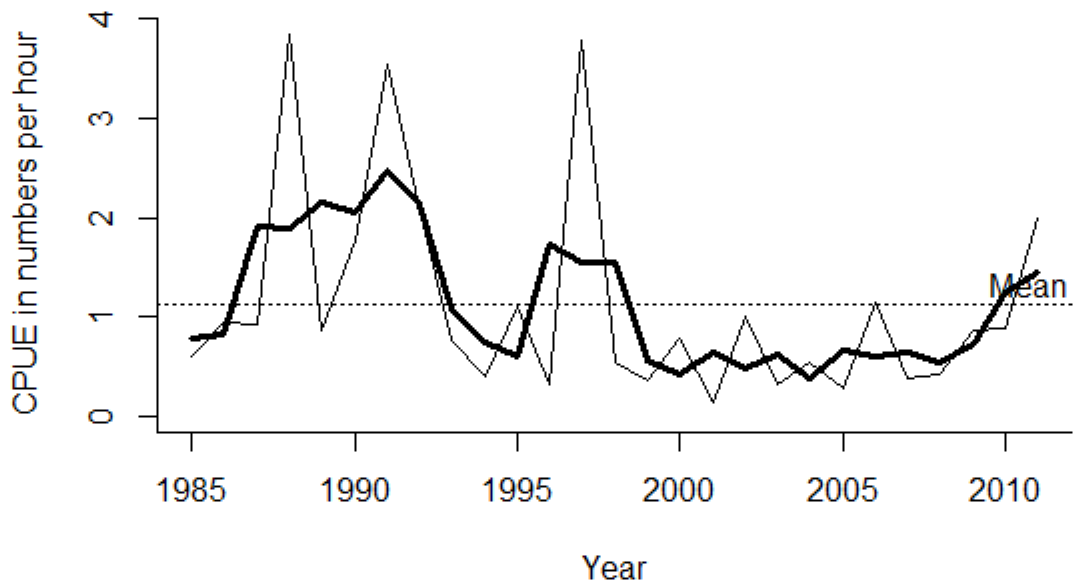

Figure 4. German EEZ abundance graph: Time series of average catch in one hour of survey trawling in ICES roundfish area 6 which includes the German Bight. The bold line is a three-year moving average to reduce scatter. The dotted line indicates the mean CPUE over the time series. [CPUE_Area_24.r]

References

ICES, 2012a. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April - 3 May 2012, ICES Headquarters, Copenhagen. ICES CM 2012/ACOM: 13: 1346 pp. URL: http://www.ices.dk/publications/library/Pages/default.aspx#k=wgnssk (April 2013).

ICES, 2012b. Sole in Subarea IV (North Sea).
Downloaded from http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/sol-nsea.pdf (April 2013).

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Sprat, Sprotte, *Sprattus sprattus*
Stock: North Sea, Subarea IV (spr-nsea), data-limited, ICES 2012a
Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.92, $2M/Z$ NA, EEZ above mean, EEZ slope horizontal

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r, CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.38					ICES M for Baltic sprat
F_{msy} (1/year)	0.38					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	4.59				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	6.42				ICES 2013b	This study
$proxySSB_{msy}$ (kg/h)	12.8				ICES 2013b	This study
Length range (cm)	5 – 15.5				ICES 2013b	This study
a	0.00289	0.00277 – 0.00301	10,639	0.954	ICES 2013b	log sd = 0.0826
b	3.36	3.34 – 3.38			ICES 2013b	This study
L_∞ (cm)	15		10,614		ICES 2013b	This study
K (1/year)	0.503	0.491 – 0.515			ICES 2013b	This study
t_0 (years)	-0.49	-0.534 - -0.446			ICES 2013b	This study
L_{m50} (cm)	8.54		4,230		ICES 2013b	This study
L_{m90} (cm)	10.3					

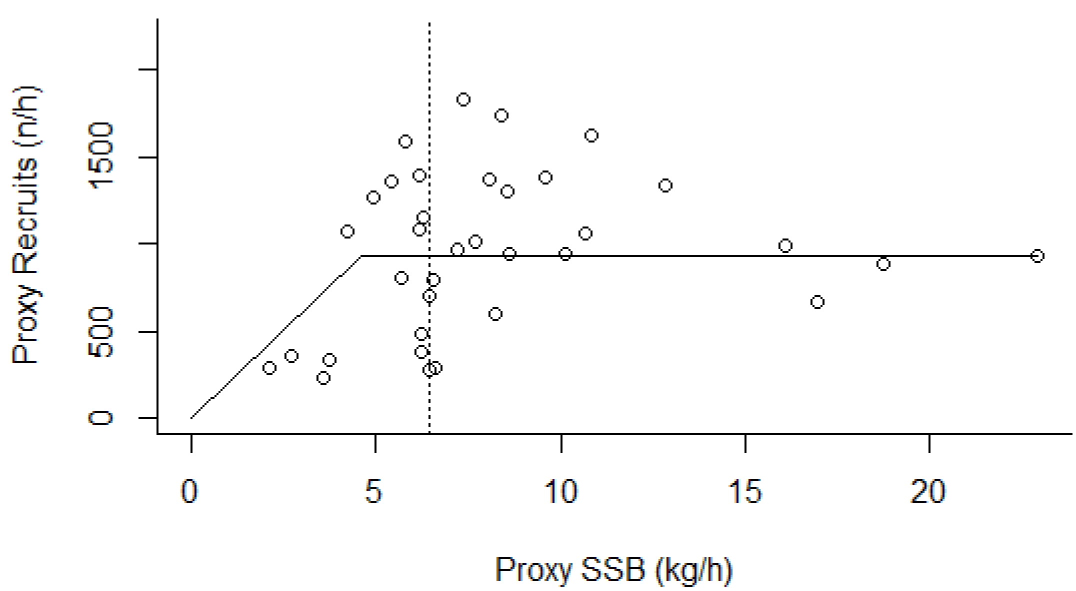

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

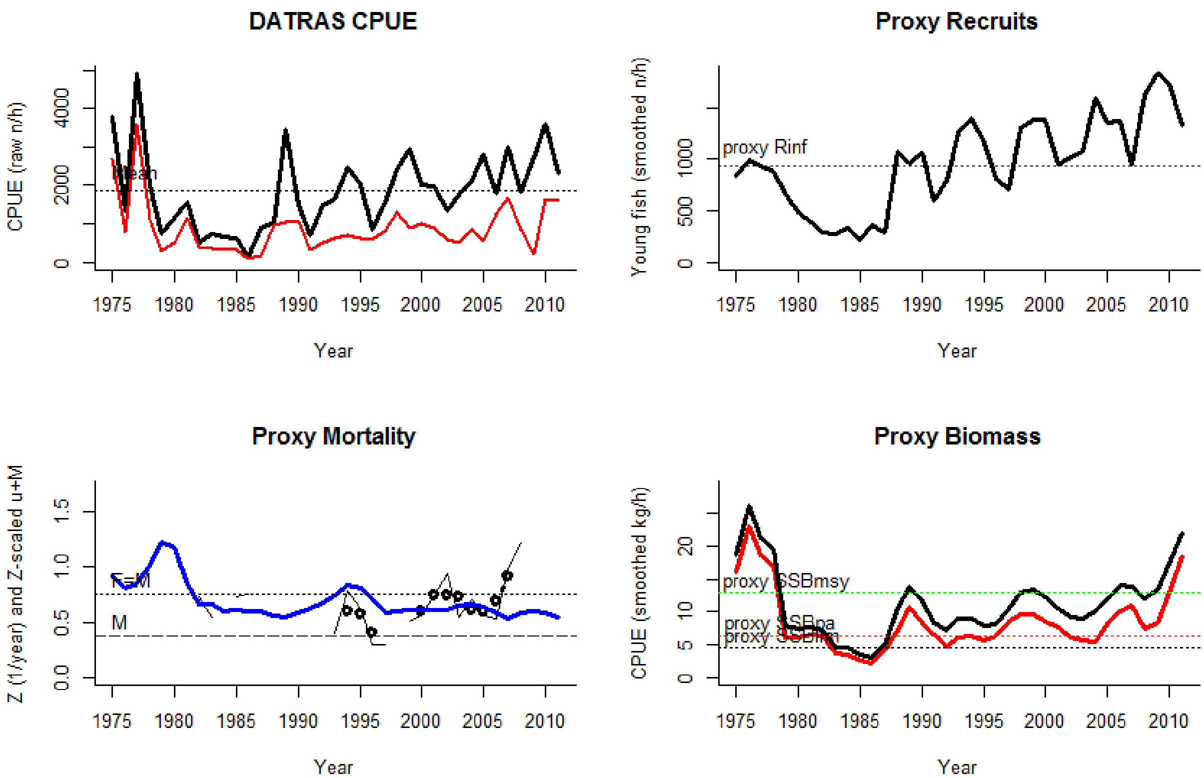

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of sprat caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

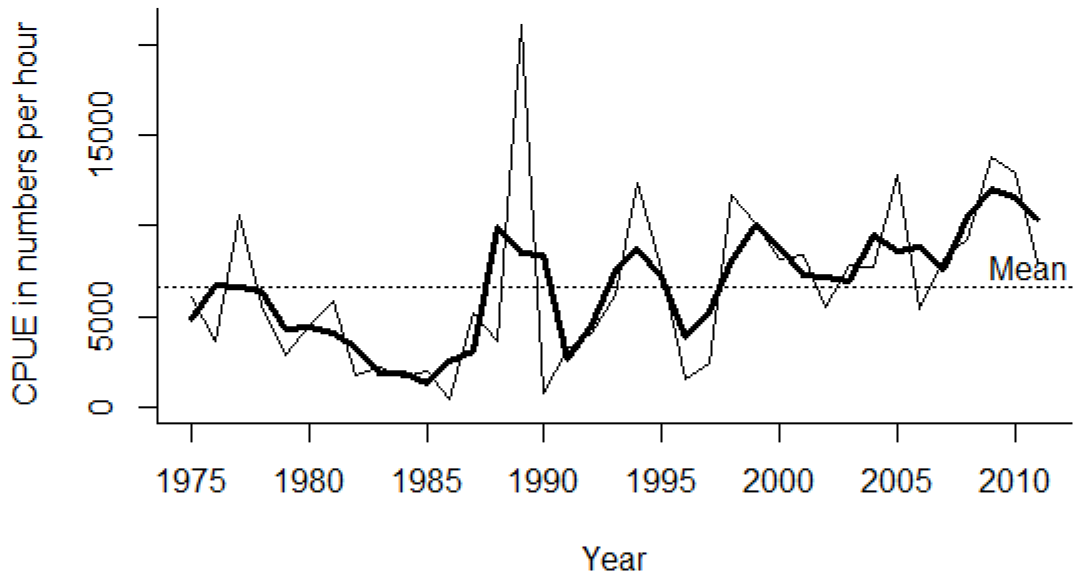

Figure 3. German EEZ abundance graph: Time series of average catch in one hour of survey trawling. The bold line is a three-year moving average to reduce scatter. The dotted line indicates the mean CPUE over the time series. [CPUE_Area_24.r]

References

ICES 2012a. ICES advice for sprat in Subdivisions IV (North Sea) in May 2013, http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/Spr-nsea.pdf

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Sprat, Sprotte, *Sprattus sprattus*
Stock: Baltic Sea (spr-2232), Sub-divisions 22-32, fully assessed
Scores in 2011: $SSB/pSSB_{msy}$ 0.79, F_{msy}/F 1.22, M/F 1.32, L_{mean}/L_{m90} 1.01, $LFIS/LFIS_{F=M}$ 1.78

EEZ below mean, EEZ slope decreasing

Table 1. Parameters, reference points, methods and data sources used for this stock. [SMALK_Analysis_25.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.38				ICES 2012a	
F_{msy} (1/year)	0.35				ICES 2012a	
SSB_{pa} (t)	510,000				ICES 2012a	
SSB_{msy}Trigger (t)	510,000				ICES 2012a	
$pSSB_{msy}$ (t)	1,020,000				ICES 2013b	This study
Length range (cm)	5.5 – 15.5				ICES 2013b	This study
a	0.00377	0.00358 – 0.00397	9,697	0.939	ICES 2013b	log sd=0.194
b	3.2	3.17 – 3.22			ICES 2013b	This study
L_∞ (cm)	15				FishBase	
K (1/year)	0.36				FishBase	
t_0 (years)	-1				FishBase	
L_{m50} (cm)	8.1		2,427		ICES 2013b	This study
L_{m90} (cm)	11.2				ICES 2013b	This study
L_{opt} (cm)	11				ICES 2013b	This study
$L_{0.66}$ (cm)	10				ICES 2013b	This study
t_{m50} (years)	1.2				ICES 2013b	This study
$t_{0.66}$ (years)	2.1				ICES 2013b	This study
$LFIS_{F=M}$	0.52				ICES 2013b	This study

Table 2. Time series of spawning stock biomass (*SSB*) (ICES 2012), fishing mortality (*F*), mean length in the catch (L_{mean}), biomass fraction of large fish in surveys (*LFIS*), and the scores of these indicators against the respective limit reference points. [NMS_Germany_Stocks_9.xlsx]

Year	SSB	F	L_{mean}	$LFIS$	SSB / $pSSB_{msy}$	F_{msy}/F	M/F	L_{mean} / L_{m90}	L_{mean} / L_{opt}	$LFIS$ / $LFIS_{F=M}$
2000	1,256,000	0.33	11.8	0.92	1.23	1.06	1.15	1.05	1.06	1.77
2001	1,137,000	0.31	12.0	0.85	1.11	1.14	1.24	1.08	1.09	1.63
2002	903,000	0.40	11.9	0.90	0.89	0.88	0.96	1.06	1.07	1.74
2003	760,000	0.43	11.6	0.87	0.75	0.82	0.89	1.04	1.05	1.67
2004	964,000	0.51	10.8	0.77	0.95	0.69	0.75	0.97	0.98	1.47
2005	1,177,000	0.47	11.0	0.67	1.15	0.74	0.80	0.98	0.99	1.29
2006	983,000	0.40	11.1	0.94	0.96	0.87	0.95	0.99	1.00	1.80
2007	892,000	0.38	11.1	0.88	0.87	0.93	1.01	0.99	1.00	1.69
2008	996,000	0.39	11.7	0.78	0.98	0.91	0.99	1.05	1.06	1.50
2009	949,000	0.45	11.2	0.86	0.93	0.77	0.84	1.00	1.01	1.65
2010	1,061,000	0.34	11.4	0.70	1.04	1.04	1.13	1.02	1.03	1.35
2011	809,000	0.29	11.3	0.93	0.79	1.22	1.32	1.01	1.02	1.78

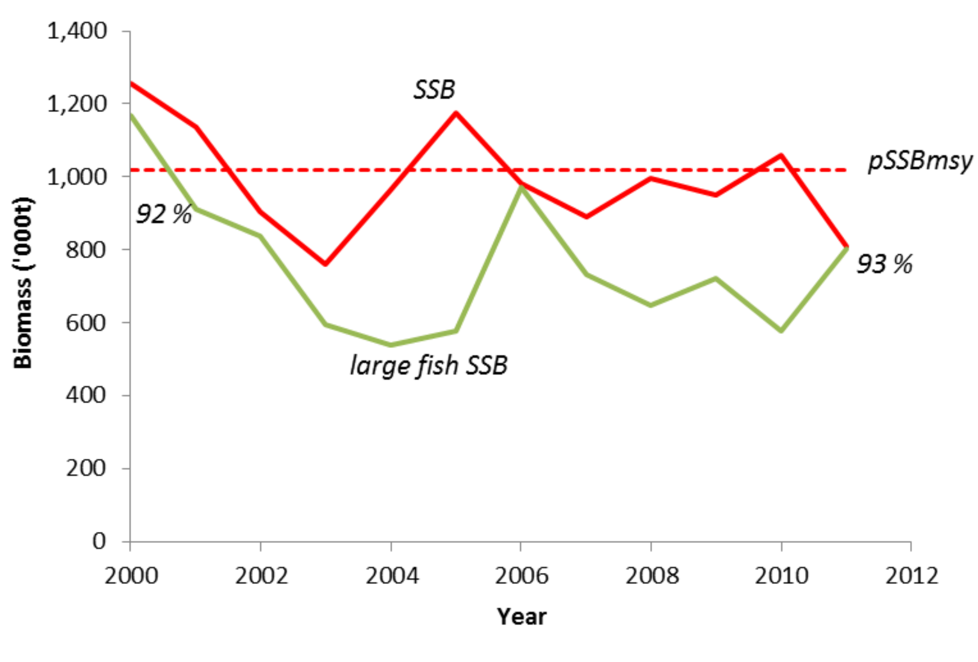

Figure 1: Status graph: Spawning stock biomass (red curve) from 2000 to 2011, with indication of the (proxy) biomass that could produce the maximum sustainable yield ($pSSB_{msy}$). The green line shows the biomass of large fish, representing 92% of *SSB* in 2000 and 93% in 2011. [NMS_Germany_Stocks_9.xlsx]

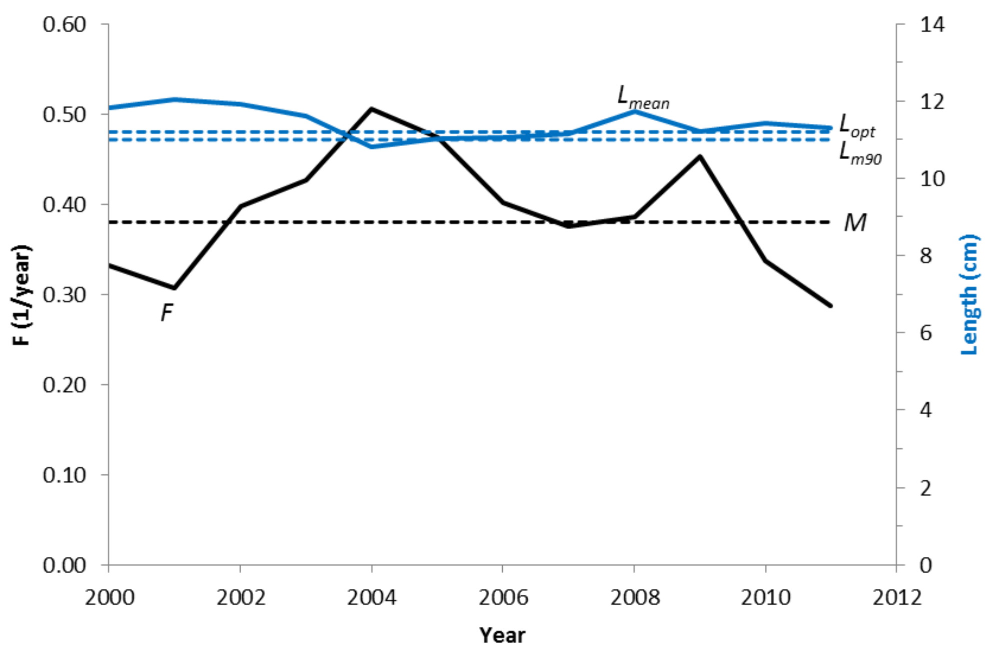

Figure 2. Pressure graph: Fishing mortality *F* and mean length in commercial catches L_{mean}, for 2000-2011. The black dashed line indicates natural mortality *M* as reference point for fishing mortality. The blue dashed lines indicate the length L_{m90} where 90% of the females have reached sexual maturity and the length L_{opt} where fishing has the least impact on size and age structure. [NMS_Germany_Stocks_9.xlsx]

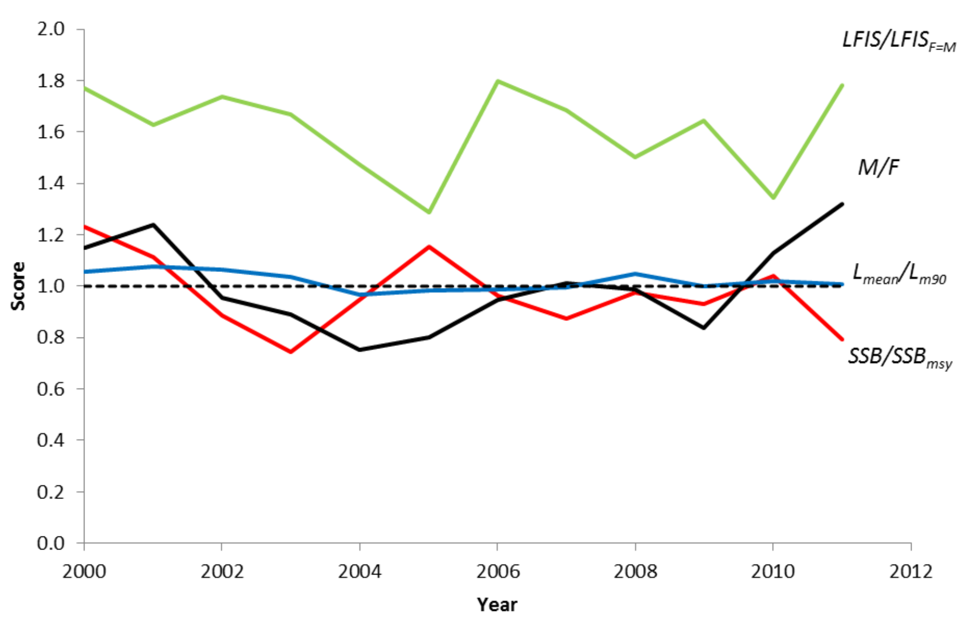

Figure 3. Score graph: Time series of scores for fishing mortality *M/F* (black curve), mean length in catches L_{mean}/L_{m90} (blue curve), spawning stock biomass SSB/SSB_{msy} (red curve), and large fish biomass $LFIS/LFIS_{F=M}$ (green curve). Scores above the dashed 1.0 line would be indicative of sustainable fishing pressure (black and blue curves) and/or a healthy stock status (red and green curves). [NMS_Germany_Stocks_9.xlsx]

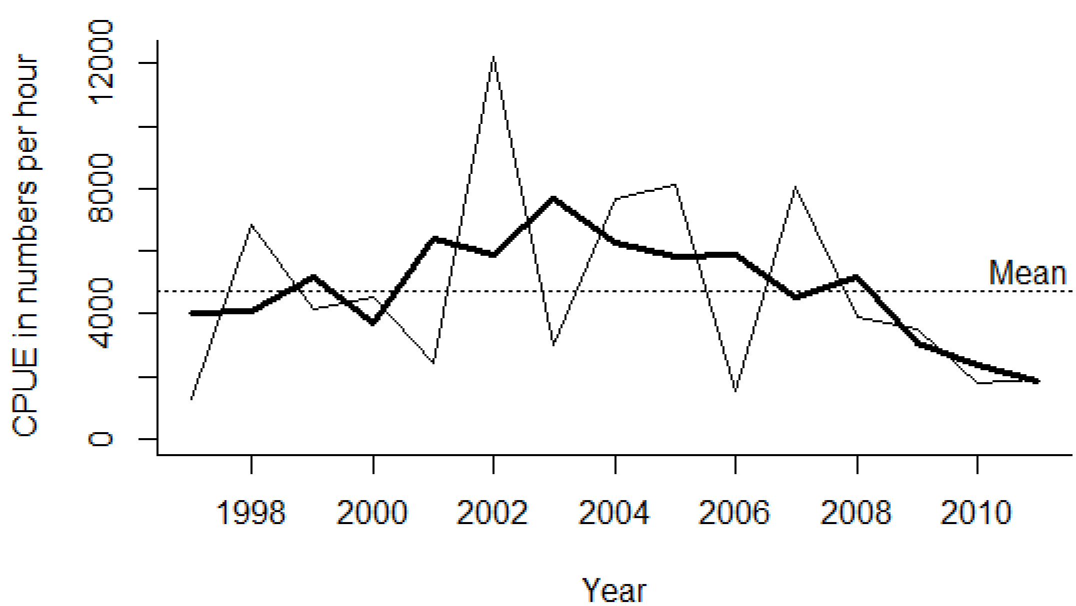

Figure 4. German EEZ abundance graph: Time series of average catch in one hour of survey trawling in ICES subdivisions 22 & 24, which include the Western Baltic. The bold line is a three-year moving average to reduce scatter. The dotted line indicates the mean CPUE over the time series. [CPUE_Area_24.r]

References

ICES, 2012. Sprat in Subdivisions 22-32, Downloaded from http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/spr-2232.pdf

ICES, 2012a. Report of the Baltic Fisheries Assessment Working Group 2012 (WGBFAS), 12 - 19 April 2012, ICES Headquarters, Copenhagen. ICES CM 2012/ACOM: 10. 859 pp. Annex 12 – Stock Annex Baltic Sprat. Downloaded from http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2012/WGBFAS/WGBFAS%20Report%202012.pdf (April 2013).

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Turbot, Steinbutt, *Scophthalmus maximus* (= *Psetta maxima*)
Stock: North Sea (tur-nsea), data-limited
Mean Scores in 2007-11: *proxySSB/proxySSB*$_{msy}$ 0.42, 2*M*/*Z* 0.54, EEZ above mean, EEZ slope horizontal

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r; CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.1					ICES *M* for flatfish
F_{msy} (1/year)	0.1					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	NA				ICES 2013b	This study
$proxySSB_{pa}$ (kg/h)	0.33				ICES 2013b	Set to largest *proxySSB*
$proxySSB_{msy}$ (kg/h)	0.65				ICES 2013b	This study
Length range (cm)	20 - 60				ICES 2013b	This study
a	0.00802	0.00584 – 0.011	101	0.982	ICES 2013b	log sd= 0.0444
b	3.26	3.17 – 3.34			ICES 2013b	This study
L_∞ (cm)	60.2		101		ICES 2013b	This study
K (1/year)	0.19	0.146 – 0.235			ICES 2013b	This study
t_0 (years)	-1.6	-2.59 - -0.6			ICES 2013b	This study
L_{m50} (cm)	28		47		ICES 2013b	This study
Hockey stick analysis not done, only low SSB during survey						

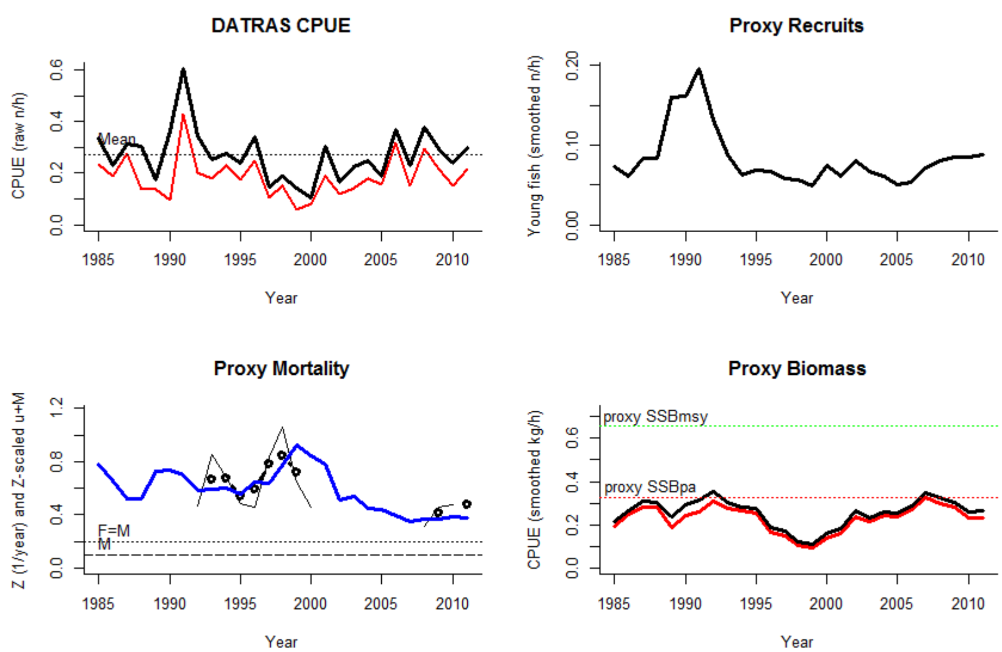

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of turbot caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

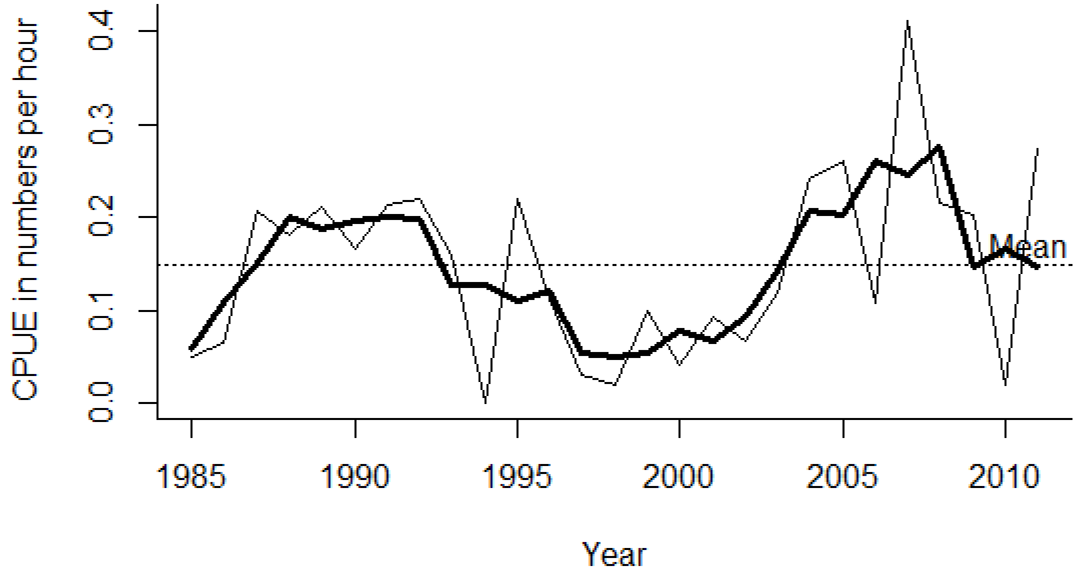

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES roundfish area 6, which includes the German Bight. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES, 2013b. ICES DATRAS Database. Downloaded in April 2013 from http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Species: Turbot, Steinbutt, *Scophthalmus maximus* (= *Psetta maxima*)
Stock: Baltic Sea in subdivisions 22-32 (tur-2232), data-limited, ICES 2012
Mean Scores in 2007-11: $proxySSB/proxySSB_{msy}$ 0.58, 2M/Z NA, EEZ above mean, EEZ slope horizontal

Table 1. Parameters, reference points and data sources used for this stock. [SMALK_Analysis_25.r; CPUE_Area_24.r]

Trait	Estimate	95% Conf. Int.	n	r^2	Data Ref.	Comment
M (1/year)	0.1					ICES M for flatfish
F_{msy} (1/year)	0.1					$F_{msy} = M$
$proxySSB_{lim}$ (kg/h)	1.33				ICES 2013	This study
$proxySSB_{pa}$ (kg/h)	1.86				ICES 2013	This study
$proxySSB_{msy}$ (kg/h)	3.72				ICES 2013	This study
Length range (cm)	9 - 56				ICES 2013	This study
a	0.0179	0.0168 – 0.019	2953	0.973	ICES 2013	log sd=0.0682
b	3.02	3 – 3.03			ICES 2013	This study
L_∞ (cm)	50		2,935		ICES 2013	This study
K (1/year)	0.116	0.115 – 0.117			ICES 2013	This study
t_0 (years)	-3				ICES 2013	This study
L_{m50} (cm)	18.9		1,115		ICES 2013	This study
L_{m90} (cm)	23				ICES 2013	This study

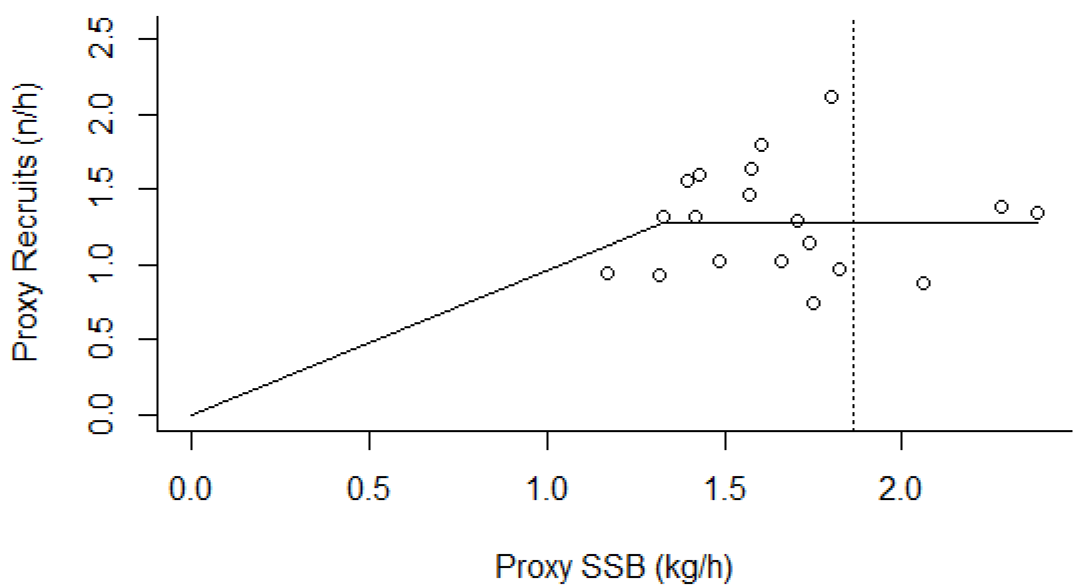

Figure 1. A preliminary stock-recruitment relationship based on CPUE in weight as proxy biomass of mature fish and number of young fish (= proxy-recruits) two years later, derived from length composition in standardized survey catches. A hockey stick was fitted by a rule-based procedure. The dotted vertical line indicates proxy SSB_{pa} as the precautionary borderline to potentially compromised recruitment. [CPUE_Area_24.r]

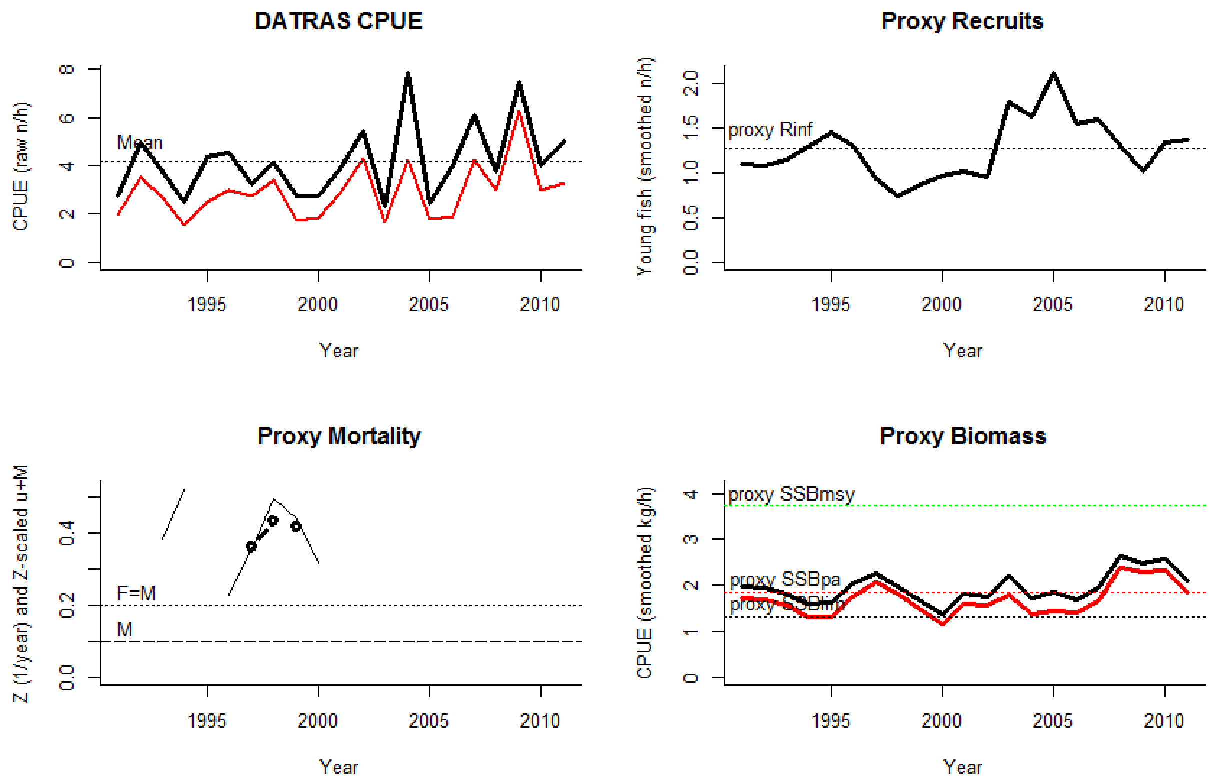

Figure 2. Assessment of data-limited stocks. The black line in the upper left graph shows the raw data obtained from the ICES DATRAS CPUE-per-length-per-area database, as numbers of turbot caught on average per year by one hour of standardized research trawling. The red line indicates the number of individuals larger than the length at 50% female maturity. The upper right graph shows the number of "youngest fish in the survey", as proxy for recruits, with the dotted line indicating the geometric mean of recruitment at large stock sizes. In the lower right graph, length of individuals was converted to weight and added up to show biomass of mature (red) and all fish (black). The dotted horizontal lines are proxy reference points for spawning stock biomass. The lower left graph shows total mortality *Z* experienced over the respective previous two years (black circles) and scaled exploitation rate *u+M*, both as a proxies for fishing mortality, with indication of natural mortality (*M*, dashed line) and total mortality if *F* = *M* (dotted line) as reference points. [CPUE_Area_24.r]

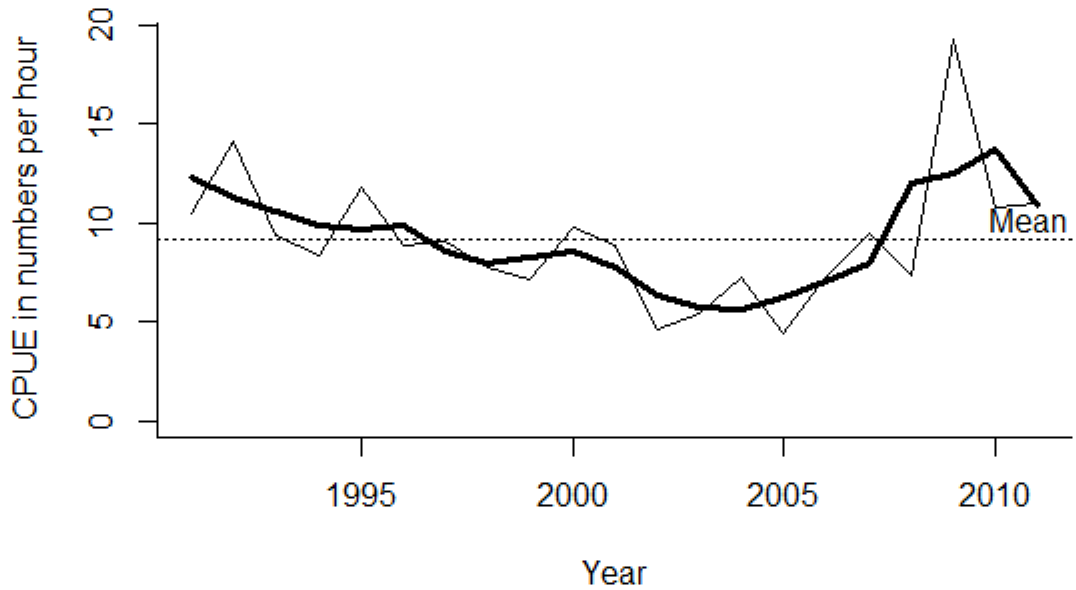

Figure 3. Average catch in numbers resulting from one hour of trawling with standardized survey gears in ICES areas 22 & 24, which include the German EEZ. The bold line represents a three-year moving average to reduce scatter and facilitate interpretation of trends. The dotted line indicates the mean catch of the time series. [CPUE_Area_24.r]

References

ICES 2012. ICES advice for turbot in subdivisions 22-32 (Baltic Sea), June 2012.
http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/tur-2232.pdf

ICES, 2013. ICES DATRAS Database. Downloaded in April 2013 from
http://datras.ices.dk/Data_products/Download/Download_Data_public.aspx .

Appendix II. Data sources and methods

Data sources

For the purpose of this study we analysed data from 2000-2011 for fully assessed stocks. For CPUE trends and data-limited stocks we also analysed previous years, if available. Data for fully assessed stocks were extracted from the ICES Stocks Summary database, downloaded from the ICES portal in April 2013. Data used were *SSB*, B_{pa} or B_{msy}Trigger, *F*, *M* and F_{msy}. Data for numbers and weight-at-age in the catch and in the stock were extracted from the full assessment reports of the respective stocks, downloaded from the ICES portal in April 2013 (see references for the respective stocks in the Appendix). Survey data were obtained from the ICES DATRAS portal, downloaded in April 2013. For the North Sea we used data from the International Bottom Trawl Surveys (NS-IBTS, ICES 2010). For the Baltic we used data from the Baltic International Trawl Survey (BITS, ICES 2011). Specifically, we used the DATRAS data set SMALK for determination of length-weight relationship, von Bertalanffy growth parameters and length at 50% and 90% of female maturity. We used the DATRAS CPUE-per-length-per-area data set for determining the catch in numbers per one hour of trawling. We aggregated CPUE across areas by dividing the sum of mean CPUEs in the respective areas by the number of areas (ICES 2012a). For abundance in the German EEZ we used ICES roundfish area 6 for the southern North Sea and ICES subdivisions 22 and 24 for the western Baltic. For the data-limited stocks we also used this data set for the estimation of proxy *SSB* and proxy *F* values, derived from CPUE at length. For data cleaning we used maximum lengths of species as reported by FishBase, to exclude e.g. sprat of 24 cm length, which were probably misidentified herring, as the maximum known length for sprat is 16 cm. Although DATRAS provided data until 2012 and first quarter of 2013, we only used data until 2011, because ICES warned that data for the last year and quarter may be incomplete and misleading.

Methods

In the following the methods applied for determining indicators and reference points are given in alphabetic order. All lengths are in cm, all weights in g and time or age are given in units of years, unless indicated otherwise. All data analysis was done with the statistical software R or with Excel spreadsheets.

a and ***b*** are parameters of the length-weight relationship given by

$$W = a\ L^b$$

where *W* is the whole body weight in g and *L* is the total body length in cm. We estimated the parameters by fitting a weighted linear regression to log-transformed values of weight and length.

F is the rate of fishing mortality, i.e., the fraction of fishes dying from fishing. This value was obtained from the ICES Stock Summary database.

K is a parameter of the von Bertalanffy growth function (VBGF), describing how fast asymptotic length or weight is approached. It was estimated by fitting the VBGF to length-at-age data in the DATRAS SMALK data set. The VBGF in length is given by

$$L_t = L_{inf}(1 - e^{-K(t-t_0)})$$

where L_t is the length at age t and L_{inf} and t_0 are additional parameters. Note that because of the high scatter in the length-at-age data we used an independent method to fix L_{inf} and only estimated K and t_0 with the curve-fitting function in R.

$L_{0.66}$ is the length above which fish are considered large. $L_{0.66}$ = 2/3 L_{inf}. See *LFIS* for main use of this length.

LFIS**:** The large fish indicator for single stocks (*LFIS*) is modelled after the large fish indicator (*LFI*) for ecosystems (Heslenfeld and Enserink 2008). The *LFIS* indicator gives the biomass of large fish relative to the biomass of all mature fish in a given stock. Fish longer than 2/3 of asymptotic length (L_{inf}) were considered as large. This length $L_{0.66}$ was chosen because it marks approximately the maximum growth rate in body weight and the end of the nearly linear growth phase in length. While relative length at first maturity varies considerably between species, life history theory suggests that fish above 2/3 L_{inf} are all mature adults (Froese and Pauly 2013). Mature fish were defined as those longer than L_{m50}, i.e. the length where 50% of the females reach maturity. The *LFIS* is then given by

$$LFIS = \frac{\sum N\, W_{L>2/3L_{inf}}}{\sum N\, W_{L \geq L_{m50}}}$$

For application with data from age-based full stock assessments, length was converted to age, i.e. L_{m50} was converted to t_{m50} and $L_{0.66}$ to $t_{0.66}$. Since fish near to or larger than L_{inf} cannot be aged by this method, we restricted the analysis to lengths <= 0.95 L_{inf}. To keep the procedure simple, we considered as mature only fishes in the integer age-classes $t >= t_{m50}$ and as large only fishes with $t >= t_{0.66}$. For the survey data, lengths were converted into weights with the respective length-weight relationship.

$LFIS_{F=M}$ is the reference point for the *LFIS* indicator. For age-based fully assessed stocks, it is derived by multiplying the average body weight in a year class with the number of survivors from a fishing mortality $F = M$ and thus a total mortality of $Z = 2\ M$. The number of survivors to the subsequent year class is then given by

$$S = e^{-2M}$$

Number in year class multiplied with mean body weight in year class gives the biomass of the year class. Adding up the biomass in year classes with $t >= t_{0.66}$ and dividing this by the sum of biomass in year classes with $t >= t_{m50}$ gives the expected *LFIS* value for fishing with $F = M$.

L_{inf} is a parameter of the von Bertalanffy growth function (VBGF), describing the asymptotic length that individuals of a population would approach if they were to live forever. The DATRAS SMALK data set contained length-at-age data which were used for fitting the VBGF. However, these data contained a high degree of scatter and fish with lengths around L_{inf} were typically not present. We therefore used the Wetherall, 1986, Weatherall et al. 1987 method for deriving direct estimates of L_{inf} from length frequency data. If this method provided unrealistic high or low estimates, we used either the maximum length in the data set or the median of annual maximum length as proxies for L_{inf}. These cases were rare and are indicated in the respective tables in Appendix I.

L_{m50} is the length where 50% of the females have reached sexual maturity. It was estimated from maturity-stage-at-length data in the DATRAS SMALK data set. For this purpose, only the standardized DATRAS maturity stages 1-4 were considered, where 1 indicates immature fishes and 2-4 indicate mature females with ovary stages from 2=maturing to 3=spawning to 4=spent. A sigmoid curve was fitted to the ratio of mature females to all females considered, using the binomial gml() function in R. From the model coefficients, estimates of the length at 50% and 90% maturity were derived.

L_{m90} is the length where 90% of the females have reached sexual maturity. See L_{m50} for methods.

L_{mean} is the weighted mean length in commercial catches. Data of commercial catch-by-length-class are not provided by ICES. We therefore used mean weight-at-age in the catch (*W*) and numbers-at-age in the catch (*N*) from the expert group assessment reports to first obtain the weighted mean weight in the catch (W_{mean}) from

$$W_{mean} = \frac{\sum N\, W}{\sum N}$$

We then used an inverted length-weight relationship to obtain L_{mean} from

$$L_{mean} = \left(\frac{W_{mean}}{a}\right)^{\frac{1}{b}}$$

where *a* and *b* are parameters of the length-weight relationship.

L_{opt} is a reference point first suggested by Sidney Holt in 1958. It is the length where catch is maximized for a given fishing mortality *F* and where consequently the theoretical maximum catch could be obtained with infinite *F* (Holt 1958). As Froese (2004) pointed out, L_{opt} is the length with maximum biomass per length class. Therefore a given catch taken only at this length has the least impact on the size and age structure of the stock. In reality, it is not possible to catch fish only at one length. However, since biomass per length class declines at lengths above L_{opt}, catching fishes only at and beyond L_{opt} results in a similarly low impact on the size and age structure as fishing at L_{opt} (Froese et al. 2008). L_{opt} can be calculated from

$$L_{opt} = L_{inf}\left(1 - \frac{3}{3+\frac{M}{K}}\right)$$

If growth parameters or natural mortality are unknown, a good proxy for L_{opt} can be obtained as 2/3 of maximum length known for the stock.

L_v is the length where a species is fully selected by a gear, here assumed to be approximated by the most abundant length in the catch. We estimated L_v as the median of the peaks in annual weighted length-frequency histograms.

M is the natural rate of mortality, i.e., the fraction of fish dying from causes such as predation, environmental hazards, diseases or old age. For the purpose of this study we used estimates of *M* as provided by ICES expert groups. If no such estimates were available, we used M values from neighbouring populations or from the life-history relationship $M = 1.5\ K$ (Jensen 1996), where K is a parameter of the von Bertalanffy growth function.

proxySSB is a proxy for spawning stock biomass derived from survey data. It is the catch in kg per hour of all fish that are larger than L_{m50}, i.e., the length where 50% of the females have reached sexual maturity. Since trends in survey catches are expected to reflect trends in stock abundance, trends in *proxySSB* will reflect trends in true *SSB*.

***proxySSB**$_{lim}$* is a proxy for the spawning stock biomass below which recruitment is reduced. It is derived from survey data as follows: the length of specimens is converted to corresponding weight using a length-weight relationship. The weight of individuals with lengths >= L_{m50} is added up to give the proxy spawning biomass *proxySSB*. Individuals shorter than L_{m50} are considered recruits. The relation between *proxySSB* and the number of recruits in a subsequent year (difference is equal to mean age of recruits) is then a proxy stock-recruitment relationship. A proxy hockey stick stock-recruitment relationship was derived as follows: the shaft of the hockey stick is the geometric mean number of recruits R_{inf} at biomasses in the upper half of the biomass range, to represent average long-term recruitment at reasonably large stock sizes. The shaft is connected to the blade at the smallest biomass which resulted in a recruitment that was at least as large as the long-term average. The tip of the blade connects to the origin of the S-R graph. The 'break point' where shaft and blade meet marks the proxy biomass SSB_{lim}, below which recruitment in the data was below the average at large stock sizes. The upper 95% confidence limit of R_{inf} was used to determine a precautionary biomass limit SSB_{pa}, by again determining the biomass below which recruitment was reduced. If this procedure resulted in a precautionary biomass that was smaller than 1.4 SSB_{lim}, then SSB_{pa} was set to 1.4 SSB_{lim}, as is often done in data-limited situations by ICES working groups. SSB_{pa} then gives the precautionary borderline to potentially compromised recruitment. Multiplying SSB_{pa} by two gives the proxy SSB_{msy} that can produce the maximum sustainable yield, see Figure 12.

***proxySSB**$_{msy}$* is a proxy for the biomass that can produce the maximum sustainable yield SSB_{msy}. It is derived by multiplying the precautionary biomass $proxySSB_{pa}$ below which recruitment may be reduced by the factor of two. This factor is derived from the text book knowledge that reduced recruitment may be expected at stock sizes below half of SSB_{msy}.

***proxySSB**$_{pa}$* is a proxy for SSB_{pa} derived from survey data, often by multiplying $proxySSB_{lim}$ with 1.4 to obtain a precautionary distance to the spawning stock biomass below which recruitment is reduced. The factor 1.4 is used by ICES for similar cases (see e.g. ICES 2012b). See longer explanation under $proxySSB_{lim}$.

***pSSB**$_{msy}$* is a preliminary placeholder for the spawning stock biomass that can produce the maximum sustainable yield (SSB_{msy}). If ICES advice documents contained estimates of SSB_{pa} or $SSB_{msy}Trigger$, then $pSSB_{msy}$ was calculated as 2 * SSB_{pa} or 2 * $SSB_{msy}Trigger$.

R_{inf} is the long-term average recruitment in numbers from reasonably large stock sizes. It is calculated as geometric mean of number of recruits produced by spawning stock sizes in the upper half of the biomass range on record.

$$R_{inf} = e^{\frac{\sum \log(SSB)}{N_{SSB}}} \mid SSB > \frac{\max(SSB) + \min(SSB)}{2}$$

SSB is the spawning stock biomass in tonnes. This value was obtained from the ICES Stock Summary database.

SSB_{pa} is a reference point estimated by ICES to indicate the spawning stock biomass below which regular recruitment may be compromised because of low abundance of spawners. SSB_{pa} estimates were taken from ICES advice documents, unless indicated otherwise (e.g. cod-2532).

SSB_{msy} is an internationally agreed reference point indicating the level of spawning stock biomass that can produce the maximum sustainable yield. ICES does not provide estimates of SSB_{msy}. We therefore used the preliminary $pSSB_{msy}$ for the purpose of this study.

$SSB_{msy}Trigger$ is a reference point estimated by ICES to indicated the lower boundary of spawning stock biomass values that may equal SSB_{msy}. $SSB_{msy}Trigger$ estimates were taken from ICES advice documents.

t_0 is a parameter of the von Bertalanffy growth function (VBGF). It accounts for the fact that at zero age organisms already have a certain size. t_0 is typically small and negative and does not affect the two other parameters of the VBGF, namely L_{inf} and *K*. See definition of *K* for additional information.

$t_{0.66}$ is the age corresponding to the length $L_{0.66}$ indicating large fishes. See t_{m50} for calculation.

t_{m50} is the age corresponding to the length where 50% of the females have reached maturity. It is calculated from

$$t_{m50} = -\frac{\ln\left(1 - \frac{L_{m50}}{L_{inf}}\right)}{K} + t_0$$

where L_{inf}, *K* and t_0 are parameters of the von Bertalanffy growth equation.

t_{opt} is the age where cohort biomass is maximum and where thus a given catch takes the least proportion of cohort biomass. It can be calculated from the corresponding length L_{opt} or directly from

$$t_{opt} = \frac{\ln(\frac{3K+M}{M})}{K} + t_0$$

where *K* and t_0 are parameters of the von Bertalanffy growth equation and and *M* is the rate of natural mortality.

Z is the total rate of mortality, consisting of natural mortality *M* and fishing mortality *F*, with $Z = M + F$. It was used as a proxy for *F* in the survey data. *Z* was estimated through a modification of the length-inverted catch curve method (Pauly 1983), where a linear regression is fitted to the descending slope of age-frequency data in a given year or haul, with the frequencies given as natural logarithms. The absolute slope of the decline in numbers per age is then *Z*. Here we used DATRAS CPUE per length per haul data, which contained no ages. We therefore used the rearranged VBGF to assign age to length.

$$t_L = -\frac{\ln(1-\frac{L_t}{L_{inf}}}{K} + t_0$$

where t_L is the age at length L_t and L_{inf}, *K* and t_0 are parameters of the VBGF. We limited this age conversion to lengths <= 95% of L_{inf} to avoid unrealistically high or infinite ages. For every year in the time series, we determined the number of individuals within a narrow length range around 1/3 L_{inf} = $L_{0.33}$. We calculated the corresponding age $t_{0.33}$. We then calculated the corresponding lengths in the subsequent years $t_{0.33}$ + 1, $t_{0.33}$ + 2, and $t_{0.33}$ + 3. We determined the observed numbers of individuals in these length classes. The decline in numbers over the three years represents the mortality rate experienced by the individuals. We fitted a linear regression to the natural-log-transformed numbers and obtained thus *Z* from the absolute slope. Note that, although variability in length increases with age, we assumed a constant width of the length ranges, based on the assumption that individuals that fell out of the range because of too slow or too fast growth would be replaced by similar individuals from the bordering length ranges. If the length class $L_{0.33}$ was not yet fully selected, i.e., $L_{0.33} < L_v$, we chose L_v as starting length range. We assigned the resulting estimates of *Z* to the last year in a sequence, i.e., the first three years in a time series did not get estimates of *Z*. If the fit over the four data points for each sequence was unsatisfactory ($r^2 < 0.5$), *Z* was assigned a NA value.

References

Froese, R. 2004. Keep it simple: three indicators to deal with overfishing. Fish and Fisheries 5:86-91.

Froese, R., A. Stern-Pirlot, H. Winker and D. Gascuel. 2008. Size matters: how single-species management can contribute to ecosystem-based fisheries management. Fisheries Research 92:231-241.

Froese, R. and D. Pauly. 2013. Fish Stocks. p. 477-487. In Simon Levin (ed.) Encyclopedia of Biodiversity. Volume 3. Academic Press, 5504 p.

Heslenfeld P. and E.L. Enserink. 2008. OSPAR ecological quality objectives: the utility of health indicators for the North Sea. ICES Journal of Marine Science 65:1392-1397.

Holt, J.S. 1958. The evaluation of fisheries resources by the dynamic analysis of stocks, and notes on the time factors involved. ICNAF Special publication I, p. 77-95.

ICES 2010. Manual for the International Bottom Trawl Surveys. ICES, Copenhagen, 69 p.

ICES 2011. Manual for the Baltic International Trawl Surveys. ICES, Copenhagen, 69 p.

ICES 2012a. NS-IBTS indices calculation procedure. Downloaded in May 2012 from http://datras.ices.dk/Documents/Manuals/Indices_Calculation_Steps_IBTS.pdf

ICES 2012b.Cod in Subdivisions 25-32, Advice May 2012. Downloaded from http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2012/2012/cod-2532.pdf

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53:820-822.

Pauly, D. 1983. Length-converted catch curves: a powerful tool for fisheries research in the tropics (Part I). ICLARM Fishbyte 1(2):9-13.

Wetherall, J.A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte 4(1):12-14.

Wetherall, J.A., J.J. Polovina and S. Ralston, 1987. Estimating growth an:d mortality in steady-state fish stocks from length-frequency data. ICLARM Conf. Proc. 13 53-74.