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Contents

Executive summary

This year's meeting was held back-to-back with the "ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB)" in order to facilitate exchange among Integrated Ecosystem Assessment (IEA) WGs within the SCICOM Steering Group on the Regional Seas Programme (SSGRSP) and to find common ground in relation to operationalization of integrated assessments. The meeting was characterised by intensive discussions and presentations of approaches and tools to operationalize IEAs. One main conclusion from the WGINOSE-meeting is that the level of coordination required to routinely run fully operational IEA cycles would need a completely new governance structure where the decision making body has full control of all the resources working on science underpinning fisheries and marine environmental management. As implementation of a new governance structure is highly unlikely over the next decade, focus of IEA working groups over the next years should be on the development of IEA tools that would fit to advise the management systems as to be implemented in the revised CFP and the MSFD rather than working towards implementation of IEA cycles of e.g. of the Levin *et al.* (2009) type.

Naturally, such a discussion meeting was less productive in terms of analyses and products. Nonetheless, WGINOSE updated the North Sea trend analyses for two areas, i.e. the Northern and Southern North Sea, approximately separated by the 50m depth line and established a preliminary Bayesian Belief Network for some major drivers and ecosystem responses of the North Sea, which might be used to explore pressure-state relationships in a probabilistic mode and thus a useful decision support tool for ecosystem management.

One essential part of IEAs is the use of different ecosystem models within the assessment process. As WGINOSE could not attract a range of modellers to participate in the group, WGINOSE decided to cooperate closely with the newly formed "Working Group on Integrative, Physical-biological, and Ecosystem Modelling (WGIPEM)" of which a co-chair, Myron Peck, was present at the WGINOSE meeting.

WGINOSE strongly supports the work of WGECO and WGISUR and CSG MFSD on developing integrated fisheries and ecosystem surveys to meet the data requirements of future IEAs.

1 Opening of the meeting

This year's meeting of WGINOSE was organized as back-to-back meeting with the ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) and kindly hosted by the Baltic NEST Institute (BNI) within the Stockholm Resilience Center/Stockholm University. Participants of the meeting were welcomed by Maciej Tomczak, co-chair of WGIAB, followed by a presentation by Christoph Humborg, head of BNI. Afterwards introductions to WGIAB and WGINOISE and their terms of references for the meeting were given by Lena Bergström, co-chair of WGIAB, and Christian Möllmann, co-chair of WGINOISE, respectively. Co-chairs developed in advance of the meeting items of common relevance for the two groups the main task being to develop scientific tools for an integrated ecosystem assessment and advice.

As an introduction to the meetings of both groups, plenary talks were given on the following topics:

- The U.S. Approach to Integrated Ecosystem Assessment (Phillip Levin, NO-AA Fisheries)
- Introduction to Stockholm Resilience Centre research – the concept of resilience (Carl Folke, Stockholm Resilience Centre)
- The HELCOM Coreset project (Samuli Korpinen, HELCOM)
- ICES Ecosystem overviews (Han Lindeboom, ICES)

At the WGINOSE-meeting Gerd Kraus (GK) and Christian Möllmann (CM) introduced the aims and vision for WGINOSE. The group is intended to contribute to the development of the Ecosystem Approach to Marine Resource Management via delivering the science-base for Integrated Ecosystem Assessments (IEAs) for the North Sea. CM furthermore gave an introduction into the Terms of Reference (ToRs) and how they relate to planned work of the meeting. The ToRs for this meeting were:

The Working Group on Integrated Assessments of the North Sea (WGINOSE), chaired by Gerd Kraus, Germany, and Christian Möllmann, Germany, will meet in Stockholm, Sweden, 26–30 March 2012 to:

a) Conduct a review on the outcome of WGIAB, WGNARS, WGEAWESS and SGIMM considering implications for the work of WGINOSE;

b) Conduct Integrated Status and Trend Assessment for different North Sea sub-systems;

c) Start using ecosystem modelling in an Integrated Ecosystem Assessment framework;

d) Promote development of Bayesian belief network modelling as decision support tools in ecosystem management and IEA's;

e) Consider to facilitate the interaction between WGINOSE and fish stock assessment as well STECF working groups.

2 Adoption of the agenda

The agenda (see Annex 2) was adopted by the group after a short discussion.

3 Introduction to meeting

WGINOSE is an initiative to develop the science-base for Integrated Ecosystem Assessments (IEA) in the North Sea started in 2011. The group works towards this goal in cooperation with similar groups within the ICES SCICOM Steering Group on the Regional Seas Programme (SSGRSP).

This first meeting of WGINOSE in 2012 had the aim to re-activate activity towards Integrated Ecosystem Assessments (IEA) for the North Sea using the groundwork of the REGNS group and WGHAME as baseline. Its focus was clearly on reviewing available (i) approaches to IEA, (ii) data for analyses on ecosystem status and trends, as well as (iii) modelling approaches to be used in a future IEA. The meeting was quite successful in that it attracted scientists from many different fields and hence set the baseline for its future work.

Participation in this year's meeting was not as good as in the first meeting (17 scientists from 6 countries) and expected expertise especially in ecosystem modelling was lacking (see chapter 6). The group hence decided to focus this year's work on (i) "Conduct Integrated Status and Trend Assessment for different North Sea subsystems (ToR b; chapter 5)", and (ii) "Promote development of Bayesian belief network modelling as decision support tools in ecosystem management and IEA (ToR d, chapter 7)".

Furthermore, a large part of the meeting was devoted to informal discussions on how to further Integrated Ecosystem Assessments and Advice within ICES and its several constituent parts. Several presentations were given in this context:

- "Examples of approaches to implement the Ecosystem Approach to Fisheries Management" (Andy Kenny)
- "Bayesian Believe Network (BBN) modelling for North Sea fisheries" (Vanessa Stelzenmueller)
- "The role of IA-WGs in ICES MSFD work" (Yvonne Walter)
- Contribution of WGECO to IEA and MSFD implementation (Dave Reid)
- An approach for integrating the indicator bases assessment of commercially exploited fish species of the North Sea (Nikolaus Probst)

Abstracts of some of the presentations are given in the appendix or can be found on the ICES SharePoint. Some of the results of the discussions are summarized in Chapter 9.

4 Conduct a review on the outcome of WGIAB, WGNARS, WGEAWESS and SGIMM considering implications for the work of WGINOSE (ToR a)

The chairs of WGINOSE reviewed the work of the related expert groups in ICES. In an effort to better link the work of the groups this year's meeting of WGINOSE was organized a s a back-to-back meeting with WGIAB. The meeting with common plenary activities furthered the exchange of ideas between the groups. Along this line the 2013 meeting of WGINOSE is planned as a back-to-back meeting with WGEAWESS, whose co-chair Dave Reid participated partly in the WGINOSE meeting this year. Additionally co-chairs of WGINOSE are in close contact to chairs of WGNARS and SGIMM.

5 Conduct Integrated Status and Trend Assessment for different North Sea sub-systems (ToR b)

Structural changes in the North Sea ecosystem – regional analysis separating the North Sea into a northern and southern part

In order to investigate structural changes in the North Sea into further detail, we improved the analysis of the previous year by separating the North Sea into a southern and northern part. This separation is relatively coarse but is a compromise between the availability of long-term time series with a sufficient spatial resolution and the differences according to hydrographic forcing (e.g. Kenny *et al.*, 2009). For a North Sea wide analysis coastal data are scarce and thus these areas were generally excluded from the analysis. Regional analyses dedicated specifically to coastal areas and the Wadden Sea were additionally performed before and were thus not repeated here (Weijerman *et al.*, 2005; Schlüter *et al.*, 2009). Similarly, biological time series from the Norwegian Trench and Skagerrak area were not available for this study, so we concentrated on the so-called open North Sea area (Figure 3.1.7). The separation into the southern and northern North Sea (subsequently abbreviated as SNS and NNS) followed approximately the 50m depth isoline, but following the borders of the ICES statistical rectangles.

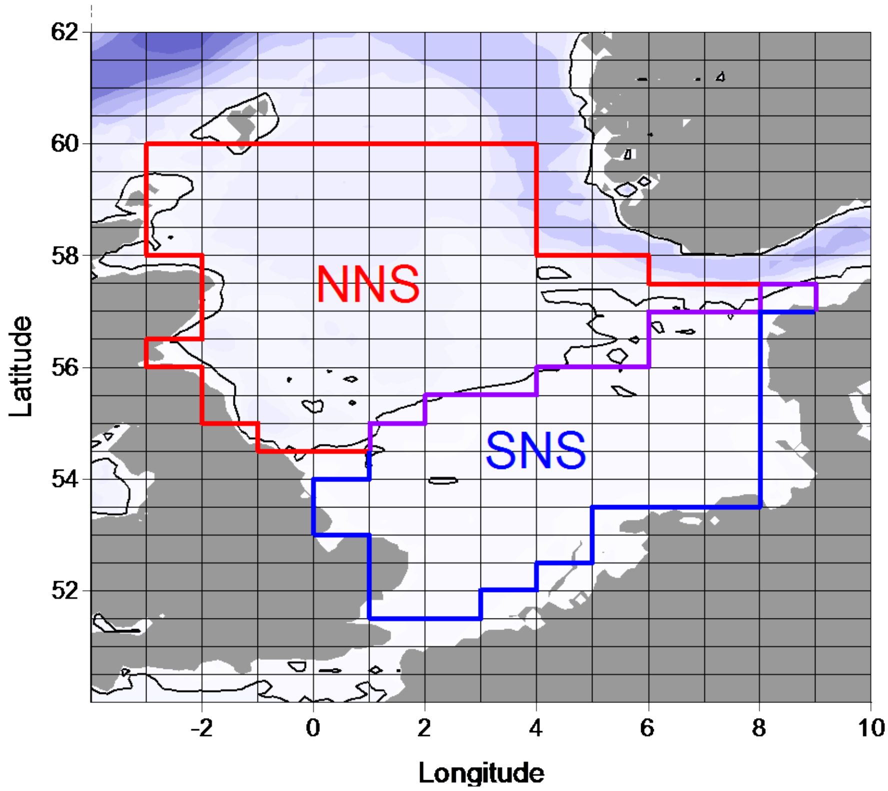


Figure 5.1. The North Sea – ICES statistical rectangles sampled by IBTS and used as basis for calculating averages of physical, plankton and fish data. Further, the rectangles assigned to the northern (NNS, red) and southern North Sea (SNS, blue) are indicated by a line. The separation between both regions follows approximately the 50 depth isoline.

Data

Biological response and environmental driving variables need to be spatially referenced with a good coverage of the entire North Sea. Therefore, our analysis was focussed on plankton and fish data as well as hydrographic measurements and large-scale atmospheric indices. So far we were not able to give reliable estimates for regional fishing pressure.

Hydrographic data were originally taken from the ICES oceanographic database but the spatial coverage of data in the NNS was insufficient. Therefore, indicators were partly taken from ECOSMO (WP2). From the model, postprocessed data on a monthly basis were only available until 2007. Updates until 2010 will be available soon and the respective calculations will be repeated.

Fish catch per unit effort values (CPUE) were extracted from the International Bottom Trawl Survey (IBTS) carried out annually in February. The catches are based on statistical rectangles covering the North Sea (see Figure 5.1). A good spatial coverage of data, indicated by the number of rectangles sampled per area and year, was guaranteed since 1974. Although primarily demersal species are targeted in the IBTS, for some pelagics relative values can give an indication about trends in abundance. The CPUEs per rectangle were averaged for the SNS and NNS as defined in Figure 5.1.

Phytoplankton and zooplankton abundance estimates were available from the CPR Survey (SAHFOS). In order to make the results comparable and avoiding as much spatial bias as possible, we assigned each sample to the respective ICES rectangles. Afterwards, all data points within one rectangle were averaged per month and additionally per season. Finally, 2nd quarter abundance values per rectangle were averaged for the two regions of the SNS and NNS (areas defined in Figure 5.1).

The final dataset comprises a time series from 1974–2008 or 2007 if environmental drivers were considered. A summary of all indicators used in the analysis is given in Table 5.1.

Methods

All analyses were performed separately for the NNS and SNS, and different approaches were used to investigate the historical ecosystem development considering the aspects of regime shifts, common trends and the potential drivers. Further, we tested the use of multivariate regression trees as a forecasting method.

First we analysed the biological response variables with a Principal Component Analysis (PCA), realising Chord Distances instead of Euclidean Distances. This distance measure circumvents some of the problems associated with the Euclidean distance, e.g. the double-zero problem and the horse-shoe effect (Legendre and Gallagher, 2001). The same multivariate dataset was subsequently investigated for abrupt changes, so-called regime-shifts, by Chronological Clustering (CC; Legendre *et al.*, 1985). For both analyses the data were previously log(x+1) transformed because the data were mostly severely right-skewed.

Afterwards, minimum/ maximum autocorrelation factor analysis (MAFA; Solow, 1994; Zuur *et al.*, 2007) was used to extract common trends in (a) the zooplankton and (b) the fish community. The resulting MAF-axes, in case they were significant, were subsequently correlated to environmental drivers. For the fish community the correlation was also explored using time-lags up to six years.

Table 5.1. List of variables and the respective abbreviations used in the analysis. Further, it is indicated if the respective variable was available for the northern North Sea (NNS) and southern North Sea (SNS), which seasonal average was used, and what was the data source.

Variable	Abbreviation	NNS	SNS	Season	Source
Hydroclimatic Drivers:					
Winter North Atlantic Oscillation index (JFM)	NAO	x	x	1st quarter	NOAA
Atlantic Multidecadal Oscillation	AMO	x	x	annual	NOAA
Surface Temperature	Tsurf	x	x	1st quarter	ECOSMO
Bottom Temperature	Tbot	x	x	1st quarter	ECOSMO
Surface Salinity	Salsurf	x	x	1st quarter	ECOSMO
Bottom Salinity	Salbot	x	x	1st quarter	ECOSMO
Temperature index of stratification	T_strat	x	x	2nd quarter	ECOSMO
Biological Response Variables:					
Pseudocalanus elongatus CIV-VI	Pseudoc	x	x	2nd quarter	SAHFOS
Temora longicornis CIV-VI	Temora	x	x	2nd quarter	SAHFOS
Oithona spp. CIV-VI	Oith	x	x	2nd quarter	SAHFOS
Acartia spp. CIV-VI	Acartia	x	x	2nd quarter	SAHFOS
Cladocera	Clado	x	x	2nd quarter	SAHFOS
Limacina spp.	Lima	x	x	2nd quarter	SAHFOS
Echinodermata larvae	Echin	x	x	2nd quarter	SAHFOS
Calanus helgolandicus (CIV-CVI)	Chel	x	x	2nd quarter	SAHFOS
Calanus finmarchicus (CIV-CVI)	Cfin	x	x	2nd quarter	SAHFOS
Metridia lucens (CIV-CVI)	Mlucens	x		2nd quarter	SAHFOS
Decapoda larvae	Decap	x	x	2nd quarter	SAHFOS
Euphausiaceae	Euph	x		2nd quarter	SAHFOS
Dinoflagellata	dinofl	x	x	2nd quarter	SAHFOS
Diatomeae	diatoms	x	x	2nd quarter	SAHFOS
Phytoplankton Colour Index	PCI	x	x	2nd quarter	SAHFOS
Clupea harengus	Clupea	x	x	1st quarter	IBTS
Dicentrarchus labrax	Dicentr		x	1st quarter	IBTS
Engraulis encrasicolus	Engraul	x	x	1st quarter	IBTS
Eutrigla gurnardus	Eutrigla	x	x	1st quarter	IBTS
Gadus morhua	Gadus	x	x	1st quarter	IBTS
Hippoglossoides platessoides	Hippplatess	x	x	1st quarter	IBTS
Lepidorhombus whiffiagonis	Lepidorh	x	x	1st quarter	IBTS
Limanda limanda	Limanda	x	x	1st quarter	IBTS
Melanogrammus aeglefinus	Melanogr	x	x	1st quarter	IBTS
Merlangius merlangus	Merlang	x	x	1st quarter	IBTS
Platichthyes flesus	Platichth		x	1st quarter	IBTS
Pleuronectes platessa	Pleuron	x	x	1st quarter	IBTS
Pollachius virens	Pvirens	x		1st quarter	IBTS
Solea vulgaris	Soleav		x	1st quarter	IBTS
Sprattus sprattus	Sprattus	x	x	1st quarter	IBTS
Trisopterus esmarkii	Trisopterusesm	x	x	1st quarter	IBTS
Trigla lucerna	Trigla	x	x	1st quarter	IBTS
Scophthalmus maximus	Scophth	x	x	1st quarter	IBTS
Scyliorhinus spp.	Scyliorh	x	x	1st quarter	IBTS
Raja radiata	Rajarad	x	x	1st quarter	IBTS
Mullus surmuletus	Mullussurm	x	x	1st quarter	IBTS

Finally, multivariate regression trees were applied. This method is especially useful for predictive purposes. It allows the recursive partitioning of quantitative variables under the control of a set of quantitative or categorical explanatory variables. Here, similar to the previously performed PCA we preserve the Chord-Distance rather than the Euclidean Distance for the response variables. The final solution getting a parsimonious tree is based on the relative error and the predictive error, the latter using a cross-validation routine (Borcard *et al.*, 2011). Due to the low number of explanatory variables without considering fishing pressure or nutrients, the overall explanatory power of this method turned out to be low but some conclusions could be drawn.

Results and Discussion

Temperature and the change in wind intensity and direction during the late 1970s initiated alterations in the location of a biogeographical boundary along the European continental shelf, being responsible for the regime shift after 1982 (Beaugrand, 2004). Additionally, large-scale hydro-climatic forcing modified local hydro-meteorological variability that affected the North Sea ecosystem directly after 1987. Figure 5.2 illustrate spring temperature and salinity anomalies in the NNS and SNS (taken from the ICES oceanographic database). Both areas show a nearly continuous temperature increase with mostly positive anomalies since the mid- to late 1980s and slightly more variability in the SNS. Very obvious in both areas is the extremely cold winter in 1979. Salinity anomalies are oscillating in both areas and are possibly related to advection.

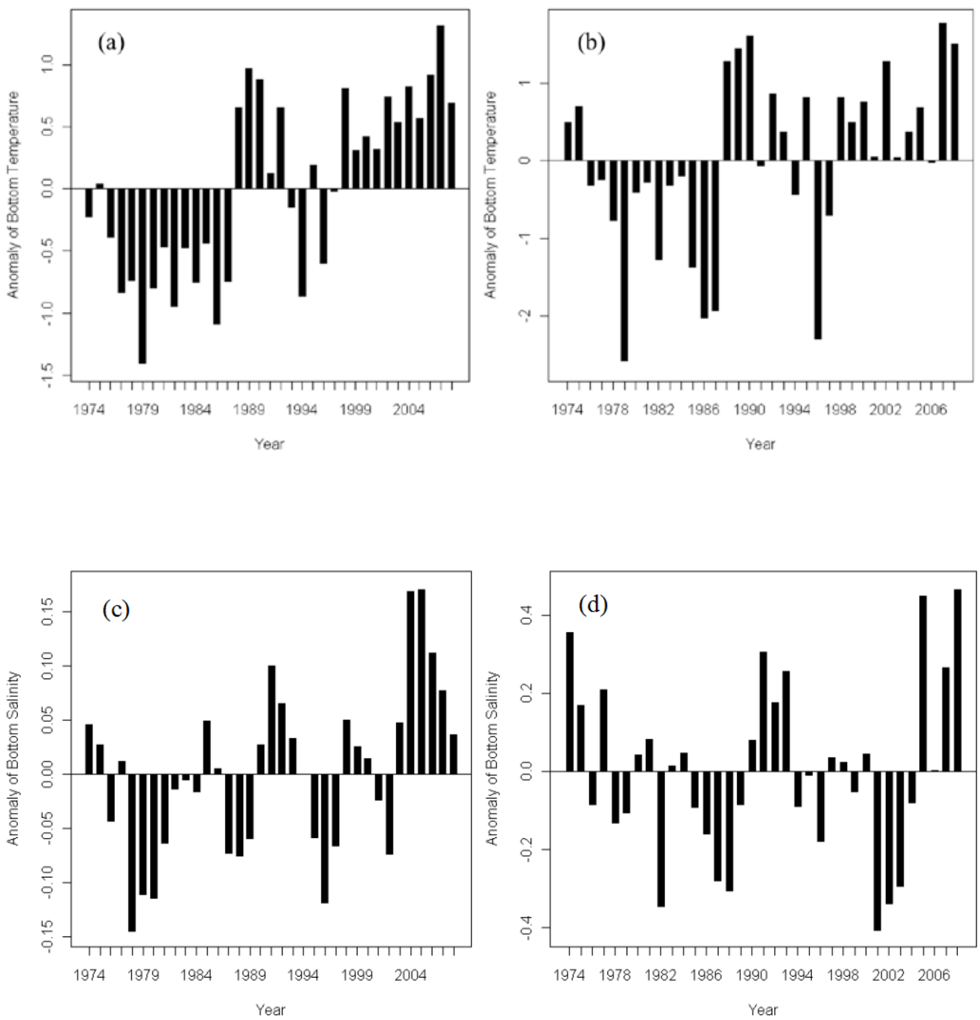


Figure 5.2. Anomalies of bottom temperatures and salinities derived from the ICES oceanographic database: (a) temperature anomalies NNS, (b) temperature anomalies SNS, (c) salinity anomalies NNS, (d) salinity anomalies SNS.

Applying PCA on biological data of the NNS resulted in a time trajectory with positive PC1 scores in the first half of the time series and negative scores in the latter half (Figure 5.3a). Variability between years is high and no so-called “stable state” is achieved. The related variable loadings (Figure 5.3b) show the well-known decrease of gadoids and *Calanus finmarchicus* over time, and the concurrent increase of e.g. *Pleuronectes platessa*, *Limanda limanda* or *Calanus helgolandicus*, as well as Decapod and Echinoderm larvae. Further, a couple of "Lusitanian species" increased in abundance, e.g. red mullet (*Mullus surmuletus*). The temporal trends in the single variables can be also seen in the traffic light plot (Figure 5.4), where variables were sorted according to their loadings on the first PC. Correspondingly, the gadoids *Gadus morhua*, *Merlangius merlangus,* and *Melanogrammus aeglefinus* showed the strongest decrease, whereas Decapod larvae, dogfish and red mullet the most pronounced increase over time.

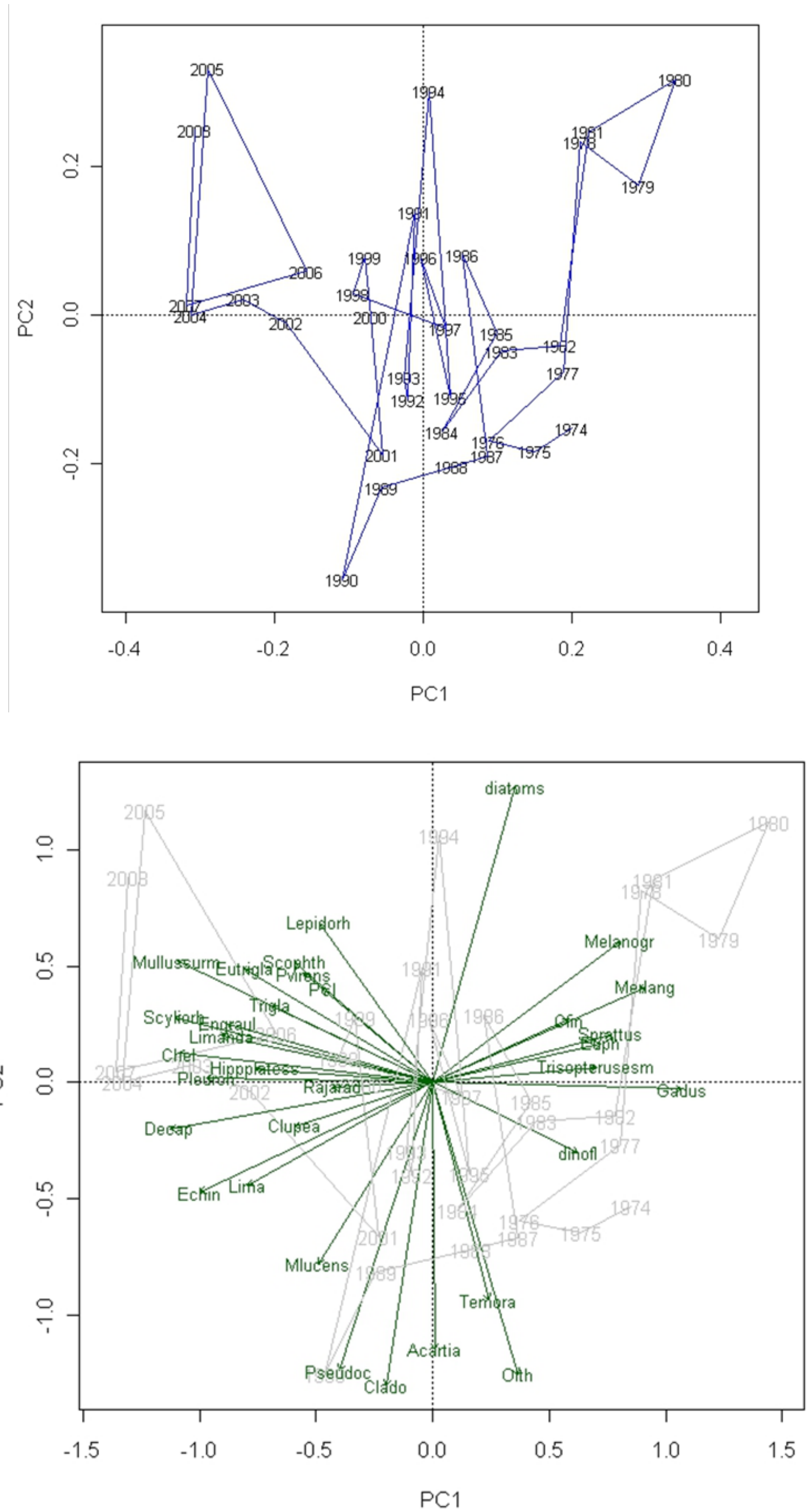


Figure 5.3. Results of the Principal Component Analysis of the NNS explaining 43.1% of the total variability on the first factorial plane. a) Time trajectory of a time period from 1974–2008 realising Chord Distances. b) Correlation biplot with time trajectory in the back and the vectors of the 34 variables, including phyto- and zooplankton parameters as well as fish CPUEs derived from IBTS surveys in the front.

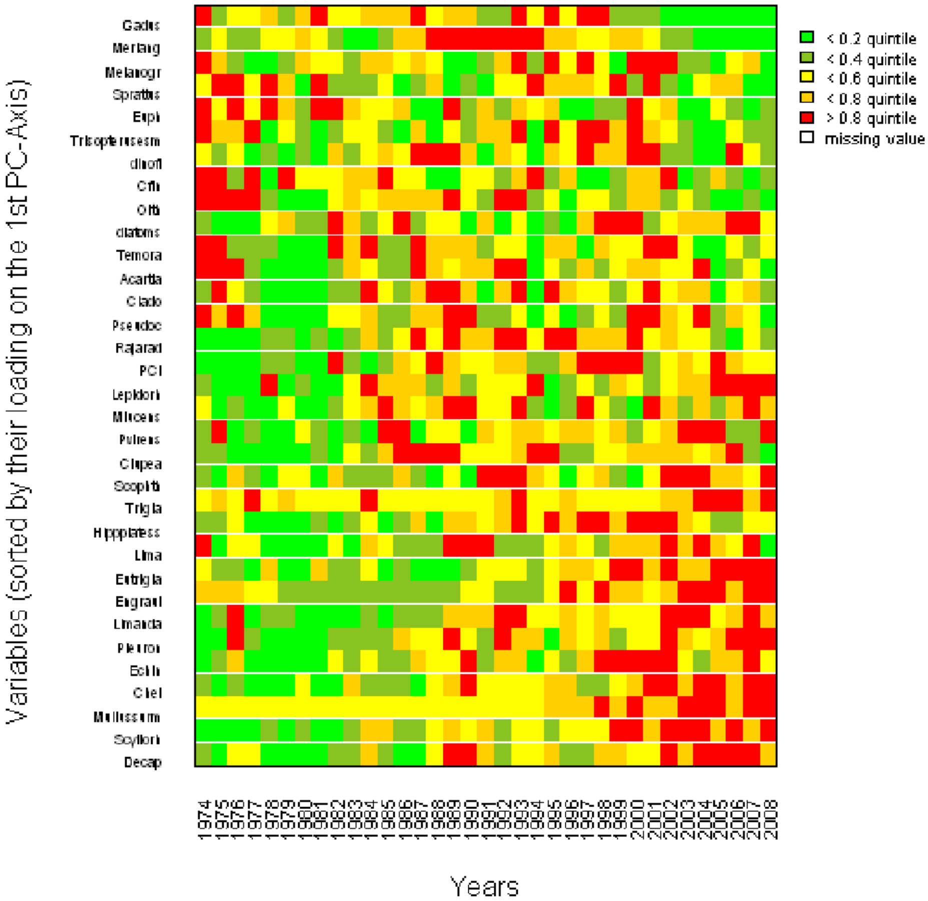
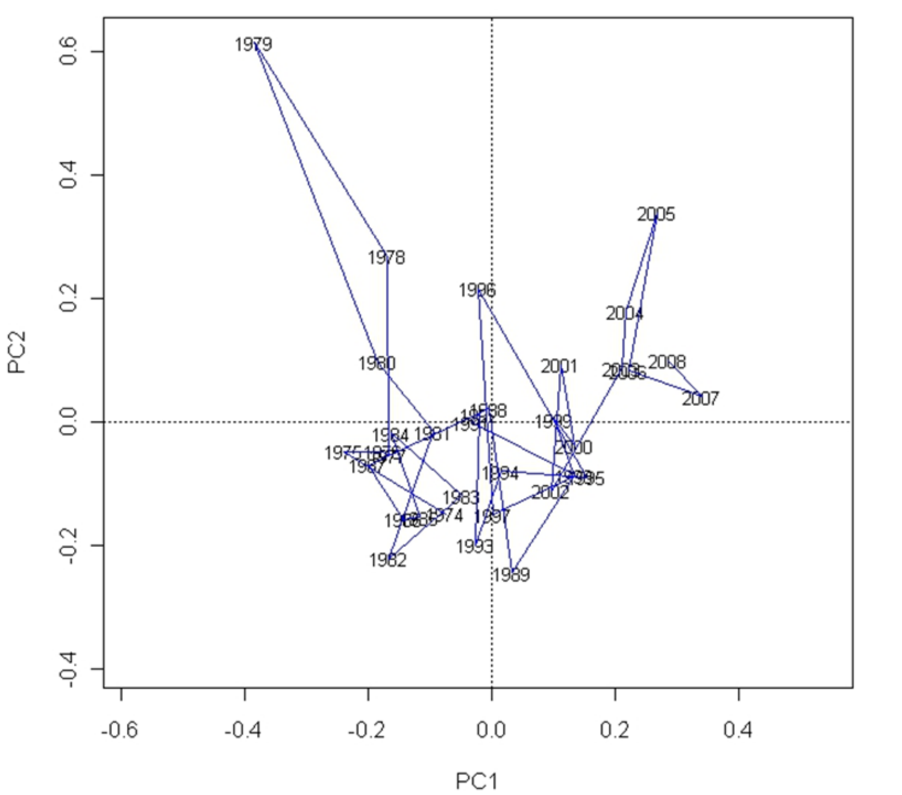


Figure 5.4. Traffic light plot of the 34 biological variables of the NNS covering the time period 1974–2008. Variables are sorted according to their loadings on the first principal component of the previously performed analysis. Raw values are categorised into quintiles with high values indicated by red, low values by green and similar colours in-between.

The PCA results of the SNS are relatively similar but with the year 1979 being very different from all other years of the time series. As this was the year following a very cold winter it is assumed that this climatic event had a strong though not persistent effect on the ecosystem structure of the shallower SNS. This effect was less evident in the NNS. The time trajectory shows that there was a continuous change from negative to positive PC1 scores over time (Figure 5.5a). Similar to the variable loadings of the NNS, the variable vectors show a decrease of gadoids and an increase of dogfish, *C. helgolandicus* and grey gurnard (*Eutrigla gurnardus*) (Figure 5.5b). The related traffic light plot (Figure 5.6) illustrates further that Lusitanian species increased in abundance, among them are e.g. the ray *Raja radiata*, and red mullet. In parallel to the development of the NNS, *C. finmarchicus* decreased and *C. helgolandicus* increased.



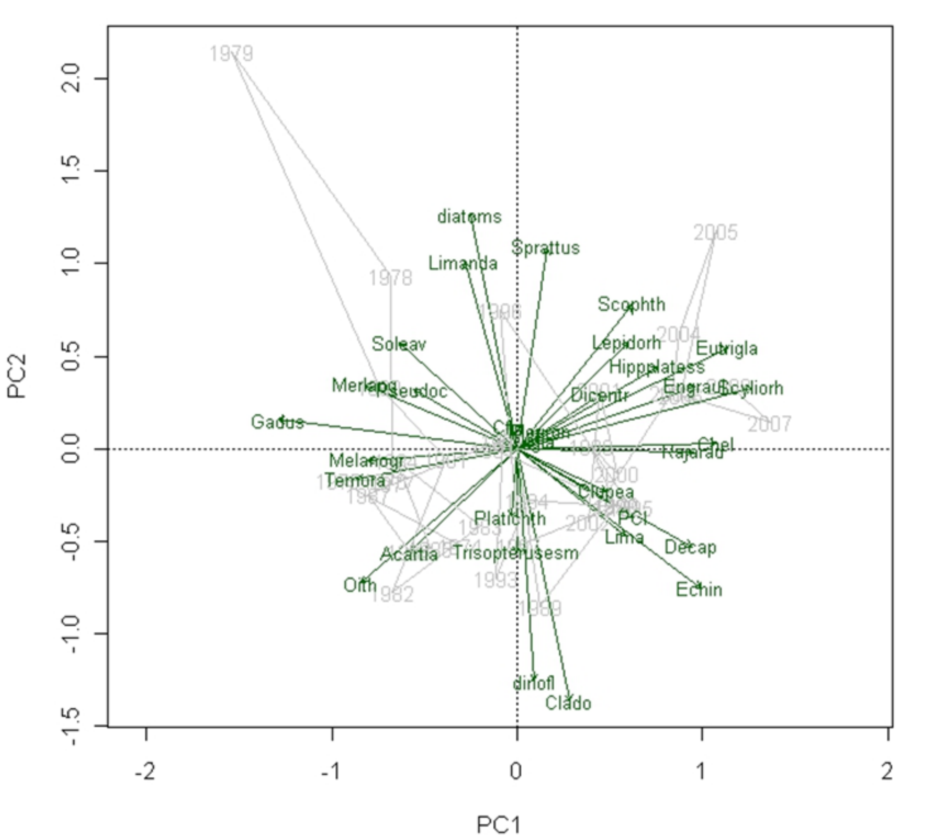


Figure 5.5. Results of the Principal Component Analysis of the SNS explaining 37.7% of the total variability on the first factorial plane. a) Time trajectory of a time period from 1974–2008 realising Chord Distances. b) Correlation biplot with time trajectory in the back and the vectors of the 34 variables, including phyto- and zooplankton parameters as well as fish CPUEs derived from IBTS surveys in the front.

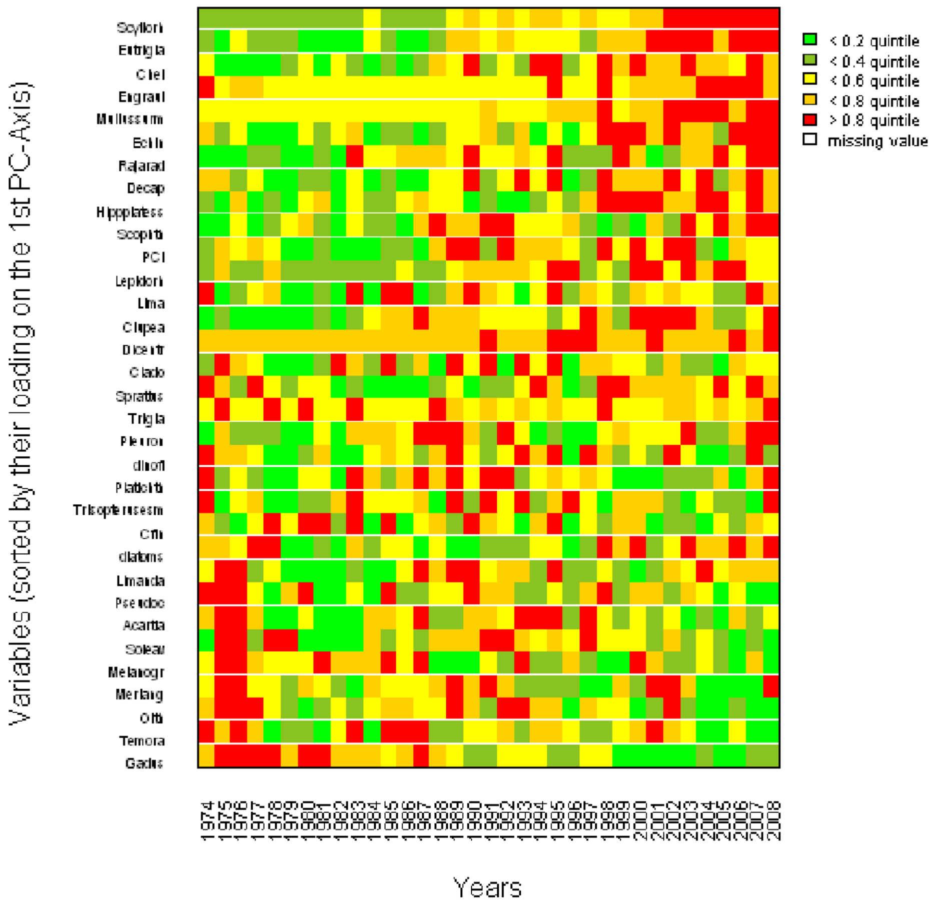


Figure 5.6. Traffic light plot of the 34 biological variables of the NNS covering the time period 1974–2008. Variables are sorted according to their loadings on the first principal component of the previously performed analysis. Raw values are categorised into quintiles with high values indicated by red, low values by green and similar colours in-between.

From the time trajectories in Figures. 5.3 and 5.5 it is obvious that year-to-year variability is high, but still clear temporal trends are obvious. When plotting PC1 and PC2 scores against time (Figures. 5.7 and 5.8), PC1 scores show a relatively continuous monotonic trend in both regions. It has to be noted that in PCA the sign of the trend has no meaning. In the NNS significant changes in the multivariate dataset were identified in the years 1980/1981 and 1989/1990, which correspond to the shifts identified by Beaugrand (2004). PC1 also shows drastic changes in the early 2000. Here, Chronological Clustering found no significant change, but this method is also less sensitive close to the end of the time series. PC2 is generally more variable with no clear trend, but extreme values are found in 1980, 1990, 1994 and 2005.

In the SNS, PC1 is nearly steadily increasing and no abrupt year-to-year steps can be observed. In 1979 the PC2 score is extremely high, possibly related to the strong winter in 1978/1979. But following 1982 PC2 scores also seem to increase steadily, and in comparison to the NNS the variability is relatively low. Chronological Clustering on the same dataset identified a shift in 1988/1989, but not one in the early 1980s. Generally, the relatively smooth trends in PC1 of both data series from the southern and northern North Sea indicate that the ecosystem exhibits a continuous rather than an abrupt structural change.

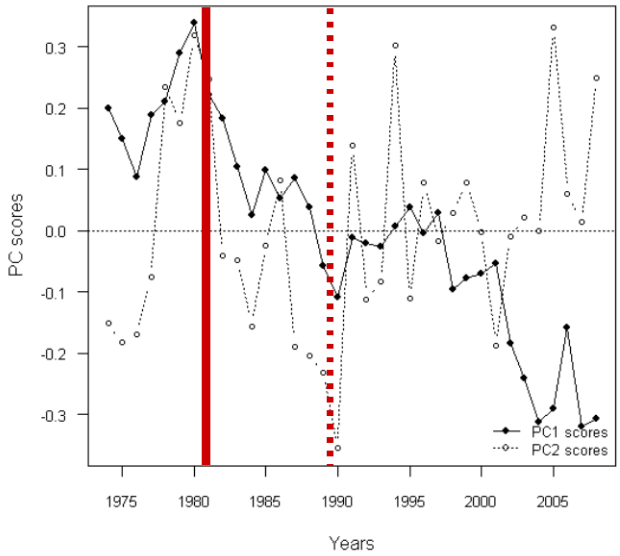


Figure 5.7. Results of the Principal Component Analysis of the NNS – Scores of years on the first two principal components (PCs). Red lines indicate the structural breaks identified by Chronological Clustering on the α=0.01 (full line) and α=0.05 (dotted line) significance level.

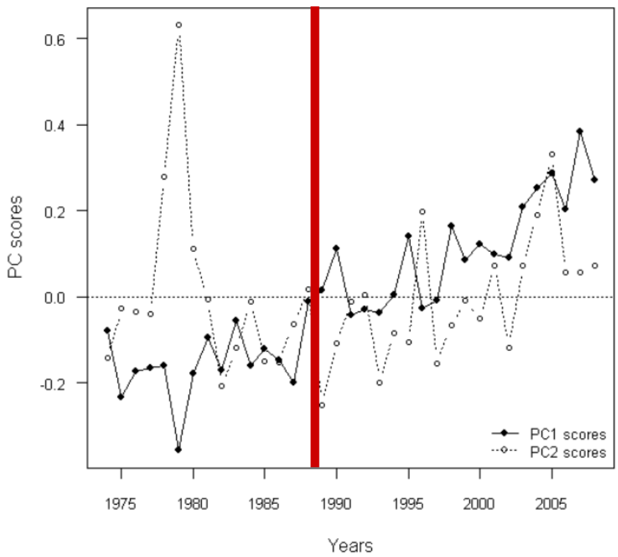


Figure 5.8. Results of the Principal Component Analysis of the SSN – Scores of years on the first two principal components (PCs). The red line indicates the structural break identified by Chronological Clustering on the α=0.01 significance level.

In a second step we analysed the zooplankton and fish component of the system separately. Using MAFA, common trends among variables should be detected. Here the first axis (MAF1) has the highest autocorrelation with lag 1, MAF2 the second highest autocorrelation, and so on. Consequently, MAF1 represents the main underlying pattern in the data and the axes can be additionally tested for significance.

Analysing common trends for the zooplankton component of the ecosystems (measured in the second quarter of each year), results in the NNS in an upward trend from 1974–1980, than a stagnant period before the upward trend continues following 1993 until the end of the time series (Figure 5.9), In the SNS there is only a slight upward trend but an abrupt step following 1997 (Figure 3.1.16). In the NNS seven taxa are strongly correlated to the MAF1 trend with r>0.4: *Oithona* spp., *C. finmarchicus* and Euphausiceae were clearly decreasing over time, whereas *Limacina* spp., Decapod and Echinoderm larvae as well as *C. helgolandicus* showed a strong increase. This also corresponds to the previous results of the PCA. The MAF1 is also significantly correlated to AMO (r=0.85), surface (r=0.54) and bottom temperature (r=0.37).

In the SNS the canonical correlations to the main trend are mostly low. Only Decapod and Echinoderm larvae as well as *C. helgolandicus* are strongly related to MAF1 (r>0.4) and all show a positive correlation indicating a general increase in abundance over time. Similar to the NNS, temperature seems to be the main driver of ecosystem change, shown by the significant correlations of AMO (r=0.69), surface (r=0.46) and bottom temperature (r=0.47) to MAF1.

MAF 2 was not significant in both areas.

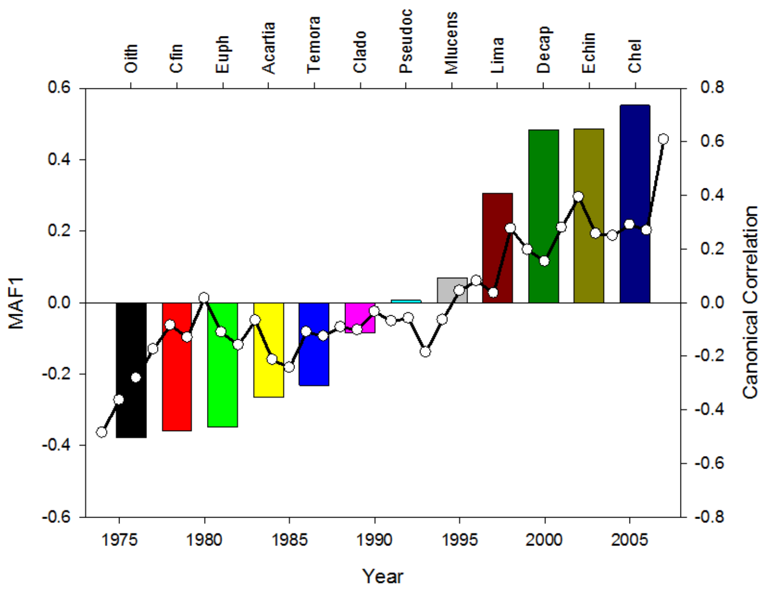


Figure 5.9. MAFA results of the NNS zooplankton component. The dots and line represents the primary multivariate temporal trend, i.e. the MAF1 scores (left axis). Superimposed are the bars representing the canonical correlation of different zooplankton taxa with the overall trend (right axis). The sign and the magnitude of canonical correlations reflect their influence on the trend of MAF1. If the correlation is positive and strong, then the original response variable follows the primary trend closely, and vice versa. Abbreviations of taxa listed at the top can be found in Table 5.1.

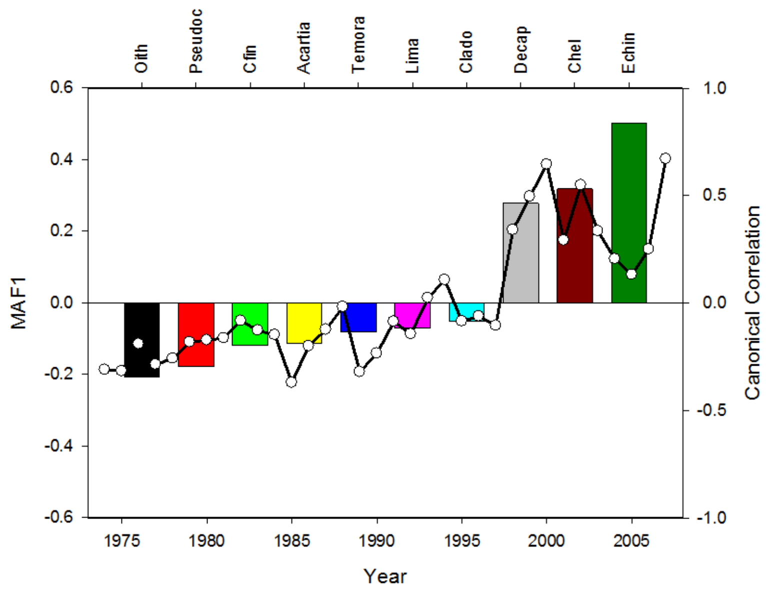


Figure 5.10. MAFA results of the SNS zooplankton component. The dots and line represents the primary multivariate temporal trend, i.e. the MAF1 scores (left axis). Superimposed are the bars representing the canonical correlation of different zooplankton taxa with the overall trend (right axis). The sign and the magnitude of canonical correlations reflect their influence on the trend of MAF1. If the correlation is positive and strong, then the original response variable follows the primary trend closely, and vice versa. Abbreviations of taxa listed at the top can be found in Table 5.1.

Investigating common trends of the fish community, both axes, MAF1 and MAF2, were significant and are shown in Figure 5.11 and 5.12. In the NNS MAF1 is oscillating until 1996. Then the MAF1 values increase strongly until 2000, which is followed by a stagnant period. MAF2 values were rather constant from 1974–1985, but then changed rapidly to negative values until they started to increase again in 1993. Figure 5.11 also illustrates the canonical correlations of fish species to the MAF1 axis. Many species show a rather strong correlation, i.e. cod and whiting are negatively correlated, and dogfish, grey gurnard, red mullet and anchovies are positively correlated to this axis. Most likely they also exhibit the step-like changes in the late 1990s. Similar to zooplankton, the structure of the fish community seems to be strongly related to temperature (AMO: r=0.68, surface temperature: r=0.43, bottom temperature: 0.42). Further, MAF2 is significantly correlated to the NAO (r=0.59). Because fish mostly respond to changes in their environment with changes in recruitment success, we must expect a certain time lag before a response is manifested in the stock size and thus the CPUE. Therefore, we also correlated the MAF-axes with environmental variables delayed 1-6 years. Even though the correlation coefficients slightly differ, the AMO remains to be the most important factor influencing the trend of MAF1, and the NAO of MAF2. The reason for this relatively small effect is possibly the high autocorrelation in the time series of the atmospheric indices.

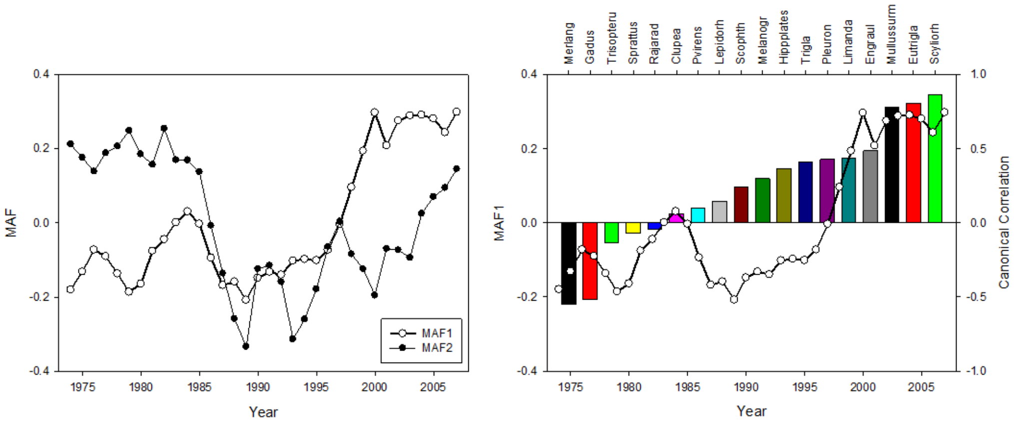


Figure 5.11. MAFA results of the NNS fish community. The dots and lines represent the primary multivariate temporal trends, i.e. the MAF1 (white dots) and MAF2 scores (black dots) – left panel. On the right panel only MAF 1 is illustrated, superimposed by the bars representing the canonical correlation of different fish taxa with the overall trend (right axis). The sign and the magnitude of canonical correlations reflect their influence on the trend of MAF1. If the correlation is positive and strong, then the original response variable follows the primary trend closely, and vice versa. Abbreviations of taxa listed at the top can be found in Table 5.1.

In the SNS the common trend indicated by MAF1 is relatively smooth (Figure 5.12). Values remain rather constant, and then increased slowly but continuously following 1993. MAF2 values show a strong decrease until 1982, and then remain constant up to 1990, followed by a strong increase again. The lowest MAF2 and MAF1 values correspond thus to the period, which Beaugrand (2004) identified as the prolonged period of the North Sea regime shift (1982–1988). Cod is again strongly negatively correlated to the main trend (MAF1), and sprat, red mullet, long rough dab (*Hippoglossoides platessoides*), dogfish and grey gurnard show a positive correlation, thus increasing in abundance. In contrast to the NNS opposite trends are found for plaice (*Pleuronectes platessa*), which is decreasing in the SNS and for sprat, which is increasing. Again temperature is the main driver of change, because AMO (r=0.81), surface temperature (r=0.46), and bottom temperature (r=0.48) are significantly related to MAF1. In contrast to the NNS no relationship was found with MAF2. However, the NAO, which showed hardly any relationship to MAF1 or MAF2, turned significant using a time lag of five and six years (r=0.42 and r=0.47). The AMO remained significantly correlated with MAF1, but correlation coefficients slightly decreased with increasing time lag.

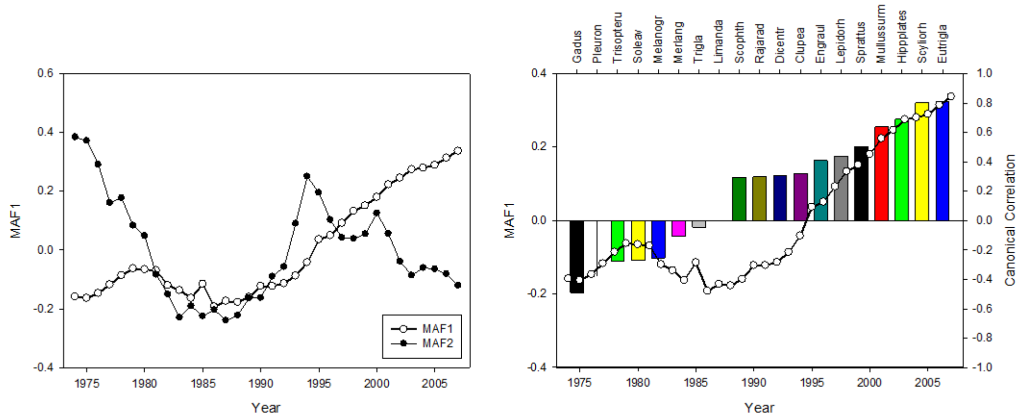


Figure 5.12. MAFA results of the SNS fish community. The dots and lines represent the primary multivariate temporal trends, i.e. the MAF1 (white dots) and MAF2 scores (black dots) – left panel. On the right panel only MAF 1 is illustrated, superimposed by the bars representing the canonical correlation of different fish taxa with the overall trend (right axis). The sign and the magnitude of canonical correlations reflect their influence on the trend of MAF1. If the correlation is positive and strong, then the original response variable follows the primary trend closely, and vice versa. Abbreviations of taxa listed at the top can be found in Table 5.1.

Finally, multivariate regression trees (MRT) were explored as a prediction tool using the same dataset as for the PCA and also preserving Chord Distances. Figure 5.13 illustrates the results using the NNS zooplankton community constrained by the environmental variables. We chose the tree with the lowest cross-validated relative error (CVRE), which splits into three leaves. The residual error of 0.711 is the reciprocal of the regression R^2. This means that only about 30% of the variability in the data can be explained by the separation into the three terminal groups. Each node is characterized by a threshold value of an explanatory variable. The first node splits the data into two groups of 24 and 10 years on the basis of bottom temperatures (threshold T=6.44°C). The second node is related to AMO, splitting the data into years with an AMO below 0.004 and above. Each leaf (terminal group) is characterized by its number of years and its relative error. The small bar plot represents the abundances of the species (in the same order as is the response data matrix). Because these bar plots are difficult to read, we additionally plotted pie charts, to illustrate the relative composition of each leaf (Figure 5.14). Differences in the composition between terminal groups are not very obvious, but especially the two *Calanus* species, Decapod larvae, *Limacina* spp. and Euphausiids seem to be affected by the environmental variables bottom temperature and AMO, and this further corresponds well to the results of the MAFA analysis.

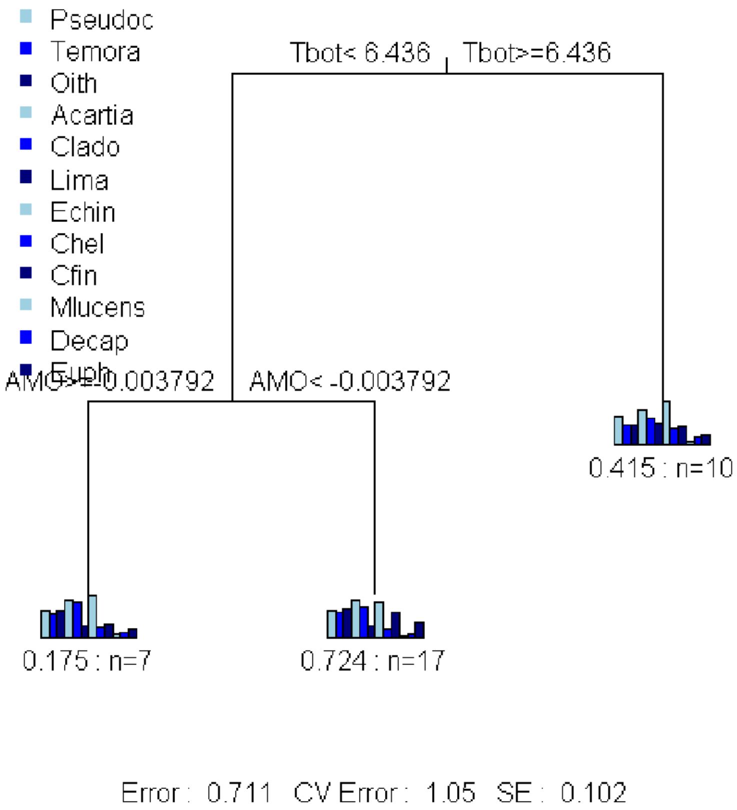


Figure 5.13. Multivariate regression tree of the zooplankton community from the North Sea explained by a set of environmental variables. Explanations can be found in the text.

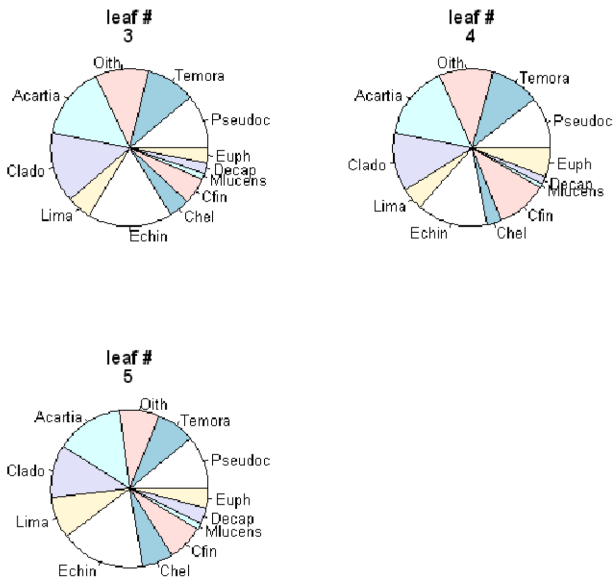


Figure 5.14. Relative composition of taxa in each of the resulting MRT leaves of Figure 3.1.19. Leaf#3 encompass seven years with an AMO>=-0.003792 and a bottom temperature<6.436°C, leaf#4 17 years with an AMO<-0.003792 and a bottom temperature<6.436°C, and leaf#5 10 years with a bottom temperature >=6.436°C. Abbreviations of taxa names can be found in Table 5.1.

Repeating MRTs for the SNS and for the fish community of both regions resulted in similar results as MAFA: Temperature and AMO were always the most important factors dividing the years into separate terminal groups NAO was a subordinate factor for structuring the fish community. The explanatory power of this analysis is low and the residual error was never smaller than 0.6 ($R^2<0.4$). However, if more forcing variables become available (like regional fishing pressure and nutrient loads), this may be improved. Then the tree can be used to allocate a new observation to one of the groups on the basis of the values of the relevant environmental variables. Because one usually retains the tree solution that has the best predictive power, rather than making selections on the basis of explanatory power (like in other ordination methods), MRT focuses on prediction, making it a very interesting tool for integrated ecosystem-based management approaches. Based on a set of environmental indicators, the composition of the ecosystem can be predicted with some certainty.

Conclusions

Investigating the southern and northern part of the North Sea separately, generally led to similar results as the combined analysis (WP3.1.2.a), and as what has been described in previous publications (Beaugrand 2004, Weijermann *et al.*, 2005, Schlüter *et al.*, 2009, Kenny *et al.*, 2009. The ecosystem of the North Sea underwent drastic changes in the past decades, but these were not as abrupt, as it has been sometimes described (e.g. Kenny *et al.*, 2009). The patterns of multivariate changes were slightly different when the SNS and the NNS are compared: Changes in the zooplankton community were more abrupt in the SNS than in the NNS and vice versa for the fish community. The SNS also seems to have more stochastic variation. Usually similar species are involved and temperate and Lusitanian species generally increased in importance. This is e.g. illustrated by the increase of *C. helgolandicus* in parallel to a decrease of *C. finmarchicus*. Further several fish species, although sporadically encountered before, seem to be established in the North Sea now. As an example red mullet has considerably increased in the past decades, although their overall abundance is still higher in the southern half of the North Sea than in the north. In agreement with the change in species composition, temperature turned out to be the main driver using any of the statistical approaches (PCA, MAFA, MRT). Usually, AMO was the best predictor. However, other important drivers like fisheries and eutrophication have been not considered here. Hopefully, reliable estimates for regional fishing pressure can be calculated in the future. If so, the MRT approach is very promising to be able to contribute to ecosystem-based management approaches.

6 Start using ecosystem modelling in an Integrated Ecosystem Assessment framework (ToR c)

One essential part of Integrated Ecosystem Assessment is the use of different ecosystem models within the assessment process. Hence WGINOSE in its first meeting in 2011 conducted a review of available models for the North Sea area. The group hoped that it could attract a range of modellers to participate in the group which was unfortunately not the case. Hence WGINOSE decided to focus its modelling activities on the use of Bayesian Belief Networks as a decision support tool (see Chapter 7). For further modelling activities WGINOSE will closely cooperate with the newly formed "Working Group on Integrative, Physical-biological, and Ecosystem Modelling (WGIPEM)" of which one Co-chair Myron Peck was present at the WGINOSE meeting.

Furthermore a plenary session was conducted of both WGIAB and WGINOSE with the following presentation

- The EU VECTORS project, North Sea ATLANTIS model progress and WGIPEM (Myron Peck)
- The BONUS ECOSUPPORT project progress (Susa Niiranen)
- The ECOSCENARIOS project (Thorsten Blenckner)
- The Biological Ensemble Modelling Approach – progress (Anna Gårdmark)

PowerPoint files with these presentations can be found on the SharePoint site.

7 Promote development of Bayesian belief network modelling as decision support tools in ecosystem management and IEA (ToR d)

1) Defining Risk Assessment

V. Stelzenmüller

There are different perceptions of what a risk assessment means in the context of an adaptive management cycle. In general, an ecological risk assessment involves an analysis of exposure of an ecological component to a stressor, the expected undesirable effects from this exposure, and finally the estimation of risk by integrating exposure and effects with the help of both a quantitative estimation and a qualitative description of risk (Hope, 2006). Quantitative risk assessments rely on mathematical models predicting the response of the ecological receptor to a changing environment, while qualitative risk assessments use a combination of attributes of the ecosystem, ecological receptor and stressor (Astles *et al.*, 2006). For instance, qualitative risk assessments were successfully used to manage Australian fisheries (Astles *et al.*, 2006; Braccini *et al.*, 2006), to assess the impacts of fishing (Campbell and Gallagher, 2007), and to prioritize issues for fisheries management (Fletcher, 2005). An ecological risk assessment must address the location-specific characteristics and interactions that define an ecosystem (Woodbury, 2003). Thus an indicator based risk assessment in an adaptive management cycle according the above described process would comprise the analysis of the sensitivity of the relationship between indicators and related pressures using time series and simulations. Formally this could be referred to a state assessment which evaluates whether or not defined management goals and operational objectives of an already implemented management plan have been met. In contrast, a risk analysis estimates the probability of not meeting defined management objectives, based on the predicted result of suggested management measures (i.e. management plan existing, not yet implemented). In other words, the state assessment evaluates the performance of a current management through monitoring and auditing, while a risk analysis evaluates the predicted effectiveness of proposed management scenarios. The latter may be rather associated to the management strategy evaluation step in an adaptive management cycle.

2) Some ideas about how to aggregate long-term model simulations

U. Callies, F. Bockelmann, M. Scharfe

A presentation on the relevance of using hydrodynamic long-term simulations for supplementing biological analyses was given by Ulrich Callies from the Helmholtz-Zentrum Geesthacht. It was argued that aggregation of variability of model output fields by principle component analysis (PCA), for instance, allows for a dramatic reduction of complexity and makes the use of output from process oriented models comparable with the use of simple proxi indices like the NAO or AMO, for instance. A companion talk given by Vanessa Stelzenmüller successfully analysed cross-correlations between variations in such aggregated hydrodynamic conditions and changing recruitment indices. Lagrangian drift simulations based on model based reconstructions of hydrodynamic conditions were proposed as possibly even more effective predictors of biological parameters. Finally, the talk addressed the use of Bayesian network technology as another approach for the aggregation of model output. It was argued, that BN-technology allows for a more detailed presentation of interactions between different variables in terms auf causal relationships. Its combination with web-GIS technology was illustrated by the presentation of an already existing application dealing with the monitoring of chronic oil pollution in the North Sea.

3) Potential applications of Bayesian networks in IEA

V. Stelzenmüller

What are Bayesian networks?

- Bayesian networks (BN) = Belief networks = Bayesian belief networks = Bayes nets = probabilistic networks are increasingly popular methods for statistical description and modelling of uncertain and complex domains such as ecosystems and environmental management.
- As such they might be well suited as risk based decision support tools in IEA.
- BNs are one branch of Bayesian modelling (-> hierachical simulation based modelling).
- The basic idea of these models is conditional dependence between variables and the updating of knowledge based on Baye's theorem: $p(B|A) = p(A|B) \times p(B) / p(A)$.
- BNs use probability as a measure of uncertainty. Beliefs about values of variables are expressed as probability distributions. The higher the uncertainty the wider the probability distribution.

Advantages and limitations of BNs

Advantages	Limitations
Handling of missing data	Limited ability to deal with continous data due to discretization of data (balance between the number of samples and breakpoints)
Allows combination of data and expert knowledge	
Facilitates learning about causal relationships between variables	
Provide method to avoid overfitting of data	
Good prediction accuracy for small samples sizes	
Can be combined with decision analytical tools to aid management	
BNs are at their best discrete domains	
Probabilistic presentation of knowlege prevents overconfidence in the strength of responses	
Data can be used to find BN model structure (structural learning)	This is very limited for environemntal applications
BNs can be combined with other Bayesian analysis	
BNs can be supplemented with varibales reflecting managerial decisions (costs and utility)	
BNs can be inferred in two directions	BNs does not support feedback loops
BNs can be used to collect and structure expert knowlege	

Table extracted from: Uusiatlo, L.. Ecological Modelling 203 (2007) 312–318.

State – Transition models and BNs

- State and transition models (STMs) allow for the integration of system dynamics, management and environmental response.
- Translating STM into a BN:

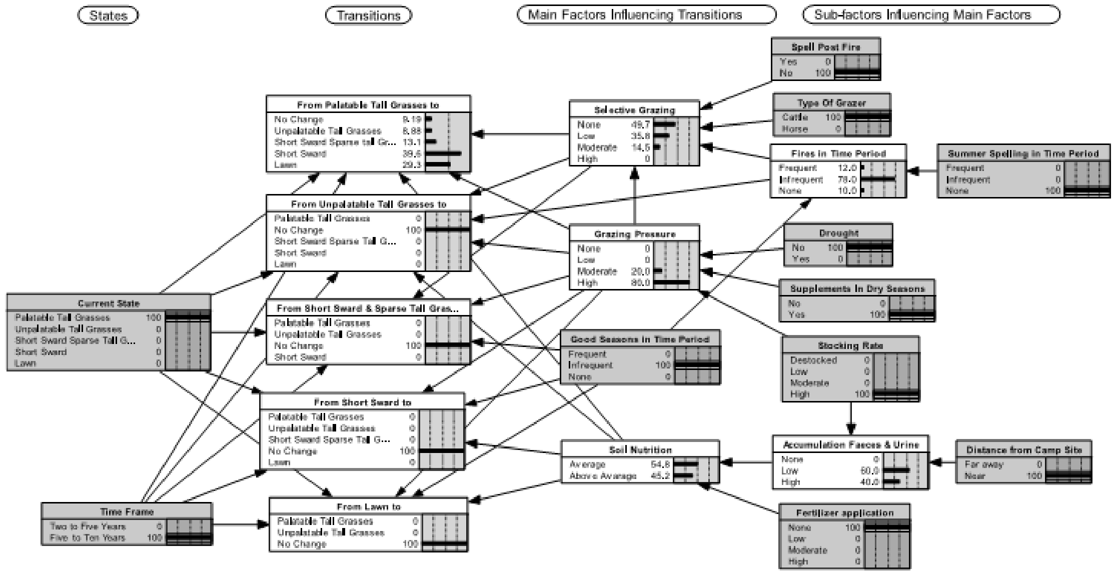


Fig. 3. State and transition model for cleared Ironbark-spotted gum woodland in the form of a Bayesian belief network. In this figure a scenario has been inserted by selecting particular classes for the nodes shaded grey. The scenario shown here is where the current state of pasture is "palatable tall grasses" (hence only transitions from palatable tall grasses are possible), the time frame is "5–10-years", spell post-fire is "no", type of grazer is "cattle", summer spelling in time period is "none", drought is "no", supplements in dry season is "yes", stocking rate is "high", distance from camp site is "near", good seasons in time period is "infrequent" and fertiliser application is "none". Under this scenario the model is predicting that the most likely transition is to "short sward" (39.6% chance).

Figure from: Bashari, H. *et al.* Agricultural Systems 99 (2009) 23–34.

- Dynamic BNs allow modelling of changes in a process or system over time
- One node is needed for each time step
- Formal description of a ST-BN model:

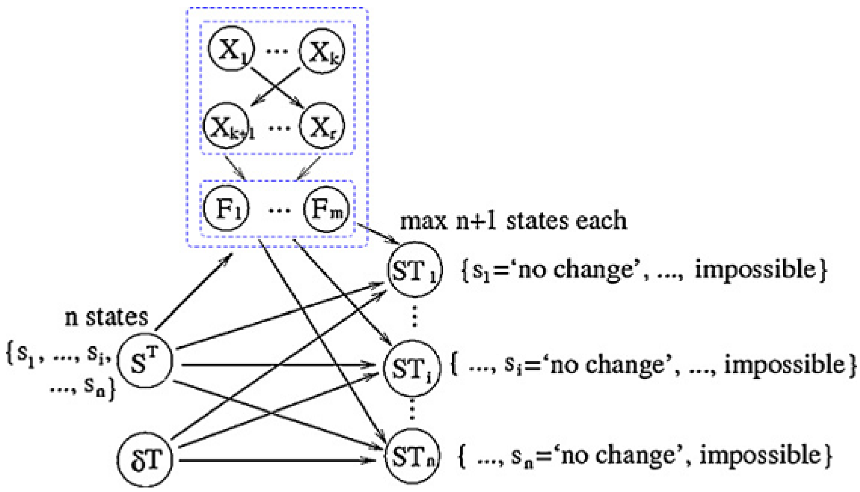
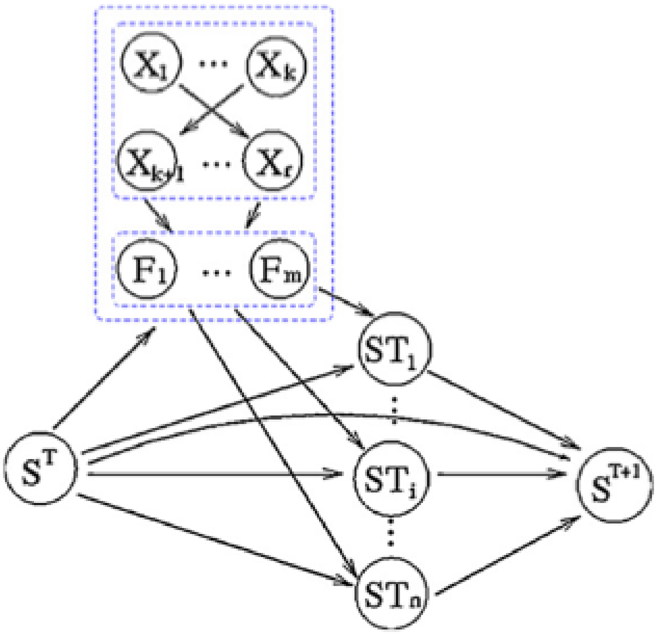


Fig. 5. The generic ST-BN: a more general formalisation of Bashari et al.'s model. S^T, the current state, may directly influence any of the environmental and management factors, which are divided into m main factors, $F_1, \ldots, F_m$ (which directly influence transitions) and other sub-factors, $X_1, \ldots, X_r$ (which influence the main factors). The transition nodes, $ST_1, \ldots ST_i, \ldots, ST_n$ represent the transitions from each state s_i, each with at most $n+1$ values, one for each state plus "impossible", giving explicit modelling of impossible transitions. δT represents the time frame.

- Combining STMs and Dynamic BNs: Future state influenced by probabilities of transitions



Figures from: Nicholson, A.E. and Flores, M.J. Ecological Modelling 222 (2011) 555–566.

- Dynamic BN could be used to:
  - integrate time series analysis of processes and system indicators
  - integrate environemntal and human drivers
  - predict future states

4) Bayesian network (BN) technology in WGINOSE

Ulrich Callies

In the group we extensively discussed the potential benefits from using Bayesian network (BN) technology for the representation of parameter interactions within the North Sea marine system. The group concluded that already a strongly simplified system is characterised by comparatively many and complex nodes and would thus require already a fairly complex Bayesian network. It was decided to keep things as simple as possible for the first trial and apply none of the above described complex dynamic extension of BNs and implement only well described and significant relationships to reduce the nodes and thus complexity of the net. We succeeded in drafting a preliminary version of a BN intended to be nothing more than a starting point for further discussion (see figure below). All aspects of the BN will have to be checked carefully in the light of existing data and previous studies. Many revisions will be needed before ending up with a description that matches and represents present knowledge satisfactorily.

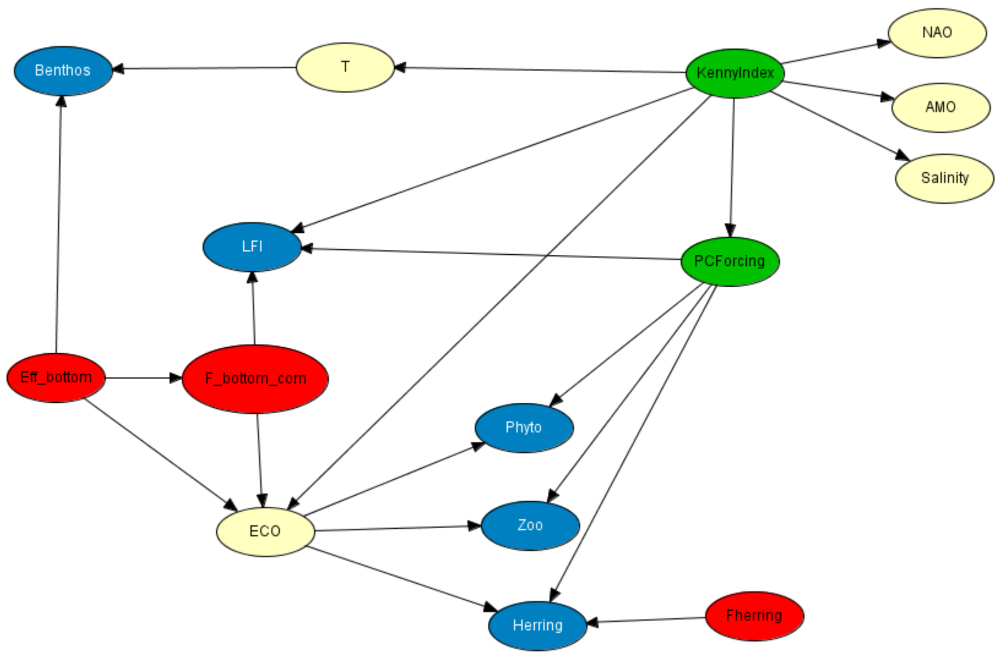


Figure: First draft for the structure of a Bayesian Network (BN) that represents the marine biologic system forced by its physical environment and anthropogenic pressures (fishing).

Lots of analyses one can draw from to parameterize the network have already been performed by different groups. In particular, techniques like principal component analysis have been used for combining different observed parameters into aggregated descriptors of a system's state. A key task will be to use such aggregated parameters jointly with the original parameters that are directly linked to observations. We agreed that only the inclusion of observations from monitoring programs will make the BN useful for applications in the context of environmental assessment programs.

In the above figure directly measured biological variables are shown in blue, while the parameter 'eco', for instance, is output from a PCA and represents an overall measure of the biological system's state. The two green nodes represent principal components obtained from an analysis of physical forcing parameters. We expect that a more in depth analysis will reveal that one of the two forcing parameters can be discarded from the diagram. Red nodes describe aspects of human pressure on the system. As with the physical forcing it is not yet clear whether such pressures should be linked to either the more integrated or the more specific parameters.

8 Consider to facilitate the interaction between WGINOSE and fish stock assessment as well STECF working groups (ToR e)

Due to a lack of time, the group could not discuss the interaction between WGINOSE and fish stock assessment as well STECF working groups in detail. However, as a response of the presentation of Han Lindeboom (see above and agenda) the usefulness and format of Ecosystem Overviews as a support for assessment and advice has been discussed. The text below is the result of a sub-group who discussed the issue.

Regional Ecosystem Overviews (REOs) – short descriptions, summarising regional temporal trends

The requirement for regional ecosystem overviews is driven by the need for the integration and assessment of ecosystem indicators to support EAFM as collected by the Common Fisheries Policy (Data Collection Framework) and the descriptors of the MSFD. There is also a need to move towards case studies which demonstrate what an EAFM could look like and how it would work in practice, e.g. through defined spatial management units and assessed according to different management scenarios. There are many approaches which can be applied to achieve an overview of ecosystem trends and status (see review in WGINOSE 2011), but their practical use and value has been limited to date by their general lack of predictive 'scenario' testing utility. The trends in ecosystem indicators should therefore be organised and presented with a structure that more directly relates to potential cause /effect relationships (e.g. as part of a management driven DPSIR framework). For fisheries related ecosystem assessments this should follow the structure proposed by the FP7 MEFEPO project (Figure 1) which highlighted the interdependence and relationship between the impacts of fisheries on fish stocks and the ecosystem, on the one hand, and the impacts of the environment on the status of fish stocks and the fishery on the other. The full range of the indicators and associated variables should therefore be organised and presented (pictorially) within this broad framework for each regional ecosystem. This also has the advantage of supporting the development of a BBN model which can quantifiably relate the drivers and pressures with certain changes in state which can then be run to examine different management scenarios, with outputs of the model runs presented (back) in the same format as the ecosystem overview.

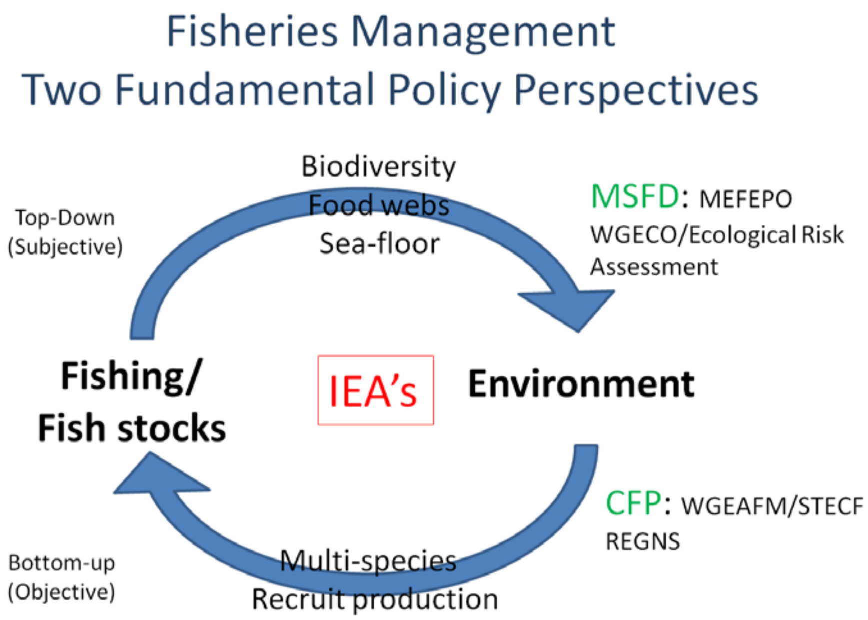


Figure 1. A general framework for organising the presentation of trends and status indicators as part of a regional ecosystem overview document. The indicators which relate to the MSFD tend to describe the impacts of fisheries and changes in stocks on the ecosystem, e.g. such as changes in foodweb structure, loss of biodiveristy, introduction of alien species etc, whereas other policy drivers such as the CFP are also concerned with assessing the impacts of the environment on recruitment success and changes in productivity e.g. fisheries yield.

An example of how this could look is given in Figure 2.

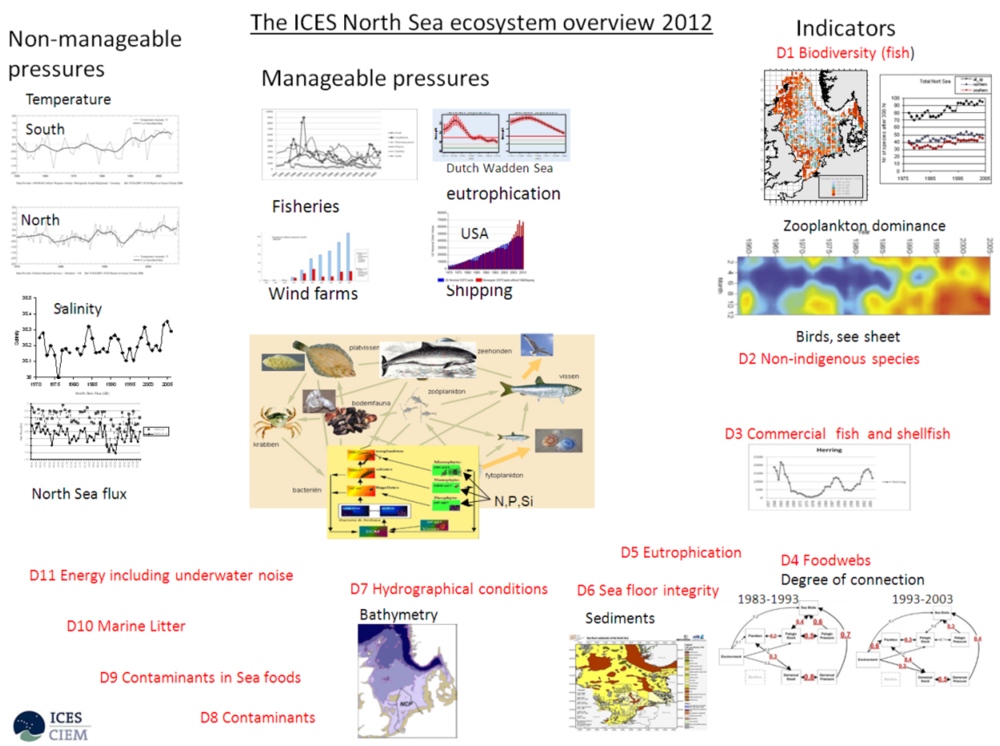


Figure 2. Possible structure for presenting status and trend data associated with each ecosystem indicator in support of a regional ecosystem overview assessment.

Potential steps to delivering an ecosystem overview coupled to adaptive management tool for ecosystem advice

1st – for each spatial management unit (LME), a description of temporal trends describing system properties could be undertaken – to include the things we routinely monitor, presented/organised according to the MSFD **descriptors** e.g. **i.** (biodiversity, alien species, fish, foodwebs, sea bed integrity, hydrographical condition); **ii.** manageable (human) pressures (contaminants, contaminants in seafood fisheries, marine litter , energy, eutrophication) and **iii.** unmanageable pressures (hydrological and chemical – nutrient- condition).

(this step would also serve to highlight potential data gaps for each region)

2nd – integrate the variables associated with each of the descriptors into appropriate **indicators**, e.g. hydrological condition which integrates, salinity, temperature, AMO, NAO, surface currents etc. – repeat for each descriptor.

3rd – assess (by way of BBN model runs) the trade-offs between descriptors, e.g. integration across descriptors to assess the relative significant of fisheries impacts on the ecosystem *vs.* ecosystem effects on fisheries/fish stocks.

(how this can contribute to more ecosystem responsive management strategies e.g. ecosystem adaptive harvest control rules)

Periods of regime change pose particular challenges to the provision of fisheries and ecosystem management advice. Accumulating evidence suggests that ecosystems may not simply flip back and forth between only two possible regimes. Hence, even when evidence for a potential regime change is detected in the oceanographic information, during the transition period of the regime shift uncertainty may be higher than at other times. Identifying such transition periods is therefore an important part of the overview process.

With good knowledge of processes, physical environment or climatic forcing fish productivity regimes should be relatively easy to identify using a BBN model and parameter estimates, and this would contribute to fisheries management advice. Also climatically driven alternate low and high productivity regimes can be incorporated in fisheries management harvest control rules once the relationships between the components presented in Figure 2 are understood and sufficiently defined in the model. For example, in the North Pacific methods are being developed to incorporate low frequency variability in fish production (regime-shifts) into harvest advice.

Progress in the medium term can be made by the use of these developing tools and insights on shifting ecosystem state to adapt assessment parameters and management advice to given productivity regimes. This can improve harvest advice, by ensuring that the exploitation rate being applied is appropriate for the regime-specific productivity of the stock. Continuing to ignore regime like changes in stock productivity means that exploitation rates estimated from observations taken over several regime changes will not be optimal for any specific set of environmental conditions and have a moderate likelihood of being excessive for any regime with lower than average productivity for a stock.

9 Conclusions and recommendations on "Future perspectives of IEA in the ICES region"

Since the beginning of the ICES IEA initiatives (e.g., REGNS) little thought has been given to the question how the IEA approaches can be transferred into routine application in ICES advice. Given the recently requested multi-species and multi-fleet advice by the EU-COM, WGINOSE and WGIAB started a discussion, if and how integrated ecosystem advice should look like and how the ICES work on IEA can be operationalized, i.e. transformed into advice tools. To this end WGINOSE / WGIAB invited Phil Levin, head of the NOAA branch working on US-Pacific IEA and ecosystem management issues, to inform both groups on the IEA development on the West coast of the US, where IEA are operational in management, now.

The US example clearly showed that the effort to integrate IEA into a closed management and advice cycle is huge and that the governance system required to run US-type IEA on regional scale in Europe is not available neither in the ICES system nor on European or national level – even if we assume the resources required would in principle be available in different institutions to be involved. The main conclusion from the WGINOSE-meeting is that the level of coordination required to run these exercises would need a completely new governance structure empowered to fully control of all the resources working on science underpinning fisheries and marine environmental management. As implementation of new a governance structure is highly unlikely over the next decade, focus of IEA working groups over the next years should be on development of IEA tools that would fit to advise the management systems as to be implemented in the revised CFP and the MSFD. Beyond this general conclusion WGINOSE has identified three major points of concern hampering their work in the ICES system and that should be taken up in the upcoming Workshop on Benchmarking Integrated Ecosystem Assessments (WKBEMIA); see also Annex 4:

1) Many of the ICES coordinated surveys carry a burden of multiple additional sampling, which has evolved over time. The result of these additional sampling requests is that the surveys are no longer specifically designed towards clearly defined fishery-related objectives, but are rather

something that is not too well defined – at least beyond the original purpose of monitoring specific fish stocks. WGINOSE recommends that the focus of ICES review initiatives on survey design and integration should be on the development of new, targeted surveys tailored to meet the data needs of integrated assessments and advice including fish stocks. The aim of this is to free the capacity required for addressing ecosystem aspects as required by the revised CFP and MFSD. ICES should act proactively towards this end and not wait until decisions about this are made elsewhere.

2) WGINOSE realised that communication between IEA expert groups and the ICES advisory system is not functioning too well. It appears to WGINOSE a forum is lacking where experts discuss ways of transferring science products into advice applications. WGINOSE recommends that ICES establishes communication channels that facilitate this to ensure that ICES advice takes sufficient advantage of innovative science. WGINOSE further recommends that a strategy be developed on how transfer of integrated ecosystem assessment methodology/tools from science to advice can be facilitated as first products will become available soon.

3) WGINOSE has invited Phil Levin, head of the NOAA branch working on IEA, to inform about the US-Pacific IEA developments. At present, a group of 60 scientists and technicians are working full time on the operational IEA for Pudget Sound. WGINOSE concluded that operationalization of an full cycle IEA for the North Sea and other regional seas cannot be achieved in the present ICES framework with expert groups and advisory services, which are largely depending on voluntary input from ICES member states. WGINOSE recommends WKBEMIA to deal with this issue and establish a dialogue with ACOM leadership to better guide IEA Expert groups on expectations of ICES and ICES clients in relation to integrated ecosystem advice.

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Annex 2: Agenda

ICES Working Group on Integrated Assessments of the North Sea [WGINOSE]; Stockholm, Sweden, 26–29 March 2012

(back-2-back meeting with the ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea [WGIAB])

AGENDA

Monday 26/03/12

Welcome session (WGIAB & WGINOSE)

1300 – 1310 Welcome and practical information (Thorsten Blenckner, Maciej Tomczak)

1310 – 1320 Presentation of Stockholm Resilience Centre and Baltic Nest Institute (*Carl Folke, Christof Humborg*)

1330 – 1340 Primary objectives and ToRs of WGIAB, presentation of participants (Maciej Tomczak & Lena Bergström)

1340 – 1350 Primary objectives and ToRs of WGINOSE, presentation of participants (Christian Möllmann & Gerd Kraus)

1400 – 1500 Key note talk on Integrated Ecosystem Assessments (NN)

1500 – 1530 *Coffee & Tea*

1530 – 1600 The HELCOM Core set project (Samuli Korpinen, HELCOM)

1600 – 1630 ICES plans on Ecosystem Overviews for advice purposes (Han Lindeboom, ICES)

1630 – 1800 **WGINOSE Introductory session**

<u>Structuring the WGINOSE – work:</u>

- Review of work on Integrated Trend Assessments for the North Sea and the development of an ecosystem overview document
- Discussion on Integrated Ecosystem Assessment – cycle development in relation to MSFD, i.e., is MSFD a useful approach to integrated assessments, what are shortcomings?

Identifying gaps in

1) Thresholds for ecosystem indicators

2) Identify simulation models for ecosystem indicators

3) Risk assessment

4) Integrated assessment of multiple indictors - explore methods

5) Testing model sensitivity in relation to indicator thresholds

- Review of WKMULTMIX
- Subgroup formation and appointment of chairs

Tuesday 27/03/12

0900 – 0930 **WGINOSE-Plenary**

Presentation: "Examples of approaches to implement the Ecosystem Approach to Fisheries Management" (Andy Kenny)

0930 – 1030 Parallel work in WGINOSE-subgroups:

1) Matching indicators and models , approaches to define targets and thresholds
2) Risk analyses and integrated assessment of multiple indicators – explore methods
3) Trend Assessments and development of ecosystem overview documents

1030 – 1100 *Coffee & Tea*

1100 – 1300 Parallel work in WGINOSE-subgroups: (to be continued)

1300 – 1400 *Lunch*

1400 – 1530 **Plenary: Modelling approaches supporting the Integrated Ecosystem Assessment Framework (WGIAB & WGINOSE)**

- EU VECTORS project & North Sea ATLANTIS model progress (Myron Peck)
- BONUS ECOSUPPORT project progress (Susa Niiranen)
- The ECOSCENARIOS project (Thorsten Blenckner)
- Biological Ensemble Modelling Approach – progress (Anna Gårdmark)

1530 – 1600 *Coffee & Tea*

1600 – 1700 Modelling approaches to be continued incl. discussion in relation to IEA

1700 – 1800 **WGINOSE Plenary**

Summary of the day

1930 – *Joint Dinner WGIAB and WGINOSE*

Wednesday 28/03/12

0900 – 1040 **Plenary: Decision support tools (WGIAB & WGINOSE)**

Presentation: „Bayesian Believe Network (BBN) modelling for North Sea fisheries" (Vanessa Stelzenmueller)

1040 – 1100 *Coffee & Tea*

1100 – 1300 Parallel work in WGINOSE-subgroups: (to be continued)

1300 – 1400 *Lunch*

1400 – 1530 Parallel work in WGINOSE-subgroups: (to be continued)

1530 – 1600 *Coffee & Tea*

1600 – 1800 **Plenary: Presentation and discussion of results from the ITA Group (WGIAB & WGINOSE)**

1930 – *Common activity WGIAB and WGINOSE*

Thursday 29/03/12

0900 – 1045 **Plenary: Marine Strategy Framework Directive session (WGIAB & WGINOSE)**

- The role of IA-WGs in ICES MSFD work (Yvonne Walter)
- Contribution of WGECO to IEA and MSFD implementation (Dave Reid)
- Discussion on future IEA work on MSFD-related issues and implications for future multi-annual ToRs

1045 – 1100 *Coffee & Tea*

1100 – 1300 Parallel work in subgroups (to be continued)

1300 – 1400 *Lunch*

1400 – 1600 **Final Session (WGINOSE)**

- Wrap-up of subgroup work
- State of the report
- Discussion on next meeting (multi-annual ToRs, venue, focus)
- Discussion on long-term strategy of WGINOSE

1600 Closure of the meeting

1930 – *Pub activity WGIAB and WGINOSE*

Annex 3: WGINOSE draft terms of reference for the next meeting

The **Working Group on Integrated Assessments of the North Sea** (WGINOSE), chaired by Andrew Kenny*, UK, and Christian Möllmann, Germany, will meet in Lisbon, Portugal, DATE February 2013 to:

a) Explore MFSD indicator based trend assessments for the Southern and Northern North Sea;

b) Provide input to ecosystem overviews to provide environmental information to fish stock assessment working groups;

c) Further develop and apply a Bayesian belief network model as a tool for integrated ecosystem assessments.

WGINOSE will report by 10 April 2013 (via SSGRSP) for the attention of SCICOM.

Supporting Information

Priority	WGINOSE aims to conduct and further develop Integrated Ecosystem Assessments for the North Sea, as a step towards implementing the ecosystem approach.
Scientific justification	Key to the implementation of an ecosystem approach to the management of marine resources and environmental quality is the development of an Integrated Ecosystem Assessment (IEA). An IEA considers the physical, chemical and biological environment, including all trophic levels and biological diversity as well as socio-economic factors and treats fish and fisheries as an integral part of the environment. The work of the group will have to goal to develop the scientific basis and the tools for implementing a full IEA. It will built on the results of REGNS and WGHAME and will to conduct (i) further analyses of ecosystem structure and function, if possible also spatially-disaggregated for different subsystems of the North Sea, (ii) implement ecosystem modelling in IEA, and (iii) coordinate its work with other groups and organisations involved in developing IEA in the North Sea and other areas. WGINOSE will contribute to the ICES Science Plan to the High Piority Research Topics “Understanding Ecosystem Functioning”, specifically the research topics Climate change processes and predictions of impacts; Biodiversity and the health of marine ecosystems; Top predators in marine ecosystems; Integration of surveys in support of EAM, “Understanding Interactions of Human Activities”, specifically the research topics Impacts of fishing on marine ecosystems, Population and community level impacts of contaminants, eutrophicationand habitat changes in the coastal zone, Introduced and invasive species, their impacts on ecosystems and interactions with climate change processes; and “Development of options for sustainable use of ecosystems”, specifically the research topics Marine living resource management tools, Operational modelling combining oceanographic, ecosystem, and population processes, Marine spatial planning, including the effectiveness of management practices and its role in the conservation of biodiversity, and Contributions to socio-economic understanding of ecosystem goods and services, and forecasting of the impact of human activities.
Resource requirements	Assistance of the Secretariat in maintaining and exchanging information and data to potential participants. Assistance of especially the ICES DATA CENTER to collect and store relevant data series
Participants	The Group will be attended by 20–30 members and guests.
Secretariat facilities	None.
Financial	No financial implications.

Linkages to advisory committees	Relevant to the work of ACOM and SCICOM.
Linkages to other committees or groups	SSGSRP, WGNARS, WGEAWESS, WGIAB, WGOOFE, SGIMM.
Linkages to other organizations	OSPAR, EU, NAFO

Annex 4: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. Many of the ICES coordinated surveys carry a burden of multiple additional sampling, which has evolved over time. The result of these additional sampling requests is that the surveys are no longer specifically designed towards clearly defined fishery-related objectives, but are rather something that is not too well defined – at least beyond the original purpose of monitoring specific fish stocks. WGINOSE recommends that the focus of ICES review initiatives on survey design and integration should be on the development of new, targeted surveys tailored to meet the data needs of integrated assessments and advice including fish stocks. The aim of this is to free the capacity required for addressing ecosystem aspects as required by the revised CFP and MFSD. ICES should act proactively towards this end and not wait until decisions about this are made elsewhere	WKBEMIA, SSGRSP, SCICOM
2. WGINOSE realised that communication between IEA expert groups and the ICES advisory system is not functioning too well. It appears to WGINOSE a forum is lacking where experts discuss ways of transferring science products into advice applications. WGINOSE recommends that ICES establishes communication channels that facilitate this to ensure that ICES advice takes sufficient advantage of innovative science. WGINOSE further recommends that a strategy be developed on how transfer of integrated ecosystem assessment methodology/tools from science to advice can be facilitated as first products will become available soon	WKBEMIA, SSGRSP, SCICOM
3. WGINOSE has invited Phil Levin, head of the NOAA branch working on IEA, to inform about the US-Pacific IEA developments. At present, a group of 60 scientists and technician's are working full time on the operational IEA for Pudget Sound. WGINOSE concluded that operationalization of an full cycle IEA for the North Sea and other regional seas cannot be achieved in the present ICES framework with expert groups and advisory services, which are largely depending on voluntary input from ICES member states. WGINOSE recommends WKBEMIA to deal with this issue and establish a dialogue with ACOM leadership to better guide IEA Expert groups on expectations of ICES and ICES clients in relation to integrated ecosystem advice.	WKBEMIA, SSGRSP, SCICOM

Annex 5: Abstracts of presentations

An approach for integrating the indicator bases assessment of commercially exploited fish species of the North Sea

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Introduction

Descriptor 3 of the Marine Strategy Framework Directive demands the assessment of the environmental status of commercially exploited fish stocks considering their abundance, fishing pressure and stock size- or age structure. In the here presented approach the 22 most important demersal species (by catch volume) of the North Sea (including the Eastern Channel and Skagerrak, ICES Areas VIId & IIIa) were assessed on the basis of the D3-indicators suggested by the EC-Commission decision 477/2010 (EU-COM, 2010).

Methods

The assessment of stock structure focused on the length structure, because this data was available from the IBTS-Q1 survey for all considered species, whereas age data is only obtained for the commercial species of major importance such as cod or plaice. For the assessment of stock size either the spawning stock biomass (SSB) from analytical stock assessments or the mean number of caught individuals per hour was used. Fishing pressure was assessed by fishing mortality (F) or harvest ratio (HR), which is the ratio of commercial landing biomass and the survey CPUE (by biomass). The length structure was assessed by the 95%-percentile of the length frequency distribution (L_{95}). Because the L_{95} has been demonstrated to be highly sensitive to the proportion of small individuals and hence recruitment processes (Probst *et al.*, 2012), the assessment of length structure was complemented by an additional size-based indicator, the mean size of the largest ten observed individuals (L_{max10}).

The assessment of good environmental status (GES) was performed for each indicator and each species. Except for the cases, where absolute reference values from analytical stock assessments were available, the trend of each indicator metric was assess with a traffic-light approach in which the last three-year's mean of the indicator metric should fall either above the 75%-quantile of the total available time-series to achieve a 'green' status or between the 75%- and 50%-quantile to achieve a yellow'. Any last—three-year's mean below the 50%-quantile was considered as 'red'. For harvest rate the GES borders were set at <25%: 'green', 25%-50% 'yellow and > 50%: 'red' (Figure 1).

To determine the GES of each species, the indicators were aggregated following two rationales: either GES was achieved, if no further detoriation occurs (GES i) or if an improvement is evident (II). Because most of the assessment is trend based and limits/and targets for most of the indicator metrics are currently unknown, GES II is more precautionary, but also harder to achieve. Accordingly, GES I was achieved, if none of the four indicator metrics of a species achieved 'red', whereas GES II was achieved, if all indicator metrics achieved 'green' (except for L_{95} which is a relative indicator and hence should at least achieve 'yellow'. This is because the number of large individuals may increase in synchrony with recruitment, hence in a growing stock L_{95} could remain stable while the stock is still improving).

At last an overall aggregation of GES of all species was performed by applying probabilities of a binomial distribution. It was assumed that for each species the random chance of achieving GES I was 0.5. According to the binomial distribution the number of species which would achieve GES with a random probability of less than 5% was therefore 15 for GES I and 9 for GES II.

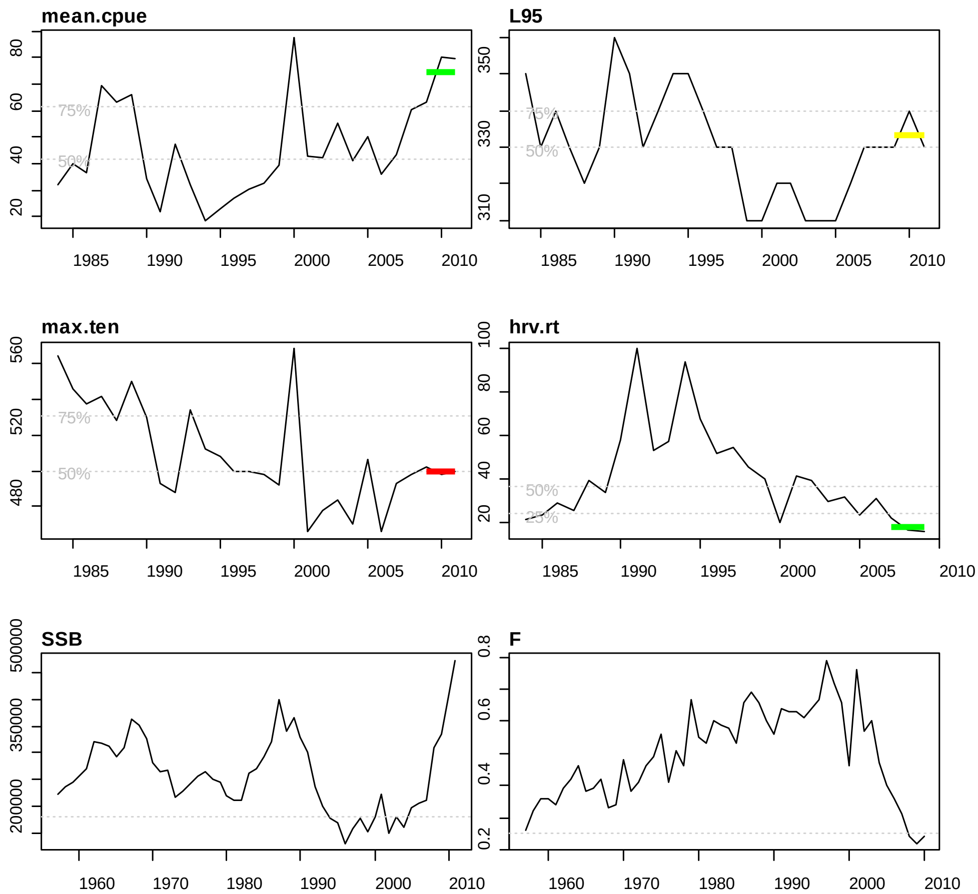

Figure 1. Example of indicator metrics for the assessment of North Sea plaice. Shown are the mean catch per unit effort (No. per hr and haul), the 95%-percentile of the length frequency distribution (L95 in cm), the mean size of the largest ten individuals (max.10 in cm), the harvest ratio (hrv.rt in % of all-time maximum), the spawning stock biomass (SSB in t) and fishing mortality (F in year^{-1}). The indicators show the status of the last three year's mean in relation to the total time-series and indicate the status of the metric by an traffic light approach. For SSB and F the ICES reference values of $B_{MSYtrigger}$ = 230.000 t and F_{MSY} = 0.23 are shown.

Results & discussion

Depending on the method of how to assess GES, only or three species achieved GES (Table 1). Accordingly, the aggregated D3-GES was not achieved in either case. In fact, GES was only achieved for three species (megrim, brill and tub gurnard) under both scenarios. This result implies that the status of commercially exploited demersal fish species in the North Sea is still critical, but also that the indicator based assessment under the MSFD can be stricter than the ICES analytical stock assessments. E.g.

plaice did not achieve GES because its size-structure, namely the L_{max10}, did not score 'yellow', whereas the ICES stock assessment indicates a long-time high of spawning stock biomass and sustainable levels of exploitation. On the other hand, the assessment of exploitation is less precise using harvest ratio instead of analytical F.: for cod, the HR performed green, whereas the ICES stock assessment indicates, that F is still above FMSY. Under the absence of absolute reference points, the trend-based assessment is associated with higher uncertainty and should be used with caution.

At the moment, there is no legal guidance on the aggregated assessment of single indicators within a criterion or descriptor. The here presented approach is an attempt to achieve this kind of aggregation on a statistically justified basis. Contrary to this approach, the one-out-all-out principle (OOAO) as applied in the water framework directive (Borja *et al.*, 2010) is often put forward as an aggregation method, meaning that if one ecosystem component fails to achieve GES, the aggregated GES cannot be achieved. The OOAO principle seems to be supported by the MSFD within descriptor 3, which explicitly states that "**all** commercial fish and shellfish species" should be in good environmental status (EU-COM, 2008). However, due to unforeseen changes in the ecosystem and the associated interaction between species and their environment, the OOAO-principle may prevent that GES to be achievable. A certain number of commercial species may decline due to climate change, competition or predation even if fishing pressure is low or absent. The 'red' status of these species hence would not be the result of regional human activities (such as fishing) and would therefore not result from an inadequate fisheries management regime, but hinder the achievement of GES. Instead, it seems advisable to determine a critical number of commercially exploited species, which should achieve GES to make the status assessment results of commercial species meaningful to fishing pressure.

Table 1. Results of indicator based-assessment of demersal fish species of the North Sea. Species with grey shades and indicators with asterisks were assessed by analytical stock assessments; the other indicator metrics were assessed by trends.

MSFD Criterion	3.1	3.3	3.3	3.2		
Species	SSB/N	L_{95}	L_{max10}	F/HR	GES I	GES II
AMBLYRAJA RADIATA						
BROSME BROSME						
CHELIDONICHTHYS LUCERNUS						
GADUS MORHUA	*			*		
GLYPTOCEPHALUS CYNOGLOSSUS						
LEPIDORHOMBUS WHIFFIAGONIS						
LIMANDA LIMANDA						
LOPHIUS PISCATORIUS						
MELANOGRAMMUS AEGLEFINUS	*			*		
MERLANGIUS MERLANGUS						
MERLUCCIUS MERLUCCIUS						
MOLVA MOLVA						
PLATICHTHYS FLESUS						
PLEURONECTES PLATESSA	*			*		
POLLACHIUS POLLACHIUS						
POLLACHIUS VIRENS	*			*		

RAJA CLAVATA						
SCOPHTHALMUS MAXIMUS						
SCOPHTHALMUS RHOMBUS						
*SOLEA SOLEA	*			*		
SQUALUS ACANTHIAS						
TRISOPTERUS ESMARKII	*					
Total species	22	22	22	22	22	22
No. species GES I	13	14	9	14	6	
% GES I	59 %	64 %	40 %	63 %	27%	
No. Species GES II	9	14	7	8		3
% GES II	40 %	64 %	32 %	36 %		14 %
Required No. of species for GES					15	15
Aggregated D3-GES						

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