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Report of the Workshop on integrated trend analyses in support to integrated ecosystem assessment (WKINTRA)

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International Council for the Exploration of the Sea
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Executive summary

The Workshop on Integrated Trend Analyses in Support to Integrated Ecosystem Assessment (WKINTRA) was held in Hamburg, Germany on 28 September 2018. The workshop, chaired by Saskia Otto (Germany) and Benjamin Planque (Norway), was attended by 12 participants from 6 countries.

Integrated trend analyses (ITA) are used by Integrated Ecosystem Assessment (IEA) groups as a way to summarize changes that have occurred in recent decades in ecosystems and highlight the possible connections between physical, biological, and human ecosystem components.

The general objective of the workshop was to develop good practices in the application of ITA and interpretation of their results to support IEA. For this purpose, a review of existing ITA methods, their strengths, and weaknesses, was prepared in advance of the workshop and discussed. In a second phase, a possible general approach for evaluating ITA method performances through simulation modelling was proposed and discussed. Sharing of information and experience between members from several ICES Integrated Ecosystem Assessment (IEA) groups was a major instrument in developing a shared vision and approach to ITA evaluations.

The report presents the review of ITA methods currently used and of some possible additional candidates. A proposition for an evaluation procedure of current and future ITA methods based on numerical simulations is also presented. Finally, a summary of the key elements discussed during the meeting and the main recommendations are outlined. The workshop reached a consensus on the necessity to conduct ITA methods evaluation and the possibility of approaching the problem through simulation studies. The workshop participants outlined specific propositions on how to conduct numerical simulations and how to use them to evaluate the performance of ITA. For this purpose, it is recommended that two workshops be conducted to follow up from WKINTRA. A first workshop to develop and compare numerical simulation protocols and algorithms, with the aim of simulating few contrasted ecosystem datasets. A second workshop to perform the evaluation of few ITA methods on the simulated datasets. It is recognized that ITA evaluations will be system specific and will require that the objectives of the ITA be explicitly defined by individual IEA groups. While the simulation exercises planned in the two future workshops will serve as 'proof of concept', evaluations of the performance of individual ITA methods in individual IEA groups will require specific applications of the evaluation approach.

If successful, the ITA evaluation protocol is expected to empower IEA groups in selecting and applying ITA methods that can provide robust interpretations of the multiple time-series available to the group. The process will also support the scoping activity of IEA groups, which is required to achieve ITA evaluation.

1 Terms of reference, agenda and participation

The general objective of the workshop is to develop good practices in the application of integrated trend analyses (ITA) and interpretation of their results for integrated ecosystem assessment. The workshop terms of reference (ToRs) are:

a) Compile an overview of current ITA methods and their use for marine IEA;

b) Review known performance and limitations of ITA methods for marine ecosystem datasets;

c) Develop a protocol for the performance-evaluation of ITA methods.

The meeting, chaired by Benjamin Planque (Norway) and Saskia Otto (Germany) was held on 28 September, from 9:00 to 16:00 at the Institute for Marine Ecosystem and Fishery Science in Hamburg. It was attended physically and remotely by 12 participants from 6 countries.

- Saskia Otto gave a presentation reviewing existing ITA methods used in IEA based on earlier work by ICES expert groups (see section 2);
- Benjamin Planque gave a presentation on the possible approach to evaluate ITA methods (see section 3).

In addition, three presentations were given by participants to the workshop:

- Erik Olsen highlighted that individual time-series can be presented in multiple ways that can communicate information differently. Selecting the appropriate presentation depends on the message one wants to convey. Traffic light plots that have been used for multiple time-series may not always be the best way to convey information about temporal patterns in an ecosystem.
- Hiroko Solvang presented an analysis of existing and possible methods for integrated trend estimation of multivariate time-series data. The presentation outlined the importance of considering the configuration and statistical characteristics of time-series before applying specific methods. It was suggested that ordinal multivariate analyses such as principal component analysis (PCA) or factor analysis should be used in forms that are adapted to time dependence, e.g. dynamic PCA. Relevant literature and tools were introduced (Kato *et al.*, 1996; Zuur *et al.*, 2003; Solvang *et al.*, 2008; Cong *et al.*, 2015; Melnikov *et al.*, 2016; Solvang *et al.*, 2018). Finally, a comparison study for dynamic factor analysis and structural time-series model was presented.
- Sean Hardison (EDAB/NEFSC) presented the results of a simulation study exploring the efficacy of common trend detection methods at detecting trends in short time-series given different magnitudes of trend and autocorrelation. The results suggested that the ability to detect trends in time-series is hampered by the influence of autocorrelated residuals when series are short (N = 10, 20, 30). Even when only weak autocorrelation was present, all trend detection methods were found to be biased at these series lengths, which resulted in departures from nominal Type I and Type II error rates. These findings highlighted shortcomings in commonly implemented approaches to trend detection for ecosystem indicator reporting, as indicator time-series are typically short with a disparate group of indicators being subject to a single statistical approach for trend detection. While all tests were biased at short series lengths, it was suggested that implementing a

parametric approach (e.g. GLS) to trend analysis would allow for estimating uncertainty and trend strengths from probability distributions. Further, the widespread application of a single test for trend was found to increase the incidence of identifying spurious trends, and it was recommended that a more hands-on approach characterizing time-series prior to testing for trend be implemented into the reporting framework.

2 Review of current ITA methods

Integrated ecosystem assessments (IEA) are a set of approaches for organizing science to inform decisions in ecosystem-based management at multiple scales and across sectors. IEAs help to analyse and synthesize information of a wide range of ecosystem components and pressures and to identify status, changes, relationships, and processes at the ecosystem level. At present, a number of methods for IEA exist or are being developed in parallel, also among the different IEA oriented ICES working groups (WG). The methods being used range from qualitative to quantitative and from a purely ecological to a socio-ecological focus. They cover indicator approaches, risk analyses, management strategy evaluations, and participatory scoping approaches. Among these approaches integrated trend analyses (ITA) are commonly applied to summarize changes that have occurred in recent decades in ecosystems and highlight the possible connections between physical, biological, and human ecosystem components. Progress has been made now to foster coordination and cooperation between working groups and exchange best practices. Based on an initiative that stems from a workshop conducted within the ICES science fund project "IEA-Exchange", ICES IEA WG chairs were requested to list the individual methods used during the past years to perform regional IEAs. They were further asked to include information on the underlying research question and management topic for each method and to carry out a so-called SWOT analysis. A SWOT analysis is a common tool in business and industry but is equally useful in any type of project and method evaluation. It helps to identify strengths and weaknesses (S-W), as well as broader opportunities and threats (O-T) for strategic planning and decision-making. Since the latter was more difficult to identify with respect to IEAs, we focused eventually on the strength and weaknesses of each method.

In total, 22 different methods were listed and evaluated by the chairs. An overview of ITA-specific methods applied by all IEA WGs is provided in Table 2.1. Some of these methods are used to describe the dynamics of the systems such as trends and sudden shifts, others to identify the main drivers that lead to the observed system dynamics. For some of these methods a free R script exist (see Diekmann *et al.*, 2012), i.e. for the traffic light plot, PCA, anomaly plots and chronological clustering, which is probably why these tools were most commonly used across WGs and often considered as 'the' ITA. The traffic light plot, for instance, is routinely used to evaluate the temporal trends for a large number of biotic and abiotic variables. This approach is useful to identify anomalies, i.e. variables that show unusually large increases or decreases over a particular period. While the order of variables included in the plot can be of any kind, in most cases they are sorted in descending manner according to their principal component analysis (PCA) loadings on the first axis. Thus, variables that show the greatest increase (positive) and the greatest decrease (negative) trends are ranked at the top and the bottom of the traffic plot respectively whereas variables that are in the middle of the table show inconclusive trends. However, this way of sorting has been criticized for being sensitive to the explanatory power of the PCA. The most commonly mentioned and agreed advantages and disadvantages of each method can be found in Table 2.1. While each method had their own set of strength and weakness, we found common issues that need to be considered in future selection of ITA tools:

1. Time-series lengths and gaps (NAs);
2. Temporal and spatial resolution;
3. Number of variables selected (e.g. 5 vs. 50);
4. Balance of variables selected (e.g. biotic vs. abiotic, number per trophic level, etc.);
5. Weighting of variables, if any;
6. Method assumptions and required data transformations (e.g. stationarity, multivariate normal distribution, collinearity, independence);
7. Choice of method setting (e.g. distance metric, sorting in traffic light plot, etc.);
8. Method simplicity and software availability;
9. Level of required system knowledge;
10. Predictive performance;
11. Certainty in the identification of underlying drivers.

The widely used Principal Component Analysis (PCA) is prone to various of the above issues (e.g. Legendre and Legendre, 1998; Diekmann *et al.,* 2012; Planque and Arneberg, 2018) and hence, requires a thorough data selection, pre-treatment, method application and interpretation. Any information on this, however, has been found missing in recent IEA reports (ICES, 2017).

In recent years, alternative ordination methods have evolved, or the software developed to apply these methods, that overcome some of the constraints the PCA faces in particular the dependence in the time-series. An overview of potential ordination techniques that could be further assessed within WKINTRA is given in Table 2.2. Some of these methods are unconstrained and serve purely a descriptive purpose, as the PCA. Others could link key dynamics in the abiotic ecosystem component with the biotic component or identify temporal as well as spatial dynamics such as the principal tensor analysis (e.g. the latest WGIAB report, ICES 2018a). Whether these methods qualify as alternative in an ITA framework and which method would perform best requires further testing.

Table 2.1. List of ITA methods used among ICES IEA working groups including data handling and identified strengths and weaknesses of each method as well as the number of working groups that applied the method.

	Type	Method	Purpose	Ecosystem component	Required data treatment	NAs allowed	Strength	Weakness	Nr of WGs
State description	Visualization (univariate)	Anomaly plots	Description of single time series	Biotic / abiotic	None	Yes	• Easy to make and understand (intuitive) • No pre-selection of variables necessary	• No integration → with many variables difficult to extract common trends and synchrony in changes	3
	Visualization (multivariate)	Heat map / Traffic light plot	**Joint** description of single time series	Biotic and abiotic	None	Yes	• Easy to make and understand (intuitive) • No pre-selection of variables necessary	• Identification of only more obvious patterns • If pattern is fuzzy, hard to interpret	7
	Unconstrained ordination (multivariate)	Principal Component Analysis (PCA)	Identification of common trends, key variables and potential drivers	Biotic / abiotic (separately and combined)	Log-transformation to linearize and standardization; conversion to distance matrix	No	• Available script and free software in R • Well-documented methods and ease of use • Separate analysis of data subsets possible	• Not sufficiently directed to answer policy questions • Prone to the selection of variable • No direct link to management actions	4
	Change point analysis (multivariate)	Chronological Clustering	Identification of **joint** shifts	Biotic	Standardization; conversion to distance matrix	No	• Different association measures can be applied • Available script and free software in R • Number of variables virtually not restricted	• Does not give indications which variables drive the changes • Prone to the choice of variables, association coefficients and data pre-treatment	3
	Change point analysis (univariate)	STARS	Identification of shifts in single time series or latent variables (PCA)	Biotic	None	Yes	• Simple method • Detects changes in mean AND variance that can be summarized to identify synchronous changes • Available as free add-on in Excel	• When run on PC scores o still prone to same weaknesses and threats as PCA o If selected PCs do not explain enough variation, analysis does not allow for conclusion on entire community	1

Process understanding	Descriptive statistical model (univariate)	Correlations	Identification of potential linkages between species or between environment and species	Biotic and abiotic	None	Yes	• Easy to make once time series are available	• May be misinterpreted as functional relationships • Non-stationary relationship makes it difficult to use correlations for prediction, e.g. to infer the effect of management actions	1
	Inferential statistical model (univariate)	Statistical models on PC scores (LM, GLM, GAM)	Identification of key drivers for main trends observed in PCA	Biotic PCscores ~ biotic	None	Yes	• Allows identification of main driver(s) for key dynamics using a limited number of models (usually 1-3 for main exes)	• Does not necessarily identify the variables that are mainly influenced by the driver • Relationships only valid for the current dataset	2
	Inferential statistical model (univariate)	Time series analyses techniques (GAM; ARIMA; Transfer Function Models; Intervention Analysis; Wavelet Analysis)	Identification of key drivers for single biotic variables	Biotic ~ abiotic	Depends; partly transformation and standardization		• Different techniques available • Allows to define temporal patterns and quantify driver effect • Prediction possible	• Prior understanding of the system is needed • Needs extensive time-series	1

Table 2.2. Overview of alternative ordination methods for state description (descriptive) and process understanding (predictive) that require further suitability evaluation.

Method	Abbreviation	Purpose / Ordination type	Type of response /relationship	Length of gradient	Nr. of tables	Distance metric
Principal Component Analysis	PCA	Descriptive / unconstrained	linear	short	1	Euclidean distance
Principal Coordinate Analysis	PCoA	Descriptive / unconstrained		short, long	1	every (common: Bray-Curtis)
Non-metric Multidimensional Scaling	NMDS, MDS	Descriptive / unconstrained		short, long	1	every
Correspondence Analysis	CA	Descriptive / unconstrained	unimodal	long	1	Chi-square distance
Detrended Correspondence Analysis	DCA	Descriptive / unconstrained	unimodal	long	1	Chi-square distance
Multiple Correspondence Analysis	MCA	Descriptive / unconstrained			1	Chi-square distance
Factor Analysis	FA	unconstrained			1	Euclidean distance
Dynamic Factor Analysis	DFA				1?	
Min/Max Autocorrelation Factor Analysis)	MAFA				1?	
Time Series Factor Analysis	TSFA				1?	
Forecastable Component Analysis	ForeCA				1?	
Locally Linear Embedding	LLE				1?	
Canonical Correlation Analysis	CCorA	Predictive / constrained	linear?		2	
Canonical Correspondence Analysis	CCA	Predictive / constrained	unimodal	short, long	2	Chi-square distance
Redundancy Analysis	RDA	Predictive / constrained	linear (both X and Y)	short	2	Euclidean distance
Distance-based RDA	db-RDA	Predictive / constrained	linear (both X and Y)	short	2	Bray-Curtis S
Co-Inertia Analysis	CoIA	Descriptive / unconstrained			2	
Partial Triadic Analysis - STATIS	PTA	Descriptive / unconstrained			1 k-table	every
CO-inertia and STATIS	COSTATIS	Descriptive / unconstrained			2 k-tables	every
Principal Tensor Analysis	PTA	Descriptive / unconstrained			1 tensor (table with >2 dimensions)	Euclidean distance

3 Numerical simulations to evaluate ITA methods

The performance of numerical methods can be assessed *a priori* by checking that they are appropriately used, following their underlying assumptions and domain of application. However, for specific applications, it may be useful or necessary to evaluate the methods performance on specifically designed simulated datasets. This is the approached followed by Hardison to quantify the performance of trend detection techniques in the presence of observation noise and autocorrelation (this report, section 1) or by Planque and Arneberg (2018) to evaluate the use of Principal Component Analysis (PCA) to detect common trends in IEA multivariate datasets. Numerical simulations have recently been applied to evaluate the performance of Multivariate AutoRegressive Models (MARs) to recover interactions in ecological systems from multiple time-series (Certain *et al.*, 2018). Runge (2018) also used multivariate simulation to evaluate the ability of several approaches to retrieve causal relationships from multiple time-series using a variety of methods. The simulation-evaluation approach can be a powerful way to evaluate the performance of generic methods when used for specific applications.

The use of simulation-based evaluation methods is not novel to ICES. It was used already 30 years ago, in 1988, by the Workshop on the Methods of Fish Stocks Assessment (ICES, 1993). At the time, ICES recognized that considerable development of new methods for fish stock assessment had occurred and that many of these new methods had not been extensively tested. In some instances, the use of different methods to assess the same stock had produced different results, leading to confusion. The 1988 Workshop was established for the purpose of testing numerical methods, which performed statistical integrated analysis of catch-at-age data and auxiliary information, and constructing and implementing appropriate datasets. The basic approach adopted was to investigate how well each method estimated certain parameters employed in creating simulated datasets. A small number of simulated datasets was produced and supplied to a number of nominated stock assessors. Each stock assessor was requested to apply a method. The performance of stock assessment methods was assessed by comparing i) the percentage discrepancy between estimate and truth and ii) indicators of bias and precision.

A similar exercise was conducted a decade later by the USA National Research Council (Anonymous, 1998). The specially appointed committee undertook a numerical simulation study which major goal was to probe the performance of commonly used stock assessment models under severe conditions, where these models were suspected not to perform well.

Interestingly, the committee recognized that such evaluation rarely appears in the published literature because the task is quite daunting and not as interesting to scientists as developing new methods. In 2018, IEA groups (rather than single-stock assessment groups) face a similar challenge and opportunity with the use of ITA (rather than stock assessment models): i) new methods have developed faster than evaluation studies, and ii) simulation-evaluation exercises may provide a sound approach to ITA evaluation.

Some key issues need to be considered in advance of a numerical simulation-evaluation study:

- What is the purpose of the ITA?
- What types of datasets should be simulated, and how many?
- What should be the key features to be incorporated in the simulated datasets?
- What type of ITA outputs should be evaluated, and how?

Some of the above questions were discussed during the workshop and possible ways to address them are provided in section 4 below.

4 Discussions, synthesis and future work

4.1 ITA motivations

The review of currently used ITA methods, and the experience of IEA group members present at the workshop, indicate that the rational and motivations for using particular ITA methods have generally not been clearly presented. The motivations can be rather vague e.g. ‘understand past dynamics of the ecosystem’ or ‘summarize past changes in ecosystem structure’. ITAs are applied to reduce the difficulty that IEA groups face when trying to interpret complex multivariate time-series. Sometimes a method has been ‘blindly’ repeated year after year, or transferred from one IEA group to another, without clear reason or simply because of the availability of a ready-made R script. IEA groups need to explicitly enunciate objectives, assumptions behind the analyses, expectations from the results and the ways in which these can be interpreted, to ensure that the ITA results can provide new information that supports the IEA and can be efficiently communicated to end-users. This applies to complex multivariate techniques, which rely on specific underlying assumptions, but also to simpler graphical approaches (e.g. heatmaps), which equally need to be interpreted in certain ways. In some cases, it might be preferable to present and analyse individual time-series – that are well understood and can be interpreted – rather than integrated analyses that may be harder to interpret and communicate. The ITA method(s) selected by an IEA group should prove helpful for better describing or quantifying how the ecosystem has developed.

Ultimately, this boils down to the key objectives of the IEA groups that should be defined during the scoping phase (Levin *et al.*, 2013).

4.2 Data integration and ecosystem overviews

There is a need for coherence between the data integration performed by IEA groups (in the form of ITA or in other forms) and the general understanding of the ecosystem dynamics outlined in the ecosystem overviews (EO). Data collection and integration (through ITA) should reflect the activities, drivers, and responses that are the key elements of the ecosystem and the known interactions that are thought to be the main driver of the system dynamics (in EOs).

4.3 Assumptions, data selection and transformation

In addition to making the motivations for ITA explicit (4.1) and linking the ITA to ecosystem overviews (4.2), it is vital that the assumptions behind the ITA method used be clearly stated. IEA groups perform data selection, by expert knowledge or through statistical procedures (or both), but this phase is often not well reported and the sensitivity of the ITA to the data selection process is rarely addressed. Similarly, data transformation (e.g. log-transformation for biological data) is often used without necessarily being reported or justified in the respective report. Transparency and reproducibility require that the details of the method be provided in a clear and comprehensive fashion so that the analyses can be reproduced by independent researchers. It was also noted that method exploration, i.e. the approach of trying different methods on a dataset until one provides a ‘desired’ result, should not be encouraged. Rather, IEA groups need to look into the assumptions behind the methods and how they suit the data and question. IEA question(s), data selection and transformation, choice of ITA method and underlying assumptions need to be communicated clearly to end-users.

It is important to note here, that the method selection and data handling should not only be communicate and described in detailed in the initial report but also in subsequent reports that present updated analyses results based on the same method. Similarly, if analyses have been conducted with single time-series, such as in Diekmann and Möllmann (2010) for subsystems of the Baltic Sea, ITA approaches in the following years should more explicitly integrate these results in the interpretation step. Such adoption would reduce the need for reading all previous annual IEA group reports to completely understand method motivation and application.

4.4 Availability of methods and numerical tools through web-based applications

A first step towards method comparison was conducted within the ICES Working Group on Comparative Analyses between European Atlantic and Mediterranean marine ecosystems to move towards an Ecosystem-based Approach to Fisheries (WGCOMEDA). For a few systems, PCA results were compared with Forecasting Component Analysis (ForeCA), Dynamic Factor Analysis (DFA), and Local Linear Embedding (LLE) (ICES 2018b). As part of this comparison a first version of a shiny app was developed that allows for easy application and communication (Figure 4.1). Here, the user can select a fish community dataset from the Baltic Sea or North Sea or upload its own dataset. From here, the user can choose specific variables and the data pre-treatment and then run one of the five methods. This shiny application, which runs on any Internet browser and is based on R, represents a suitable platform for the envisioned implementation of a standardized ITA testing procedure.

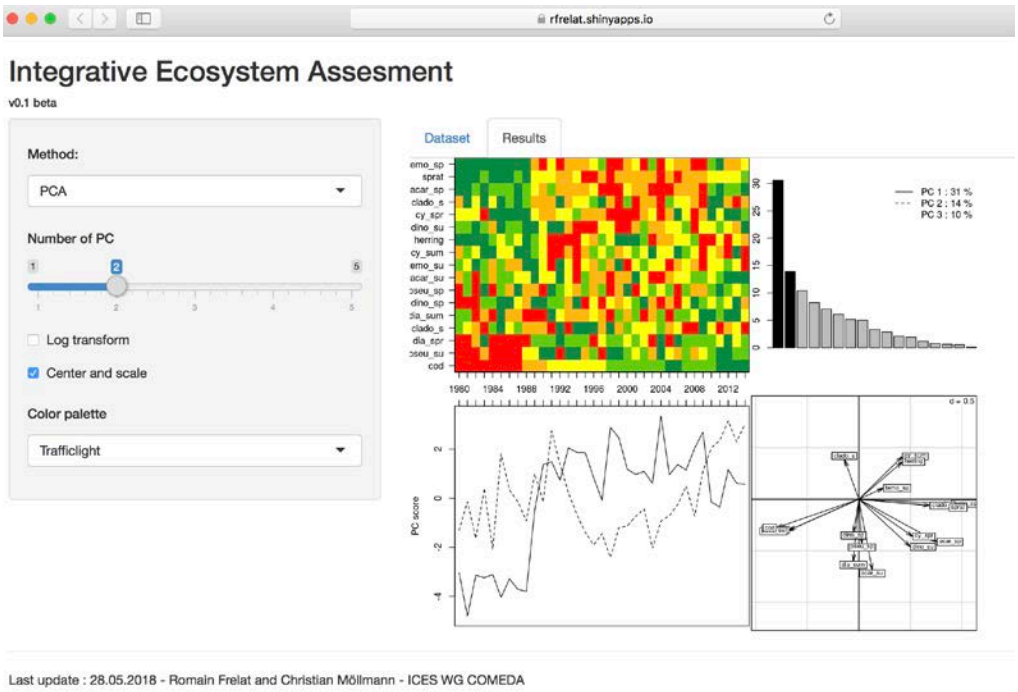

Figure 4.1. Shiny application displaying the main outputs of several methods potentially used in the framework of Integrative Ecosystem Assessment (IEA).

4.5 Key requirement for simulated datasets

Simulated datasets should have properties similar to those found in the observational datasets currently used by IEA groups. Although the datasets vary between different IEA groups, these typically include multidecadal (20 to 40 years) multivariate time-series, with one observation per year for a set of variables (~10 to 30) that include climate indices, local environmental conditions, biological indices of unexploited (e.g. plankton, benthos) and exploited (fish stocks) taxa, and fisheries (e.g. catches, F).

Individual time-series have specific properties that need considering in the simulations. These include:

- statistical distribution
- autocorrelation
- trend
- observation error

The underlying processes that drive ecosystem dynamics need considering in the simulations. These include:

- causal effects of climate/environment on biological/human responses.
- feedback controls between biological/human variables (top down and bottom up controls)
- non-linear relationships
- time-lags
- natural variability (process error)
- step changes in the ecosystem state or functioning (regime shifts)

It is proposed that simulation-evaluation studies should use simulated datasets with the properties outlined above. The simulated datasets will be simple 'caricatures' of the real-world systems that IEA groups are trying to understand. Despite their simplicity, they can still be used to evaluate the performance of ITA methods. If a model does not work for a simple system, it cannot work for a more complicated one.

4.6 Common expectations from ITA's

It is difficult to identify what are the exact expectations of IEA groups from ITA's, often because these are not expressed clearly, or because there is not a clear consensus from the group about what to expect from ITAs. Yet, it is still possible to identify some key elements that are common to many IEA groups:

- Identification of common trends across time-series:
    - are there common temporal patterns (i.e. trends) among ecosystem components?
    - how many?
    - What are the characteristics of these temporal patterns?
- Detection of discontinuities:
    - Has there been abrupt changes in the ecosystem functioning?
    - Can these classify as (non-linear) regime shifts?
    - Do they reflect changes in the causality chains in the ecosystem?
- Key drivers and driver-response relationships
    - Can we identify the key drivers (human, environmental)?
    - Can we identify the key driver response relationships?
    - Are these relationships linear or non-linear (hysteresis)?

Most IEA groups have a primary focus on describing and understanding past ecosystem dynamics. In addition to describing past changes, some methods (e.g. multivariate autoregressive models, MARs) provide a framework that can be used for predicting future ecosystem state. These could be used in situations where IEA groups' objectives explicitly include *coordinated exploration of possible future trajectories of human and natural systems* for the purpose of *informing for management options* (Weyant *et al.*, 1996).

5 Conclusion and recommendation

The workshop participants recognized the limitations of the ITA methods currently in use in IEA groups. A consensus was reached on the necessity to conduct an evaluation of ITA methods. The problem can be approached through simulation studies. The workshop participants outlined specific propositions on how to conduct numerical simulations and how to use them to evaluate the performance in the context of IEAs.

It is recommended that two workshops be conducted to follow up from WKINTRA. A first workshop to develop and compare numerical simulation protocols and algorithms, with the aim of simulating few contrasted ecosystem datasets. A second workshop to perform the evaluation of few ITA methods on the simulated datasets. It is recognized that evaluations of ITA will be system specific and will require that the objectives of the ITA be explicitly defined by individual IEA groups. While the simulation exercises planned in the two future workshops will serve as 'proof of concept', evaluations of the performance of individual ITA methods in individual IEA groups will require specific applications of the evaluation approach.

6 Bibliographic references

Anonymous 1998. Improving fish stock assessments, National Academic Press, Washington D.C., USA.

Certain, G., Barraquand, F., and Gårdmark, A. 2018. How do MAR(1) models cope with hidden nonlinearities in ecological dynamics? Methods in Ecology and Evolution, 9: 1975-1995.

Cong, F., Lin, Q.-H., Kuang, L.-D., Gong, X.-F., Astikainen, P., and Ristaniemi, T. 2015. Tensor decomposition of EEG signals: A brief review. Journal of Neuroscience Methods, 248: 59-69.

Diekmann, R., and Möllmann, C. (Eds). 2010. Integrated ecosystem assessments of seven Baltic Sea areas covering the last three decades. ICES Cooperative Research Report No. 302. 90 pp.

Diekmann, R., Otto, S.A. & C. Möllmann (2012): "Towards Integrated Ecosystem Assessments (IEAs) of the Baltic Sea - Investigating ecosystem state and historical development". In: "Climate Impacts on the Baltic Sea: From Science to Policy", Reckermann, M., Brander, K., MacKenzie, B.R., Omstedt A. (eds.), Springer Earth System Sciences Series, Berlin, Heidelberg, p. 161-201

ICES 1993. Reports of the working group on methods of fish stock assessments. ICES Cooperative Research Report, 191: 256pp.

ICES. 2017. Report of the Workshop on Integrated Ecosystem Assessment methods (WKIDEA), 11-12 October 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/SSGIEA:15. 26 pp.

ICES. 2018a. Final Report of the ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB). 16-20 April 2018. Tartu, Estonia. ICES CM 2018/IEASG:08. 24 pp.

ICES. 2018b. Interim Report of the Working Group on Comparative Analyses between European Atlantic and Mediterranean marine ecosystems to move towards an Ecosystem-based Approach to Fisheries (WGCOMEDA). 29-31 May 2018, Sète, France. ICES CM 2018/IEASG:09. 29 pp.

Kato, H., Naniwa, S., and Ishiguro, M. 1996. A bayesian multivariate nonstationary time series model for estimating mutual relationships among variables. Journal of Econometrics, 75: 147-161.

Legendre, P. & Legendre, L. (1998). Numerical Ecology. 2nd edn. Elsevier Science B.V., Amsterdam.

Levin, P. S., Kelble, C. R., Shuford, R. L., Ainsworth, C., deReynier, Y., Dunsmore, R., Fogarty, M. J., et al. 2013. Guidance for implementation of integrated ecosystem assessments: a US perspective. ICES Journal of Marine Science, 71: 1198-1204.

Melnikov, O., Raun, L. H., and Ensor , K. B. 2016. Dynamic Principal Component Analysis: Identifying the Relationship between Multiple Air Pollutants. arXiv, 1608: 03022v1.

Planque, B., and Arneberg, P. 2018. Principal component analyses for integrated ecosystem assessment may primarily reflect methodological artefacts. . ICES Journal of Marine Science, 75: 1021-1028, DOI: 1010.1093/icesjms/fsx1223.

Runge, J. 2018. Causal network reconstruction from time series: From theoretical assumptions to practical estimation. Chaos: An Interdisciplinary Journal of Nonlinear Science, 28: 075310.

Solvang, H. K., Subbey, S., and Frank, A. S. J. 2018. Causal drivers of Barents Sea capelin (Mallotus villosus) population dynamics on different time scales. ICES Journal of Marine Science, 75: 621-630.

Solvang, H. K., Taniguchi, M., Nakatani, T., and Amano, S. 2008. Classification and similarity analysis of fundamental frequency patterns in infant spoken language acquisition. Statistical Methodology, 5: 187-208.

Weyant, J., Davidson, O., Dowlabathi, H., Edmonds, J., Grubb, M., Parson, E. A., Richels, R., et al. 1996. Integrated assessment of climate change: An overview and comparison of approaches and results In Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change pp. 367-396 Ed. by J. P. Bruce, E. F. Haites, and H. Lee. Cambridge University Press Cambridge, United Kingdom and New York, NY, USA

Zuur, A. F., Fryer, R. J., Jolliffe, I. T., Dekker, R., and Beukema, J. J. 2003. Estimating common trends in multivariate time series using dynamic factor analysis. Environmetrics, 14: 665-685.

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Annex 2: Agenda

09:00-09:15	Welcome round, rapporteur
09:15-09:45	**Review of existing ITA approaches**, their strengths and limitations and potential alternatives (by Saskia Otto)
09:45 - 10:15	Additional presentations on novel ITA approaches
10:15 - 12:00	**Discussion** and flexible coffee break
12:00 - 13:00	Lunch
13:00 - 13:30	**Development of protocol** for evaluation of ITA methods (by Benjamin Planque)
13:30 - 16:00	**Discussion** and flexible coffee break
16:00	Closure of meeting

Annex 3: WKINTRA2 – Draft Resolution

The second Workshop on integrated trend analyses in support to integrated ecosystem assessment (WKINTRA2), chaired by Saskia Otto, Germany, and Benjamin Planque, Norway, will meet in Gothenburg, Sweden on 13–15 September 2019.

The general objective of the workshop is to develop good practices in the application of integrated trend analyses (ITA) and interpretation of their results for integrated ecosystem assessment. The workshop will:

a) Identify key properties of multivariate ecological datasets that need to be reproduced in simulated data (linking to the following science plan: code 2 (Understanding ecosystems) and code 4 (Observation and exploration));

b) Identify simulation approaches that can be used to produce a set of contrasted multivariate ecological time-series (linking to the following science plan: code 5 (Emerging techniques and technologies);

c) Generate simulated datasets and anonymously archive them, together with relevant meta-data, for the purpose of further ITA evaluations (linking to the following science plan: code 5 (Emerging techniques and technologies) and code 6 (Conservation and management)).

WKINTRA2 will report by November 2019 for the attention of IEASG.

Supporting Information

Priority	The use of ITA is widespread in the ICES integrated ecosystem assessment community, and recent publications have challenged the interpretation of its results. Thus, the priority should be considered medium to high.
Scientific justification	The first workshop on integrated trend analyses in support to integrated ecosystem assessment (WKINTRA) recognized some of the limitations in the ITA methods currently used as a standard tool by ICES IEA groups. It was recommended to approach the evaluation problem through simulation studies, in a way similar to that used earlier in ICES for stock assessment models (ICES, 1993). The second workshop (WKINTRA2) will develop and compare numerical simulation protocols and algorithms, with the aim of simulating few contrasted ecosystem datasets. These will form the basis of ITA methods evaluation. ICES 1993. Reports of the working group on methods of fish stock assessments. ICES Cooperative Research Report, 191: 256pp.
Resource requirements	No major resourcing
Participants	Statisticians and researchers from across the IEASG network.
Secretariat facilities	None.
Financial	No financial implications for ICES.
Linkages to advisory committees	Link to ACOM through the development of ecosystem overviews
Linkages to other comn tees or groups	Links across all ICES IEA working groups
Linkages to other orgar zations	Links to IEA groups in the Arctic and PICES Working Groups working on similar topics.

Annex 4: Recommendations

Recommendation	Addressed to
1. Provide a short description of the rational and expectations behind the ITA method used in the IEA(s).	All IEA groups