THE SECOND WORKSHOP ON INTEGRATED TREND ANALYSES IN SUPPORT TO INTEGRATED ECOSYSTEM ASSESSMENT (WKINTRA2)

VOLUME 1 | ISSUE 86
Executive summary

The second Workshop on Integrated Trend Analyses in Support to Integrated Ecosystem Assessment (WKINTRA2) was held to develop good practices in the application of integrated trend analyses (ITA) and interpretation of their results to support integrated ecosystem assessments (IEA).

The type of ITA methods used by different ICES-IEA groups and the motivations for using these methods can vary substantially. These differences were investigated through a survey, which showed that: (1) the level of numerical literacy varies between groups (as reported by the working group chairs); (2) there is no clear consensus on why specific methods were selected; (3) the individual IEA groups do not always have a clear rational for the selection of individual methods; and (4) there is a sense that some methods may not be applicable in the context of the IEA.

The approach outlined in the first WKINTRA workshop held in 2018 involved testing various ITA methods using simulated datasets. In this second workshop, the aim was to select approaches to simulated ecosystem time series which preserve key properties of multivariate ecological datasets as well as to produce these surrogates for nine case studies. Two strategies were developed: The first uses phase-randomization surrogate time-series based on observations. With this method, each variable is simulated independently. The second uses time-series based on outputs from different statistical and foodweb/ecosystem models, where relationships between variables are explicit. Some programming code for generating these simulated time-series was developed during the workshop. This report provides details about the simulation methods used and the resulting datasets. All case study-and strategy-specific simulated datasets will serve as basis for the following third workshop in which a set of ITA methods will be evaluated and compared across systems.
ii  Expert group information

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<td>Saskia Otto, Germany</td>
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<td>Meeting venue(s) and dates</td>
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1 Terms of reference, agenda and participation

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

The Terms of Reference of the workshop WKINTRA-2 were:

a) Identify key properties of multivariate ecological datasets that need to be reproduced in simulated data (Science plan codes 4.1, 4.2, and 6.5);

b) Identify simulation approaches that can be used to produce a set of contrasted multivariate ecological time-series (Science plan codes 4.1, 4.2, and 6.5));

c) Generate simulated datasets and anonymously archive them, together with relevant meta-data, for the purpose of further ITA evaluations (Science plan codes 4.1, 4.2, and 6.5).

In 2018, a first workshop (WKINTRA-1) was held in Hamburg, Germany (ICES, 2018). It was then recommended that two further workshops should be conducted. A second workshop to develop and compare numerical simulation protocols and algorithms, with the aim of simulating few contrasted ecosystem datasets (WKINTRA-2). A third workshop to perform the evaluation of few ITA methods on the simulated datasets (WKINTRA-3). The WKINTRA-2 took place this year (2019) while the latter will be conducted in 2020.

The workshop WKINTRA-2 was held at the Swedish Institute for the Marine Environment, University of Gothenburg, Sweden on the 13-15 September 2019 and was attended by 12 participants from 7 countries.

Saskia Otto and Benjamin Planque opened the meeting. The agenda was adopted. Participants were informed about the new ICES practice regarding report authorship and the new code of conduct. No conflicts of interest were identified by the participants or the chairs. The introduction to the meeting was followed by a brief introductory round table of the participants.
2 Choice of ITA methods by IEA groups

WKINTRA-1 recommended that all IEA groups should provide a short description of the rationale and expectations behind the ITA method(s) used. A survey was setup to help IEA groups answer this question in a structured way, using the online tool LimeSurvey (https://ita4iea.limequery.com/51896?lang=en).

There were three main questions to the survey:

- **Q1:** Did your group conduct or plan to conduct an Integrated Trend Analysis in 2018/2019?
- **Q2:** Which numerical method(s) did your group use (or plan to use) for the ITA (several responses possible)?
- **Q3:** Are there numerical method(s) your group used for the ITA before 2018 but that are no longer in use (several responses possible)?

For each method listed under Q2 and Q3, the respondents were asked to further describe the motivation(s) for using/not using the specified method(s) by selecting among a set of predefined answers.

Six IEA group responded to the survey, namely WGCOMEDA, WGINOSE, WGINOR, WGEAWESS, WGIAB and WGIBAR. The number of ITA methods used vary greatly between groups, from zero in WGINOR to eight in WGCOMEDA and WGEAWESS (Figure 1). Among the methods, principal component analysis (PCA) remains the most commonly used method (4 IEA groups use or plan to use it), while only two groups use almost all ITA methods (Figure 2). The motivations for using PCA are multiple (Figure 3). The most commonly listed motivations are: it provides a graphical summary of the data, it is used to identify the drivers of change in the system and the computer code is available to the IEA group.

The lack of selection for ‘identification of causal relationships’, ‘feedbacks’, and ‘pressure-response’ seems in conflict with the motivation to ‘identify the drivers of changes’ above mentioned. The ensemble of motivations for the various ITA methods used by the six IEA groups are summarized in Table 1.

Some methods have been abandoned by IEA groups. This was mainly due to the recognition by the groups of methodological limitations, when applying the approach to their specific datasets. These include Chronological clustering, change point analysis on multivariate time-series, PCA and heatmaps (when based on PCA results). Two-table ordination was also abandoned due to the lack of group consensus on the interpretation of the results. Still, PCA remains the most common ITA tool but has been abandoned by WGINOR for methodological reasons, following Planque and Arneberg (2018).

Some conclusions emerge from the online survey:

- The reported level of numerical literacy varies between groups
- There is no clear consensus between groups on why to select specific methods
- There is not always a clear rational from the individual groups on why to select individual methods
- There is a sense that some methods may not be applicable in the context of the IEA

A caveat of the survey is that the results are based on the input from only 1 or 2 respondents from each IEA group, who might have a different understanding of specific ITA tools and the motivation for using them as other WG members. Despite their limited representativeness, the
survey results support the need for following the work initiated by WKINTRA-1, i.e. to evaluate the performance of ITA methods to address the questions raised by the different IEA groups.

**Figure 1.** Number of ITA methods used by the six different IEA groups who responded to the survey.

**Figure 2.** Number of groups using specific ITA methodologies. Anom_S: anomaly plots on single variables; Traffic: traffic light/heatmap plots; PCA: Principal component Analysis; CA: Correspondence Analysis (or other ordination method); RDA: two table ordination method; PTA: K-table ordination method; ChangePoint_S: change point analysis on univariate time-series; ChangePoint_M: change point analysis on multivariate time-series; Clustering: chronological clustering; GAMs: generalized additive models on ordination outputs; IRA: integrated resilience analysis (Vasilakopoulos et al. 2017); Other: other methods not listed. These included MAFA (Min/Max Autocorrelation Factors) and structural trend models.
Figure 3. Motivations of individual IEA groups for using principal component analysis as a way to perform ITA. The score (y-axis) denotes the number of groups who choose a particular motivation.

Table 1. Motivations of individual IEA groups for using various ITA methods. The values in each cell denote the number of groups who choose a particular motivation.
3 Summary of WKINTRA1 and workplan for WKINTRA2

A brief presentation of the work conducted during WKINTRA-1 was given by Benjamin Planque, followed by a discussion. The general goal of an IEA can be defined as to “synthesize and evaluate information on physical, chemical, ecological, human and environmental process affecting ecosystems”. ITAs can support this goal by providing way of summarizing available quantitative information, as long as the summary is informative. A challenge is that most ITA method (e.g. those listed in section 1) work best when there are few distinct time-series, many observations, stationary data, small observation error and well known causal relationships BUT most datasets in IEA groups consist of many distinct time series, few observations (for each individual series), non-stationary data (i.e. trends), substantial observation error and not-so-well known causal relationships. Consequently, it should not be taken for granted that ITA summaries are informative. Rather, this should be evaluated. The approach taken by WKINTRA is first to identify ITA methods that could work on large marine ecosystem datasets, and second to evaluate the performance of the methods on these types of datasets. The evaluation approach relies on simulated data, with specified properties. The general principles are as follows:

- Define a model that describes a marine ecosystem
- Simulate the ecosystem dynamics
- Simulate the observation process
- Use ITA to recover the key information about changes in ecosystem components and their interactions

The intention is to simulate datasets that share common properties with the datasets usually available to IEA groups. Typically, these consist of multivariate time-series of length 30-50y. These time-series include abiotic (e.g. temperature), biotic (biomass) and fisheries (landings) variables. The simulation models can include a range of process models, from purely stochastic simulations to mechanistic ecosystem/End-to-end models, and a range of observation models, from perfect observations (the simulated process is directly observed) to explicit sampling design (e.g. survey indices). Prior to the workshop, two webex meetings were organized to start preparing the simulations. The selected simulation/observation schemes were:

- Independent time series with specified temporal structures,
- Multivariate autoregressive (+ trend) models + observation errors,
- Mechanistic simulations using the E2E model ISIS-FISH + observation errors,
- Non-deterministic network dynamic model simulations + observation errors

The geographical regions covered by the above were: Baltic Sea, North Sea, Mediterranean Sea, Cadiz, Northern Spain, Bay of Biscay, English Channel, Norwegian Sea, Barents Sea. It was also agreed to anonymise the simulated datasets before method evaluation. The use of the simulated datasets to evaluate the performance of ITA methods is planned for the third WKINTRA workshop, scheduled in 2020.

The general principles used for model evaluation in WKINTRA are rooted in earlier work conducted by ICES (1993) and NOAA (Anonymous, 1998) to evaluate stock assessment models. At the time, both institutions were facing an increase in the number of available stock assessment models and needed to evaluate their performance. For this purpose, they conducted simulation/anonymization analyses. More recently, Hardison et al. (2019) conducted an evaluation of trend detection analyses on single time-series using simulated time-series of different length,
trend and autocorrelation. In both cases, simulations are used as proxies for the real system and the methods are evaluated by comparing the method results to the underlying properties of the simulated data. This approach is summarized in Figure 4. These earlier efforts led to specific recommendations about which method (or which version of a method) to use for assessment/trend detection. The WKINTRA group does not have the working capacity to evaluate all the ITA methods used in ICES IEA groups for all ecoregions and under all simulation/observation schemes. In addition, given the very broad (and often still unclear) set of goals that IEA are aiming at, it is unlikely that the work conducted in WKINTRA can lead to clear recommendations on which method to use to conduct an ITA. Rather, the intention in this work is to empower IEA groups by providing recommendations on how to evaluate themselves the method that they intend to use to provide informative summaries about the ecosystem. In this way, IEA groups should be able to select and evaluate the tools that will best fit their needs, given data availability, ecosystem properties and specific questions.

Figure 4. From expectation to evaluation. Top: An ITA is performed on observations collected from a real ecosystem. One expects that the interpretation of the ITA results can provide useful information about the underlying ecosystem. Bottom: an ITA is performed on pseudo-observations from a simulated ecosystem. It is then possible to evaluate if the interpretation of the ITA is consistent with the simulated ecosystem dynamics.

The workplan for the workshop included a review of the datasets prepared prior to the meeting, further preparation of the datasets during the meeting and a plan for anonymizing and archiving of the simulated ecosystem datasets. These are developed in the sections below.
4 Data and simulations available for different ecosystems, prior to the workshop

4.1 Baltic Sea, North Sea, Mediterranean Sea, Cadiz and Northern Spain

Marcos Llope opened the presentations session describing the characteristics of some datasets that have been put together as result of previous projects or that exist at his home institution (IEO). The Baltic Sea (1975-2013) and North Sea (1964-2018) belong to the first category and consist of abiotic and biotic variables, the latter category includes not only fish but also plankton. The Baltic Sea abiotic list of variables is much longer than that of the North Sea and includes salinity or nutrients, as well as the typical fishing mortality or sea surface temperature. These two systems are well studied and their development over the last decades is well known. Also, ITA methods have been previously applied using these datasets.

Regarding the information collected by IEO, the institution holds biotic data from the (i) Cantabrian Sea and Galicia (1983-2012), both coastal seas are in the south Bay of Biscay (N Spain), (ii) the Gulf of Cadiz (1993-2015, SW Spain), and (iii) Alboran Sea and the Iberian coast (1994-2017), both coastal seas being Mediterranean subregions. The biotic variables consist of species biomasses, except for the Gulf of Cadiz were these have been clustered by functional groups. Abiotic variables are mainly derived from satellite telemetry and there is fishing effort indicators in some of the systems. These southern coastal seas are less well studied compared to the previous two and only recently ITA methods are starting to be applied.

4.2 Bay of Biscay and English Channel

Morgane Travers-Trolet presented the ITA work currently ongoing within IFREMER for the Bay of Biscay ecosystem (ICES areas 8a,b). A review of available dataset highlighted two periods: 1987-present for which only information about abiotic environment, demersal fish and landings are available and 2000-present during which primary production and small pelagic fish are also sampled. For the purpose of WKINTRA, only the longer time series is used and includes large-scale abiotic indices (NAO, AMO), main river outflows, and satellite-derived sea surface temperature and suspended particulate matters. Biotic variables are the biomass and mean weight of the main fish species caught by bottom trawl. Main landings realized in the Bay of Biscay represent fishing activity. These datasets are currently analysed through min-max autocorrelation factor analysis to perform an ITA in the area.

4.3 Norwegian Sea and Barents Sea using Mar(X) + Trend models

Hiroko Solvang introduced the simulation method based on statistical time series modelling. The data collected in the Norwegian and Barents Sea were used as example from the application of the method. Since the time series data occasionally present non-stationary trend, the time series model used for simulation includes both stationary and non-stationary components. A polynomial regression model was used to describe the non-stationary trends. Two models were considered to analyse the residuals: 1) MAR model for investigating mutual relationships among biotic variables and 2) AR model for inference from abiotic variable that is taken as exogeneous
(X) variable in addition to MAR model. The optimum time-span of MAR/AR models was identified by a statistical criterion. The MAR/AR parameters were estimated by numerical algorithm or least-squares method. Once MAR/AR coefficients were estimated, the simulation data can be generated by the estimated trend and the estimated MAR(X) models using random number. The random number is assumed to obey to normal distribution with zero mean and variance of the residual. To the simulation data, we applied same modelling procedure again. The estimated MAR/AR coefficients and variance of the residuals are used to perform spectral analysis to interpret statistical property or physical meaning of the estimates. Using the analysis, we can evaluate the consistency for statistical properties between data and simulation data.

For this method, we discussed about sampled time points to obtain robust statistical property. The observed time series data usually include less 50 time points (which means less 50 years). It is known that MAR models for such short time-series are often not robust (Solvang and Subbey 2019). On the other hand, the simulation data can be generated over 50 time points and it is possible to keep robust statistical property while over 50 years data (e.g. data including 100 years) is not realistic. Simulation data series of the same length as observational data and simulation data including longer time periods can help to investigate uncertainty for the statistical property that we evaluate.

4.4 Norwegian and Barents Sea using surrogates and NDND

The method of surrogate time series has been used to simulate multivariate time-series datasets in which each individual time-series simulation preserves specific properties of the original data, such as mean, variance, trend and autocorrelation. Because the time-series are generated independently from each other, it is assumed that relationships between time-series can only emerge by chance. The simulated time series are presented in Planque and Arneberg (2018). An example of original and simulated time-series is provided in Figure 5.
Figure 5. Examples of original (observed) and simulated datasets for the Barents Sea, using the surrogate method. Left: annual time-series of the North Atlantic Oscillation (NAO), the Spawning Stock biomass of cod (CodSSB), the recruitment of cod (CodRec), the biomass of krill (KrillBio), landings of polar cod (PolarCodLand) and of minke whales (MinkeLand). Middle: for each variable, two simulated random time-series with the same trend and residual mean and variance as the observations. The trends are highlighted as dashed-red lines. Right: for each variable, two simulated random time-series with the same trend and residual mean, variance and autocorrelation as the observations.

The Non-Deterministic Network Dynamics model (NDND) is a foodweb model in which the trophic interactions are not specified by trophic functional relationships, but rather by random interactions, given a set of constraints (Planque et al., 2014). A version of the model exists for the Barents Sea (Lindstrøm et al., 2017) and has been extended to produce simulated time-series for WKINTRA. The foodweb structure (Figure 6) includes 9 species groups, primary production and fishing. Abiotic variables are simulated using the surrogate method above and do not contribute to any change in the foodweb dynamics. An example of the model simulations is presented in Figure 7.
Figure 6. The foodweb structure in the NDND model for the Barents Sea. Green arrows represent links from prey to predators. Orange arrows represent ageing recruits entering the population (plain) and the production of new recruits from the stock (dashed). Simulated landings (blue arrows) were not available at the time of the workshop.

Figure 7. Simulated time series using the NDND. Each point represents the biomass of a group (tonne.km²). Arctic water extent (ArW), Kola section temperature (Kola) and the North Atlantic Oscillation index (NAO) are simulated independently using the phase-randomization method.
5 Data simulation approach

5.1 General considerations and simulation strategy

Several datasets are planned to be prepared and shared in order to conduct the ITA evaluation exercises. These include the observational datasets, surrogate time-series constructed with the phase-randomization technique, simulations using multivariate autoregressive models with environmental variables, mechanistic and statistical foodweb/ecosystem models, and possibly surrogate time series from the ecosystem models.

The observational data are used as a reference and as a data input for the construction of surrogate time-series.

The phase-randomization surrogate time-series are used as a model in which the structure of individual time-series is preserved, but the relationships between time series are absent (or random). This is similar to the null approach used by Planque and Arneberg (2018). It is expected that results of ITA performed on these datasets are analogue to what is often termed a ‘control’ or a ‘blank’ in experimental setups. This means that results from an ITA on observational data should significantly depart from the results obtained on the surrogate (the ‘blank’) to be considered informative. In some cases, it is possible that the surrogates do not constitute adequate ‘blank’ for the system dynamics. This issue is discussed further below.

Multivariate autoregressive (MAR) models are statistical stationary process models in which the state of each individual variable at a given time is expressed as a function of the state of all variables at present and past time-steps. In MAR, the relationships between variables are explicit. MAR can be used to simulate multivariate time-series or to estimate the likely value of model parameters given observational data. It is expected that results of ITA performed on MAR outputs should recover some information about the relationships between variables, that were explicitly included via the model parameters. Interestingly, it is possible to estimate MAR model parameters from observational data, simulate new datasets with the fitted MAR model and recover the parameters by fitting new MAR to the simulated data. If the data presents non-stationary trend, the trend model can be considered in addition to MAR model. Furthermore, if effects from abiotic factors should be considered in the model, these can be expressed as exogenous variables (X). The formula is given by MARX or MARX+Trend. In any case, this multistage fitting-simulation-fitting process can give insights into the performance of MAR(X) + Trend as a tool for ITA.

Foodweb and ecosystem models come in various forms and some models exists for most ecoregions considered in WKNTRA. As for MARs, foodweb/ecosystem models can be used to simulate ecosystem dynamics with specified structure and functional relationships between ecosystem components. It is expected that results of ITA performed ecosystem model output should recover some information about the relationships between variables, that were explicitly included in the models.

Finally, it is possible to use ecosystem model outputs as input data to phase-randomization surrogate time-series analysis. By doing this, it is possible to run parallel ITAs on model outputs and model-surrogate outputs to test if some of the model structure (i.e. the relationships between variables in the system) are retained in the surrogate time-series. In this way, it is possible to assess if the surrogate time-series operate as adequate ‘blanks’ or not.

The sections below further develop how the different datasets are prepared.
5.2 Observational data

These are the datasets usually compiled and used by the different IEA groups. These consist of tables in the form [year x variables], in which the different variables relate to abiotic, biotic, fisheries or other components of the system. For each dataset, two tables are prepared in the following format:

*Table_dataset*: a table in which each row is a year and each column in a variable. The first row is a header which contains the name of the variables. The first column contains the year value.

*Table_metadata*: a table in which each row is a variable, matching the list of variables in the *Table_dataset*. The table has the following four columns:

- **Variable**: the name of the variable
- **Units**: the unit (e.g. ‘tonnes’, ‘thousands’, ‘degree Celsius’, ‘unitless’)
- **Transformation**: TRUE or FALSE to indicate if the data in the original unit should be transformed when performing the ITA. In most cases, abiotic data remain untransformed while biotic data are transformed.
- **Info**: Additional information about the variable (full name, source, …)

The observational datasets are archived on the WKINTRA2 sharepoint under /06. data/observation_time_series. These comprise dataset for the ecoregions: Barents Sea, Bay of Biscay (BoB), Central Baltic Sea (CBS), North Sea Skagerrak (NS_Skagerrak) and Norwegian Sea.

5.3 Phase-randomization surrogate time-series

Phase randomization is a technique that uses the Fourier transformation and back-transformation, between the time domain and the frequency domain, to simulate random time-series that share the same mean, variance and autocorrelation as their original counterparts (Schreiber and Schmitz, 2000). The method assumes stationarity and normality. In cases when these assumptions are not met, it is important to make time-series stationary (by removing a linear time-trend) and normalize the time-series (by transforming the original data).

A R-script has been written by Romain Frelat to construct surrogate time-series based on the observational data provided for each ecoregion: *createSurrogate*. This is archived in the WKINTRA2 sharepoint under /07. software.

The main steps of the phase randomization function are as follows:

- Read the observational data (data and meta-data tables)
- For selected variables: normalize using the double-square-root transformation
- For all variables: compute the linear time trend; perform 1000 phase-randomization on residuals; add the trend to randomized residuals
- For selected variables: back-transform with double-square
- Save the results in Rdata format

The surrogate datasets are archived in R format. The R object contains the dataframe *dat* with the original data, the dataframe *meta* with the original metadata and the list *surList* of 1000 matrices of simulated multivariate time-series. The surrogate datasets are archived on the WKINTRA2 sharepoint under /06. data/surrogate_time_series as Rdata files. These comprise dataset for the ecoregions: Barents Sea, Bay of Biscay (BoB), Central Baltic Sea (CBS), North Sea Skagerrak (NS_Skagerrak) and Norwegian Sea.
5.4 MAR (X) + Trend models

The observed time series data display stationary and non-stationary components. In statistical time series modelling, the stationary and non-stationary parts are separately considered in the model because the statistical property of non-stationary process is different from the property of stationary process. In this simulation study, non-stationary part is represented by trend model like polynomial regression model or stochastic differential equation model. Once the trend component is estimated, MAR and AR (if we account abiotic as taken exogeneous variable (X)) models are applied to the residual parts obtained by extracting trend from the observation. The simulation and evaluation procedures are summarized as below: 1. Apply the polynomial trend model to the observation; 2. Apply MAR (for biotic) and AR (for abiotic) to the residual obtained by extracting the estimated trend from the observation; 3. Using the estimated MAR(AR) coefficients and trend, the simulation data are generated by the time series model with random noise that obeys to normal distribution with zero mean and the estimated variance (covariance); 4. Apply trend and MAR(X) model to the simulated data again; 5. Using the estimated MAR(AR) coefficients by observation and simulation data, calculate power spectrum to evaluate the statistical property. The simulation datasets are saved as mat format by MATLAB according to the models, MAR, MAR + Trend, and MARX + Trend. The sampled time points can be set as the same number or over 100 time points. The code for generating the data and checking statistical property in the case of Baltic Sea is written by Hiroko Solvang and the folder MAR_sim including all relevant codes is archived under /07. Software. This version is for applying MAR+Trend model.

5.5 Foodweb/Ecosystem models

NoBa Atlantis

NoBa Atlantis is a deterministic end-to-end model for the Barents and Norwegian seas. Environmental forcing are generated by ROM models and input the ecological module. The model is spatially resolved in 60 polygons selected to represent environmentally homogenous areas. It is also resolved in 7 layers of depth and one layer of seabed sediments. The ecological module consists of 57 trophospecies (individual species or group of taxa with similar functions), among which the vertebrates are divided in age classes (up to ten). Diffusion, recruitment, trophic interactions and fisheries are the main drivers of temporal changes in biomasses in the polygons. Possible outputs of the model include time series of all physical and biological variables. We decided to use NoBa model outputs as they result from the combined effects of multiple biological and environmental interactions. This should reflect the complexity of natural system.

Simulations were run under 4 socio-political scenarios corresponding to different fishes strategies (0.6, 0.8, 1.0 and 1.1 xFMSY). For each of those scenarios, 14 simulations were run, each forced by an individual pattern of mesozooplankton growth. Details on the simulations are described in Hansen et al. 2019.

ISIS-Fish

ISIS-Fish is a deterministic fisheries dynamic simulation model designed to investigate the consequences of alternative policies on the dynamics of resources and fleets for fisheries with mixed-species harvests (Mahevas and Pelletier, 2004; Pelletier et al., 2009). The Eastern Channel application focuses on the French fleets operating in ICES area 7d and on the most valuable species landed by French fleets (more particularly netters, bottom trawlers, mixed trawlers and dredgers). The model describes the dynamics of scallops (2 populations), sole, plaice, red mullet and
cephalopods (2 populations of squids, a population of cuttlefish). The biological models account for spatial distribution and migration of populations in course of the year. Recruitment is modelled through empirically adjusted stock-recruitment relationships and random noise is added in projection. Fishing mortality is the result of the interaction between the spatial distribution of population abundance resulting from the population submodel and the spatial distribution of fishing effort provided by the exploitation and management submodels at a monthly time-step. Fleet behavior is modelled through the dynamical modification of effort allocation on métiers in course of the simulation. A gravity model accounts for the mix of tradition and opportunist behavior of fishers when they choose which métier to practice. More details about the EEC application can be found in Lehuta et al. (2015).

According to the common fisheries policy, a transition to FMSY is implemented for the species under quota regulation (sole, plaice, cod and whiting). It is implemented in the model through TACs computed as much as possible the same way as ICES Working Groups do. The main difference comes from the fact that ISIS-Fish is not coupled with the assessment models of the species, thus SSB is assumed perfectly known on December 31st of the previous year, and recruitment is assumed equal to the last three years average. For WKINTRA the model is projected 30 years forward under the CFP management plans and strict implementation of the landing obligation. The main outputs are time series of abundance of fish populations, mean weight of populations (proxy for the age distribution), annual catches per species and/or fleet and effort at sea (which can be limited when TACs are reached but cannot be increased).

Ecopath with Ecosim

Ecopath with Ecosim (EwE) is a mass-balanced ecosystem model system that has seen wide application in marine ecosystems around the world. For the WKINTRA case studies EwE models are available for the Baltic Sea, English Channel and North Sea ecosystems with species and biophysical processes that are similar to what is observed through surveys and used as input to the regional IEA groups. Run speed of EwE is sufficiently fast to run 1000+ simulations to generate time-series of the biophysical components with measures of uncertainty that can be used as input data for the simulation strategy. For the North Sea we will used time series already developed as part of the Mackinson et al. (2018) study evaluating multi-annual plans, thus generating datasets simulating alternative management scenarios.

Foodweb statistical model

Two generalized dynamic foodweb models were presented and discussed, one for the North Sea (Lynam, Llope et al. 2017) and one for the Baltic Sea (Blenckner, Llope et al. 2015). These are coupled empirical models (GAMs) that allow for regime-dependent dynamics (tGAM) depending on whether the system is below or above a given value of a threshold variable. The modelling approach consists of two steps: first an individual statistical model is fit to each trophic level, then the separate models are coupled together into a joint foodweb model that is able to reproduce the observed population dynamics based on external drivers and the trophic interactions emerging from the individual models. This generalized dynamic foodweb model can be subsequently used to simulate the system under a range of conditions. We decided to use the Baltic Sea model due to its more simple configuration (fewer foodweb components) and because it accounts for the regime shift that took place in this marine ecosystem in the late 1980s. Regime shifts are an ecological feature that ITA methods are supposed to be able to detect and, therefore, outputs from the Baltic Sea model can be a good candidate dataset to evaluate different ITA methods.
Output data consists of 100 realizations of the ecosystem for a range of fishing pressures (from 0 to 1.4, every 0.05) under two different sets of environmental conditions. The latter were sampled from values observed during the first or the second regime (before/after 1989).

NDND

The Non-Deterministic Network Dynamics model is a minimal model of ecosystem variability (Mullon et al., 2009, Planque et al., 2014). Simulations from the NDND lie between phase-randomizations, in which all series are generated independently, and deterministic ecosystem models, in which the relationships between species groups and the environment are made explicit. In the NDND, the dynamics of all species groups are coupled via mass conservation, but there is no deterministic formulation of the trophic interactions between species, and these are occurring at random. For the Barents Sea, the version of the NDND model presented in Lindstrøm et al. (2017) has been modified to include recruitment and environmental time series. The dynamics of recruits is driven by random trophic interactions (as for all other species) and the pool of recruit is initiated each year with 1% of the stock biomass of the same species group in the previous year. At the end of each year, the new biomass of recruits enters the stock biomass.

Fisheries catches are assumed to equate landings and are determined using fixed harvest control rules (HCRs) with Bpa set to 0.625 t.km⁻² and Fmsy to 0.15 and 0.3 for pelagics and demersals respectively. In plain words: Fishing mortality (F) increases proportionally to the stock biomass. F reaches Fmsy when the stock biomass reached Bpa (F=Fmsy*(Biomass/Bpa)). When the biomass exceeds Bpa, the value of F is fixed to F=Fmsy.

For the dynamics of environmental time-series, three variables are considered: the North Atlantic Oscillation index (NAO), the surface temperature at the Kola section (Kola) and the area occupied by Arctic water (arW). The three time-series are simulated using the phase-randomization technique and are – by construction – decoupled from the foodweb dynamics.

The code for simulating the biomass time-series is included in the R object that contains one NDND simulation outputs in the WKINTRA2 sharepoint under /07. software. The code for the environmental dataseries is the createSurrogate code mentioned in the above section 5.3. The outputs from 1000 simulations are provide in a Rdata object in the WKINTRA2 sharepoint under /06. data/Ecosystem_models_time_series/NDND_BarentsSea.

Surrogate time-series on ecosystem model outputs

The preparation of phase-randomization surrogates from the output of ecosystem models has been discussed during the workshop. However, no attempt has been made, yet, to produce such data. The motivation for simulating data in such way (expressed in section 5.1) is to is run parallel ITAs on model outputs and model-surrogate outputs to test if some of the model structure (i.e. the relationships between variables in the system) are retained in the surrogate time-series. In this way, it is possible to assess if the surrogate time-series operate as adequate ‘blanks’ or not.
6 Way forward and recommendations

Not all datasets have been finalized during the workshop. Most simulations from ecosystem model remain to be done and the dataset will need to be archived on the ICES WKINTRA share-point. This will be conducted intersessionally.

The approach to be used to test ITA methods using simulated data was further discussed beyond the general description provided in section 3 (Figure 4). In particular, it is important to identify which outputs of an ITA method are used to build an interpretation of the ecosystem past dynamics or is used to improve our understanding of how the system functions. Three analyses were discussed as starting examples: heatmaps, integrated resilience assessment (IRA) and principal component analysis (PCA).

**Heatmaps** are a way to graphically visualize the time varying changes in multiple variables, on a standardized colour-scale. The order of the time series is often (but not always) set by a previous analysis (e.g. PCA) and the heatmaps display a pattern that is usually characterized by a more or less homogeneous coloured area on one corner and the opposite colour (given the chosen colour spectrum) in the opposite corner. There was no clear conclusion on how to compare heatmaps from observational versus simulated data. This is because most of the heatmap interpretations are in the form of narratives rather than quantitative outputs. The emergence in the simulated datasets of the diagonal colour pattern above-mentioned could be used to test for methodological artefacts.

**Integrated Resilience Analysis** (IRA, Vasilakopoulos et al., 2017) is a complex multistage numerical analysis which involves PCA on biotic and abiotic components followed by piecewise (or threshold) generalized additive models (GAMs). This offers the possibility of testing the method at its different steps and compare, for example, the probability of finding the threshold in a given year from the simulated data, against the probability assigned by the analysis on the observational data.

**Principal Component Analysis** (PCA) has been the focus of the ITA testing work by Planque and Aneberg (2018). As in the case of IRA the first principal component on biotic variables is often used to related drivers (abiotic) of the system to their biological response (PC1). One way to evaluate this approach can be to compare the relationship ($r^2$) between observed drivers and the PC1’s obtained in the observational and simulated datasets.

The analyses to be performed (during WKINTRA-3) on the simulated datasets are not limited to the above list which is only provided as illustrative examples. The main goals of the third workshop will be: first, perform selected ITAs on the observational and simulated datasets, with clearly defined protocols for the interpretation of the ITAs; second, define a set of criteria to evaluate the method’s performance and third, report the measured performance of the ITAs.
7 References


Annex 1: List of participants


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Annex 2: Agenda

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<tr>
<th>13th September</th>
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<tr>
<td>09:30 - 09:45 Welcome round, nomination of rapporteur</td>
<td>Saskia</td>
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<tr>
<td>09:45 - 10:30 Review of ITA approaches used by different IEA groups and the motivations for using them</td>
<td>Benjamin</td>
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<td>10:30 – 11:00 Break</td>
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<tr>
<td>11:00 – 12:00 Report from the first WKINTRA workshop and following workplan</td>
<td>Benjamin</td>
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<td>12:00 – 13:00 Lunch</td>
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<tr>
<td>13:00 – 13:30 Simulated datasets #1: Baltic Sea, North Sea, Mediterranean Sea, Cadiz and Northern Spain</td>
<td>Marcos</td>
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<tr>
<td>13:30 – 14:00 Simulated datasets #2: Bay of Biscay and English Channel</td>
<td>Morgane</td>
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<tr>
<td>14:00 – 14:30 Simulated datasets #3: Norwegian and Barents Sea using MARs</td>
<td>Hiroko</td>
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<td>14:30 – 15:00 Break</td>
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<tr>
<td>15:00 – 15:30 Simulated datasets #4: Norwegian and Barents Sea using surrogates and NDND</td>
<td>Benjamin</td>
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<td>15:30-16:00 Discussion on key properties of simulated ecological datasets</td>
<td>Benjamin</td>
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<tr>
<td>09:00 - 10:00 Discussion on key properties of simulated ecological datasets (continues)</td>
<td>Benjamin</td>
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<td>10:00 - 12:00 Group work to report on simulation approaches (flexible break during the time period)</td>
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<td>12:00 - 13:00 Lunch</td>
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<td>13:00 – 15:30 Refinement of simulations, documentation of assumptions, simulation protocols and outputs</td>
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<tr>
<td>15:30 – 16:00 Discussion on meta-data, anonymisation and archival of datasets</td>
<td>Saskia</td>
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<th>15th September</th>
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<tr>
<td>09:00 – 10:00 Reporting on the state of individual simulations</td>
<td>Benjamin</td>
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<tr>
<td>10:00 – 10:30 ToRs for WKINTRA-3</td>
<td>Benjamin</td>
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<td>10:30 – 11:00 Break</td>
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<tr>
<td>11:00 – 12:00 Finalization of work, task assignments in preparation for WKINTRA-3</td>
<td>Saskia</td>
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Annex 3: WKintra3 Draft Resolution

The third workshop on integrated trend analyses in support to integrated ecosystem assessment (WKINTRA-3), chaired by Saskia Otto, Germany, and Benjamin Planque, Norway, will meet in 8-10 December 2020 at ICES-HQ in Copenhagen, Denmark.

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

a) Review the simulated multivariate ecological datasets prepared during and following WKINTRA-2 (Science plan codes 1.3 and 1.9)

b) Evaluate a selection of Integrated Trend Analysis (ITA) methods (Science plan codes 1.3 and 1.9).

For this:
- a set of ITA methods will be selected,
- the R code to run the analyses will be provided,
- method-specific qualitative or quantitative criteria will be defined that allow for an objective comparison across simulated datasets
- the ITA methods will be applied on relevant simulated datasets outcomes will be assessed on a case study- and approach-specific basis

c) Develop guidelines for IEA groups to evaluate ITA methods, including a comprehensive documentation of data generation and method application using the R environment (Science plan code 6.5)

WKINTRA3 will report by 1st February 2021 for the attention of IEASG.