A stochastic surplus production model in continuous time

Surplus production modelling has a long history as a method for managing data-limited fish stocks. Recent advancements have cast surplus production models as state-space models that separate random variability of stock dynamics from error in observed indices of biomass. We present a stochastic surplus production model in continuous time (SPiCT), which in addition to stock dynamics also models the dynamics of the fisheries. This enables error in the catch process to be reflected in the uncertainty of estimated model parameters and management quantities. Benefits of the continuous-time state-space model formulation include the ability to provide estimates of exploitable biomass and fishing mortality at any point in time from data sampled at arbitrary and possibly irregular intervals. We show in a simulation that the ability to analyse subannual data can increase the effective sample size and improve estimation of reference points relative to discrete-time analysis of aggregated annual data. Finally, subannual data from five North Sea stocks are analysed with particular focus on using residual analysis to diagnose model insufficiencies and identify necessary model extensions such as robust estimation and incorporation of seasonality. We argue that including all known sources of uncertainty, propagation of that uncertainty to reference points and checking of model assumptions using residuals are critical prerequisites to rigorous fish stock management based on surplus production models.
Effectiveness of fully documented fisheries to estimate discards in a participatory research scheme
A key challenge for fisheries science and management is the access to reliable and verifiable catch data. In science, the challenge is to collect reliable, precise and traceable data to provide sound advice. In management, the challenge is that catch documentation is necessary to enforce regulations. Currently, catch inspection at sea, self-reporting through e-log and on-board observers are the primary methods to document catches at sea. However, at-sea control and on-board observers are costly and have limited coverage, while self-reporting
is susceptible to fraud and provides limited coverage. New cost-effective methods are currently emerging involving Remote Electronic Monitoring (REM) and on-board cameras. Previous studies have tested REM with promising results. However, evaluation of the potential biases of REM is needed before full benefits can be obtained. We deployed REM with on-board cameras on 14 fishing vessels and were able to inspect 56% of 1523 hauls made in the 6 month trial period, using an estimated 582 man-hours of video audit. The results showed an overall good agreement between the fishers self-reported discards and the video inspectors discard estimates. However, there was large variation in precision between individual vessels and species. Additionally, trial setup and process errors were shown to have a large effect on the precision of the video inspectors discard estimates. Nevertheless, despite challenges, REM was evaluated to have the potential to streamline monitoring and scientific documentation in a medium-size fishing fleet.

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Validation of ecological state space models using the Laplace approximation

Many statistical models in ecology follow the state space paradigm. For such models, the important step of model validation rarely receives as much attention as estimation or hypothesis testing, perhaps due to lack of available algorithms and software. Model validation is often based on a naive adaptation of Pearson residuals, i.e. the difference between observations and posterior means, even if this approach is flawed. Here, we consider validation of state space models through one-step prediction errors, and discuss principles and practicalities arising when the model has been fitted with a tool for estimation in general mixed effects models. Implementing one-step predictions in the R package Template Model Builder, we demonstrate that it is possible to perform model validation with little effort, even if the ecological model is multivariate, has non-linear dynamics, and whether observations are continuous or discrete. With both simulated data, and a real data set related to geolocation of seals, we demonstrate both the potential and the limitations of the techniques. Our results fill a need for convenient methods for validating a state space model, or alternatively, rejecting it while indicating useful directions in which the model could be improved.

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Organisations: National Institute of Aquatic Resources, Section for Marine Living Resources, Department of Applied Mathematics and Computer Science
Authors: Thygesen, U. H. (Intern), Albertsen, C. M. (Intern), Berg, C. W. (Intern), Kristensen, K. (Intern), Nielsen, A. (Intern)
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Accounting for correlated observations in an age-based state-space stock assessment model

Fish stock assessment models often rely on size- or age-specific observations that are assumed to be statistically independent of each other. In reality, these observations are not raw observations, but rather they are estimates from a catch-standardization model or similar summary statistics based on observations from many fishing hauls and subsamples of the size and age composition of the data. Although aggregation mitigates the strong intra-haul correlation between sizes/ages that is usually found in haul-by-haul data, violations of the independence assumption can have a large impact on the results and specifically on reported confidence bounds. A state-space assessment model that allows for correlations between age groups within years in the observation model for catches and surveys is presented and applied to data on several North Sea fish stocks using various correlation structures. In all cases the independence assumption is rejected. Less fluctuating estimates of the fishing mortality is obtained due to a reduced process error. The improved model does not suffer from correlated residuals unlike the independent model, and the variance of forecasts is decreased.

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Authors: Berg, C. W. (Intern), Nielsen, A. (Intern)
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Explaining the catch efficiency of different cod pots using underwater video to observe cod entry and exit behaviour

Cod pots are considered seal-safe fishing gear and are proposed as a solution to mitigate the ongoing seal-fisheries conflict in the Baltic Sea. This study examined various factors which could affect the entry and exit behaviour of cod in relation to cod pots. Statistical modelling was used to determine which of these factors most affected the pots’ catch per unit effort (CPUE). Two fishing trials were conducted off the coast of Bornholm, Denmark, using six pot types with different design features, equipped with underwater camera systems to record the behaviour of the cod in relation to the pots. Four pot types were floating pots with one entrance and two were bottom standing with three entrances. Different pot types showed significantly different CPUEs and the pot type was an explanatory factor for entry and exit rates for both trials. In trial 1 artificial light was used for filming and results showed an increase in entry rates during the night time, suggesting that lights attract fish to the pot when the dark surroundings make the effect of the light more noticeable. Exit rates in trial 1 increased with an increasing number of fish in the pot while they decreased with soak time. In trial 2, when no artificial light
was used, a saturation effect was found in that the probability of cod entering the pot lessened as the number of cod already in the pot increased. However, the exit rates in trial 2 also decreased with increasing number of fish in the pot. The study offers greater depth to the understanding of CPUE results by examining fish behaviour around the pots and not just the raw catch data. This in turn contributes to the ongoing search for the most favourable pot designs.

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Organisations: National Institute of Aquatic Resources, Section for Marine Living Resources, Section for Ecosystem based Marine Management, Swedish University of Agricultural Sciences
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Identification of high-risk areas for harbour porpoise Phocoena phocoena bycatch using remote electronic monitoring and satellite telemetry data
The bycatch of harbour porpoise Phocoena phocoena is an issue of major concern for fisheries management and for porpoise conservation. We used high-resolution spatial and temporal data on porpoise abundance and fishing effort from the Danish Skagerrak Sea to identify areas with potentially higher and lower risk of porpoise bycatch. From May 2010 to April 2011, 4 commercial gillnet vessels were equipped with remote electronic monitoring (REM) systems. The REM system recorded time, GPS position and closed-circuit television (CCTV) footage of all gillnet hauls. REM data were used to identify fishing grounds, quantify fishing effort and document harbour porpoise bycatch. Movement data from 66 harbour porpoises equipped with satellite transmitters from 1997 to 2012 were used to model population density. A simple model was constructed to investigate the relationship between the response (number of individuals caught) and porpoise density and fishing effort described by net soak time, net string length and target species. Results showed that a model including both porpoise density and fishing effort data predicted bycatch better than models containing only one factor. We therefore conclude that porpoise telemetry or REM data allow for identification of areas of potential high and low bycatch risk, and better predictions are obtained when combining the 2 sources of data. The final model can thus be used as a tool to identify areas of bycatch risk

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Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Section for Marine Living Resources, Section for Monitoring and Data, Aarhus University, University of St Andrews
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Influence of twin and multi-rig trawl systems on CPUE in the Danish Norway lobster (Nephrops norvegicus) fishery

One of the most effective ways to alter catch and length compositions in trawls is to adjust the meshsize or add selective devices such as sorting grids and selective netting panels. These changes are often introduced into the fishery in a top
down manner whereby fishermen are forced to comply with specific legislation. However, fishermen have also introduced gear modifications that have contributed to improving species selectivity in trawls. One of the simplest and most effective modifications that came from industry was the development and introduction of twin and multi-rig trawls. Here we analyse catch rates of four target species, Norway lobster (Nephrops norvegicus), cod (Gadus morhua), plaice (Pleuronectes platessa) and haddock (Melanogrammus aeglefinus), to try and understand how the use of multi-rig trawls have altered catch rates within the Danish demersal trawl fishery over the last 16 years (1997–2012). Results showed that catch rates of Nephrops in multi-rig trawls were significantly higher (1.89–2.03) than those in single trawls. For cod, haddock and plaice there was no significant effect of gear type. The results are discussed in relation to the Common Fisheries Policy reform and the increasing importance of industry introduced gear modifications.
TMB: Automatic differentiation and laplace approximation

TMB is an open source R package that enables quick implementation of complex nonlinear random effects (latent variable) models in a manner similar to the established AD Model Builder package (ADMB, http://admb-project.org/; Fournier et al. 2011). In addition, it offers easy access to parallel computations. The user defines the joint likelihood for the data and the random effects as a C++ template function, while all the other operations are done in R; e.g., reading in the data. The package evaluates and maximizes the Laplace approximation of the marginal likelihood where the random effects are automatically integrated out. This approximation, and its derivatives, are obtained using automatic differentiation (up to order three) of the joint likelihood. The computations are designed to be fast for problems with many random effects (approximate to 10⁶) and parameters (approximate to 10³). Computation times using ADMB and TMB are compared on a suite of examples ranging from simple models to large spatial models where the random effects are a Gaussian random field. Speedups ranging from 1.5 to about 100 are obtained with increasing gains for large problems.
Long-term effects of an offshore wind farm in the North Sea on fish communities

Long-term effects of the Horns Rev 1 offshore wind farm (OWF) on fish abundance, diversity and spatial distribution were studied. This OWF is situated on the Horns Reef sand bank in the North Sea. Surveys were conducted in September 2001, before the OWF was established in 2002, and again in September 2009, 7 yr post-establishment. The sampling surveys used a multi-mesh-size gillnet. The 3 most abundant species in the surveys were whiting Merlangius merlangus, dab Limanda limanda and sandeels Ammodytidae spp. Overall fish abundance increased slightly in the area where the OWF was established but declined in the control area 6 km away. None of the key fish species or functional fish groups showed signs of negative long-term effects due to the OWF. Whiting and the fish group associated with rocky habitats showed different distributions relative to the distance to the artificial reef structures introduced by the turbines. Rocky habitat fishes were most abundant close to the turbines while whiting was most abundant away from them. Species diversity was significantly higher close to the turbines. Overall, these results indicate that the artificial reef structures were large enough to attract fish species with a preference for rocky habitats, but not large enough to have adverse negative effects on species inhabiting the original sand bottom between the turbines.

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Optimal bæredygtig udnyttelse af tilgængelige torskebestande for dansk fiskeri

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Robust statistical method in a single species age-structured state-space assessment model

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Sustainable development of the Nephrops fishery in the Kattegat-Skagerrak region

General information
Time-varying selectivity is one of the main challenges in single species age-based assessment models. In classical deterministic VPA-type models the fishing mortality rates are unfiltered representations of the observed catches. As a consequence the selectivity becomes time-varying, but this representation is too fluctuating, because it includes the observation noise. In parametric statistical catch at age models a common assumption is that the selectivity is constant in all years, although time-varying selectivity can be introduced by splitting the data period in blocks with different selectivities, or by using smoothing splines and penalized time-deviances. However, these methods require subjective choices w.r.t. the degree of time-varying allowed. A simple state-space assessment model is presented as an alternative, which among other benefits offers an objective way of estimating time-varying selectivity pattern. The fishing mortality rates are considered (possibly correlated) stochastic processes, and the corresponding process variances are estimated within the model. The model is applied to North Sea cod and it is verified from simulations that time-varying selectivity can be estimated.
Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models

Indices of abundance from fishery-independent trawl surveys constitute an important source of information for many fish stock assessments. Indices are often calculated using area stratified sample means on age-disaggregated data, and finally treated in stock assessment models as independent observations. We evaluate a series of alternative methods for calculating indices of abundance from trawl survey data (delta-lognormal, delta-gamma, and Tweedie using Generalized Additive Models) as well as different error structures for these indices when used as input in an age-based stock assessment model (time-constant vs time-varying variance, and independent versus correlated age groups within years). The methods are applied to data on North Sea herring (Clupea harengus), sprat (Sprattus sprattus), and whiting
(Merlangius merlangus), and the full stock assessments are carried out to evaluate the different indices produced. The stratified mean method is found much more imprecise than the alternatives based on GAMs, which are found to be similar. Having time-varying index variances is found to be of minor importance, whereas the independence assumption is not only violated but has significant impact on the assessments.

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Web of Science (2006): Indexed yes
Statistical aspects of fish stock assessment

Fish stock assessments are conducted for two main purposes: 1) To estimate past and present fish abundances and their commercial exploitation rates. 2) To predict the consequences of different management strategies in order to ensure a sustainable fishery in the future.

This thesis concerns statistical aspects of fish stocks assessment, which includes topics such as time series analysis, generalized additive models (GAMs), and non-linear state-space/mixed models capable of handling missing data and a high number of latent states and parameters. The aim is to improve the existing methods for stock assessment by application of state-of-the-art statistical methodology. The main contributions are presented in the form of six research papers.

The major part of the thesis deals with age-structured assessment models, which is the most common approach. Conversion from length to age distributions in the catches is a necessary step in age-based stock assessment models. For this purpose, GAMs and continuation ratio logits are combined to model the probability of age as a smooth function of length and spatial coordinates, which constitutes an improvement over traditional methods based on area-stratification. GAMs and delta-distributions are applied for the calculation of indices of abundance from trawl survey data, and different error structures for these are investigated.

Two extensions to the state-space approach to age-structured stock assessment modelling are presented. The first extension introduces multivariate error distributions on survey catch-at-age data. The second extension is an integrated assessment model for overlapping sub-stocks subject to joint exploitation in the area of overlap. Estimation and inference is carried out using maximum likelihood.

Finally, a biomass dynamic model based on stochastic differential equations is presented. This work extends the classical approaches to biomass modelling by incorporating observation errors on the catches, and allowing for missing and non-equidistant samples in time.
Strategies for fitting nonlinear ecological models in R, AD Model Builder, and BUGS

Ecologists often use nonlinear fitting techniques to estimate the parameters of complex ecological models, with attendant frustration. This paper compares three open-source model fitting tools and discusses general strategies for defining and fitting models. R is convenient and (relatively) easy to learn, AD Model Builder is fast and robust but comes with a steep learning curve, while BUGS provides the greatest flexibility at the price of speed. Our model-fitting suggestions range from general cultural advice (where possible, use the tools and models that are most common in your subfield) to specific suggestions about how to change the mathematical description of models to make them more amenable to parameter estimation. A companion web site (https://groups.nceas.ucsb.edu/nonlinear-modeling/projects) presents detailed examples of application of the three tools to a variety of typical ecological estimation problems; each example links both to a detailed project report and to full source code and data.
Modelling the mixing of herring stocks between the Baltic and the North Sea from otolith data

Herring catches in the western Baltic, Kattegat and Skagerrak consist of a mixture of stocks, mainly North Sea autumn spawners (NSAS) and western Baltic spring spawners (WBSS), which is managed through a single TAC. Catches of these two stocks are split using otolith microstructures from Danish and Swedish commercial landings and surveys samples for the purpose of stock assessment. But the split estimates from sampling data are highly variable and noisy. Better understanding of the migration and exploitation patterns involved could therefore potentially improve the stock assessment as well as provide solutions to the complex management of this mix. The stock-specific seasonal trends in distribution of the two main stocks from otolith data were analysed using a generalized linear mixed model (GLMM) of stock composition. The results show a clear seasonal and age-related pattern and are consistent with existing ideas about the migration patterns of WBSS and NSAS within Division IIIa and adjacent waters. This work therefore provides the foundation for the development of a more rational management of the herring stocks in this area.

Offshore windfarms and their impact on fish abundance and community structure

Deployment of offshore windfarms (OWF) is rapidly expanding. A before–after control impact (BACI) approach was used to study the impact of one of the world’s largest offshore windfarms (Horns Rev Offshore Windfarm) on fish assemblages and species diversity. Fish were generally more abundant in the control than the impact area before the establishment of the OWF. Eight years later fish abundance was similar in both the impact and control area but the abundance of one of the most frequently occurring species, whiting, was much lower compared to 2001. However, the changes in whiting reflected the general trend of the whiting population in the North Sea. The introduction of hard bottom resulted in higher species diversity close to each turbine with a clear spatial (horizontal) distribution. New reef fish such as goldsinny wrasse (Ctenolabrus rupestris), viviparous eelpout (Zoarces viviparous), and lumpsucker (Cyclopterus lumpus), established themselves on the introduced reef area. In contrast very few gobies were caught near or at the OWF, presumably owing to the highly turbulent hydrographical conditions in the OWF. We suggest that the lack of this common prey fish is the main reason for the absence of larger predatory fish species.
Spatial age-length key modelling using continuation ratio logits

Many fish stock assessments are based on numbers at age from research sampling programmes and samples from commercial catches. However, only a small fraction of the catch is typically analyzed for age as this is a costly and time-consuming process. Larger samples of the length distribution and a so-called age-length key (ALK) is then used to obtain the age distribution. Regional differences in ALKs are not uncommon, but stratification is often problematic due to a small number of samples. Here, we combine generalized additive modelling with continuation ratio logits to model the probability of age given length and spatial coordinates to overcome these issues. The method is applied to data gathered on North Sea haddock (Melanogrammus aeglefinus), cod (Gadus morhua), whiting (Merlangius merlangus) and herring (Clupea harengus) and its implications for a simple age-based survey index of abundance are examined. The spatial varying ALK outperforms simpler approaches with respect to AIC and BIC, and the survey indices created using the spatial varying ALK displays better internal and external consistency indicating improved precision.
The Gordian knot: managing herring (Clupea harengus) bridging across populations, fishery units, management areas, and politics

The management of western Baltic spring spawning (WBSS) herring is challenged by the highly complex stock structure with a temporal and geographical distribution leading to conflicting interests among different stakeholder groups. The stock is exploited in the Baltic Sea (Subdivisions 22–24) and the North Sea (Division IIIa) by various EU—and in the latter case also non-EU—fishing fleets. For the two separate management areas, TACs are set at different times in the yearly TACsetting process by the EU and negotiating counties, which often result in conflicts over quota allocations among different management units. The WBSS herring stock spawns in the western Baltic Sea and migrates into the Kattegat and Skagerrak areas, where it mixes with North Sea autumn spawning (NSAS) herring. Recent development of otolith shape analysis has enabled a high-resolution separation of herring stocks in these waters, giving a more detailed picture of the actual stock mixing potentially undermining the current assumption of only three population components. We discuss how a higher resolution of spawning components may facilitate the estimation of local population-related productivity, and how this in turn may be applied in an advanced future management of several populations within one management unit.
Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years after Construction: Follow-up Seven Years after Construction

Estimation methods for nonlinear state-space models in ecology

The use of nonlinear state-space models for analyzing ecological systems is increasing. A wide range of estimation methods for such models are available to ecologists, however it is not always clear, which is the appropriate method to choose. To this end, three approaches to estimation in the theta logistic model for population dynamics were benchmarked by Wang (2007). Similarly, we examine and compare the estimation performance of three alternative methods using simulated data. The first approach is to partition the state-space into a finite number of states and formulate the problem as a hidden Markov model (HMM). The second method uses the mixed effects modeling and fast numerical integration framework of the AD Model Builder (ADMB) open-source software. The third alternative is to use the popular Bayesian framework of BUGS. The study showed that state and parameter estimation performance for all three methods was largely identical, however with BUGS providing overall wider credible intervals for parameters than HMM and ADMB confidence intervals.
Estimation of feeding patterns for piscivorous fish using individual prey data from stomach contents

The problem of estimating temporal feeding patterns using stomach data is considered, where the time of ingestion for each prey item can be predicted through a gastric evacuation model. The arrival of prey is modelled as a nonhomogeneous Poisson process with known periodic intensity. A maximum likelihood approach is used to estimate the intensity, which is assumed to be the same for all predators, incorporating different uncertainties for the arrival time of each prey item. The method is applied to a case where a population of whiting (Merlangius merlangus) is feeding on sandeel (Ammodytes marinus), and peak feeding periods around dusk and dawn are identified.

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources
Authors: Berg, C. W. (Intern), Temming, A. (Ekstern)
Pages: 834-841
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Canadian Journal of Fisheries and Aquatic Sciences
Volume: 68
Issue number: 5
ISSN (Print): 0706-652X
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.56 SJR 1.322 SNIP 1.163
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.256 SNIP 1.051 CiteScore 2.22
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.443 SNIP 1.379 CiteScore 2.6
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.421 SNIP 1.081 CiteScore 2.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.324 SNIP 1.196 CiteScore 2.29
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.423 SNIP 1.09 CiteScore 2.13
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.425 SNIP 1.118
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.451 SNIP 1.196
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.589 SNIP 1.379
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.621 SNIP 1.236
Size-based assessment of ecosystem effects of fishery management decisions

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources
Authors: Andersen, K. H. (Intern), Berg, C. W. (Intern)
Publication date: 2010
Main Research Area: Technical/natural sciences
Links:
http://www.ices.dk/products/CMdocs/CM-2010/C/C2510.pdf
Source: orbit
Source-ID: 278032
Publication: Research › Journal article – Annual report year: 2011

Online bestandsvurdering af torsk i Nordsøen

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Berg, C. W. (Intern)
Pages: 6
Publication date: 2009
Publication information
Pages (from-to): 6
Newspaper: Fiskeritidende
Volume: 16
No.: 2
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 249853
Publication: Communication › Newspaper article – Annual report year: 2009
Projects:

**PhD Scholarship in Fish Stock Assessment and Population Dynamics Modelling**
National Institute of Aquatic Resources
Period: 01/05/2017 → 30/04/2020
Number of participants: 4
Phd Student: Mildenberger, Tobias (Intern)
Supervisor: Berg, Casper Willestofte (Intern)
Kokkalis, Alexandros (Intern)
Main Supervisor: Nielsen, J. Rasmus (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

**Eastern Baltic cod - New knowledge of growth and mortality is the way to improved management advice (39366)**
The aim of the project is to improve the knowledge and data basis for stock assessment and management for cod in the eastern Baltic Sea.

In later years, changes in growth and natural mortality of cod have presumably taken place and new knowledge on these parameters is essential for restoring analytical stock assessment for Eastern Baltic cod that is currently lacking. Improved knowledge on cod growth and mortality is therefore a prerequisite for being able to evaluate the stock status in relation to management targets and implement management plans that are built on quantitative stock assessment.

Ecological situation in the Baltic Sea has changed in later years, which requires updated biological information. This is done in the project using different approaches, bringing together expertise of different research areas. The approaches applied include molecular-genetic analyses of cod growth, bioenergetic modelling, and analyses of monitoring data on predation and condition/growth of cod. An important component of the project is cooperation with fishing industry to support tagging experiments of Baltic cod, to obtain updated estimates of cod growth.

Finally, the project combines the new knowledge on cod that becomes available from this and other relevant projects to ensure that the assessment of stocks status and management advice is based on best available scientific information.

This project is coordinated by DTU Aqua.

The project is funded by the Ministry of Environment and Food of Denmark and the European Maritime and Fisheries Fund (EMFF).

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management

**Research areas: Ecosystem based Marine Management & Fish Biology & Marine Populations and Ecosystem Dynamics & Population Genetics & Marine Living Resources & Fisheries Management**

Project participant:
Storr-Paulsen, Marie (Intern)
Tomkiewicz, Jonna (Intern)
Hansen, Jakob Hemmer (Intern)
Neuenfeldt, Stefan (Intern)
Christensen, Asbjørn (Intern)
Kindt-Larsen, Lotte (Intern)
**Tagging Baltic cod (TABACOD) (39333)**

The aim of this project is to improve the management of eastern Baltic cod by 1) providing new information on growth and mortality patterns, and 2) develop a validated method for deriving this information from historic and future samples.

In recent years, the traditional age-based stock assessment had to be abandoned owing to extensive uncertainties in stock trends. These uncertainties were to a large extent attributable to inconsistencies in age estimation. As a consequence thereof, the current stock status is unknown.

Estimates of growth and mortality rely on unbiased age information. TABACOD will provide this information through a large scale tagging experiment, where 20,000 cod are tagged with and externally visible tag as well as with an internal tag on their otoliths. This experiment will also provide the samples for the development and validation of a new age estimation method based on the chemical composition of the cod's otoliths.

The knowledge gained will be incorporated in length-based assessment models and their performance compared to the traditional methods evaluated in order to provide the ICES stock assessment group with the relevant tools to provide a reliable advice and to improve stock exploitation.

This project is coordinated by DTU Aqua.

The project is funded by BalticSea2020.

National Institute of Aquatic Resources

Section for Oceans and Arctic

Swedish University of Agricultural Sciences

Johann Heinrich von Thünen-Institute

National Marine Fisheries Research Institute

**Period:** 01/01/2016 → 31/12/2019

**Number of participants:** 7

**Research areas:** Marine Populations and Ecosystem Dynamics & Fish Biology & Marine Living Resources

**Project participant:**

Olesen, Hans Jakob (Intern)

Andersen, Niels Gerne (Intern)

Storr-Paulsen, Marie (Intern)

Thygesen, Uffe Høgsbro (Intern)

Berg, Casper Willestofte (Intern)

**Phd Student:**

Nielsen, Kristian Ege (Intern)

**Project Coordinator:**

Hüssy, Karin (Intern)

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**Assessment and management of linked stocks (39325)**

The purpose of this project is to develop operational models for linked stocks.

Fish stocks are not isolated units. Fish eat, and are eaten, by fish from other stocks. The definition of fish stocks is often arbitrary or determined by management considerations. The bottom line is that some linkage must be expected between the defined stocks. For some stocks these effects are essential to give reliable assessment and management.

Single species assessment and management does not include effects from linked stocks.

Ecosystem and multi-species assessment models are not practically operational for assessment and management. These models are designed to describe all interactions between all important species in an ecosystem. These models often attempt to estimate detailed effects between all length- or age groups. These models often require data, which are not routinely available.

This project will develop models, which are directly applicable in the scientific advice. The aim is not to describe all
interactions, but simply to harvest the main benefits of considering two or more stocks in a joint model. The aim is to identify few links between the stocks, which describes the main part of the interaction, and to base the models only on standard data sources.

The models will be developed to be generally applicable, but applied to two important cases (Cod EB and WB, and Cod stocks around Kattegat).

Final tool will be available via stockassessment.org, so it can easily be applied to any stocks defined there.

This project is coordinated by DTU Aqua.

The project is funded by the Ministry of Environment and Food of Denmark and the European Maritime and Fisheries Fund (EMFF).

National Institute of Aquatic Resources
Section for Marine Living Resources
Period: 14/12/2015 → 13/12/2017
Number of participants: 5
Research area: Marine Living Resources
Project participant:
Berg, Casper Willestofte (Intern)
Kristensen, Kasper (Intern)
Thygesen, Uffe Høgsbro (Intern)
Phd Student:
Albertsen, Christoffer Moesgaard (Intern)
Project Coordinator:
Nielsen, Anders (Intern)
Project

**Forward management of sandeel in the North Sea (39318)**
The project will define and align the management of sandeel considering the goals and desires of the fishing industry, administration and science while taking the biology and importance of the sandeel in the ecosystem into account.

The project is structured by several work-packages, each dealing with specific aspects of sandeel biology and/or fishery relevant for management. Among these will the sandeel population structure and its influence on stock assessment, CPUE and counselling be discussed. Analyses of fisheries development and sandeel availability over the fishing season will enable a more accurate calculation of fishing mortality. Furthermore, it is examined whether the increasing concentration of fishing effort on certain banks potentially causes an error in the stock assessment in relation to recruitment from unfished banks. The project will perform a statistical evaluation of fisheries-independent data for sandeel in the North Sea and evaluate existing and alternative methods of stock assessment for sandeel in the North Sea with current and alternative management areas, including implementing an analytical stock assessment of sandeel in sandeel area 4. Finally the project will evaluate existing biological and management reference points, and discuss these in relation to ecosystem reference points.

Throughout the project period, a series of workshops and meetings will be held in order to discuss possible management strategies for sandeel in the North Sea. These discussions will imply a number of fundamental prerequisites defined in collaboration between management, fisheries and science in order to form the basis for an optimal management of sandeel.

This project is coordinated by DTU Aqua.

The project is funded by the Ministry of Environment and Food of Denmark and the European Maritime and Fisheries Fund (EMFF).

National Institute of Aquatic Resources
Section for Marine Living Resources
Danish Pelagic Producers Organisation
Danish Fishermen's Association
Marine Ingredients Denmark
Period: 11/11/2015 → 16/11/2017
Number of participants: 8
Research areas: Marine Living Resources & Population Genetics & Fish Biology & Marine Populations and Ecosystem Dynamics & Fisheries Management & Ecosystem based Marine Management
Improvement of the foundation for stock assessment for data limited stocks with importance for Danish fishery (39310)

Objectives
The aim of this project is to improve the knowledge basis, data, and methodology for providing robust stock assessment and short term forecast according to MSY for data limited fish stocks with importance for Danish commercial fishery.

Background
A number of fish stocks in the Baltic, Skagerrak-Kattegat and North Sea area with importance for Danish commercial fishery either as target species, commercially important by-catch species, or as unintended by-catch species are data limited stocks with no analytical stock assessment. More than 60% of fish stocks that ICES gives advice on are category 3 and 4. These categories include stocks for which the data and knowledge are insufficient to conduct a full analytical assessment of their state and exploitation. Until now, ICES has not been able to assess their state relative to the objective of achieving MSY (Maximum Sustainable Yield) sustainability. A major task of fisheries management is broadening from the narrow analysis of few main commercial species toward accounting for by-catches, i.e. the great range of species and sizes of lesser importance caught at the same time in non-selective fisheries (mixed-fisheries). This unwanted part of catches is becoming politically important because it may trigger restrictive management decisions for the commercial fisheries, both as part of the ecosystem-based marine management (EU MSFD), and because of the potential of these species to become limiting for some fleets in the frame of the landing obligation (=discard ban) of the EU CFP, i.e. when a fishery can be closed because it has reached the authorized catch quantity (quota) of a low-value species even though it still has some quota left for more valuable commercial species (so-called “choke species” effect).

Tasks and Deliverables
- Develop assessment and forecast models and methods for stocks in the categories 3-4 and integrate them as standard models and software in the ICES advisory framework in relation to method development and assessing data poor stocks in special working groups (ICES WKLIFE V-VI, ICES WKPROXY) and in standard stock assessment working groups covering the Skagerrak-Kattegat, Baltic Sea and North Sea areas (ICES WGNSSK, ICES WGBFAS).
- Apply the models to selected fish stocks with importance for Danish fishery with the aim of promoting analytical and benchmark assessments to assess stock status relative to MSY objectives. Application of these methods mean that the status of those category 3 and 4 stocks can be classified as desirable or undesirable in relation to MSY objectives, and the stocks can be lifted to category 2 or 1 stocks with analytical assessments. The stocks are selected in close collaboration and agreement with the Ministry of Environment and Food (several directorates), the fishing industry and associations (DF), NGO environmental stakeholders and Science (DTU Aqua).
- The work includes estimation of fish stock growth parameters, performing yield per recruit analyses, and conducting stock assessments with application of a stochastic stock production model and/or a length based stochastic assessment model, as well as where possible a stochastic age based VPA stochastic assessment model.
- Management Strategy Evaluation (MSE) for selected stocks: Establishment of biological (biomass- or fishing mortality based) reference points for each of the selected stocks involving growth models and logistic models (ogives). MSE for establishing output-based harvest control rules according to short to medium term forecasts for the selected stocks. This includes provision and further development of model software to carry out MSE of the selected stocks.

This project is coordinated by DTU Aqua.

The project is funded by the Danish Ministry of Environment and Food (under Framework Contract with DTU).
Tender for scientific support to the Saudi Arabian fisheries sector (SaudiTender I) (39153)

Objective
The general aim of the Fisheries Program at the Marine Studies Section, Center for Environment and Water, Research Institute, King Fahd University of Petroleum and Minerals (KFUPM/RI), is to establish a modern system of data collection, biological and ecological assessment, stock assessment modelling, and government management, in order to evaluate the exploitation status and enhance the sustainability of finfish and invertebrate stocks of Saudi Arabia (SA) Exclusive Economic Zone in the Arabian Gulf. The overall principle underlying this effort is the food security of SA, and the duty to carry out the best efforts to guarantee sustainable exploitation of fishery resources and ensure economic viable fisheries.

The Program is organized in four main branches, or Work Packages: Population Dynamics and Stock Assessment, Essential Fish Habitats, Environmental Impacts of Fishing Methods, and Management Strategy Framework.

Background
The KFUPM/RI of Saudi Arabia and AZTI-Tecnalia, Marine and Food Research Institute of the Basque Country, Spain, in partnership with DTU-Aqua, runs this project with an extensive collaboration program in fisheries monitoring, research, and management advice. A service contract according has been signed between KFUPM/RI and AZTI. A sub-contract to this service contract has been made between AZTI and DTU Aqua where parts of the service contract forms an integral part of the subcontract and where DTU Aqua is co-responsible for the below listed specific tasks and deliverables.

Tasks and Deliverables
Population Dynamics and Stock Assessment: Provision and further development of suitable model software to carry out stock assessment for data limited fish stocks. Stock assessment models suitable to data-poor fisheries are applied to historical catch and effort data (2002-2012) and to data from the new Data Collection Framework (2013-) for major stocks. DTU Aqua is responsible for provision of model software to carry out assessments and application of this to 5 major finfish stocks out of the appointed 13 major stocks exploited by SA in the area. The work include estimation of fish stock growth parameters, performing yield per recruit analyses, and conducting stock assessments with application of a stochastic stock production model using the above data to estimate MSY (Maximum Sustainable Yield) sustainability reference levels according to exploitation. Templates for assessment and advice are developed on the basis of the data and knowledge available in cooperation with AZTI which includes a Stock Summary Sheet for each of the stocks.

Management Strategy Evaluation (MSE) for Major Stocks: Conducting and reporting MSE for data-poor fisheries considering several prospective harvest control rules in the short to medium term according to MSY. This involves identification of biological reference points (biomass- and fishing mortality based reference points) and identification of input or output based harvest control rules according to short term forecast for the 5 major fish stocks. Also, this involves provision and further development of model software to carry out MSE according to MSY in the short to medium term.

Management Strategy Framework: Provision of formal considerations, evaluations, recommendations and reporting of relevant and appropriate management regimes and systems of data collection and stock assessments for scientifically-based advice to the SA Ministry of Agriculture on basia of current fishery system and exploitation of the 13 major stocks. This addresses needs for data, methods, institutional set-up, provision of advice, and possible management systems.

This project is coordinated by AZTI Technalia, Spain. The project is funded by AZTI Technalia, Spain as to KFUPM University Saudi Arabia.
Development of a by-catch excluder for the Danish and European trawl fisheries (39265)
The project aims to develop and test a widely usable gear that effectively sorts out unwanted species and sizes of fish during trawling. This objective should be seen in light of a future discard ban for the EU—a ban which, in Denmark and in other European countries, will result in a growing demand for technical solutions that can increase the sorting of fish in the gear during fishing.

The development work of the project is based on a so-called "Excluder system" that can be integrated into most standard trawl gears. The "Excluder system" is developed for the North American market by Tor-Mo Trawl in Hirtshals in collaboration with the Green Line Fishing Gear. The Excluder is used today on a voluntary basis by approximately 15 large fishing vessels in Alaska, but is not directly applicable in Danish and European fisheries because the species composition, trawl size and type of vessel is significantly different in fisheries in Alaska.

The project's main result will be the development, testing and documentation of an Excluder system, which is targeted the Danish and European trawl fisheries.

In light of the political development in EU, a very large market potential is expected to appear for such an Excluder and the redemption of this market potential will result in 1) more successful implementation of the discard ban, 2) more selective and sustainable fisheries, and 3) increased growth and revenue for companies in the project.

This project is coordinated by Denmark's Pelagic Producer Organisation.

The project is funded by the Danish Ministry of Food, Agriculture and Fisheries through the Green Development and Demonstration Program (GUDP).

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management
Denmark's Pelagic Producer Organisation
Greenline Fishing Gear
Tor-mo trawl ApS
HG62 Beinur
Period: 01/01/2015 → 31/12/2016
Number of participants: 5
Research areas: Fisheries Management & Fisheries Technology
Project participant:
Krag, Ludvig Ahm (Intern)
Berg, Casper Willestofte (Intern)
Thaarup, Flemming (Intern)
Feekings, Jordan P. (Intern)
Project Manager, academic:
Eigaard, Ole Ritzau (Intern)

Optimal sustainable use of cod stocks accessible for Danish fisheries (DEL-TORSK) (39147)
Optimal sustainable utilization of cod stocks that contain several biological sub-populations requires taking population structure into account in stock assessment and management. The aim of this project was to develop scientific basis for cod management decisions in the North Sea and the Baltic that takes biological units of cod and their dynamics into account.

Methodological challenges concerning advising on stocks that contain sub-populations with differences in dynamics and biological parameters are common for North Sea and the Baltic. Therefore, the project considered both seas, in terms of developing methodological basis for addressing population structure in management advice. The results were presented at ICES benchmarks for North Sea and Baltic Sea cod in 2015, and used to developing further the management basis for optimal use of cod stocks.
The project included mapping of distribution of sub-populations using genetic analyses and modelling of transport of early life stages. These results were combined with existing knowledge on cod population structure both in the Baltic and North Sea, to identify distribution areas of sub populations. This information was then incorporated in area-specific stock assessment analyses.

This project was coordinated by DTU Aqua.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management
Period: 17/07/2013 → 30/04/2015
Number of participants: 8
Research areas: Ecosystem based Marine Management & Marine Populations and Ecosystem Dynamics & Population Genetics & Fish Biology & Marine Living Resources & Fisheries Management
Project participant:
Hansen, Jakob Hemmer (Intern)
Mariani, Patrizio (Intern)
Berg, Casper Willesstofte (Intern)
Hüsey, Karin (Intern)
Huwer, Bastian (Intern)
Nielsen, Anders (Intern)
Eg Nielsen, Einar (Intern)
Project Coordinator:
Eero, Margit (Intern)

Statistisk modellering af marine økosystemer
Department of Informatics and Mathematical Modeling
Period: 01/11/2009 → 30/08/2013
Number of participants: 7
Phd Student:
Berg, Casper Willesstofte (Intern)
Supervisor:
Nielsen, Anders (Intern)
Thygesen, Uffe Høgsbro (Intern)
Main Supervisor:
Madsen, Henrik (Intern)
Examiner:
Andersen, Ken Haste (Intern)
Cadigan, Noel G. (Ekstern)
Nielsen, Søren F. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Bridging the gap between science, stakeholders and policy makers (GAP 1 & GAP 2) (38133 & 38860)
Stakeholders and scientists involved in GAP1 initiated cooperative research by making plans to combine knowledge in participatory research through a series of European and regional workshops. GAP1 represented phase 1 of a three-phase program that aimed to explore the complementary nature of alternative knowledge and investigate how to combine it in ways that will enhance understanding and management of natural resources. Tied to knowledge, GAP1 was an evidence-based approach that used participation as the vehicle to improve understanding of fisheries research and management issues of common concern to stakeholders, scientists and policy makers. Through initiation of cooperative research and facilitating the building of the capacity of stakeholders to engage in participatory research, GAP1 contributed towards the wider aspiration of the Science in Society program. In particular, enhancing the democratic debate with a more engaged and informed public, thus providing better conditions for collective choices on scientific issues relating to sustainable management, conservation of ecosystem integrity and biodiversity of the marine environment.
GAP2 was about making a difference to an issue of significance to the whole of society; the wellbeing of the marine environment and the sustainability of fisheries upon which society depends for food. It continued the relationships, processes and plans made in GAP1 by enabling Mobilization and Mutual Learning (MML) actions that promoted stakeholder participation in the debate and development of research knowledge and structures relevant to emerging policy on fisheries and the marine environment. The aims were to promote and enable processes for open and effective participation of stakeholders in research and management, demonstrate through specific examples and critical evaluation the role and value of stakeholder driven science in the governance of fisheries and the marine environment. DTU Aqua was the case study leader of one of the selected cases of GAP2.

Find full list of participants at the website of GAP2.

These projects were coordinated by the Centre for Environment, Fisheries and Aquaculture Science, UK.

The projects were funded by EU, Framework Programme 7.

National Institute of Aquatic Resources
Section for Marine Living Resources
Cefas
Universidade da Coruña
Aalborg University
University of Tromsø
Swedish Board of Fisheries
Istituto Superiore per la Protezione e la Ricerca Ambientale
Pelagic Regional Advisory Council
Baltic Sea Regional Advisory Council
Period: 01/01/2008 → 31/12/2015
Number of participants: 4
Research areas: Marine Living Resources & Population Genetics & Fisheries Management
Project participant:
Mosegaard, Henrik (Intern)
Ulrich, Clara (Intern)
Berg, Casper Willestofte (Intern)
Project Manager, organisational:
Worsøe Clausen, Lotte (Intern)

Spatially-explicit management methods for North Sea cod – a Danish fishermen-science collaboration (REX, REX II, REX III) (38430, 38431, 38541)

The REX project started in 2006 as a protest from the Danish Fishermen Association because fishers had a less pessimistic perception of the status of the cod stock in the North Sea than ICES, and they considered the agreed TAC levels far too low. In particular the fishermen considered the scientific surveys as inappropriate due to extremely low catches of large cod because of wrong gear and fishing on smooth bottom only. This seemed to call for more spatially-explicit oriented approaches and REX was born with an aim of getting closer to a common understanding of the true number of adult cod in the North Sea by focusing on communication and collaboration in developing and implementing a scientifically sound and robust survey strategy with commercial ships in a north-eastern area selected by the Danish Fishermen Association using three vessels presenting different fishing methods (flyshooter, trawler and gillnetter).

The development of the fishermen-scientists collaboration with mutual respect has increased the understanding on both sides. In particular the emphasis on defining common goals, facing and solving conflicts immediately and extending thorough collaboration from survey planning, conducting of field work to interpretation of results during workshops have contributed to bridging the communication gap.

A better understanding of cod biology has also been a focal point in these projects through the new field studies incorporating fishermen’s knowledge. This includes distribution and migration, feeding behavior and importance of Hot-Spots (e.g. ship wrecks). Electronic tags were applied to learn about migration also in the Baltic. Together with the aim of continuing to obtain better assessments of the stocks such more mechanistically oriented studies are needed to answer two apparently simple questions “Where are the cod and why?”

The REX projects have strengthened the scientific collaboration with fishermen and produced several results and types of knowledge that will influence future work on developing spatial explicit management tools. REX also represents capacity
building for DTU Aqua’s interdisciplinary field research and monitoring towards the spatial dynamics of cod.

The project is coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Marine Living Resources
Danish Fishermen’s Association
Period: 01/01/2006 → 31/01/2010
Number of participants: 17
Research area: Marine Living Resources
Project participant:
Pedersen, Eva Maria (Intern)
Olesen, Hans Jakob (Intern)
Andersen, Ken Haste (Intern)
Thygesen, Uffe Høgsbro (Intern)
Kristensen, Kasper (Intern)
Berg, Casper Willestofte (Intern)
Storr-Paulsen, Marie (Intern)
Vinther, Morten (Intern)
Christensen, Per (Intern)
Jensen, Rasmus Frydenlund (Intern)
Pedersen, Jan (Intern)
Grønby, Søren Larsen (Intern)
Thaarup, Flemming (Intern)
Project Manager, organisational:
Neuenfeldt, Stefan (Intern)
Project Manager, academic:
Beyer, Jan (Intern)
Andersen, Niels Gerner (Intern)
Wieland, Kai (Intern)

Activities:

**ICES - Benchmark Workshop for North Sea Stocks - WKNSEA (External organisation)**
Period: 2015
Casper Willestofte Berg (Participant)
National Institute of Aquatic Resources
Section for Marine Living Resources
Degree of recognition: International

**Related external organisation**

**ICES - Benchmark Workshop for North Sea Stocks - WKNSEA**
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

**ICES - Working Group on Improving use of Survey Data for Assessment and Advice - WGISDAA (External organisation)**
Period: 2015
Casper Willestofte Berg (Participant)
National Institute of Aquatic Resources
Section for Marine Living Resources

**Related external organisation**

**ICES - Working Group on Improving use of Survey Data for Assessment and Advice - WGISDAA**
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar
ICES - Data Compilation for Benchmark Workshop on North Sea stocks - DCWKNSEA (External organisation)
Period: 2014
Casper Willestofte Berg (Participant)
National Institute of Aquatic Resources
Section for Marine Living Resources
Degree of recognition: International

Related external organisation
ICES - Data Compilation for Benchmark Workshop on North Sea stocks - DCWKNSEA
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

ICES - Working Group on Improving use of Survey Data for Assessment and Advice - WGISDAA (External organisation)
Period: 2014
Casper Willestofte Berg (Participant)
National Institute of Aquatic Resources
Section for Marine Living Resources
Degree of recognition: International

Related external organisation
ICES - Working Group on Improving use of Survey Data for Assessment and Advice - WGISDAA
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

ICES - Workshop on Integrated DATRAS Products - WKIDP (External organisation)
Period: 2014
Casper Willestofte Berg (Participant)
National Institute of Aquatic Resources
Section for Marine Living Resources
Degree of recognition: International

Related external organisation
ICES - Workshop on Integrated DATRAS Products - WKIDP
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar