

ICES SYMPOSIA REPORTS 2014

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The Second Fishery Dependent Information (FDI) Symposium
Rome, Italy, 3–6 March 2014

ICES/PICES Symposium on "Ecological basis of risk analysis for marine ecosystems"
Porvoo, Finland, 2–4 June 2014

Symposium on "Effects of fishing on benthic fauna and habitat: Change in ecosystem composition and functioning in response to fishing intensity, gear type and discard"
Tromsø, Norway, 17–19 June 2014

International Eel Symposium 2014: Are the eels climbing back up the slippery slope?
Quebec City, Canada, 17–21 August 2014

Johan Hjort Symposium on Recruitment Dynamics and Stock Variability
Bergen, Norway, 7–9 October 2014

The Firth International Otolith Symposium 2014
Palma de Mallorca, Spain, 20–24 October 2014

PICES Meeting 2014
BIO/MEQ Topic Session (S3)
Yeosu, Korea, 21 October 2014

PICES Meeting 2014
BIO/MEQ Topic Session (S8)
Yeosu, Korea, 23 October 2014

PICES Meeting 2014
FIS Topic Session (S5)
Yeosu, Korea, 22–23 October 2014

PICES Meeting 2014
POC/MONITOR Topic Session (S9)
Yeosu, Korea, 23 October 2014



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International Council for
the Exploration of the Sea

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1 The Second Fishery Dependent Information (FDI) Symposium

Venue and dates: Rome, Italy, 3–6 March 2014

The 2nd Fishery Dependent Information (FDI) Symposium took place from 3–6 March 2014 at the Food & Agriculture Organization (FAO) headquarters in Rome, Italy. This Symposium advanced findings and conclusions from the 1st Symposium held in Galway, Ireland in 2010. The Symposium was sponsored by several organizations including, the International Council for the Exploration of the Seas (ICES), the National Oceanic and Atmospheric Administration (NOAA), the Norwegian Institute of Marine Research, the European Commission's Joint Research Center, FAO, and the Marine Institute of Ireland. Traveling from 33 developed and developing countries, the 168 participants were comprised of scientists, fishing industry representatives, policy makers, and members of non-governmental organizations, who presented close to 150 verbal presentations and posters. In addition, representatives from the USA, New Zealand, Norway, and the Netherlands presented 4 keynote messages. The Symposium also included 2 workshops, one on monitoring tools for small-scale fisheries, and the other focused on the challenges and benefits of full-catch retention policies.

The Symposium program included topics on the design and collection of fishery dependent data and the use of these data to support conventional and novel approaches to fisheries science and management, and the role of fishers in co-management and policy setting. Under these themes presenters discussed research on methods to improve estimates of catch and effort, the design and analysis of data from self-sampling fleets or artisanal fisheries, improving strategies for monitoring changes in the ecosystem, electronic monitoring techniques, industry-science collaboration, and examples of participatory management. A day of presentations was devoted to the European Union's EcoFishMan project, which is promoting a "responsive fisheries management system" (RFMS) across European fisheries, whereby the resource users are responsible for documenting the targets to achieve specified management objectives.

A key point made throughout the 4-day Symposium was the need for effective fisheries stakeholder integration in fisheries science and management. Discussions focused on how and whether fishers can contribute to the data collection process and development of management policies, because ultimately, their involvement in both helps build trust in the data and in fishery policies. Stakeholder confidence in the science and policies is becoming even more paramount in an era of increased catch accountability. The Symposium explored the challenges of "fully documented fisheries" (FDF) from the standpoint of fishing businesses, monitoring and compliance, and scientific evaluation, and explored ways to engage fishers more in the process as FDF policies are developed.

In conclusion, the 2nd Fishery Dependent Information Symposium showcased ways in which different styles of fishery dependent data collection and collaboration can improve fisheries management and ultimately, the sustainability of the fishery resource. Data collection offers opportunities for collaboration and trust-building, and collaboration builds trust for more effective policy making. Examples of "best principles" regarding the collection and utilization of fishery dependent information that emerged from the keynotes and the presentations included:

- a) Fishers and fisher communities provide valuable information to monitoring and assessing multiple aspects of the fisheries system through their local knowledge and experience.
- b) Rather than discard information from fishers as “anecdotal”, one should see it as a crucial, observational starting point of the scientific method.
- c) Engaging fishers in data collection and decisions about management alternatives improves trust in the science and buy-in to policy measures.
- d) Whilst trust often is first developed in informal settings, a structured and formalized communication process is often necessary to achieve buy-in to policy measures.
- e) Listening to fisher views and asking the right questions is essential.
- f) Cooperation among all stakeholders requires time, flexibility, open-mindedness, listening skills, and creativity.

Selected contributions from the Symposium have been published in the ICES Journal of Marine Science, under the banner, “Fishery Dependent Data Symposium”. For a more detailed overview of the Symposium, see:

Dörner, H., *et al.* 2014. From cooperative data collection to full collaboration and co-management: a synthesis of the 2014 ICES symposium on fishery-dependent information. ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu222

2 ICES/PICES Symposium on "Ecological basis of risk analysis for marine ecosystems"

Porvoo, Finland, 2–4 June 2014

Conveners: Sakari Kuikka (Finland), Tony Smith (Australia) and Alexei Orlov (PICES)

The world's marine ecosystems are facing an increasing number of challenges. Fishing intensity is high, and there are several other threats such as possible oil spills from drilling and transportation, climate change, eutrophication, and risks associated with aquaculture. The aggregate analysis of multiple interacting risk factors is a challenging task for scientists. While risk assessment methods are well established in scientific disciplines like finance, health, and insurance, they are less established in resource management and climate change.

About 80 scientists from 18 countries (Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, New Zealand, Norway, Philippines, Spain, Sweden, Switzerland, Russia, United Kingdom, and USA) gathered near the bank of the Porvoo River in the famous old city of Porvoo, Finland, on 2–4 June 2014, for a symposium on the "Ecological basis of risk analysis for marine ecosystems".

The aim of the symposium was to support ICES' strategic goal to evaluate the uncertainties related to the sustainability of marine-related industries and production of integrated advice to decision makers. Further, it was to enhance co-operation between ICES and other bodies relevant to risk-based management of marine activities, and to broaden the diversity of scientists participating in these activities. In providing scientific advice, one of the main tasks of ICES advisory and scientific activities is to assess risks and incorporate risk analyses in an integrated and scientifically justified way and to successfully communicate these to scientists in other fields, to managers and to a wider audience. This allows identification of potential risks and leads to better opportunities to manage or control these risks.

The symposium was organized around six overarching themes:

- Fisheries management under uncertainty;
- Decision modelling in fisheries management;
- Probabilistic fish stock assessment;
- Oil spill and eutrophication risk analysis;
- Environmental risk assessment for marine areas;
- Risk analysis in aquaculture.

3 Symposium on "Effects of fishing on benthic fauna and habitat: Change in ecosystem composition and functioning in response to fishing intensity, gear type and discard"

Tromsø, Norway, 17–19 June 2014

Conveners: Lene Buhl–Mortensen, Carsten Hvingel and Børge Holte (Norway), Francis Neat (Scotland) and Mariano Koen–Alonso (Canada)

Introduction

An international ICES symposium on the Effects of fishing on benthic fauna, habitat and ecosystem functioning was held on 17–19 June 2014 in Tromsø, Norway. The Symposium was organised by Institute of Marine Research (IMR-Norway) and attended by more than 100 scientists from 18 countries including Europe, New Zealand, Australia and North America. The objectives of the symposium was to review the physical and biological effects of fishing activities to sea bottom ecosystems, look at various technical conservation measures designed to mitigate these effects and ultimately try to quantify the overall ecosystem impact. The symposium was structured around fisheries impacts on different seabed types and communities with sessions divided into the following themes:

- Soft bottom/infauna (macrobenthos) community composition
- Mixed bottom/epifauna and habitat forming megafauna
- Gear effects and development.

Members of organising committee were: Lene Buhl-Mortensen, head of committee (IMR-Norway), Børge Holte (IMR-Norway), Carsten Hvingel (IMR-Norway), Mariano Koen-Alonso (DFO-Canada), Francis Neat (Marlab-Scotland).

Technical support was delivered by the ICES Secretariat and IMR.

The symposium was sponsored by ICES, Northwest Fisheries Organisation (NAFO) and IMR.

Proceeding

A special issue of Marine Biology Research will be published based on presentation given at the symposium. Thirty-one, abstracts have been submitted.

Highlights of the symposium

The Symposium covered a wide variety of topics and approaches in 44 oral presentations (including 7 key note papers) and 28 posters. Thirty papers dealt with trawling impacts on the benthic community composition and ecological functioning and 14 papers dealt with technological innovations to mitigate the trawling impact. Four papers used a modelling approach to explore trawling impacts and 2 dealt with indicators for trawling impact. The six key note papers reviewed the session topics: effects on soft bottom communities with main focus on shallow North Sea, effects on mixed bottom communities covering VMEs (e.g. coral and sponge communities) from continental shelf to deep sea mounts, bottom impact from fishing gear and gear development. The gears covered were otter trawls targeting crustaceans and roundfish, dredges targeting scallops, beam trawls targeting flatfish, and long lines.

Trawling impact

The majority of papers reported on field studies dealt with changes in benthos that was studied along a trawling intensity gradient. The studies showed that the effect of trawling was context dependent and differed between habitats. Trawling impacts were generally less in areas of high natural disturbance. Although there are difficulties around confidentiality issues and data access for VMS data they were widely used to quantify the trawling gradients. Problems related to the use of VMS data as proxy for pressure were discussed. Depending on depth, gear and bottom type quantification of pressure on the seafloor and benthos from VMS data can be a major challenge. However, results of studies attempting to collate VMS data across large geographic areas and countries were presented and looked promising.

Recovery

Relatively few studies dealt with the recovery of the benthic ecosystem, however regrowth in a protected coral reef was presented (poster).

Ecosystem functioning

Key note papers emphasized the importance of biodiversity in the functioning and resilience of benthic ecosystems. The number of papers dealing with ecosystem functioning were relatively few, in particular experimental studies in the field. Only one paper studied the effect of bioturbation on the nutrient dynamics and the benthic-pelagic coupling. Two papers used a modelling approach to study the impact of trawling on ecosystem functioning. Most other papers tackled the problem by relating the community composition in terms of functional traits (bioturbation, biodeposition, etc) with the trawling intensity. Two papers addressed the question how trawling may influence the food of benthivorous fishes.

Tool development for ecosystem based management

Few papers dealt with the development of tools to be used in fisheries management.

Gear innovations

Five papers dealt with gear innovations and studied how these may mitigate the adverse impacts on the benthic ecosystem. Promising results were reported on reducing sea bed contact by using (semi-) pelagic otter boards. Four papers studied the effect of pulse trawls tested in the North Sea flatfish and brown shrimp fisheries, either in field experiments or in laboratory experiments.

Overall, the following observations can be made.

- The trait based approach to estimate the effect of trawling on ecosystem functioning is adopted globally with great expectations; however studies on mixed bottoms and large long-lived organisms are few in Europe. There is a need for empirical studies on ecosystem functioning to test the assumptions that are inherent in traits analysis due to lack of ecological information on species level.
- VMS data analysis needs further standardisation and more detailed quantitative descriptions of the major fishing gears used are required to estimate trawling impact at a comparable scale across regions and across fishing gears.

- There is a need to develop tools to be used in integrating the benthic ecosystem in the ecosystem approach to fisheries management. First explorations were presented at the Symposium.
- The research questions addressed and the approach taken are relevant and state of the art.

4 International Eel Symposium 2014: Are eels climbing back up the slippery slope?

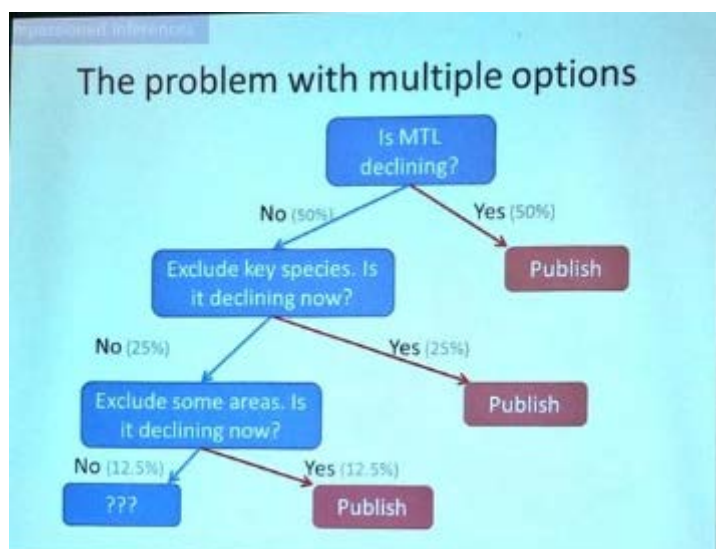
Quebec City, Canada, 17–21 August 2014

Conveners: Martin Castonguay (Canada), John Casselman (Canada), Willem Dekker (Sweden)

The eel symposium was kicked off with a fantastic presentation by Louis Bernatchez on genomic studies on North Atlantic. Eel are one population, and every generation has selectivity which would result in evolutionary adaption of the species except that it is mixed up again at every generation. There is clearly a divergence between Europe and North America, with the increase in recruitment in Europe, not being seen in America and no wide scale management action in the USA and limited in Canada.

The fishing down the food session have a very interesting clash between Villy Christensen and Trevor Branch. It was good to have scientists from the “sized based modelling” session also present.

Trevor Branch criticised fishing down the food web studies with this slide:



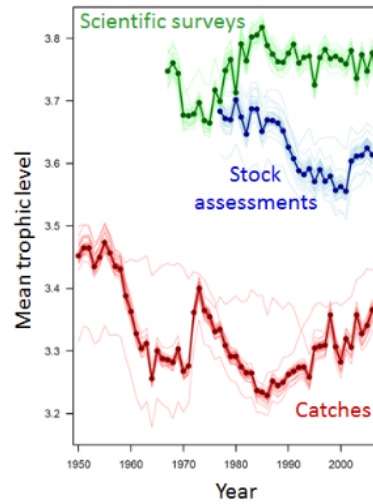
MTL= mean trophic level

Trevor suggested that the estimates of mean trophic level were very sensitive to the assumed trophic level of cod. He showed his reworked estimates of global catch by trophic level.

All available data

All increasing in
recent decades

Catches a poor
predictor of
ecosystem health



Branch TA et al. (2010) The trophic fingerprint of marine fisheries. Nature 468:431-435

The meeting was very vibrant meeting and well attended with over 1500 scientists. It was about two thirds marine fisheries and one third freshwater. Many Europeans attended from UK, Ireland, Germany, Norway, Denmark and Iceland.

5 Johan Hjort Symposium Recruitment Dynamics and Stock Variability

Bergen, Norway, 7–9 October 2014

Conveners: Richard D.M. Nash/ Chair of SSC (Norway), Olav Sigurd Kjesbu (Norway), C. Tara Marshall (Scotland) and Svein Sundby (Norway)

The Hjort Symposium was attended by 130 participants from 23 countries across the world. Their expertise covered a broad range of disciplines within marine research, ranging from basic biology via stock assessment methodology to large scale oceanographic modelling. This diversity made it possible for this Symposium to address recent progresses made within several of the novel theories postulated by Johan Hjort. Several plenary discussions, as well a special poster session, were the starting points for stimulating dialogues on emerging research questions. A special funding program was included to promote participation from early career members (including Masters and PhD students), both within and outside Europe. In order to address in a holistic way this challenging field of research, six single sessions were run consecutively to make it possible to integrate knowledge across themes. The city of Bergen, where Johan Hjort undertook much of his influential work in fisheries research, was selected as the natural place to hold this Symposium.

The background for this symposium was the fact that it is 100 years since Johan Hjort published his seminal 1914 book *Fluctuations in the Great Fisheries of Northern Europe*. The importance of this volume cannot be overstated, particularly Hjort's new conceptual ideas about the formation of strong year classes based on age determination from fish scales. For this reason several scientific events in 2014 honoured Johan Hjort's achievements, including the publication of a special issue of the ICES Journal of Marine Science (H. Browman (ed.) *Fluctuations in the great fisheries of northern Europe – Commemorating 100 years since Hjort's 1914 treatise*, and, of course, the ICES Hjort Symposium. This Symposium will result in a special symposium volume of the Canadian Journal of Fisheries and Aquatic Sciences, emphasising the strong links Dr Hjort established with Canadian colleagues and institutions.

Hjort (1914) states that 'the object can never be fully attained; new questions will constantly arise, as the knowledge obtained creates the demand for new, and it will always be possible to increase and intensify our comprehension of the vital conditions affecting the organisms in question'. Therefore, in this Symposium, we addressed the level of knowledge about these vital rates (natural mortality, growth and recruitment) and explored integrated studies including environmental drivers within an ecological framework. In particular, we asked whether modern techniques (such as individual based models and large-scale analytic tools) have made reliable predictions possible. Consequently, this Symposium explored Johan Hjort's legacy through oral and poster presentations given in six theme sessions, as well as included an Opening Keynote, a Hjort Dinner Speaker (in Håkon's Hall, the King's Banqueting Hall, hosted by the City of Bergen) and a Summing-Up Speaker:

- Fisheries in the face of environmental variation and change (Opening Keynote: Julia Blanchard, UK)
- Spawning dynamics and parental effects (Session Keynote: Fran Saborido-Rey, Spain)
- Early life stages and 'the critical period' (Session Keynote: Myron Peck, Germany)

- Spatial aspects and drift (Session Keynote: Geir Huse, Norway)
- Natural mortality and growth (Session Keynote: Pierre Pepin, Canada)
- Environmental drivers – fluctuations and change (Session Keynote: William Cheung, Canada)
- Exploratory analyses, uncertainty and predictions (Session Keynote: C oil n Minto, Ireland)
- Hjort, the man (Hjort Dinner Speaker: Michael Sinclair)
- Summing-Up (Symposium Review Speaker: Brian Rothschild, USA)

Totally 98 abstracts were presented in this Symposium, of which 55 were oral and 43 poster contributions. The Book of Abstracts can be freely downloaded at the Symposium website (www.imr.no), or via ICES's official website. In addition to ICES, the Symposium was sponsored by the Research Council of Norway; the Institute of Marine Research, Norway; The Municipality of Bergen, and the Hjort Centre for Marine Ecosystem Dynamics, Bergen.

The above-mentioned special volume from this Symposium is scheduled for publication in late 2015.

6 The Firth International Otolith Symposium 2014

Palma de Mallorca, Spain, 20–24 October 2014

The 5th international Otolith Symposium was held on Peguera, Calvia, Mallorca Island (Spain) from 20 to 24 November 2014. Despite the economic difficulties worldwide, a total of 329 registrants from 45 countries attended the Symposium. Thanks to the support offer to students a total of 87 participated providing opportunities to early career scientists. Many of the attendees expressed that the venue was excellent and the program was well executed (<http://www.ices.dk/news-and-events/symposia/otolith/Pages/default.aspx>).

The purpose of this summary is to provide a final overview of the conference to report to ICES with acknowledgements to the hosting organizations and sponsorship.

Getting ready: previous activities

An invitation was received in 2009 from the 4th International Otolith Symposium (IOS) Steering Committee to organize and host the 5th IOS in 2014. Valuable insight was provided by some of the previous organizers and especially from the chairs of the 4th IOS. The information provided a framework to organize IOS2014 which was chaired by Beatriz Morales-Nin (IMEDEA, CSIC/UIB, Spain) and Audrey Geffen (UoB & IMR, Norway).

The first step was to obtain support from ICES, support that was granted by the ICES Science Committee in December 2011 (Res. 2011/3/SSGSUE01). To provide scientific and organizing assistance an international Steering Committee was nominated composed by 20 scientists representing 15 countries (Table 1). Afterwards the Symposium was widely announced and a scientific program was planned by the Chairs with the support of the Steering Committee. A local committee provided support with conference organization and logistics.

Results of the symposium

The Symposium included a scientific program with four main themes and a day dedicated to workshops, three social events and an art and science collaborative initiative. A steering committee meeting was held to revise developments and to propose a new venue for the 6th IOS. Two offers to host the next IOS were presented and the Steering Committee selected Taiwan and the year 2018 for the next venue.

Scientific Program

The symposium focused on the research and applications for the development of ecological indicators based on calcified tissues. A special effort was made to broaden the scope of the Symposium including paleontologist and fresh-water experts.

The scientific program was organized around four themes: Environmental indicators, Community indicators, Population indicators, and Individual indicators. Each theme was developed along an entire day and was opened by a key speaker, followed by oral presentations. Wednesday was dedicated to a Shape Analysis and an Age Validation Workshops with specific organizers. <http://ices.dk/news-and-events/Documents/Symposia/Otolith/IOS2014%20Book%20of%20Abstracts.pdf>

Tuesday evening was dedicated to a special Poster session providing the opportunity to discuss them with the authors.

The high number of submissions (364 by the end of June) made necessary to limit the number of presentations by author to one oral communication and one poster resulting in 340 presentations. To adapt the number of presentations to the time available, they were organized as: oral presentations, oral 5 minute presentations (oto-chuki), print posters and posters for a slide-show. The two kinds of posters were up all week. In Table 2 the presentations are summarized.

The high participation, superior to previous IOS Symposiums, and many late registrations and presentation changes required to develop measures (see Table 3). It is interesting to note that the app to provide and updated version of the program including the abstracts, was an innovative approach developed using a free tool. In general, once the novelty was overcome, the oto-chuki were considered as successful and an interesting way of communicating the new information and presenting first results.

Workshops

An Age Validation Workshop was held on Wednesday (22 October) to cover issues associated with accurate age determination of fishes. The workshop included a series of platform presentations by the workshop organizers that addressed some of the main issues in age validation, coupled with a selection of presentations on other associated subjects. Because of the large number of submissions to make oral contributions to the workshop, the session was organized similar to the symposium, but with more flexibility for open and extended discussions. Age validation methods that were presented and discussed covered a diverse range of simple to complex applications with an emphasis on discussing the efficacy of each approach (i.e. early growth only to fully ontogeny). The topics covered ranged from refinements in bomb radiocarbon dating and its use as a tool in age estimate bias and use various methods to validate annual growth in complex otolith structure (oxygen-18, marginal increment) to tests of symmetry and age prediction and various approaches validating early growth (daily increments). In addition, a special session was added to the end of the workshop that allowed poster-presenters to provide a short 5-minute oral synopsis of their work. The workshop organizers selected the posters and presenters were solicited for a contribution, resulting in 6 short presentations at the end of the day. The discussional sessions that resulted from each session led to in-depth exchanges of pros and cons of the various methods used, such as a lively discussion on uses of stable isotopes, bomb radiocarbon, and lead-radium dating. Corroborative approaches, such as tracking cohorts by length frequencies, or comparing ages using otoliths and other hard parts, were well illustrated. More direct approaches were also demonstrated, such as mark-and-recapture of wild halibut, or enclosure experiments of anchovies and sardines. A review of tests of symmetry explained how to use this statistical approach, which has been increasing in the literature. Several studies combined these various approaches to add to a compelling view of best practices for investigating the age and growth of fishes. Overall, this workshop synthesis revealed that age validation is no longer a forgotten requirement of ageing studies, but is a thriving endeavor of increasing importance.

A workshop on otolith shape analysis was held on Wednesday (22 October). The aim of the workshop was to provide an up-to-date overview of the theory and practice of otolith shape analysis through a combination of oral presentations, demonstrations and interactive exercises. The workshop opened with a presentation from Audrey

Geffen who provided the historical context for the development of otolith shape analysis; from subjective recognition of herring races based on the appearance of fish and their otoliths (1950s) to contemporary mathematical tools for quantifying inter- and intra-specific otolith shape variation, facilitated by developments in computing and digital imaging.

There followed a selection of oral contributions dealing with the determinants of otolith shape variability. Lotte Worsøe Clausen and co-authors used otolith shape and genetic analyses of herring in the North and Baltic Seas to illustrate how otolith morphometry is under the combined influence of ontogeny, genetics and the environment. The authors propose that otolith shape measurements could provide an index of overall stock complexity (genetic and ecological) to simplify the management of mixed stocks. Matthias Vignon presented a machine learning approach to disentangling the multiple drivers of otolith shape variation across various spatial and taxonomic scales. Marie Baudouin and co-authors used a combination of analytical approaches (geometric morphometrics and Fourier analysis) to examine population structure of common dentex (*Dentex dentex*) at fine spatial scales around Corsica Island.

Lotte Worsøe Clausen and Antoni Lombarte then lead us through the process of image acquisition. Lotte made a series of recommendations for producing standardized images that are free of artefacts. She used examples of poorly prepared images to illustrate the importance of otolith cleaning and positioning, the choice of medium, background and light settings. Antoni showed how analysis of internal features could complement otolith outline analysis and presented some tools for capturing the detail of the sulcus acusticus (drawing, photography, SEM, X-ray Microtomography, 3D scanning). He also demonstrated how poorly captured images could be corrected using digital post-production (background homogenization, image correction, removal of artefacts, reconstruction of broken otoliths standardization of size and position) and offered some solutions for mass production of otolith images (e.g. Irfan view).

Deirdre Brophy ran an interactive exercise which gave the participants the opportunity to generate outlines from otolith images using Image J and to extract standardized Elliptical Fourier Descriptors using the Momocs package in R. Variability in EFDs due to imaging artefacts was examined and recommendations were made regarding how to deal with potential sources of error. Lisa Libungan presented the newly released ShapeR package which provides a comprehensive tool for extracting outlines, performing Discrete Wavelet and Normalized Elliptic Fourier transforms as well as conducting multivariate analysis and visualization of group differences.

Deirdre Brophy opened the afternoon session with a brief introduction to the analysis of otolith shape data. In the interactive session that followed, Alf Harbitz used otolith outlines from Greenland halibut and cod to illustrate how imaging artefacts can influence assignment success when otolith shape analysis is used for stock discrimination. Using script prepared in R, he presented some analytical approaches to dealing with pixel noise and showed how the influence of image artefacts can be statistically evaluated. Henrik Mosegaard and co-authors delivered an interactive demonstration of a freely available online tool, built in R which allows for the unbiased estimation of the proportions of multiple populations contributing to a mixed stock. Using a dataset of herring otolith shape descriptors, the classification success rates obtained using various approaches to classification were compared using Monte Carlo simulation.

In the final session of the day a series of selected presentations on recent advances in otolith shape analysis were delivered. Two systems for automated species identification were presented, one based on otolith contour analysis (Youssef El Habouz et al); and a second on geometric morphometrics and Elliptical Fourier Descriptors (Jin-Yung Wong, Kar-Hoe Loh *et al.*). Contributions to this session also included a mathematical modification of three existing fourier techniques which improves outline reconstruction (Alf Harbitz); a new method for extracting shape descriptors from three dimensional images which enables bulk processing of images (Pere Marti-Puig et al) an application of Computer Assisted Age and Growth Estimation (CAAGE) to the analysis of otolith images for separation of herring spawning groups (Mark Fisher et al) and an affordable 3D scanning system for small otoliths (0.5-5mm) (Andreas Zitek et al).

The closing discussion centered on some of the available analytical methods for partitioning sources of otolith shape variability (e.g. regression tree approach) and the limitations of length and age standardization methods. There was also a good deal of exchange regarding approaches to image standardization and quality control.

There were 43 participants in attendance at the workshop. The support provided by Claire Welling and the ICES secretariat ensured that participants could access material via the ICES SharePoint and engage with the interactive elements of the workshop. As the use of otolith shape analysis techniques becomes increasingly widespread, the synthesis and opportunity for dialogue provided by the workshop was timely and worthwhile. The workshop organizing committee intends to follow this up with the publication of an ICES Cooperative Research Report on otolith shape analysis in 2015/16.

Awards

Ming-Tsung Chung from the University of Southampton received the best student oral presentation award for the work entitled: "Functional diversity and behavioral responses to depth gradients revealed by otoliths morphology in deep-sea fishes".

Manuel Muntoni from the University of Cagliari received the best student poster award for the work entitled "Lapilli vs sagittae: results from the comparison of settlers of the striped red mullet".

A special award was for **Claire Welling** from ICES for her patience and infatigable support before and during IOS2014. **Erlend Moksness** was awarded by his life-time efforts in consolidating European sclerochronology.

Acknowledgements

The success of the Symposium was possible by the contributions of numerous individuals and organizations. ICES provided a wide support fundamental for the successful development of the Symposium. Calvia City (Mallorca, Spain) provided free access to the excellent venue facility at Peguera Casal and offered technical support during the Symposium. Palmira Hotels (Mallorca, Spain) and specially Yolanda Carasco, greatly facilitated the social aspects and provided a wonderful housing and amenities at special discount rates. Palma Aquarium (Mallorca, Spain) sponsored the IOS2014 bags. The Fisheries Society of the British Islands, the American Fisheries Society (Early Life History and Estuarine Sections) provided support for student' awards. MediaCybernetics contributed to the sponsorship. The University of the Balearic Islands supported the event, as well as the Chairs institutions: IMEDEA (CSIC/UIB), UoB and IMR.

Last but not least, the Steering Committee, local committee, moderators and the IMEDEA's Fish Ecology Team helped to a smooth and successful development.

Table 1. IOS2014 Steering Committee.

| First Name | Last Name | Affiliation | City | State/Province | Country |
|------------|-------------|---|------------------------|------------------|---------|
| Henrique | Cabral | Lisboa University | Lisboa | | PT |
| Gregor | Cailliet | Moss Landing Marine Laboratories | Moss Landing | CA | USA |
| Steven | Campana | Fisheries and Oceans Canada | Dartmouth | NS | CAN |
| Hélène | de Pontual | Ifremer | Plouzané | | FRA |
| Anthony | Fowler | SARDI | Adelaide | | aust |
| Bronwyn | Gillanders | University of Adelaide | University of Adelaide | South Australia | AUS |
| Karin | Hussy | AUA DTU | Copenhagen | Denmark | DK |
| Cynthia | Jones | Center for Quantitative Fisheries Ecology | Norfolk | VA | USA |
| Karin | Limburg | SUNY College of Environmental Science & Forestry | Syracuse | NY | USA |
| Antoni | Lombarte | ICM | Barcelona | Barcelona | ESP |
| Erlend | Moksness | IMR | Arendal | | NO |
| JACQUES | PANFILI | IRD | DAKAR | DAKAR | SEN |
| David | Secor | University of Maryland Center for Environmental & Estuarine Science | Solomons | MD | USA |
| Michael | Smale | | | | ZA |
| Diane | Tracey | NIWA | Kibirnie | | NZ |
| Yvonne | Walther | SLU | Karlskrona | | SW |
| Chia-Hui | Wang | National Museum of Marine Biology and Aquarium | Checheng | Pingtung | CHN |
| Brian | Wells | NMFS | Santa Cruz | | USA |
| Peter | Wright | MARLAB | Aberdeen | | UK |
| Yoh | Yamasida | Kyoto University | | Kyoto | Japan |
| Audrey | Geffen | Bergen University | Bergen | | Norway |
| Beatriz | Morales-Nin | IMEDEA (CSIC/UIB) | Esporles | Baleairc islands | Spain |

Table 2. Summary of presentations.

| | SESSIONS | PRESENTATIONS |
|-----------|----------|---|
| Plenary | 4 | 31 (including 4 Keynotes) |
| Parallel | 8 | 62 |
| Oto-chuki | 4 | 51 |
| Posters | | 164 (including 27 from the Workshops and 26 for the slide-show) |
| Workshops | 2 | 30 |

Table 3. Stressors-response.

| STRESSOR | ACTION UNDERTAKEN |
|---|--|
| Too many submissions for the duration of the Symposium | Limit the number of presentations by author Implement oto-chuki oral presentations Implement a slide-show |
| Too many late registrations & changes impeding to have an updated print program | Develop informatic tools that allowed continuous updating: An on-line program at the ICES web page Create an app including the abstracts and offering a powerful tool free of charge |
| Many posters by theme and for the available space | Keep the posters up during all the Symposium to allow enough time to consult them Develop a slide-show as a dynamic tool using a big electronic monitor |
| Too many participants in the Shape Analysis Workshop | Limit the number of users of the provided tools and allow assistants to participate in the discussions |

7 PICES Meeting 2014. BIO/MEQ Topic Session (S3)

Tipping points: defining reference points for ecological indicators of multiple stressors in coastal and marine ecosystems

Yeosu, Korea, 21 October 2014

Conveners: Rebecca G. Martone, USA, Ian Perry, Canada, Jameal Samhouri, USA, Motomitsu Takahashi, Japan, Maciej T. Tomczak, Sweden/ICES and Chang Ik Zhang, Korea

Background

Many coastal and marine ecosystems, ranging from reefs to estuaries to pelagic systems, are exposed to multiple stressors, which can lead to rapid changes with significant, long-term consequences that are often difficult to reverse. Changes in ocean climate, the abundance of key species, nutrients, and other factors drive these shifts, which affect ocean foodwebs, habitats, and ecosystem functions and people's livelihoods and well-being. Determining indicators of ecological changes due to multiple stressors and defining reference points for those indicators are key steps for managers to avoid ecological degradation and loss of key goods and services. Setting ecological reference points in ecological systems presents a challenge to resource managers because (a) reference points are often difficult to determine due to the complexity of natural systems, including the presence of thresholds, tipping points, and non-linearities; (b) the paucity of theoretical modelling and empirical understanding needed to address these complexities, identify ecological thresholds and develop early warning indicators means that managers must make decisions based on high levels of uncertainty; and, (c) many institutional and governance structures do not allow managers the necessary flexibility to take up this information and react within relevant time frames. This session will address these pressing challenges, and explore promising approaches to tackling them with the goal of catalysing new research and management innovation. In particular, we invite presentations that (i) define the conceptual basis for reference points and management objectives surrounding reference points; (ii) use theoretical, modelling and observational approaches to identify potential reference points for indicators of changes in marine ecosystems; (iii) incorporate risk and sources of error (measurement, model, process) in such analyses; (iv) discuss how reference points may be used in helping to manage marine ecosystems, specifically in relation to the decision-making process related to evaluating and deciding on acceptable levels of risk. These discussions will be guided by the FUTURE science themes, with special attention to examining climate and anthropogenic drivers of ecological change, and identifying early warning indicators to enable forecasting to avoid crossing ecological thresholds. The outcomes will contribute to the work of PICES Working Group 28 on Development of ecosystem indicators to characterize ecosystem responses to multiple stressors.

Summary of Presentations

This session provided a very interesting overview of how tipping points pertain to marine species and ecosystems. It was well attended and there was a great diversity of presentations, featuring many different geographies and at many different scales – from ecosystem-wide changes in response to tipping points to threshold responses of individual animals and fisheries stocks.

In his Invited Presentation, Dr Phillip Levin addressed the important topic of how to respond to regime shifts in social-ecological systems. He focused on the importance of integrated ecosystem assessments (IEAs), and how they can be applied to counteract regime shifts. He suggested that the first question to answer as part of an IEA is whether the existing regime is desired, and then further broke this question down into three parts. First, do people see the world the same way? Dr Levin illustrated that people do not necessarily view the world the same way using a folk taxonomy example, and suggested that regime shifts are likely not to be perceived the same way either. Second, Dr Levin posed the question: does anyone care if a regime shifts? Using the example of regime shifts from kelp forests to sea urchin barrens and back again, he illustrated how different groups of people are likely to have different preferences for each regime. The third question Dr Levin addressed focused on defining the target regime. Via the lens of eelgrass restoration, Dr Levin described a novel approach for determining public preferences for different ecosystem configurations. Overall, he argued that portfolios of indicators need to be accompanied by portfolios of reference points that reflect people's preferences for alternative ecosystem configurations.

Dr Jake Rice asserted that the one thing managers should avoid is to make a tipping point a target. This argument stems from the fact that rapid changes in the ecosystem happen near tipping points, and those changes may not be desirable. However, Dr Rice showed that identifying tipping points is analytically challenging. Nonetheless, he made a strong case for managers to: avoid tipping points with high probability, emphasize that objective even more so than an objective of achieving targets, and avoid optimizing along a single ecosystem dimension (e.g. a single fishery).

Dr Rebecca Martone provided an overview of a multi-institutional collaborative project called "Ocean Tipping Points." The project includes scientists and lawyers from universities, government agencies, and NGOs and consists of synthesis and application components. The synthesis component includes compilation of a global database of marine ecosystem shifts ($n > 100$ studies, few from the western Pacific), a meta-analysis of non-linear relationships in pelagic systems, a law review that demonstrated that regulations incorporating thresholds yield better environmental outcomes, and a management review of 50 case studies of current management contexts showing that explicit use of tipping points in management yields improved environmental outcomes. The application components focus on coral reefs in Hawaii, USA, and the herring foodweb in Haida Gwaii, BC, Canada.

Dr Maciej Tomczak described an impressive body of work showing that overexploitation, changes in climate, and nutrient loading combined to cause a shift from a cod-dominated to a sprat-dominated Baltic ecosystem. Dr Tomczak defined this phenomenon as a regime shift, i.e. a foodweb reorganization and redirection of energy flow pathways. He used a network indicator called Redundancy to suggest that resilience has declined in the Baltic over time, in response to an overall forcing index (inclusive of changes in climate, fishing, etc.).

Dr Takahashi and colleagues presented the results from an expert judgment survey to determine relative risks of coastal and marine habitats in the Eastern, Central and Western Regions of the Seto Inland Sea. Results indicate regional variation within the Seto Inland Sea to a suite of stressors. Coastal engineering and development affects strongly all ecosystems across the regions. Commercial activities, including fishing, have stronger impacts in the eastern waters. Nutrient input and HABs have higher risk in the central and eastern areas. Dr Takahashi presented spatially explicit tem-

poral data that corroborate many of the outcomes from the expert judgment survey. For example, tidal flats and seagrass beds have decreased in areas of the Seto Inland Sea. Stressor-specific risk scores indicate regional variability linked to population density and geographical features in the Seto Inland Sea. Future comparisons with results from global models and other regional models will help identify gaps and biases in expert judgement. These results can help identify priorities for research and management of cumulative impacts to ecosystems at regional spatial scales.

Dr Ian Perry presented work in the Salish Sea examining the drivers of change acting on the Strait of Georgia in the Salish Sea, British Columbia. Using redundancy analysis, Dr Perry identified regime-like transitions of the Strait of Georgia since 1970. Dr Perry then presented an examination of potential predictors for typical system behaviours prior to significant shifts in the system, including variance, autocorrelation at lag-1, and conditional heteroskedasticity. Standard deviation and the autocorrelation are not correlated with the regime shifts and thus do not act as good predictors. Interestingly, conditional hetero-skedasticity of SST and North Pacific Gyre Oscillation within the moving window of 37 months was well correlated with the regime shift and possibly could be used as an early warning indicator. Dr Perry described some of the challenges associated with choosing which indicators, which predictors for early warnings of regime shifts, choice of period (e.g. moving windows), and how to identify significance. Early warning indicators appear promising, but the real world is messier than simulated data. Several indicators are likely necessary, particularly lower trophic level biological variables, and combining these in a probability approach might be good way forward.

Dr Bill Sydeman focused on the importance of understanding how changes in community structure relate to changes in ecosystem functions and processes, with emphasis on tipping points of mid-trophic level invertebrates and fish and meso-predators. Meso-predators may serve as indicators of variability in ecosystem function as they may be the most responsive to the forage fish community variability. Dr Sydeman showed that there are many non-linear responses of ecosystems to changes in mid trophic level (MTL) fish, (e.g. changes in breeding success of seabirds) and that shapes of the relationships can be used to determine which indicators might be more sensitive to ecosystem changes. The global model for seabird breeding success indicates a threshold that around the mean long-term trend. Dr Sydeman then explored whether there is variability in the threshold numerical response between forage fish abundance and seabirds, either among predator species, prey species or the parameter examined. Interestingly, among some predator and prey species, the threshold holds but for other species, there are different relationships, but despite this variation North Pacific seabird threshold range is similar to the global model. Furthermore, the threshold tends to hold for different parameters; however, there is high uncertainty associated with this because of data limitations. Ultimately, predator-prey threshold relationships may provide insight to ecosystem state shifts. Future work on population-level responses, multispecies predator-prey numerical responses, and how differences in mean abundance or life-history characteristics (e.g. diet specialization) might affect the threshold, will be useful to understand threshold responses in ecosystem indicators.

Dr Wen Yu presented on the effects of acute gamma radiation on the survival and physiological indices of the Chinese black sleeper. Existing studies from UNSCEAR (2008) indicate that fish are the most sensitive species based on LD50 reference points but few focus on data from marine fish and there are no data in China. By examining the Chinese black sleeper, Dr Yu's study fills important gaps in our understanding of

the response of marine species to radiation, particularly as it may be more susceptible to pollution and is economically important. Dr Yu presented the results of a dose-response experiment that examined 5 irradiated groups and a control groups, with 60 individuals per group. Preliminary results indicate that with the three higher levels of irradiation, 100% mortality occurred within a few days, while the lowest level of radiation was similar to the controls. The calculated LD50 was 7.1 (6.3-7.9) Gy, which is lower than the 10–25 Gy summarized from UNSCEAR. Future research will include additional experiments to confirm these results, along with research on other local species and tests of the effects of chronic radiation.

Mr Kyung-Su Kim described his research on the combined effects of elevated CO₂ and temperature on the physiological conditions of olive flounder larvae, *Paralichthys olivaceus*. Using a MFC controller and mixing chambers Mr Kim described the experimental settings, including three different CO₂ concentrations, based on current day 2100 mild and strong emissions based on IPCC predictions and two temperatures, optimum and high temperature. Both total length and wet weight increased with CO₂ at lower temperatures, but variable responses occurred when CO₂ was combined at higher temperatures. Skeleton malformation occurred more frequently with higher CO₂ conditions, and bone density decreased with increasing CO₂ conditions. Results from histomorphology did not show any malformation in tissues under higher CO₂ conditions. Dr Kim's study illustrated that CO₂ and temperature have variable interactive effects on growth (positive) and bone density (negative), suggest that these types of studies are necessary to tease apart the multiple effects of stressors on condition, which may have implications for population dynamics and ecosystems.

For his invited presentation Dr Tetsuo Yanagi described eutrophic and oligotrophic processes in the Seto Inland Sea and their relation to the Satoumi concept. Eutrophication (TN:TP) in recent years has decreased in the Seto Inland Sea and fish stocks have also seen similar declines, suggesting regime shifts related to changes in productivity driven by nutrient inputs. Dr Yanagi explored models of phytoplankton population dynamics using relationships with different strengths of non-linearity for a variety of parameters. The relation between fish catch and nutrient concentration is non-linear and there is hysteresis due to sediment pollution. Oligotrophic conditions may lead to changes in stratification and ability of fish to eat sinking phytoplankton, leading to hypoxia and possibly a new regime. Dr Yanagi then suggested that there is a possibility to move from oligotrophic conditions back to eutrophic conditions with higher productivity, which is the preferred state, and introduced the Satoumi concept. The Satoumi concept developed by Dr Yanagi supports the idea that coastal seas can have high biodiversity and productivity under human interactions, where both over and under- use can lead to low biodiversity and productivity. For example, decreases of eelgrass beds in the Seto Inland Sea led to decrease of fish catch by set-nets, which in turn led local fishers to create eelgrass beds. Now both eelgrass beds and fish catches by set-nets are increasing. Currently Dr Yanagi has a new project supported by the Ministry of the Environment to develop coastal management method to realize the sustainable coastal sea, in which physical, biological, social sciences, and governance will support integrated, community-based management, to realize clean, rich and prosperous seas.

Dr Kazumi Wakita presented research on the diversity of perceptions and utility of marine ecosystem services. With an online survey of 1100 residents of Japan, Dr Wakita examined people's perceptions of different ecosystem services and the utility or satisfaction experienced by different people could be used as a basis for decision-making. In addition, she explored the how utility that residents derive from marine

ecosystem services affect their behavioural intentions for marine conservation, assuming that where there is higher the perceived indispensability, the greater the utility, and the higher the indispensability the greater its influence on enhancing behavioural intentions for marine conservation. Using factor analysis and structural equation modelling to determine the causal relationships between perceived value and their intentions of behaviour for conservation of marine biodiversity, Dr Wakita uncovered three hidden factors including (1) Essential Benefits, including food, life satisfaction, health, etc; (2) Indirect Benefits, which was primarily composed of provisioning services and regulating services; and, (3) Cultural Benefits. Dr Wakita found that cultural benefits were most important in driving behavioural intentions for marine conservation. Essential benefits also contributed to behaviour assessments, whereas indirect benefits were not significant. Essential benefits had highest indispensability, followed by indirect benefits, while cultural benefits scored lower on indispensability. These results indicate that indispensability does not correlate with conservation behaviours. Focusing on the landlocked Nagano residents, Dr Wakita also performed factor analysis to examine the scarcity principle. The same three factors were identified, but their contents were different. Perception of marine ecosystem could vary reflecting scarcity of the services in their place of residents, which will be different for different communities. Dr Wakita's talk emphasizes the need for more attention for cultural aspects of marine ecosystem services.

Dr Christopher Aura assessed the magnitude and interrelationships of seasonal phytoplankton bloom occurrence at the Japanese scallop farming area of Okhotsk Sea, Hokkaido Japan. To define tipping points, Dr Aura and colleagues defined different bloom types, including the spring bloom, ice bloom, and open water bloom, using time-series data sources including chl_a, sea ice, surface windstress. By identifying the mechanism of bloom occurrence, Dr Aura was able to identify that a decline of windstress leads to increased ice edge blooming and decreased open water bloom variability. In addition, using PCA and Pearson correlation matrices, he found that there are distinct relationships between scallop landings, sea ice cover, and bloom variability. Where there is a strong negative relationship between sea ice days and open water bloom, while open water blooms are positively correlated with scallop landings. Thus, tipping points can be described by windstress and solar radiation.

Dr Jameal Samhouri and colleagues explore what has happened once a tipping point has been crossed, where multiple pressures shift systems over ecological thresholds and lead to different ecosystem states. Dr Samhouri described how examining systems that have crossed tipping points might help guide the recovery of ecosystems, specifically working toward the development of theory to reassemble marine systems. Dr Samhouri examined what types of ecosystem reassembly strategies are currently in use, what strategies are likely to be the most effective using a theoretical model, and finally, determined if and where the most effective strategies that have been identified from models are being used. Dr Samhouri identified three main reassembly strategies, where lower trophic levels recover first, higher trophic levels recover first, or simultaneous recovery occurs. Using a theoretical toy model of a generalist predator and multiple prey species, Dr Samhouri asked whether who goes first matters about ecosystem reassembly, specifically examining these three strategies. Simultaneous recovery (to equilibrium) of both predator and prey is fastest while predator first is the slowest, but predator first is the most direct in terms of amplification volume, without noisy transient dynamics. From the literature, the least common strategy is where highest trophic level recovery first, suggesting that the most effective strategies, specifically simultaneous reassembly and lower trophic lev-

el first, are the most common. Additional future work examining stochastic dynamics and multiple trophic levels in the system may help identify how regimes shift and the possibility of priority effects under more realistic scenarios.

Dr Kulik presented work examining potential reference points for mean trophic level of macrofauna in the Sea of Okhotsk. Trophic level, a common indicator of fisheries status, can be determined by stable isotope ratio of nitrogen, but this depends both on seasonal delivery of nitrogen with spring blooms and on the age of the consumer. To address this variability, Dr Kulik used an adjusted mean weighted average trophic level (muTL) of every catch, using information on weight at length from fishery data and stable isotope ratio information from data of species in the benthic-pelagic zone. Using trophic level of 67 fish, 6 squid and 5 decapod species and 148 species from FishBase, Dr Kulik and colleagues estimated muTL from 9926 trawls in pelagic waters from 1984–2013 and from 6321 bottom trawls from 1977–2010. Dr Kulik examined spatial and temporal variation of muTL using Generalized Additive Models with splines for coordinates, horizon of trawling, years and months. Dr Kulik's results indicate that there is deviation from the global mean of muTL in pelagic waters over time in the Sea of Okhotsk, and during the period of 2003–2013, he estimated that the linear rate of increase in muTL of catches was 0.007 per year. Spatial variation also occurs in muTL, with deeper pelagic waters showing lower than average muTL in the pelagic fisheries, but for bottom trawls, the deeper pelagic waters demonstrate higher than average muTL. This research illustrates the need to understand spatial and temporal variation in reference points of indicators in order to understand ecosystem shifts.

Dr Yusheng Zhang and colleagues described the fate and potential impacts from radionuclides in the NW Pacific following the Fukushima Nuclear Disaster (FND). Transfer of radionuclides can occur from water to fish through the foodweb and directly through contact with water. On a series of cruises beginning in June 2011, Dr Zhang and colleagues collected tissue samples from three species – squid, saury, and dolphin fish. They used these samples to analyse radionuclide concentrations of ^{134}Cs , ^{137}Cs , and ^{110m}Ag , using the gamma spectrometry method. All radionuclides were detected in all three collected species of marine animals, including ^{134}Cs and ^{110m}Ag , which are important indicators of nuclear accident pollution and are not usually seen. Squid showed higher concentrations than saury and dolphinfish, though radionuclide contents varied among tissue types. Dr Zhang also developed spatial maps of exposure, indicating where the nuclide samples were found and their magnitudes, and examined temporal patterns in radionuclide concentrations in tissues. Concentrations of most radionuclides in squid peaked in November 2011, and dropped precipitously, except for ^{90}Sr , which showed a very different temporal pattern. Dolphin fish radionuclide concentrations also exhibited declines over time. Dr Zhang indicated that though radionuclide concentrations in marine animals increased following FND, they were lower than the limit reference point for seafood safety.

Dr Hyeong-gi Kim presented work regarding thermal influence on nematodes, the most numerous metazoans worldwide and a potentially informative indicator group because of their abundance, occurrence in a wide range of habitats, habitat specificity, and a broad range of feeding types and generation times. Dr Kim focused on the effects of thermal discharge from nuclear power plants on nematode communities in Gori coastal waters of the southern East Sea / Sea of Japan. The nematode community consisted of six dominant species, but a much larger number of species were extremely rare. Most nematodes were non-selective deposit-feeders, and sediment type was a

dominant factor determining nematode community composition. Interestingly, bottom temperature was not significantly correlated with the abundance of most nematodes.

Mr Delvan Neville from Oregon State University discussed reference points in the context of radioecology. In this field, reference points are referred to as Derived Consideration Reference Level. Mr Neville determined distribution of radionucleotides in the bodies of several Northern California Current marine species including *Thunnus aluluna* (albacore tuna). Concentrations were generally low, such that only a 10,000-fold increase in ^{137}Cs would exceed safe limits. Pink shrimp and several other species exhibited much larger responses than those seen in tuna.

Some overall comments:

- Tipping points are an integrative concept for social-ecological systems and pertain to many issues of strong interest to PICES, including climatic shifts, changes in top predator abundances, ecosystem responses to multiple pressures, and more.
- However, a clear definition is challenged by this same feature. It seemed that the implicit and most general definition that emerged in S3 focused on the existence of a non-linear change in a dynamical system. Defined this way, tipping points can occur in individual animals in response to environmental challenges (e.g. radiation, CO_2), to harvested fish stocks because of spawner-recruit relationships, and to entire foodwebs and ecological communities because of non-linear predator-prey and competitive interactions.
- Early warning indicators of tipping points may be difficult to identify and anticipating or forecasting tipping points may not be possible. However, retrospective analysis and modelling can illustrate general lessons and rules of thumb, as well as help identify potential trajectories of recovery and guide management actions.
- Tipping points are inherent to social-ecological systems, but do not in and of themselves tell us anything about objectives and targets. Rather, knowledge of tipping points can help guide decisions about objectives and targets.
- While desired states of the social ecological system are important to consider for decision-making, it is the biophysical system that defines what states are possible. Thus while it is important to define desired states within the tipping points framework, it is important to manage expectations about what is possible to achieve.

We are seeing an increasing amount of integration of social-ecological effects within ecosystems PICES activities across the North Pacific. This is a good sign for the FUTURE program.

8 PICES Meeting 2014. BIO/MEQ Topic Session (S8)

Marine debris in the Ocean: Sources, transport, fate and effects of marine Litter

Yeosu, Korea, 23 October 2014

Report by: Jesús Gago

The session was held on Thursday 23 October, with 17 presentations and about 50 attendants during the day.

The objective of this session was to present the status and trend information for marine plastic debris pollution and its environmental consequences in the PICES region.

Key topics were on (i) models, enabling to understand circulation of debris and associated rafted species, the evaluation of sources, including backtracking, and a global estimation of plastic in the North Pacific where according to recent estimations 38% of worldwide floating plastics are found; (ii) the degradation processes and associated problems of plastic materials such as degradation of polystyrene (EPS), the major component of aquaculture buoys in Korea; (iii) the transfer and release of contaminants from plastics like PCB; (iv) beach surveys of marine litter in NW Pacific (Russia, South Korea and China); (v) microplastics; (vi) monitoring, including the development of original methods for the evaluation of quantities (webcam, wavegliders); and finally (vii) management with consideration to sources and harbour management.

The MSFD monitoring programme was also presented (ICES represented by Francois Galgani Invited Speaker and Jesús Gago Convener) as an example of an integrated programme. The ICES contribution to the meeting was highly appreciated by local organizers, specially taking into account that two conveners were not able to attend.

Overall, the session was very active with a lot of interest from the Pacific science community and the involvement of all countries. Due to the strong interest of the audience, it was agreed by the conveners to organize a round table with all the invited speakers plus conveners. It was concluded that a marine debris observing system is needed to better understand transport, identify sources and predict impacts on the marine environment.

9 PICES Meeting 2014. FIS Topic Session (S5)

Ecosystem considerations in fishery management of cod and other important demersal species

Yeosu, Korea, 22–23 October 2014

Co-Convenors: Gordon H. Kruse (USA), Sukgeun Jung (Korea). Alexei Orlov (Russia), Xianshi Jin (China), Jacquelynne King (Canada), and Kenneth Drinkwater (Norway /ICES)

Background

Pacific cod (*Gadus macrocephalus*) sustain important commercial fisheries throughout the North Pacific Ocean and, historically, Atlantic cod (*Gadus morhua*) have supported some of the most valuable commercial fisheries in the North Atlantic Ocean. Their dynamics have been linked to fishing, climate and other commercially important demersal species. Cod are also extremely important ecologically. As predators, they have been implicated in the decline or lack of recovery of shrimp, king crab, capelin and herring. As prey, they are important forage for pinnipeds; some research implicates seal predation in the lack of recovery of some Atlantic cod stocks, and other studies implicate Pacific cod in the lack of recovery of Steller sea lions in the western Gulf of Alaska and Aleutian Islands. Multispecies models demonstrate co-variation of cod with other important demersal species, as well as explicit tradeoffs in cod and forage fish populations with implications on the joint setting of catch quotas. Moreover, cod recruitment and spatial distribution can be strongly influenced by climate-driven changes in oceanography on decadal and shorter time scales, implying that catch levels must be adjusted for bottom-up changes in productivity. For these and other reasons, ecosystem considerations must be taken into account in cod fishery management. By drawing upon insights gained from different systems, as well as from studies of other important co-occurring demersal species (e.g., walleye pollock, small yellow croaker), this session will deepen our understanding of the roles of cod in the marine ecosystem and their implications on fishery management. Contributions were sought that consider stock identification, stock assessment and population dynamics, effects of climatology and oceanography on recruitment and biomass, trophodynamics, movements and distribution with respect to oceanographic features, multispecies models and their implications on management strategies, and other ecosystem approaches to the management, including aquaculture alternatives. Presentations were welcome from marine ecosystems in the North Pacific and North Atlantic.

Summary of presentations

During this session, 16 oral presentations were given; no posters were presented. Three invited speakers kicked off the session. The first invited talk was presented by Ken Drinkwater of ICES. He began his talk with a review of the relationships between Atlantic cod and gadid relatives in the North Pacific. Pacific cod and walleye pollock emerged as a result of migrations of Atlantic cod to the Pacific during a warm period 3.5 Myr ago, respectively. Ken went on to provide an extensive review of Atlantic cod throughout their range in the North Atlantic Ocean. He reviewed climate-related changes in cod distribution, as well as variable relationships of cod recruitment to temperature and spawning biomass with latitude.

The second invited talk was presented by Yasunori Sakurai, who provided an overview of decades of his research on reproductive characteristics and strategies of Pacific gadid fishes. Two reproductive modes were identified. Species, such as Atlantic cod and walleye pollock, produce separate pelagic eggs at intervals of a few days. Other species, such as Pacific cod and saffron cod, lay slightly adhesive demersal eggs in a single spawning event within a minute. Sakurai-san went on to discuss the importance of experimental studies on reproductive characteristics, including the need to examine reproductive strategies and early life stages under conditions experienced during climate regime shifts and global warming.

The final invited speaker, Robyn Forrest, reported on efforts to understand variability in Pacific cod catches in British Columbia, as well as fishery management strategies that are robust to uncertainties in these processes. A number of hypotheses have been proposed to explain cycles in cod catches, including environmental drivers, predator-prey cycles, and density-dependent survival. Recent analyses with updated datasets were unable to pinpoint the exact underlying mechanism(s), because of large historical changes in fishery management, difficulties in ageing, and uncertainties in abundance estimates. A management strategy evaluation explored the tradeoffs of three alternative harvest control rules with respect to these uncertainties.

Contributed talks covered a wide range of topics from population-level processes to multispecies and ecosystem models. At the population-level Maria Rabchun discussed a genetic study of Pacific cod from six areas of the Sea of Okhotsk and Bering Sea using two genetic markers: mtDNA and the gene Cyt b. Two haplotypes of Cyt b were unique to samples collected in Tauiskaya Bay (northern Sea of Okhotsk) and the northern Kurils, whereas a control region of mtDNA revealed a haplotype that was unique to Tauiskaya Bay only and another haplotype that was specific to the Southern Kurils and northern Bering Sea. Nadezhda Aseeva reported on a comprehensive study of the parasites of Pacific cod, which affect their commercial value. The frequency of infestation and species diversity of parasites decrease with increasing latitude. Olga Novikova reviewed the fisheries for saffron cod in the Russian Far East. Commercial catches of saffron cod averaged 27.0 thousand tons during 2003–2013. More than two-thirds of the harvest is taken from the Sea of Okhotsk and western Bering Sea. The fishery is prosecuted Danish seine and trawls, as well as fixed net gear types.

Three contributed papers addressed various aspects of reproduction. Libby Logerwell presented two papers on behalf of her colleagues, Sandi Neidetcher and Kimberly Rand. Sandi studied spawning phenology and geography of Pacific cod in the Aleutian Islands and eastern Bering Sea. Temporal and spatial analyses of visual maturity samples revealed that the spawning season spans late February to mid-April and most spawning occurs between 100 and 200 m depth. Specific spawning concentrations were identified in the Aleutian and Pribilof Islands, as well as the shelf break near Zhemchug Canyon in the eastern Bering Sea. Kimberly analysed the movements of cod that were tagged north of Unimak Island in the eastern Bering Sea and recovered by commercial fisheries. Results showed that cod are widely distributed across the eastern Bering Sea during summer and demonstrate homing tendencies during spawning migrations in late winter and early spring. Minkyong Bang investigated relationships between water properties and biological characteristics of walleye pollock from the East Sea/Sea of Japan, a stock that collapsed in the 1990s and 2000s. Fish size decreased and gonadosomatic index (GSI) increased with warmer temperatures according to an alternating pattern of temperatures: warm phase in 1971–1980, cool phase in 1981–1987, warm in 1988–1993, and cool in 1994–2003. High-

er GSI during low abundance in the 2000s compared to high abundance in the 1970s and 1980s provided some evidence of density-dependent effects.

A series of presentations examined effects of environment on gadids. Zhe Li received the FIS-committee's best oral presentation award for his talk on effects of temperature and ontogeny on vertical movement of newly hatched Pacific cod larvae. Larval cod were reared at various temperatures in experimental columns in the laboratory during the initial 3 d post hatch period. Larvae swam upward in the column. Specific gravities of the larvae generally did not change over the initial 3 d, but decreased with ontogenetic development. Results suggest that Pacific cod larvae maintain vertical position initially by upward swimming and thereafter by near-neutral buoyancy.

Heeyong Kim discussed relationships between the Siberian High and formation of Yellow Sea bottom cold water (YSBCW). Pacific cod catches are lowest when YSBCW is restricted to the center of the Yellow Sea and highest when YSBCW covers the entire seafloor of the Yellow Sea. Sukgeun Jung demonstrated that climate regime shifts and subsequent ecological impacts can occur asynchronously between upper and deep layers of the ocean. Consistent with a sharp increase in temperature at 50–100 m in the Ulleung basin of the East Sea/Sea of Japan during 1987–1989, commercial catches of epipelagic species shifted from cold-water to warm-water species. On the other hand, cold bottom water intensified in 1992/1993 and was followed by a shift in benthopelagic species from warm-water to cold-water species.

Pat Livingston explored ecosystem factors responsible for synchrony in recruitment patterns of Pacific cod and walleye pollock in the eastern Bering Sea. Despite a comprehensive review of similarities and differences in life history, no single factor explains these patterns in recruitment. Mikhail Stepanenko considered factors responsible for good and poor recruitment of pollock in the Bering Sea. Strong year classes did not seem to occur during warm or cold periods, but rather during transitions between these two conditions. A connection between zooplankton and survival of young-of-the-year pollock was suggested. Rapid changes between warm and cold conditions and vice versa may be associated with increased diversity of zooplankton size groups, perhaps favouring feeding and survival. Franz Mueter gave a presentation for Elizabeth Siddon, which further explored relationships between pollock growth/survival and zooplankton. Modelling evidence was provided that a spatial mismatch between juvenile walleye pollock and growth 'hot spots' contribute to poor recruitment while a higher degree of overlap results in higher recruitment. Moreover, results indicated that climate-driven changes in prey quality and composition can impact growth of juvenile walleye pollock, potentially severely affecting recruitment variability.

Presentations were also given on ecosystem and multispecies modelling. Konstantin Gorbatenko developed a mass-balance food web model for the northeastern part of the Sea of Okhotsk. This large model involved 3994 inequalities for 166 equations with 2034 flows. Although an exact solution could not be obtained, a least-squares solution provided a basis for further investigation. The uncorrected food web model showed that aggregate flows to Pacific cod and walleye pollock are about 1.6% of primary production. Finally, Gordon Kruse gave a presentation on behalf of Tadayasu Uchiyama on a multispecies predator-prey model of major groundfish species, including Pacific cod and walleye pollock, in the eastern Bering Sea. Multispecies models were able to reconstruct patterns of major groundfishes revealed by trawl surveys. However, reference points, such as virgin biomass and MSY, estimated by multispecies models were lower than the sum of those estimates from single-species

models. Temperature also affected the strength of predation. Model results supported the hypothesis that colder bottom temperatures provide a larger refuge to juvenile pollock from predators. Temperature effects were largest for arrowtooth flounder predation on age-1 pollock.

Excellent discussions were held after each half-day session. Participants recommended that a cross-basin and cross-ocean comparison of cod stocks may help elucidate underlying mechanisms (e.g., roles of temperature and fishing) on cod population dynamics. Interest was also expressed to conduct additional work on cod within PICES. Finally, the convenors are exploring the possibility of publishing papers from session S5 as a special journal issue.

10 PICES Meeting 2014. POC/MONITOR Topic Session (S9)

Variability in advection and its biological consequences for Subarctic and Arctic ecosystems

Yeosu, Korea, 23 October 2014

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Background

The advection of water masses and their associated nutrients and plankton is critical to biological processes within the subarctic gyres and on the productive shelf regions bordering the gyres. Cross-shelf and along-shelf advection and vertical fluxes regulate the supply of nutrients and plankton to these shelves, thereby affecting the productivity and species composition of the prey organisms that support higher trophic levels. Moreover, the advection of larvae to suitable nursery areas has been linked to the recruitment success of fish and shellfish species in many regions, including the subarctic waters of both the Pacific and Atlantic. Interannual variability in advection has long been understood as an important source of biological variability, while variability at shorter time scales (days to weeks) has only recently received more attention due to the increased availability of high-frequency observations and the development of high resolution models. This session explored how variability in the fluxes of nutrients, plankton, and early life stages of fish at all scales affects marine ecosystem dynamics in the Subarctic and Arctic.

Summary

The session consisted of 15 oral presentations spanning most of the subarctic Pacific from the Western Subarctic Gyre, the Oyashio Region and the Sea of Okhotsk to the Aleutian Islands, Bering Sea, Chukchi Sea and the Canadian Basin. In addition, two presentations addressed advective processes in the Atlantic Arctic. An invited presentation by Dr. Georgina Gibson (University of Alaska) highlighted interannual differences in the transport of zooplankton onto the eastern Bering Sea shelf in response to differences in wind forcing, particularly in the direction of the prevailing winds. In spite of these differences, consistent transport pathways in the vicinity of submarine canyons were identified using an individual-based particle tracking model.

Several presentations examined the impact of reduced sea ice on the biological pump and on CO₂ fluxes in the Chukchi Sea and Canada Basin. Reduced ice results in less light limitation, enhanced stratification due to increased warming and freshwater discharge, and changes in nutrient inputs through enhanced upwelling and eddy activity. However, the combined effects of these changes on primary production remain uncertain. Observations of biological fluxes using sediment traps, combined with modelling, suggest that mesoscale eddies originating at the Beaufort shelf break are associated with enhanced production and export of biogenic materials from the surface to the deep Northwind Abyssal Plain (Harada *et al.*). Fluxes were highest at the onset of winter (November/December) in 2010 and 2011, but very limited fluxes were observed in 2012. Much of the biogenic fluxes consisted of resting spores and vegetative valves of diatoms, including many ice-associated species (Onodera *et al.*).

The lack of pronounced biogenic fluxes in 2012 was likely associated with an intensification and westward shift of the oligotrophic waters of the Beaufort Gyre (Onodera *et al.*). Measurements of primary production in 2004 and 2009 suggested that reduced primary production was associated with stronger stratification, while enhanced primary production was observed around the edges of an eddy due to upward vertical fluxes of nutrients (Yun *et al.*). In addition to changes in production, vertical fluxes associated with the biological pump, as well as horizontal advection, contribute to the role of the Bering Sea shelf and the northern Chukchi Sea shelf as important CO₂ sinks (Futsuki *et al.*).

Tsukazaki *et al.* (presented by I. Imai) highlight the importance of resting stages of diatoms to seed both the ice-associated spring bloom and the phytoplankton bloom. Resting stage cells reflect the species composition in the water column and occur in densities as high as 7 million cells per cm³ of water. Cells are re-suspended to seed the water column in the spring or summer and are embedded in the ice when it forms in the fall. Spring bloom dynamics at the melting ice edge were examined by Fujiwara *et al.* (presented by S.-I. Saitoh). Earlier ice retreat was associated with larger phytoplankton in the ice-associated spring bloom averaged over the 14 days following ice retreat. This was attributed to under-ice blooms utilizing nutrients in the surface water, followed by rapid thermal stratification after the ice melts. In contrast, when the ice retreats early, thermal stratification occurs more gradually and higher nutrient concentrations may have resulted in blooms of larger diatom species.

Zooplankton distributions in the Chukchi Sea differ among water masses with most groups more abundant in Bering Sea and Anadyr water compared to Alaska coastal waters and with higher abundances in recent years (2008, 2010) compared to an earlier period (1991/1992, Sasaki *et al.*). Enhanced zooplankton production was also observed in an eddy originating off the western Aleutian Islands in early 2010. The cold-core eddy entrained colder Alaska Stream waters in late winter and propagated southeast for 5 months prior to sampling (Saito *et al.*). Advection associated with the summer monsoon over Asia affect zooplankton dynamics in Peter the Great Bay (Zuenko and Nadtochy). A weaker summer monsoon was associated with stronger stratification in the bay and reduced onshore advection of predatory species (e.g. *Sagitta elegans*). Although the stronger stratification resulted in reduced production, zooplankton appeared to have sufficient food and the abundances of coastal, non-predatory zooplankton species actually increased, presumably because of reduced predation.

Two presentations addressed the role of advection in transporting fish eggs and larvae. Walleye pollock off Northeast Sakhalin Island spawn in very cold waters over the shelf, rising into the warmer surface layer and drifting south in the East Sakhalin current as they develop (Kim *et al.*). Eggs and larvae may be entrained in the East Sakhalin counter current to reach their (unknown) nursery grounds. Mueter *et al.* contrasted advection from the Subarctic to the Arctic between the Pacific and Atlantic Oceans and compared life history adaptations of fish in each region to these contrasting patterns, concluding that it is unlikely that major fish populations will expand into the Pacific Arctic in the foreseeable future, whereas species in the Atlantic are well positioned to take advantage of new and expanding open water areas.

Phytoplankton dynamics in the western Pacific were the subject of two other presentations. Fujiki *et al.* showed that phytoplankton in the western Subarctic Gyre are nutrient stressed during summer, even though macronutrients were not limiting. Incubation experiments revealed continued growth after iron enrichment. Therefore

the magnitude and duration of the phytoplankton bloom in the western subarctic gyre appears to be controlled by the availability of iron. Kuroda *et al.* advance a compelling and well supported hypothesis for the advective processes that contribute to the intense spring bloom observed off the east coast of Hokkaido Island. According to this hypothesis, East Sakhalin Current water exits the Sea of Okhotsk through Kuna-shiri Strait forming coastal Oyashio water. The water includes iron-rich waters from the Amur River and mixes with Oyashio water to support the intense spring bloom.

Finally, Drinkwater reviewed outflows from the Arctic to the Subarctic in the Barents Sea, Fram Strait and through the Canadian Archipelago. Outflows through the latter consist of 40–60% Pacific source waters, affecting stratification and advecting Arctic zooplankton species (*Calanus hyperboreus*) as far south as the Gulf of Maine and Mid-Atlantic Bight. Similarly, outflows from Fram Strait continue through Denmark Strait and can affect stratification and the timing of the bloom in both the East Greenland and West Greenland currents. These outflows also export plankton from the Arctic, including large numbers of ice algae, and may have carried the Pacific phytoplankton *Neodenticula seminae* into the Atlantic in the late 1990s and early 2000s.

Clearly, vertical and horizontal fluxes of freshwater, nutrients and plankton are important to understanding the dynamics of subarctic-Arctic interactions. While much progress has been made in understanding fluxes of salt, heat and nutrients, resolving biological fluxes and their spatio-temporal patterns of variability will require sampling and higher temporal and spatial resolution in combination with modelling. As the invited presentation demonstrated, short term wind events and meso-scale eddies can have important and disproportional influences on the advection of nutrients and plankton (Gibson *et al.*).