ISSN 1066-7881

GLOBAL OCEAN ECOSYSTEM DYNAMICS

GLOBEC Special Contribution No. 5

Report of the first meeting of the SPACC/IOC Study Group on “Use of environmental indices in the management of pelagic fish populations”

(3-5 September 2001, Cape Town, South Africa)

GLOBEC is a Programme Element of the International Geosphere-Biosphere Programme (IGBP).It is co-sponsored by the Scientific Committee on Oceanic Research (SCOR)and the Intergovernmental Oceanographic Commission (IOC)

The GLOBEC Report Series (Ed. Manuel Barange) is published by the GLOBEC International Project Office and includes the following:

No. 1. Towards the development of the GLOBEC Core Program (CP).A report of the first International GLOBEC planning meeting. Ravello, Italy, March 31-April 2, 1992.

No. 2. Report of the first meeting of an International GLOBEC working group on Population Dynamics and Physical Variability. Cambridge, United Kingdom, February 1-5, 1993.

No. 3. Report of the first meeting of the International GLOBEC working group on Sampling and Observation Systems. Paris, France, March 30 –April 2, 1993.

No. 4. Report of the first meeting of the ICES/International GLOBEC working group on Cod and Climate Change. Lowestoft, England, June 7 –11, 1993.

No. 5. Report of the first meeting of the International GLOBEC working group on Development of an International GLOBEC Southern Ocean Program. Norfolk, Virginia, USA, June 15 –17, 1993.

No. 6. Report of the first meeting of the International GLOBEC working group on Numerical Modelling. Villefranche-sur-Mer, France, July 12 –14, 1993.

No. 7. Southern Ocean Implementation Plan. Bremerhaven, Germany, June 6 –8, 1994.

No. 8. Report of the first planning meeting on Small Pelagic Fishes and Climate Change Program. La Paz, Mexico, June 20-24, 1994.

No. 9. IGBP Report No. 40. Global Ocean Ecosystem Dynamics Science Plan.

No. 11. Small Pelagic Fishes and Climate Change Programme Implementation Plan.

No. 12. Report of the first SPACC Modelling workshop. Ispra, Italy, 14-16 October 1996.

No. 13. IGBP Report No. 47. Global Ocean Ecosystem Dynamics Implementation Plan.

No. 14. Report of a Workshop on the Use of the Continuous Underway Fish Egg Sampler (CUFES) for Mapping Spawning Habitats of Pelagic Fish.

GLOBEC Special Contributions:

No. 1. Predicting and Monitoring of the Physical-Biological-Chemical Ocean. A. R. Robinson (Ed.)

No. 2. An Advanced Modelling/ Observation System (AMOS) For Physical-Biological- Chemical Ecosystem Research and Monitoring (Concepts and Methodology). GLOBEC International Working Groups on Numerical Modelling and Sampling Observational Systems.

No. 3. GLOBEC Workshop on the Assimilation of Biological data in Coupled Physical/ Ecosystems Models. A. R. Robinson and P. F. J. Lermusiaux (Eds.)

No. 4. Report on the GLOBEC National,Multi-National and Regional Programme Activities 2001.

Other GLOBEC Reports

Interdisciplinary Model Formulation and Parameterization. Report of the Second meeting of the International GLOBEC Numerical Modeling Working Group. Nantes, France,17-20 July 1995

Report of US Southern Ocean GLOBEC Planning Workshop. National Science Foundation, Arlington, VA, 31 - 1 October 1998.

Fisheries Oceanography 1998, Volume 7, Numbers 3 &4. GLOBEC Special Issue.

Additional copies of these reports are available from:

Dr Manuel Barange
GLOBEC International Project Office
Plymouth Marine Laboratory
Prospect Place
Plymouth PL1 3DH
United Kingdom

Tel: +44 (0)1752 633160
Fax: +44 (0)1752 633101
email: m.barange@pml.ac.uk
Homepage: www.globec.org

GLOBEC is a Programme Element of the International Geosphere-Biosphere Programme (IGBP).
It is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC).

Executive Summary

The SPACC/IOC Study Group on "Use of Environmental Indices (EI) in the management of pelagic fish populations was appointed by GLOBEC-SPACC and approved by the sponsors, the Intergovernmental Oceanographic Commission (IOC), with the following terms of reference:

- To provide a comprehensive review of the use of environmental indices as hindcasting/ nowcasting and forecasting tools of the fluctuations of pelagic fish in selected areas.
- To develop a scientific framework to understand the linkages between environmental variables and pelagic fish fluctuations, at relevant spatial and temporal scales.
- To investigate the requirements to incorporate environmental indices into stock assessment models and operational management procedures.
- To propose a set of environmental variables of use in the management of pelagic fish populations to be included in local and global monitoring programmes.

The first meeting of the Study Group was held at the Marine and Coastal Management Research Aquarium, Beach Rd, Cape Town, South Africa, 3-5 September 2001. In this first meeting the SG attempted to address the first three ToR, and drafted a plan of activities of the SG for the next 12 months to ensure that a response to the four terms of reference can be provided after the second meeting of the SG in 2002.

In preparation for the meeting the SG prepared summaries of assessment information on selected pelagic fish stocks for which environmental data may potentially be used in their management. These summaries are included in section 6.0 of this report. The selection was determined by the experience of the SG members and was therefore not exhaustive. It is expected that analyses on these stocks may bring other stocks forward for similar treatment.

A document to frame the work of this SG in context with other relevant initiatives was prepared beforehand, and included as item 7.0 of this report.

During the meeting discussions were held on three specific technical questions:

a) What is the potential use of EI to update parameters and determine biological reference points (Section 8.0 in this report)
b) What is the potential use of EI to reduce management risk or/and increase yield (Section 9.0 in this report)
c) What are the technical requirements for EI to be incorporated into management procedures (Section 10.0 in this report).

On the third day of the meeting the SG was divided into three subgroups to synthesise the discussions and to outline a plan of action for the future. Their reports are included in section 11.0, and summarised here:

Subgroup 1 - Review of case studies where EI are used in management procedures
The review on the use of environmental indices in the assessment and management of pelagic fish stocks world-wide revealed that in some cases ancillary environmental information is already used to assess the status of several fish stocks and is partly applied in their management. Of the 18 stocks considered, 6 stocks are managed making use of environmental information:

- In the Californian anchovy and sardine environmental information is used as a proxy for stock size and distribution,
- In the Peruvian anchovy (anchoveta) environmental information is used to predict recruitment in short-term predictions,
- In the Japanese sardine EI are applied for medium-term forecast of recruitment strength per spawning stock,
- In the Brazilian sardine for nowcast recruitment success, and
- In the Baltic herring in the Gulf of Riga to predict recruitment in short-term predictions.

In some additional cases environmental information has been occasionally used, but not on a regular basis, (e.g. Bay of Biscay anchovy), or has been abandoned due to cut-back in monitoring efforts (e.g. Black Sea stocks). The group concluded that:

- *Action 1: specification of the underlying process appears to be a necessary step in the completion of the review and utilization of the compiled information (e.g. common processes identified) in subsequent working steps of the Study Group. This task is scheduled to be finalized intersessionally until the 2nd meeting of the Study Group.*

Subgroup 2 – Framework to establish linkages between environmental forcing and pelagic fish responses

Subgroup 1 outlined the need to understand the physical and biological processes through which environmental variation may influence fish stocks before environmental indices can be used in management procedures. Therefore subgroup 2 identified the following activity to be carried out by the Study Group:

- *Action 2: Investigate the pattern of seasonal and interannual variation in sea surface temperature and in wind-driven Ekman upwelling based on longshore wind speed and determine the level of association of these environmental variables with patterns of variability in growth and recruitment.*

The WG initially restricted its recommendation for a comparative study to a number of systems in order to simplify interpretation (see table under section 11.2). To overcome the problems of data disparity and treatment, the SG recommended that standardized data sources be used for all regions of interest. The standardized information would consist of satellite imagery (9 km/8 day averages available from the Jet Propulsion Laboratory) and the geostrophic winds (6 h averages from NCEP re-analysis).

Subgroup 3 – Requirements to incorporate EI in pelagic stock assessment

Subgroup 3 recommended that the SG conduct three activities over the next 12 months:

- *Action 3: Conduct a simulation analysis to evaluate the benefits of using environmentally linked recruitment predictors in the management of anchovy stocks*. Essentially an extension of the simulation analysis presented at the meeting by J de Oliveira for the South African anchovy (see section 9.0) extended to the anchovy fisheries in the Bay of Biscay and Humboldt Current. J. de Oliveira would take the lead.

- *Action 4: Investigate environmental effects on adult fish parameters and common biological reference points used in management.* Adult sardine biological factors respond to environmental variation in stocks off California, Japan and off Portugal. Under the leadership of M. F. Borges the SG should conduct a collaborative analysis to ascertain a) whether climatic effects on adult fish are important in calculating biological reference points and b) whether adjustments to reference points based on adult fish biology might be a sufficient basis for changing management in response to climate change.

- *Action 5: Explore synchronies in rate-based measures of productivity and recruitment in small pelagic fishes. A* recent paper published by SPACC scientists indicates that production rates are more sensitive and likely better measures of climatic effects on fish stocks than catch data or biomass estimates. A subgroup of the SG agreed to collaborate in an analysis of the synchrony and variability in production rates in stocks with long time series of data (e.g. Japanese sardine, California sardine, Peruvian anchoveta and California anchovy). This work will involve exploring density dependent effects and variations in production versus variations in regional and global environmental time series, using analytical techniques based on Moran's theorem to pelagic fish. The group will try to quantify the degree of synchrony between proximate versus remote fish populations, preferentially using estimates of surplus production and recruitment.

The Study Group will conduct these activities through electronic mail, and would reconvene in the Northern Hemisphere fall of 2002, at a European venue to be designated.

This document may be cited as:

Barange, M. (Ed.) 2001. Report of the 1st meeting of the SPACC/IOC Study Group on "Use of environmental indices in the management of pelagic fish populations (3-5 September 2001, Cape Town, South Africa). GLOBEC Special Contribution No. 5, 122 pp.

Table of Contents

1.0 Introduction

The Small Pelagic fish and Climate Change (SPACC) programme is a regional initiative of GLOBEC, a core project of the International Geosphere-Biosphere Programme (IGBP). GLOBEC is aimed at understanding how global change, in the broadest sense, will affect the abundance, diversity and productivity of marine populations comprising a major component of oceanic ecosystems. GLOBEC is co-sponsored by the Scientific Committee on Oceanic Research (SCOR), the Intergovernmental Oceanographic Commission (IOC) and the IGBP.

The objective of SPACC is to forecast how changes in ocean climate will alter the productivity of small pelagic fish populations. An implementation plan for the programme was published in 1997 (GLOBEC Report 11), specifically noting the global coverage of the programme, the participation of many developing as well as developed countries, and its emphasis on capacity building and training.

At a recent meeting of the SPACC Executive Committee meeting in La Jolla, USA, March 2000, it was decided to focus SPACC activities along four research themes:

- *Theme 1 - Long term Changes in Ecosystems* Leaders: J Alheit (Germany), T. Baumgartner (Mexico).
- *Theme 2 - Comparative Population Dynamics* Leader: M Barange (GLOBEC IPO, UK).
- *Theme 3 - Reproductive Habitat Dynamics* Leaders: D Checkley (USA) and C Roy (South Africa)
- *Theme 4 - Economic Implications of Climate Change* Leader: J Hunter (USA).

A number of activities have been planned under the four themes. The Intergovernmental Oceanographic Commission (IOC) expressed its intention of supporting SPACC activities under Theme 2. In this document we describe a line of research entitled "Use of environmental indices in the management of pelagic fish populations", to be developed between SPACC and IOC over the next three years.

Problem

Modern fisheries management is characterised by sophisticated models aimed at assessing the status of fish stocks and predict their dynamics. In recent years substantial effort has been placed on developing the technical and mathematical aspects of these models, sometimes at the expense of searching for causes and explanations for model predictions. While statistical improvements are necessary the need to reduce the biological uncertainty surrounding most fish management systems has only been encouraged if the cost could be justified in terms of increased quotas[1].

This emphasis has distanced fisheries management from the natural processes behind fish population dynamics. For example, there is a general consensus that the physical environment plays a significant role in determining the fate of fish populations. However, the inclusion of environmental variables in fisheries models has not received enthusiastic support, as simulations have indicated that they may result in limited short-term benefits, such as increased yields or reduced risks[2]. This is primarily because the precise effects of the environment on fish populations are still unquantifiable and intrinsically unpredictable[3], but also because our present models do not cope well with the complexity of natural systems.

This inability of modellers and fisheries scientists to encapsulate the true variability of fish populations in our management procedures is severely affecting our ability to manage these resources in a sustainable manner, as the current crisis in world fisheries clearly demonstrates[4]. In the case of pelagic fish, the collapses in the Humbolt anchovy and Benguela sardine in the 1970s, or the Japanese and Humboldt sardines in the early 1990s, are salient examples, and constitute the rationale behind the SPACC programme. In addressing this challenge, some fisheries modellers point out that we need to make more effectively use of our increasing knowledge of the factors and relations influencing fish stocks, including the effects of a varying physical environment and multispecies interactions[5]. This is the objective of this Study Group.

[1] Cochrane 1999. ICES J. mar. Sci. 56:917-926
[2] Basson 1999. ICES J. Mar. Sci. 56: 933-942
[3] Walters and Collie 1988. Can J. Fish. Aquat. Sci. 45: 1848-1854
[4] Garcia and Newton 1997.Global trends: fisheries management. American Fisheries Symposium, 20: 2-27
[5] Ulltang 1998. J Northw. Atl. Fish. Sci. 23: 133-141.

Rationale

Small pelagic fish account for about one third of the world catches, and are particularly abundant in upwelling regions. These regions have remarkable parallelisms: they are characterised by negative anomalies in sea surface temperature near the coast and positive anomalies at their edges, which result in a number of common, associated processes[6]. They generally support at least one anchovy and one sardine assemblage, which tend to spawn in different seasons or regions, to minimise competition while maximising environmental forces. They also tend to feed on different components of the food web[7]. These fish species appear to be extremely vulnerable to a delicate balance of physical ocean processes. Their recruitment success is linked to what is known as the optimal environmental window[8], according to which fish could only thrive at specific combinations of wind and currents, and is thus linked to the state of their environment.

Therefore, it seems plausible to provide a consensuated response to the question:

- *Can we use environmental data in the assessment and management of small pelagic fish in upwelling areas?*

The fact that so many pelagic fish stocks fluctuate following "boom and bust" scenarios[9] indicate that the Optimal Environmental Window hypothesis may be too simplistic. Combined with the observed synchrony in these fluctuations this dynamics suggest that:

a) the effect of the environment on pelagic fish species may not be linear,
b) that these species may have more than one equilibrium point,
c) that they are likely to compete with each other, and
d) that perhaps other biological processes (e.g. predation) substantially affect the above.

If we want to encapsulate the true variability of pelagic fish stocks in fisheries management procedures we need to get clear answers to a number of *key questions*:

a) Can we use environmental indices as hindcasting/ nowcasting and forecasting tools?

A number of studies have made use of environmental parameters to hindcast pelagic fish stock fluctuations. In the southern Benguela, oil yields and SE winds have been used to quantify the relationship between upwelling intensity and anchovy recruitment[10]. In the NW Africa Current periods of high sardine abundance have been linked to periods of intensification of north-easterly trades and upwelling[11]. In the Humboldt Current environmental proxies are thought to regulate the relative dominance of anchovy and sardine[12],[13]. Even in temperate seas, as in the SW coast of the United Kingdom, these relationships seem to exist. Pilchard appear to dominate during warm periods, while herring is more abundant during cold periods[14]. Many other examples are available in the literature, but few, if any, have managed to translate these hindcasting explanations into forecasting tools. Reasons for this vary, and may include non-linear responses, density-dependencies and fluctuations between limiting factors (e.g. food versus transport). The objective of this activity would be *to provide a comprehensive review of successes and failures in hindcasting versus forecasting tools for adult fish as well as recruits, and the reasons behind these. In the process, environmental indices that both environmentalists and modellers believe to be useful in management and stock assessment of pelagic fishes will be identified, particularly w.r.t. their forecasting capability.*

b) Can we use of environmental indices to reduce uncertainty, thus reducing the risk under which the populations are managed, or increase yield while maintaining the same level of risk?

Simulations have indicated that the average catch of South African anchovy could increase by up to 48% if a very precise estimate of recruitment could be made available at the start of the fishing season[15].

[6] Bakun 1995. CalCOFI Report 26: 30-40
[7] van der Lingen 1994. Mar. Ecol. Prog. Ser. 109: 1-13
[8] Cury and Roy 1989. Can. J. Fish. Aquat. Sci. 46: 670-680
[9] Schwartzlose et al. 1999. S. Afr. J. mar. Sci. 21: 289-347
[10] Boyd et al. 1998. Global versus Local changes in Upwelling systems. Orstom, Paris. p.195-210
[11] Binet et al. 1998. Global versus Local changes in Upwelling systems. Orstom, Paris. p.211-233
[12] Serra 1989. Long term variability of pelagic fish populations and their environment. Pergamon Press. p. 175-182
[13] Yañez et al. 1994. Remote sensing foe marine and coastal environments. Michigan, USA. p. 149-162.
[14] Southward et al. 1988. J. Mar. Biol. Ass. UK 68: 423-445
[15] Cochrane and Starfield 1992. S. Afr. J. Mar. Sci. 12:891-902

However, in furthering these ideas many hurdles have been encountered. Modellers have pointed out the importance of exploring likely benefits and feasibility of incorporating environmental factors in management procedures before investing time and effort. In this regard, it has been argued that in the management of gadoid-like populations these benefits are largely negligible[2]. Recently, de Oliveira (MCM, South Africa, pers. comm.) concluded that incorporating an environmental index in the management procedure of the South African anchovy could attain up to a 20% increase in mean catch, but only if this index could fully explain fluctuations in stock size. If the index were only capable of explaining 50% of this variability, then only a moderate improvement (2-7%) in catch would be achieved. Rooted in this lack of success lies the difficulty in predicting environmental parameters and the strength of the relationships between these parameters and the size of the fish stock, but also the inability of our models to incorporate noisy and complex relationships. *In this activity we will review the role of environmental factors in the design of pelagic fish management procedures in upwelling regions. In particular we will explore and quantify the benefits of incorporating environmental variables in current, and potentially future management procedures, perhaps as predictors of extreme environmental perturbations and their effects. The provision of scenarios where these variables would be of use, would be a priority.*

c) Can we use environmental indices to update parameters and reference points in population models of stock size, such as recruitment *R*, weight at age *W*, maturity at age *O* and natural mortality at age *M,* which are often fixed or averaged over long periods?

Most studies in the literature have attempted to incorporate environmental indices into stock management procedures as predictors of fish recruitment or stock size. While recruitment variability may have to be accepted as a fact-of-life in fisheries management, the influence of the environment in determining specific reference points may be more practical objective. For example, management procedures that use different stock-recruit curves during periods of warming/cooling of the system[16], or that include indices related to the occurrence of El Niño events[17] could be explored. Little effort has been devoted to questioning the assumption that spawning biomass is proportional to reproductive potential, particularly under unfavourable environmental conditions. Presumably it would be possible to use environmental indices to modify other reference points, such as natural mortality, weight at age or maturity at age. Examples to investigate could include: the influence of density-dependent factors, predator abundance and/or dramatic environmental perturbations (e.g. El Niño events) on the natural mortality of pelagic fish; the potential of spatially-weighted indices of weight, maturity and mortality; the value of population fecundity indices that would use other factors than spawning biomass, etc. *The objective in this activity would be to investigate potential updates in reference points based on the observed influences of environmental parameters on these. The role played by environmentally-induced changes in the spatial distribution of pelagic fish on these reference points would be specifically addressed.*

d) The identification of relevant observational systems to generate or maintain useful environmental indices.

International initiatives, such as the IOC-GOOS, are currently underway to accurately describe the present state of the oceans and its living resources, and to forecast future conditions of the sea, including proxies for climate change. These initiatives require the involvement of the scientific community in identifying the relevant ocean parameters worth monitoring. *Through this initiative, SPACC would be able to identify those environmental parameters (oceanographic, atmospheric, remote sensing, model outputs, and geological) that should be monitored for the management of pelagic fish populations world-wide.*

[16] Swartzman et al. (1983) Can. J. Fish. Aquat. Sci. 40: 524-539
[17] Pauly and Sukuyama 1987. ICLARM Studies and Reviews 15.

Terms of Reference

The SPACC Executive Committee would like to initiate activities leading to evaluating the present, and potentially future use of environmental indices in the management of pelagic fish populations, through a Study Group. The Study Group shall:

- Provide a comprehensive review of the use of environmental indices as hindcasting/ nowcasting and forecasting tools of the fluctuations of pelagic fish in selected areas.
- Develop a scientific framework to understand the linkages between environmental variables and pelagic fish fluctuations, at relevant spatial and temporal scales.
- Investigate the requirements to incorporate environmental indices into stock assessment models and operational management procedures.
- Propose a set of environmental variables of use in the management of pelagic fish populations to be included in local and global monitoring programmes.

Implementation

It is envisaged that the task team will meet 2-3 times over the next 2-3 years (starting 2001) and will work through e-mail in between meetings. The end product will be a comprehensive document able to stand up to scientific review, to be published in the GLOBEC Report Series as well as in the main literature.

The SPACC Theme 2 leader (M. Barange) and an appointee from the IOC will act as technical Secretaries of the Task Team.

The GLOBEC International Project Office will administer the project on behalf of the sponsors and will respond to the appropriate bodies at IOC regarding financial management.

The Study Group will consist of 10-12 scientists, selected on the basis of their past and present work and commitment to SPACC and GLOBEC activities, in consultation with IOC. It is proposed that the SG be selected on the basis of applications to the task team leader, following a call for participants from the GLOBEC International Office. Statements reflecting the potential contributions of each applicant to the task team will be evaluated. The SG should also reflect the major areas of SPACC fieldwork: the Benguela Current, the Humboldt Current, the California Current, the Bay of Biscay and the Japanese Sea, although scientists working on pelagic fish in other areas would also be considered.

The SG will be convened by M. Barange, leader of SPACC-Theme 2, on behalf of the SPACC Executive Committee.

Calendar

2000 - Call for membership of the Study Group
Selection of members
Preparation of agenda and background documents
2001 - First meeting
Submission of 1st annual report to IOC and SPACC
2002 - Second meeting
Submission of 2nd annual report to IOC and SPACC
Submission of final scientific report* (unless a third meeting is deemed necessary)

2.0 Study Group membership

Manuel Barange (Convenor) GLOBEC IPO Plymouth Marine Laboratory Prospect Place Plymouth PL1 3DH, UK m.barange@pml.ac.uk	Maria de Fatima Borges[18] Instituto de Investigacao das Pescas e do Mar Av. Brasilia - 1449-006 Lisboa, Portugal Mborges@umassd.edu	Angel Borja AZTI Herrera Kaia Portualdea s/n 20110 Pasaia, Spain aborja@pas.azti.es
Luis Cubillos Instituto de Investigación Pesquera, P.O. Box 350 Talcahuano, Chile. lcubillos@inpesca.cl	Georgi M. Daskalov[19] Institute of Fish Resources PO Box 72, 4, Primorski Bd. 9000, Varna, Bulgaria Gdaskalov@hotmail.com	Jose A. A. De Oliveira Marine & Coastal Management Private Bag X2 Rogge Bay 8012, South Africa jdolivei@mcm.wcape.gov.za
Larry Jacobson NMFService Northeast Fisheries Science Center 166 Water Street Woods Hole, MA 02543-1026 USA Ljacobso@whsun1.wh.whoi.edu	Fritz W. Köster Institut fur Meereskunde Dusternbrooker Weg 20 24105 Kiel Germany Fkoester@ifm.uni-kiel.de	Miguel Niquen Carranza IMARPE Esq. Gamarra y Gral. Valle s/n Chucuito, Callao Peru Mniquen@imarpe.gob.pe
Pierre Pepin Department of Fisheries and Oceans P.O. Box 5667 St John's NF A1C 5X1, Canada Pepin@athena.nwafc.nf.ca	Benjamin Planque IFREMER Laboratoire d'Ecologie Halieutique, BP21105 44311 Nantes, Cedex 03 France Benjamin.Planque@ifremer.fr	Claude Roy IRD research associate Oceanography Department University of Cape Town Rondebosch 7701 South Africa croy@pop.uct.ac.za
Akihiko Yatsu National Research Institute of Fisheries Science Fukuura 2-12-4 Kanazawa-ku Yokohama, Japan 236-6848 Yatsua@fra.affrc.go.jp	**Alternates:** Tokio Wada for A Yatsu Pierre Petitgas for B Planque Andres Uriarte for A Borja Miguel Santos for Fatima Borges	

Invited guests to the Cape Town meeting:

- Andy Bakun, IRI, 101 Monell Building, LDEO, 61 Route 9W Palisades, NY 10964-8000, USA. Andrewbakun@hotmail.com/ bakun@iri.ldeo.columbia.edu
- Philippe Cury, IRD research associate, Oceanography Department, University of Cape Town, Rondebosch 7701, South Africa. curypm@uctvms.uct.ac.za.
- Pierre Freon, IRD research associate, Marine & Coastal Management, Private Bag X2, Rogge Bay 8012, South Africa, pfreon@mcm.wcape.gov.za.
- Sue Painting, Marine & Coastal Management, Private Bag X2, Rogge Bay 8012, South Africa, painting@mcm.wcape.gov.za

[18] currently at: School for Marine Science and Technology SMAST, University of Massachusetts, 706 South Rodney French Boulevard, New Bedford, Massachusetts 02744-1221, USA, phone:(508) 910 6348, fax:(508) 999 8193, mborges@umassd.edu
[19] currently at: National Marine Information & Research Centre (NatMIRC), Ministry of Fisheries and Marine Resources, PO Box 912, Swakopmund, Namibia, gdaskalov@mfmr.gov.na.

3.0 Agenda of the meeting

Venue: Reseach Aquarium, Marine and Coastal Management, Beach Road, Sea Point, Cape Town, South Africa.

Day 1 - Monday 3 September 2001

09:00 – 10:30 Session 1. Setting the scene.
09:00-09:05 Welcome, approval of agenda (Barange)
09:05-09:25 Study Group objectives, TOR, terminological issues (Barange)
09:25-09:45 Population dynamic models incorporating an environmental variable: Can we make it simple? (Pierre Freon)
09:45-10:10 The IOC/SCOR WG 119 on Quantitative ecosystem indicators for Fisheries Management (Philippe Cury)
10:10-10:30 Local vs global indices, comparing models vs comparing indices (Daskalov)

10:30 - 11:00 Tea

11:00 - 13:00 Session 2. Background studies and species selection. 20' presentation plus 10' discussion on specific species/stocks. A form for each species/stock should be made available at the meeting to assist, as well as a 1-2 page abstract on the nature of the presentation. The objective of this topic is:
a) To assist in the selection of species to be considered by the Study Group
b) To prepare the ground for Sessions 4-6
d) To provide basic information for the report, and possibly to form the skeleton of a review publication.

The focus of the presentations should be on:

1 - Evidence that the species concerned (stock size or recruitment) fluctuate(s) in phase with environmental variability,
2 - Review of the processes through which environmental variability causes the species concerned (stock size or recruitment) to fluctuate in synchrony, and
3 - Can we use the above to set up forecasting tools?

- South African anchovy/ sardine - Roy/ de Oliveira
- Californian anchovy/ sardine - Jacobson
- Peruvian anchoveta - Niquen
- Chilean anchovy (others?)- Cubillos

13:00- 14:00 Lunch

14:00 - 16:30 Continuation Session 2

- Japanese sardine - Yatsu
- Bay of Biscay pelagics? - Planque/ Borja
- Portuguese sardine - Borges
- Baltic Sea pelagics - Koester
- Black Sea pelagics - Daskalov

Day 2 - Tuesday 4 September 2001

09:00 - 10:00 - Session 3. Our Study Group in context.
Lead: Pierre Pepin (assisted by Fritz Koester and Angel Borja)
Review of past/ ongoing initiatives of relevance to our discussions. In particular emphasis will be placed on approaches, achievements and future plans of the EU programme SAP, and the ICES Study Group on incorporating process information into stock recruitment models.

10:00 - 10:30 Tea

Sessions 4, 5 and 6 are Working sessions. Each has a lead, which is encouraged to prepare a personal view of the topic to introduce the debate. In so doing he/she may contact other members of the group for input. A brief outline of his/her views (even as a bullet list) is encouraged to assist in report writing and in preparation of Day 3 and future meetings of the group.

10:30 - 12:30 - Session 4. Potential use of environmental indices to update parameters and determine biological reference points.
Lead : Fatima Borges (As this may be a long topic I suggest that Fatima is assisted by assisted by Cubillos, Daskalov and Niquen)

12:30 - 13:30 Lunch

13:30 - 15:00 Session 5. Potential use of environmental indices to reduce management risks or/and increase yield.
Lead: Jose de Oliveira

15:00 - 15:30 Tea

15:30 - 17:00 Session 6. Technical requirements for environmental indices to be incorporated into management procedures.
Lead: Larry Jacobson

<u>Day 3 - Wednesday 5 September 2001</u>

09:00 - 10:30 Breakdown into three groups to deal with technical issues.

- Subgroup 1 - Review of case studies where EI are used in management procedures
- Subgroup 2 – Framework to establish linkages between environmental forcing and pelagic fish responses
- Subgroup 3 – Requirements to incorporate EI in pelagic stock assessment

10:30-11:00 Tea

11:00 - 12:30 Presentation of the group recommendation in plenary. Followed by debate.

12:30 - 13:30 Lunch

13:30 - 15:00 Drafting teams: Outline report, selection of species/ case studies, recommendations

15:00-15:30 Tea

15:30 - 16:30 Way forward. Assignation of tasks, including finalising report, preparation of paper(s), commissioning of specific analyses, preparation of 2002 meeting.

4.0 Terminology

Biomass – The weight of a fish stock.
Catchability (q)– Fraction of a fish stock which is caught by a defined unit of fishing effort.
Catch per unit effort (CPUE) – the catch of fish caught by a defined unit of effort.
Environmental factors – Biotic and abiotic factors, other than fisheries, that impact upon the fish population.
Exploitation rate – The ratio of fish caught to total mortality (F/Z)
Fishing effort (f) – Total fishing gear in use for a specific period of time.
Fishing intensity – Fishing effort per unit area.
Fishing mortality rate (M) – Fraction of the initial stock caught by the fishery.
F_{max} – Value of fishing mortality that maximises yield per recruit.
$F_{0.1}$ - Value of fishing mortality at which the incremental gain in yield for an increase in fishing mortality is 10% of the yield per recruit produced at very low levels of F.
F_{MSY} – The value of fishing mortality that produces MSY.
Indicator. A variable, pointer, or index related to a criterion. Its fluctuations reveal the variations in those key elements of sustainability in the ecosystem, the fishery resource or the sector and social and economic well-being. The position and trend of an indicator in relation to reference points or values indicate the present state and dynamics of the system.
Maximum sustainable yield (MSY) – The largest average catch that can continuously be taken from a stock under existing environmental conditions without significantly affecting the reproduction process.
Natural mortality – Deaths from all causes except fishing.
Parameter – a constant or numerical description of some property of a population.
Recruitment – For the purpose of this study group recruitment is the number of fish estimated at the youngest age-class for which an index of abundance is available.
Reference point - A value derived from technical analysis, which represents a state of the fishery or population, and which is believed to be useful for the management of the population. A reference point indicates a particular state of a fisheries indicator corresponding to a situation considered as desirable ("target reference point"), or undesirable and requiring immediate action ("limit reference point" and "threshold reference point").
Reference variable – a variable for which a reference point has been established.
Spawning Stock Biomass – For the purpose of this study group SSB is the biomass of adult fish, both males and females.
Statistic- the estimate of a parameter which is obtained by observation, and which is subject to a sampling error.
Surplus production – Production of new weight by a fishable stock, plus recruits, less what is removed by natural mortality.
Surplus production models – Models that assume that the net growth rate of a stock is related to its biomass (maximised at a certain biomass value).
Total mortality rate – total number of fish that dies during a year, divided by the initial number.
Yield per recruit models – Models that aim at maximising the average yield from each recruit entering the fishery. Used when age/seize at recruitment is known.

5.0 Working references

Bakun, A . 1998. Ocean Triads and Radical Interdecadal Stock Variability: Bane and Boon for Fishery Management Science. pp. 331-358. In: T.J. Pitcher, P.J.B. Hart and D. Pauly (eds.) Reinventing Fisheries Management. Chapman and Hall, London.

Basson, M. 1999. The importance of environmental factors in the design of management procedures. ICES J. mar. Sci., 56: 933-942.

Beverton, R.J.H. 1990. Small pelagic fish and the threat of fishing; are they endangered? J. Fish. Biol. 37: 5-16.

Borja, A., A. Uriarte, J. Egaña, L. Motos and V. Valencia. 1998. Relationships between anchovy (engraulis encrasicolus) recruitment and environmentin the Bay of Biscay (1967-1996). Fisher. Oceanogr. 7: 375-380.

Butterworth, D.S, M.O. Bergh and R. Spark. 1986. Prospects for incorporating environmental and species interaction effects in Benguela pelagic resource projections. Unpublished manuscript.

Csirke, J. 1988. Small shoaling pelagic fish stocks. Fish Population Dynamics (Second Edition) 271-302.

Daskalov, G. 1999. Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. Fisheries Research 41:1-23.

Frank, F.T., R.I. Perry and K.F. Drinkwater. 1990. Predicted Response of Northwest Atlantic Invertebrate and Fish Stocks to CO_2 –Induced Climate Change. Transactions of the American Fisheries Society 119:353-365.

Fréon, P., Mullon, C. et Pichon, G. 1993. CLIMPROD: Experimental Interactive Software for Choosing and fitting Surplus Production Models Including Environmental Variables. FAO Computerized Information Series fisheries, 5 : 76 p.

Gislason, H., M. Sinclair, K. Sainsbury and R. O'Boyle. 2000. Symposium overview: incorporating ecosystem objectives within fisheries management. ICES J. mar. Sci., 57:468-175.

Goodyear, C.P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. *In* S.J. Smith, J.J. Hunt and D. Rivard (ed.) Risk evaluation and biological reference points for fisheries management. Can. Spec.Publ. Fish. Aquat. Sci. 120:67-81.

Healey, M.C. 1990. Implications of Climate Change for Fisheries Management Policy. Transactions of the American Fisheries Society 119:366-373.

Hofmann E.E. and T M. Powell, 1998. Environmental variability effects on marine fisheries: four case histories. Ecological applications, 8, 1 supplement, S23-S32.

Iles, T.C., and R.J.H. Beverton. 1998. Stock, recruitment and moderating processes in flatfish. Journal of Sea Research 39:41-55.

Jacobson, L.D. and A.D. MacCall. 1995. Stock-recruitment models for Pacific sardine (Sardinops sagax). Can. J. Fish. Aquat. Sci. 52: 566-577.

Jacobson, L.D., J.A.A. De Oliveira, M. Barange, M.A. Cisneros-Mata, R. Felix-Uraga, J.R. Hunter, J.Yeong Kim, Y. Matsuura, M. Niquen, C. Porteiro, B. Rothschild, R.P. Sanchez, R. Serra, A. Uriarte and T. Wada. 2001. Surplus production, variability, and climate change in the great sardine and anchovy fisheries. Can. J. Fish. Aquat. Sci., 58: in press.

Kylashtorin, L.B., 1998. Long-term climate change and main commercial fish production in the Atlantic and Pacific. Fisheries Research 37:115-125.

Mace, P.M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Can. J. Fish. Aquat. Sci., 51: 110-122.

Myers, R. A. 1998. When do environment-recruitment correlations work? Reviews in Fish Biology and Fisheries 8: 285-305.

Myers, R.A. and N.J. Barrowman. 1994. Is fish recruitment related to spawner abundance? ICES C.M./G:37, Ref. H.

Nakata, H., S. Funakoshi, M. Nakamura. 2000. Alternating dominance of postlarval sardine and anchovy caught by coastal fishery in relation to the Kuroshio meander in the Enshu-nada Sea. Fish, Oceanogr., 9: 248-258.

Noto, M. and I. Yasuda. 1999. Population decline of the Japanese sardine, Sardinops melanostictus, in relation to sea surface temperature in the Kuroshio Extension. Can. J. Fish. Aquat. Sci., 56: 973-983.

O'Brien, C.M., C.J. Fox, B. Planque and J. Casey. 2000. Climate variability and North Sea Cod. Nature, 404:142.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Exlor. Mer, 39(2):175-192.

Perry, R.I. 1999. Ecosystem processes, fish catches, and fisheries management – a Canadian perspective. Bull. Tohoku Natl. Fish. Res. Inst. No. 62:181-193.

Ranta, E., P. Lundberg, B. Kaitala and J. Laakso. 2000. Visibility of the environmental noise modulating population dynamics. Proc. R. Soc. Lond. B 267:1851-1856.

Rothschild, B.J. 1995. Fishstock fluctuations as indicators of multidecadal fluctuations in the biological productivity of the ocean. *In* R. J. Beamish Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci,. 121:201-209.

Schwartzlose, R.A., J. Alheit, A. Bakun, T.R. Baumgartner, R. Cloete, R.J.M . Crawford, W.J. Fletcher, Y. Green-Ruiz, E. Hagen, T. Kawasaki, D. Lluch-Belda, S. E. Lluch-Cota, A. D. MacCall, Y. Matsuura, M.O. Nevarez-Martinez, R.H. Parrish, C. Roy, R. Serra, K.V. Shust, M.N. Ward and J.Z. Zuzunaga. 1999. Worldwide Large-Scale Fluctuations of Sardine and Anchovy Populations. S. Afr. J. mar. Sci. 21:289-347.

Scott, B., G. Marteinsdottir and Peter Wright. 1999. Potential effects of maternal factors on spawning stock-recruitment relationships under varying fishing pressure. Can. J. Fish. Aquat. Sci., 56:1882-1890.

Shannon. L.J., G. Nelson, R.J.M. Crawford and A.J. Boyd. 1996. Possible impacts of environmental change on pelagic fish recruitment: modelling anchovy transport by advective processes in the southern Benguela. Global Change Biology 2:407-420.

Shepherd, J.G., J.G. Pope and R.D. Cousens. 1984. Variations in fish stocks and hypotheses concerning their links with climate. Rapp. P.-v. Reun. Cons. Int. Explor. Mer, 185:255-267.

Trippel, E.A. 1999. Estimation of Stock Reproductive Potential: History and Challenges for Canadian Atlantic Gadoid Stock Assessments. J. Northw. Atl. Fish. Sci., 25:61-81.

Ulltang, O. 1996. Stock assessment and biological knowledge: can prediction uncertainty be reduced? ICES J. mar. Sci., 53:659-675.

Ulltang, O. 1998. Where is Fisheries Science Heading – How can Fish Stock Assessments be Improved? J. Northw. Atl. Fish. Sci., 23:133-141.

Ulltang, O. 1998. Explanations and predictions in fisheries science – problems and challenges in a historical and epistemological perspective. Fisheries Research 37:297-310.

Wada, T., and L.D. Jacobson. 1998. Regimes and stock-recruitment relationships in Japanese sardine (Sardinops melanostictus). Can. J. Fish. Aquat. Sci., 55:2455-2463.

Walters, C.J. and J.S. Collie. 1988. Is research on environmental factors useful to fisheries management? Can. J. Fish. Aquat. Sci., 45:1848-1854.

Walters, C. J. 1989. Value of short-term forecasts of recruitment variation for harvest management. Can. J. Fish. Aquat. Sci. 46: 1969-1976.

Walters, C. J. and J. S. Collie 1988. Is research on environmental factors useful to fisheries management? Can. J.Fish. Aquat. Sci. 45: 1848-1854.

Wantanabe, Y., H. Zenitani and R. Kimura. 1995. Population decline of the Japanese sardine Sardinops melanostictus owing to recruitment failures. Can J. Fish. Aquat. Sci., 52: 1609-1616.

6.0 Species selection

To address this topic the participants were requested to complete forms describing the assessment procedures and the stock characteristics of the species on which they are experts.

6. 1- South African anchovy and sardine (submitted by Jose de Oliveira and Claude Roy)

Sardine and anchovy are the two most important small pelagic species commercially exploited in the Southerm Benguela. Catches of sardine have been recorded from 1950 onwards. During the 1950s, sardine catches were relatively stable at around 130 000 t, and then increased rapidly to a maximum of around 400 000 t over the period 1961-1963. Catches then declined rapidly until 1967 and remained at a low level until the mid 1990s. From 1994 onwards, sardine catches have been steadily increasing. The drastic decline in sardine catches in the early 1960s led the industry to target anchovy. Anchovy catches increased steadily from 1964 onwards, reaching a peak of approximately 600 000 t in 1987 and 1988. Since then, anchovy catches decreased, with some variability, to a minimum of 40 000 t in 1996, and then increased sharply.

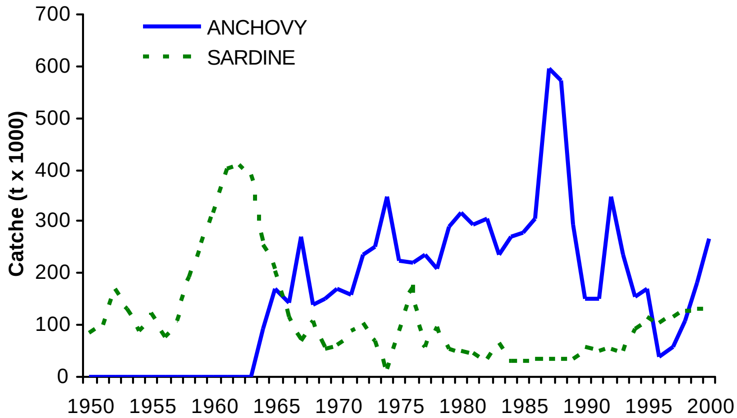
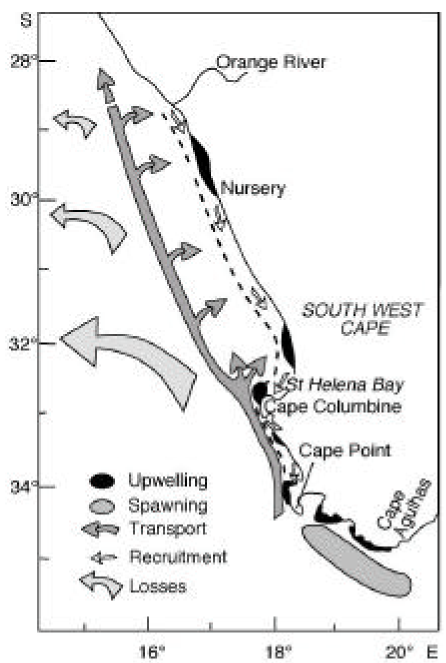


Figure 6.1.1: Time-series of annual catch of sardine and anchovy in the southern Benguela.

A unique reproductive strategy (Fig. 6.1.2)



In most upwelling areas, the location of small pelagic fish spawning and nursery grounds overlaps: eggs and juveniles develop in the same area. Two eastern boundary regions have spatially distinct spawning and nursery grounds: the Southern Benguela and the Bay of Biscay. In the Southern Benguela anchovy spawn between September and December on the Agulhas Bank with a peak season during mid-November. Eggs and larvae are then transported by a coastal jet current to the West Coast nursery, where they grow as juveniles. Sardine spawning seems to be more protracted. During the last decade, most spawning occurred over the Western part of the Agulhas Bank, with also spawning off the West Coast, nearby St Helena Bay, being recorded. Recently, there is indication of an eastward shift in anchovy spawning habitat over the Agulhas Bank (van der Lingen et al., 2001)

Figure 6.1.2: A conceptual model of the anchovy reproductive strategy in the southern Benguela. Eggs and larvae are transported by a strong jet current from the spawning ground located on the Agulhas Bank to the West Coast nursery ground(Hutchings, 1992).

Biomass (Fig. 6.1.3)

VPA estimates of biomass of sardine and anchovy are available for the historical period. From 1984-2000, annual hydro-acoustic surveys estimates of spawner biomass are available. Sardine biomass peaked in 1959, after which it decreased sharply until 1967. From 1985 onwards, stock size increased continuously. Anchovy may have increased slightly after 1973, although VPA estimates of biomass may reflect catches.

After 1985, the anchovy stock showed large fluctuations, which increased in magnitude towards the end of the time-series

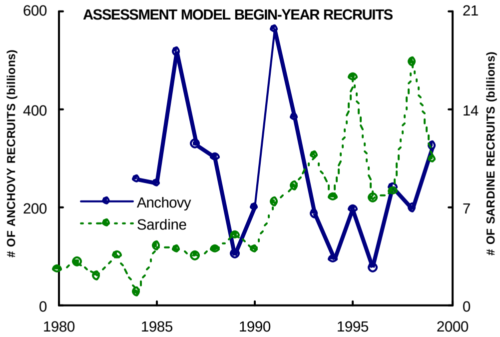


Fig. 6.1.3: Time-series of anchovy and sardine spawner biomass derived from hydroacoustic surveys in November.

Recruitment variability (Fig. 6.1.4)

Estimates of recruitment strength derived from Virtual Population Analysis (VPA) are available for 1950-1980 for sardine and from 1964-1980 for anchovy. For the period 1985-2000, the number of recruits at the start of each year is estimated using a population assessment model that incorporates information from hydroacoustic surveys and commercial landings. Direct estimates of anchovy and sardine recruits, from hydroacoustic surveys, are also available for the period 1985-present. Anchovy recruitment in 2000 and 2001 is about 4 times higher than the previous historical record. Sardine recruitment has been increasing since the last 15 years with large interannual variations. Anchovy recruitment shows a downward trend up to 1999, characterised also by a large interannual variability.

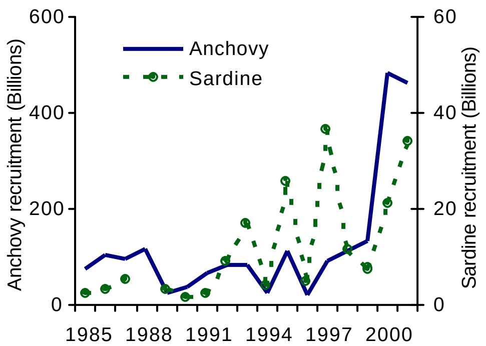


Figure 6.1.4: Times series of sardine and anchovy recruitment estimated from hydroacoustic surveys.

Factors affecting anchovy recruitment in the Benguela

Hutchings et al. (1998) did a comprehensive review of the factors affecting South African anchovy recruitment. They concluded that "... events within all of the spawning, transport and nursery areas appear to have contributed to the recruitment strength to both the fishery and the spawning population over the past 13 years. In any one year, several plausible but different factors appear to operate, making it difficult to generalize and to design a simple monitoring programme that will supply the information necessary to predict recruitment strength with sufficient certainty."

However, for the anchovy in the Benguela two environmental factors appear to have direct effects on eggs abundance or larvae survival: 1)-upwelling intensity, estimated by wind direction, intensity or frequency and possibly related to transport success (Boyd et al.,1998) and 2)-temperature on the spawning ground, measured during cruises or using satellite sensors and related to spawner biomass, food availability, spawning intensity (Richardson et al., 1998). Modelling experiments have also been used to explore the impact of transport processes on larval survival (Shannon et al., 1996; Shannon 1998).

***References**:*

Boyd A.J., L.J. Shannon, F. H. Schulein and J.T. Taunton-Clark, Food, transport and anchovy recruitment in the Southern Benguela upwelling system of South Africa. In : Durand M.H., P. Cury, R. Mendelssohn, C. Roy, A. Bakun and D. Pauly (eds). Global versus local changes in upwelling systems. Editions ORSTOM Paris. p195-209.

Hutchings L., Barange M., Bloomer S.F., Boyd A.J., Crawford R.J.M., Hugget J.A., Kerstan M., Korrubel J.L., De Oliviera J.a., Painting S.J., Richardson A.J., Shannon L.J., Schulein F.H., Van de Lingen C.D. and H.M. Verheye. 1998. Multiple factors affecting South African anchovy recruitment in the spawning, transport and nursery areas. *In:* Benguela Dynamics: Impacts of variability on shelf-sea environments and their living resources. Pillar, S. C., Moloney, C., Payne, A. I. L. and F. A. Shillington (Eds). *S. Afr. J. mar. Sci* 19: 211-225.

Richardson A.J., Mitchell-Innes B.A., Fowler J.L., Bloomer S.F., Verheye H.M., Field J.G., Hutchings L. and S.J. Painting. 1998. The effect of sea temperature and food availability on the spawning success o cape anchovy *Engraulis capensis* in the southern Benguela. In Benguela Dynamics. Pillar S.C., Moloney C.L., Payne A.I.L., and F.A. Shillington (Eds). *S. Afr. J. mar. Sci*. 19: 275-290.

Shannon L. 1998. Modelling environmental effects on the early life history of the south african anchovy and sardine: a comparative approach. In Benguela Dynamics. Pillar S.C., Moloney C.L., Payne A.I.L., and F.A. Shillington (Eds). *S. Afr. J. mar. Sci*. 19: 291-304.

Shannon L., G. Nelson, R.J.M. Crawford and A.J. Boyd. 1996. Possible impacts of environmental change on pelagic fish recruitment : modelling anchovy transport by advective processes in the southern Benguela. *Global Change Biology*, 2, 407-420.

van der Lingen C.D., L. Hutchings, D. Merkle, J.J. van der Westhuizen and J. Nelson. Comparative spawning habitats of anchovy (engraulis capensis) and sardine (Sardinops sagax) in the Southern Benguela upwelling ecosystem. In press. In: G. H. Kruse, N. Bez, T. Booth, M. Dorn, S. Hills, R. Lipcius, D. Pelletier, C. Roy, S. Smith, and D. Witherell (eds). Spatial Processes and Management of Marine Populations, University of Alaska Sea Grant, Fairbanks.

Stock: South African sardine (Sardinops Sagax)
Author: José De Oliveira
Date: August 20, 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	Based on allozyme and mtDNA work, there is no difference between South African and Namibian sardine. There is some evidence of a physical barrier between these stocks in the form of a strong upwelling cell off Lüderitz, Namibia. Tagging work in the 1950's and 60's showed very little mixing between these stocks. For management purposes, the South African stock stretches from the Orange River on the west coast to Port Elizabeth (Kwazulu-Natal in winter) in the East.
1.2	Stock structure	
1.2	Spatial structure	The assessments contain no spatial structure presently (apart from the sample allocation algorithm that preserves spatial information). There are spatial differences in the size structure of the population that may be useful to consider in future (particularly for the bycatch of juvenile fish).
1.3	Single/multi-species	Single species, in the assessment, but managed as a multi-species fishery (with anchovy and round herring) in the management procedures.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Landed catches are considered in the assessment. Although dumping does occur in both the directed fishery for sardine (adults, when the netted catch is larger than the amount requested by factories) and the directed fishery for anchovy (where juvenile sardine are taken as a bycatch and dumped if too many are mixed in with the anchovy), the level of dumping is difficult to quantify and is not considered in the assessment. Sampling of catches for species composition, length frequencies, otoliths, etc. are fully documented.
2.2	Indices of abundance	Hydroacoustic survey estimates of: a) the spawning stock (relative, where bias is assumed to be known) b) the recruitment (relative, where bias is estimated). The surveys are based on pre-stratified, randomly spaced parallel transects that are designed to obtain unbiased estimates of stock size and sampling variance. It should be noted that hydroacoustic surveys were originally designed to survey the then more abundant anchovy, and therefore that the survey design is not ideally suited for sardine. Potential indices are being developed from the pre-recruit survey and the SARP line (egg and larvae abundance – the SARP line is sampled all year round).
	Catch per unit effort	CPUE indices are not used for sardine, although work is currently underway to obtain a standardized CPUE series.
	Gear surveys (e.g. trawl, longline)	N/A
	Acoustic surveys	Acoustic surveys cover the entire distribution of both spawners and recruits, although only a pre-specified range is used in the calculation of the abundance indices.
	Egg surveys	Pre-recruit surveys are held each year that assess egg and larvae (pre-recruit stages). Currently, information is being collected for possible application of the Daily Egg Production Method for sardine. Eggs and larvae are sampled on the "SARP" line throughout the year to provide an index of egg/larval abundance, currently not used for management.
	Larvae surveys	
	Juvenile surveys	Recruit surveys mentioned above.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Samples from the commercial catches are collected from a number of field stations based near the main ports where fish are landed. These samples are used for catch-, weight- and size-at-age information. Reproductive and other biological information is collected during routine hydroacoustic surveys. A sample allocation algorithm is used to raise length frequency information from samples to the entire catch. Ageing error has been evaluated, but is not currently considered in the assessments.
2.4	Tagging information	Tagging no longer done.
2.5	Environmental data	Relative to anchovy, the understanding of the recruitment processes for sardine is poor. The use of environmental data for forecasting sardine recruitment is lacking, mainly because data collection for forecasting is not really geared toward sardine, and there is a lack of researchers.
2.6	Fishery information	Fishers and rights-holders are involved in the development of harvest control rules (management procedures) and other management issues through communication fora set up for this purpose.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	An age-structured model is used, the main assumptions being year-invariant natural mortality (confounded with estimates of recruitment strength), the spawning stock index of abundance is positively biased by 50%, and there is no error in the catch and age information. VPA models were used in the past, but some of the assumptions (e.g. about

		terminal F's) were found to be too restrictive. A length-based model is being developed, which would allow use of information stretching further back than hydroacoustic surveys (the age-structured model spans only over the period for which hydroacoustic survey estimates are available).
3.2	spatially explicit or not	No, but possibly necessary to take into account spatial differences in size structure of the population – see 1.2.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Bayesian integration is not used. Natural mortality is split up into a juvenile and adult component, but is assumed not to vary from year to year. The choice of natural mortality values is made on the basis of model fits to the data.
	Recruitment	Recruitment values for every year of the assessment are treated as estimable parameters of the assessment.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	Maximum likelihood estimation is used for the assessment, explicitly incorporating observation error, and assuming lognormal distributions for the input data. Sampling variance in the form of CVs associated with survey estimates is incorporated, but additional variance is estimated. Both process and observation error are considered in management procedure simulations.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile – bootstrapping - bayes posteriors	Bootstrap estimation is used to calculate uncertainty in model parameters. Results are presented as confidence bounds but the actual distributions are used in management procedure simulations.
3.6	Retrospective evaluation	Harvest control rules are evaluated in terms of future realisations of a number of assessments (robustness trials), so the focus is not on evaluating the "correctness" of any particular assessments, but rather finding harvest control rules (in the form of management procedures) that are robust to a range of plausible assessments.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

Step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	An age-structure, multi-species (in terms of operational interaction of different components of the pelagic fishing fleet) operating model is used for projecting a range of assessments into the future for management procedure evaluations. The operating model is not really used in the sense of a prediction, but rather provides the framework for testing alternative management procedures.
4.2	Spatially explicit or not	Not
4.3	Key model parameters	The assessments provide a joint probability distribution for the parameters, preserving serial and other correlation between both parameters and projected data series.
4.4	Recruitment	Recruitment is drawn from a stock-recruit relationship fitted to the results of the particular assessment being used, and incorporates recruitment variability and serial correlation. Depensation is not considered.
4.5	Evaluation of uncertainty	Uncertainty in model parameters is incorporated in the form of a joint probability distribution of the parameters as estimated in the particular assessment being used. Management procedure results are presented in the form of summary statistics, which allow comparison of the performance of alternative management procedures. Uncertainty in model parameters is implicitly incorporated in the performance of summary statistics. Structural uncertainty is incorporated as robustness trials for selected management procedures.
45.6	Evaluation of predictions	See 3.6 and 5.1
4.7	Biological reference points	The summary statistic "risk" is based on the biological reference point of 0.2K (K=average pre-exploitation spawner biomass). Management procedures are implemented for a fixed period (3-5 years) and the definition of risk is re-evaluated when a new management procedure is developed.

Stock: South African anchovy (Engraulis capensis)
Author: José De Oliveira
Date: August 20, 2001

1. General

Step	*Item*	*Considerations*
1.1	Stock definition	Based on allozyme and mtDNA work, there is no difference between South African and Namibian anchovy. However, the occurrence of anchovy off Namibia has all but ceased. For management purposes, the South African anchovy stock stretches from the Orange River on the west coast to Port Elizabeth in the East.
1.2	Stock structure	
1.2	Spatial structure	The assessments contain no spatial structure presently (apart from the sample allocation algorithm that preserves spatial information).
1.3	Single/multi-species	Single species, in the assessment, but managed as a multi-species fishery (with sardine and round herring) in the management procedures.

2. Data

Step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Landed catches are considered in the assessment. Dumping of anchovy may occur where juvenile sardine are mixed in with the catches and this mixture is considered to contain too much juvenile sardine. The level of dumping is difficult to quantify, however, and is not considered in the assessment. Sampling of catches for species composition, length frequencies, otoliths, etc. are fully documented.
2.2	Indices of abundance	Hydroacoustic survey estimates of: a) the spawning stock (relative, where bias is estimated) b) the recruitment (relative, where bias is estimated). The surveys are based on pre-stratified, randomly spaced parallel transects that are designed to obtain unbiased estimates of stock size and sampling variance. Daily Egg Production Method (DEPM) estimates of spawning stock (absolute index of abundance) are available up to 1991. Potential indices are being developed from the pre-recruit survey and the SARP line (egg and larvae abundance – the SARP line is sampled all year round).
	Catch per unit effort	CPUE indices are not used for anchovy, although work is currently underway to obtain a standardised CPUE series.
	Gear surveys (e.g. trawl, longline)	N/A
	Acoustic surveys	Acoustic surveys cover the entire distribution of both spawners and recruits, although only a pre-specified range is used in the calculation of the abundance indices.
	Egg surveys	Pre-recruit surveys are held each year that assess eggs and larvae (pre-recruit stages). Eggs and larvae are sampled on the "SARP" line throughout the year to provide an index of abundance, currently not used for management.
	Larvae surveys	
	Juvenile surveys	Recruit surveys mentioned above.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Samples from the commercial catches are collected from a number of field stations based near the main ports where fish are landed. Age-determination has been problematic for anchovy, to the extent that age information is not used directly in the assessment and management procedure simulations for anchovy. Reproductive and other biological information is collected during routine hydroacoustic surveys. A sample allocation algorithm is used to raise length frequency information from samples to the entire catch.
2.4	Tagging information	No tagging.
2.5	Environmental data	The following data series (available from 1984) are used in an Expert System (to forecast below average recruitment, but currently not used for management): wind data, sea surface temperature, gonad atresia, starvation index, egg abundance – all collected at the time of the November survey (from the November survey and other sources). Oil yields are also used, and are collected from the factories for Oct-Dec. Weekly time series of Sea Surface Temperature (SST), extracted from the OISST database, are used as surrogates for characterising the upwelling intensity at two locations: the Cape Peninsula and the West Coast regions. These two indices are incorporated in a statistical bi-variate model to explore the effect of upwelling on anchovy recruitment (1984 to present).
2.6	Fishery information	Fishers and rights-holders are involved in the development of harvest control rules (management procedures) and other management issues through communication fora set up for this purpose.

3. Assessment model

Step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	An age-structured model is used, the main assumptions being year-invariant natural mortality (confounded with estimates of recruitment strength), the DEPM index of abundance is absolute, and there is no error in the catch information. Catch-at-age

		information is not based on age data, but rather on simple assumptions about age-composition of the catches
3.2	spatially explicit or not	Not
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Bayesian integration is not used. Natural mortality is split up into a juvenile and adult component, but is assumed not to vary from year to year. The choice of natural mortality values is made on the basis of model fits to the data.
	recruitment	Recruitment values for every year of the assessment are treated as estimable parameters of the assessment.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	Maximum likelihood estimation is used for the assessment, explicitly incorporating observation error, and assuming lognormal distributions for the input data. Sampling variance in the form of CVs associated with survey estimates is incorporated, but additional variance is estimated. Both process and observation error are considered in management procedure simulations.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	Bootstrap estimation is used to calculate uncertainty in model parameters. Results are presented as confidence bounds but the actual distributions are used in management procedure simulations.
3.6	Retrospective evaluation	Harvest control rules are evaluated in terms of future realisations of a number of assessments (robustness trials), so the focus is not on evaluating the “correctness” of any particular assessments, but rather finding harvest control rules (in the form of management procedures) that are robust to a range of plausible assessments.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

Step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	An age-structure, multi-species (in terms of operational interaction of different components of the pelagic fishing fleet) operating model is used for projecting a range of assessments into the future for management procedure evaluations. The operating model is not really used in the sense of a prediction, but rather provides the framework for testing alternative management procedures.
4.2	Spatially explicit or not	Not
4.3	Key model parameters	The assessments provide a joint probability distribution for the parameters, preserving serial and other correlation between both parameters and projected data series.
4.4	Recruitment	Recruitment is drawn from a stock-recruit relationship fitted to the results of the particular assessment being used, and incorporates recruitment variability and serial correlation. Depensation is not considered. Environmental influences on recruitment have been incorporated in the work presented at this workshop.
4.5	Evaluation of uncertainty	Uncertainty in model parameters is incorporated in the form of a joint probability distribution of the parameters as estimated in the particular assessment being used. Management procedure results are presented in the form of summary statistics, which allow comparison of the performance of alternative management procedures. Uncertainty in model parameters is implicitly incorporated in the performance of summary statistics. Structural uncertainty is incorporated as robustness trials for selected management procedures.
4.6	Evaluation of predictions	See 3.6 and 5.1
4.7	Biological reference points	The summary statistic “risk” is based on the biological reference point of 0.2K (K=average pre-exploitation spawner biomass). Management procedures are implemented for a fixed period (3-5 years) and the definition of risk is re-evaluated when a new management procedure is developed.

6.2- Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) (submitted by Larry Jacobson)

Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*) and the fisheries they support are well studied with catch data for the main fisheries in California available since 1916. Biomass estimates are available for sardine during 1932-2000 and for anchovy during 1953-1994. A wealth of biological information is available for both stocks.

A portion of the range of both stocks off southern California is surveyed quarterly by the CalCOFI ichthyoplankton survey program. The CalCOFI survey covered a broader area prior to the early 1980's and the sampling area is sometimes increased to support special studies. Collaborative surveys and research involving Mexico and Canada have been carried out during recent years to good effect. Currently, there are no hydroacoustic surveys or commercial catch rate data.

Both Pacific sardine and northern anchovy occupy coastal waters between northern Mexico and southern Canada, but sardine occur farther offshore and over a broader range of latitude. The center of distribution for both stocks seems to in the area between northern Mexico and central California. Large sardine migrate to northern feeding grounds when biomass is high and environmental conditions are favorable. Movements of anchovy appear more restricted. Spawning is opportunistic and occurs year round in both stocks but appears concentrated off northern Mexico and the southern United States. The range of sardine increases dramatically when biomass is high and the stock is productive.

Pacific sardine are usually assumed to have a relatively low natural mortality rate of $M=0.4\ y^{-1}$ and a lifespan of about 10 y. Northern anchovy are generally assumed to have a relatively high natural mortality rate ($M=0.8\ y^{-1}$) and lifespan of about 4 y.

Life history characteristics for both sardine and anchovy are difficult to estimate precisely because the stocks are not homogeneously distributed and incompletely sampled. However, sardine may have larger maximum sizes, higher growth rates and higher fecundity when environmental conditions are favorable, stock biomass levels are high, and the stock covers a wide geographic range. Possible changes in life history characteristics for sardine may be due to migratory behavior that allows large adults to forage in northern feeding grounds.

Sardine experienced a prolonged period (30 y) of relatively high exploitation rates (30-70% per year) prior to the mid-1960's when the stock collapsed. Current exploitation rates for Pacific sardine are likely about 10% per year. Northern anchovy experienced a short period (3 y) of moderate exploitation rates (20-30% per year) and current exploitation rates are low. Exploitation rates and catches are low because sardine and anchovy fisheries in U.S. waters are of minor economic importance.

U.S .policy under the Sustainable Fisheries Act (which uses MSY reference points as limits and thresholds), lack of economic importance, the wealth of available information, interest in using pelagic fishes as forage, and memory of the dramatic collapse in the Pacific sardine fishery have all contributed to progressive management approaches in the U.S. In particular, Pacific sardine are managed based on a harvest control rule that uses sea surface temperature dependent estimates of F_{MSY} as threshold (limit) reference point. The documentation that supports this management decision includes some sensitivity analyses to evaluate the relative advantages and disadvantages of using environmental information in fishery management.

Biomass seems to affect recruitment rates in sardine and surplus production rates in northern anchovy. Short-term environmental variability is important in surplus production and recruitment of both stocks. However, recruitment and surplus production rates in sardine show dramatic "regime" shifts linked to decadal scale variability in sea surface temperature temperatures. Productive regimes occur during prolonged warm periods when, it is hypothesized, large sections of the coast (e.g. areas beyond northern Mexico) become suitable as spawning and feeding habitat. As with many other stocks, recruitment and surplus production rates vary almost randomly in northern anchovy but are autocorrelated in sardine. Most of the surplus production in both stocks likely occurs before the first birthday.

Pacific sardine biomass has been more variable over long term time periods than northern anchovy biomass and most of the variability in Pacific sardine has been associated with regimes. On a year-to-year basis, surplus production and recruitment rates are autocorrelated for sardine, but not autocorrelated and more variable for anchovy. Years with negative surplus production rates are less common in Pacific sardine (50% of all years) than in northern anchovy (33% of all years). The longest runs of positive and negative runs of annual surplus production rates were 10 vs. 3 years for Pacific sardine and 4 versus 3 years for northern anchovy.

The mechanism responsible for regime shifts in sardine is linked to decadal scale environmental variability in sea surface temperature. A very simple hypothesis is that a very large and productive area of potential habitat along the coast of northern Mexico, the United States and southern Canada become suitable for sardine when average sea surface temperatures remain warm over an extended period. Pacific sardine may simply bloom into the “empty” northern habitat areas following an extended warming period. During 1983-1995 following the onset of warming in the late 1970’s, for example, Pacific sardine biomass increased at an average rate of 33% per year in the presence of small fishery. Although sardine and anchovy are found in the same general area, the response of the two stocks to environmental change has been entirely different.

Stock: Northern anchovy (*Engraulis mordax)*
Author: Larry Jacobson
Date: 20 August 2001

1. General

Step	*Item*	*Considerations*
1.1	Stock definition	West coast of North American from northern Mexico to Central California. Other small stocks to north.
1.2	Stock structure	Historical tagging studies demonstrate some movement along the coast
1.2	Spatial structure	The stock is not randomly distributed with respect to size and distribution depends on environmental conditions and season. In general, larger individuals are furthest north and further offshore.
1.3	Single/multi-species	Single species assessment techniques are used

2. Data

Step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Catch data available for main fisheries in California since 1916. Discards likely small.
2.2	Indices of abundance	Daily egg production estimates of spawning biomass are available. Abundance data start in 1956. Biomass estimates start in 1932.
	Catch per unit effort	Not applicable.
	Gear surveys (e.g. trawl, long line)	Selectivity for ichthyoplankton and spawning biomass surveys based on maturity at age, fecundity at age, etc.
	Acoustic surveys	None recently.
	Egg surveys	CalCOFI estimates of egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity, etc. are available Surveys do not currently cover the entire range of the stock.
	Larvae surveys	CalCOFI estimates of abundance, production, mortality, spawning stock sex and maturity structure, fecundity, etc. are available Surveys do not currently cover the entire range of the stock.
	Juvenile surveys	Not applicable
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Many life history aspects are hard to measure precisely because of lack of sampling and non-homogeneous spatial distribution. Special "simple" modeling techniques used to accommodate these problems.
2.4	Tagging information	Historical tagging to demonstrate movement.
2.5	Environmental data	The harvest control rule used Fmsy as a threshold reference point. Fmsy is based on recent average sea surface temperatures. A wealth of oceanographic (biological and physical) information is available.
2.6	Fishery information	California Department of Fish and Game personnel are familiar with the fishery.

3. Assessment model

Step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	A biomass dynamic model is currently used.
3.2	spatially explicit or not	No
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability recruitment	Natural mortality assumed constant.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	Process errors (mainly in recruitment) and survey measurement errors are accommodated in modeling. Log normal distributions generally assumed for measurement errors.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	Bootstrapping and asymptotic variances
3.6	Retrospective evaluation	Retrospective patterns are evaluated periodically

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

Step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-	Predictions not currently carried out.

	structured prediction model	
4.2	Spatially explicit or not	
4.3	Key model parameters	
4.4	Recruitment	
4.5	Evaluation of uncertainty	
4.6	Evaluation of predictions	
4.7	Biological reference points	Fmsy used as a threshold or limit reference point

Stock: Pacific sardine (*Sardinops sagax*)
Author: Larry Jacobson
Date: 17 August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	West coast of North American from northern Mexico to southern British Columbia, Canada
1.2	Stock structure	Historical tagging studies demonstrate movement (often seasonal) along the coast
1.2	Spatial structure	The stock is not randomly distributed with respect to size and distribution depends on environmental conditions and season. In general, larger individuals are furthest north.
1.3	Single/multi-species	Single species assessment techniques are used

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Catch data available for main fisheries in California since 1916. Discards likely small.
2.2	Indices of abundance	Daily egg production estimates of spawning biomass are available, but these are likely "minimum" estimates because of sardine outside the area surveyed. Several relative indices are available but the relationship with abundance is likely non-linear. Abundance data start in 1951. Biomass estimates start in 1932.
	Catch per unit effort	Not applicable.
	Gear surveys (e.g. trawl, long line)	Most abundance indices saturate because they are carried out in the center of the stocks distribution. Selectivity for ichthyoplankton and spawning biomass surveys based on maturity at age, fecundity at age, etc.
	Acoustic surveys	Not applicable.
	Egg surveys	CalCOFI estimates of egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity, etc. are available Surveys do not currently cover the entire range of the stock.
	Larvae surveys	CalCOFI estimates of abundance, production, mortality, spawning stock sex and maturity structure, fecundity, etc. are available Surveys do not currently cover the entire range of the stock.
	Juvenile surveys	Not applicable
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Many life history aspects are hard to measure precisely because of lack of sampling and non-homogeneous spatial distribution.
2.4	Tagging information	Historical tagging to demonstrate movement.
2.5	Environmental data	The harvest control rule used Fmsy as a threshold reference point. Fmsy is based on recent average sea surface temperatures. A wealth of oceanographic (biological and physical) information is available.
2.6	Fishery information	California Department of Fish and Game personnel are familiar with the fishery.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	An age structured model is currently used (a derivative of Cagean).
3.2	spatially explicit or not	Explicit but crude.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability recruitment	Natural mortality assumed constant.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	Process errors (mainly in recruitment) and survey measurement errors are accommodated in modeling. Log normal distributions generally assumed for measurement errors.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	Bootstrapping and asymptotic variances
3.6	Retrospective evaluation	Retrospective patterns are evaluated periodically

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-	A long-term simulation model (biomass dynamic, environmentally forced recruitment) was

	structured prediction model	used to evaluate management options.
4.2	Spatially explicit or not	No.
4.3	Key model parameters	Best available estimates.
4.4	Recruitment	Autocorrelated and environmentally driven spawner-recruit modeling.
4.5	Evaluation of uncertainty	Uncertainty summarized in terms of distributional statistics.
4.6	Evaluation of predictions	Not applicable
4.7	Biological reference points	Fmsy used as a threshold or limit reference point

6.3 – Peruvian anchoveta (submitted by Miguel Niquen)

Stock: Peruvian Anchovy stock (Northern-Central Peru stock) **Author: Miguel Niquen**
Date: September 2nd, 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock 05°S – 15° S Northern-Central off Peru
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Tagging studies. Distribution and main spawning grounds.
1.2	Spatial structure	Is or should the assessment be spatially structured? The assessment contain no spatial structure
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single species assessment

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Landed catches are considered in the assessment. Sampling for species composition, length structure, spawning are fully documented. No records of discards.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? CPUE (relative index as function of Tonnage Register Gross (TRB), also since 1996 with TRB-fishing effort) Spawning biomass (DEPM), absolute index since 1990
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? All the fleet of purse seiners is considered. Standardization by size structure of fleet. Zero catches are not considered.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? No. Survey covers entire range of the stock.
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys cover the entire distribution of stock., and there is special trawlings for species composition. TS is estimated and periodically verified.
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Since 1990 there is annual survey.
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)?
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Sampling design consider samples from commercial catches along Peruvian coast, daily for length and weekly for reproduction and growth. Also there is technical observers on board of commercial fleet.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No tagging
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? Environmental information is permanent, as in fixed stations as in surveys. Also a new Project about El Niño have installed 4 oceanographical buoys.
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Yes, now there is some Scientific Technician of IMARPE on board of commercial fleet. We combine this information with data of Satellite System ARGOS.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? Virtual population analyses, in biannual basis, the main assumption is M constant, no error in the catch by age matrix.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? No
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality: usually constant, but any treatments use low M after El Niño period, assuming decrease predators. Vulnerability, fishing mortality and catchability, estimated yearly or biannual.
	recruitment	Recruitment pattern are estimated for every year or semester
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? Process errors: recruitment pattern. Observation errors are considered in the sum of squares
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? Results are presented as confidence bounds.
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Retrospective pattern evaluated

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Single specie, considered age, size and fleet structured. Short term, medium and large term.
4.2	Spatially explicit or not	Not
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? The source is surveys and fisheries. Variability is high.
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? Recruitment is incorporated from acoustic survey.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? Uncertainly is implicitly incorporated in the parameter estimation.
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. We did it after one acoustic survey, we correct the last prediction.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? Fo.1, F40% SSB as a target.

6.4- The small pelagic fish along the Chilean coast: a review regarding evidence for causes of population fluctuations (submitted by Luis Cubillos)

Historically, five small pelagic fish contribute more than 90% of the Chilean landings: anchovy (*Engraulis ringens*), jack mackerel (*Trachurus symmetricus murphyi*), sardine (*Sardinops sagax*), common sardine (*Strangomera bentincki*) and mackerel (*Scomber japonicus*). Important fluctuations in populational size of these species have occurred during the last 30 years, and regimes of high and low abundance of sardine and anchovy have important effects on the structure, dimension and dynamics of fisheries. In this paper, an overview of fluctuations of Chilean small pelagic fish is presented. The emphasis is on evidence for cause of populational fluctuations in sardine, anchovy, common sardine, and jack mackerel, considering coherent changes in the physical environment.

Anchovy has two discrete stocks along the Chilean coast, one of them is a shared stock between southern Peru and northern Chile (16° - 27° S), and the other one is located in the central-south area off Chile (34° - 40° S). Catch history of anchovy can reveal coherent large-scale fluctuations in productivity of anchovy stocks between 1960 and 1999, and also important short-term variability.

Long-term versus short-term time-scale analysis of anchovy catches in the Humboldt current system (HCS) was done by using a Lowess smoother. The residuals between the original and smoothed data were defined as the short-term, high-frequency variation. Long-term changes were highly coherent for the three stocks of anchovy distributed in the HCS, while there were differences for the short-term variation. North-Central Peru stock was more similar with Southern Peru-Northern Chile stock in terms of high-frequency variation. Long-term, low-frequency variation, suggests that long-term environmental variability causes the anchovy to fluctuate in a synchronous pattern in the HCS.

The first important period of high abundance and productivity of the anchovy stocks was between 1960 and 1976. Short-term abundance variation of anchovy seems explained by the fishing intensity and by El Niño-La Niña events impacting on recruitment. From a long-term perspective, northern Chile anchovy stock seems affected by a warm period, with more intense coastal upwelling and turbulence, established between 1976 and mid-1980s in the HCS.

The lower abundance period of anchovy stocks extends between 1976 and mid-1980s. Coincidentally, in that period the sardine stock dominated in abundance. Apparently there are four relatively discrete stocks of sardine in the HCS: a northern stock off north-central Peru, a shared stock off southern Peru and northern Chile, a Coquimbo stock (29°31'S) and a Talcahuano stock, but these stocks are probably shared when sardine abundance is high. The turning date of the initial change from a regime of anchovy to one of sardine are far of clear, probably due to sardine recruiting at more advanced age than anchovy. However, there are evidence supporting that recruitment sardine increased from the early 1970s, and started to decrease again from about 1988-1990.

In central-southern Chile, common sardine and anchovy catches are coherent with the regime of an anchovy-dominated system. In other words, common sardine is out of phase with sardine regime. It must be mentioned that anchovy conforms mix schools with common sardine, which promote an interesting mechanism of biological interaction between the species in this area. A short-term alternation between common sardine and anchovy was observed during the 1990s, but there are not a replacement between species on the long-term. Recently, Cubillos and Arcos (submitted) have postulated that the conditions of the 1997-98 El Niño in central-southern area off Chile affected the survival of common sardine offspring and that this small cohort was important for the recruitment success of anchovy through a biological mechanism of interaction such as the "school trap" (Bakun and Cury, 1999) operating in the early school dynamics of the species.

In central-southern Chile, jack mackerel abundance was growing during the 1970s. Jack mackerel is a highly migratory species, inhabiting coastal and oceanic waters off Chile. According to Serra (1991), there are only a single self-sustained stock off Chile. El Niño-Southern Oscillation events impact on the population structure by increasing the availability of juveniles in southern feeding-areas, where adults jack mackerel are distributed. Furthermore, year-to-year jack mackerel recruitment is related to changes in sea surface temperature in the spawning oceanic area, located between 80° -90°W and 30° - 40° S.

Small pelagic fish inhabiting along the Chilean coast reveal important short-term and long-term variations. Short-term fluctuations are related to El Niño-Southern Oscillation phenomena, and probably to the fishing intensity, through recruitment variability. Long-term variation are revealed from catch history in the last 30 years, but the short length of most recruitment series does not permit powerful hypothesis tests. In this longer period, coherent changes in anchovy stocks have been observed, and this synchronous pattern is out of phase with large-amplitude sardine regimes on oceanic scales (Lluch-Belda et al., 1989). Decadal and interdecadal climate variability seem to be the main cause for long-term fluctuations in small pelagic fish. Existing information may be able to respond to short-term variability in recruitment, but large-amplitude regime shifts may be more important since they can cause appearance and disappearance of entire fisheries.

Stock	**: Chilean-Peruvian Anchovy stock**
Autor	**: Rodolfo Serra**
Date	**: August 2001**

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock 15° S – 24°S. From southern Peru to northern Chile.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Tagging studies. Main spawning grounds and distribution of abundance.
1.2	Spatial structure	Is or should the assessment be spatially structured? No Information.
1.3	Single/multi-species	Choose single-species or multi-species assessment.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Sampling design is documented. No records of discards. Saturation of the hold capacity is a factor of discarding. There is the believe that it is not important because of the few times it happens.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Up to now: Cpue; Larval index (relative index as function of spawning stock); Starting this year: Spawning biomass (DEPM), estimates are available for six years; Recruitment surveys (Acoustic).
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? Gross estimate. Standardization by relative efficiency of size structure of the fleet. All the fleet is considered. Zero catches are not considered.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? Purse seine
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys to estimate recruitment strength.. Research underway to Catches are done for species identification and biological information. TS is estimated and periodically verified.
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Yes, since 1995. This year all the information was re-processed under standardized procedures to have spawning stock estimates.
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Nursery area; acoustic surveys with extensive sampling (Catch)
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age,	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. catch-at-age: yes weight-at-age: yes

	age-specific reproductive information	Maturity-at-age: yes Size-at-age: yes age-specific reproductive information: no, converted from size. Sampling design: stratified by area and time (month). Sampling for size and age length key. Sample size are high however the error level has not been assessed. No aging error considered.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered?
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? No environmental information has been used yet. The priority was given to have more reliable auxiliary information. Obvious process candidates are: catchability, recruitment pattern, recruitment (year class size) and growth.
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Yes. This information is used in the diagnosis.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? ADAPT. No error in the catch at age matrix; constant M; Separability assumption for the last year.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? No. This aspect has not been examined.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. natural mortality: constant vulnerability: recruitment pattern estimated each year fishing mortality: estimated catchability: estimated
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? Observation errors are considered in the sum of square; the weight is the inverse of the variance of the observations. Process errors: recruitment pattern; catchability
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? Bootstrapping
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Retrospective pattern evaluated.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

We do projections, not predictions. Short and long-term.

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ?
4.2	Spatially explicit or not	
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? Reference points: Target: $F_{2/3SSB}$ Limit: $F_{40\%SSB}$ They are estimated each year.

Stock : Chilean anchovy – Southern stock (*Engraulis ringens*)
Author : Luis A. Cubillos
Date : August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock? The stock of common sardine is distributed between 33° - 40° S.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Comparative life history parameters, and morphometric studies have been used to define stock unit.
1.2	Spatial structure	Is or should the assessment be spatially structured? The assessment is not spatially structured.
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single-species assessment.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Total catches are included in the assessment. There are not discards.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? The following relative indexes of relative abundance are obtained in the entire distribution range of the stock: a) Monthly catch per unit effort as and index of the average monthly exploitable biomass. Period: 1990 - 2001. b) Acoustic biomass and abundance of recruits. Years: 1995, and from 1999 to 2001. c) Acoustic biomass and abundance of adults (2001 first year of survey).
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? 80 - 95% of the fleet data are included. Monthly catch rates are standardized using conventional methods. Catch and effort statistics are collected from fishing companies.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed?
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys are carried out for adults in winter spawning time (August) and for young of the year (Age 0) in December-January. 100% of the area is covered. Probably there is a bias due to coastal distribution of fish.
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? There are not egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area There are not larvae surveys
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juvenile abundance is quantified by hydroacoustic on young of the year (age 0). The area is 100% covered by the surveys.
2.3	Age, size and sex-structure: Catch-at-age, Weight-at-age, Maturity-at-age, Size-at-age, Age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Monthly length-frequency data are from random daily samples obtained from the catch of vessels operating in the fishery. A minimum of 32 sampling units per month, distributed by weeks and size of vessels are obtained regularly. Specific biological data from individual fish (total length, weight, maturity, sex proportion, female gonadal weight) are obtained from weekly random samples from the fishery. Monthly length-frequency data are used for estimation of age-structure.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? There is not a tagging program.
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? Sea surface temperature (SST) from tidal stations, and a coastal upwelling index (CUI) based on wind data. Average SST and CUI for July-August (spawning peak) and August-December (pre-recruitment phase) are used as proxies for recruitment. Potential candidate variables are the rainfall and river runoff in winter time (July-August), or a multivariate index based on SST, CUI, Rainfall and River Runoff.

2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Catch and effort data are routine collected from the fishery by personnel of IIP, daily contact with fishing company team and fishermen.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? Monthly cohort-structured model. An ADAPT approach is used for estimation of parameters by using CPUE data as auxiliary information. A single cohort is produced per year, which is identified in catch-at-length data by length-frequency analysis.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? It is not spatially explicit.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality is assumed to be constant by cohort and year. Catchability is estimated freely and assumed to be constant. Recent research is suggesting to consider a time varying catchability.
	recruitment	A recruitment index based on acoustic surveys carried out since 1999 should be incorporated in future assessments.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? At present, an integrated statistical catch-at-length method of estimation is in progress. This method will include maximum likelihood methods of estimation (e.g. multinomial error structure for catch-at-length composition, log-normal error for abundance index and catch biomass). A transition matrix will be used for transforming age-structured population processes into length-frequency. Recruitment will be estimated by considering environmental indexes.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds?
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development?

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short-term projection of abundance by using current estimates of abundance, and a monthly exploitation pattern (average for the last two years).
4.2	Spatially explicit or not	
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? Average recruitment and variance of log-transformed data.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? F40%SSB as a target. How often are they re-estimated? How stable are they with respect to changes in input parameters? No yet evaluated.

Stock : Chilean common sardine (*Strangomera bentincki*)
Author : Luis A. Cubillos
Date : August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock? The stock of common sardine is distributed between 33° - 40° S.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Comparative life history parameters, and morphometric studies have been used to define stock unit.
1.2	Spatial structure	Is or should the assessment be spatially structured? The assessment is not spatially structured.
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single-species assessment.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Total catches are included in the assessment. There are not discards.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? The following relative indexes of relative abundance are obtained in the entire distribution range of the stock: d) Monthly catch per unit effort as and index of the average monthly exploitable biomass. Period: 1990 - 2001. e) Acoustic biomass and abundance of recruits. Years: 1995, and from 1999 to 2001. f) Acoustic biomass and abundance of adults (2001 first year of survey).
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? 80 - 95% of the fleet data are included. Monthly catch rates are standardized using conventional methods. Catch and effort statistics are collected from fishing companies.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed?
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys are carried out for adults in winter spawning time (August) and for young of the year (Age 0) in December-January. 100% of the area is covered. Probably there is a bias due to coastal distribution of fish.
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? There are not egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area There are not larvae surveys
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juvenile abundance is quantified by hydroacoustic on young of the year (age 0). The area is 100% covered by the surveys.
2.3	Age, size and sex-structure: Catch-at-age, Weight-at-age, Maturity-at-age, Size-at-age, Age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Monthly length-frequency data are from random daily samples obtained from the catch of vessels operating in the fishery. A minimum of 32 sampling units per month, distributed by weeks and size of vessels are obtained regularly. Specific biological data from individual fish (total length, weight, maturity, sex proportion, female gonadal weight) are obtained from weekly random samples from the fishery. Monthly length-frequency data are used for estimation of age-structure.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? There is not a tagging program.
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? Sea surface temperature (SST) from tidal stations, and a coastal upwelling index (CUI) based on wind data. Average SST and CUI for July-August (spawning peak) and August-December (pre-recruitment phase) are used as proxies for recruitment. Potential candidate variables are the rainfall and river runoff in winter time (July-August), or a multivariate index based on SST, CUI, Rainfall and River Runoff.

2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Catch and effort data are routine collected from the fishery by personnel of IIP, daily contact with fishing company team and fishermen.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? Monthly cohort-structured model. An ADAPT approach is used for estimation of parameters by using CPUE data as auxiliary information. A single cohort is produced per year, which is identified in catch-at-length data by length-frequency analysis.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? It is not spatially explicit.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality is assumed to be constant by cohort and year. Catchability is estimated freely and assumed to be constant. Recent research is suggesting to consider a time varying catchability.
	recruitment	A recruitment index based on acoustic surveys carried out since 1999 should be incorporated in future assessments.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? At present, an integrated statistical catch-at-length method of estimation is in progress. This method will include maximum likelihood methods of estimation (e.g. multinomial error structure for catch-at-length composition, log-normal error for abundance index and catch biomass). A transition matrix will be used for transforming age-structured population processes into length-frequency. Recruitment will be estimated by considering environmental indexes.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds?
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development?

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short-term projection of abundance by using current estimates of abundance, and a monthly exploitation pattern (average for the last two years).
4.2	Spatially explicit or not	
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? Average recruitment and variance of log-transformed data.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? F40%SSB as a target. How often are they re-estimated? How stable are they with respect to changes in input parameters? No yet evaluated.

6.5 - Small Pelagics in the Northwestern Pacific Ocean (submitted by Akihiko Yatsu)

Japanese sardine, anchovy and chub mackerel are dominant small pelagic fishes in the Northwestern Pacific and are important for Japanese fisheries. Many factors have been discussed in relation to stock fluctuations of these small pelagics in this region. For the future forecasting of stock variability, summarized here are stock characteristics of the Pacific stocks of these species and possible factors affecting recruitment variability from available literature.

Maternal conditions

While sardine population and egg production increased, lipid content of adult sardine drastically decreased in the late 1980's and early 1990's (Kawasaki and Omori, 1995). During this period, spawning grounds of sardine shifted from coastal area to offshore area across the Kuroshio in southern Japan, resulting in higher ambient temperatures for spawners. In a tank experiment, Shiraishi et al. (2001) found that mature sardines kept at 20°C temperature spawned smaller eggs with shorter intervals of spawning compared to those kept at 15°C, and those kept at 17°C showed intermediate condition. If smaller eggs produced from thin spawners are subject to larger mortality, offshore expansion of spawning grounds would adversely affect recruitment success.

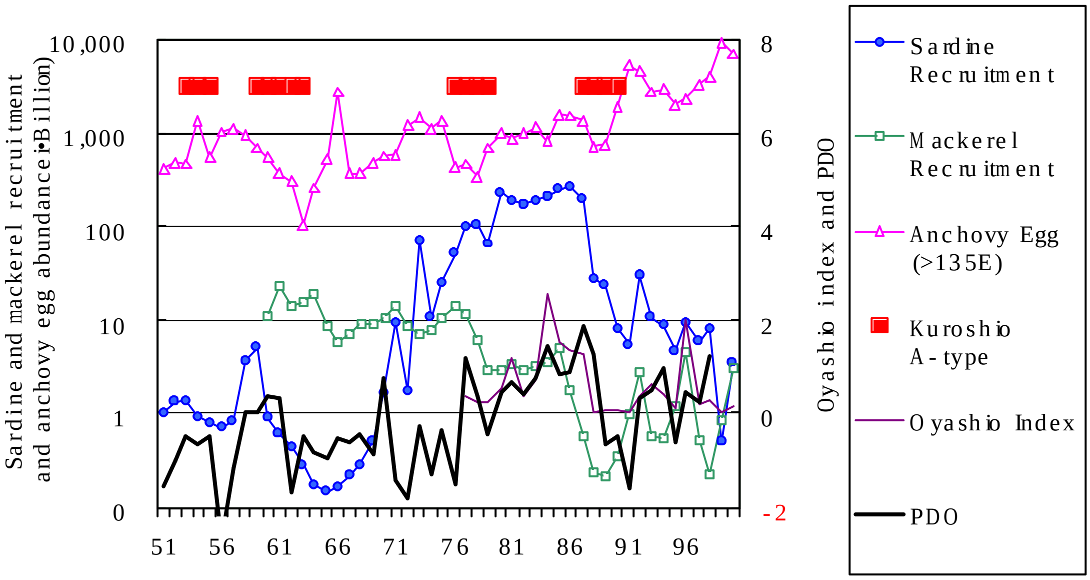


Fig. 6.5.1. *Stock abundance of Pacific stocks of anchovy, chub mackerel and sardine (left axis), Oyashio Index and Pacific Decadal Oscillation (PDO) (right axis) and Kuroshio A-type path, in winter. For details, see text.*

Kuroshio path type

A-type path (large meandering) is empirically known unfavorable for all small pelagics (Watanabe, 1983; see Fig. 6.5.1 and item 7). In fact, during 1953-55, 1957-62, 1976-79, and 1987-90, recruitment of sardine and mackerel and egg abundance of anchovy declined with some exceptions (Fig. 6.5.1). However, anchovy egg abundance drastically increased since 1990 and replaced sardine in 1991 and later in terms of egg abundance. Kuroshio path type affects both productivity of nursery grounds and transportation of eggs and larvae. Chlorophyll-a concentration and abundance of copepods is low during A-type path except for first year of A-type (Nakata et al., 1994). In the Enshu-nada, one of the major nurseries in central Japan, however, the A-type is favorable for sardine spawning and offshore transport (Table 6.5.1; Nakata et al., 2000).

Table 6.5.1. *Kuroshio patterns and effects on sardine and anchovy populations. Italics and underline indicate favorable conditions for sardine and anchovy respectively.Note that favorable conditions for sardine are not necessarily unfavorable for anchovy, and vice versa.*

	Kuroshio path patterns	
Conditions of Enshunada area	Non-meander (N type)	Meander (A type)
Water temperature (for spawning)	Low	*High*
Current field		
Onshore transport	Small	*Large*
Onshore retention	<u>Large</u>	Small
Food availability	<u>Increase in the shelf region</u>	Decrease in the shelf region

Transportation to favorable/unfavorable nursery grounds

Nakata et al. (1995) compared RNA/DNA ratios of sardine larvae between Kuroshio frontal region and offshore side of Kuroshio and concluded that low production of food organisms may be a general characteristic of the offshore side of Kuroshio. The offshore shift of spawning grounds in the late 1980's would be one of the causes of recruitment failures because of the transportation of larvae to the poor food-condition area.

SST and zooplankton in Kuroshio/Oyashio Transition Zone

Strength of Oyashio and SST anomalies in the Kuroshio Extension South Area (KESA) are significantly correlated to recruitment success of sardine (Ebisawa and Kinoshita 1998; Noto and Yasuda, 1999, Fig. 6.5.1). KESA is assumed as the one of the nursery grounds, though it has not been verified. Strength of Oyashio as indexed by the area of less than 10ºC SST south of 37ºN is correlated to PDO in winter (Fig. 6.5.1). While underlying mechanisms of effect of SST anomaly in KESA area has not been hypothesized, those of Oyashio index had been related to prey abundance in Kuroshio/Oyashio Transition Zone (TZ). Watanebe et al. (1995) found no relation between sardine larval abundance and YOY, and concluded that recruitment success had not been determined by the stage of post-feeding larvae. On the basis of pre-recruitment survey in the TZ, abundances of juveniles of sardine and chub mackerel were fairly correlated with YOY of each species (Nishida et al., 2000).

Despite the general view that Kuroshio Extension (KE) is oligotrophic waters thought the year, Saito et al. (2001) found that sardine larvae >33mm SL had full stomachs with selectivity for larger copepods (>= 0.8 mm BL) such as *Calanus pacificus* in KE, Saito et al. (2001) also reported that those 26-31mmSL sardine had stomachs with much less fullness and fed on small (< 0.8 mm BL) zooplankton such as *Paracalanus* spp. despite the smaller zooplankton was much more abundant than large planktons. This suggests small sardine larvae had not developed feeding ability, thus timing of spring bloom, size compositions of zooplankton and match/mismatch of sardine and their prey will significantly affect growth and survival of sardine larvae. These results indicate the importance of environmental conditions of KE and TZ and juvenile abundance for predicting recruitment success.

Individual growth rates as a proxy of recruitment success

Growth rates of sardine larvae had positive correlations to ambient temperature, nauplii density, and chlorophyll-a concentrations (Oozeki and Zenitani, 1996; Umeda, 2001). Only sardine and anchovy that quickly passed their larval and juvenile stages had survived as evidenced from comparative analyses of daily ring increments of wild juveniles survived and growth of those found in the stomachs of their predators were slow (Sugisaki, 2001; Kimura et al., 2000). Better food availability and optimum temperature are most plausible candidates of explanatory variables for the growth rate variability. Examination of RNA/DNA ratios, Kimura et al. (2000) concluded starvation is not a prevalent cause of mortality since no starved larvae of sardine were observed around the Kuroshio current. Therefore, growth rates are good proxy of survival, and abundance of predators is also the key factor for survival.

Intra- and inter-species competitions

Sardine, anchovy and chub mackerel primarily feed on zooplankton, particularly copepods, from their larval stages (Nakata et al., 1994). Adult sardine preys also on phytoplankton (Kawasaki, 1983). Juvenile and adult chub mackerel also feeds on fishes, particularly anchovy (Castro Hernandez and Santana Ortega, 2000.). Feeding ratio of sardine and anchovy larvae was inversely correlated to the density of sardine and anchovy larvae, respectively (Matsushita et al., 1988). Sardine recruitment was affected by both sardine and chub mackerel stock numbers (Kishida and Matsuda, 1993). Length-at-age data of sardine indicated density-dependent growths (Wada and Kashiwai, 1991). These finding suggest existence of intra- and inter-species competitions at least among sardine, anchovy and chub mackerel. Owing to the omnivorous feeding habits of sardine, carrying capacity and possibly intrinsic growth rate of sardine population must be much higher than those of mackerel and anchovy.

Predation

Around the Kuroshio Extension, sardine larvae were preyed by the chaetognaths and amphipods, and these predatory zooplanktons were more abundant in the southern side of the KE front (Sugisaki, 2001). Chub mackerel, Pacific pomfret, albacore, sharks, squids, minke whales and other predators are substantial consumers of small pelagics and their feeding habits are generally opportunistic, i.e., preys on dominant species (Yatsu et al., in press). Thus, chub mackerel will decrease anchovy (and possibly sardine) population through predation.

Retrospective overview of species replacement and environmental conditions

In the late 1980's, while both sardine and mackerel recruitments and anchovy egg abundance drastically declined corresponding to Kuroshio A-type path and very low Oyashio index, anchovy egg rapidly increased in 1990 when Kurothio path was C-type but Oyashio index was still low. In the late 1970's, anchovy egg production and mackerel recruitment declined corresponding to A-type path but sardine recruitment slightly decreased probably owing to the southward shift of spawning grounds (Nakata et al., 1994) and may be related to moderate Oyashio index. In the early 1970's when Kuroshio path was N-type, sardine recruitment drastically increased because RPS of sardine was extremely high and mackerel recruitment slightly increased. From the late 1950's to early 1960's, mackerel recruitment was high and anchovy egg production and sardine recruitment decreased. In the period of A-type path during the early 1950's, sardine recruitment and RPS also declined but did not affect anchovy egg abundance. Thus, neither Kuroshio path nor Oyashio index can be a perfect explanatory variable.

References

Castro Hernandez, J.J. and A.T. Santana Ortega. 2000. Synopsis of biological data on the chub mackerel *(Scomber japonicus* Houttuyn, 1782). FAO Fish. Synop., 157: 1-77.

Ebisawa, Y. and T. Kinoshita. 1998. Relationship of surface water temperature in Boso-Sanriku area sea and recruitment per spawning biomass of the Japanese sardine. Bull. Ibaragi Fish. Exp. Sta., 36: 49-55. (In Japanese)

Kawasaki, T. 1983. Why do some pelagic fishes have wide fluctuations in their numbers? FAO Fisheries Rep., 291: 1065-1080.

Kawasaki, T. and M. Omori. 1995. Possible mechanisms underlying fluctuations in the far eastern sardine population inferred from time series of two biological traits. Fish. Oceanogr. 4: 238-243.

Kimura, R., Y. Watanabe, and H. Zenitani. 2000. Nutrional condition of first-feeding larvae of Japanese sardine in the coastal and oceanic waters along the Kuroshio Current. ICES J. Mar. Sci., 57: 240-248.

Kishida, T. and H. Matsuda. 1993. Statistical analyses of intra- and interspecific density effects on recruitment of chub mackerel and sardine in Japan. Fish. Oceanogr., 2: 278-287.

Mantua, N.J. and S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Amer. Meteorol. Soc., 78: 1069-1079.

Matsushita, K., M. Shimizu, and Y. Nose. 1988. Food density and rate of feeding larvae of anchovy and sardine in patchy distribution. Nippon Suisan Gakkaishi, 54: 401-411.

Nakata, H., S. Funakoshi, M. Nakamura. 2000. Alternating dominance of postlarval sardine and anchovy caught by coastal fishery in relation to the Kuroshio meander in the Enshu-nada Sea. Fish. Oceanogr., 9: 248-258.

Nakata, K., A. Harada and Y. Matsukawa. 1994. Variations in food abundance for Japanese sardine larvae related to the Kuroshio meander. Fish. Oceanogr., 3: 39-49.

Nakata, K., H. Zenitani, and D. Inagake. 1995. Differences in food availability for Japanese sardine larvae between the frontal region and the waters on the offshore side of Kuroshio. Fish. Oceanogr., 4: 68-79.

Nishida,H., Watanabe C, Yatsu A. 2001. Forecasting the recruitment abundance of Japanese sardine and chub mackerel based on the juvenile abundance in the Kuroshio-Oyashio Transition Regions. Fish. Bio. Oceanogr. Kuroshio, 2001; 2: 77-82. (In Japanese)

Noto, M. and I. Yasuda. 1999. Population decline of the Japanese sardine, *Sardinops melanostictus*, in relation to sea surface temperature in the Kuroshio Extension. Can. J. Fish. Aquat. Sci., 56: 973-983.

Oozeki, Y. and H. Zenitani. 1996. Factors affecting the recent growth of Japanese sardine larvae (*Sardinops melanostictus*) in the Kuroshio Current. pp. 95-104, In Survival Strategies in early life stages of marine resources, A.A. Baklkema, Rotteldam.

Shiraishi, M., K. Fujii, T. Yamamoto and H. Furuita 2001. Maturation and spawning processes of Japanese sardine. Summary of Bio-Cosmos Project: 155. (In Japanese)

Saito, H., A. Tsuda and H. Kasai. 2001. A possible scenario of large population fluctuation caused from a small change in prey abundance. Summary of Bio-Cosmos Project: 157. (In Japanese)

Sugisaki, H. 2001. Transportation and survival of Japanese sardine larvae in the offshore area, east of Honshu Island. Summary of Bio-Cosmos Project: 149. (In Japanese)

Umeda, S. 1996. Survival of first feeding larvae of Japanese sardine. Kuroshio, Spec, Publ., 10: 3-10. (In Japanese)

Wada, T. and M. Kashiwai. 1991. hanges in growth and feeding ground of Japanese sardine with fluctuation in stock abundance. pp. 181-190. in K. Kawasaki et al. (eds.) Long-term Variability of Pelagic Fish Populations and their Environment, Pergamon Press, Oxford.

Watanabe, T. 1983. Stock assessment of common mackerel and Japanese sardine along the Pacific coast of Japan by spawning survey. FAO Fish. Rep., 29: 1-22.

Wantanabe, Y., H. Zenitani and R. Kimura. 1995. Population decline of the Japanese sardine *Sardinops melanostictus* owing to recruitment failures. Can. J. Fish. Aquat. Sci., 52: 1609-1616.

Yatsu, A. and T. Kinoshita. in press. Application of a surplus production model to the Japanese common squid over three different regimes. 'Ikarui-shigen-kenkyu- kaigi-houkoku Heisei 13 nendo' (Proceedings of the 2001 Annual Meeting of Squid Stock Research). (In Japanese)

Yatsu, A., K. Nagasawa and T. Wada. in press. Decadal changes in abundance of dominant pelagic fishes and squids in the Northwestern Pacific Ocean since the 1970'S and their implications to fisheries management. Trans. Amer. Fish. Soc.

Stock: Anchovy *Engraulis japonicus* Pacific Stock of Japanese waters
Author: Yukichika Okada, Minoru Ishida and Akihiko Yatsu
Date: 27 August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Three populations have been recognized as the stocks for assessments around the Japan: Tsushima current stock, Seto Inland Sea stock and Pacific stock. The Pacific stock is distributed along the Pacific coast of Japan; eastern limit of distribution extends as east as ca 180 degree longitude in the juvenile stage regardless the stock level and both juveniles and adults at the high stock levels. Western limit extends to the east coast of the Kyusyu islands.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? No tagging experiments have been performed. MtDNA analysis revealed no genetic differentiation between Tsushima Current stock and Pacific stock.
1.2	Spatial structure	Is or should the assessment be spatially structured? Spawning grounds extend from east coast of Kyushu Island to northern Japan and to the pelagic areas off Honshu Island when stock level is high, but shrink to coastal areas at low stock level. Thus, it is unnecessary to perform spatially structured approach.
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single species assessment. Recently Ecopath/Ecosim approach was initiated in the major feeding area - Kuroshio/Oyashio Transition Zone.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Catches by major fisheries (purse seine and set nets,) are included; sports fishing - negligible amount – was excluded. Discarding has never been assessed. Sampling biases have never been studied. “Shirasu” or white bait fishery data have been also collected.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Drift gillnet surveys have been carried out in the coastal and offshore areas in the northeastern Japan by several research institutes mainly in summer and autumn for juveniles and adults. Midwater trawl surveys for juveniles and adults in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone started in 1996 and 1999, respectively. Russia performed trawl surveys in the Oyashio and its adjacent areas from 1983 to 1995. Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast using the NORPAC nets. Egg abundance data have been used as a relative index of adult (age 1 and older) population.
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? We do not use CPUE of commercial fleets CPUE data have not been used.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? We use midwater trawl and drift gillnet as sampling gears. One of the midwater trawl surveys covers almost entire distribution of juveniles and another one covers adult distribution. Driftnet surveys mostly cover coastal areas and at three fixed longitudes in the open waters at 155, 170, 175E longitudes. Selectivity of driftnets has been assessed using simultaneous deployments of different meshed nets. Gear saturation of driftnets for mackerel is probably negligible. Effects of time of day and towing speed were examined for midwater trawl nets (25m high x 34m wide opening and 26m x 57m opening) and it was concluded that night-time operations towed at more than 3 knots for 30 minuets were suitable for sampling adult anchovy.
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys have been tried but not established for this species because it is difficult to distinguish it among the mixed species. Recently, midwater trawl gear efficiency was studied by comparing trawl catches and corresponding acoustic estimations for several pure anchovy schools (unpublished).
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast. Egg stages are unspecified. Egg survey data have been used for stock assessments.
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area. Egg/larvae surveys have been intensively carried out along the entire coastal/offshore

		waters along the Pacific coast. Prelarvae and postlarvae are distinguished. Drift out of the covered area is a serious problem because of the vast distribution of the mature adults as east as 180E longitude in the 1990's.
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? One of the midwater trawl surveys covers almost entire distribution of juveniles (age 0) in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone during spring. Effects of time of day and towing speed were examined for mid-water trawl net (25m high ×34m wide opening and 25×57m opening) and it concluded that towing speed of 3 knots for 30 minuets are suitable for sampling juveniles and adults regardless the time of day.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Age-disaggregated stock assessment has not been performed because only a small portion of the catches was routinely aged. No high-grading are recognized.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No tagging experiments were performed.
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? The environmental information (condition of Kuroshio and/or Oyashio current, SST of the coastal area) is only used to forecast the fishing condition.
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Many fishery scientists in Japan, particularly those who belong to prefecture research stations, are familiar with fisheries (purse seine, set net, "shirasu" or white bait fishery). In order to exchange information on stock status, sea conditions, economics, etc., they have been frequently contacting with fishers, fishing company representatives and local market staffs.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? Since batch fecundity is positively correlated to SST and spawning interval is inversely correlated to SST, SST-adjusted annual egg production method has been used for stock assessment since 1978.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? It is unnecessary to perform spatially explicit assessments because of the stock structure and fishery status.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Adult biomass has been estimated by the egg production model by month. Total biomass is extrapolated from length frequency data and adult biomass. Batch fecundity (BF) per 10g body weight (BW) is calculated as a function of GSI and sea surface temperature (SST, ºC) (Imai et al., 1998): BF = (-2176 + 182 SST) GSI when SST<22 or BF = 1828 GSI when SST>=22. Spawning interval (SI) is also empirically estimated: SI = 7.85 – 0.243 SST.
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? No statistical formulations have been performed.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? Uncertainty has not been evaluated.
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Retrospective analysis has not been performed.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? No predictions on stock abundance have been carried out.

4.2	Spatially explicit or not	Spatially not explicit.
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? *F30% SPR* and 0.8 *F30%SPR* are used as limit and target reference points. If *Fcurrent* (averaged *F* of recent 3 years) is smaller than *F30% SPR*, then *Fcurrent* is adopted.

Stock: Chub Mackerel *Scomber japonicus* Pacific Stock of Japanese waters
Author: Chikako Watanabe and Akihiko Yatsu
Date: 27 August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Two populations have been recognized as the stocks for assessments around the Japan: Tsushima current stock and Pacific stock. The Tsushima current stock is distributed in the East China Sea and Sea of Japan. The Pacific stock is distributed along the Pacific coast of Japan; eastern limit of distribution extends as east as ca 180 degree longitude in the juvenile stage regardless the stock level and both juveniles and adults at the high stock levels. Western limit extends to the east coast of the Kyusyu islands.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Some tagging surveys indicated that the immigration/emigrations between the Pacific Stock and the Tsushima Current Stock had been recognized but probably very rare. The major spawning area of the Pacific Stock is located around Izu-islands waters (central Japan) with minor areas in western Japan. Recruitment from the western area to central Japan has been assumed. Growth rates of first 2 years were different between the western and eastern areas. Russian scientists reported that there were two populations, coastal and oceanic, in the Pacific stock distributed along the Pacific coast of the northern part of Honsyu Island using the genetic and parasitological analyses (Pozdnyakov and Vasilenko 1994, Belyaev and Ryabov 1987). But it is unclear whether the two putative stocks have distinct spawning grounds.
1.2	Spatial structure	Is or should the assessment be spatially structured? Spawning, catch and probably biomass are mostly concentrated in the central and northern areas. Thus, it is unnecessary.
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single species assessment. Recently Ecopath/Ecosim approach was initiated in the major feeding area - Kuroshio/Oyashio Transition Zone.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Catches by major fisheries (purse seine, dip net and set net) are included; sports fishing - negligible amount – was excluded. Discards are negligible. Sampling biases have never been studied.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Drift gillnet surveys have been carried out in the coastal and offshore areas in the northeastern Japan by several research institutes mainly in summer and autumn for YOY and adults. Midwater trawl surveys for juveniles and adults in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone started in 1996 and 1999, respectively. Russia performed trawl surveys in the Oyashio and its adjacent areas from 1983 to 1995. Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast using the NORPAC nets, but the production estimates include eggs/larvae of spoted mackerel *S. austlarasicus* (see below). Only age 0 data from trawl and driftnet survey are used as relative abundance of juveniles having linear relations.
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? We do not use CPUE of commercial fleets CPUE data of purse seine fishery are routinely collected but not standardized. CPUE data have not been used as a tuning index of VPA because of the lack of age-disaggregated data.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? We use midwater trawl and drift gillnet as sampling gears. One of the midwater trawl surveys covers almost entire distribution of juveniles and another one covers adult distribution. Driftnet surveys mostly cover coastal areas and at three fixed longitudes in the open waters at 155, 170, 175E longitudes. Selectivity of driftnets has been assessed using simultaneous deployments of different meshed nets. Gear saturation of driftnets for mackerel is probably negligible. Effects of time of day and towing speed were examined for midwater trawl nets (25m high x 34m wide opening and 26m x 57m opening) and it was concluded that night-time operations towed at more than 3 knots for 30 minuets were suitable for sampling adult mackerel.
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys have been tried but not established for this species because it is difficult to distinguish it among the mixed species.

	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast. But estimates include the production of eggs and larvae of spotted mackerel *S. austlarasicus*. Spotted mackerel is distributed mainly around the western and central areas of the Pacific coast of Japan and their spawning grounds are in close proximity to that of chub mackerel. Although egg diameters of chub mackerel are slightly smaller than those of spotted mackerel with the aid of mtDNA analysis, it is practically difficult to distinguish the all collected eggs and larvae between two species. Maturation of adults is investigated in the major spawning area - around the Izu Islands. Spawning stock sex ratios and maturity are assessed routinely using the biological samples. Batch fecundity and spawning frequency were investigated in some reports. Egg stages are unspecified.
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area. Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast, but estimates include the eggs/larvae of spotted mackerel *S. austlarasicus* (see above). Prelarvae and postlarvae are distinguished. Drift out of the covered area is presumably negligible at low stock periods.
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? One of the midwater trawl surveys covers almost entire distribution of juveniles (age 0) in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone during spring. Effects of time of day and towing speed were examined for mid-water trawl net (25m high ×34m wide opening and 25×57m opening) and it concluded that night-time operations towed at 3> knots for 30 minuets are suitable for sampling juveniles and adults.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Catch at age data are processed from (1) commercial catch in weight by month and by major fishing ground and (2) corresponding length frequency data of major fisheries, purse sine, set net and dip net, and (3) an age-length key. Scales are used for age determinations. Weight-at-age data area obtained from the same data set. Maturity-at-ages is estimated from biological samples. The ageing error maybe exist in older fishes(5 years-old and /or older) because of the concentration of annual rings. Catch-at-age estimations of old fish may subject to sampling errors because they were very rare in samples. No high-grading are recognized.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No tagging data is used for stock assessments.
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? The environmental information (condition of Kuroshio and/or Oyashio current, SST of the coastal area) only used to forecast the fishing condition. Strong meandering of Kuroshio Current in central Japan (A-type) adversely affected survival of mackerel larvae probably due to low productivity around the Kuroshio Current.
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Many fishery scientists in Japan, particularly those who belong to prefecture research stations, are familiar with fisheries (purse seine fishery, dip net fishery and set net fishery). In order to exchange information on stock status, sea conditions, economics, etc., they have been frequently contacting with fishers, fishing company representatives and local market staffs.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? VPA have been used for stock assessment. As tuning indices for age 0 fish, the relative abundance of juveniles estimated by the above trawl survey (since 1996) and a driftnet survey (since 1985) and that of the wintering immature fishes calculated using the CPUE data of purse sine fishery. The total efforts per year of purse seine were also used as a tuning index of fishing mortality coefficient *F* of the total stock. VPA time series covers 1970-2000. Sexes are combined in the model used since no sexual differences were observed for growth and maturation.
3.2	Spatially explicit or not	If not, is it necessary, and if yes, why not implemented? It is unnecessary to perform spatially explicit assessments because of the stock structure and fishery status.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality coefficient *M* is assumed 0.4 per year based on the empirical relation between life span and *M*. This *M* value is used for all ages and all years. Fishing mortality coefficient *F* is calculated from VPA, where *F* of the oldest age group (age 6 and older) is

		assumed equivalent to *F* of age 5 because of no substantial ecological difference between age 5 and age 6+.
	Recruitment	Recruitment increased from the middle of 1960's, peaked in the end of 1970's then declined to 1990's. In 1992 and 1996, year-class strengths were high in spite of the level of spawning stocks were very low.
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? In the current VPA, no weighting were performed since we have no prior information for weighting indices.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? Only a sensitivity analysis of effect of *M* and assumption of recruitment numbers on VPA results and ABC determinations has been conducted.
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Retrospective analysis was performed but not published because of short time series of the tuning indices (all three indices were available only since 1996).

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? A forward VPA is currently used for short term prediction. Matsuda et al. (1992, Res. Popul. Ecol., 34) presented a long term (500 years) simulation using an inter-species competition model (sardine, anchovy and chub mackerel) incorporating random environmental fluctuations on the intrinsic growth rates of populations; this study examined only theoretical aspects of species replacements and parameters were selected to ensure a long-term sustainable fluctuations of 3 species.
4.2	Spatially explicit or not	Spatially not explicit.
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? In the forward VPA, constant M and F for all ages and years are assumed. Recruitment numbers are assumed on the basis of the trawl survey for juveniles.
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? Recruitment levels in the next year are judged by the above trawl survey. Juvenile abundance index from the trawl survey showed a fairly good correlation with VPA-derived stock numbers of age 0 fish, although this time series started in 1996. The Ricker-type spawning stock-recruitment relationship is hypothesized when the spawning stock levels are more than 450,000 tons. When the spawning stock levels are low, no spawning stock-recruitment relationship is hypothesized. Recruitment levels in the next year are judged by the above trawl survey. Recruitment may be predicted if future conditions of Kuroshio path types are forecasted (see item 2.5). Given the decadal-scale species replacements between sardine, anchovy and chub mackerel in the Northwestern Pacific, associated with ocean-climate changes, it is necessary for the future stock management of small pelagics to proceed process studies and a long-term monitoring for validation of these study results.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? Uncertainty of model parameters is evaluated only sensitivity analyses of *M* and assumed recruitment levels, for the latter bootstrap resampling of recent recruitment numbers were performed.
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. Predictions of stock abundance are evaluated one-year after only in a qualitative manner.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? *Frecovery* and 0.8 *Frecovery* are used as limit and target reference points; *Frecovery* is a F by which current SSB can be raised to more than 450,000 tons within 5 years.

Stock: Japanese sardine *Sardinops melanostictus* Pacific Stock of Japanese waters
Author: Akihiko Yatsu and Minoru Ishida
Date: 27 August 2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Two stocks of the Japanese sardine have been recognized: Pacific stock and Tsushima Current stock, which are distinguished by distribution and migration pattern. Pacific stock distributes along the Pacific coast of Japan; eastern boundary extends as east as ca 180 degree longitude at the high stock levels but in the low stock levels only juveniles are transported to the Central North Pacific. Western boundary coincides with that of spawning grounds that extend from eastern coast of Kyushu Island to northern Japan when stock level is high. During low stock level period, spawning grounds are confined to southern coast of Shikoku Island and Central Japan. Juveniles are transported to NE direction via Kuroshio Current. Feeding grounds are mainly located in the Oyashio and Kuroshio-Oyashio Transition Zone in summer and autumn.
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Extremely low genetic distance were observed among samples around Japan (Okazaki et al., 1996, Mar. Biol., 126) suggesting no genetic differentiation between the two stocks. No tagging programs were preformed for sardine in Japan.
1.2	Spatial structure	Is or should the assessment be spatially structured? Spatially structured assessment is unnecessary, because of the seasonal migration between the southern spawning grounds and northern feeding areas and because of the above genetic uniformity, in spite of the separation of spawning grounds into tow areas (see above) at low stock level.
1.3	Single/multi-species	Choose single-species or multi-species assessment. Single species assessment has been carried out. Recently Ecopath/Ecosim approach was initiated in the major feeding area - Kuroshio/Oyashio Transition Zone.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? Catch of all fisheries (mainly purse seine, set nets) are included; sports fishing - negligible amount – was excluded. Discarding is presumably rare and negligible. Sampling biases have never been studied. "Shirasu" or white bait fishery data have been also collected but never used for VPA because of the difficulty in estimating catch numbers and M.
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Egg/larvae surveys along the entire coastal-offshore regions have been routinely carried out using NORPAC nets. Drift gillnet surveys in the pelagic area (155º, 170º, 175ºE longitudes) and offshore areas in the northeastern Japan continued since 1982 mainly in summer. Midwater trawl surveys for juveniles and adults in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone started in 1996 and 1999, respectively. Russia performed trawl surveys in the Oyashio and its adjacent areas from 1983 to 1995. Egg survey index is considered to represent spawning stock biomass, but not used as a tuning index. Age 0 index from the trawl survey is assumed linearly related to juvenile stock abundance with a linear relation.
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? We do not use CPUE of commercial fleets CPUE (catch per shot) data of purse seine fishery are routinely collected but not standardized. CPUE data have not been used as a tuning index of VPA because of the lack of age-disaggregated data.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? Selectivity of driftnets has been assessed using simultaneous deployments of different meshed nets. Gear saturation of driftnets for sardine is probably negligible. Effects of time of day and towing speed were examined for midwater trawl nets (25m high x 34m wide opening and 26m x 57m opening) and it was concluded that night-time operations towed at more than 3 knots for 30 minuets were suitable for sampling adult sardine.
	Acoustic surveys	Validation of species mix and target strength, area coverage? Acoustic surveys have been tried but not established for this species because of the difficulty of discriminating mixed species.
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast using NORPAC nets. Maturation of adults has been

		investigated in the major spawning area around the spawning grounds. Stages of eggs are unspecified.
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area Egg/larvae surveys have been intensively carried out along the entire coastal/offshore waters along the Pacific coast using NORPAC nets. Prelarvae and postlarvae are distinguished. Drift out of the covered area is presumably negligible at low stock periods.
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? One of the midwater trawl surveys covers almost entire distribution of juveniles (age 0) in the Kuroshio Extension and Kuroshio-Oyashio Transition Zone during spring.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. Catch-at-age data are processed from (1) commercial catch in weight by month and by major fishing grounds and (2) corresponding length frequency data of mainly purse seine fishery and (3) an age-length key. Scales are used for age determinations. Weight-at-age data are obtained from the same data set. Maturity-at-age is estimated from biological samples. Sampling is designed on the basis of a traditional method (usually fisheries, period or areas with large landings). No high-grading are recognized. Ageing error is never assessed.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No tagging data is used for stock assessments.
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? Reproductive success of this stock are significantly correlated with (1) strengths of Oyashio in winter and (2) sea surface temperature (SST) anomaly in the southern area of Kuroshio Extension (KESA) during winter-spring and possibly with (3) Kuroshio path types. High survival rates from post-larval stage to age 1 fish were observed when SST is low in both KESA and Kuroshio-Oyashio Transition Zone (TZ). Strong meandering of Kuroshio Current in central Japan (A-type) adversely affected survival of sardine larvae probably due to low productivity around the Kuroshio Current. Relatively higher zooplankton biomasses in the TZ in the cooler periods and around the Kuroshio Current in non-A-type path period may be related to high reproductive successes.
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Yes, many fishery scientists in Japan, particularly those who belong to prefecture research stations, are familiar with purse seine fishery and other fisheries such as set-net and *shirasu* (whitebait) fishery. In order to exchange information on stock status, sea conditions, economics, etc., they have been frequently contacting fishers, fishing company representatives and local market staffs.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? VPA and egg survey results have been used for stock assessment. As a tuning index for age 0 fish, the above trawl survey results (since 1996) have been used. Egg abundance time series shows similar trend to that of spawning stock biomass obtained from VPA since 1951. Sexes are combined in the model used since no sexual differences were observed for growth and maturation. No alternative models were considered.
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? It is unnecessary to perform spatially explicit assessments because of the stock structure and fishery status.
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality coefficient M is assumed 0.4 per year based on the empirical relation between life span and M. This M value is used for all ages and all years. Fishing mortality is calculated from VPA, where fishing mortality coefficient F of the oldest age group (age 5 and older) is assumed equivalent to F of age 4 because of no substantial ecological differences between age 4 and age 5+.
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? In the current VPA, no weighting were performed since only a single tuning index (trawl survey for juveniles, see above) is used.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? Only a sensitivity analysis of effects of M and RPS on VPA results and ABC determinations has been conducted.

	- bayes posteriors	
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Retrospective analysis was performed but not published because of short time series of the tuning index (since 1996).

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? A forward VPA is currently used for short term prediction. Matsuda et al. (1992, Res. Popul. Ecol., 34) presented a long term (500 years) simulation using an inter-species competition model (sardine, anchovy and chub mackerel) incorporating random environmental fluctuations on intrinsic growth rates of populations; this study examined only theoretical aspects of species replacements and parameters were selected to ensure a long-term sustainable fluctuations of 3 species.
4.2	Spatially explicit or not	Spatially not explicit.
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? In the forward VPA, constant *M* and *F* for all ages and years are assumed. Recruitment numbers are assumed on the basis of the trawl survey for juveniles.
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? No spawning stock-recruitment relationship is hypothesized. Recruitment per spawners (RPS) was closely related to Oyashio strength and SST of KESA. Recruitment levels in the next year are judged by the above trawl survey. Juvenile abundance index from the trawl survey showed nice correlation with RPS, although time series started in 1996. Thus, recruitment of sardine can be predicted if future conditions of Kuroshio and Oyashio are forecasted. Given the decadal-scale species replacements between sardine, anchovy and chub mackerel in the Northwestern Pacific, associated with ocean-climate changes, it is necessary for the future stock management of small pelagics to proceed process studies and a long-term monitoring for validation of these study results.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? Uncertainty of model parameters is evaluated only sensitivity analyses of *M* and assumed RPS.
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. Predictions of stock abundance are evaluated one-year after only in a qualitative manner.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? *Frecovary* and 0.8 *Frecovary* are used as limit and target reference points; *Frecovary* is an *F* value by which current SSB (the lowest since 1988) can be doubled within 10 years.

6.6 - Pelagic fish in the Bay of Biscay and Iberian Peninsula (prepared by Benjamin Planque and Angel Borja)

General environmental features

Geographical boundaries

The area considered here corresponds to ICES areas VIIIa,b,c,d and IXa. This area is bounded North by the 48°N parallel, west by the 11°W, South by 36°N, and east by the coasts of France, Spain and Portugal.

The bathymetry is characterised by narrow continental shelves along the Spanish and Portuguese coasts. The continental shelf along the French coast is narrow in the south (few km) and gets larger with latitude (>100 km). The depth ranges from few meters in the coastal areas to >4000m on the abyssal plain. The area can be divided geographically in 3 coasts: Iberian west, Iberian north and French west.

Remarkable hydrological features

The slope current is a dominant hydrological feature, which links the three coasts. This current transports warm saline water from Mediterranean origin towards the north, mostly during autumn and winter.

Wind driven upwellings are observed on the three coasts, but the activity is greatest on the Iberian west coast. Upwellings influence primary productivity, particle transport and river plumes geographical location. Upwelling activities are more predominant during spring and summer.

There are many additional meso-scale features that result from the interaction of the different waters masses in the area, rivers runoff and wind. These structures are not permanent, and are generally found during particular season. These meso-scale structures are important and play a key role in the distribution of plankton and fish.

Selected species

Anchovy (Engraulis encrasicolus)

Anchovy is present in all of the Bay of Biscay area, with major concentrations in the south-east corner (Cantabria, Basque Country and Atlantic coast of France up to southern Brittany). Spawning is principally concentrated in the south-eastern part of the bay, in front of the Adour and Gironde estuaries. The anchovy population undergo seasonal migrations, and so does the fisheries. Fish are mature at 1-year, and 1-2 year groups constitute most of the catch and the life span extends to 6 years. 1-year old fish spawn mainly in the estuaries while 2-year old spawning takes place on the continental shelf break. Assessment by cohort analysis goes back to 1987. Recruitment indices are available since 1967 and catch data / landings since early 20^{th} century.

Sardine (Sardina pilchardus)

The Iberian Sardine Stock is distributed along VIIIc and IXa ICES. Two main nursery areas located in the Gulf of Cadiz and in IXa Central North. Adult fish are mainly located in the south of Portugal and in VIIIc. However, the number of older fish in VIIIc decreased and the relative abundance of older fish increased in the south of Portugal. Recruitment at area starts in March. Assessment by cohort analysis goes back to 1978 and catch data / landings since 1940.

Mackerel (Scomber scombrus & S. japonicus)

The North-eastern Atlantic Mackerel (NEAM) is distributed widely along the European coasts, being a well-known migratory species. ICES assumes the existence of three spawning components one in the North Sea, another in the southern area (Divisions VIIIc and IXa) and another in the western area (spawning over all remainder areas, VIIIa,b,d, VII and VI). The mackerel from the southern and western areas are strongly connected, having a somewhat similar pattern of migration; tagged mackerel from the southern area are caught in summer, autumn and winter within the western fisheries area. The major spawning grounds of the NEAM are located along the edge of the continental shelf, along the mid-southern part of the European coasts, from the northwest of Ireland to the northwest of Spain. Maximum egg abundance records occur in the vicinity of Great Sole Bank. Spawning starts and ends earlier in the southern areas (March-June, with a peak in April), than in the mid-western grounds (April- July). The optimum range of sea surface temperatures for spawning is 13-15.5 ºC. The latitudinal propagation of spawning appears to follow the increase of sea surface temperatures in the spring; this is coupled with the spring spawning migration of adults. Recruitment areas of juvenile NEAM (about 4-10 months old) occur in the nearshore areas along the coast of the spawning areas, as in the northwest of Portugal and Spain, the Cornwall Peninsula, the northwest of Ireland and other areas (including North Sea). Recruitment indices are available since 1967 and catch data / landings since middle 20^{th} century.

Environmental indices

Upwelling indices

There are several ways of calculating upwelling indices. In the Bay of Biscay 3 solutions have been experimented: (1) geostrophic calculation from SLP measurements following the approach of Bakun (1973), (2) volume of vertically upwelled water derived from 3D hydrodynamical modelling and (3) area occupied by abnormally cold water.

Slope current intensity

To our knowledge, there is no index of slope current intensity, and although the current has been described (mainly by numerical modelling), the degree of interannual variability has received little attention.

Stratification breakdown and turbulence

An index of stratification breakdown has been developed for the shelf in the Bay of Biscay, during late spring - early summer, using 3D hydrodynamical modelling. It mainly reflects strong wind events during the early summer season. Various turbulence indices (reflecting wind-induced turbulent mixing) have been constructed in the Bay of Biscay.

Mesoscale features

Many features have been described (see e.g. Koutsikopoulos and Le Cann, 1996); they vary between seasons and between years. No indices.

North Atlantic Oscillation (NAO) index

The North Atlantic Oscillation is known to influence weather patterns over Europe, but the effects of the NAO are region dependent. Variability in precipitation, temperature or wind in the Bay of Biscay are not related to the state of the NAO, whilst precipitations and wind to the west of the Iberian peninsula are.

Linkage between indices and pelagic fish fluctuations

Upwelling: Two indices have been proposed to relate Bay of Biscay anchovy recruitment to the environment: (1) the geostrophic upwelling index (Borja, et al., 1998), and a combination of 3D modelled upwelling and stratification breakdown (Allain, et al., 2001).

NAO: Borja, et al. (in press), have found slightly significant negative relationships between NAO and mackerel recruitment, but not with anchovy. The NAO, together with Ekman offshore transport and SST can explain 75% of the variability in sardine recruitment (Cabanas and Porteiro, 1998)

Turbulence: Turbulence (expressed as the cube of wind velocity) has been used to explain some variability in the recruitment of anchovy and mackerel. In the first case, (Borja, et al., 1996) stated that turbulence might be a second important factor in the success of anchovy's recruitment, linked to the above-mentioned upwelling index. In the case of mackerel (Borja, et al., in press), have recently established that about 50% of the variability in recruitment of this species can be explained by a turbulence index calculated for the entire area of distribution (by summing different periods along the European coasts, coinciding with the migration and spawning time).

Current use of environmental indices by the ICES WG on AMHMSA (Anonymous, 2001)

The indices proposed for the recruitment of anchovy are received by the WG. They are used in the context of forecasting for ICES area VIII, but they are not included in the tuning procedure. Their use remains rather informal at present. For sardine, environmental effects are discussed at the WG, and it is thought that the information should be used, but this is not done at present. For Mackerel, environmental indices are not considered by the assessment Working Group.

References

Allain, G., Petitgas, P. and Lazure, P. 2001. The influence of meso-scale ocean processes on anchovy (*Engraulis encrasicolus*) recruitment in the Bay of Biscay estimated with a three-dimensional hydrodynamic model. Fisheries Oceanography, 10: 151-163.

Anonymous. 2001. Report of the working group on the assessment of mackerel, horse mackerel, sardine, and anchovy. ICES CM, 2001/ACFM: 06.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-71. National Marine Fisheries Service, Communication, 74-50004: 1-104.

Borja, A., Uriarte, A. and Egaña, J. in press. Environmental factors and recruitment of mackerel, Scomber scombrus L. 1758, along the north-eastern Atlantic coasts of Europe. Fisheries Oceanography.

Borja, A., Uriarte, A., Egaña, J., Motos, L. and Valencia, V. 1998. Relationships between anchovy (*Eugralis encrasicolus*) recruitment and environment in the Bay of Biscay (1967-1996). Fisheries Oceanography, 7: 375-380.

Borja, A., Uriarte, A., Valencia, V., Motos, L. and Uriarte, A. 1996. Relationships between anchovy (*Engraulis encrasicolus* L.) recruitment and the environment in the Bay of Biscay. Scientia Marina, 60 (Suppl. 2): 179-192.

Cabanas, J.M. and Porteiro, C. 1998. Links between North Atlantic sardine recruitment and its environment. ICES CM, 1998/R:23: 10pp.

Koutsikopoulos, C. and Le Cann, B. 1996. Physical processes and hydrological structures related to the Bay of Biscay anchovy. Scientia Marina, 60 (Suppl. 2): 9-19.

Stock: *Bay of Biscay anchovy (Engraulis encrasicolus)* Author: *A Borja, B Planque and A Uriarte* Date: *June 2001*

1. General

Step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock *ICES area VIIIa,b,c (continental shelf, west of France and North of Spain)*
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? *No definition of stock structure. Morphological heterogeneity was found in some studies (Prouzet & Metuzals 1994, Junquera 1993). Genetic studies are underway and current results suggest little genetic variability within the Bay of Biscay.*
1.3	Spatial structure	Is or should the assessment be spatially structured? *Based on several considerations (well defined spawning site and parallelism between fish migration and fisheries movement) the ICES assessment WG considers a single management unit for assessment purpose.*
1.4	Single/multi-species	Choose single-species or multi-species assessment. *Single species*

2. Data

Step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? *Discards are not recorded in the French or Spanish fisheries. It is estimated that less than 5% of Spanish purse seine catches are not landed but used as live bait for tuna fishing. The fishing statistics are considered accurate and the fishery is well known.*
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? *Catch statistics: absolute index for age-disaggregated abundance.* *Egg surveys: absolute index for SSB* *Acoustic surveys: index for TB, used as relative by the WG*
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? CPUE for Spanish and French fleet are compiled, but not used in assessment. Spanish CPUE is not area desaggregated (so not 0 catches are met). French CPUE is restricted to positive rectangles (across years) NOTE: French pelagic trawl CPUE are used in a forecasting mode to estimate anchovy biomass at the start of the fishing season. Zero catches are not considered. Pelagic trawl CPUE and purse-seiner CPUE can not be compared.
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? *Pelagic trawling are done in combination with acoustics (i.e they are qualitative), they don't contribute directly to the assessment.*
	Acoustic surveys	Validation of species mix and target strength, area coverage? Schools are monospecific and distinct school types are related to distinct echo traces based on the catches from hauls carried out during the acoustic surveys. The survey covers the Bay of Biscay Continental shelf. Sampling design is transects perpendicular to the isobaths and equally spaced (10-12 nautical miles). Target strengths are based on historical relationships (per species per length) which are kept unchanged. *Acoustic survey data are available since 1983, with gaps in 1985-1988, 1993, 1995, 1996*
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? *Egg surveys since 1987 (gap in 1993). DEPM: all above mentioned parameters estimation in all years except in 1996, 1999 and 2000. In these years the estimation is only based on egg production estimations and in the historical regression between SSB and egg production.*
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area *No surveys for quantitative purpose, but for larval conditions.*
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? *The European project Juvesu had 2 experimental surveys in 1998-1999.*
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. *Catch-at-age by quarter, by country and by ICES subareas (VIIIbc for Spain, VIIIab for France)* *Weight-at-age by semester, by country.* Maturity-at-age. Anchovies are mature at age 1. Fecundity is proportional to body weight. *Length distribution by quarter by country and by ICES subareas (VIIIabc for Spain, VIIIab*

		for France) *Biological sampling of the catches are considered sufficient. However, an increase of the sampling effort seems useful to have a better knowledge of the age structure of the catches during the second semester in the North of the Bay of Biscay. Sampling precision is low for age 3+.* *Age reading is considered accurate and cross reading is currently done between Spain and France. Otoliths typology is made. Indirect validation with the fluctuation of the stock (2 years old validation).*
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? *No tagging program*
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? A geostrophic wind based upwelling index is currently used as an environmental proxy linked to anchovy recruitment in ICES area VIII. The index is not predictable at the moment but wind observations are used to nowcast year-class strength in the year of birth. *Note that, hydrodynamic-model derived upwelling intensity is fairly different from wind-based calculations. Other processes, such as strong wind events during larval phase are now being taken into consideration.* *Other environmental information exists, either from observations (e.g. temperature, water stratification, river runoff) or from hydrodynamic model output (e.g. river plume extent, transport currents, turbulence).* *The recruitment time-series is short, and consequently, the risk of spurious correlations between environment and recruitment is high.*
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? *There are 2 main fisheries, a Spanish one in Spring fishing only with purse seine and a French one using mainly the pelagic trawl. A small fleet of French purse-seiners fish in the South and in the North of the Bay of Biscay. (Details on the fisheries data is available in Prouzet et al 1999. Estimation of fishing (F) and natural mortality (N) from direct assessment methods of small pelagic fish. EU contract 95/PROP/018 final report (in French).*

3. Assessment model

Step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered? How is the performance in comparison? Time span covered? *Integrated Catch Analysis (ICA) 1987-now. Inputs to the model are:* *-Catch-at-age, Weight-at-age (in catch and stock), natural and fishing mortality at age, DEPM surveys, acoustics surveys. The output of the ICA is strongly conditioned by the DEPM estimates.* *No other model is considered.*
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? *The current assessment model is not spatially explicit, and this has not been considered necessary by the assessment WG.*
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Natural mortality is set to 1.2 and invariant, although it is considered variable and probably higher some years. *Catchability for the DEPM index is assumed to be 1 (absolute estimator of SSB)*
	Recruitment	*No stock/recruitment relationship is assumed. However, below 18,000 tonnes(Blim) a link between recruitment and spawner abundance is assumed.*
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? *Accuracy of the data are not taken into account. The model is a weighted sum of squares, weights allows to translate the validity of the information used. They are determined arbitrarily. Errors are assumed to be log-normal.*
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile – bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? *Asymptotic estimates of variances.* *No explicit evaluation of the uncertainty*
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realizations of assessments evaluated? How much contrast in the stock development? *Not done so far (2000)*

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

Step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? *Age predictions models* *Based on ICES deterministic projections (IFAP).*
4.2	Spatially explicit or not	*The predictions are not spatially explicit.*
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? *Fishing mortality and catchability assumption for DEPM, natural mortality.*
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? Are environmentally driven reductions or increases in recruitment considered? *In 1999 an environmental index was used in a quantitative way, but in 2000 it was not applied, due to some problems. In 2000, 2 environmental indices were proposed to the WG, which evaluated there ability to hindcast recruitment but did not use them formally. This is now on the state of refinement.*
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? *The uncertainty is visible. Input uncertainty is not used in the estimation procedure of parameters. Output uncertainties of the assessment parameters are used as input for the short term projection (1 year ahead), using short term sensitivity analysis (Cook 1993).*
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. *Insufficiently developed. Only a single year prediction made in 1999.*
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? *Blim: 18000 t., Bpa: 36000 t., established by ICES, but subjected to revision.(36000t is not the Bpa as defined by the ad'hoc ICES WG, but the minimum biomass so that the following year's biomass equals at least 18000t in case of poor recruitment).*

Stock: ***Iberian sardine*** **Author:** ***A Borja, B Planque and A Uriarte*** **Date:** ***June 2001***

1. General

Step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock *The management area for this stock is ICES area VIIIc and IXa (North and West of the Iberian Peninsula). The spatial distribution of the population extends further North, and the spatial extent is related to the stock size. Location and extent of spawning areas also varies through time. There is not a full understanding of the migration patterns and how they might have changed through time. Qualitative information about distribution of sardine North of the management area is used by the assessment WG.* *A review of the stock dynamics has been done last year (ICES CM2000/ACFM:5).There are two main nursery areas located in the Gulf of Cadiz and in IXa Central North. Adult fish are mainly located in the south of Portugal and in VIIIc. However, the number of older fish in VIIIc decreased and the relative abundance of older fish increased in the south of Portugal. Recruitment at area starts in March.*
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? *Meristic and morphometric studies have been carried out. There appear to be a latitudinal cline in these characteristic, rather than clear separation points. The conclusions of these studies on the separation of Iberian sardine in distinct sub-units are not straightforward.*
1.2	Spatial structure	Is or should the assessment be spatially structured? *The assessment is not spatially structured, the stock is.*
1.3	Single/multi-species	Choose single-species or multi-species assessment. *Single species*

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? *Catches are included in the assessment. 99% of the catches were covered by the sampling programme. The bulk of the catches are taken by purse seiners with no discards.. There are no estimates of discard available from this stock*
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? *Catch statistics: absolute index of abundance disagregated by age* *Egg surveys: absolute index of SSB* *Acoustic surveys: absolute index of biomass, used as a relative index* *Four time series of age disaggregated indices area available, Portuguese November acoustic survey, Portuguese March acoustic survey, Portuguese August acoustic survey and Spanish March acoustic survey. Daily Egg Production Method was undertook in 1988, 1990 and 1999 and estimated SSB is available.*
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? *CPUE for Spanish and Portuguese purse seine fleet are considered.*
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? *Pelagic trawling are done in combination with acoustics (i.e they are qualitative).*
	Acoustic surveys	Validation of species mix and target strength, area coverage? Three series of acoustic surveys area presently available. None of these covers the whole distribution area of the stock. The Portuguese November acoustic started in 1984; there are two gaps, from 1988 to 1992 and from 1993 to 1997. The Portuguese March acoustic survey has continuity since 1996 covering as well the Gulf of Cadiz; other two survey covering the Portuguese area in March were undertook in 1986 and 1988. The Spanish March acoustic survey begun in 1986; no surveys for 1989 and 1994 are available. 1995 survey is not used because the different period in which it was carried out. In addition, French surveys are carried north of the assessment area. In VIIIb since 1989 (with the exception of 1995, 1996, 1999) and in VIIIa,b, for 2000 and 2001. With the coming of contractual agreement with the EU, this last survey will be done annually, together with the collection of eggs using CUFES and surface environmental parameters. Potential concentrations of sardines in shallow waters are not studied by these acoustic surveys at present. *Schools are monospecific and distinct school types are related to distinct echo traces based on the catches from hauls carried out during the acoustic surveys. Sampling design is transects perpendicular to the isobath and equally spaced (10-12 nautical miles). Target strengths are based on historical relationships (per species per length) which are kept unchanged.*

	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? *DEPM was conducted for the whole area in 1997 and 1999. The whole area except Cadiz was also covered in 1988. In 1990 a new survey covered only the Spanish area.* *Adult parameters are derived from the Eastern Cantabric area only.*
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area *No surveys.*
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? *No surveys*
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. *Catch-at-age by quarter, by country and by ICES subareas (VIIIc east, VIIc west, IXa North, IXa Centre-North, IXa Centre-South, IXa South)* *Weight-at-age and length-at-age by quarter, by subdivision..* *Biological samples are done in a quarterly and ICES Sub-division basis. Data are pooled from this basis. Age groups are disaggregated up to 6+. Maturity ogive, weight at age are calculated each year. Last years, different otolith structures has been observed; this might led to a miss-allocation of age groups in younger fish. Otolith exchanges and the study of the daily otolith increments are implemented. Fish from VIIIc are in general longer and heavier than those of the IXa .*
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? *No tagging program*
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? *No environmental information is used at present. Some potential candidates are the intensity of upwelling along the Iberian western coast, SST, NAO index (related to the west-Iberian upwelling) and the Gulf Stream index (which is statistically related to recruitment).*
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ?

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? *Integrated Catch Analysis (ICA) back to 1977. Inputs to the model are:* *-Catch-at-age, Weight-at-age (in catch and stock), natural and fishing mortality at age, DEPM surveys, acoustics surveys, CPUE indices from 2 purse seine fleets.* *Other models are considered (but the outputs are not reported by the Working Group)*
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? *The current assessment model is not spatially explicit, and this option has not yet been considered by the assessment WG.*
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. *Natural mortality is fixed at 0.33 for all ages.* Fishing mortality is considered unreliable, mainly due to changes in selection patterns over time. *Two separable periods with different selection pattern are assumed (from 1987 to 1993 and from 1994 onwards).* *Acoustic indices fitted with linear catchability.* *DEPM are used as absolute indices.*
	Recruitment	*No stock/recruitment relationship is assumed .*
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? *Accuracy of the data are not taken into account. The model is a weighted sum of squares. Weights are all set to 1 except for catch-at-age data for which they are determined arbitrarily.*
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile – bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? *No explicit evaluation of uncertainty. Exploratory analysis of the data is done for sensitivity purposes.*
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? *No*

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

Step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? *Age predictions models based on ICES deterministic projections (IFAP). Single species.*
4.2	Spatially explicit or not	*The predictions are based on 2 scenarios, for the whole area, and for VIIIc and IXa divisions. .*
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? *Fishing mortality from the last assessment. Weights in the stock and in the catches as the mean of the last three years. Maturity ogive from the last year. Age group 1 in 2000, estimated as the projection of geometric mean of the last 6 recruitment at age 0.*
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? Are environmentally driven reductions or increases in recruitment considered? *Geometric mean of the last six years as estimated by the ICA model. No S/R relationship, no environment, no depensation or autocorrelation.*
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? *There is no evaluation of uncertainty.*
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. *There is no post-hoc evaluation of prediction.*
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? *The assessment WG (CM 1999:ACFM:6) has decided not to calculate reference points because of uncertainty in model structure and in particular of the 'absence' of visible SSB/R relationship.* *In 2000 (CM2000:ACFM:5) however, biological reference points were calculated: Blim 230 000 tonnes and Bpa 320 000 tonnes.*

Stock: *North-East Atlantic Mackerel*
Author: *Angel Borja, Andrés Uriarte*
Date: *July 2001*

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock *The spatial extent of the North East Atlantic mackerel (Scomber scombrus), covers ICES areas IIIa, IV, VI, VII, VIIIa,b,c,d,e, and Ixa, that is from Iberian to the west of Ireland and the North Sea. This is all considered now as a single management unit, which is composed of three components: southern, western and North sea.* *Stock components are separated on the basis of catch distribution, which is more reflecting management considerations and different historical information available than biological evidence: Western component: spawning in subareas and Div. VI, VII, VIIIabde, distributed also in IIa, Vb, XII, XIV; North-Sea component: spawning in IV and IIIa (but as the North Sea component is almost non-existent, most of the catches in IVa and IIIa actually belong to the Western component); Southern component: spawning in VIIIc and IXa. Possible problems with species mixing (S. japonicus) in the Southern part of the area.*
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? *There are many surveys for tagging, interesting results have been achieved in the last years, establishing the migration routes. A recent genetic study indicates several subpopulations. Clearly, there are important mixing between mackerel from western and southern areas all year round. On the other hand the North Sea mackerel appears as a separate unit.*
1.2	Spatial structure	Is or should the assessment be spatially structured? *It is not possible, the recent tendency is to unify.*
1.3	Single/multi-species	Choose single-species or multi-species assessment. *Single-species*

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how?
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)?
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished?
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed?
	Acoustic surveys	Validation of species mix and target strength, area coverage?
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity?
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)?
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors.
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered?
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates?
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ?

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered?
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented?
3.3	key model parameters:	Are these parameters assumed to be constant or are they estimated? If they are

	natural mortality, vulnerability, fishing mortality, catchability	estimated, are prior distributions assumed? Are they assumed to be time-invariant.
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known?
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds?
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development?

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ?
4.2	Spatially explicit or not	
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters?

6.7 - Sardine ICES IXa +VIIIc (Atlantic Iberia) (submitted by M. Fatima Borges and Miguel P. Santos)

In Western Portugal the Summer upwelling conditions play an important role in the success of the yearly recruitment of Sardine to the nursery. Long-term changes have been observed in alongshore winds off Portugal in the last decades in winter months. During sardine spawning season (winter), northerly winds that favor upwelling lead to unfavorable conditions for egg and larval survival. Decadal changes have been observed in the annual catch of sardine (*Sardina pilchardus*).

By using time series analysis, we investigated the effect of NAO and wind conditions on the recruitment strength of sardine population We also investigated the time lag between recruitment strength and its turnout in catches. Our time series retrospective analyses lead to the possibility of forecasting sardine recruitment by using key environmental variables – the winter wind conditions. We conclude that recruitment is forced to a lower bound when northerly wind overpasses a certain limit in winter.

Stock: Sardine ICES IXa +VIIIc (Atlantic Iberia)
Author: M.F. Borges
Date: 27 August 2001

1. General

step	Item	Considerations
1.1	Stock definition	What is the spatial definition of the stock *The ICES stock for management advice under assessment is from Gibraltar- Division IXa to the VIIIc Division close to Cape Breton* *ICES defined the stock according to the existing directed fisheries to give management advice*
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? *No*
1.2	Spatial structure	Is or should the assessment be spatially structured? *Yes*
1.3	Single/multi-species	Choose single-species or multi-species assessment. *Single Species*

2. Data

step	Item	Considerations
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? *The sampling design is documented in ICES Working Groups Reports as well sampling intensity*
2.2	Indices of abundance Acoustic Survey indices are relative SSB indices relative and absolute Daily egg production	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)?
	Catch per unit effort *Survey indices*	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? *Commercial cpue is only used for recruitment information and are only relative to the nursery area*
	Gear surveys (e.g. trawl, longline) *Not applicable*	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? *Not aplicable*
	Acoustic surveys *Yes*	Validation of species mix and target strength, area coverage? *This was made and reported in the ICES Planning Group of the Surveys*
	Egg surveys *DEPM*	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? *ICES Working Group for Sardine Egg Production for sampling design and protocols*
	Larvae surveys *SURVIVAL project experiment in the main nursery of the northwest Portugal*	Stage, size specific abundance, production, consideration of drift out of covered area *Larvae number, drift, stage.*
	Juvenile surveys *One in the Autumn /Winter and another in March, covering the recruitment season and spawning season which starts in the Autumn*	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? *The Autumn survey covers the area from Gibraltar to Minho river covering the nurseries during the spawning time*
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors. *All are very good. The only problem is that the sardine distributes north of the defined stock up to Ireland and for that there are not sampling, but some information was available from surveys on anchovy or herring . More recently the acoustic survey extended the northern boundary further north.* *Further South there is not a monitoring survey of the north Africa contiguous sardine.*
2.4	Tagging information *No*	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered?
2.5	Environmental data *They are not used yet but there are some research towards using Winter wind or upwelling indices*	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates?
2.6	Fishery information *Yes, very much*	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ?

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model ICA !978-2000 *Separable model i.e constant structure over the period not allowing emigration or emigration*	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered? There is interest for alternative models.
3.2	spatially explicit or not not spatial explicit	If not, is it necessary, and if yes, why not implemented? *Modelling difficulties*
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. *Assumed to be Constant*
	recruitment	*For predictions is assumed only for 0 group in the next year*
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? *Tuning is not weighted by the inverse of variance* *For log normal distributions SS and ML are the same see literature*
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? *Confidence bounds only for tuning process exploratory analysis*
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? *Yes. No contrast.*

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short term Medium term for 5 years. Assumed R/S relationship for medium term and risk assessment considering Bpa or Blim
4.2	Spatially explicit or not	*Not*
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for? *None*
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? SSB/R relationship Beverton and Holt
4.5	Evaluation of uncertainty Not presented to the managers	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model?
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions.
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? Biomass pa

6.8 - Clupeids in the Baltic Sea (submitted by Fritz W. Köster)

The presentation will give a brief summary on trends in landings, fishing mortalities, abundance and biomass of sprat and herring, being by far the dominating pelagic fish species in the Baltic. While sprat showed a pronounced increase in stock size and landings from the late 1980's to mid 1990's, herring landings and biomass decreased throughout the last 20 years. Despite increasing fishing mortalities, the herring abundance has been relatively stable, i.e. the decline in landings and biomass is mainly caused by a drastic decline in weight at age from early 1980's to mid 1990's.

Different hypothesis have been put forward to explain this change in apparent growth rates: i) a reduction in size selective feeding by cod, preying predominantly on smallest individuals within a herring age-group, ii) different developmental success in sub-stocks exhibiting different growth rates, and iii) limitation in food supply. For sprat a similar decline in weight at age occurred since the early 1990's, i.e. a period when the cod stock, as the major predator in the system, was already on a historic low level, excluding the first hypothesis as an explanation. Furthermore, the stock structure of sprat is considerably less heterogeneous than in herring, i.e. considering the Central Baltic sprat to be a unit stock appears to be more realistic. Consequently all sprat stock sub-components exhibit a similar reduction in weight at age. However, the third hypothesis seems to hold for sprat, as prey availability for individual sprat declined concurrently with the weight at age. While in the 1980's the decline in *Pseudocalanus elongatus*, a major calanoid copepod prey species of both herring and sprat, was compensated by an increase in standing stocks of *Acartia* spp. and *Temora longicornis* utilized by sprat, the drastic increase in the sprat stock size due to high reproductive success and low fishing intensity resulted in a food limitation during the 1990's. In accordance, a highly significant relationship between sprat weight at age and stock sizes is obvious and may be used for prediction purposes.

The negative development of standing stocks of *Pseudocalanus* and mysiids, both important prey of herring, are coupled to decreasing salinities in the Baltic caused by the lack of inflows from the North Sea and an increase in river runoff. The increase in standing stocks of especially *Acartia* are coupled to high spring temperature caused by warm winters. The latter situation clearly favours sprat, although biomass values of above 2.5 mio. t approach obviously the carrying capacity of the system, as density dependent processes become apparent. In this respect, it should be added, that in specific areas and during periods characterized by specific hydrographic conditions an intensive egg cannibalism has been detected, which may act as a further compensatory process.

Predation by cod is a major source of clupeid mortality, with all age-groups of sprat suffering from predation, while herring is preyed upon intensively only as juveniles. The drastic decline in the cod stock throughout the 1980's caused a substantial reduction in predation mortality and in fact utilizing MSVPA output predation mortality may be predicted simply by the biomass of adult cod. The shift in distribution of the cod stock, or more precisely the concentration of the remaining stock in south-western areas of the Central Baltic with a virtual extinction in the north-eastern areas, resulted in still relatively high predation intensity in the former area, while in the latter the predation mortality is negligible. Again the sprat stock benefited from the reduction in predation mortality more than herring, however, in most recent years compensated by a developing industrial fishery.

Species specific spawning stock biomass and recruitment showed an overall similar trend, increasing in sprat since the late 1980's and slightly decreasing in herring since the early 1980's. However, a considerable interannual variability in recruitment independent of the SSB suggests in specific years a de-coupling of reproductive success from the spawning stock size. Pre-requisite for an analysis of the driving forces of underlying processes is a reliable determination of the reproductive effort and surviving offspring. While this appears to be possible for sprat, for herring the complex stock structure is a major obstacle.

Different stock components of the Central Baltic herring stock reproduce with considerably different success. While the herring in the open sea areas of the Central Baltic showed pronounced negative developments in SSB and recruitment, with the autumn spawning herring being already on a very low level since the 1970's, the herring in the Gulf of Riga and the Bothnian Sea increased substantially in stock size throughout the last 15 years. For the latter stocks, separate assessment are conducted, making them suitable as case studies. In Gulf of Riga herring, recruitment at age 1 is significantly related to SSB, temperature in April and zooplankton abundance in May. The April temperature, being a measure of the severity of the winter, is assumed to be related to the magnitude of egg production and timing of spawning, while the zooplankton abundance in May is a proxy for larval food availability. All three variables are highly significant, explaining 75% of the variability in recruitment at age 1, however, with temperature and zooplankton being as well significantly related. Similarly temperature affects the recruitment of herring in the Bothnian Sea and Bay, while an impact in other areas in the Central Baltic has not been detected yet, perhaps due to summarizing different stock components encountering deviating hydrographic conditions.

For sprat, an exploratory analysis for the two sub-areas most intensively investigated, revealed significant relationships between SSB and realized egg production, realized and surviving egg production as well as surviving egg production and larval abundance. However, no relationship between larval abundance and 0-group recruitment exists. This suggests the larval stage to be the most critical life stages in sprat reproduction, confirming results for Gulf of Riga herring, showing also no statistically significant relationship between larval abundance and recruitment. The relatively high unexplained variability in the SSB - realized egg production relationship indicates furthermore, that maturation processes and changes in fecundity may introduce substantial variability in recruitment success. In fact incorporating the growth anomaly (as a proxy of nutritional condition of the adults) and temperature in the intermediate water in May (being also a proxy of winter severity), besides the spawning stock biomass enhances the relationship to the realized egg production from ichthyoplankton surveys. However, not only the amount of egg production may be determined by temperature conditions, but also egg survival. Lab experiments showed a reduced hatching success below 4°C, which corresponds to results obtained earlier for North Sea sprat. In fact the relationship of early and late egg stage production as obtained from ichthyoplankton surveys is enhanced by including temperature as an additional variable.

In an attempt to identify processes affecting the larval stage, various environmental variables reported to affect larval survival, i.e. i) temperature in the intermediate water, ii) oxygen concentration within and below the halocline, iii) wind speed anomaly, iv) larval retention in spawning areas or transport to shallow more productive waters, v) nauplii and juvenile calanoid abundance and vi) 0-group weight anomaly were tested by including them successively and in various combinations in a larval abundance – year-class strength relationship. The only significant and biologically sensible variable was temperature in the intermediate layer, most likely reflecting food availability due to enhanced nauplii and early copepodite production, although not directly visible from the available zooplankton data.

Including SSB, temperature and growth anomaly as variables in simple multiple linear regression models first for single subareas and then combined for the entire Central Baltic revealed 0-group recruitment estimates following in general the observed pattern, however, with considerable deviations in most recent years. Especially in 1996 predicted recruitment was substantially overestimated. In general, there is a close correlation between winter temperatures in the upper water column affecting sprat maturation processes and May/June temperatures in the intermediate water affecting egg survival and larval food production. However, this was not the case in 1996, when after a relatively cold winter the intermediate water during spawning was already relatively warm. Thus, conditions may have favoured high egg survival, but maturation and fecundity rates may have been low. This example emphasises the problem of integrating a single variable representing various processes into stock-recruitment relationships.

Apart from the larval stage in sprat, also the early juvenile stage may be affected by variability in food supply. Daily otolith increment widths of surviving juveniles showed substantial intra-annual deviations, with specific time periods obviously sustaining substantially higher growth rates than others.

In summary, hydrographic conditions, i.e. temperature (T), oxygen concentration in and below the halocline (O_2), salinity (S) and wind stress (W), forced by large-scale climatic processes impact on the population dynamics of sprat in various ways:

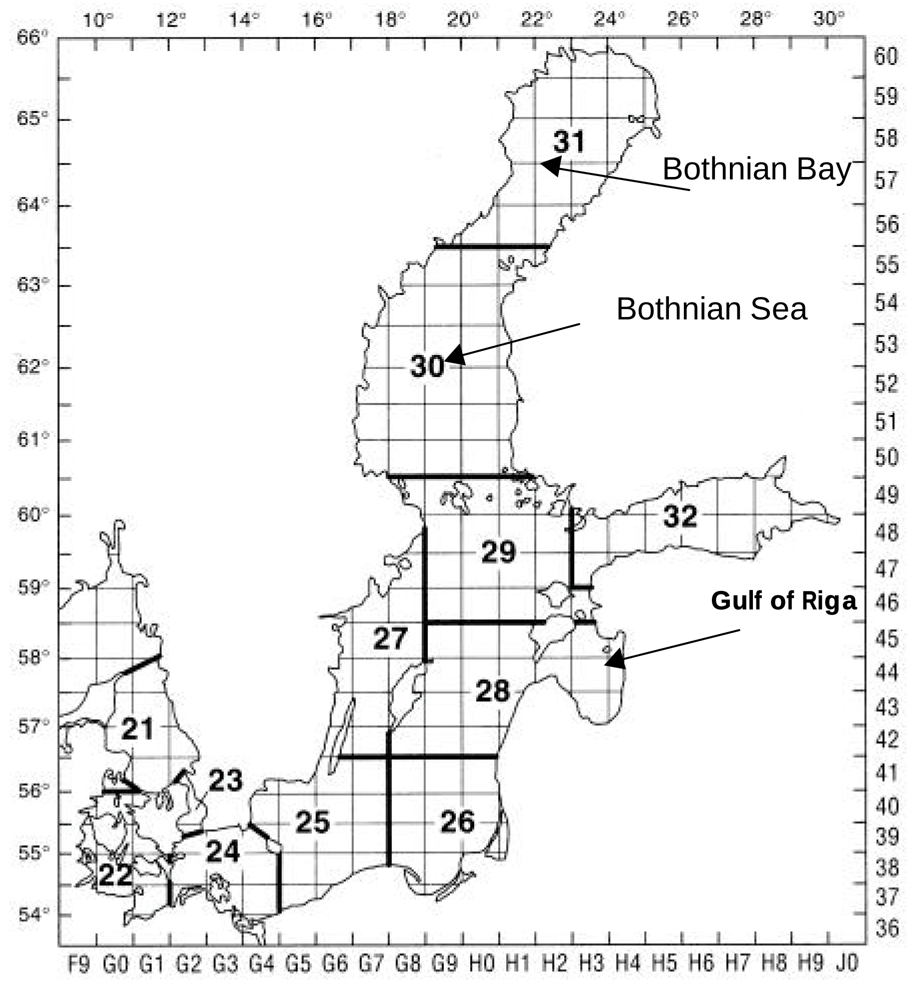
-directly by affecting i) distribution and thus utilization of suitable spawning areas as well as availability to the fishery (T and O_2 in winter), ii) growth rates (T, perhaps S and O_2), iii) maturation and fecundity (T in late winter/spring), iv) fertilization success (S) and v) development and survival of eggs (T and perhaps O_2 in spring/early summer);

-indirectly by affecting i) food availability of adults impacting on egg production (copepod standing stocks related to T and S), ii) food supply for larvae (nauplii and early copepodite stage availability related to T, S and W in spring/early summer), iii) cannibalism on eggs (vertical predator/prey overlap related to T and O_2

in spring/early summer), iv) predation on juveniles by cod (stock development of predator depending on S and O_2).

Apart from our conceptual understanding of different interacting processes enhanced in most recent years, derivation of relationships or proxies to be utilized in the hind-, now- and forecasting of the sprat stock development is still in its infancy in the Baltic. For herring, the situation is even less promising. Due to their mostly coastal or shallow water spawning and nursery areas as well as their heterogeneous stock structure, spatial variability in dominant processes can be expected to be considerably more pronounced, making general conclusions and the definition of environmental indices for larger management units extremely difficult.

Fig. 6.8.1 ICES Sub-divisions and statistical rectangles in the Baltic



Stock: Sprat in the Baltic
Author: Fritz Köster
Date: 19.08.2001

Reference: ICES (2001/ACFM:18), otherwise stated (see reference list)

1. General

Step	*Item*	*Considerations*
1.1	Stock definition	Entire Baltic (ICES Sub-divisions 22-32, see Fig. 1)
1.2	Stock structure	Morphometric including otolith analysis and genetics suggest at least two stocks: SD 22-24 and SD 26-32 (with nearly no sprat in SD 30 and 31) (Parmanne et al. 1994), SD 25 is somewhat controversial (Ojaveer 1989, Sjöstrand 1989) with present consensus that the area belongs to the eastern stock (SD 25-32); furthermore SD 26 and 28 as well as SD 27, 29-32 have been argued to be separate stocks (Ojaveer 1989), however the evidence is not generally accepted.
1.2	Spatial structure	The multispecies assessment separates between western and eastern stocks (ICES 1997/J:2), however, the single species assessment being basis of the management, utilising predation mortalities from the eastern multispecies assessment summarizes the entire Baltic as one stock with the argumentation that the western stock is very small; additionally MSVPA runs for single SD 25, 26 and 28 containing major spawning areas exist, but are presently not used in assessment (Köster et al. 2001a).
1.3	Single/multi-species	Choose single-species or multi-species assessment. As the single species assessment utilizes predation mortalities from regularly updated MSVPA (ICES 2001/H:4) the assessment is basically a multispecies assessment, spatial dis-aggregation has been argued to be important as the predator cod is virtually absent in SD 28-32 and thus predation close to zero (ICES 1999/H:5).

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Catch at age statistics before 1974 unreliable; unallocated landings and discards are not included, more problematic the sampling intensity of the industrial fishery developed throughout the 1990 is not sufficient.
2.2	Indices of abundance	Abundance indices used are from annual international hydroacoustic survey carried out since late 1970's in autumn and cover basically all age-groups, with problems for 0-group concentrating in shallow water (<20m) not covered by the survey; surveys in 1992, 1993 and 1997 not reliable, due to ship, equipment and personnel changes, however, Latvian/Russian survey in SD26 & 28 also in these years acceptable; unused indices for sub-areas: hydroacoustic survey in May/June (ICES 1999/H:5) and concurrent egg surveys (Köster et al. 2000).
	Catch per unit effort	None used.
	Gear surveys (e.g. trawl, longline)	The hydroacoustic survey covers the entire stock area, in former years not always most northern areas (SD 30-32); the survey is internationally standardized; calibration of equipment and intercalibration between ships performed each survey.
	Acoustic surveys	To separate between sprat and herring, approximately 100-150 trawl hauls are carried out in dependence of ship capacity available, otherwise see above.
	Egg surveys	Egg surveys regularly conducted in SD 25, 26 and 28 since the late 1950's, stage specific abundance available since early 1970's, with in general 3-4 surveys covering the spawning time with least reliability in SD 25 since 1990 (Köster et al. 2000); problems in area coverage during late spawning activity in summer; temperature dependent egg development rates from North Sea (Thompson et al. 1981), Baltic specific experiments conducted (STORE 2001); maturity at age knife edge and sex ratios (overall equal, but skewed with size/age) constant over time, although significant interannual variability exist however with limited impact on SSB – egg stage production relationship; fecundity fluctuates significantly between years (Alekseeva et al. 1997) probably in dependence of T, spawning frequency determined (Kraus et al. 2001).
	Larvae surveys	Larvae surveys conducted as above, but no stage and only for sub-sets length dependent data available; drift out of covered survey area depends on wind forcing and may be substantial (Voss et al. 2001), additionally data available for 1970-1980's in SD 29 (Sjöstrand 1989).
	Juvenile surveys	Age-group 1 covered in hydroacoustic survey; O-group in Polish young fish survey (bottom trawl) in SD 25 & 26 since 1976 (noisy); fingerlings in former USSR IKMT survey in SD 26 & 28 since 1979 (Sjöstrand 1989), interrupted from 1992-1998.
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Sampling effort not high enough in the industrial fishery especially in SD 27, no information on unallocated catches and discards (so far probably of minor importance); ageing routines well established. Weight at age in the catch used as weight at age in the stock, although data from hydroacoustic in spring and autumn available (however no major difference according to ICES 1999/H:5). Maturity at age data sampled and historic data being compiled, but not used presently (ICES 2001/ACFM:24); further reproductive information see above.

2.4	Tagging information	No information.
2.5	Environmental data	Presently no environmental information used. Potential candidates are: - Temperature in 1st quarter affects egg production (Köster et al. 2000) and timing of spawning (Elwertowski 1960), temperature in 2nd quarter affects vertical distribution and egg survival (STORE 2001), as well as prey production of larvae, i.e. nauplii of *Acartia* spp. and *Temora longicornis* (Grauman and Yula 1989); as a consequence of these dependences, temperature in spring in the intermediate water (reflecting also winter conditions) may be used to predict recruitment; due to coupling of temperature to large-scale climate process predictions of 1-group recruitment 18 months ahead (MacKenzie and Köster 2000). - Calanoid copepod abundance is positively related to temperature (*Acartia spp.* and *Temora longicornis*) and salinity in spring (*Pseudocalanus elongatus*), the latter copepod reproduction being in turn negatively related to spring temperature (Möllmann et al. 2000); availability of these copepods per sprat affects growth rates (Horbowy and Swinder 1989) and as a consequence weight at age is closely related to stock size and may also be predicted this way (ICES 2000/ACFM:14). - Oxygen conditions within and below the permanent halocline are expected to have an impact on egg survival (STORE 2001); predictions of oxygen concentrations possible within a given year and in eastern areas also one year ahead (Köster et al. 2001b). - Wind conditions determine how rapid transport into higher productive shallow waters occurs (Hinrichsen et al. 2001a), which appears to be coupled to larval prey abundance (Hinrichsen et al. 2001b), however, no indication of coupling to reproductive success yet (Köster et al. 2000); predictability very limited. - Cannibalism on eggs may be intensive, if the vertical overlap between predator and prey is high (Köster and Möllmann 2000), i.e. if sprat during their daily feeding period are staying relatively high in the water column, mainly because of lack of oxygen in the bottom water. - Cod abundance is related to predation mortality on 0-group sprat (Sparholt 1994) and predation mortalities may be predicted via cod SSB according to ICES (1993/Assess:17); predictability is coupled to the ability to forecast the cod stock development. - Water volume suitable for overwintering, i.e. temperature > 4°C and > 2ml/l oxygen concentration, affects the distribution of the stock (Vasilieva 1996) and, thus also the regional egg production and fisheries activities mostly concentrating on (pre-)spawning concentrations.
2.6	Fishery information	The contact of scientific and technical personnel to fisheries is reasonably well established, specifically EU-funded sea sampling programmes improved the sampling quality and the collaboration to the fisheries, nevertheless the relationship could be enhanced, especially on organizational level in western European countries.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	Standard assessment model: XSA (Shepherd 1999), utilizing MSVPA output (Vinther 2001), alternatively ICA (ICES 1997/Assess:12) and a multispecies stock production model (Horbowy 1996) have been used, revealing similar stock development trends, in case of the ICA, however, being more unstable; consideration of species interaction, first of all predation by cod, stabilizes the assessment, as historically predation mortality was far above fishing mortality (ICES 1997/J:2).
3.2	spatially explicit or not	Standard assessment not spatially explicit, as IBSFC manages sprat as one unit stock in the Baltic, however, MSVPA runs for various areas (SD 22-24), SD 25, 26 and 28 exist, especially the three latter areas covering the major part of the stock; adding up the independent estimates (migration represented by catch distribution only), revealed similar stock sizes, SSB and fishing mortalities as estimated by the standard assessment (Köster et al. 2001a).
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability, recruitment	Natural mortality composed of residual mortality (constant with age and time) and predation mortality (varying over age and time), Vulnerability to fishing activity and catchability assumed to be constant over time, although indications exist that the distribution may be affected by winter temperature and oxygen conditions within and below the halocline, see above. Fishing mortality determined by XSA tuned with two hydroacoustic surveys covering SD 25-32 and SD 26 & 28, the latter covering the entire time series back to 1983 (except for 1993). Recruitment for short-term predictions are determined for the assessment year by regression of log-transformed year-class strength at age 1 from XSA vs. 0-group abundance from hydroacoustic survey; for subsequent two year-classes geometric means are applied. Recruitment in medium-term predictions has been derived either by i) a stock-recruitment relationship assuming a linear increase in recruitment from origin to Bpa and constant recruitment at SSB > Bpa with log-normal errors (ICES 2000/ACFM:14) or ii) a Beverton and Holt recruitment model assuming as well log-normal errors.
3.4	Statistical formulation:	Different tuning surveys are weighted according to the inverse variance in the abundance

	- what process errors - what observation errors - what likelihood distr.	indices time series (Shepherd 1999). To account for process and observation errors especially in most recent years, shrinkage to a mean F over the last 5 years and age-groups 5-7 as well as shrinking survivor estimates to the population mean for ages < 4 applied, catchability of ages 5-7 assumed to be the same as in age-group 4 and in age-groups 1-3 coupled to stock size.
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	Tests for significance in catchability time trends.
3.6	Retrospective evaluation	Retrospective analyses are routinely carried out, with largest deviations (overestimation of fishing mortalities and underestimation of abundance) for early 1990's as well 1997 and 1998. Historical realisations of assessments are evaluated in larger time intervals (e.g. Sjöstrand 1989, Parmanne et al. 1994). Contrast in stock development is high with strongly increasing stock sizes from late 1980's to mid 1990's.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short- and medium- to long-term prediction are age-based, with no sex or fleet structure. Sex appears to be relatively unimportant, although sex ratio skewed to dominance in females with age, as in age-groups mainly constituting the SSB the sex ratio is still rather equal.
4.2	Spatially explicit or not	Not in standard assessment; a trial to construct a spatially explicit stock-recruitment relationship exists, covering most important SD's considering temperature in the intermediate water at spawning time and growth anomaly from 3rd to 2nd quarter (Köster et al. 2000).
4.3	Key model parameters	Recruitment estimated as described above, natural mortality, exploitation pattern, maturity ogives and in short-term predictions also weight at age set constant as averages over most recent years; In medium- to long-term predictions uncertainty in input variables is considered in the utilized stock recruitment relationship and by applying CV's to initial stock sizes and weight at age. Interdependences between different parameters are not accounted for.
4.4	Recruitment	As described above, in medium- to long-term predictions a dependence of recruitment on SSB at low stock sizes is assumed or a Beverton and Holt stock recruitment relationship applied, log-normal errors considered; autocorrelation and environmental impact is presently not accounted for.
4.5	Evaluation of uncertainty	CV's in initial stock sizes are derived from variability in XSA estimates and in weight at age from observations within a specific range of recent years. SSB and yield percentiles are presented for different F-options. Structural uncertainty is not considered in the models.
4.6	Evaluation of predictions	No.
4.7	Biological reference points	Following fishing mortality reference points are determined yearly by the Baltic Fisheries Assessment WG: Fpa equals Fmed, an alternative is Zpa considering different levels of predation mortality and weight at age changes, however, applying presently only averages over different periods and no interdependence; FO.1 as traditional standard value; Flow and Fhigh to demonstrate the impact of low and high recruitment. Following biomass reference points are determined by the ICES Advisory Committee on Fisheries Management: Bpa and Blim. A sensitivity study on the stability of various limit and target fishing and biomass reference points considering predation by cod by running coupled medium-term projections revealed a high sensitivity of all reference points to changes in predator abundance forced by variable reproductive success or fishing activity, in conclusion multispecies reference points are rather 3-D planes than single points (Gislason 1999).

Stock: Herring in the Baltic
Author: Fritz Köster
Date: 26.08.2001

Reference: ICES (2001/ACFM:18), otherwise stated (see reference list)

1. General

step	*Item*	*Considerations*
1.1	Stock definition	Western Baltic, IIIa and partly North Sea (not considered here) Central Baltic Baltic (ICES Sub-divisions 25-29 & 32 incl. Gulf of Riga, for areas see Fig. 1) Gulf of Riga Bothnian Sea (Sub-division 30) Bothnian Bay (Sub-division 31)
1.2	Stock structure	Morphometric including otolith analysis and differences in spawning times and locations as well as natural tags suggest a series of different stocks in the Central Baltic (Ojaveer 1989), with however no evidence of corresponding genetic differences (Ryman et al. 1985). Autumn spawning and spring spawning herring, with the latter consisting of coastal and open sea herring, coastal herring groups are distributed along the Swedish coast in SD 27, the polish coast in SD 25 and 26 and in the Gulf of Riga (also assessed as a separate stock), open sea herring inhabit areas to the west and north of Gotland (basically SD 27), to the east of Gotland (SD 28 & 29 without the Gulf of Riga) and in the southern central areas (SD 25 & 26); for review see ICES (2001/ACFM:10).
1.2	Spatial structure	Both the single- and multispecies assessments treat the Central Baltic herring in SD 25-29 & 32 (including the Gulf of Riga) as a unit stock, which is increasingly questioned and in fact was handled differently in the assessment throughout the 1980's, when SD 25-27, SD 28 & 29 south and also the Gulf of Riga were treated as separate stocks (Sjöstrand 1989); in addition, MSVPA runs for single SD 25, 26 and 28 exist, but are presently not used in assessment (Köster et al. 2001a). In the 1980's, the northern Baltic herring was not only separated according to SD's but divided into i) the eastern parts of SD 29 north & 30, ii) the eastern part of SD 31, iii) the western parts of SD 29 north, 30 & 31 and iv) SD 32 (Sjöstrand 1989), which however, due to the overlapping statistical areas was difficult to maintain and is presently not considered as a practicable approach.
1.3	Single/multi-species	As the single species assessment in SD 25-29 & 32 utilizes predation mortalities from regularly updated MSVPA (ICES 2001/H:4) the assessment is basically a multispecies assessment, spatial dis-aggregation has been argued to be important as the predator cod is virtually absent in SD 28-29 and thus predation is close to zero in contrast to the 1980's (ICES 1999/H:5). For other stock units a singlespecies assessment is performed.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Catch at age statistics before 1970 (Gulf of Riga), 1974 (SD 25-29 & 32), 1980 (SD 30, 31) unreliable; unallocated landings and discards are not included in SD 25-29 & 32, even more problematic is the sampling of the industrial fishery on sprat developed throughout the 1990. Other stock units: unallocated landings are included, but no discards.
2.2	Indices of abundance	SD 25-29 & 32: abundance indices used are from annual international hydroacoustic survey carried out since late 1970's in autumn and cover age-groups 1+; surveys in 1992, 1993 and 1997 not reliable, due to ship, equipment and personnel changes, recruits at age 1 are considered be not representative, due to limited coverage of shallow water areas in which most recruits are located (Aro 1989). Other stock units: no survey time series available, but SD 30 covered in most recent years by international hydroacoustic survey in autumn; additionally new hydroacoustic survey implemented in Gulf of Riga in 1999.
	Catch per unit effort	SD 25-29 & 32: only for subcomponents, i.e. SD 29 and 32 from Finnish pelagic trawlers. Gulf of Riga: trap-net from 1980-2000, short time series for trawlers presently not used in the assessment. Bothnian Sea and Bothnian Bay: trap-net, bottom and pelagic trawler fleet covering 1980-2000.
	Gear surveys (e.g. trawl, longline)	SD 25-29 & 32: the international hydroacoustic survey covers the entire stock area, in former years not always most northern areas (SD 29 north and 32). Water depths <20m are not sampled, which in autumn does not affect the stock estimate of adults, as herring concentrate on their open sea feeding grounds. SD 25-28: Catch rates from the international bottom trawl survey directed to cod in the 1^{st} and partly 4^{th} quarter available since 1982, however, not covering shallow waters, in which spring spawning herring in early spring concentrate; 4^{th} quarter surveys are not yet allowing to construct catch rate time series; catchability of bottom trawls expected to be dependent on oxygen conditions. SD 30 and Gulf of Riga in most recent years covered by hydroacoustics, but not utilized for tuning yet.

	Acoustic surveys	During the international hydroacoustic survey separation between sprat and herring is done by approximately 100-150 trawl hauls, carried out in dependence of ship capacity available; the survey is internationally standardized; calibration of equipment and intercalibration between ships performed each survey.
	Egg surveys	None.
	Larvae surveys	Larvae surveys have been conducted in the Gulf of Riga, SD 29 north, 30 and 32 (Sjöstrand 1989) since mid 1970's, however, only the first is still continued, but with some missing years in early 1990 (ICES 2000/ACFM:14); all data sets contain length specific information.
	Juvenile surveys	1-group covered in hydroacoustic survey, but due to missing coverage of shallow areas, these estimates may be biased; O- and 1-group from international bottom trawl survey in SD 25-28 in principal available, however only the Polish time series still updated, but extremely noisy (ICES 1997/Assess:12).
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Sampling intensity has improved during the 1990's due to international sampling programme in ports and on vessel, however, coverage of SD 27 and 31 insufficient, i.e. assessment in latter area questionable; in most areas stock separation done by otolith analysis, which is not unproblematic. Sampling effort not high enough in the industrial fishery on sprat; information on unallocated catches available only for few stock components, i.e. Gulf of Riga, SD 30 and 31; ageing routines reasonably well established. Weight at age in the catch used as weight at age in the stock, although data from hydroacoustic surveys in autumn available. Maturity at age data sampled and historic data being compiled, but not used presently (ICES 2001/ACFM:24).
2.4	Tagging information	Data from historic tagging experiments in some areas, e.g. in the northern Baltic, available (e.g. Parmanne and Sjöblom 1986).
2.5	Environmental data	Presently only temperature in April and zooplankton abundance in May are used to predict year-class strength of the Gulf of Riga herring for the current assessment year (Kornilovs 1995); other potential candidates are: - Water temperature in winter/spring affecting recruitment success of herring in the Bothnian Bay and Bothnian Sea; may be predicted within a specific year. - Besides temperature in April affecting sexual maturation, spawning time and egg developmental rates of Gulf of Riga herring, salinity as a factor influencing metabolic processes and growth as well as migratory behaviour (Evtyukhova et al. 1989); long-term trends in salinity may allow medium-term projections. - Besides zooplankton abundance in May as prey for larvae, general processes affecting secondary production (e.g. eutrophication, high westerly wind stress in winter and spring increasing vertical convection and upwelling, temperature in upper water layers in spring) have been suggested to enhance reproductive success especially of the coastal herrings (Kalejs and Ojaveer 1989); long-term trends in eutrophication may allow medium-term projections, time horizon for prediction of other variables is less then one year. - For deeper spawning open sea herring (spring and autumn) oxygen conditions may as well be important (Kalejs and Ojaveer 1989); time horizon of prediction within a given year and in eastern areas potentially one year ahead (Köster et al. 2001b). - Predation mortality on 0-group herring is related to cod abundance (Sparholt 1994) and may be predicted via cod SSB according to ICES (1993/Assess:17); thus predictability is coupled to the ability to forecast the cod stock development. - Calanoid copepod abundance is positively related to temperature (*Acartia spp.* and *Temora longicornis*) and salinity in spring (*Pseudocalanus elongatus*), the latter copepod reproduction being in turn negatively related to spring temperature (Möllmann et al. 2000); availability of these copepods affects growth rates (Cardinale and Arrhenius 2000), although other processes like size dependent predation by cod (Beyer and Lassen 1994) and different development in sub-stocks exhibiting different growth rates (Sparholt 1994) have been suggested as explanations and most likely contributed to the drastic decile in weight at age; nevertheless prediction of weight at from food availability or stock density may be feasible (Horbowy 1997).
2.6	Fishery information	The contact of scientific and technical personnel to fisheries is reasonably well established, specifically the EU-funded sea sampling programmes improved the sampling quality and the collaboration to the fisheries, nevertheless the relationship could be enhanced, especially on organizational level in western European countries.

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	Standard assessment model: XSA (Shepherd 1999) utilizing MSVPA output (Vinther 2001) for southern stocks, i.e. SD 25-29 & 32, alternatively ICA (ICES 1997/Assess:12) and a multispecies stock production model (Horbowy 1996) have been used, revealing similar stock development trends.
3.2	spatially explicit or not	The standard assessment considers SD 25-29 & 32 inclusive Gulf of Riga as a unit stock, which is questionable, see above; however, separate assessments for various areas: SD 25-27, 28-29 & 32 excl. Gulf of Riga and Gulf of Riga integrated over the larger stock unit revealed limited deviations between spatially dis-aggregated and aggregated assessments.
3.3	key model parameters:	Natural mortality is assumed to be constant with age and time, with exception of SD 25-29

	natural mortality, vulnerability, fishing mortality, catchability, recruitment	& 32, here predation mortalities from MSVPA output are used (varying over age and time). Fishing mortality determined by XSA tuned with international hydroacoustic survey (SD 25-29 & 32), in other areas by CPUE from trap-net, additionally in SD 30 and 31 by CPUE from demersal and pelagic trawler fleets, however, in these fisheries a trend in increasing catchability has been attributed to an increase in trawl sizes. Apart from this, vulnerability to fishing activity and catchability assumed to be constant over time, although indications exist that the distribution may be affected by winter temperature and oxygen conditions within and below the halocline. Recruitment in short-term predictions for SD 25-29 &32 are assumed to be averages over preceding years from XSA output, as reliability of recruitment estimates (age 1) from hydroacoustic survey are doubtful. For Gulf of Riga, year-class originated in assessment year predicted from temperature in April and zooplankton abundance in May. For SD 30 & 31 similar procedure than for the Central Baltic stock. Recruitment in medium-term predictions has been derived by a stock-recruitment relationship assuming a linear increase in recruitment from origin to Bpa and constant recruitment at SSB > Bpa with log-normal errors (SD 25-29 &32) or a simple Beverton and Holt recruitment model assuming as well log-normal errors (all other stock units).
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	To account for process and observation errors, especially in most recent years, shrinkage to a mean F over the last 5 years and a number of oldest age-groups as well as shrinking survivor estimates to the population mean for juveniles was applied, in juveniles catchability related to stock size and in older age-groups assumed to be similar to intermediate age-groups well represented in the catch. If different tuning surveys are used, they are weighted according to the inverse variance in the abundance indices time series (Shepherd 1999).
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	Tests for significance in catchability time trends.
3.6	Retrospective evaluation	Retrospective analyses are routinely carried out, with successively increasing deviation (underestimation of fishing mortalities and overestimation of SSB) from 2000 to 1994 in SD 25-29 & 32, a slightly better behaviour in the other areas. Historical realisations of assessments have been evaluated in larger time intervals for the Central Baltic herring (e.g. Sjöstrand 1989, Parmanne et al. 1994), but not for Gulf herring stocks. Contrast in stock development is relatively low with slightly decreasing abundances in SD 25-29 & 32 and a continuous increase in the Gulf of Riga and SD 30, while for SD 31 a more sever decrease is indicated.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	Short- and medium- to long-term prediction are age-based, with no sex or fleet structure.
4.2	Spatially explicit or not	Yes separate predictions for SD 25-29 & 32, Gulf of Riga, SD 30 and 31, with trial short-term predictions conducted also for SD 25-27 and 28, 29 & 32 excl. Gulf of Riga.
4.3	Key model parameters	Recruitment estimated as described above, natural mortality, exploitation pattern, maturity ogives and weight at age set constant as averages over most recent years. In medium- to long-term predictions uncertainty in input variables is considered in the utilized stock recruitment relationship and by applying CV's to the initial stock size as well as randomly drawing weight at age from observed normal distributions (the latter only for SD 25-29 & 32). Interdependence between different parameters are not accounted for.
4.4	Recruitment	As described above, in medium- to long-term predictions a dependence of recruitment on SSB at low stock sizes is assumed or a Beverton and Holt stock recruitment relationship applied, log-normal errors considered; autocorrelation and environmental impact is presently not accounted for.
4.5	Evaluation of uncertainty	CV's in initial stock size were derived from variability in XSA estimates, StdD. for weight at age from observations within last 10 years (the latter only for SD 25-29 & 32). SSB and yield percentiles are presented for different F-options. Structural uncertainty is not considered in the models.
4.6	Evaluation of predictions	No.
4.7	Biological reference points	Following fishing mortality reference points are determined yearly by the Baltic Fisheries Assessment WG for all stock components, with the exception of SD 31: Fpa equals Fmed, Flim equally Floss, FO.1 as traditional standard value, Flow and Fhigh to demonstrate the impact of low and high recruitment. Following biomass reference points are determined by the ICES Advisory Committee on Fisheries Management: Bpa and Blim equals Bloss (at least in most cases). A sensitivity study on the stability of various limit and target fishing and biomass reference points considering predation by cod by running coupled medium-term projections revealed a high sensitivity of all reference points to changes in predator abundance forced by variable reproductive success or fishing activity, in conclusion multispecies reference points are rather 3-D planes than single points (Gislason 1999).

References for Baltic stock summary sheets

Alekseeva, E.I., Baranova, M.M., Dmitrieva, M.A., and Ryazantseva, E.F. 1997. Ovaries maturation, batch eggs forming, batch fecundity and distribution during sex cycle of Baltic sprat *Sprattus sprattus Balticus*. ICES CM 1997/U:02.

Aro, E. 1989. A review of fish migration patterns in the Baltic. Rapp. P. -v. Réun. Cons. int. Explor. Mer 190: 72-96.

Beyer; J.E. and H. Lassen, H. 1994. The effect of size-selective mortality on the size-at-age of Baltic herring. Dana 10: 203-234.

Cardinale, M. and Arrhenius, F. 2000. Decreasing weight-at-age of Atlantic herring (*Clupea harengus*) from the Baltic Sea between 1986 and 1996: a statistical analysis. ICES J. Mar. Sci., 57: 882-893.

Elwertowski, J. 1960. Biologische Grundlagen der Sprottenfischerei in der östlichen und mittleren Ostsee. Fisch. Forsch. 3 (4): 1-19.

Gislason, H. 1999. Single and multispecies reference points for Baltic fish stocks. ICES J. Mar. Sci. 56:571-583.

Grauman, G.B. and Yula, E. 1989. The importance of abiotic and biotic factors in early ontogenesis of cod and sprat. Rapp. P-v Réun. Cons. Int. Explor. Mer 190: 207-210.

Hinrichsen, H.-H., St. John, M., Aro, E., Grønkjær, P., Voss, R., 2001. Testing the larval drift hypothesis in the Baltic Sea: retention vs. dispersion due to influence of wind driven circulation. ICES J. Mar. Sci. (in press).

Hinrichsen, H.-H., Möllmann, C., Voss, R., Köster, F.W. and Kornilovs, G. 2001b. Bio-physical modelling of larval Baltic cod (*Gadus morhua*) survival and growth. Can. J. Fish. Aq. Sci. (submitted).

Horbowy, J. 1996. The dynamics of Baltic fish stocks on the basis of a multispecies stock-production model. Can. J. Fish. Aq. Sci. 53: 2115-2125.

Horbowy, J. 1997. Growth of the Baltic herring as a function of stock density and food resources. Acta Ichthyol. Pisc. 27: 27-38.

Horbowy, J. and Swinder, M. 1989. Growth of Baltic sprat in relation to stock density and food biomass. Rapp. P-v Réun. Cons. Int. Explor. Mer 190: 102-104.

ICES 1993. Report of the Working Group on Assessment of Pelagic Stocks in the Baltic. ICES C.M. 1993/Assess:17.

ICES 1997. Report of the Baltic Fisheries Assessment Working Group. ICES CM 2000/Assess:12.

ICES 1997. Report of the Study Group on Multispecies Model Implementation in the Baltic. ICES CM 1997/J:2.

ICES 1999. Report of the Study Group on Multispecies Model Implementation in the Baltic. ICES CM 1999/H:5.

ICES 2000. Report of the Baltic Fisheries Assessment Working Group. ICES CM 2000/ACFM:14.

ICES 2001. Report of the Study Group on Herring Assessment Units in the Baltic. ICES CM 2001/ACFM:10.

ICES 2001. Report of the Baltic Fisheries Assessment Working Group. ICES CM 2001/ACFM:18.

ICES 2001. Report of the Study Group on Baltic Herring and Sprat Maturation. ICES CM 2001/ACFM:21.

ICES 2001. Report of the Study Group on Multispecies Predictions in the Baltic. ICES CM 2001/H:4.

Kalejs, M., and Ojaveer, E. 1989. Long-term fluctuations in environmental conditions and fish stocks in the Baltic. Rapp. P-v Réun. Cons. Int. Explor. Mer 190: 153-158.

Köster, F.W. and Möllmann, C. 2000. Egg cannibalism in Baltic sprat *Sprattus sprattus*. Mar. Ecol. Prog. Ser. 196: 269-277.

Köster, F.W., Hinrichsen, H.-H., Schnack, D., St. John, M.A., MacKenzie, B.R., Tomkiewicz, J.,, Möllmann, C., Kraus, G., Plikshs, M. and Makarchouk, A. 2000. Recruitment of Baltic cod and sprat stocks: Identification of critical life stages and incorporation of environmental variability and spatial heterogeneity into stock-recruitment relationships. ICES CM 2000/N:16.

Köster, F.W., Möllmann, C., Neuenfeldt, S., Plikshs, M. and Voss, R. 2001a. Developing Baltic cod recruitment models I: Resolving spatial and temporal dynamics of spawning stock and recruitment for cod, herring and sprat. Can. J. Fish. Aquat. Sci 58: Sci. 58: 1516-1533.

Köster, F.W., Schnack, D. and Möllmann, C. 2001b. Scientific knowledge on biological processes potentially useful in fish stock predictions. Scientia Marina (submitted).

Kornilovs, G. 1995. Analysis of Baltic herring year-class strength in the Gulf of Riga. ICES CM 1995/J:10.

Kraus, G. and Köster, F.W. 2001. Duration, frequency and timing of sprat spawning in the Central Baltic: Preliminary results of a maturity stage based analysis. ICES CM 2001/J:25.

MacKenzie, B.R. and Köster, F.W. 2000. Sprat recruitment and temperature-NAO-ice conditions in the Baltic Sea. Symposium on Fish Stock Assessments and Predictions: Integrating Relevant Knowledge, 4-6 December 2000, Bergen.

Möllmann, C., Kornilovs, G. and Sidrevics L. 2000. Long-term dynamics of main mesozooplankton species in the Central Baltic Sea. J. Plank. Res. 22 (11): 2015-2038.

Ojaveer, E. 1989. Population structure of pelagic fishes in the Baltic. Rapp. P-v Réun. Cons. Int. Explor. Mer 190: 17-21.

Parmanne, R. and Sjöblom, V. 1986. Recaptures of Baltic herring tagged off the coast of Finland in 1982-85. ICES CM 1986/J:18.

Parmanne, R., Rechlin, O. and Sjöstrand, B. 1994. Status and future of herring and sprat stocks in the Baltic Sea. Dana 10: 29-59.

Ryman, N., Lagercrantz, U., Andersson, L., Chakruborty, R. and Rosenberg, R. 1985. Lack of correspondence between genetic and morphologic variability pattern in Atlantic herring (*Clupea harengus*). Heredity 53:687-704.

Shepherd, J.G. 1999. Extended Survivors Analysis: An improved method for the analysis of catch-at-age data and abundance indices. ICES J. Mar. Sci. 56 (5): 584-591.

Sjöstrand, B. Assessment review: Exploited pelagic stocks in the Baltic. Rapp. P-v Réun. Cons. Int. Explor. Mer 190: 235-252.

Sparholt, H. 1994. Fish species interactions in the Baltic Sea. Dana 10: 131-162.

Sparholt, H. 1994. Growth changes of herring in the Baltic. Tema Nord 1994, No. 532.

STORE 2001. Environmental and fisheries influences on fish stock recruitment in the Baltic Sea. EU-Project FAIR CT98 3959, Consolidated Progress Report, Part I, 336 pp.

Thompson, B.M., Milligan, S.P. and Nichols, J.H. 1981. The development rates of sprat (*Sprattus sprattus* L.) eggs over a range of temperatures. ICES CM 1981/H:15.

Vasilieva, 1996. Sprat distribution in the south-eastern Baltic Sea during 1994-1995. ICES CM 1996/J:4.

Vinther, M. 2001. ad hoc Multispecies VPA tuning applied for the North Sea and Baltic Sea fish stocks. ICES J. Mar. Sci. (in press)

Voss, R., Hinrichsen, H.-H. and St. John, M.A. 1999. Variations in the drift of larval cod (*Gadus morhua* L.) in the Baltic Sea: combining field observations and modelling. Fish. Oceanogr. 8 (3): 199-211.

6.9 – Fish stocks in the Black Sea (submitted by Georgi M. Daskalov)

Locally-weighted regression or *loess* (Cleveland, 1993) and Seasonal-Trend decomposition based on *loess* (STL Cleveland *et al*., 1990) are used to analyse time-series. Principal component analysis (PCA, Lebart *et al*., 1995) is applied in order to compare long-term patterns in multiple series. Fish recruitment is modelled in relation to the adult stock and environmental factors using Generalized Additive Models (GAM, Hastie and Tibshirani, 1990; Daskalov, 1999).

Various hydroclimatic (SST, SLP, wind, run-off...), biological (phyto- and zooplankton, jelly-fishes...) and fish stocks (recruitment and parental stock abundance of anchovy, sprat, horse mackerel and whiting) long-term data are studied in order to describe and compare the main trends and fish-environment relationships in the Black Sea ecosystem. Long-term patterns are analysed on different temporal scales: trend, interdecadal, decadal and interannual variation. The results show evidence of coherent patterns between physical, biological and anthropogenic series. Temperature, atmospheric pressure, wind and run-off series are significantly correlated with most of the biological and fish stocks indices.

Significant correlations appear between fish recruitment, stock biomass and physical environment. Patterns of the recruitment response to wind forcing and sea level atmospheric pressure are similar in four fish species. Recruitment in the off-shore reproducing sprat and horse mackerel is less dependent on the parental stock biomass and is related to the thermo-haline circulation, while in the coastal species - anchovy and whiting - is related to the river run-off.

The established correlations allow formulating hypotheses on the causal links between the abiotic environment, productive processes and population dynamics. The physical environment is recognised being the main factor driving the biological productivity and essentially influencing all processes in the sea. Other factors responsible for a great part of the observed variability in marine data series are biological interactions and anthropogenic impact (Daskalov, 2001). The rise in overall productivity after 1970 can be explained by several factors acting simultaneously: hypothetical favorable climatic regime, increased eutrophication, and trophic cascade effect due to the predator's extinction propagating down the pelagic food-web. The obtained results can enable the integration of reliable environmental indices in the procedures of fisheries and ecosystem assessment and management. The statistical methods used are found to be suitable tools for fisheries and environmental data analysis, providing flexible and powerful way to explore and model non-linear relationships.

Key words

Fish-environment, climate regimes, decadal change, recruitment, ecosystem structure, *loess*, GAM, Black Sea.

References

Cleveland, W. S. (1993). Visualizing data. Hobart Press, Summit, NJ.

Cleveland, R.B., Cleveland, W.S., Mc Rae, J.E., Terpenning,I. (1990). STL: A seasonal-trend decomposition procedure based on loess. Journal of Official Statistics, 6 (1): 3-73.

Daskalov, G.M., 1999. Relating fish recruitment to stock and physical environment in the Black Sea using generalized additive models. Fisheries Research 41: 1-23.

Daskalov, G.M., 2001 Overfishing drives a trophic cascade in the Black Sea. Mar Ecol Prog Ser (in press)

Hastie T. and R. Tibshirani 1990. Generalised Additive Models. Chapman and Hall, London.

Lebart, L., Morineau, A., Piron, M. 1995. Statistique exploratoire multidimensionnelle. Dunod, Paris.

Stock: Black sea sprat Sprattus sprattus
Author:Georgi M. Daskalov
Date:18.08.2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Black Sea
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Yes. Unit stock
1.2	Spatial structure	Is or should the assessment be spatially structured? not necessarily
1.3	Single/multi-species	Choose single-species or multi-species assessment. single species.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? no
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Recruitment and biomass from SPA (ICA, XSA) Recruitment from juvenile survey Age-structured adult stock abundance from mid-water trawl survey All indices are by assumption absolute but more frequently are used as relative
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? Multi-fleet disagregated data used in SPA
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? All the range of the stock is covered
	Acoustic surveys	Validation of species mix and target strength, area coverage? Not used as an index
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area Larvae surveys: tow
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juveniles: trawl 0 group (~3 months old)
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors catch-at-age, weight-at-age, Size-at-age,
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? SST, run-off, COADS, phosphorus,hypoxia, hydrogene sulphide
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Ukraina, Russia, Romania, Bulgaria, Turkey

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered Separable VPA, 1945-77, XSA, ICA 1978-93 overall stock (international data) 1978-1999 ICA only Bulgarian data

3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? Not but it is possible to extend based on national CPUE data
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. M0.5 years =0.72 1945-1969 M1-5=1.2, 1970-1999, M1-5 =0.95 estimated from age composition from surveys and justified by different predation pressure Assumed lower vulnerability of the oldest ages to the fishery
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? The model is weighted sum of squares terms weighted arbitrary log-normal errors
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? asymptotic estimates of variance,
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Performance of alternative methods: VPA, XSA, ICA is evaluated. XSA and ICA present consistent retrospective patterns

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short term age-based stock and catch projections based on + - 10% Fsquo Yield per recruit and production models are used ate different stages
4.2	Spatially explicit or not	Not
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered? Recruitment from SPA and based on regression (log-log) between SPA estimate and survey.
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? No
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. No
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? No

Stock: Black sea Anchovy Engraulis encrasicolus
Author:Georgi M. Daskalov
Date:18.08.2001

1. General

step	Item	Considerations
1.1	Stock definition	What is the spatial definition of the stock Black Sea
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Yes. Unit stock
1.2	Spatial structure	Is or should the assessment be spatially structured? not necessarily
1.3	Single/multi-species	Choose single-species or multi-species assessment. single species.

2. Data

step	Item	Considerations
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? no
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Recruitment and biomass from VPA Recruitment from juvenile survey Egg and larvae surveys Hydroacoustic and DEPM for some years but not still used in age-structured assessment model All indices are by assumption absolute but more frequently are used as relative
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? Not standardized
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? All the range of the stock is covered
	Acoustic surveys	Validation of species mix and target strength, area coverage? Validated by control trawling
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area Larvae surveys: tow
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juveniles: trawl 0 group (~1 month old)
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors catch-at-age, weight-at-age, Maturity-at-age, Size-at-age,
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? SST, run-off, COADS, phosphorus,hypoxia, hydrogene sulphide
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Ukraina, Russia, Romania, Bulgaria, Turkey

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered VPA on a seasonal basis 1967-1994
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? Not
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Constant M=0.8 assumed
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? VPA
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? No
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? No

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Yeild per recruit
4.2	Spatially explicit or not	Not
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? No
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. No
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? No

Stock: Black sea Horse Mackerel Trachurus mediterraneus
Author:Georgi M. Daskalov
Date:18.08.2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Black Sea
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? There is evidence of migration and mixing of stocks from the Mediterranean
1.2	Spatial structure	Is or should the assessment be spatially structured? not necessarily
1.3	Single/multi-species	Choose single-species or multi-species assessment. single species.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? no
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Recruitment and biomass from VPA Recruitment from juvenile survey Egg and larvae surveys All indices are by assumption absolute but more frequently are used as relative
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? Not standardized
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed?
	Acoustic surveys	Validation of species mix and target strength, area coverage?
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area Larvae surveys: tow
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juveniles: trawl 0 group (~1 month old)
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors catch-at-age, weight-at-age, Size-at-age,
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? SST, run-off, COADS, phosphorus,hypoxia, hydrogene sulphide
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Ukraina, Russia, Romania, Bulgaria, Turkey

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered VPA 1950-1994
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented?

		Not
3.3	key model parameters: natural mortality, vulnerability, fishing mortality, catchability	Are these parameters assumed to be constant or are they estimated? If they are estimated, are prior distributions assumed? Are they assumed to be time-invariant. Constant M=0.5 assumed
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? VPA
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds? No
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? No

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Short term age-based stock and catch projections based on + - 10% Fsquo
4.2	Spatially explicit or not	Not
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? No
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. No
5.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? No

Stock: Black sea whiting Merlangius merlangus
Author:Georgi M. Daskalov
Date:18.08.2001

1. General

step	*Item*	*Considerations*
1.1	Stock definition	What is the spatial definition of the stock Black Sea
1.2	Stock structure	Has tagging, micro-constituents, genetics and/or other morphometrics been used to define stock unit? Unit stock
1.2	Spatial structure	Is or should the assessment be spatially structured? not necessarily
1.3	Single/multi-species	Choose single-species or multi-species assessment. single species.

2. Data

step	*Item*	*Considerations*
2.1	Removals: catch, discarding, fishery induced mortality	Are removals included in the assessment? Are biases and sampling designs documented. Are discards included and if so, how? no
2.2	Indices of abundance	For all indices, consider whether an index is absolute or relative, sampling design, standardization, functional form of relationship between index and population abundance. What portion of the stock is indexed (e.g. spawning stock)? Recruitment and biomass from SPA (XSA) Recruitment from juvenile survey: absolute Age-structured adult stock abundance from mid-water trawl survey: relative
	Catch per unit effort	What portions of the fleets are included and how is data standardized? How are zero catches treated? What assumptions are made about areas not fished? Not used in assessment
	Gear surveys (e.g. trawl, longline)	Is gear saturation a problem? Does survey design cover entire range of the stock? How is gear selectivity assessed? Northern part of range of the stock is covered
	Acoustic surveys	Validation of species mix and target strength, area coverage?
	Egg surveys	Estimation of stage specific egg abundance, production, mortality, spawning stock sex and maturity structure, fecundity? Egg surveys
	Larvae surveys	Stage, size specific abundance, production, consideration of drift out of covered area
	Juvenile surveys	Which age-groups covered? Survey design (e.g. gear, area coverage of nursery areas)? Juveniles: trawl 0 group (~3 months old)
2.3	Age, size and sex-structure: catch-at-age, weight-at-age, Maturity-at-age, Size-at-age, age-specific reproductive information	Consider sampling design (temporal and spatial), sample size, high-grading selectivity and ageing errors catch-at-age, weight-at-age, Size-at-age,
2.4	Tagging information	Consider both tag loss and shedding and tag return rates. Was population uniformly tagged or were samples recovered? No
2.5	Environmental data	How are environmental information presently used, what processes are represented by which variables, proxies etc.; what are potential other candidate variables, how are they monitored, how predictable are they? What are dangers of searching databases for correlates? SST, run-off, COADS, phosphorus,hypoxia, hydrogene sulphide
2.6	Fishery information	Are people familiar with the fishery? Who have spent time on fishing boats, consulted and involved in discussions of the value of different data-sources. Is this information used and if how ? Ukraina, Russia, Romania, Bulgaria, Turkey

3. Assessment model

step	*Item*	*Considerations*
3.1	Age, size, length or sex-structured model	What model is currently used? What are the main assumptions? Are alternative models considered?, how is the performance in comparison? Time span covered VPA, XSA 1970-91 separately on the northern and southern components of the stock
3.2	spatially explicit or not	If not, is it necessary, and if yes, why not implemented? Not
3.3	key model parameters:	Are these parameters assumed to be constant or are they estimated? If they are

	natural mortality, vulnerability, fishing mortality, catchability	estimated, are prior distributions assumed? Are they assumed to be time-invariant. Constant M=0.7
	recruitment	
3.4	Statistical formulation: - what process errors - what observation errors - what likelihood distr.	If the model is in the form of a weighted sum of squares, how are the terms weighted? If the model is in the form of maximum likelihood, are variances estimated or assumed known? log-normal errors
3.5	Evaluation of uncertainty: - asymptotic estimates of variance, - likelihood profile - bootstrapping - bayes posteriors	How is uncertainty in model parameters or between alternative models calculated? What is actually presented, a distribution or only confidence bounds?
3.6	Retrospective evaluation	Are retrospective patterns evaluated and presented? Are historical realisations of assessments evaluated? How much contrast in the stock development? Performance of alternative methods: VPA, XSA, is evaluated.

4. Prediction model(s) (for different time frames separately, e.g. short-, medium-, long-term)

step	*Item*	*Considerations*
4.1	Age, size, sex or fleet-structured prediction model	What models are currently used? What are the main assumptions? Are alternative models considered? Single- or multispecies ? Yeild per recruit
4.2	Spatially explicit or not	Not
4.3	Key model parameters	What is the source of the parameters, how is variability and dependence between different parameters accounted for?
4.4	Recruitment	How is recruitment incorporated into the prediction model ? Is a relationship between spawning stock and recruitment assumed? If so, what variance is allowed? Is depensation or autocorrelation considered? are environmentally driven reductions or increases in recruitment considered?
4.5	Evaluation of uncertainty	How is uncertainty in model parameters incorporated? How are results presented? Is uncertainty in model parameters visible at output level, and if so, how? Structural uncertainty in the model? No
4.6	Evaluation of predictions	Are predictions evaluated post-hoc? If so, how? Which performance indicators are applied to evaluate predictions. No
4.7	Biological reference points	What type of reference points (e.g. target, limit) are determined? How often are they re-estimated? How stable are they with respect to changes in input parameters? No

Other stocks for which environmental indices can be used in assessment:
- Black Sea Shad Alosa kessleri pontica: index VPA 1969-1991, relationships with the run-off
- Black Sea Turbot Psetta maeotica index VPA 1968-1985, relationships with the run-off and SST
- Bonito Sarda sarda index landings of young-of-the-year 1925-2000, relationships with SST

Another characteristics that should be considered are stock productivity (basic, actual) and economic value and length of the time-series

References

Arkhipov, A. G. 1993. Estimation of abundance and peculiarities of distribution of the commercial fishes in the early ontogeny. Vopr. Ihktiologii, Moskow, 33(4): 511-522. *En russe*

Daskalov, G. 1998. Using abundance indices and fishing effort data to tune catch-at-age analyses of sprat *Sprattus sprattus*, whiting *Merlangius merlangus* and spiny dogfish *Squalus acanthias* in the Black Sea. Options Mediterraniens, 35:215-228.

Daskalov, G. 1999. Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. Fisheries Research 41:1-23.

Daskalov, G. and Prodanov, K. 1994. Variability in growth of sprat *Sprattus sprattus* L. off Bulgarian Black Sea coast with reference to the environmental changes in the sea. Black Sea'94: Proceedings of the International Conference with a Workshop on regional cooperation project for integrated research and -monitoring of the Black Sea - 12 - 17 Sep. 1994 Varna, 81-85.

Daskalov, G. and Prodanov, K. 1998. Marine environmental conditions and fishery productivity in the Black Sea. *Dans* Durand, M.-H., Ph. Cury, R. Mendelssohn, C. Roy, A. Bakun and D. Pauly (Eds). Local *vs.* global changes in upwellling systems. Ed. ORSTOM, Paris. pp. 249-266.

Daskalov, G., Prodanov, K., Shlyakhov, V. and Maxim, K., 1996. Stock assessment of sprat *Sprattus sprattus L* in the Black Sea during 1945-1993 using international fishery and research data. Izv. IRR, Varna, 24: 67-93.

Faschuk, D. Ya., Arkhipov, A. G. and Shlyakhov, V. A. 1995. Concentration of the Black Sea mass commercial fishes in different ontogenetic stages and factors of its determination. Vopr. Ihktiologii, 35(1): 34-42. *En russe..*

Ivanov, L, 1983. Population parameters and limiting methods of sprat *Sprattus sprattus L.* catches in the Western Black sea. Izv. IRR, Varna, 20: 7-46. *En bulgare, résumé en anglais.*

Ivanov, L. and Beverton, R.J.H., 1985. The fisheries resources of the Mediterranean, part two: Black Sea. FAO Studies and reviews, 60. 135pp.

Ivanov, L. and Kolarov, P. 1979. On the relations between the catches of the Danube shad (*Alosa kessleri pontica*) and the solar activity. Soc. Inter. Limniol. XIX Jubiläumstramgung Donauforsch. Bulg.Akad.Wiss.: 389-395.

Mikhajlyuk, A.N. 1985. Factors determining the abundance of young Black sea scad. *Dans* Oceanographic and fisheries investigations of the Black Sea, VNIRO, Moskou. pp. 81-86. *En russe, résumé en anglais.*

Panov, B. N., Trotsenko, B. G., Korshunova, G. P., Hlopushina, S. I., Belozersky, V. O. 1993. Water state pecularities of the North-western part of the Black Sea determining the sprat fisheries efficiency and its forecast possibility. Oceanology, Moskow, 33: 73-78. *En russe, résumé en anglais.*

Prodanov, K., Mikhaylov, K. and Daskalov, G. 1994. On the problem of commercial fishing influence on the abundance and biomass of mackerel (*Scomber scombrus*), bonito (*Sarda sarda*) and bluefish (*Pomatomus saltatrix*). Proc. of the Black Sea Symposium, Istanbul, 16-18 Sept. 1991, Published by the Black Sea Foundation. pp. 167-174.

Prodanov, K., K. Mikhaylov, G. Daskalov, K. Maxim, E. Ozdamar, V. Shlyakhov, A. Chashchin, A. Arkhipov, 1997. Environmental management of fish resources in the Black Sea and their rational exploitation. Studies and Reviews. GFCM. 68. Rome, FAO . 178pp.

Simonov, A.I., Ryabinin, A. I. and Gershanovitch, D. E. (Eds) 1992. Project “The USSR seas”. Hydrometeorology and hydrochemistry of the USSR seas. Vol. 4: Black Sea, no. 1: Hydrometeorological conditions and oceanological bases of the biological productivity. Hydrometeoizdat, Sankt Peterbourg. 219 pp. *En russe*

Tkatcheva KS, Benko YuK (eds) 1979. Resources and raw materials in the Black Sea, AztcherNIRO, Pishtchevaya promishlenist, Moskow In Russian

7.0 Our study group in perspective (Discussion Lead: Pierre Pepin)

There have been two major efforts aimed at the study of approaches for the incorporation of environmental information in population assessment. The first was undertaken as part of a Concerted Action of the European Union dealing with Stock Assessment and Prediction (SAP). The objectives of this Action were to review existing information concerning patterns of environmental variability, investigating their link with fluctuations in population abundance (either through understood mechanisms or reasonable linkages), identifying existing or required methods for the application of this knowledge, and identifying areas that require further investigation. The second was the ICES Study Group on the Incorporation of Process Information into Stock-Recruitment Models (SGPRISM). The activities of this group were requested by the WG on Recruitment Processes to investigate medium-term projection methodologies that take into account characterizations of patterns in recruitment, incorporate realistic variability in parameters to evaluate the impact of environmental information on stock and recruitment projections, and consider the application of results from specific large scale projects into extant methodologies of stock assessment and projection.

The two groups differed in the breadth of their discussions, with SAP focussing on five major ecosystems (Boreal/Arctic areas, Baltic Sea, North Sea and adjacent areas, the Iberian upwelling, and the Mediterranean) which included species with a wide range of life histories, while SGPRISM focussed on two case studies (cod and anchovy) within the ICES context. In both instances, the groups relied largely on the results of ongoing or completed research projects to identify possible environmental relationships as well as consider the level of understanding and effective reliability of that knowledge. There was limited effort directed at developing a common synthesis of information about overall variations in the physical and biological characteristics of a wide range of ecosystems. The diversity of structure and information was simply too extensive to allow an effective base from which one could generalize at this time.

Fundamentals

One of the fundamental aspects that must be addressed before considering the inclusion of environmental information into the assessment process is the quality and nature of the data available for a stock. Although models represent the means by which knowledge in transformed into prediction, it is essential that the data used in the model's derivation is reliable and descriptive. As the level of biological knowledge concerning inter-annual variations in the state of a stock (e.g. age, length distribution), its reproductive state and potential production (e.g. maturity, fecundity) and geographic and migratory distribution, the more likely we are to provide a valuable understanding and input for short- to medium-term forecasts of a population's dynamics. As one moves to more global indications of stock status (e.g. biomass), or the environmental information is represented by a summary variable (e.g. an environmental index), then the likelihood that changes in processes may be misrepresented begins to increase. For example, the North Atlantic Oscillation (NAO) is a good descriptor of general atmospheric driving forces in the eastern north Atlantic yet at a local or regional scale other physical forces may alter the response of marine systems depending on the state of the NAO (i.e. non-linear processes).

Understanding is the second fundamental element for the incorporation of environmental influence into stock forecasts. The existence of a fundamentally sensible environmental relationship should be considered with caution if there have been no attempts to verify the mechanistic nature of that relationship. As the level of understanding of a process increases, or the consistency of an environmental relationship among populations becomes more apparent, then the application of such information can be carried out with more certainty, keeping in mind that retrospective and forecasting analysis should be carried out on a routine basis.

Environment–population forecasting

The nature of the environment under consideration, and the quality of data available to establish environmental relationships appear to be two of the primary factors that have limited the application of ecological knowledge to population forecasting. The diverse systems considered by SAP highlighted the difficulty of deriving and applying ecological knowledge in complex marine systems. Areas where the greatest level of understanding appeared to have significant reliability were those ecosystems where the complexity of species assemblages and environmental interactions were low. The Barents and Baltic seas are two areas where multispecies interactions appear to be dominated by a few very abundant species. Similarly, the environmental forcing in those systems appears to be dominated by a few processes that appear to show a great deal of correlation with numerous biological, chemical and physical elements of those systems. As the complexity of the ecosystems increases, such as in the case of the North Sea or Mediterranean Ocean, the local experts pointed to increasing levels of uncertainty in the derivation of environmental relationships. Moving from simple to complex systems generally resulted in moving from strategic to empirical models.

The structure of the environmental signal is an important factor determining how such information can be used to forecast stock abundance. Situations where one or several variables acting together result in high levels of inter-annual variability in growth or recruitment (i.e. situations where the "environment" can be treated as white noise) appear to be effective only in terms of short-term forecasting. When one moves beyond one or two years, input into the forecasting process probably should be treated as a random draw from the existing base of knowledge. However, the true value of environmental variables comes when these exhibit a certain degree of predictability. The long term periodicity that are typical of many physical variables as well as those of lower trophic levels may provide a basis for providing a characterization of the fluctuations in the environment. Although forecasting of environmental variables remains restricted to a lead time of only a few months, the use of autocorrelative models of environmental time series can be used effectively as a way to project environmental condition that can be effective in developing medium (3-5 yr) to long (5-10 yr) term projections. Alternatively, changes in state (e.g. regime shifts) may provide simpler descriptors of the environment – one only has to deal with the onset of changes, during which uncertainty may increase. Results from SGPRISM suggest that the level of predictability remains relatively low and that most of the benefits of environmental inputs are restricted to medium term forecasting. However, one of the key limitations of forecasting methods remains the quality of the information dealing with anthropogenic effects on population dynamics associated with fishing. This is particularly important in situations where fishing mortality is elevated.
The findings and recommendations of SGPRISM and SAP can be summarized as follows:

Biological knowledge may be used in the assessment-prediction procedures in a variety of ways:

1. If an environmental measurement explains a factor such as catchability, the this will affect the assessment towards reducing its variance.
2. An environmental variable may help to "clean up" a signal, such as a stock-recruitment relationship. This will improve the mean level in predictions. Since few environmental variables can be predicted, the factors needs to be added back again in the form of noise.
3. Most environmental variables have some associated time series structure, which may be possible be described using some form of autocorrelative model. This structure may be used to generate stochastic future values of environmental conditions. There is considerable potential with this methodology to enhance the error structure in predictions although it will not change the mean (I'm not quite certain I believe this).

Basic questions to be answered by regional groups:

- Is the environment represented by proxies or by knowledge of direct effects on processes?
- What is the underlying accuracy and representativeness of existing environmental time series?
- What are the underlying statistical properties of ancillary variables and can they be predicted (or forecasted using some type of autocorrelative models)?
- What inputs to stock assessment models are sensitive to environmental variations (S/R relationships, growth, maturity, natural mortality) and how do they affect outputs?
- What is a realistic level of complexity for the population dynamic model being used?

Issues to be resolved:

- Is there stock-substructure that can impact on the development of management advice that is uniformly applied to the entire stock?
- Is there a genetic effect of fishing that may have altered the response of a population to environmental variables?
- What are the effects of predation at low stock levels?
- What is a good (or adequate) measure of reproductive potential for a stock?

Recommendations for future research:
- To gain a better understanding and a better predictive ability of the processes that affect recruitment dynamics of key species, the use of quantitative comparative approaches and modelling should be

pursued.

- In areas of complex species assemblages or where environmental extremes are less likely to impact on species dynamics, investigate the accuracy and predictability of methods that aggregate data into functional groups (e.g. trophic levels, size classes).
- Using simulations based on realistic structural relationships, assess how environmental and spatially disaggregated information can be used to predict the impact of management actions for a range of life history characteristics (e.g. short- versus long-lived species).

The various types of population dynamics models used in stock projections can be broadly classified according to their level of complexity, ranging from simple stock production models to the more complex models which incorporate age, size, species and area (possibly further including sex and maturity). In the simpler models, it may be possible to include factors such as multispecies interactions in a relatively simple way. When it comes to predictions, simple approximations (or predictions) from more complex one can be used. It is recommended that highly complex models can be used in an assessment phase but that simpler and more robust methods may be better suited for prediction.

Moving forward

One of the roles of this group is to assess what has been learned and what can be accomplished from the incorporation of environmental (or process) information into the assessment process. One clear approach to this is to investigate the behaviour of recommendations of exploitation rates for populations (stocks) where there is a known environmental relationship relative to when such information is ignored (or unknown). By comparing the results for different stocks, we can hope of establish some of the generalities. One of the advantages of this approach is that the inherent error in population estimates, stock dynamics, knowledge of the fishery as well as the representation of environmental signal are realistic. However, one of the disadvantages is that we don't truly know the inherent error in population estimates, stock dynamics, knowledge of the fishery as well as the representation of environmental signal. When we discover something new about the nature of the data we are using to estimate stock abundance and establish projections, we have no effective method to forecast how our understanding of the importance of environmental information will actually change our ability to project changes in stock abundance and recruitment. A concern that we face when trying to contrast actual applications of environmental information to stock projections is that we are more likely to find positive examples appearing in the literature rather than negative ones. Thus comparisons may show a bias towards significant cases – whether this is a reflection of reality or not will be unknown. A second source of concern is the length of the time series used for such studies. Most do not have enough data to show instances that would be characteristic noise levels that truly reflect the inherent variability of complex ecosystems.

The alternative to using case studies involves setting up artificial ones where one can control the levels of uncertainty as well as their structure. The advantages are that the probability distribution can be manipulated to develop characteristic "case studies", perform a extensive set of stochastic realisations (which can be done with natural populations as well), and get some representation of the range of responses (i.e. quality of projections) we might expect to get under different scenarios. One disadvantage of this approach is in representing the inherent error in a realistic enough manner to be useful for real life situations. Another, and probably more difficult issue, involves representing a realistic fishery. The work of Walters (1989) and Basson (1999) hinged a great deal on the very nature of the fishery they were simulating. One of the important points raised in the discussions of SGPRISM was that the fishery is rarely perfect. Catch indices are variable, total catches are rarely known exactly (discards, lies, errors, etc.). Consequently the feedback between stock and recruitment will be affected by the very nature of the information we build into any exercise undertaken in this line.

One alternative to these two approaches may involve a compromise between the two. this would require that we identify a few case studies where the environmental influence (on recruitment) to be incorporated has different characteristic periodicities (e.g. white *vs* red noise). What could then be manipulated is the inherent strength of the relationship between environment and recruitment. The underlying fishery data and recruitment information would remain unchanged (and therefore imperfect in a realistic sort of way), while the structure of the environmental signal could be altered in an understandable manner. The issues then become how do we measure performance of our forecasts relative to inaction (i.e. no environmental knowledge) and how do we set up the stochastic nature of the relationship(s).

The work of SGPRISM has provided an example of how to investigate the benefits of different approaches to stock forecasting, based on new information gained from hindcast analyses. However their metrics were based on population estimates rather than management objectives. It is not for scientists alone to establish the agenda for stock management yet the information provided can be presented from different points of view. The traditional reference points form one set of perspectives but changes in the environment as well as the behaviour of the fishers are likely to make any mid- to long-term measures of forecast performance irrelevant to society. So measures of stock performance such as recruitment levels and stock biomass may be readily studied from hindcasting analyses. Issues of sustainability and our ability to forecast important changes in population dynamics can only be considered in context with the unpredictability of other changes that govern population dynamics (e.g. anthropogenic effects).

The SG must address the following before we can address the benefits of incorporating of environmental information (EI) into the assessment process:

- What are the metrics we intend to use to measure performance?
- What is (are) the time scales of importance?
- How do we hope to investigate the importance of EI on stock assessment?
- How do we put the effect of EI in context with other unknowns?
- What are the elements that form the basis for contrasting case studies?

On a final note, we might also consider the very nature of the assessment process. This was done to a large extent by SAP but there was great reluctance to suggest a complete change in the approach taken during assessment – it would likely fall on deaf ears. However, many assessment approaches rely heavily on fishery derived information, which can be misleading. With the closure of some important groundfish fisheries in the northwest Atlantic, scientists have been forced to think of other means of providing advice. Survey indices and biological information take on greater weight. The SG might consider the nature of assessments in the absence of fishery data and how EI might improve forecasting.

8.0 Potential use of EI to update parameters and determine biological reference points (Discussion Lead: Maria Fatima Borges)

Summary of the discussion held during the course of the meeting:

The rationale of this section was explored departing from the crucial concept that Spawning Stock Biomass and recruitment (S-R) relationship occupies in fish population dynamics for the definition of biological reference points. Biological reference points are calculable quantities that describe a population state. They can be used as targets for optimal fishing as well as for setting overfishing thresholds.

Stock- recruitment theory generally considers Recruitment as parametrically dependent upon the Spawning Stock Biomass (Ricker, 1954; Beverton and Holt, 1957) and is determined from the empirical relationship between the spawning stock size at a given year, and the subsequent recruitment of the year class produced by that spawning.

Analyses of S-R relationships are performed by fits of various curves to the observations and there are usually considerably deviations from the best fitting parametric curve. These deviations can arise because the assumptions leading to the derivation of the parametric S-R relationship are not constant over time due to environmental factors.

Data reflecting multi-decadal climatic changes have been recorded for centuries, although research on its effect upon fish stock productivity is relatively recent (Kawasaki 1992; Luch-Belda et al. 1992; Iles and Beverton, 1998). This is because by nature, the causal environmental processes are extremely complex interacting in different spatial and time scales (Rothschild, 1995) and are region specific. For example, (Bakun, 1996 suggested that upwelling intensity was linked to large-scale climatic effects, thus linking climate change to the rate of nutrient transport into the eutrophic upper ocean layer, and ultimately to changing primary production.

Furthermore in most fish stocks the number of historical S-R observations is relatively scarce to infer, with acceptable statistical confidence, that the bias from the best fit can actually be the environmental effect. Should that be the case this effect would have to be retained and incorporated in the S-R model.

Based on the rationale of multi-decadal climatic changes and their links to environmental localized effects in fish populations (Klyashtorin, 1998) the group discussed that it was possible to define associated periods of low and high fish productivity or regime shifts over time (Steele, 1996).

Periodical environmental changes are likely to be reflected in the physiology of adult fish. This is likely to be reflected in their growth rate, reproductive capacity, fecundity, condition factor, and gonado-somatic indices, which are crucial to the calculation of long-term biological reference points. One particular case this session discussed was the well studied Japanese sardine (Wada and Jacobson, 1998) in which is demonstrated a favourable regime from 1971 to 1987 and an unfavourable regime during 1951-1970 and 1988-1991 (Fig. 8.1). This stock will be one of the case studies in which the possibility of fitting two different S-R relationships will be explored for the definition of biological reference points.

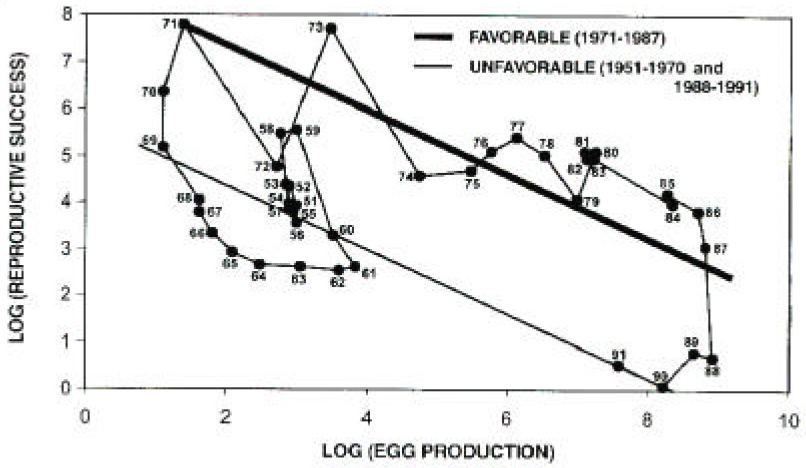


Figure 8.1. Log reproductive success versus log annual egg production for Japanese sardine during 1951-1991 with predicted values from the best fitted regression model for favourable and unfavourable regimes. From Jacobson and Wada (1998), Can. J. Fish. Aquat. Sci. 55: 2455-2463

In particular the Study Group session discussed how to track the inter-annual changes during the transient path between regime shifts, the updating of the biological parameters as environmental indicators of change in response to local climate forcing in spatial system to which the species population is adjusted.

In conclusion, it seemed promising to use several pelagic species case studies under favourable and unfavourable climatic regimes to productivity, with technically appropriate historical data sets (see section 6) to define biological reference points useful for fisheries management and appraise the question:

(i) What difference does it make in terms of the current biological scientific tools for provision of fisheries management advice when pelagic fish productivity regimes are alternatively high and low depending of climatic or environmental effects?
(ii) What are the implications in the precautionary approach for fisheries management advice?

9.0 Potential use of environmental indices to reduce management risk or/and increase yield (Discussion lead: Jose de Oliveira)

Background

The South African anchovy formed the basis of a case study to see whether there would be any benefits in terms of average catch (over a 20-year projection period) and risk (probability that spawner biomass falls below 20% of carrying capacity K at least once during the projection period) if a recruitment predictor (in the form of an environmental index) were used directly to set TACs.

The South African anchovy fishery is essentially a recruit fishery where over 70% (by mass) of the catch each year comprises juvenile fish (spawned in the most recent spawning period). The spawning peak is in November and recruitment to the fishery occurs from March/April onwards, when juvenile fish are targeted during their return migration to spawning areas (the nursery and spawning grounds are spatially separated). Two hydroacoustic surveys take place each year, the first in November to survey the adult component of the stock, and the second in May/June (the earliest time this is possible) to survey the incoming recruits. An estimate of the year's recruitment is thus available only 2-3 months after fishing has commenced on these recruits.

The fishery is managed by TAC. An initial TAC is set at the start of the fishing season and is based on the biomass estimated from the preceding November survey and assumes that forthcoming recruitment will be average. Because the bulk of the catch will comprise the year's recruitment, this TAC is revised as soon as an estimate of recruitment becomes available, replacing the assumption of average recruitment with the actual estimate from the recruit survey. It is in this context that a predictor of recruitment, used at the time the initial TAC is set, may provide increased benefits (in terms of higher average catch for a given level of risk) when compared to just assuming that forthcoming recruitment will be average.

Several authors have looked at incorporating environmental indices to improvement management. Cochrane and Starfield (1992) found that the average catch for South African anchovy (a highly productive stock) could be increased by up to 48% for very precise short-term predictors of recruitment. For gadoid-like species (i.e. of relatively low productivity), Basson (1999) concluded that there were no gains when the environmental index was used in the short-term prediction of recruitment. However, when it was used to change fishing mortality references points in the longer term, gains were possible when the environmental index could be well predicted. Walters (1989) found that improvements in management performance depended strongly on the average productivity of a stock and the flexibility of the in-season regulatory system used to manage this stock. For example, productive stocks managed with inflexible annual quotas showed very large improvements (30-50%) if perfect pre-season forecasting were practical, but unproductive stocks showed only modest improvements regardless of the in-season regulatory system used. These findings were consistent with those mentioned above.

Methods

This study focuses on environmental indices as short-term predictors of recruitment. In addition, where benefits are possible with such indices, it looks at how these benefits are eroded as different levels of uncertainty associated with the environmental index are incorporated in the analysis, an aspect that none of the above authors considered in their studies. A Monte Carlo simulation approach, similar to that used by Basson (1999), was used, and catch-risk curves similar to those plotted by Cochrane and Starfield (1992) are shown.

In the study, "true" recruitment is generated as follows:

$$R_{true} = \overline{R}\, e^{e_{true}}$$

$$e_{true} = r s_R T_{true} + \sqrt{1-r^2}\, s_R h$$

where r^2 is the amount of variation explained by the environmental index T_{true} (normalised to reflect a N[0;1] distribution), s_R^2 is the variance of the log-recruitment residuals, $\ln R_{true} - \ln \overline{R}$, and h is a random variable with a N[0;1] distribution. [$\overline{R}$ could be replaced by a stock-recruit relationship in the equation, but such a relationship is not evident in South African anchovy.]

"Predicted" recruitment is generated in five ways, each time incorporating additional levels of uncertainty, as follows:

I Parameters are known exactly, there is no measurement error:

$$R_{pred} = \overline{R}\, e^{r s_R T_{true}}$$

II Parameters are estimated, there is no measurement error:

$$R_{pred} = \overline{R}\, e^{\hat{b}_0 + \hat{b}_1 T_{true}}$$

$$\hat{b}_0 \text{ and } \hat{b}_1 \text{ estimated from } \{e_{true}; T_{true}\}$$

III Parameters are estimated, measurement error is included:

$$R_{pred} = \overline{R}\, e^{\hat{b}_0 + \hat{b}_1 T_{merr}}$$

$$\hat{b}_0 \text{ and } \hat{b}_1 \text{ estimated from } \{e_{merr}; T_{merr}\}$$

IV Parameters are estimated and selected (p=5%), measurement error is included:

$$R_{pred} = \overline{R}\, e^{\hat{b}_0 + \hat{b}_1 V_1 + \hat{b}_2 V_2 + \hat{b}_3 V_3}$$

$$\hat{b}_0, \hat{b}_1, \hat{b}_2 \text{ and } \hat{b}_3 \text{ estimated from } \{e_{merr}; V_1; V_2; V_3\}$$

$$\text{where } V_1 = T_{merr} \text{ and } V_{2/3} \text{ is drawn from } N[0;1]$$

V Parameters are estimated and selected (p=50%), measurement error is included:

As IV but the selection criteria (for inclusion of a parameter by forward selection in a multiple regression) is not as strict.

The initial TAC is then adjusted according to how R_{pred} compares with the distribution of R_{true} values: if R_{pred} falls within the lower third of the distribution, then the TAC is adjusted down by x, if it falls within the top third, the TAC is adjusted up by x, otherwise no adjustment is made to the TAC. Values of x considered where 0 (i.e. the environmental index is effectively not used), 50, 100 and 200 thousand tons.

Results

Figure 9.1 shows catch-risk curves where r^2=0.25 for all five prediction models (I-V above), with each panel showing curves for different values of x. Figure 2 repeats these plots for r^2=0.5. For a given level of risk (40%), Table 9.1 summarises the improvements in average catch for x=50, 100 and 200 thousand tons for different values of r^2 (0, 0.1, 0.25, 0.5 and 1) for each of the five prediction models, when compared to the case where no environmental index is used.

Table 9.1 Improvements in average catch for a risk level of 40%, when compared to when no environmental index is used. Results are shown for a range of r^2 and x ("TAC adj") values for all five recruitment prediction models (I-V).

	r^2=0.00	r^2=0.10	r^2=0.25	r^2=0.50	r^2=1.00
	TAC adj = 50 000t				
I	0%	1%	2%	7%	11%
II	1%	0%	2%	7%	11%
III	0%	0%	0%	5%	8%
IV	0%	0%	1%	4%	8%
V	0%	-1%	1%	4%	8%
	TAC adj = 100 000t				
I	0%	1%	3%	6%	15%
II	0%	0%	2%	6%	15%
III	-1%	-2%	0%	5%	11%
IV	-1%	-1%	1%	4%	11%
V	-2%	-5%	2%	5%	11%
	TAC adj = 200 000t				
I	0%	-4%	3%	5%	20%
II	-2%	-5%	1%	5%	20%
III	-3%	-5%	-3%	4%	15%
IV	-2%	-7%	-6%	2%	15%
V	-8%	-10%	-6%	2%	14%

Figure 9.1 Catch-risk curves for recruitment prediction models I-V for the case $r^2=0.25$. Average catches (x-axis) are in thousand tons, and risk is shown on the y-axis.

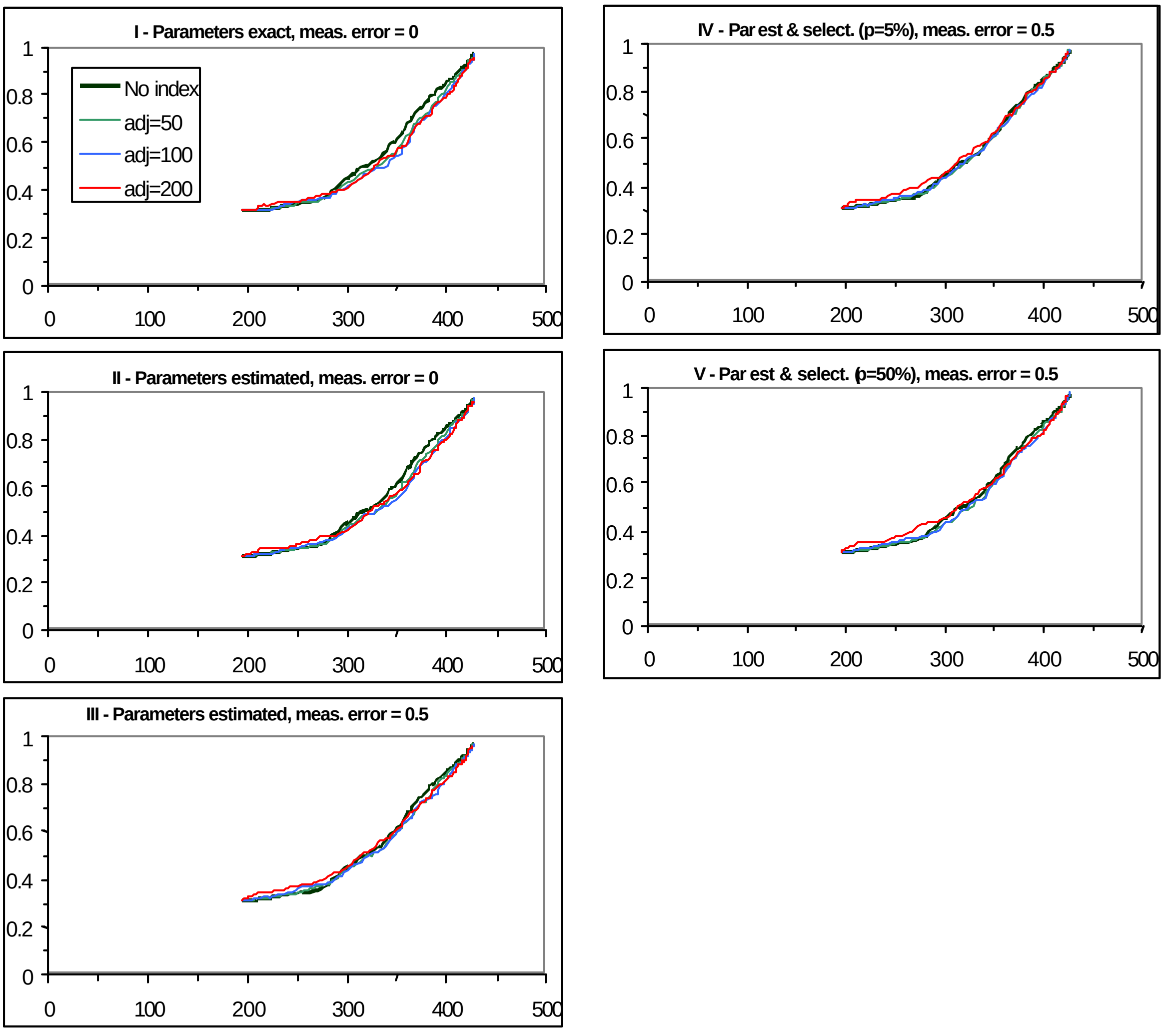
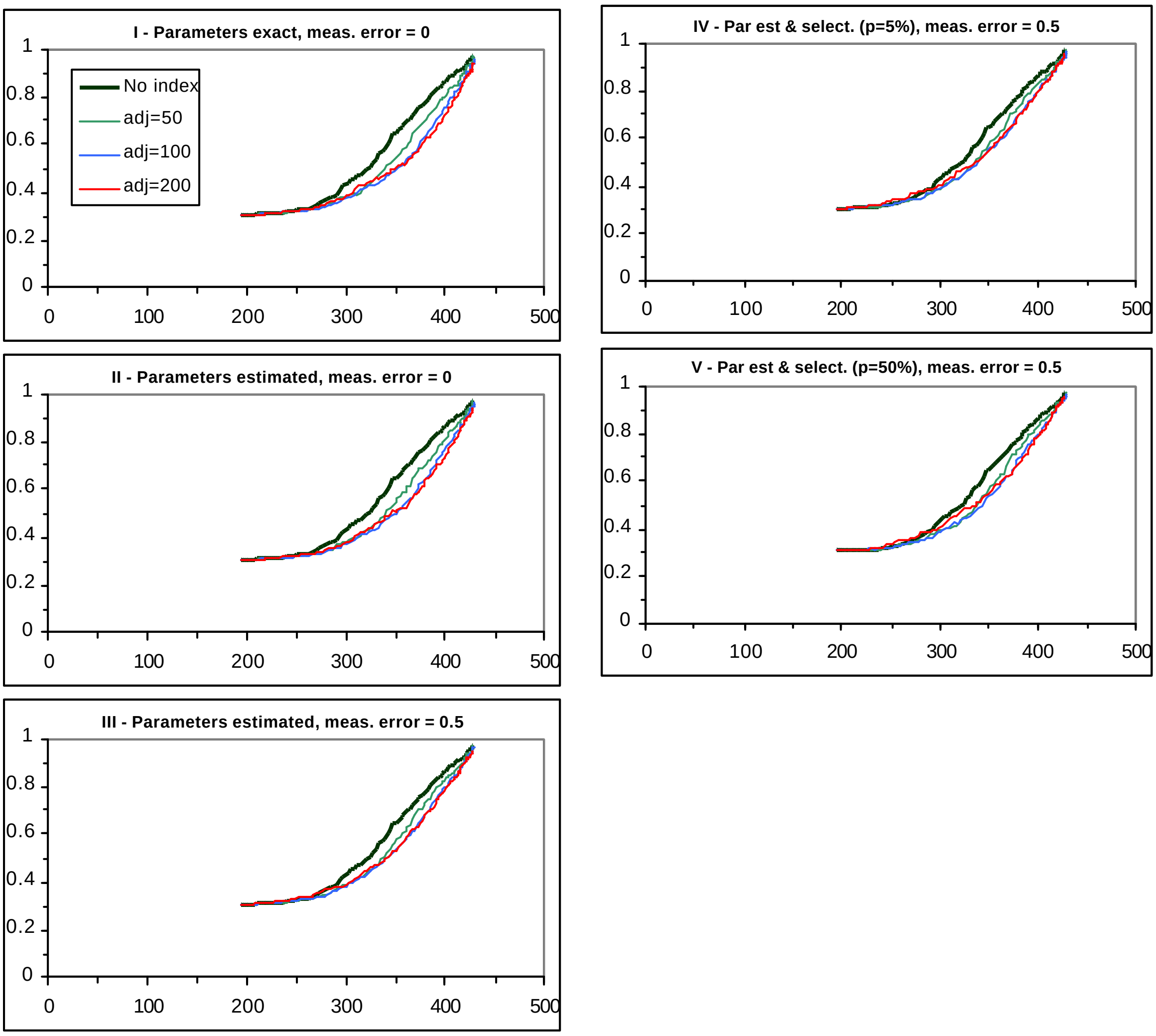


Figure 9.2 Catch-risk curves for recruitment prediction models I-V for the case r^2=0.5. Average catches (x-axis) are in thousand tons, and risk is shown on the y-axis.

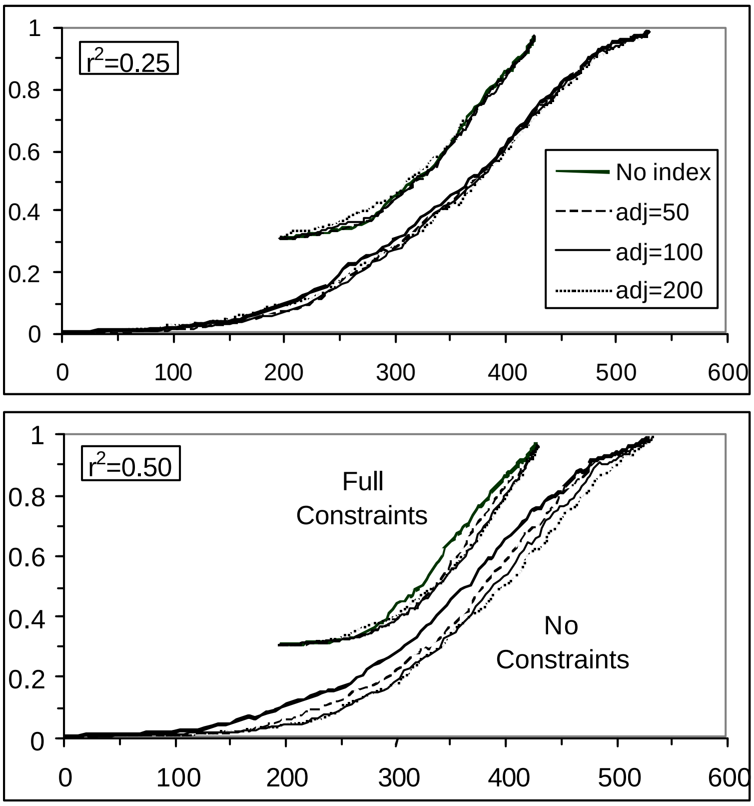


For Figures 9.1 and 9.2 and Table 9.1, TACs are subject to a number of constraints that attempt to keep these TACs from fluctuating downwards too rapidly, and to ensure that they remain within bounds that are acceptable to the fishing industry. Improvements in performance in terms of average catch and risk are possible if these TAC constraints are relaxed, and this is demonstrated in Figure 9.3, which contrasts catch-risk curves with and without constraints for both r^2=0.25 and 0.5 for recruitment prediction model IV. For a given level of risk (40%), Table 9.2 summarises the improvements in average catch for x=50, 100 and 200 thousand tons for different values of r^2 (0, 0.1, 0.25, 0.5 and 1) for each of the five prediction models, when compared to the case where no environmental index is used (no TAC constraints are applied in all cases).

Table 9.2 Improvements in average catch for a risk level of 40%, when compared to the case where no environmental index is used. Results are shown for a range of r^2 and x ("TAC adj") values for all five recruitment prediction models (I-V). In all cases, no TAC constraints are applied.

	r^2=0.00	r^2=0.10	r^2=0.25	r^2=0.50	r^2=1.00
	TAC adj = 50 000t				
I	0%	2%	4%	8%	11%
II	0%	2%	4%	7%	11%
III	0%	2%	3%	7%	11%
IV	0%	1%	3%	7%	11%
V	0%	0%	4%	8%	11%
	TAC adj = 100 000t				
I	0%	2%	7%	11%	20%
II	0%	3%	5%	11%	20%
III	0%	3%	5%	10%	20%
IV	-1%	1%	3%	9%	19%
V	-2%	1%	5%	10%	20%
	TAC adj = 200 000t				
I	0%	3%	9%	16%	32%
II	-1%	2%	10%	15%	32%
III	-1%	2%	6%	10%	29%
IV	-2%	0%	2%	9%	29%
V	-4%	-2%	5%	9%	29%

Figure 9.3 Catch-risk curves for recruitment prediction model IV for r^2=0.25 and 0.5. Results are shown for when TAC constraints are included (upper left hand side curves, corresponding to Figures 1 and 2) and for when no TAC constraints are applied (lower right hand side curves). Average catches (x-axis) are in thousand tons, and risk is shown on the y-axis.



Although removing TAC constraints leads to a general improvement in performance in terms of risk and average catch (Figure 3), and greater benefits when compared to the "no index" case (Table 2), this is accompanied by higher levels of inter-annual variation in average catch, as demonstrated in Table 3.

Table 9.3 Inter-annual variation in catch for a risk level of 40%. Results are shown for a range of r^2 values for the case where no index is used and for all five recruitment prediction models (I-V). The first set of results is for when TAC constraints are included, and the second for when they have been excluded. For the five prediction models, x=50 000t.

	r^2=0.00	r^2=0.10	r^2=0.25	r^2=0.50	r^2=1.00
	Full Constraints				
No index	29%	29%	29%	29%	29%
I	29%	29%	30%	31%	32%
II	29%	29%	30%	31%	32%
III	29%	29%	30%	31%	32%
IV	29%	29%	30%	31%	32%
V	29%	29%	30%	31%	32%
	No constraints				
No index	48%	48%	48%	48%	47%
I	48%	49%	50%	52%	52%
II	49%	49%	50%	51%	52%
III	49%	49%	50%	51%	51%
IV	49%	49%	49%	51%	51%
V	49%	49%	50%	51%	51%

General conclusions

- The environmental index needs to explain roughly 50% or more of the total variation in recruitment to start showing benefits in terms of risk and average catch.
- This figure is reduced by half if TAC constraints are relaxed, but relaxing TAC constraints may not be in the best interests of the fishing industry.

It should be noted that the above analysis:

- assumes the form of the recruit vs. index relationship is linear;
- assumes that this relationship holds throughout the implementation period of the management procedure;
- assumes serial correlation in recruitment residuals is known exactly, and that the environmental index is subject to the same serial correlation; and
- uses 30 years of "data" for parameter estimation

Recommendations brought up during discussion (see also item11.3)

- The study should be broadened to possibly include Peruvian anchoveta and Bay of Biscay anchovy.
- The amount of benefit may be linked to lead-time (from when environmental index is available to when actual recruitment measure takes place).
- Use of the index as a short-term predictor of recruitment vs. longer-term indicator of shift in productivity was discussed – perhaps this issue is not as important for anchovy as, say, for sardine?
- Apart from average catch and risk, which other performance indicators should be considered? (e.g. keeping average biomass high?)
- The influence of TAC constraints should be investigated.

10.0 Technical requirements for environmental indices to be incorporated into management procedures (Discussion Lead: Larry Jacobson)

Main topics discussed:

1) Variance, sensitivity and bias
   a. Binary (off/on) or continuous measurements (qualitative vs. quantitative variation)
2) Frequency of measurements vs. time frame of biological processes vs. management time frame
3) Time lags in data collection, management and biological response
4) Spatial scale of measurements vs. spatial scale of biological processes
5) Data for model-based vs. model-independent management
6) Logistical and cost considerations
7) Length of time series
8) Underlying hypotheses and data collection
9) Spurious correlations and competing causalities (e.g. overfishing vs. climate change?)
10) Sampling tools: satellites vs. bucket temperatures?
11) Data for short-term vs. long-term planning
12) Management based on data from prey, predators or ecologically linked species
13) Physical vs. biological variables
14) Habitat area and spawning area

Report:

Technical issues described below were discussed by the working group during the course of the meeting. By far, the most important and general issue was the importance of hypotheses in modeling fish-environmental interactions. As described below, there are many factors that likely obscure environmental linkages and many factors that likely lead to overconfidence in apparent relationships. Hypotheses about mechanisms appear to be the most useful tools for guiding exploratory analyses, avoiding spurious relationships, and evaluating the plausibility of apparent relationships.

1) **Model generated vs. "real" data**: Environmental data time series originate from at least three type of sources: 1) simple environmental measurements which are relatively easy to collect (e.g. SST measurements from cruises, satellite, buoys, etc.); 2) simple environmental measurements that are transformed into a synthetic variable (e.g. an index of offshore Ekman transport derived from wind speed data and used as an upwelling index); and 3) calculations from 3D hydrodynamic models (more common recently). A number of issues arise in this situation. Firstly, the statistical properties of the synthetic variable (including precision and bias) are usually unknown. The strength of the correlation between the synthetic variable and the environmental process is unknown. Details regarding collection of the original data (including number of measurements per time step, instruments used to collect the data, spatial distribution of measurements, etc.) are obscure and likely to change over time. Mathematical models used to transform the real data may change over time. For example, products such as the NCEP/NCAR reanalysis give consistent long time-series (1950' to present) from a single model run, however one should be aware that discontinuities might arise from changes in the assimilation of satellite data (SST) after the 1980's. All of these issues are potentially important in using synthetic environmental variables in fishery models. Scientists working on fishery problems should become as familiar as possible with synthetic variables used in modeling.
2) **Length vs. consistency of time series**: Long time series are most informative but long time series are plagued by changes in data collection and processing. Long time series may require more complicated modeling approaches that account for changes in underlying parameters.
3) **Fishery derived data:** Most fish stock assessment models use fishery data (e.g. CPUE, catch and fishing effort) to measure or infer trends in productivity, abundance, recruitment and fishing mortality. However, fishery data are affected by changes in fishing gear and fishing practices that increase efficiency. Steady increases in efficiency tend to mask concurrent changes in biological factors. For example, a 48% change in catch rates over a ten-year period might be due to increased productivity and abundance resulting from decadal scale climatic variability. Alternatively, a 48% change in catch rates could be due to 4% annual increase in fishing efficiency compounded over ten years. Increases in fishing efficiency have occurred steadily in most fisheries due to continuous investment and the introduction and improvements in marine electronics, availability of environmental data used to locate fish, and many other factors. Fishery data are also affected by misreporting, inaccurate reporting,

size/age selectivity of gear, the distribution of the stock, prices, and many other factors. Many of these factors depend on fishery regulations. A 48% decrease in and abundance over a ten-year period might be due to decadal scale climate change or, alternatively, to minimum size regulations that result in the death and discard of small fish that is not accounted for in the catch data. Scientists working on fishery problems should make an effort to use fishery independent data where possible. Long time series of fisheries data may require more complicated modeling approaches that account for changes in fishing efficiency and fishing practices. Where possible, fishery data series should be "standardized" based on adjustments for factors (including season, time of day, location, gear, vessel type, etc.) that account for changes in fishing efficiency using standard general linear model approaches. Finally, modelers should become aware of management and economic factors that might affect fishery data.

4) **Environmental effects on abundance versus effects on catchability:** Using annual time series, it is not always easy to distinguish between these two types of effects. This problem may be pronounced in short-lived species when recruitment is related to the environment or on any species when the environment is supposed to modify the growth.
5) **Are statistical properties of the data known?** Quantitative interpretation of environmental indices is enhanced if the data have statistical properties (autocorrelation, stationarity, variance, etc.) that can be described.
6) **Independent vs. autocorrelated observations**: Correlation and regression analysis are often used by scientists studying relationships between fish and climate. Ideally, variability in data (due to process or measurement errors) should be independent for correlation analysis. However, autocorrelation in time and/or space is frequently encountered and often unavoidable. Autocorrelation reduces statistical power and tends to inspire overconfidence in correlation and regression analyses. Scientists carrying out correlation analyses should adjust p-values for autocorrelation where necessary; try pre-whitening procedures, estimate statistical power by simulation, be honest about the problem, and foster an attitude of skepticism about apparent relationships between fish and environmental variables. Most importantly, decisions about the plausibility of apparent correlations should be based on an underlying hypothesis or physical mechanism.
7) **Multiple comparisons**: Correlation analyses based on random data will give statistically significant ($p<0.05$) but spurious correlation results in 5% of cases. The overall risk of a spurious result increases as additional correlation analyses are performed, particularly in "data mining" or exploratory analyses. Scientists carrying out multiple correlation analyses should adjust p-values for multiple comparisons (e.g. use a p-value of 0.5/N where N is the number of correlation analyses). More importantly, be honest about the problem, and foster an attitude of skepticism about apparent relationships between fish and environmental variables. As described above decisions about the plausibility of apparent correlations should be based on an underlying hypothesis or physical mechanism.
8) **Variance, sensitivity and bias**: Sensitive environmental indices tend to have high variance while more stable indicators tend to be biased because of lags. In constructing models and choosing indices, fishery scientists should the tradeoffs between variance and bias.
9) **Categorical vs. continuous variables:** The response of fish stocks to climate may discrete (e.g. regime shifts in stock-recruitment of Japanese sardine) or continuous (e.g. recruitment of California sardine is a non-linear function of average SST). Environmental variables may be discrete (e.g. El Nino) or continuous. The advantages and disadvantages of modeling based on categorical or continuous measurements depend on the circumstances. Categorical data are readily modeled, measurement errors tend to be reduced when continuous variables are reduced to categorical variables, and modeling results may have low variance. However, continuous data are also readily modeled and information (and degrees of freedom) may be lost in converting continuous measurements to categories. When non-linear, linear or categorical effects are suspected, a recommended two-step approach is first to initially explore the data using non-parametric scatterplot smoothers in GAM models. Using the non-parametric curves as a guide, identify components best represented by non-linear, linear and categorical terms. Finally, fit a second (usually simpler) GAM or GLM model with the appropriate nonlinear, linear and categorical terms.
10) **Interactions between environmental variables and biological characteristics of the stock (e.g. spatial distribution, age structure)**: For example, SST affects maturity of age 1 fish in California anchovy. If fish age 2 and older are rare due to high mortality rates (from predation or fishing), and age one fish constitute the bulk of the spawning biomass structure, then SST may have a pronounced effect on egg production and recruitment. In contrast, when fish age 2+ are more common, SST may have less effect on egg production and recruitment. It may be important in modeling to incorporate important interactions and time lags.

11) **Muticollinearity (redundant variables)**: Time series are often correlated and give similar information. Fitting models to redundant data will result in imprecise parameter estimates and predictions. For example, river runoff and phosphorous loading in the Baltic Sea are closely related. Principal components analysis (PCA) can be used in exploratory analyses to generate a few, uncorrelated time series for use in modeling.
12) **Frequency of measurements vs. time frame of biological processes vs. management time frame**. An environmental characteristic might act over a period of 1-2 months, require measurements that take 6-12 months to complete, and be used in a management process that is annual or biannual. Seek environmental variables that predict biological response over useful time lags.
13) **Hypotheses for environmental-biological linkages**. What biological characteristic does an environmental index affect? Confidence in environmentally based predictions is highest when the relationship between environmental data and fish population is understood.
14) **Logistical and cost considerations:** Data collection, processing and analytical costs must be appropriate for expected benefits.
15) **Biological-physical variables**: Biological data for the fish stock under consideration may be useful in climate linked stock assessment models. For example, Condition factors, oil content, stomach contents, age/size at first maturity may contain information about current environmental conditions. A shift in spawning season implies a change that may be important to managers.
16) **Habitat area/selection and spawning area/selection**: Inexpensive measures of habitat area (potentially based on presence-absence data) may provide an index of abundance for (for highly mobile and fast growing) pelagic fish. Habitat and spawning area may indirectly measure environmental conditions that affect fish productivity. A change in habitat or spawning area usually implies a change that may be important to management.
17) **Spurious correlations and competing causalities**: Global warming and overfishing have increased during recent decades. How can they be distinguished?
18) **Spatial and temporal correspondence of biological processes and environmental indices:** Biological processes in fish that occur over broad areas (e.g. feeding and spawning migrations) may be poorly correlated with environmental indices for small areas, or vice-versa. Similarly, biological processes in fish that occur over short time periods (e.g. months) may be poorly correlated with environmental indices measured over longer periods (e.g. years) or vice-versa. Temporal and spatial correspondence of biological processes and environmental indices should be carefully considered in fish stock assessment modeling. Spatial shifts and temporal lags should he incorporated where necessary.
19) **Precise vs. probabilistic response to environmental variables**: Many factors affect fish population dynamics. A strong environmental even effecting recruitment may be enhanced or diminished by other environmental or biological factors. In addition, environmental effects may not be reversible on short time scales due to ecosystem complexity and interactions. Therefore, it may be difficult to make accurate predictions about the biological response of a fish population, even if data are precise and the underlying mechanisms are known exactly. These considerations suggest that environmental factors might best be used to predict the probability of different outcomes. An expectation for precise predictions may be overly optimistic.
20) **Prediction at different time scales**: in many pelagic stocks, especially sardine and sardine-like fish, there are obvious time scales of variation in abundance and productivity that range from intra-decadal to inter-decadal. Discussions focused mainly on intra-decadal scale variation in relation to environmental processes because the intra-decadal time scale is compatible with short-term management decisions. However, dynamics at the inter-decadal scale might be easier to model, understand and predict. The autocorrelation of inter-decadal changes in productivity of many pelagic fish is so high that reasonable predictions of average abundance over 5-10 year periods might be made using time-series analysis tools (ARIMA, ARCH, etc.). However, this approach may be useful for identifying or predicting turning points or regime shifts. The time scale of economic investments (e.g. life-span of a boat) is of the order of 30 years, suggesting that inter-decadal suggestions should be useful for fishery management.

11. Working Group reports

On day three of the meeting the Study Group was divided into three working groups to identify relevant activities that this study group will follow in the next 12 months in pursue of the objectives set up at the beginning of the meeting. The three working groups were aimed at:

- Reviewing case studies where environmental information is used in the management of pelagic fish populations,
- Develop a scientific framework to understand the linkages between environmental variables and pelagic fish fluctuations, and
- Identify requirements before environmental indices can be incorporated in the management of pelagic fish.

The report of these groups form the actions of the study group between now and the next meeting of the group in 2002.

11.1. Review of case studies where EI is used in management procedures (Lead: Fritz Koester)

The conducted review on the use of environmental indices in the assessment and management of pelagic fish stocks world-wide (Table 11.1.1) revealed that in several cases ancillary environmental information is already used to assess the status of the stock and partly also applied in the management. The present compilation may be incomplete, as it necessarily reflects the expertise represented in the Group. Activities collecting ancillary information can be classified into two groups:

(i) *Activities related to the abundance and distribution of pre-recruits and adults*:

- predicting the short-term development of the stock by pre-recruit surveys (e.g. South-African sardine, Japanese sardine and mackerel, as well as Black Sea stocks),
- forecasting distribution of the stock in relation to environment as basis of a forecast of fishing operations (Japanese anchovy and mackerel: path types of Kuroshio and/or Oyashio and SST, Peruvian anchoveta: SST),
- applying predation mortality rates in the different assessment components (Baltic sprat and herring).

(ii) *Information on bio/physical environmental conditions affecting reproductive success and/or somatic growth*. These are in general less commonly gathered and more difficult to obtain. Examples for evidence of environmental conditions affecting the stock development are:

- proxies for transport in South African anchovy, upwelling and stratification breakdown in the Bay of Biscay anchovy, Kuroshio path types in Japanese stocks, upwelling index in Chilean stocks, intensity of south Atlantic Central water intrusion in Brazilian sardine and wind forcing in the Black Sea stocks.
- SST related to the distribution and productivity of Californian anchovy and sardines, recruitment of Peruvian/Chilean and South African anchovy, Japanese and European Sardine, Baltic and Black Sea sprat.

However, from the 18 stocks considered, only in 6 cases the environmental information is presently utilized in the assessment and management:

- Californian anchovy and sardine as a proxy for stock size and distribution,
- Peruvian anchovy to predict recruitment in short-term predictions,
- Japanese sardine for medium-term consideration impacting on recruitment per spawning stock,
- Brazilian sardine for nowcast recruitment success,
- Baltic herring in the Gulf of Riga to predict recruitment in short-term predictions.

In some additional cases environmental information has been used sometimes, but not on a regular basis, e.g. Bay of Biscay anchovy, or has been abandoned due to cut-back in monitoring efforts e.g. Black Sea stocks. Zooplankton standing stocks have been related to recruitment success in 3 stocks (South African anchovy here via the condition of adults, Japanese sardine and Gulf of Riga herring here via the food supply for larvae).

It is likely that these variables (and also others identified in single stocks, e.g. stratification breakdown, atmospheric pressure) are interlinked. For example, the dependence on SST may actually represent processes as transport, primary or secondary production or a direct impact on early/juvenile stage survival (or any combination of these). In turn, a given process may need to be described by different variables/proxies in different systems, e.g. upwelling along the Ivory Coast is independent of wind forcing, while in other areas wind conditions closely reflect upwelling conditions. Thus, specification of the underlying process appears to be a further necessary step in the completion of the review and utilization of the compiled information (e.g. common processes identified) in subsequent working steps of the Study Group. This task is scheduled to be finalized intersessionally until the 2nd meeting of the Study Group. It will consider also how close the environmental information actually is to the process in question and whether an improvement of the relationship(s) might be possible and realistically achievable (effort, time frame etc.). An example for which a substantial improvement is considered to be needed, but extremely difficult to achieve, is the measurement of secondary production suitable and available as food supply for larvae/early juveniles. Here physical proxies might be an easier way of realisation within the foreseeable future.

Apart of this, in a considerable number of stocks regularly collected information has the potential to be utilized to explore the stock dependence on environmental conditions more closely, e.g. data applied to estimate the daily egg production as a measure of the spawning stock (available in 13 out of 18 considered stocks) may be utilized for detecting spatial and temporal shifts in spawning activity related to environmental forcing or stock density affecting the reproductive success of a stock. Attempts or potentials in this respect will be reported as well.

Table. 11.1.1 Overview on the use of environmental indices as hindcasting/nowcasting and forecasting tools in selected areas

Species	**Area**	**Environmental data/process suitable for hind- and nowcasting**	**Used in assessment/ management**	**Environmental data/process suitable for forecasting**	**Used in assessment/ management**	**Author**
Engraulis capensis	South Africa	Recruitment related to SST and wind (in different areas as a proxy of upwelling/ transport)	No	Expert system to predict recruitment using wind data, SST, atresia, starvation index, egg abundance Age-structured, multi-fleet model utilizing SRR incorporating variability and serial correlation	No Scenario projection utilizing joint probability distributions	Claude Roy
Engraulis japonicus	Japan	Egg production survey	Yes	State of Kuroshio and/or Oyashio, SST related to fishery	No	Akihiko Yatsu
Engraulis encrasicolus	Bay of Biscay	Recruitment related to upwelling index & index of stratification breakdown	Nowcast year-class strength	Recruitment related to upwelling indices & index of stratification breakdown	Yes in 1999, no in 2000	Benjamin Planque
Engraulis encrasicolus	Black Sea			Pre-recruit survey Atmospheric pressure, wind forcing & runoff related to recruitment, SST as a proxy for heat content	Former USSR used pre-recruit surveys and SST in short-term forecasts	Georgi Daskalov
Engraulis mordax	California	Maturity of age 1 fish during peak spawning season (when surveys are conducted) is controlled by ocean temperatures	Yes	None	Assessments use SSB data and relative abundance indices based on ichthyoplankton data. Therefore, interpretation of abundance data in stock assessment models requires adjustments to maturity of age one fish based on ocean temperature data	Larry Jacobson
Engraulis ringens	Peruvian coast	Stock biomass & distribution related to SST	Yes	Reproductive success dependent on hydrographic regime	Index of recruitment in effort regulation	Miguel Niquen Carranza
Engraulis ringens	Chilean-Peruvian coast	Recruitment related to SST & upwelling index based on wind data	No	No	No	Luis Cubillos

Engraulis ringens	Southern Chile	Recruitment related to SST & upwelling index based on wind data	No	Recruitment rate, ln(R/SSB), inversely related to recruitment rate of sardine, suggesting a biological mechanism of interaction.	No	Luis Cubillos
Sardinops sagax	South Africa			Pre-recruit and recruit surveys	Yes	Claude Roy
Sardinops melanosticus	Japan	Pre-recruit survey Recruitment related to Oyashio in winter, SST anomaly in southern Kuroshio extension in winter/spring & Kuroshio path types	Yes	Pre-recruit survey Recruitment related to Oyashio in winter, SST anomaly in southern Kuroshio extension in winter/spring & likely to Kuroshio path types and related zooplankton biomass	Short-term forecast Yes to predict recruitment success (RPS) based on SST anomaly in Oyashio region	Akihiko Yatsu
Sardina pilchardus	Iberian coast			Recruitment related to intensity of upwelling, SST, NAO & Gulf stream index	No	Benjamin Planque
Sardinops sagax	California	Recruitment, geographic area of potential habitat, and stock biomass related to medium-term average SST.	Yes. MSY parameters related to average SST. Recent recruitment estimates based partly on predictions from a temperature dependent stock-recruit model.	Future recruitment related to average SST.	Harvest control rule uses temperature-dependent Fmsy estimated as a threshold reference point The control rule is based on a precautionary approach and long-term simulations with stock assessment measurement errors, autocorrelation and variability in recruitment.	Larry Jacobson
Sardinella brasiliensis	southeast Brazil Bight	Recruitment related to interannual variation in intensity of south Atlantic Central Water intrusion	Yes	Predominant wind data during austral summer, primary/secondary productions in coastal regions	No	Yasunobu Matsuura
Strangomera bentincki	Southern Chile	Recruitment related to SST & upwelling index based on wind data	No	Recruitment related to SST at peak spawning & coastal upwelling index in pre-recruit phase	No	Luis Cubillos
Scomber japonicus	Japan	Pre-recruit survey	Yes	Pre-recruit survey Meandering of Kuroshio affects larval survival	Short-term forecast No	Akihiko Yatsu

				State of Kuroshio and/or Oyashio, SST related to fishery	Forecast of fishing conditions	
Sprattus sprattus	Baltic	Predation mortality by cod from MSVPA Weight at age dependent on calanoid copepod biomass & sprat stock size	Yes No	Predation based on cod stock size (& prey suitabilities), weight at age variability SRR incorporating temperature in intermediate water	Short-term prediction, scenario projection and reference points No	Fritz Köster
Sprattus sprattus	Black Sea			Pre-recruit survey Atmospheric pressure, wind forcing & runoff related to recruitment, SST as a proxy for heat content	Former USSR used pre-recruit surveys and SST in short-term forecasts	Georgi Daskalov
Clupea harengus	Baltic	Predation mortality by cod from MSVPA Weight at age dependent on calanoid copepod biomass & clupeid stock size	Yes No	Predation based on cod stock size (& prey suitabilities) Recruitment of Gulf of Riga component in dependence of temperature & zooplankton biomass	Short-term prediction, scenario projection and reference points Short-term prediction	Fritz Köster

Background information on specific case studies

The following section gives additional background information on the use of environmental information in the assessment of specific stocks. For those stocks not covered here, all relevant information is given in the text accompanying the stock assessment checklists (section 6).

Case study 1. Anchovy in the southern Benguela *(by Claude Roy)*

In the Southern Benguela, hydro-acoustic surveys are conducted annually during the anchovy spawning season (November) and during the subsequent recruitment period (May/June). This quantitative assessment of the resources enabled the development of a management procedure for anchovy based on surveys estimates of the abundance of spawners and recruits. Acoustic surveys results of spawner biomass in November are used to determine initial TAC for the following fishing season. This is revised after the mid-year survey (May/June) in which actual recruitment is estimated. Simulation studies by Cochrane and Startfield (1992) indicated that a valuable increase in mean annual yield could be achieved if recruitment variability could be correctly predicted at the start of the fishing season. This has motivated research toward designing expert systems that would incorporates environmental and biological information to predict the level of recruitment at the beginning of the following year (Bloomer et al., 1994; Painting and Korrubel, 1998; Korrubel et al., 1998). An empirical model incorporating two environmental factors has also been recently developed (Roy et al., in prep.).

The development of expert systems to forecast anchovy recruitment success

The rule based model of Bloomer et al. (1994) used environmental variables in the spawning, transport and nursery areas of the anchovy to predict recruitment. From simple correlation analysis, qualitative rules are constructed relating recruitment success to Sea Surface Temperature (SST), wind (frequency and velocity) and an index of spawner biomass. Output is a semi-quantitative prediction of recruitment in numbers of recruits. The model was calibrated using the data from 1984-1991 and used to predict the 1992 recruitment (predicted recruitment value was 15% lower than observed).

Using data from 1985 to 1992, Cochrane and Hutchings (1995) developed a conceptual model of the factors influencing anchovy recruitment and investigated 10 biological and environmental factors that could be used to make such forecast. Five of the indicators were shown to affect anchovy recruitment variability and the authors proposed three scenarios under which recruitment in the forthcoming season was “likely” to be “below average”. This approach was investigated further (Korrubel et al., 1998) by developing a rule-based expert system to predict below-averaged recruitment of anchovy on the basis of environmental and biological information collected during the November survey. The following description of the model is extracted from Korrubel et al. (1998). A number of workshops were organized to compile data for the model: scientific experts were invited to provide variables that could be used to predict anchovy recruitment. A subset of predictor variables was selected from the initial list of potential predictors on the basis of data availability and ease of monitoring (Fig. 11.1.1). Quantitative thresholds were set for each variable, defining whether individual points lie above or below the threshold and therefore have an impact on recruitment. The output of the model is a qualitative forecast of recruitment, either ABOVE or BELOW the long-term median value. After tuning, the final version of the model used four differentially weighted indicators: egg production, upwelling off the West Coast (16°C isotherm), gonad atresia, ENSO. The performance of the model during the 1985-1994 time period is presented in Fig. 11.1.2. The “very likely below average recruitment” that was forecasted by the model for 1994 has been confirmed later when the 1994 recruitment’s estimate became available. Painting and Korrubel (1998) give a detailed evaluation of the performance of the model using monthly data collected during the monthly SARP surveys that covered the spawning seasons of 1993/1994 and 1994/1995.

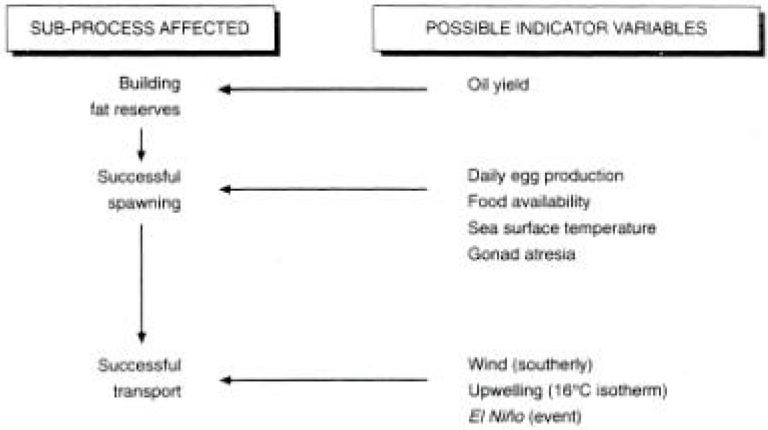


Figure 11.1.1 *Conceptual model of the major sub-processes and possible indicator variables influencing anchovy recruitment in the Southern Benguela (from Korrubel et al., 1998).*

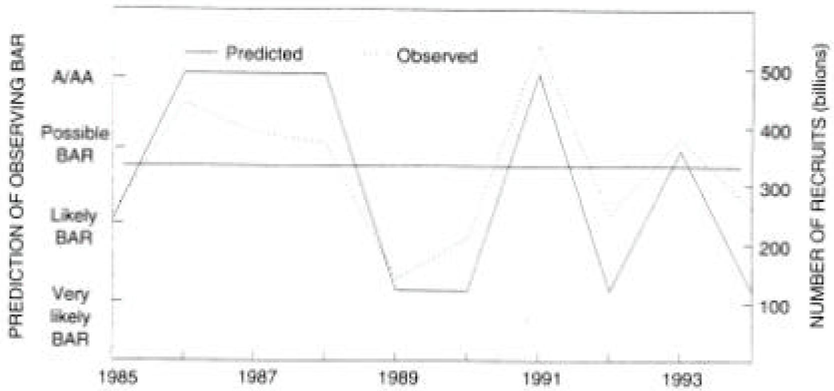


Figure 11.2 *Observed and predicted anchovy recruitment as provided by the expert system in the Southern Benguela (from Korrubel et al., 1998).*

Since their publications, these models have not been updated on a regular basis and their performances have not been further evaluated. Using the expert system, an attempt to forecast anchovy recruitment for 1999 was not as successful as the forecast made in 1994 (S. Painting, comm. pers.).

An empirical model of anchovy recruitment variability

A long list of potential processes contributing to anchovy recruitment variability in the Benguela has been proposed (Hutchings et al, 1998). Shannon et al. (1996) and Shannon (1998) explored the effect of transport processes on eggs and larvae. Boyd et al. (1998) highlighted the importance of successful transport for anchovy recruitment success: using wind data as a surrogate for upwelling intensity over the whole spring-summer season, a statistically significant negative relationship was found between recruitment and south-east wind-run anomalies with positive south-east wind anomaly leading to low recruitment success. An update using more recent recruitment data resulted in a significant drop of the r-square. Moreover, the record high-level of anchovy recruitment observed in 2000 (the highest recruitment recorded since the beginning of the time-series in 1984) corresponds to the strongest positive south-east wind anomaly over the past 40 years (see Fig. 3 in Roy et al., 2001).

Roy et al. (2001) and Roy et al. (in press) carried a review of the short-term variability of the environment during the 1999-2000 upwelling season (the spawning season that lead to the massive anchovy recruitment in 2000). The 1999-2000 upwelling season was characterized by an extreme warm event (total collapse of the upwelling) in mid-December 1999 that lasted for 2 weeks. This warm event was followed during January by moderate upwelling conditions. By taking into account these observations, they proposed that, when investigating the linkage between recruitment and environmental factors, it might be more important to consider the temporal succession of events within the season and their magnitude, than just the mean conditions over the whole season. They hypothesised that the succession of contrasted oceanographic events observed in the Southern Benguela during the 1999-2000 summer season and their respective timing with the anchovy reproductive strategy, might well represent the canonical pattern of environmental conditions for anchovy recruitment success.

The validity of this assumption has been tested using an empirical approach (Roy et al., in prep.). Two environmental indices (Sea Surface Temperature anomalies) are used as surrogates of the upwelling intensity off the Cape Peninsula (in December) and the West Coast (in January) upwelling regions. They are aimed at describing the pattern of upwelling variability following the anchovy's spawning peak that occurs in November over the Agulhas Bank. Scatter plots show that anchovy recruitment decreases as upwelling increases off the Cape Peninsula in December while there is a dome-shaped relationship between recruitment and upwelling intensity off the West Coast in January (Fig. 11.1.3). A statistical model has been calibrated using the 1985-1994 time-series: the above two indices are the independent variables and the recruitment is the dependent variable. The model is then used to hindcast the remaining part (1995-2000) of the recruitment time-series. The hindcast provided by this empirical model appears to confirm that weak upwelling off the Cape Peninsula in December followed by moderate upwelling off the West Coast region in January generally contribute to favour anchovy recruitment success. However, the model failed to predict the 2001 anchovy recruitment that will be, according to the estimation from the May 2001 recruits survey, almost as high as in 2000 and well above the averaged recruitment during the period over which the model has been calibrated. With a spawning biomass in November 2000 being more than two times higher than the previous record, other processes than just environmental control of eggs and larvae survival may have become important.

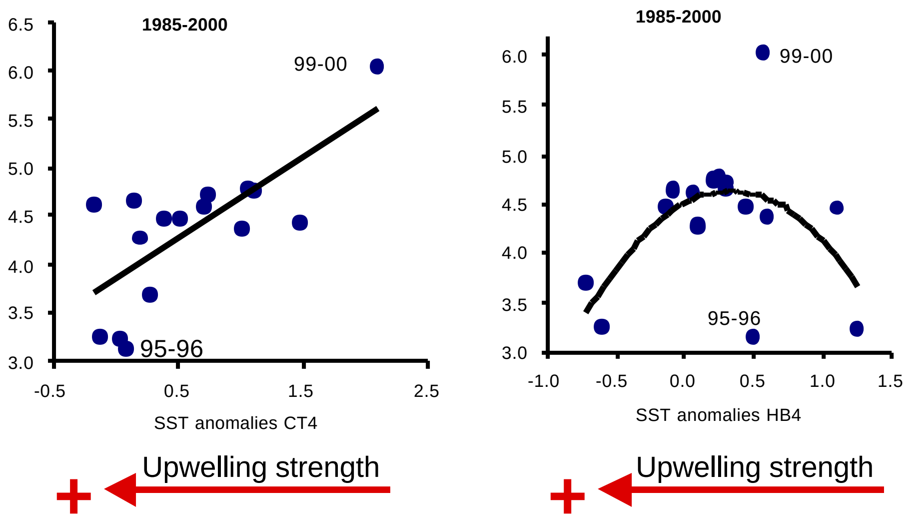


Figure 11.1.3 Scatter plots of 1-anchovy recruitment and SST anomalies in December off the Cape Peninsula and 2- anchovy recruitment and SST anomalies in January off the West Coast.

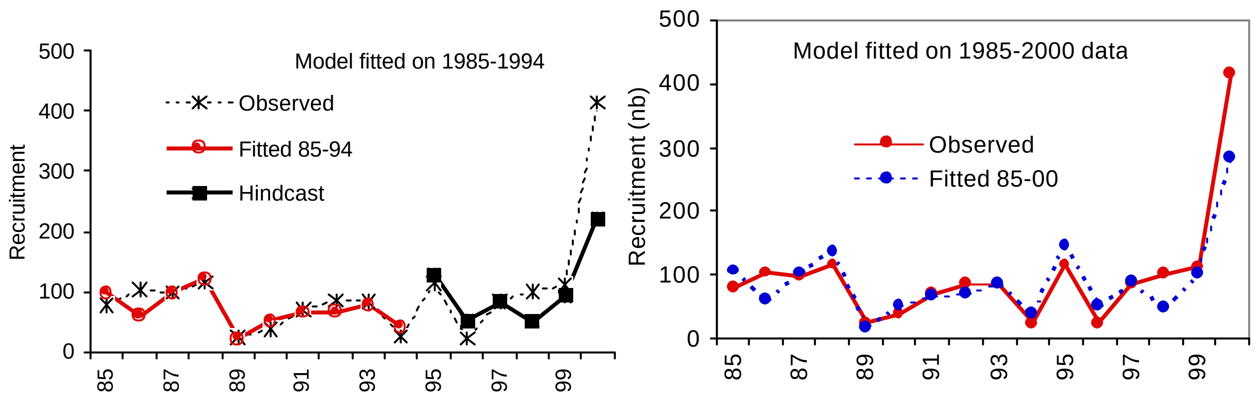


Figure 11.1.4 Observed and adjusted anchovy recruitment time-series in the Southern Benguela by an empirical model incorporating two environmental variables. Left panel presents the hindcast of recruitment for 1995 to 2000 given by the model adjusted on the 1985-1994 time-period. Right panel presents the model adjustment on the 1985-2000 recruitment time-series.

References

Bloomer S.F., K.L. Cochrane and J.G. Field. 1994. Towards predicting recruitment success of anchovy *Engraulis capensis* in the Southern Benguela system using environmental variables: a rule based model. *S. Af. J. mar. Sci*., 14:107-119.

Boyd A.J., L.J. Shannon, F. H. Schulein and J.T. Taunton-Clark, Food, transport and anchovy recruitment in the Southern Benguela upwelling system of South Africa. In : Durand M.H., P. Cury, R. Mendelssohn, C. Roy, A. Bakun and D. Pauly (eds). Global versus local changes in upwelling systems. Editions ORSTOM Paris. p195-209.

Cochrane K.L. and L. Hutchings, 1995. A structured approach to using biological and environmental parameters to forecast anchovy recruitment. Fishery Oceanography. 4:102-107.

Hutchings L., Barange M., Bloomer S.F., Boyd A.J., Crawford R.J.M., Hugget J.A., Kerstan M., Korrubel J.L., De Oliviera J.a., Painting S.J., Richardson A.J., Shannon L.J., Schulein F.H., Van de Lingen C.D. and H.M. Verheye. 1998. Multiple factors affecting South African anchovy recruitment in the spawning, transport and nursery areas. *In:* Benguela Dynamics: Impacts of variability on shelf-sea environments and their living resources. Pillar, S. C., Moloney, C., Payne, A. I. L. and F. A. Shillington (Eds). *S. Afr. J. mar. Sci* 19: 211-225.

Korrubel J.L., S.F. Bloomer, K.L. Cochrane, L. Hutchings and J. G. Field. 1998. Forecasting in South African pelagic fisheries management: the use of expert ad decision support systems. *In:* Benguela Dynamics: Impacts of variability on shelf-sea environments and their living resources. Pillar, S. C., Moloney, C., Payne, A. I. L. and F. A. Shillington (Eds). *S. Afr. J. mar. Sci* 19: 415-423.

Richardson A.J., Mitchell-Innes B.A., Fowler J.L., Bloomer S.F., Verheye H.M., Field J.G., Hutchings L. and S.J. Painting. 1998. The effect of sea temperature and food availability on the spawning success o cape anchovy Engraulis capensis in the southern Benguela. In Benguela Dynamics. Pillar S.C., Moloney C.L., Payne A.I.L., and F.A. Shillington (Eds). S. Afr. J. mar. Sci. 19: 275-290.

Roy C., van der Lingen C., Weeks, S. Rouault M., Coetzee J., Nelson G .and R. Barlow 2001. The Southern Benguela Anchovy population reached an unpredicted record level of abundance in 2000: another failure for fisheries oceanography ? *GLOBEC International Newsletter*, Vol,. 7, 1, p9-11.

Roy C., Weeks S., Rouault M., Nelson G., Barlow R. and C. van der Lingen. In press. Extreme oceanographic events recorded in the Southern Benguela during the 1999-2000 summer season. *South African Journal of Science.*

Roy C., P. Fréon and C. van der Lingen. In preparation. An empirical model of anchovy recruitment variability in the Southern Benguela.

Shannon L. 1998. Modelling environmental effects on the early life history of the South African anchovy and sardine: a comparative approach. In: Benguela Dynamics. Pillar S.C., Moloney C.L., Payne A.I.L., and F.A. Shillington (Eds). *S. Afr. J. mar. Sci.* 19: 291-304.

Shannon L., G. Nelson, R.J.M. Crawford and A.J. Boyd. 1996. Possible impacts of environmental change on pelagic fish recruitment: modelling anchovy transport by advective processes in the southern Benguela. *Global Change Biology*, 2, 407-420.

Case Study 2. Anchovy in the Humboldt Current System (by Luis Cubillos)

Southern Peru-Northern Chile stock of anchovy

The Southern Peru - Northern Chile stock of anchovy (*Engraulis ringens*) is annually assessed by Virtual Population Analysis using an ADAPT approach (e.g. Gavaris, 1988) in which the unknown parameters are estimated by minimizing the squared differences between the observed and estimated catch per unit effort (CPUE). No errors in catch-at-age data are considered, and the rate of natural mortality ($m=1.0\ yr^{-1}$) is assumed to be constant across age groups and years. However, evaluation of uncertainty in carried out by bootstrapping (Serra comm. pers, rserra@ifop.cl).

Time series of catch-at-age data are available from 1984 (Barría, 1996), and fishery-independent information from surveys from 1995 (Oliva et al., 2000). In fact, since 1995 surveys are conducted annually during the anchovy spawning season (August) and during the subsequent recruitment period (December/January). The spawning biomass is quantified by the Daily Egg Production Method (DEPM), while recruitment is quantified by hydroacoustic.

No environmental information is currently used inn stock assessment because priority has been give to have more reliable auxiliary information like the DEPM and acoustic estimates. However, changes in distribution related to El Niño – Southern Oscillation events are documented, and the effects of environmental indices on recruitment and catchability are usually proposed (e.g. Barría et al., 1999; Yáñez et al., 2001). During the last 1997-98 El Niño event, a reduction of 16% in body weight of individuals was observed (CPPS-ERFEN, 1999).

Central-South Chile

The most southern anchovy stock of the Humboldt Current System is distributed mainly between 34°S and 40°S (Castro et al., 2001). In central-southern Chile, anchovy forms mix schools with common sardine (*Strangomera bentincki*) and fishermen do not prefer either anchovy or common sardine, because price is equal for both species, and can be caught either separately or together.

Spawning time of anchovy and common sardine occurs in winter (between July-September, and peak in August Southern Hemisphere, Cubicles et al., 1999; 2001). Subsequent recruitment of the species occurs three to four month after peak of spawning, at 6-7 cm of total length. After recruitment, a fleet of seiner starts to fish more frequently and the catches are supported mainly by the annual pulse of recruitment. Stock assessment is carried out by considering monthly catch-at-length data, from which single cohorts per year can be identified. Then abundance of cohorts is quantified by Cohort Analysis using an ADAPT approach (e.g. Gavaris, 1988) in which the unknown parameters are estimated by minimizing the squared differences between the observed and estimated CPUE (Cubillos et al., in press).

Time series of monthly catch-at-length data are available from 1990, but fishery independent information only in recent years. Since 1999, recruitment is assessed by a hydroacoustic surveys in December-January each year. However, this information is currently not incorporated into stock-assessment. However, in 2001 the hydroacoustic estimate of recruitment was used to determine the total allowable catch.

For the 1965-1977 time period, Fonseca et al. (1986) found that a higher catch per unit effort (CPUE) of both species in a given year was related to warmer non-El Niño conditions during the spring of the previous year. However, a lower CPUE was observed when strong El Niño events occurred. Similarly, Yáñez et al. (1990, 1992) concluded that the relative abundance of common sardine and anchovy was inversely related with the fishing effort, as well as with the sea surface temperature, and the turbulence induced by winds.
In the 1990s, a short-term alternation between common sardine and anchovy was observed. Recruitment of anchovy was negatively related to recruitment of the common sardine (Cubillos and Arcos, MS). Furthermore, the conditions of the 1997-98 El Niño in central-southern area off Chile affected negatively the survival of common sardine offspring and the small cohort size was important for the recruitment success of anchovy. Because the recruitment rate of the species are inversely related, and because anchovy conforms mix schools with common sardine, it was hypothesized that a biological mechanism of interaction between the species could be operating through the “school trap” mechanism (Bakun and Cury, 1999) in the early school dynamics of the species.

Catch history between 1960 and 1999 suggests that common sardine and anchovy catches are coherent with the regime of an anchovy-dominated system. In other words, anchovy and common sardine is out of phase with the sardine regime (i.e. *Sardinops sagax*) of the other ecosystems. Between 1976 and 1987, a low productivity of the anchovy and common sardine was observed, with concurrent changes in local environmental time series. Sea surface temperature was warmer in that period, sea mean level was higher, and upwelling index based on wind data remained lower.

In this context, sea surface temperature and upwelling index are potential environmental variables than can be used as proxy for short-term predictions of recruitment. According to Cubillos and Arcos (MS), recruitment of common sardine showed significantly negative relationship with SST anomalies during the pre-recruitment period, as well as with the upwelling index during the peak of spawning (e.g. July-August). However, the recruitment of anchovy did not seem to be affected by the environmental changes observed in the 1990s.

References

Bakun, A., Cury, P., 1999. The “school-trap”: a mechanism promoting large-amplitude out-of-phase population oscillations of small pelagic fish species. Ecology Letters 2, 349-351.

Barría, P., 1996. Investigación y evaluación del stock de anchoveta 1995, I y II Región. Informe Técnico Instituto de Fomento Pesquero, 31 p. + anexos

Barría, P., Zuleta, A., Böhm, G., Catasti, V., Barbieri, M.A., Yánez, E., Gonzalez, A., Nieto, K., Silva, C., Espíndola, F., 1999. Análisis de la dinámica del patrón de explotación de la flota cerquera en la zona norte y su relación con el medio ambiente. Informes Técnicos FIP, FIP-IT/96-03, 120 p. + anexos

Castro, L.R., 2001. Studies of the environmental conditions and larval survival of the southermost anchoveta stock of the Humbold Current during the winter spawning season. *GLOBEC International Newsletter*, Vol. 7, 2, p 15-17.
Cubillos, L., Canales, M., Bucarey, D., Rojas, A., Alarcón, R., 1999. Epoca reproductiva y talla media de primera madurez sexual de *Strangomera bentincki* y *Engraulis ringens* en la zona centro-sur de Chile en el período 1993-1997. Invest. Mar. Valparaíso 27, 73-86.
Cubillos, L.A., Arcos, D.F., Canales, M., Bucarey, D., 2001. Seasonal growth of small pelagic fish off Talcahuano (37°S-73°W), Chile: a consequence of their reproductive strategy to seasonal upwelling?. Aquat. Living Resour. 14, 115-124.
Cubillos, L.A., Bucarey, D.A., Canales, M. Monthly abundance estimation for common sardine *Strangomera bentincki* and anchovy *Engraulis ringens* in the central-southern area off Chile (34-40°S). Fish. Res. (in press).
Cubillos, L.A., Arcos, D. (MS) Recruitment of common sardine (*Strangomera bentincki*) and anchovy (*Engraulis ringens*) off central-south Chile in the 1990s and the impact of the 1997-98 El Niño. (Manuscript submitted to Aquatic Living Resources, September 2001).
Fonseca, T.R., Yánez, E., Barra, O., 1986. Relación entre la temperatura superficial del mar y capturas comerciales en el área de Talcahuano entre 1965 y 1976. *In*: Arana, P. (Ed.), La Pesca en Chile, Escuela de Ciencias del Mar, UCV, Valparaíso, pp. 243-248.
Gavaris, S., 1988. An adaptatitve framework for the estimation of population size. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 88/29, 12 p.
Oliva, J., Braun, M., Córdova, J., Castillo, J., Valenzuela, V., Catasti, V., Blanco, J., Martínez, C., 2000. Evaluación del stock desovante de la anchoveta en la I y II Regiones, 1999. Informes Técnicos FIP, IT-FIP/99-10, 97 p.
Yáñez, E., Barbieri, M.A., Montecinos, A., 1990. Relaciones entre las variaciones del medio ambiente y las fluctuaciones de los principales recursos pelágicos explotados en la zona de Talcahuano, Chile. In: Barbieri, M.A. (Ed.), Perspectivas de la Actividad Pesquera en Chile, Escuela de Ciencias del Mar, UCV, Valparaíso, pp. 49-62.
Yáñez, E., Barbieri, M.A., Santillán, L., 1992. Long-term environmental variability and pelagic fisheries in Talcahuano, Chile. In: Payne, A.I., Brink, L., Mann, K.H., Hilborn, R. (Eds.), Benguela Trophic Functioning. S. Afr. J. Mar. Sci. 12, 175-188.
Yánez; E., Barbieri, M.A., Silva, C., Nieto, K., Espíndola, F., 2001. Climate variability and pelagic fisheries in northern Chile. Progress in Oceanography 49, 581-596.

Case Study 3. Anchovy and sardine off California (by Larry Jacobson)

This case study was fully described in section 6.2. References complementing information given in Table 11.1.1 on the use of environmental indices as hindcasting/nowcasting and forecasting tools:

Deriso, R.D., J.T. Barnes, L.D. Jacobson, and P.R. Arenas. 1996. Catch-at-age analysis for Pacific sardine (*Sardinops sagax*), 1983-1995. Calif. Coop. Oceanic Fish. Invest. Rep. 37: 175-187.
Jacobson, L. D., and A. D. MacCall. 1995. Stock-recruitment models for Pacific sardine. Can. J. Fish. Aquat. Sci. 52: 566-577.
Jacobson, L.D., N.C.H. Lo, and J.T. Barnes. 1994. A biomass based assessment model for northern anchovy *Engraulis mordax*. Fish. Bull. U.S. 92: 711-724.
Methot, R.D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. Am. Fish. Soc. Symp. 6: 66-72.
Pacific Fishery Management Council. 1998. The coastal pelagic species fishery management plan. Pacific Fishery Management Council. Portland, Oregon, USA.

Case Study 4. Sprat and herring in the Baltic Sea (by Fritz Köster)

Predation by cod is a major source of clupeid mortality in the Baltic, with all age-groups of sprat suffering from predation, while herring is preyed upon intensively only as juveniles (Sparholt, 1994a). A drastic decline in the cod stock throughout the 1980's as the major predator in the system caused a substantial reduction in predation (Parmanne et al., 1994) and in fact utilizing Multispecies Virtual Population Analysis (MSVPA) output, predation mortality rates may be predicted simply by the biomass of adult cod (ICES, 1994). The highly significant relationship may, however, to a certain extend be artificially created by some of the assumptions in the MSVPA (e.g. constant suitability coefficients over time) (Neuenfeldt and Köster, 2000). The shift in distribution of the cod stock, or more precisely the concentration of the remaining stock in south-western areas of the Central Baltic with a virtual extinction in the north-eastern areas, resulted in remaining high predation intensity in the former area, while in the latter the predation mortality is negligible (Köster et al. 2001a).

Apparent changes in herring growth rates have been explained by: i) a reduction in size selective feeding by cod, preying predominantly on smallest individuals within a herring age-group (Beyer and Lassen, 1994), ii) different developmental success in sub-stocks exhibiting different growth rates (Sparholt, 1994b), and iii) limitation in food supply (Cardinale and Arrhenius, 2000). For sprat a similar decline in weight at age started later (ICES, 2001), i.e. in a period when the cod stock was already on a historic low level, excluding the first hypothesis as an explanation. Furthermore, all sprat stock sub-components exhibit a similar reduction in weight at age (ICES, 2001), restricting the potential explanation to the 3rd hypothesis. In fact, available zooplankton data suggests that individual prey availability declined concurrently with the weight at age. While in the 1980's the decline in *Pseudocalanus elongatus* (Möllmann et al., 2000), a major calanoid copepod prey species of both herring and sprat (Möllmann and Köster, 1999), was compensated by an increase in standing stocks of *Acartia* spp. (Dippner et al., 2000), the drastic increase in the sprat stock size due to high reproductive success, low predation pressure and low fishing intensity resulted in a food limitation during the 1990's. As mysiids, a further major prey of herring, showed as well a negative development in standing stocks, an even more pronounced impact of food limitation on herring growth is likely. In accordance, highly significant relationships between sprat weight at age and stock size and herring weight at age (Cardinale and Arrhenius, 2000; ICES, 2000) and clupeid stock sizes may be used in predictions. The negative stock development of *Pseudocalanus* and mysiids are coupled to decreasing salinities caused by lack of inflows from the North Sea and increased river runoff, while the increase in Acartia spp. is coupled to high spring temperature caused by predominantly warm winters (Dippner et al., 2000; Möllmann et al., 2000).

A considerable interannual variability in recruitment independent of the spawning stock biomass (SSB) suggests in specific years a de-coupling of reproductive success from the SSB in both sprat and herring. Pre-requisite for an analysis of the driving forces of underlying processes is a reliable determination of the reproductive effort and surviving offspring. While this appears to be possible for sprat, for herring the complex stock structure is a major obstacle (Köster et al., 2001a), i.e. different stock components of the Central Baltic herring stock reproduce with considerably different success. Only separately assessed sub-components may be utilised as a case study. Recruitment of the Gulf of Riga herring is significantly related to SSB, temperature in April and zooplankton abundance in May (Kornilovs, 1995). The April temperature, being a measure of the severity of the winter, is assumed to be related to the magnitude of egg production and timing of spawning, while the zooplankton abundance in May is a proxy for larval food availability. All three variables are highly significant, however, with temperature and zooplankton being as well significantly correlated.

For sprat, an exploratory analysis revealed significant relationships between SSB and realized egg production, realized and surviving egg production as well as surviving egg production and larval abundance (Köster et al., 2001b). However, no relationship between larval abundance and 0-group recruitment exists. This suggests the larval stage to be the most critical life stages in sprat reproduction. A relatively high unexplained variability in the SSB - realized egg production relationship indicates, that maturation processes and changes in fecundity may introduce substantial variability in recruitment success. In fact incorporating the growth anomaly (as a proxy of nutritional condition of the adults) and temperature in the intermediate water in May (being also a proxy of winter severity), besides the spawning stock biomass enhances the relationship to the realized egg production from ichthyoplankton surveys (Köster et al., 2001b). Furthermore, Lab experiments showed a reduced hatching success of sprat eggs below 4°C and in fact the relationship of early and late egg stage production as obtained from ichthyoplankton surveys is enhanced by including temperature as an additional variable (STORE, 2001). In contrast, processes affecting the larval stage have hardly been identified yet. The only significant and biologically sensible variable is temperature in the intermediate layer during spawning time, most likely reflecting food availability due to enhanced nauplii and early copepodite production, although not visible in available zooplankton data. Including SSB, temperature and growth anomaly as variables in simple multiple linear regression models first for single subareas and then combined for the entire Central Baltic revealed 0-group recruitment estimates following in general the observed pattern, however, with considerable deviations from observed recruitment in years, when the intermediate water temperature during spawning time did not reflect winter severity impacting on maturation processes and fecundity (Köster et al., 2001b).

References

Beyer; J.E. and H. Lassen, H. 1994. The effect of size-selective mortality on the size-at-age of Baltic herring. Dana 10: 203-234.

Cardinale, M. and Arrhenius, F. 2000. Decreasing weight-at-age of Atlantic herring (*Clupea harengus*) from the Baltic Sea between 1986 and 1996: a statistical analysis. ICES J. Mar. Sci., 57: 882-893.

Dippner, J.W., G. Kornilovs and L. Sidrevics. - 2000. Long-term variability of mesozooplankton in the Central Baltic Sea. J. Mar. Sys., 25: 23-32.

ICES. 1994. Report of the Working Group on the Assessment of Demersal and Pelagic Stocks in the Baltic. ICES C.M. 1994/Assess:17.

ICES 2000. Report of the Baltic Fisheries Assessment Working Group. ICES CM 2000/ACFM:14.

ICES 2001. Report of the Study Group on Multispecies Predictions in the Baltic. ICES CM 2001/H:4.

Köster, F.W., Möllmann, C., Neuenfeldt, S., Plikshs, M. and Voss, R. 2001a. Developing Baltic cod recruitment models I: Resolving spatial and temporal dynamics of spawning stock and recruitment for cod, herring and sprat. Can. J. Fish. Aquat. Sci 58: Sci. 58: 1516-1533.

Köster, F.W., Hinrichsen, H.-H., Schnack, D., St. John, M.A., MacKenzie, B.R., Tomkiewicz, J.,, Möllmann, C., Kraus, G., Plikshs, M. and Makarchouk, A. 2000b. Recruitment of Baltic cod and sprat stocks: Identification of critical life stages and incorporation of environmental variability and spatial heterogeneity into stock-recruitment relationships. ICES CM 2000/N:16.

Kornilovs, G. 1995. Analysis of Baltic herring year-class strength in the Gulf of Riga. ICES CM 1995/J:10.
Möllmann, C. and F.W. Köster. - 1999. Food consumption by clupeids in the Central Baltic: evidence for top-down control? ICES J. Mar. Sci., 56 (suppl.): 100-113.
Möllmann, C., Kornilovs, G. and Sidrevics L. 2000. Long-term dynamics of main mesozooplankton species in the Central Baltic Sea. J. Plank. Res. 22 (11): 2015-2038.
Neuenfeldt, S., and F.W. Köster. - 2000. Trophodynamic control on recruitment success in Baltic cod: the influence of cannibalism. ICES J. Mar Sci., 57: 300-309.
Parmanne, R., Rechlin, O. and Sjöstrand, B. 1994. Status and future of herring and sprat stocks in the Baltic Sea. Dana 10: 29-59.
Sparholt, H. 1994a. Fish species interactions in the Baltic Sea. Dana 10: 131-162.
Sparholt, H. 1994b. Growth changes of herring in the Baltic. Tema Nord 1994, No. 532.
STORE 2001. Environmental and fisheries influences on fish stock recruitment in the Baltic Sea. EU-Project FAIR CT98 3959, Consolidated Progress Report, Part I, 336 pp.

Case Study 5. Anchovy and sprat in the Black Sea (by Georgi Daskalov)

Research and management of the Black Sea stocks have been done separately by the surrounding countries besides the existence of the Joint Commission for the Fisheries in the Black Sea until 1991 which included Bulgaria, Romania and the former USSR but not Turkey. After the changes in the former Eastern block the Commission ceased its function and a new international Convention for the fisheries was prepared is expected to be signed by all the countries. Meanwhile an international project (Prodanov *et al.* 1997) including scientists from Bulgaria, Romania, Turkey and Ukraine accomplished joint stock assessments of the most important fish stocks, which were recommended by the General Fisheries Council for the Mediterranean/FAO Fisheries as a background for future fisheries assessment and management.

Consequently most of the studies of environment – fish relationships were carried out either by institutions/scientist from particular country or in the frame of this project, and companion studies (Prodanov *et al.* 1997, Daskalov, 1998, Daskalov, 1999).

Survey information. Fisheries and biological surveys have been carried out by different countries on a more or less regular basis through international co-operation. Most of the regular abundance and ichthyoplankton surveys covering the overall or the major part of the stock distributions were performed by the former USSR in collaboration with the other countries and were used as absolute indices of abundance for fisheries assessment and management advice. Regular pre-recruit surveys have been carried out by the former USSR (now Ukrainian) institute YugNIRO, Kerch from early 1960's to 1993 (using revised methodology from 1981, Tkacheva and Benko, 1979; Arkhipov, 1993). Absolute estimates of adult sprat biomass by mid-water trawl surveys were derived for 1976-1993 (Prodanov *et al.* 1997). During 1988-1992 experimental hydroacoustic surveys were performed in co-operation with Bulgaria and Romania. Long-term monitoring of the fat content of sprat from chemical analyses (at least 30 years) have been done by both USSR and Bulgarian institutes. Adult stock of anchovy was surveyed by hydroacoustic at the hibernating site in the Eastern part of the Black Sea (along Georgia coast) by YugNIRO. Experimental DEPM surveys have been performed in the late 1980s early 1990s in co-operation with Bulgaria and Romania. Occasionally hydroacoustic surveys have been performed in Turkish water in the past. There is no information for hydroacoustic or DEPM surveys by Turkey at present.

Relationships between recruitment and environmental variables have been explored by Daskalov, (1999) and Panov et al. (1993). Anchovy reproduction seems to be related to the coastal habitat and favoured by stratification induced by river run-off and higher SST. Sprat is mostly an open sea spawner and its recruitment appears to be less dependent on the parental stock biomass and is negatively related to SST and river discharge. Both species show positive or dome shaped relationships with wind stress.

Environmental indices (SST, indices of atmospheric circulation) have been used for short term projections of catches of anchovy and sprat by YugNIRO, Kerch.

References

Arkhipov, A. G., 1993. Estimation of abundance and peculiarities of distribution of the commercial fishes in the early ontogeny. Vopr. Ihktiologii, 33 (4): 511-522. (In Russian)
Panov, B. N., Trotsenko, B. G., Korshunova, G. P., Hlopushina, S. I., Belozersky, V. O. 1993. Water state pecularities of the North-western part of the Black Sea determining the sprat fisheries efficiency and its forecast possibility. Oceanology, Moskow, 33: 73-78. (In Russian)
Prodanov, K., K. Mikhaylov, G. Daskalov, K. Maxim, E. Ozdamar, V. Shlyakhov, A. Chashchin, A. Arkhipov, 1997. Environmental management of fish resources in the Black Sea and their rational exploitation. Studies and Reviews. GFCM. 68. Rome, FAO . 178p.
Daskalov, G., 1998. Pêcheries et changement environmental à long-term en mer Noire. PhD thesis. Centre d'océanologie de Marseille, Univ. Aix-Marseille II. 262pp.

Daskalov, G. 1999. Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. Fish. Res. 41(1): 1-23.

Tkatcheva KS, Benko YuK (eds) 1979. Resources and raw materials in the Black Sea, AztcherNIRO, Pishtchevaya promishlenist, Moskow. (In Russian)

11.2. Framework to establish linkages between environmental forcings and pelagic fish responses (Lead: Pierre Pepin)

WG2 was asked to focus its discussion on issues that would allow the SG to address the second term of reference which has for objective the

> *Development of a scientific framework to understand the linkages between environmental variables and pelagic fish fluctuations, at relevant spatial and temporal scales.*

Many of the summary presentations for the different regions given on the first day of the meeting had outlined correlations between either growth or recruitment with some indicators of environmental status. Two environmental variables or factors were identified as frequent correlates or processes that reflect the influence of the environment on the dynamics of either anchovy or sardine populations: sea surface temperature (SST) and transport.

Environmental temperature can either have a direct effect on the physiological processes of organisms (such as metabolism), or through overall changes in the state of the environment (such as patterns of overall productivity or predatory activity). It is not always clear whether the effect is direct (i.e. through physiology) but there is considerable evidence from other analyses and from laboratory studies of survival potential in the absence of predators that may allow some inferences. According to these studies, variations in reproductive success (i.e. recruitment) would tend to show a positive relationship with temperature at the lower (colder) physiological range of a species and the opposite at the upper (warmer) range. Some of the results from WG1, suggest that this may the case. The same is likely to occur for growth.

The effects of transport may be somewhat less ambiguous. If eggs and larvae are not able to remain in the most appropriate environment for survival, then any force that moves then away from that environment will have a detrimental effect on the reproductive success of the population. However, different stocks may respond differently to the effect of variations in transport. Many of the sardine and anchovy stocks considered by the SG occur in coastal upwelling systems where the spawning and nursery areas appear to overlap substantially. There are two notable exceptions: the South African anchovy and the Japanese sardine. In both these instances, spawning occurs some distance away from the optimal nursery area. Transport to those areas is thus important but once the nursery is reached, dispersal is likely to reduce recruitment. However, only a limited number of studies have been able to find a strong relationship between recruitment variability and transport estimated wind stress measurements. In upwelling systems, there should be some relationship between offshore Ekman transport and temperature: strong transport should be reflected in lower temperatures. However, upwelling will also increase productivity of the systems and maybe therefore be more beneficial to a population at an intermediate level (Optimal Window). Could it be that the differential effects of upwelling and temperature in different systems is in fact a reflection of the balance of forces acting on the dynamics of the whole ecosystem (temperature) and the transport of eggs and larvae out of the optimal environment? Can we gain some understanding of the balance of forces acting on populations of sardine and anchovies by contrasting the levels of variability and correspondence among environmental variables?

One of the concerns of the WG was that often, the information reported among the different studies made it unclear whether the effects of both temperature and upwelling driven transport were assessed simultaneously in all the studies considered. It is clear that there should be some relationship between temperature and the level of upwelling. However, other factors may limit the strength of this relationship (e.g. atmospheric effects on surface temperature). As a result, the WG recommended that similar analyses be undertaken in each area where small pelagics are well studied and commercially important to assess the relationship of recruitment and growth to both of these environmental variables.

One of the important considerations of the WG was comes from the differences in treatment of the information conducted by the different investigators. There are issues about the methods of averaging that are used as well as the sources of data applied to the study of each region of interest. Furthermore, information quality and accessibility in the different regions is also an issue that was raised by the WG as well as in the general discussion of the SG. As a result, the WG recommends that the following be carried out in a number of upwelling areas (Table 1)

Investigate the pattern of seasonal and interannual variation in sea surface temperature and in wind-driven Ekman upwelling based on longshore wind speed and determine the level of association of these environmental variables with patterns of variability in growth and recruitment.

The work should be carried out by local experts familiar with the region and who can identify the critical areas for the spawning, recruitment and growth of the small pelagic stocks in their region. The WG initially restricted its recommendation for a comparative study to a number of upwelling systems in order to simplify interpretation (Table 1). This represents the fundamental level of exploratory analysis required by the WG. However, after discussion with the remainder of the SG, contributions from all members would be sought.

To overcome the problems of data disparity and treatment, the WG recommends that a comparative analysis be performed based on standardized data sources for all regions of interest. The standardized information would consist of satellite imagery (9 km/8 day averages available from the Jet Propulsion Laboratory) and the geostrophic winds (6 h averages from NCEP re-analysis). As indicated above, the sources of data for each area should be readily available to the investigators. For those wishing to make use of global satellite observations, information can be located at the NASA Jet Propulsion Laboratory website (http://podaac.jpl.nasa.gov). Sea surface temperature (SST) data may be obtained from this source, as a number of other data types. The NCEP re-analysis information is available at the NOAA website where instructions are available (http://wesley.wwb.noaa.gov/reanalysis.html).

The approach for analysis of SST data follows that used by Claude Roy (South Africa/France) for the Benguela upwelling system. Mean monthly SST maps for a grid spanning the key habitat and extending several 100s of km offshore are to serve as the basis for estimating the spatial extent of interannual variations in environmental conditions. From these monthly means, interannual anomalies can be computed from the 1987-2000 data series. To simplify the interpretation, the experts should focus in on cross-shelf transects that encompass and cross the key habitat for the region. The results of this analysis would then allow experts to identify the areas where the greatest level of variability in SST occurs. From the SST transects, it will also be possible to provide some indication of the upwelling intensity along the transect (by difference in SST with some distant point at the extreme west of the region of interest) as well as the extent (the region where the difference exceeds 2°C).

Analysis of patterns of variation in winds will focus more on the temporal variability in a region. Because wind speed and direction varies on a shorter time scale than SST, the approach should focus on variations in the mean as well as variations in the variability of winds during the spawning and drift periods (e.g. in the case of recruitment). Angel Borja (Spain) has provided a model of the information that can be estimated from the geostrophic winds. The variables include wind speed cubed (a potential measure of turbulence), offshore Ekman transport, eastward Ekman transport, upward vertical velocity and Sverdrup transport along the coast. These combined variables would provide a measure of both the longshore and offshore transports as well as an alternate measure of upwelling intensity to that derived form the SST information. The will likely be some limitations in the use of geostrophic winds in proximity to the equator (20N-20S). Analysis for Peru may have to rely on local sources of wind data.

The estimates derived for the suited of environmental variables will then the contrasted with recruitment time series and estimates of first year growth rates (where available). Details of the computation procedures will be standardized among members through continued discussion. On of the critical considerations of our objectives was in the development of relationships that could serve as an operational basis for forecasting population dynamics but that can be directly contrasted as providing comparable views of the environment.

In providing their reports, it is the responsibility of the regional members to provide a summary of the understanding of the circulation patterns within those systems in context with the levels of variability estimated for those areas. The WG agreed that that if the reproductive habitat or range is known to have changed, the statistics should be estimated for the “before” and “after” environments throughout the available time series if possible given the data being analyzed.

Table 1.

Stock Area	Contributor
Peruvian upwelling	Miguel Niquen Carranza
Chiliean upwelling	Luis Cubillos
Benguela upwelling	Philippe Cury/Claude Roy
Western Iberian upwelling	Miguel Santos
Bay of Biscay	Angel Borja
California Current upwelling	co-ordinated Andy Bakun/P. C
Northern Benguela	Georgi Daskalov
Morocco	Angel and Claude to contact someone from there

11.3. Requirements to incorporate environmental indices in pelagic fish stock assessment (Lead: Larry Jacobson)

Three topics for intersessional work were identified and outlined by participants in a small discussion group (F. Borges, L. Cubillos, P. Freon, J. de Oliveira and L. Jacobson). Both topics could probably lead to at least one scientific paper. The discussion group agreed to collaborate on work described below and to report on progress at the next meeting.

1) ***Simulation analysis of using environmentally linked recruitment predictor in management of anchovy fisheries***. Discussion was based on a simulation analysis (carried out and presented by J. de Oliveira) of potential benefits from an environmentally based recruitment predictor in the South African anchovy fishery. The South African anchovy fishery targets recruits primarily. TAC's are set initially based on an expectation of average recruitment and updated later (after some fishing occurs) based on an acoustic recruitment survey. The most important questions are
    a. What are the potential benefits of using an environmentally based recruitment prediction in setting the initial TAC, relative to the potential benefits of using a more expensive recruitment survey?
    b. How do benefits depend on the precision of the predictor and the precision of the survey?
    c. How do benefits depend on the statistical properties of recruitment (e.g. mean, variance and autocorrelation) in anchovy stocks around the world?
    d. How do benefits depend on the strength of density-dependent (spawner-recruit relationship) and density-independent (environmentally driven) factors?
    e. How do benefits depend on the overall level of fishing?

    The type of benefits to be considered in the simulation analysis would include average catch and variability in catch. In addition, because anchovy are important as forage, average biomass, variance in biomass and the probability of low biomass conditions might be considered.

    The simulation model developed for South African anchovy could probably be extended and used to evaluate potential benefits of using an environmental recruitment predictor in management of fisheries for anchovy fisheries in the Bay of Biscay and Humboldt Current. Members of the discussion group agreed to consider extending the analysis to these stocks and to potentially collaborate on analyses under the leadership of J. de Oliveira.

2) ***Environmental effects on adult fish parameters and common biological reference points used in management***. Environmental studies generally focus on recruitment but environmental factors also affect growth, natural mortality, size and age at maturity and other biological characteristics of adult fish. In turn, characteristics of adult fish are important in calculation biological reference points. Some biological reference points depend on both recruitment and adult fish biology (e.g. F_{msy} and F_{Rep}). Other biological reference points depend only on adult fish biology (e.g. $F_{0.1}$, F_{Max}, $F_{20\%}$, etc.). In many fisheries, recruitment is difficult to predict but biological parameters of adult fish are relatively easy to measure. This suggests that it may be easier and more practical to accommodate environmental variability in fisheries management by adjusting reference points based on adult fish biology. The most important question is whether climatic effects on recruitment and adult fish biology are important in calculating the biological reference points used to manage fisheries. Another important question is whether adjustments to reference points based on adult fish biology might be a sufficient basis for changing management in response to climate change.

    Adult fish biological factors respond to environmental variation in sardine stocks off California, Japan and off Portugal in the Atlantic around the Iberian Peninsula. The discussion group, led by F. Borges (with the collaboration of A. Yatsu and L. Jacobson), agreed to prepare a collaborative analysis for these stocks prior to the next Study Group meeting. In particular, A. Yatsu and F. Borges agreed to analyze physiological indices, such as condition factors and gonadosomatic indices, as a means of tracking and predicting regime changes in the Japanese sardine. This approach could be very useful in identifying or predicting regime shifts and in providing management advice.

3) ***Synchrony in rate-based measures of productivity and recruitment in small pelagic fishes****.* A recent paper published by SPACC scientists indicates that production rates are more sensitive and likely better measures of climatic effects on fish stocks than catch data or biomass estimates because the latter are effected by economic factors, fisheries management or time lags. A small group (M. Barange, L. Cubillos, P. Cury, P. Fréon, L. Jacobson, M. Niquen, C. Roy and A. Yatsu) agreed to collaborate in an analysis of the synchrony and variability in production rates in stocks with long time series of data (e.g. Japanese sardine, California sardine, Peruvian anchoveta and California anchovy). An important element of this work will be to apply analytical techniques based on Moran's theorem to pelagic fish. Moran's theorem is widely used in terrestrial ecology to relate density-dependent and density independent factors controlling variation in productivity. This work will involve exploring density dependent effects in pelagic fish stocks (i.e. changes in productivity due to high stock biomass levels or under different patterns of dominance between species). It will also involve elucidating relationships between variation in production and variation in regional and global environmental time series. Finally, the group will try to quantify the degree of synchrony between proximate (e.g. different populations in the Humboldt system) versus remote fish populations (e.g. stocks in the Japanese and Humboldt systems). Rate based estimates of surplus production and recruitment will be considered preferentially, but new potentially rate-based approaches based on catch statistics may be used as well.

4) ***Other topics for future research****. The Discussion group developed some good ideas for future research.*

   a. The first topic is related to the precautionary approach to fisheries management and response of management to environmental change. Do precautionary management approaches make complicated environmentally based management procedures and complicated stock assessment models that incorporate environmental data more or less important?
   b. The second topic is related to the first. Biomass based harvest control rules, widely advocated and used in many fisheries, reduce fishing mortality rates as biomass declines. It can be argued that biomass based harvest rules incorporate environmental conditions to the extent that the environment affects fish stock biomass. The question, then, is whether biomass based harvest control rules provide the same practical benefits as complicated stock assessment and management procedures that incorporate environmental variables.
   c. The third topic concerns use of catch data to study climate change. For many fisheries, catch data are the only long-term information available. Gross changes in catch levels may be related to changes in productivity driven by the environment. However, large changes in catch levels may also be due to development of markets, new fishing grounds, improved fishing equipment, better data collection or economic investment in fisheries. A recent paper suggests that the timing of changes in catch and response of catches to non-climate and non-biological factors complicate interpretation of catch data. It may be possible to develop better indices of climate change based on catch data based, for example, on proportional changes in catch over short time periods when non-climate and non-biological factors can be considered reasonably constant.