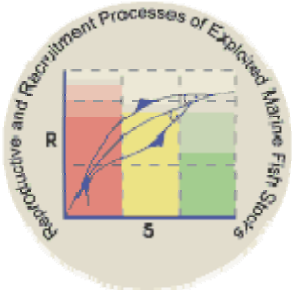
Reproductive and Recruitment Processes of Exploited Marine Fish Stocks



Convened by:

Edward A. Trippel
Fisheries and Oceans
St. Andrews Biological Station
Canada
TrippelE@mar.dfo-mpo.gc.ca

Richard D. Brodeur
Estuarine and Ocean Ecology Program
Northwest Fisheries Science Center
USA
Rick.Brodeur@noaa.gov

Mark Dicky-Collas
IMARES
Wageningen University Research
The Netherlands
Mark.dickeycollas@wur.nl

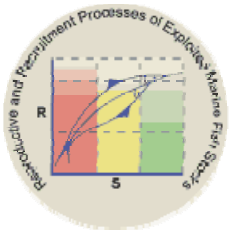
Foreward

Welcome to the joint NAFO/PICES/ICES Symposium on " Reproductive and Recruitment Processes of Exploited Marine Fish Stocks" convened by Ed Trippel (NAFO – Canada), Richard Broduer (PICES – USA)and Mark Dickey-Collas (ICES-The Netherlands) and and organized by the NAFO Secretariat. The Symposium is held in conjunction with the 29th Annual Meeting of NAFO, at the Altis Hotel, Lisbon Portugal and hosted by EU-Portugal during 1-3 October 2007. The Scientific Steering Committee consists of Suam Kim, Korea (PICES); Fritz Köster, Denmark (ICES); C. Tara Marshall, U.K. (ICES); M. Joanne Morgan, Canada (NAFO); Hilario Murua, Spain (NAFO); and Anthony Thompson (NAFO Secretariat)

This booklet contains the Abstracts of papers and posters presented at this symposium. Please note that any subsequent changes will be announced by the co-convenors.

Presented papers and posters are eligible for consideration for the Symposium Proceedings to be published as a special issue of the NAFO *Journal of Northwest Atlantic Fishery Science*.

September 2007 NAFO Secretariat



Timetable-at-a-glance

Monday		Tuesday		Wednesday	
0830-0900	Registration				
0900-0915	welcome	900	2-5 keynote	900	3-11 keynote
0915-1000	keynote	930	2-6	930	3-12
1000-1005	Session1	950	2-7	950	3-13
1005	1-1 keynote	1010	2-8	1010	3-14
1035	1-2	1030	2-9	1030	3-15
1055	1-3	1050	2-10	1050	break
1115	Break	1110	break	1110	Session 4
1135	1-4 keynote	1130	2-11	1115	4-1 keynote
1205	1-5	1150	2-12	1145	4-2
1225	1-6	1210	2-13	1205	4-3
1245	1-7	1230	2-14	1235	4-4
1305-1425	Lunch **(1 hour, 20m)**	1250-1410	lunch **(1 hour, 20m)**	1255-1415	lunch **(1 hour, 20m)**
1425	1-8	1410	Session 3	1415	4-5 keynote
1445	1-9	1415	3-1 keynote	1435	4-6
1505	1-10	1445	3-2	1455	4-7
1525	1-11	1505	3-3	1515	4-8
1545	break	1525	3-4	1535	4-9
1605	Session 2	1545	3-5	1555	Break
1610	2-1 keynote	1605	break	1615	4-10
1640	2-2	1625	3-6	1635	4-11
1700	2-3	1645	3-7	1655	4-12
1720	2-4	1705	3-8	1715	Summing up
		1725	3-9		
1800-2100	Poster Display and Reception	1745	3-10		

Monday, 1 October 2007

0830-0900 Registration

0900-0915 Welcome by Antonio Vazqez, NAFO Scientific Council Chair

0915-1000 *KEYNOTE ADDRESS* - **Emerging from Hjort's Shadow** - Ed Houde

1000-1005 *SESSION 1 – ORAL* - **Age and Size at Sexual Maturity**

1005-1035 1-1 **Session 1 Keynote - Quantifying the relative influence of maturation on stock recovery** - Marshall, C. Tara

1035-1055 1-2 - **Estimating onset of reproduction, reproductive investment and growth rate from individual growth trajectories in fish** - Mollet, Fabian M., Thomas Brunel, Bruno Ernande, Adriaan D. Rijnsdorp

1055-1115 1-3 - **Age and size at maturity of Flemish Cap cod: where is the limit?** - Saborido-Rey, F., R. Domínguez-Petit, A. Alonso-Fernández and A. Pérez-Rodríguez

1115-1135 **Break**

1135-1205 1-4 **Keynote Address - Disentangling Sources of Variability in Age and Size at Maturation** - Mikko, Heino

1205-1225 1-5 - **Hepatosomatic index and the probabilistic maturation reaction norm of cod** - McAdam, Bruce J. and C. Tara Marshall

1225-1245 1-6 - **Trends in age and size based probabilistic maturation reaction norms of cod (Gadus morhua L.) in the Kattegat and Sound correlate with variability in juvenile growth** - Svedäng, H., Vitale, F and. Vainikka, A.

1245-1305 1-7 - **Effects of fisheries-induced adaptive changes on the reproductive characteristics of exploited stocks** - Dunlop, Erin S., Katja Enberg, Mikko Heino, and Ulf Dieckmann

1305-1425 **LUNCH** (1 hour and 20 minutes)

1425-1445 1-8 - **The Influence of Stock Structure on Fisheries-induced Evolution in Age and Size at Maturation of Icelandic Cod** - Pardoe, H., E. Dunlop, G. Marteinsdóttir, and U. Dieckmann

1445-1505 1-9 - **Changes in maturation pattern and reproductive potential of Baltic cod stocks** - Storr-Paulsen, Marie, Jonna Tomkiewicz and Fritz Köster

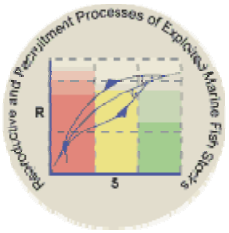
1505-1525 1-10 - **Catch curves are misleading, gonads are revealing: age of sexual maturation versus recruitment in Pacific herring (*Clupea pallasi*)** - Hay, Doug, Tom Therriault and Bruce McCarter

1525-1545 1-11 - **Effect of maternal fat reserves on the fatty acid composition of sardine (Sardina pilchardus) oocytes** Garrido, Susana, Rui Rosa, Radhouan Ben-Hamadou, Maria Emilia Cunha, Maria Alexandra Chícharo, Carl D. van der Lingen

1545-1605 **Break**

1605-1610 *SESSION 2 – ORAL* - **Fecundity and Spawning Success**

1610-1640 2-1 **Keynote Address - Reproductive Success in Marine Fish Populations: Why Should We Closely Monitor Fish Fecundity?** - Lambert, Yvan



1640-1700 2-2 - **Reproductive strategy of Atlantic horse mackerel *Trachurus trachurus* and the regulatory role of surplus energy and condition indices -** Ndjaula, Hilkka O.N., Tom Hansen, Maria Krüger-Johnsen, and Olav Sigurd Kjesbu

1700-1720 2-3 - **Can temperature benefits justify extensive up-current migrations in the Northeast Arctic cod? -** Opdal, Anders Frugård, Frode Vikebø and Øyvind Fiksen

1720-1740 2-4 - **Sperm reserves of primiparous snow crab (*Chionoecetes opilio*) females in the eastern Bering Sea: inter-annual variation and spatial patterns relative to available males -** Slater, Laura M., Kirsten A. Gravel, and Douglas Pengilly

1800-2100 **Poster Display** and Reception

Tuesday, 2 October 2007

0900-0930 2-5 **Keynote Address - Eggs and Larvae are Starting Ingredients in a Menu of Recruitment that Often Goes Wrong: Lessons from High Latitude Majid Crabs -** Armstrong, David, Lobo Orensanz, Bernard Sainte-Marie, and Billy Ernst

0930-0950 2-6 - **Frequency of skipped spawning in Norwegian spring-spawning herring -** Kennedy, J., Skjæraasen, J.E., Nash, R.D.M., Slotte, A. and Kjesbu, O.S.

0950-1010 2-7 - **Timing and determination of skipped spawning in Atlantic cod -** Skjæraasen, Jon Egil, James Kennedy, Anders Thorsen, Richard Nash, Olav S Kjesbu

1010-1030 2-8 - **Relationships between maternal body size, condition and potential fecundity for Northwest Atlantic flatfishes -** Rideout, R.M. and M.J. Morgan

1030-1050 2-9 - **An attempt to trace the contribution of different spawning components to the surviving population of juvenile cod in Icelandic waters -** Gudrun Marteinsdottir, , Christophe Pampoulie, David Brickman, Lorna Taylor, Kai Logemann and Daniel Ruzzante

1050-1110 2-10 - **A method to accurately estimate the daily spawning fraction of Japanese flounder *Paralichthys olivaceus* considering a wide range of ambient temperature -** Kurita, Yutaka, Yuichiro Fujinami and Masafumi Amano

1110-1130 **Break**

1130-1150 2-11 - **Understanding the effect of seasonal forcing on the reproductive traits of a multiple-batch spawner in the context of the Dynamic Energy Budget (DEB) theory: the Bay of Biscay anchovy (*Engraulis encrasicolus*) -** Pecquerie, Laure, Pierre Petitgas , Sebastiaan A.L.M. Kooijman

1150-1210 2-12 - **Collapsing and recovering fisheries depend on the quality of female spawners -** Venturelli, P. A., C. A. Murphy, T. A. Johnson, P. J. van Coeverden de Groot, P. T. Boag, J. M. Casselman, W. C. Leggett, R. Montgomerie, M. D. Wiegand, and B. J. Sutter

1210-1230 2-13 - **Maternal age-related influences on larval production of Pacific ocean perch (*Sebastes alutus*) -** Parker, Steven J., Robert W. Hannah, Donald M. Van Doornik, Steven R. Millard, Ewann A. Berntson and Paul Moran

1230-1250 2-14 - **Is spawning success of Atlantic cod escapees influenced by differences in sperm competition? -** Mayer, I., J. J. Meager, J. E. Skjæraasen, G. Rudolfsen, Ø. Karlsen, O. Moberg, A. Staby, O. Kleven & A. Fernø

1250-1410 **LUNCH** (1 hour and 20 minutes)

1410-1415 *SESSION 3 – ORAL* - **Survival of Eggs and Larvae**

1415-1445 3-1 **Keynote Address - Oceanography meets Fisheries Conservation - Opportunities for Success** - Brian MacKenzie

1445-1505 3-2 - **Fishery-induced demographic changes in the timing of spawning; consequences for reproductive success** - Wright, Peter, Ed Trippel and Jonna Tomkiewcz

1505-1525 3-3 - **Effects of egg size, parental origin and feeding conditions on growth of larval and juvenile cod (*Gadus morhua* L.)** - Paulsen, H., V. Bühler, R.A.J. Case, C. Clemmesen, G. Carvalho, W.F. Hutchinson, O. S. Kjesbu, E. Moksness, H. Otterå, A. Thorsen and T. Svåsand

1525-1545 3-4 - **Differential egg mortality of Georges Bank cod and haddock** - Lough, R. G., L. O'Brien, L.J. Buckley

1545-1606 3-5 - **Identification of Eastern Baltic cod nursery grounds: a hydrodynamic modeling approach** - Hinrichsen, Hans-Harald and Gerd Kraus

1605-1625 Break

1625-1645 3-6 - **Density-dependence in post-recruit Japanese sea bass in the Chikugo estuary, Japan** - Shoji, Jun and Masaru Tanaka

1645-1705 3-7 - **Behavioural adaptations of larval fish to vertical gradients and oceanography: predictions from evolutionary models** - Fiksen, Øyvind

1705-1725 3-8 - **Recruitment process of Baltic herring populations** - Cardinale, Max, Valerio Bartolino, Christian Möllmann, Michele Casini, Georgs Kornilovs and Tiit Raid

1725-1745 3-9 - **Growth and temporal origin of juvenile sprat in the German Bight (North Sea)** - Baumann, Hannes, Arne M. Malzahn, Rudi Voss, Axel Temming

1745-1805 3-10 - **Selection for fast development and growth for late larval and early juvenile Pacific sardine, *Sardinops sagx*, in the California Current region** - Takahashi, Motomitsu and David M. Checkley, Jr.

1805- ???? **Poster Display**

Wednesday, 3 October 2007

0900-0930 3-11 **Keynote Address - Recruitment variability of small pelagic fish populations in the western North Pacific** - Watanabe, Yoshiro, Motomitsu Takahashi, Akinori Takasuka, Yoshioki Oozeki

0930-0950 3-12 - **Winter recruitment of young-of-the-year bluefish: habitat use, feeding ecology and energetics** - Juanes, Francis, John Murt and Peter Clarke

0950-1010 3-13 - **Abundance and growth of larval cod around Iceland - Passive transport under variable environmental conditions and modelling approaches** - Jónasson, J. P., K. Logemann, B. Gunnarsson, D.Brickman, and G. Marteinsdóttir

1010-1030 3-14 - **Physical-biological interactions in the life history of small pelagic fish in the Western Iberia Upwelling Ecosystem** - Santos, A. Miguel P., Alexandra Chícharo, Antonina Dos Santos, Teresa Moita, Paulo B. Oliveira, Álvaro Peliz, Pedro Ré

1030-1050 3-15 - **Predation dynamics of mackerel foraging on populations of larval and juvenile anchovy: is survival of anchovy linked to growth?** - Robert, Dominique, Akinori Takasuka, Sayaka Nakatsuka, Hiroshi Kubota, Yoshioki Oozeki, Hiroshi Nishida and Louis Fortier

1050-1110 **Break**

1110-1115	SESSION 4 – ORAL - **Stock Assessment and Management Implications**
1115-1145	4-1 **Keynote Address - Integrating reproductive biology into scientific advice for fisheries management -** Morgan, M. Joanne
1145-1205	4-2- **Eastern Baltic cod recruitment depends on environment, can scientific advice on fisheries management ignore this ? -** Fritz Köster, Morten Vinther, Brian MacKenzie and Maris Plikshs
1205-1235	4-3 - **Evolutionary effects of fishing and marine reserves on size at maturation and movement -** Miethe, Tanja, Calvin Dytham, Jon Pitchford
1235-1255	4-4 - **Variations in proportions of lethal malformations observed in recently spawned eggs from North East Arctic Cod explained by population parameters -** Korsbrekke, Knut, Valeri Makhotin and Per Solemdal
1255-1415	**LUNCH** (1 hour and 20 minutes)
1415-1435	4-5 **Keynote Address - Larval Dispersal and MPAs: Implications of the Distance Between Reproduction and Recruitment for Spatial Management -** Louis Botsford
1435-1455	4-6 - **Estimating Baltic cod (*Gadus morhua* L.) population sizes from egg production -** Kraus, Gerd, Hans-Harald Hinrichsen, Rüdiger Voss, Jonna Tomkiewicz, Eske Teschner, Matthias Schaber, Friedrich W. Köster
1455-1515	4-7 - **The influences of maternal age of spawning, recruitment variability, and life-history pattern upon harvest reference points and fisheries management -** Spencer, Paul D. and Yasmin Lucero
1515-1535	4-8 - **Meta-analysis of anchovy egg production parameters -** Somarakis, Stylianos, Eudoxia Schismenou and Athanassios Machias
1535-1555	4-9 - **When recruitment regimes vary, can we still manage North Sea herring in a precautionary manner? -** Simmonds, John (FRS), Mark Dickey-Collas (IMARES) and Richard Nash (IMR)
1555-1615	**Break**
1615-1635	4-10- **Using Life-History Models to Explore Environmental Effects on Stock Reproductive Potential of Several Cod Stocks -** L. O'Brien, N. Yaragina ,Y. Lambert, G. Kraus, T. Marshall, G. Marteinsdottir, H. Murua, F. Saborido-Rey, J. Tomkiewicz, and P.Wright
1635-1655	4-11 - **Managing fluctuating populations: what is the value of stock assessment? -** Myrseth, Johanna, Øyvind Fiksen and Mikko Heino
1655-1715	4-12 - **Reproduction patterns of commercially important flatfishes in Portuguese fisheries: implications for management -** Cabral, H. N., C. M. Teixeira and M. I. Batista
1715-1800	**SUMMING UP** - Keith Brander, ICES

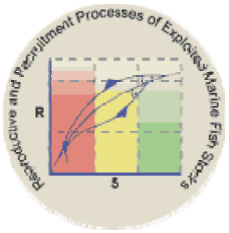
Keynote Address

Emerging from Hjort's Shadow

Ed Houde

Early in the 20th century, Johann Hjort developed compelling arguments and hypotheses to explain recruitment variability that dominated research agendas for >75 years. A cautious emergence from Hjort's shadow began late in the 20th century. Hjort's "Critical Period" hypothesis, i.e., failure of first-feeding larvae to find food, and a corollary, "Aberrant Drift" of eggs and larvae, were proposed as mechanisms responsible for recruitment variability. Tests of the Critical Period hypothesis became an obsession, although support for it is inconsistent and equivocal. The single-minded research on the Critical Period hypothesis gave way to realization that recruitment variability was the outcome of complex trophodynamic and physical processes acting over many temporal and spatial scales and throughout pre-recruit life. A complex mix of main effects and interacting factors can easily generate order-of-magnitude variability in recruitments via small effects on mortality and growth rates during the abundant egg and larval stages. New considerations and evaluations of compensatory mechanisms that dampen variability and stabilize recruitments emerged. A little density dependence, especially in the relatively long juvenile stage, can regulate recruitment. Multidisciplinary programs instituted in the 1990s, combined with rapid development of coupled bio-physical modeling, offered new insights into mechanisms generating recruitment variability. Despite progress, forecasting recruitments remains a formidable challenge. 'Solving the recruitment problem' is no longer the holy grail of fishery science. Appreciating recruitment variability, explaining probable causes, considering implications for management, and understanding it in the context of broader variability in marine ecosystems are worthy goals.

Ed Houde ehoude@cbl.umces.edu
University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
P.O. Box 38
Solomons, MD
20688 USA



SESSION 1 – ORAL

Age and Size at Sexual Maturity

Session Convenor:

Ed Trippel

(Canada)

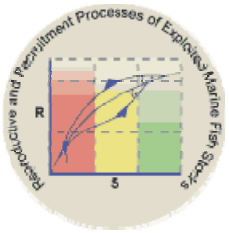
1-1 **session 1 Keynote**

Quantifying the relative influence of maturation on stock recovery

Marshall, C. Tara

The rate at which collapsed stocks recover depends on several factors including *r*, the intrinsic rate of population growth. *r* has also been interpreted as a measure of the resiliency of the stock to harvesting. Ecologists frequently regard *r* as a static parameter that is specific to either the species or the stock. This rather abstract conceptual view fails to recognise that fluctuations in the life history traits that collectively determine *r* (mortality, maturation and fecundity) will necessarily induce temporal variation in "realized" *r*. For example, a long-term trend towards earlier maturation has frequently been observed in exploited fish stocks. Irrespective of the cause of this long-term trend, it will have consequences for *r*. Life tables constructed for individual cohorts of the Northeast Arctic cod stock revealed a long-term trend towards increasing *r*. Elasticity analysis indicated that was partly due to the markedly earlier maturation of cohorts spawned since 1980. The apparent resiliency of this cod stock to high rates of fishing mortality is partly due to earlier maturation leading to higher values of cohort-specific *r*. This conclusion runs counter to the widely held view that earlier maturation has deleterious effects on stock dynamics. For Northeast Arctic cod the higher intrinsic rates of population growth, which can partly be attributed to the trend towards earlier maturation, have compensated for higher rates of population loss due to fishing. This may have prevented the Northeast Arctic cod stock from collapsing despite experiencing levels of fishing mortality that were sufficient to collapse cod stocks having lower values of *r*. When rebuilding depleted stocks it is imperative to scale the target fishing mortality to the observed life history traits of the cohorts that comprise the stock.

C. Tara Marshall c.t.marshall@abdn.ac.uk
School of Biological Sciences
University of Aberdeen
Tillydrone Ave., Aberdeen AB24 2TZ
Scotland, UK



1-2

Estimating onset of reproduction, reproductive investment and growth rate from individual growth trajectories in fish

Mollet, Fabian M., Thomas Brunel, Bruno Ernande and Adriaan D. Rijnsdorp

A new methodology is presented to estimate life history parameters (growth, reproductive investment and onset of maturity) by fitting an energy allocation models through individual growth trajectories. The performance (accuracy and precision) of the method is analysed as a function of parameter values and levels of environmental variation using simulated data. No systematic bias in the estimated life history parameters and their covariance structure was observed, although the estimation error is relatively larger for early onset of maturation and/or low reproductive investment. Interannual environmental variability increases the estimation error but does not cause a bias. The estimated correlation structure between life history parameters depends on the energy allocation model used and on the scaling exponents within. The method is applied to back-calculated growth curves of individual female plaice revealing an increase in growth rate and reproductive investment as well as a decrease in the age of first maturation. The application of the method is discussed for the study of fisheries-induced evolutionary changes and recruitment dynamics.

Fabian Mollet Fabian.Mollet@wur.nl
Wageningen IMARES
Haringkade 1
Postbus 68
1970 AB IJmuiden
Netherlands

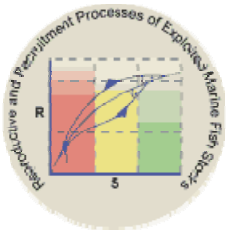
1-3

Age and size at maturity of Flemish Cap cod: where is the limit?

Saborido-Rey, F., R. Domínguez-Petit, A. Alonso-Fernández and A. Pérez-Rodríguez

A decreasing trend in age and size at maturity in Flemish Cap cod has been well documented during many years since 1990 to 1999. Drastic changes in abundance were hypothesized as the major cause of these reductions. In spite of fishing ban in 1994 and the lack of commercial catches, it has not been observed signals of stock recovery and the size and age at maturity still decreases in the period 2000-2006. Age at maturity is estimated in 2006 in 2.5 years, compared with an age at maturity of 5 years in 1992. However in recent years size at maturity remains constant. In this paper we hypothesize on the existence of changes in reaction norms in cod that combined with denso-dependent shifts in latest years produced a lower stock reproductive potential, this together with observed changes in the ecosystem have prevented the stock recovery.

Fran Saborido-Rey fran@iim.csic.es
Institute of Marine Research
Eduardo Cabello 6
36208 Vigo
Spain



1-4 **Keynote Address**

Disentangling Sources of Variability in Age and Size at Maturation

Mikko, Heino

Changes in age and size at maturation influence both the numbers and characteristics of individuals in the spawning stock. Age and size at maturation have been reported to have declined over past decades in many heavily exploited stocks. Earlier age and smaller size at maturation give shorter generation time, but have also negative impacts: fisheries yield is likely declining as individuals invest more to reproduction and less to body growth, and recruitment may be negatively affected because of size and age effects on spawner quality. The extent to which earlier age and smaller size at maturation can be attributed to (1) changes in age and size structure caused by increased mortality, cf. Baranov's fishing up effect, (2) plastic changes, especially facilitation of maturation by improved somatic growth, and (3) evolutionary changes in maturation schedule, in particular in response to selection from fishing mortality, has recently been much debated. With conventional statistical methods, disentangling the relative importance of these factors in explaining field observations is notoriously difficult, and novel approaches are called for. Probabilistic maturation reaction norms are a major step towards that direction. In their simplest form, they allow studying maturation changes independently from demographic changes and main effects of growth-related phenotypic plasticity. In most studied cases, significant trends in maturation tendency remain. These trends are in accordance with predictions from life history theory under increased mortality, and suggest widespread evolutionary changes in maturation schedules. Since unaccounted factors will always contribute to changes in maturation, conclusive evidence for evolutionary changes can never be obtain through this approach, but both the magnitude of changes and their uniform direction strongly suggest that fisheries-induced evolution is widespread.

Heino Mikko mikko@imr.no
Institute of Marine Research
P.O. Box 1870 Nordnes
N-5817 Bergen
Norway

1-5

Hepatosomatic index and the probabilistic maturation reaction norm of cod

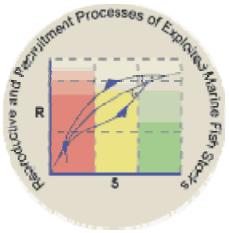
McAdam, Bruce J. and C. Tara Marshall

Mikko Heino's keynote address described how probabilistic maturation reaction norms (PMRNs) allow us to study maturation changes independantly of demographic changes and growth related phenotypic plasticity. He noted that in most studied cases a significant trend consistent with fisheries induced evolution remains, but that unnaccounted factors also contribute to changes.

It is, therefore, of interest to account for more factors that affect maturation. Key among these is bioenergitic condition, and recent results (Grift et al 2007) have used a morphometric measure of condition (Fulton's K) as a third explanatory variable, resulting in three dimensional PMRNs.

In cod, bioenergetic condition may be measured by the hepatosomatic index (HSI, liver weight as fraction of body weight). We have access to a long term record of annual length-class structured HSI for northeast arctic cod. Unfortuately, the structure of the database is not amenable to analysis with existing PMRN fitting approaches. We have developed a simulation based method for fitting PMRNs and investigated a variety of models using HSI as an additional explanatory variable.

Bruce McAdam b.mcadam@abdn.ac.uk
Zoology Building
Tillydrone Avenue
University of Aberdeen
Aberdeen AB24 2TZ
UK



1-6

Trends in age and size based probabilistic maturation reaction norms of cod (Gadus morhua L.) in the Kattegat and Sound correlate with variability in juvenile growth

Svedäng, H., Vitale, F and. Vainikka, A.

The Probabilistic Maturation Reaction Norm (PMRN) approach has been put forward as a mean to distinguish between the effects of genetic selection and phenotypic plasticity on maturation probability. In recent years, changes in age and length based PMRN have been elicited in many marine fish stocks. However, this view has lately been seriously challenged, as it is essentially focusing on the evolutionary effects of size selection on the maturation pattern and not on the physiological interplay between the organism and its environment, the proximate causes of maturation.

The aim of the study was to elucidate the possible effects of varying growth conditions on PMRN in two neighbouring cod stocks in the Kattegat and the Sound (eastern North Sea region). These two stocks can be regarded as ecologically separated, showing marked differences in survival and density, linked to differential fishing patterns, as well as in migratory patterns. This “experimental set-up” has thus some interesting similarities to a common garden study, assuming similar environmental conditions but for fishing mortality regimes.

An astonishingly good correlation was found between the mean bottom temperature in both areas during the second quarter of the year of birth and mean length at age 1 and two-dimensional Lp50 as a function of age and length (length of 50% probability to mature), indicating that growth processes during the early life stages may explain variation in PMRN. This means that size and age specific maturation probabilities are directly related to events taking place at the very start of the ontogeny, however also modified by experienced growth at higher ages.

Furthermore, the change in PMRN could not be corroborated with any systematic change in fishing mortality as far as the cod stock in the Kattegat is concerned, as it has been continuously at a high level for the whole studied period of time. It was therefore suggested that the variation in size and age at maturity for these cod stocks was directly or indirectly related to the growth/ temperature history at early life stages.

Although the PMRN approach is overly inadequate for studies of evolutionary changes in maturation patterns, it is still informative concerning how maturation patterns in a specific population unit has varied in a certain ecological context.

Henrik Svedäng
Swedish Board of Fisheries
Institute of Marine Research
Box 4
S-45321 Lysekil
Sweden
henrik.svedang@fiskeriverket.se

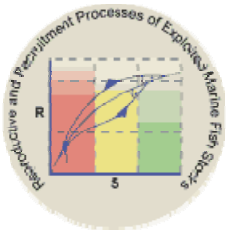
1-7

Effects of fisheries-induced adaptive changes on the reproductive characteristics of exploited stocks

Dunlop, Erin S., Katja Enberg, Mikko Heino and Ulf Dieckmann

There is mounting evidence that fishing can induce genetically based adaptations towards earlier ages and smaller sizes at maturation. However, the effects of these changes on reproductive characteristics including population fecundity, newborn survival, and reproductive success are not known. In this study, we present evidence from an eco-genetic model that fishing induces rapid evolution of multiple life-history traits and that these responses have consequences for stock dynamics, reproductive output, and fishery catches. The evolutionary responses to fishing that are predicted by our model are multi-dimensional, and in many cases lead to decreased population biomass, depleted harvestable biomass, reduced body sizes, and lower reproductive output. Most startling is that the evolving traits do not show any significant sign of recovery after a moratorium is implemented. We also show how density-dependent processes affect the evolutionary responses and resultant reproductive characteristics of exploited populations. Our results highlight the need for fisheries managers to be concerned with evolutionary changes induced by fishing because these changes alter the reproductive and recruitment processes of stocks, diminish the quality and quantity of fishery yields, and take substantial time to reverse - if such reversal is feasible at all.

Erin Dunlop erin.dunlop@imr.no
Department of Biology,
University of Bergen
P.O. Box 7800,
N-5020 Bergen, Norway



1-8

The Influence of Stock Structure on Fisheries-induced Evolution in Age and Size at Maturation of Icelandic Cod

Pardoe, H., E. Dunlop, G. Marteinsdóttir and U. Dieckmann

Changes in life-history traits, particularly in age and size at maturation, have been reported in a number of commercially exploited fish stocks. Several studies have found fisheries-induced evolution to be a plausible explanation for the observed trends. Many fish species show evidence of component structure resulting from behavioural, life history, and in some cases, genetic differences among subpopulations. One such stock is Icelandic cod, for which spawning, life-history characteristics, condition, and abundance vary spatially, and for which there is also evidence of geographic genetic structure. Furthermore, the fishing mortality on Icelandic cod is distributed unevenly across the Icelandic shelf. Preliminary investigations suggest that age and size at maturation in this stock have declined over the last few decades. In line with the majority of fish stocks, Icelandic cod is currently managed as a single homogenous unit. However, failure to recognise and account for stock structure could produce misleading stock assessment results, which may have severe ecological consequences. Through the development and application of an individual-based eco-genetic model, we will investigate the emergence and subsequent dynamics of genetic structure in a stock such as Icelandic cod. Consideration of different and variable fishing pressures on individual stock components will help us to assess the influence of such stock structure on the rate, magnitude, detection, and management of fisheries-induced evolution.

Heidi Pardoe heidi@hafro.is
Marine Research Institute
Skulagata 4
121 Reykjavik
Iceland

1-9

Changes in maturation pattern and reproductive potential of Baltic cod stocks

Storr-Paulsen, Marie, Jonna Tomkiewicz and Fritz Köster

During the last decades, the stocks cod (*Gadus morhua*) in the Kattegat, Western and Eastern Baltic Sea have experienced increasing fishing pressure and changing environmental conditions. These changes are likely not only to decrease stock size and biomass, but also the reproductive capacity of the stock. We present data on growth and maturity derived from International Trawl Surveys in the Baltic and Kattegat during the time period 1972-2007 including data from Sweden, Denmark, Germany, Poland, Russia and Latvia. The data show substantial spatial and temporal variation in growth and maturation patterns within and among the cod stocks. Males matured generally at smaller size than females and for both sexes, the size at 50% maturation decreased over time in all areas. The changes in maturation pattern and stock structure affected the reproductive potential of the spawning stocks. Maturation of males at smaller size than females caused a dominance of males in the spawning stock at low stock size in recent time. Large size and higher life expectancy of females resulted in female dominance of the spawning stock the 1980ies. However, the earlier maturation in recent time independent of growth rate compensated to some degree that the stock has become smaller and younger. The spawning stock biomass of the three cod stocks based on the new maturity ogives and weight data are compared to the recent assessment where these data have been constant for 10 years.

Marie Storr-Paulsen msp@difres.dk
Danish Institute for Fisheries Research
Dept. of Marine Fisheries
Charlottenlund Castle
DK-2920 Charlottenlund
Denmark

1-10

Catch curves are misleading, gonads are revealing: age of sexual maturation versus recruitment in Pacific herring (*Clupea pallasi*)

Hay, Doug, Tom Therriault and Bruce McCarter

We examined age composition and sexual maturity data from commercial fishery and research catch data of Pacific herring (*Clupea pallasi*) from southern and northern British Columbia (BC). Catch curves from northern BC had approximately equal proportions of age-3 and age-4 fish, the two youngest and numerous age groups in the catches. In contrast, age compositions in southern BC had a higher frequency of age-3 fish. This is consistent with the hypothesis of full recruitment at age 3 in the south and incomplete recruitment at age 3 in the north. Previous workers assumed that northern BC, herring were not sexually mature or fully recruited until age 4 and that a substantial proportion of the age-3 cohort is immature. To examine this we complied and analyses data related to gonad maturity for each of the five major and two minor British Columbia herring stocks. Age-specific maturation was classified according to three sets of independent analyses: (1) histological analyses, from a small subset of data, (2) the Hjort maturity index based on a visual assessment of gonads and (3) gonad weights and gonosomatic index (GSI), from over one million fish collected since the early 1980's. Based on these three methods virtually all age-3 herring examined from all years and all areas were classified as sexually mature. Therefore, in northern BC there is an apparent contradiction between catch curve analyses indicating incomplete maturity (or recruitment) and gonad analysis showing nearly complete maturity at age 3. This contradiction can be explained by differences age-specific behaviour and seasonal variation of maturation cycles. Virgin fish, spawning for the first time, may not yet have grown sufficiently large to aggregate with, and spawn with, the older (age 4+) mature, adults component of the stock. They tend to spawn later, often at slightly different locations, and may be less vulnerable to the commercial fishery that targets the largest, earlier spawning fish. Therefore assumptions about age-specific maturity based on catch carve analyses can be misleading in a species such as Pacific herring. Herring stock assessment models are calibrated using estimated of spawn deposition from all spawning fish. Therefore the impact of an incorrect assumption about age-specific maturity can lead to erroneous inflation of spawning stock biomass.

Doug Hay hay.doug@shaw.ca
Dept. of Fisheries & Oceans
Pacific Biological Station
Nanimo, BC
Canada

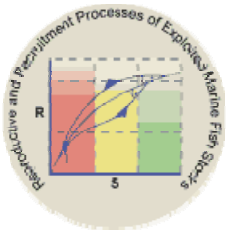
1-11

Effect of maternal fat reserves on the fatty acid composition of sardine (Sardina pilchardus) oocytes

Garrido, Susana, Rui Rosa, Radhouan Ben-Hamadou, Maria Emilia Cunha, Maria Alexandra Chícharo, Carl D. van der Lingen

We compared the fatty acid (FA) composition of the muscle and gonads of female Iberian sardines with hydrated oocytes collected during the 2002/03 spawning season off southern Portugal (November and February) and off western Portugal (February). Sardine condition and total FA concentration in the muscle decreased between the two sampling dates, while the gonadosomatic index was similar between samples. Total monounsaturated FA concentrations in sardine gonads were different for the three samples while saturated and polyunsaturated FA concentrations were similar. Significant linear relations were found between FA concentrations in female muscle and oocytes, including eicosapentaenoic acid (EPA; 20:5n-3) and arachidonic acid (AA; 20:4n-6), both being essential for normal larval development. The concentration of docosahexaenoic acid (DHA; 22:6n-3) in oocytes was independent on muscle concentration, probably resulting from its selective transfer to the oocytes. The EPA/DHA ratio was highly conserved in sardine tissues, while DHA/AA and EPA/AA ratios varied significantly between samples. These results indicate that the FA content of eggs produced by sardines varies throughout the spawning season, egg FA concentrations decreasing as females lose condition, and FA composition also shows spatial variability. Both types of variability may have a significant impact on egg quality, particularly on the amount of reserves available to larvae affecting their resistance to starvation, and the appropriate FA composition required for normal growth.

Susana Garrido sgarrido@ipimar.pt
IPIMAR-Dep. Recursos Marinhos
Av. Brasilia, 1449-006
Lisboa
Portugal



SESSION 2 – ORAL

Fecundity and Spawning Success

Session Convenor:

Guðrún Marteinsdóttir

Iceland

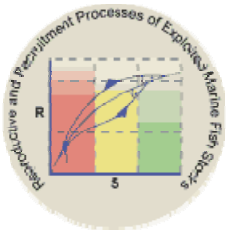
2-1 **Keynote Address**

Reproductive Success in Marine Fish Populations: Why Should We Closely Monitor Fish Fecundity?

Lambert, Yvan

Reproductive success, best defined as lifetime total offspring to reach maturity, is the product of fecundity per season, adult reproductive life span and offspring survival to maturity. Life history traits at the population level can be seen as a collective measure of the fate of individuals through their life cycle. For practical purposes, reproductive success is often separated in two components: reproductive potential and offspring survival to maturity. Further simplification has been introduced, especially in exploited marine fish populations, by using spawning stock biomass (SSB) as an indicator of reproductive potential. However, by doing so, the number of offspring produced (i.e. fecundity), a key component necessary for the determination of the reproductive success, had been given a very minor importance and measured very infrequently. The use of SSB which underlies the assumption of constant relative fecundity of a stock (time-invariant fecundity per unit of biomass) is challenged. Important variations in the number of offspring per season and lifetime production of offspring are observed in relation to parents quality, resource availability, environmental and evolutionary factors. Availability of new data on fecundity and development of models to hindcast fecundity variations have been used to show that reproductive potential of stocks estimated by total egg production can lead to different perceptions of the reproductive effort of a stock. With the development of methods to rapidly measure potential fecundity of fish, it is now possible to routinely measure fecundity. Combining the monitoring of fecundity to demographic parameters largely available for exploited marine fish stocks allows the monitoring of reproductive success. One possible outcome of measuring reproductive success is the calculation of the intrinsic rate of population increase (r), an essential parameter in population dynamics and evolutionary ecology which can be used in determining sustainable harvesting, resilience, and potential rates of recovery of populations.

Yvan Lambert lamberty@dfo-mpo.gc.ca
Dept. of Fisheries & Oceans
Maurice Lamontagne Institute
850 de la Mer Road
PO Box 1000
Mont-Joli, QC
Canada G5H 3Z4



2-2

Reproductive strategy of Atlantic horse mackerel *Trachurus trachurus* and the regulatory role of surplus energy and condition indices

Ndjaula, Hilkka O.N., Tom Hansen, Maria Krüger-Johnsen and Olav Sigurd Kjesbu

The reproductive strategy and tactics of a species is important for the fisheries advice and management on a stock as this essentially determines egg and larval production and successful recruitment thereafter. This study aims to clarify whether developing oocyte production in horse mackerel is determinate or indeterminate. In addition, this study provides information on energy allocation patterns and quantification of the energy investment in reproduction. Horse mackerel (n=202 males and females) from the North Sea were kept in captivity and fed to satiation for 13 months (Oct. 2005 to Nov. 2006) in two adjacent circular tanks. To our knowledge this is the first time horse mackerel has been monitored for this long in an experimental situation. Sampling for gonad development and fish condition was undertaken monthly during that period. Histological examination of the ovaries indicated that vitellogenic oocytes were present at all times throughout the study period, and the intensity of atresia was substantial. The oocyte diameter threshold between previtellogenic and vitellogenic oocytes and the mean oocyte diameter of the leading cohort was investigated. Variation in gonadosomatic index (GSI), hepatosomatic index (HSI) and condition factor (Fulton's CF) was correlated with fat content (as measured by use of a Distell fish fatmeter).

Hilkka O.N. Ndjaula hilkka.ndjaula@imr.no
Institute of Marine Research (IMR)
Nordnesgaten 50
P.O.Box 1870 Nordnes
5817 Bergen
Norway

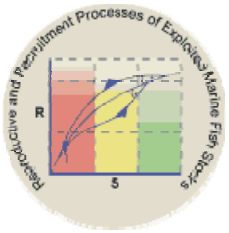
2-3

Can temperature benefits justify extensive up-current migrations in the Northeast Arctic cod?

Opdal, Anders Frugård, Frode Vikebø and Øyvind Fiksen

The Northeast Arctic cod, *Gadus morhua*, is well known to perform extensive up-current migrations from their feeding grounds in the Barents Sea to various spawning banks along the Norwegian coast. Prior to the 1990's these banks where located on a wide latitudinal range from Finnmark (~71°N) to Møre (~63°N), or even on the south-western coast of Norway (~60°N), with the highest densities around Lofoten (~69°N). For the last 25 years the Northeast Arctic cod have, however, abandoned their southernmost spawning grounds in favour of the banks around the Lofoten area. One potential explanation is, that prior to the 1990's larger individuals could increase their own and their offspring's fitness by spawning further south where temperatures are higher. Modern fisheries in the Barents Sea have truncated the size distribution, favouring increased energy allocation to reproduction, and reducing the fraction of older and larger individuals. To investigate if such a temperature-benefit-hypothesis is plausible we utilize a regional oceanographic model system, ROMS, together with an individual based model, IBM, to track the drift of particles released at six known spawning grounds. By accounting for temperature, growth, and natural mortality during the particles northbound drift, we observe that particles released at southern banks experience significantly higher temperatures than the rest. This is due to a mixture of higher sea-temperatures and favourable retention above and around the spawning ground. Particles released above the most important spawning grounds in Vestfjorden, however, experienced the lowest temperatures of all, and less retention than more southerly spawning grounds. These results strongly suggest a latitudinal gradient in local temperatures and retention, but also that differences in prey availability may modify the profitability of spawning grounds.

Anders Frugård Opdal
University of Bergen
Bergen
Norway
anders.opdal@bio.uib.no



2-4

Sperm reserves of primiparous snow crab (*Chionoecetes opilio*) females in the eastern Bering Sea: inter-annual variation and spatial patterns relative to available males

Slater, Laura M., Kirsten A. Gravel and Douglas Pengilly

The snow crab (*Chionoecetes opilio*) stock in the eastern Bering Sea supports an important commercial fishery in which only males of a minimum size are harvested and from which 30-thousand t to 149-thousand t were harvested annually during 1990-1999. The stock's mature biomass abruptly declined by 60% during the year prior to the 2000 fishery, however, and during 2000-2007 annual harvests have been only 11-thousand t to 17-thousand t. Female snow crabs possess sperm storage organs and, if sufficiently inseminated, can store sperm for successive clutch fertilization, a feature that could conceivably buffer the stock from recruitment overfishing by the males-only fishery. However, studies performed on the reproductive potential of the eastern Bering Sea snow crab stock following the stock decline showed relatively low sperm loads in the sperm storage organs of females. To better understand the factors affecting the reproductive potential of females, including those that could be due to the removal of large males by the fishery, the Alaska Department of Fish and Game initiated a monitoring program of female snow crab sperm reserves in 2005. Average estimated sperm cell reserves in primiparous snow crabs from the northern Bering Sea in 2005 (3.62 x 106; n = 56) were much lower than similar studies found in Japan and the Gulf of St. Lawrence, Canada. In fact, results showed that more than half of the females did not have sufficient sperm reserves to fully fertilize a second clutch of eggs. In 2007, sperm reserves will be analyzed from primiparous snow crab collected over a wider geographic range in the eastern Bering Sea. Comparisons between primiparous sperm reserves in 2005 and 2007 and analysis of the spatial distribution of sperm reserves relative to the number and maturity status of males will be presented.

Laura M. Slater laura.slater@alaska.gov
Bering Sea/Aleutian Islands Tanner & Snow Crab Research Biologist
Alaska Department of Fish and Game
Division of Commercial Fisheries
Alaska, USA

2-5 **Keynote Address**

Eggs and Larvae are Starting Ingredients in a Menu of Recruitment that Often Goes Wrong: Lessons from High Latitude Majid Crabs

Armstrong, David, Lobo Orensanz, Bernard Sainte-Marie and Billy Ernst

Stocks of majid crabs support a number of fisheries worldwide but most significant are the industrial fisheries for snow crab (*Chionoecetes opilio*) in the North Pacific, Bering Sea, and eastern Canada. All majids share noticeable peculiarities in their life histories, most prominently a terminal molt associated with maturity as part of a complex reproductive ecology. Experimental work conducted in the Gulf of St. Lawrence (GSL) addressed issues of early benthic life-history, growth, maturity and mating behavior, while surveys in the eastern Bering Sea (EBS) have documented large-scale patterns in significant aspects of the life history (ontogenetic migrations, size-at-maturity, etc.). Biological complexities are intertwined with fisheries that selectively target a specific life-history stage: large, mostly morphologically mature males. Long-term regime shifts and resultant changes in faunal communities have further implications for stock structure and, ultimately, egg and larval production. Although there are apparent commonalties in the basic life-history calendar between stocks from the EBS and GSL, the environmental templates that structure these two populations are seemingly very different. An Environmental Ratchet hypothesis has been formulated to account for profound decrease in abundance and distribution of snow crab in the EBS over the last 20 yr. While egg production is spatially highly variable in this system due to several contributing aspects of life history, overall shift in spawning biomass relative to prevailing current patterns may be of greater significance. Circulation models indicate that much of the spawning pool is now "down current" relative to historic distribution which makes uncertain how the species will repatriate the former range of high abundance. Lessons drawn suggest that eggs and larvae are only starting ingredients in the intricate life history menu that determines recruitment and year class success.

David Armstrong davearm@u.washington.edu
School of Aquatic and Fishery Sciences
University of Washington
1122 NE Boat Street, 116 Fishery Sciences
Box 355020
Seattle, WA 98195-5020
USA

2-6

Frequency of skipped spawning in Norwegian spring-spawning herring

Kennedy, J., Skjæraasen, J.E., Nash, R.D.M., Slotte, A. and Kjesbu, O.S.

There is mounting evidence that skipped spawning is common among many iteroparous fish species, and there are several theories/reasons as to why this occurs such as life history, energy availability and unsuitable environmental conditions. Recent work has detected this phenomenon in Norwegian spring-spawning (NSS) herring, which is among the largest commercial fish stocks in the world with SSB estimated at 8 million tonnes. It has been hypothesised that up to 1 in 2 herring may skip their second reproductive season. This has been inferred from a lower than expected number of 2nd time spawners on the spawning grounds, which is based upon otoliths readings taken from herring on the spawning grounds. There is however no direct evidence of skipped spawning in NSS herring. The aim of our study was to find direct evidence of skipped spawning in herring. As the decision to proceed with gonad development is made many months before spawning, the decision to skip may be detectable before the spawning migration occurs and the population is still mixed. We sampled herring from the feeding grounds in the Norwegian Sea during July and August and from the over-wintering grounds in October and November during 2006 and will repeat this in 2007. The occurrence of skipping was not detected in the numbers predicted with only 4 fish of 124 sampled in 2006 from the over-wintering grounds looking as though they will not spawn in the coming season. The results from the samples taken from the feeding grounds in 2007 will also be presented and discussed.

James Kennedy
Universitetet i Bergen
Institutt for biologi
Postboks 7800
N-5020 Bergen
Norway

james.kennedy@bio.uib.no

2-7

Timing and determination of skipped spawning in Atlantic cod

Skjæraasen, Jon Egil, James Kennedy, Anders Thorsen, Richard Nash, Olav S Kjesbu

Forecasting stock size is an integral part of responsible and sustainable management of marine resources, and requires intimate knowledge of stock-recruitment relationships. Models that accurately depict these relationships have therefore long been sought. These models have evolved in complexity from models using correlations between spawning stock biomass (SSB) and recruitment to models including various indices of individual condition. Life history theory further predicts that reproductive investment should depend on age and size-at-age, and incorporating age-structure also increased the explanatory power of recruitment models. Emerging evidence suggest however that there is a critical time window during early vitellogenesis, which is highly influential for potential fecundity and the decision to skip spawning, a common occurrence in many mature fish. Knowledge of the energy reserves of the mature population during this critical time may therefore have considerable implications for stock-recruitment theory. We examined this hypothesis in North East Arctic cod (*Gadus morhua*).

To examine if there is a time window that is linked to the decision to skip spawning we examined energy reserves, past spawning history and the incidence of skipped spawning in wild cod caught at the feeding grounds in the Barents Sea from August to February. The results will give important information on the occurrence and mechanisms regulating skipped spawning in North East arctic cod. The studies will also shed new light on the reproductive physiology of gadoids in general, an important group of commercial finfish, subject to overexploitation throughout their range.

Jon Egil Skjæraasen
Department of Biology
University of Bergen
P.O. Box 7800
N-5020 Bergen, Norway
jon.skjaeraasen@bio.uib.no

2-8

Relationships between maternal body size, condition and potential fecundity for Northwest Atlantic flatfishes

Rideout, R.M. and M.J. Morgan

Potential fecundity data for three species of Northwest Atlantic flatfish (*Hippoglossoides platessoides*, *Pleuronectes ferruginea*, *Glyptocephalus cynoglossus*) were recently reported for the period 1993-1998 and represent the first fecundity data for these populations in the past 30-40 years. Here we use this data to examine relationships between fecundity and various body metrics in order to (i) evaluate potential proxies for fecundity and (ii) suggest potential causes of observed spatial and temporal variability in fecundity for these species. Fish weight and ovary weight were the best proxies for fecundity for all three species but showed a marked difference among species with the amount of explained variability in fecundity being higher for *H. platessoides* (r^2=79%, 81%), intermediate for *G. cynoglossus* (r^2=56%, 72%) and low for *L. ferruginea* (r^2=34%, 32%). Indices of condition were not good single-factor predictors of fecundity. The addition of condition indices to length-based fecundity models improved model fit by a significant but small amount (≤ 6%) and did not improve the fit of models based on fish weight.

Rick Rideout RideoutR@DFO-MPO.GC.CA
Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
P.O. Box 5667
St. John's, NL
Canada A1C 5X1

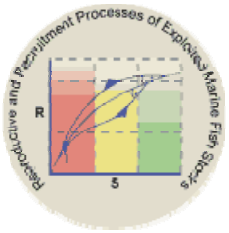
2-9

An attempt to trace the contribution of different spawning components to the surviving population of juvenile cod in Icelandic waters

Marteinsdottir, Gudrun, Christophe Pampoulie, David Brickman, Lorna Taylor, Kai Logemann and Daniel Ruzzante

Among fish species, offspring survival and performance is strongly influenced by time and position of spawning. Due to variation in ocean processes, small changes in spatial and temporal position of eggs of broadcast species such as gadoids can result in large changes in direction of transport and ultimately the final destiny of offspring. Reproductive strategies practised by gadoids are characterized by high fecundities and limited parental care. Despite this, parental selection of spawning sites may be a crucial factor in determining the survival probabilities of the offspring. In Iceland, cod spawn at various locations all around the country. Survival of offspring from the main spawning grounds at the southwest coast is thought to be influenced by the strength and direction of the Irminger and coastal currents carrying eggs and larvae from the main spawning ground onto the northwest and northern located nursery grounds. In order to explore and estimate the contribution of different spawning sites to the surviving population of juvenile cod attempts were made to 1) construct an atlas of spawning sites, 2) estimate the egg production associated with each spawning site, 3) track the drift and dispersal of eggs and larvae up to juvenile age with hydrodynamic and particle tracking models, and 4) estimate origin of 0-group cod based on back-calculated hatch date distribution and genetic composition.

Gudrun Marteinsdottir runam@hi.is
University of Iceland
Marine Research Institute
P.O. Box 1390
Skulagata 4, Reykjavik
Iceland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2-10

A method to accurately estimate the daily spawning fraction of Japanese flounder *Paralichthys olivaceus* considering a wide range of ambient temperature

Kurita, Yutaka, Yuichiro Fujinami and Masafumi Amano

Accurate estimates of daily spawning fraction and batch fecundity are required in order to study the response of reproductive output to varying environment and to improve stock assessment. Necessary information to estimate spawning fraction is the frequency distribution of daily spawning period and the duration of each oocyte/postovulatory follicle (POF) stage which relates to spawning. The latter should change due to varying ambient temperature. This study examined this necessary information using captive Japanese flounder, *Paralichtys olivaceus*, under a wide range of temperature, and developed a method to accurately estimate spawning fraction at different temperatures. Spawning occurred throughout the day (24 hrs) with two peaks at around dawn and dusk. Duration of each oocyte/POF stage strikingly decreased as temperature increased from 11.3 to 19.7 °C; 24 to 3 hrs, 12 to 5 hrs, 14 to 5 hrs, and 16 to 4 hrs for early migratory nucleus stage (MN(E)), late migratory nucleus stage (MN(L)), hydration stage (HD), and new POF, respectively. Spawning fraction (S) is estimated as S = (24/ti) x Si; where Si is the prevalence of the i-th oocyte/POF stage, and ti is the duration of the corresponding stage. The correction factor (24/ti) changed considerably as temperature increased; e.g. 1.7 at 11.3 °C and 4.8 at 19.7 °C for HD. Another method, which is more robust, to estimate S is combining some oocyte/POF stages so that the total duration of those stages is approximately 24 hours, that is, the correction factor is 1.0; e.g. MN(L)+HD at 11 °C (total duration, 25 hrs) and MN(E)+MN(L)+HD at 17 °C (25 hrs). These results stress the importance of considering ambient temperature in estimating spawning fraction especially for fish species with extended daily spawning periods.

Yutaka Kurita kurita@affrc.go.jp
Tohoku National Fisheries Research Institute
Shinhama 3-27-5
Shiogama, Miyagi
985-0001 Japan

2-11

Understanding the effect of seasonal forcing on the reproductive traits of a multiple-batch spawner in the context of the Dynamic Energy Budget (DEB) theory: the Bay of Biscay anchovy (*Engraulis encrasicolus*)

Pecquerie, Laure, Pierre Petitgas and Sebastiaan A.L.M. Kooijman

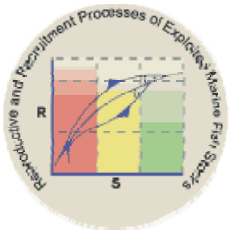
Aquaculture production of Atlantic cod (*Gadus morhua*) is expected to increase dramatically over the next decade, particularly in Norway. There is growing concern over the environmental impact of farmed escapees, especially the consequences of genetic introgression with wild coastal cod. Given the fact that Norwegian coastal cod stocks are presently at a historical low, knowledge on how farmed escapees can impact these wild populations through genetic introgression is of paramount importance. The ability of cod escapees to interact with their wild counterparts will depend on a number of factors including gamete quality.

In order to determine whether spawning success of farmed escapees can be correlated to differences in sperm competition we undertook a spawning study using farmed and wild cod from the same putative coastal population. Multiple cross fertilizations were performed under controlled conditions using eggs from both wild and farmed females fertilized using milt of equal quantities from a wild and farmed male. Male paternity of the offspring was determined by microsatellite DNA analysis. In addition, blood samples were taken for steroid hormone analysis. Sperm quality parameters, in terms of percentage motile sperm and sperm motility were evaluated by Computer Assisted Sperm Analysis (CASA).

Spawning success, as determined from the male parentage of the offspring, was correlated to both sperm quality and other male reproductive parameters including plasma steroid levels and gonadosomatic index.

Laure Pecquerie
Depatment EMH
rue de l'Ile d'Yeu
B.P. 21105
44311 Nantes Cedex 03
France

laure.pecquerie@ifremer.fr



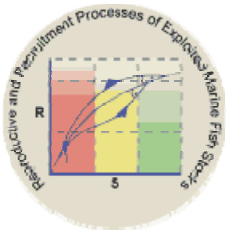
2-12

Collapsing and recovering fisheries depend on the quality of female spawners

Venturelli, P. A., C. A. Murphy, T. A. Johnson, P. J. van Coeverden de Groot, P. T. Boag, J. M. Casselman, W. C. Leggett, R. Montgomerie, M. D. Wiegand, and B. J. Sutter

Stock-recruitment theory assumes that offspring survival is independent of parental quality, despite evidence form laboratory and hatchery experiments to the contrary. However, the strength of this association in nature and its effects on harvested stocks remains an enigma. Here we combine field experiments, population modeling, and stock data to show that maternal quality and harvest-induced demographics can have a strong effect on juvenile survival and recruitment dynamics. Our results suggest that larger females are essential to harvest sustainability because they contribute disproportionately more to recruitment through positive effects of egg size on offspring survival. We argue that size-selective harvests that protect rather than target females are practical strategies that would contribute significantly to the development of sustainable fisheries.

Paul Venturelli paul_venturelli@hotmail.com
Dept. of Ecology and Evolutionary Biology
University of Toronto
25 Harbord Street
Toronto, ON
Canada M5S 3G5



2-13

Maternal age-related influences on larval production of Pacific ocean perch (*Sebastes alutus*)

Parker, Steven J., Robert W. Hannah, Donald M. Van Doornik, Steven R. Millard, Ewann A. Berntson and Paul Moran

The Pacific ocean perch (*Sebastes alutus*) population off the West Coast of the U.S. is a depleted commercial stock which has been in rebuilding status since 1981. Infrequent and variable recruitment success has hindered rebuilding performance. Reproductive output as incorporated into many stock assessment models typically assumes that the quality of eggs or larvae produced is equal among all mature females in the population. As part of a histological age-at-maturity study, we found age-related structure in the development of oocytes, with some adolescent (5-9 years old) and mature, but young females (10-18 years old) showing abortive maturation characterized by mass atresia of the developing class of vitellogenic oocytes. Genetic analyses also showed that polyandry is prevalent in Pacific ocean perch (71% of samples with up to 4 sires), and that older females tend to spawn with multiple males. Differential reproductive characteristics by older females can lead to increased variability in recruitment depending on population age structure and environmental conditions. These two effects, whether biologically independent or related, influence our understanding of the dynamics of reproductive success in Pacific ocean perch and support the argument that age structure may be an important variable in reproductive performance.

Steve Parker s.parker@niwa.co.nz
National Institute of Water and Atmospheric Research
Private Bag 14901, Wellington 6241
New Zealand

2-14

Is spawning success of Atlantic cod escapees influenced by differences in sperm competition?

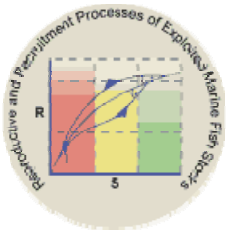
Mayer, I., J. J. Meager, J. E. Skjæraasen, G. Rudolfsen, Ø. Karlsen, O. Moberg, A. Staby, O. Kleven and A. Fernø

Aquaculture production of Atlantic cod (*Gadus morhua*) is expected to increase dramatically over the next decade, particularly in Norway. There is growing concern over the environmental impact of farmed escapees, especially the consequences of genetic introgression with wild coastal cod. Given the fact that Norwegian coastal cod stocks are presently at a historical low, knowledge on how farmed escapees can impact these wild populations through genetic introgression is of paramount importance. The ability of cod escapees to interact with their wild counterparts will depend on a number of factors including gamete quality.

In order to determine whether spawning success of farmed escapees can be correlated to differences in sperm competition we undertook a spawning study using farmed and wild cod from the same putative coastal population. Multiple cross fertilizations were performed under controlled conditions using eggs from both wild and farmed females fertilized using milt of equal quantities from a wild and farmed male. Male paternity of the offspring was determined by microsatellite DNA analysis. In addition, blood samples were taken for steroid hormone analysis. Sperm quality parameters, in terms of percentage motile sperm and sperm motility were evaluated by Computer Assisted Sperm Analysis (CASA).

Spawning success, as determined from the male parentage of the offspring, was correlated to both sperm quality and other male reproductive parameters including plasma steroid levels and gonadosomatic index.

Ian Mayer ian.mayer@bio.uib.no
Department of Biology
University of Bergen
N-5020 Bergen
Norway



SESSION 3 – ORAL

Survival of Eggs and Larvae

Session Convenor:

Mark Dickey-Collas

Netherlands

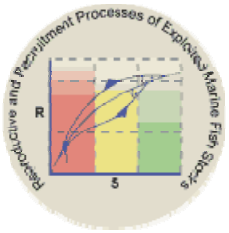
3-1 **Keynote Address**

Oceanography meets Fisheries Conservation - Opportunities for Success

MacKenzie, Brian

Fisheries oceanographers spend great amounts of resources trying to understand factors affecting survival of fish eggs and larvae. We do this because we hope to learn why fish populations have fluctuated in the past, and especially to learn how much of this variation is due to effects of fishing (via removal of spawning biomass and the production of new eggs) or to effects of ecosystem variability. Some of us also hope to use this knowledge to help conserve and rebuild populations. This implies that we use our understanding in forward projections of populations - how will fish populations react to changes in fishing effort, climate, habitats, biodiversity and food web structure, etc.? In this presentation, I will show case study examples where recruitment process knowledge is, or starting to be, used in applied aspects of fisheries assessment and management including the prediction of future fishing yields and spawner biomass levels. Incorporation of this information must proceed cautiously and critically, but when successful will help develop an ecosystem-based approach to fisheries management, while simultaneously increasing the value of fisheries oceanographic research.

Brian MacKenzie brm@difres.dk
Technical University of Denmark and University of Århus
Department of Marine Ecology and Aquaculture
Danish Institute for Fisheries Research
Kavalergården 6
DK-2920 Charlottenlund
Denmark



3-2

Fishery-induced demographic changes in the timing of spawning; consequences for reproductive success

Wright, Peter, Ed Trippel and Jonna Tomkiewcz

Inter-annual variation in spawning time is a critical factor in reproductive success because it affects the early environmental conditions experienced by progeny and the period they have to complete phases of development. This review considers the consequence of reproductive timing to progeny survival and the effect that reductions in the size and age composition of the spawning stock have on this relationship. In many multiple batch spawners, individuals spawn progressively earlier and produce more egg batches over a longer period as they get older, thus extending their lifetime spawning duration. As a consequence stock demography can have a significant effect on reproductive timing and the magnitude of such an effect is comparable to environmentally induced variability. Empirical estimates of selection on birth date, using otolith microstructure, demonstrate that there is considerable variation in selection on birth date during a spawning season. The few multi-year studies that have linked egg production with the survival of progeny to the juvenile stage further highlight the uncertainty that adults face in timing their spawning to optimize offspring survival. Model simulations indicate that protracted spawning can be seen as a response to this uncertainty. The production of many small batches of eggs over a long period of time is likely to decrease the variance and increase the mean progeny survival. Hence, by impacting the average lifetime spawning duration within a fish stock, fishing pressure could be increasing the variability in reproductive success and reducing the long term reproductive potential of a stock.

Peter J. Wright
Fisheries Research Services
Marine Laboratory
PO Box 101
375 Victoria Road
Aberdeen AB11 9DB
Scotland, UK

P.Wright@marlab.ac.uk

3-3

Effects of egg size, parental origin and feeding conditions on growth of larval and juvenile cod (*Gadus morhua* L.)

Paulsen, H., V. Bühler, R.A.J. Case, C. Clemmesen, G. Carvalho, W.F. Hutchinson, O. S. Kjesbu, E. Moksness, H. Otterå, A. Thorsen and T. Svåsand

A comprehensive experimental study was performed to disentangle maternal and environmental effects in larval growth and survival of Atlantic cod (*Gadus morhua*) under semi-natural (mesocosm) conditions. Eggs were collected during the spawning season from 30 spawning pairs (families) kept separately in specially designed spawning compartments. Newly hatched larvae were simultaneously released in two mesocosms of 2500m^3 and 4400m^3. Growth of the larvae was monitored by samplings during a period of ten weeks, after which juveniles were transferred to on-growing tanks, where they were kept for up to two years. Maternal origin was determined by individual genotyping of a total of 3949 larvae sampled during the mesocosm period, and 600 juveniles from each mesocosm were tagged for tracking of growth during tank rearing. The results showed significant positive correlations between egg and larval size during the whole mesocosm period. Correlations weakened with time and were not significant at the first tank-rearing sampling at age 9 month. Family-specific differences in growth affected size relations between families. Variation in size of larvae during the mesocosm period was calculated as coefficient of variation (CV). Between family CV was 51% to 81% of within family CV. Differences in zooplankton densities between the two mesocosms were reflected in larval growth and condition. During low zooplankton density growth was generally reduced, particularly in families attaining large size during previous good feeding conditions. This suggests that genetically determined large size at hatching and/or fast growth may not always be an advantage.

Helge Paulsen hep@difres.dk
Danish Institute for Fisheries Research
Hirtshals
Denmark

3-4

Differential egg mortality of Georges Bank cod and haddock

Lough, R. G., L. O'Brien and L. J. Buckley

Georges Bank Atlantic cod and haddock stocks have undergone significant changes over the last 40 years with the reduction of older spawners and the greater maturity of younger fish that have lower egg viability and larval survival. Spawning stock biomass (SSB), derived from virtual population analysis, traditionally has been used as a metric of spawning potential. The NEFSC's ichthyoplankton surveys also have provided an independent estimate of SSB. For many of the MARMAP years (1977-87), the survey initial cod egg abundance over estimated the SSB-derived initial egg abundance by as much as an order of magnitude, but reversed during GLOBEC years (1995-99). Comparing the ratios of the two egg abundance estimates versus the total combined SSB of cod and haddock, the ratio is high when haddock was abundant and closer to one when cod comprised the greater part of the total SSB. It appears that when haddock abundance is high, the survey egg abundance is inflated due to assigning a portion of the excess haddock mortality to cod. Numbers of early stage eggs of the two species are indistinguishable, but are estimated by apportioning the total egg abundance at a station by the late stage abundance, assuming equal mortality for the two species. These ratios appear to explain about 50% of the variability, while other factors might be related to fecundity, age-class composition of the SSB and others. Our findings suggest that haddock egg mortality is greater than cod so that initial spawning abundance estimates from egg surveys based on constant egg mortality may not be accurate.

R. Gregory Lough
NOAA/NMFS
Northeast Fisheries Science Center
166 Water Street,
Woods Hole, MA
02543-1097 USA

glough@whsun1.wh.whoi.edu

3-5

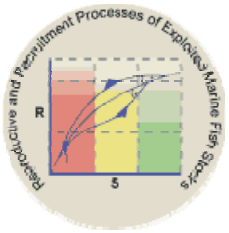
Identification of Eastern Baltic cod nursery grounds: a hydrodynamic modeling approach

Hinrichsen, Hans-Harald and Gerd Kraus

A prerequisite for the identification of Baltic cod nursery grounds is to resolve the dynamics in spatial and temporal distribution of demersal juveniles. In this study we use a hydrodynamic model to examine the spatial distribution of Baltic cod early life stages. The transport patterns of Baltic cod larvae spawned on the three major spawning grounds in Central Baltic Sea was investigated by detailed drift model simulations for the years 1979-2004. We analysed potential habitats of late larvae and early juveniles for their suitability to enable the change from pelagic to demersal life. The results of these exercises yielded a clear dependence of the probability for successful settling on wind-induced drift of larval cod, which is controlled by the local atmospheric conditions over the Baltic Sea. Furthermore, there we found evidence that the final destinations of juvenile drift routes are subjected to the effects of decadal climate variability.

The identified nursery areas were partly overlapping with regions of high fishing effort in autumn targeting sprat and herring in a small meshed fishery. Size and location of potential nursery areas identified in this study are e.g. planned to be used in the design of potential Marine Protected Areas within a large scale fishery simulation study to assess the impact of spatial management measures on Baltic Sea resources and fisheries.

Hans-Harald Hinrichsen hhinrichsen@ifm-geomar.de
IfM-GEOMAR
Düsternbrooker Weg 20
D 24105 Kiel
Germany



3-6

Density-dependence in post-recruit Japanese sea bass in the Chikugo estuary, Japan

Shoji, Jun and Masaru Tanaka

Japanese sea bass *Lateolabrax japonicus* migrate from Ariake Bay to the estuarine turbidity maximum (ETM) zone of the Chikugo River and inhabit there through the post-migration period (15-20 mm in standard length). Density-dependence in feeding, growth and mortality was evident in the post-migration period. Based on otolith microstructure analysis, the weight-specific growth coefficient (G, d-1) and abundance-at-age was estimated for the post-recruit sea bass from 1990 to 2000. Abundance at recruitment (15 mm, A15) and at 20 mm (A20), and mortality coefficient during the post-recruit period (M, d-1) were estimated for each year by the use of the larval production method. The A15 varied by 24 times during the 11-year period and its variability had a significant effect on G, M, A20 and the ratio of M to G as an index of sea bass relative recruitment potential. G was low and M, ratio of M to G, and A20 were high when recruitment was successful. A lower coefficient of variation (%) was observed in A20 (25.0) than in A15 (33.5) for the 11 years. A significant effect of A15 was also found on the prey ingestion of the post-recruit sea bass. Mean of the gut fullness (gut contents weight body weight-1) was low when recruitment was successful. Density-dependent regulation through competition for prey resource does operate on sea bass at the post-recruit period corresponding with the migration from Ariake Bay to the Chikugo River, a spatially restricted nursery.

Jun Shoji jshoji@hiroshima-u.ac.jp
Takehara Fisheries Research Station
5-8-1 Minato-machi, Takehara
Hiroshima 725-0024
Japan

3-7

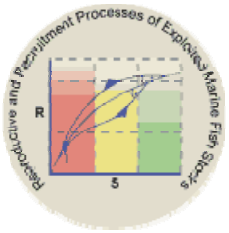
Behavioural adaptations of larval fish to vertical gradients and oceanography: predictions from evolutionary models

Fiksen, Øyvind

Marine fish are adapted to place their eggs and larvae in favourable locations and times of the season. The importance of being born at the right position in space and time depends on oceanography, but also on larval fish behaviour. Pelagic environments are highly structured in the vertical - light, temperature, and currents constitute gradients that even larval fish can exploit to enhance survival, growth and retention. These gradients may also involve dilemmas for larvae and juveniles, since they frequently have to choose between maximising growth, survival or retention through habitat selection. The advent of fine-grained oceanographic circulation models have now made it possible to study these trade-offs, and to explore fitness-consequences of time and place of birth, including behavioural strategies of larvae. An understanding of offspring fitness as a function of where and when they are born is also a key element to understand parental behaviour (migrations) and life history strategies (energy allocation). There is therefore an intimate link between larval ecology and parental life history traits. I will present some recent models showing the potential for adaptive larval behaviour in modifying effects of environmental factors such as prey availability and circulation patterns.

Øyvind Fiksen
Dept of Biology,
Univ of Bergen
Pb 7800 HiB
N-5020 Bergen
Norway

oyvind.fiksen@bio.uib.no



3-8

Recruitment process of Baltic herring populations

Cardinale, Max, Valerio Bartolino, Christian Möllmann, Michele Casini, Georgs Kornilovs and Tiit Raid

We conducted a meta-analysis of processes affecting recruitment of Baltic Sea herring stocks, i.e. the Western Baltic (WB, ICES SD 21-24), the Main Basin (MB, SD 25-29&32 excl. Gulf of Riga), the Gulf of Riga (GOR), the Bothnian Sea (BS, SD 30) and the Bothnian Bay (BB, SD 31). A number of biological and hydro-climatic variables were used as predictor and tested for effect on recruitment by using Generalized Additive Models (GAMs). Recruitment success (Rs) or recruitment anomalies (Ra) were used as response variables. First, all the hypothesized predictors (selected a priori on the basis of known ecological, biological and physiological mechanisms) were included in the model and a backward stepwise regression based on the GCV information criteria was applied to find the best possible set of predictors. The selected predictors in the best model were then screened using the ecological criterion, assuring that the sign of the relationship of a predictor with recruitment is ecologically meaningful and thus significant but spurious correlation are discarded. For all stocks except for the GOR, spawning biomass was found to significantly affect recruitment. A parental effect of the stock structure (indexed by the biomass of ages 5+) on recruitment anomalies (Ra) and recruitment (R) was found for WB and GOR herring. An effect of adult condition (indexed as weight-at-ages 3+) on Ra was only found for the MB herring. In most of the analyses (except for WB using Rs and BB using Rs) hydroclimatic variables were important predictors in the recruitment models. The Baltic Sea Index was found to be a significant climatic predictor of recruitment except for GOR and BB. For all stocks, temperature was a significant predictor of recruitment and if complete zooplankton data were available, (i.e. MB and GOR), the food supply was significantly related to recruitment, suggesting that a part of changes in climate and hydrography affect recruitment via prey availability. Predation mortality was a significant predictor for sprat but not for herring. Here we shown that spawning biomass is in general the most important factor in explaining recruitment dynamic. However, due to the peculiar hydrographical situation of the Baltic, recruitment is affected also by the highly variable hydrography, probably via shaping zooplankton abundance and species composition.

Massimiliano Cardinale massimiliano.cardinale@fiskeriverket.se
IMR
PO Box 4
Lysekil
Sweden

3-9

Growth and temporal origin of juvenile sprat in the German Bight (North Sea)

Baumann, Hannes, Arne M. Malzahn, Rudi Voss and Axel Temming

An important basic question in recruitment-related research is from what time window and region those individuals originate that occur later in the year as successful survivors of the early life stages. For the present GLOBEC study, the spatio-temporal origin of sprat *Sprattus sprattus* juveniles, sampled during 3 consecutive surveys (August-October 2004) in the German Bight, was inferred from otolith microstructure analysis and contrasted with spatial and seasonal patterns in sprat reproduction, as observed during 6 monthly plankton surveys to the German Bight and its adjacent areas. The majority of juveniles measured between 6 - 9 cm total length and originated mainly from April and May 2004, which notably preceded the peak spawning and larval production in May and June inside the German Bight. We concluded that juvenile sprat survivors rather originated from more western areas, where high spawning activity was already measured in April. From August to October, length and age distributions of sprat juveniles indicated the temporal presence of multiple cohorts in the German Bight. From each survey to the next, later born individuals appeared in the sampled population, thereby shifting the mean day-of-first-increment-formation (proxy for hatch day) from mid-April (August survey) to the beginning of May (October survey). Furthermore, between-survey analyses of otolith-based growth and back-calculated lengths suggested that bigger and faster growing juveniles selectively disappeared from the German Bight, either as a consequence of selective mortality or selective emigration. Our results emphasise the complex retention character of the system German Bight, where multiple cohorts of sprat juveniles from a range of different North Sea areas, temporal origins, and therefore growth patterns appear to temporarily co-occur.

Hannes Baumann hannes.baumann@uni-hamburg.de
Institute of Hydrobiology and Fishery Science
Olbersweg 24
22767 Hamburg
Germany

3-10

Selection for fast development and growth for late larval and early juvenile Pacific sardine, *Sardinops sagx*, in the California Current region

Takahashi, Motomitsu and David M. Checkley, Jr.

We hypothesized that faster growth and development by larvae of Pacific sardine results in higher survival. Growth and development rates of late larvae were estimated from the analysis of daily increments in otoliths from and linear measurements of late larvae (< 35 mm in standard length; SL), juveniles (35-110 mm SL), and pre-recruits (110-160 mm SL) collected in spring and fall and in spring of the subsequent year, respectively, off California. Fish were assigned to two cohorts based on hatch date: early March to early April (Mar-Apr) and late April to early May (Apr-May). The Apr-May cohort was more developed (snout-to-anus length and body depth, each relative to SL) than the Mar-Apr cohort for ages from 35 to 55 d. Increment width at 40-d age was 5.5 ± 0.9 μm for the Mar-Apr cohort and 7.3 ± 1.0 μm for the Apr-May cohort, implying that somatic growth rate was faster for the Apr-May cohort. Increment width at 40-d age for the juveniles had a bi-modal distribution with peaks at 5-6 μm and 7-8 μm, and proportion of the number of individual fish in the latter group was higher than in the former group. Hatch date of the juveniles and pre-recruits ranged from late March to mid August with a peak in May. Thus, larvae spawned in May grew faster and were a greater fraction of fish sampled as juveniles and pre-recruits, consistent with our hypothesis.

Motomitsu Takahashi takahamt@coast.ucsd.edu
Integrative Oceanography Division
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla, CA
USA

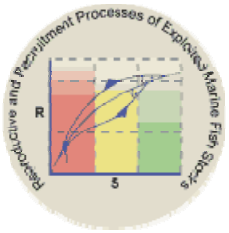
3-11 **Keynote Address**

Recruitment variability of small pelagic fish populations in the western North Pacific

Watanabe, Yoshiro, Motomitsu Takahashi, Akinori Takasuka and Yoshioki Oozeki

Among the small pelagic fishes inhabiting the western North Pacific, Japanese sardine *Sardinops melanostictus* experienced a drastic resurgence in the 1970s, historical peak in the 1980s, and precipitous decline in the 1990s. Chub mackerel *Scomber japonicus*, Pacific saury *Cololabis saira*, and Japanese anchovy *Engraulis japonicus* have fluctuated with the great fluctuation of the sardine in a decadal time scale. Processes of the population decline of sardine have been well documented. Mortality from eggs to age-0 recruits suddenly increased by one order in 1988 and 89 and further increased by one order in 1990 and 91. This increase in natural mortality was not explained by relatively instantaneous mass mortality in the first feeding stage, but cumulative mortality in late larval and juvenile stages was responsible for it. Eggs and early larvae are swiftly transported by the western boundary current "Kuroshio" and its downstream jet "Kuroshio Extension", and reach the nursery grounds located north of the current in 2-3 weeks. Late larvae metamorphose to juveniles in the nursery grounds and migrate north to the western subarctic gyre "Oyashio" across the subarctic front. Growth and developmental rates of metamorphosing larvae of anchovy depend on temperature, and fast growers in late larval and early juvenile stages have higher probability of successful recruitment. Optimum temperature for growth is higher in anchovy than in sardine. SST in the nursery grounds changes with the climate-ocean regime shift in the North Pacific. Warming and cooling of the epipelagic ecosystem in the nursery grounds seems to be closely linked to the recruitment failure of sardine after the end of 1980s, and alternating population growth of anchovy.

Yoshiro Watanabe
University of Tokyo
Tokyo, Japan
ywatanab@ori.u-tokyo.ac.jp



3-12

Winter recruitment of young-of-the-year bluefish: habitat use, feeding ecology and energetics

Juanes, Francis, John Murt and Peter Clarke

Bluefish, *Pomatomus saltatrix*, is a globally distributed species with directed commercial and recreational fisheries across its range. In North America bluefish undergo seasonal migrations from Florida to Maine. Spawning occurs in the South Atlantic Bight in the spring, larvae and juveniles are advected northwards by the Gulf Stream, and YOY fish recruit into Middle Atlantic Bight (MAB) estuaries in early summer. Juveniles and adults migrate south in the winter. In contrast to spring, summer, and fall, little is known about winter distributions, feeding ecology or energetics of YOY bluefish. We examined winter estuarine use by YOY bluefish in the SAB by quantifying recruitment to and distributions in four estuaries located in northeastern Florida using Generalized Linear Models. Three distinct YOY cohorts as well as age 1+ fish were identified using otolith microstructural analysis. Cohort arrival was spread out from October to January with a peak in relative abundance (CPUE) of all cohorts observed in December. In contrast to estuarine use in northern estuaries, in Florida, bluefish preferentially used inlets. Similar to previous work, diet analysis indicated that fish were the primary source of prey for all size classes, but in Florida diets were dominated by large (over 50% of bluefish body length) mullets. Contrary to expectations bluefish also accumulated lipid reserves during their winter residency. Mullets had the highest lipid content of any fish prey species in the system suggesting that the strong selectivity for mullet may be a consequence of their relative lipid levels and may represent an important part of the nursery value of Florida estuaries during winter bluefish recruitment.

Francis Juanes juanes@forwild.umass.edu
Department of Natural Resources Conservation
University of Massachusetts
Amherst, MA
01003-4210 USA

3-13

Abundance and growth of larval cod around Iceland - Passive transport under variable environmental conditions and modelling approaches

Jónasson, J. P., K. Logemann, B. Gunnarsson, D.Brickman and G. Marteinsdóttir

Currents play an important role in the retention or dispersal of progeny to favorable nursery grounds and habitats, directly influencing year-class strength and subsequent recruitment success. Variation in growth during the transport have subsequently shown to cause fluctuations in recruitment. In Iceland, recruitment of cod has been correlated with zooplankton abundance and the strength of the coastal current. As such, the coastal current has been shown to influence the spatial distribution, abundance, size and spawning origins of pelagic juvenile cod. Accordingly, the west- and northward flowing coastal current off Iceland, induced by freshwater runoff provides a transport mechanism for pelagic eggs and larvae derived from the main spawning grounds off the southwest coast to the main nursery grounds off the north and east coasts. In the present study, dispersal, abundance and growth of larvae cod were recorded during a series of cruises (2-3 every year) conducted along the drift route southwest and west of Iceland in 1998-2001. The cruises were timed so as to coincide with the beginning of the spawning season, during peak time of hatching and one was conducted in mid June to provide information on 2-4 week old larvae along the drift route. Large annual variations were observed in abundance, hatch dates and growth of cod larvae. Temperature was shown to influence the growth and retention of larvae was found in low saline or coastal waters. Directional drift based on particle tracking exercises and abundance between cruises was also estimated.

Jónas P. Jónasson jonasp@hafro.is
Askja
Sturlugata 7
101 Reykjavík
Iceland

3-14

Physical-biological interactions in the life history of small pelagic fish in the Western Iberia Upwelling Ecosystem

Santos, A. Miguel P., Alexandra Chícharo, Antonina Dos Santos, Teresa Moita, Paulo B. Oliveira, Álvaro Peliz, Pedro Ré

We describe processes related to the 'ocean triad' (enrichment, concentration, transport/retention) that could explain the fluctuations of small pelagic fishes (e.g., sardine and anchovy) in the Western Iberia Upwelling Ecosystem, which are, at least partially, explained by environmental variability (e.g., changes in coastal upwelling). Based on observations of local oceanographic features, such as buoyant plumes from river discharge (the Western Iberia Buoyant Plume-WIBP) and the Iberian Poleward Current (IPC), complemented with ichthyoplankton sampling, a mechanism for retention and concentration of fish eggs and larvae in the NW Iberia is proposed. The IPC and the WIBP introduce important fluctuations in the transport patterns of the region, and modulate the impact of winter upwelling events in the survival of larval fish. Furthermore, the presence of the WIBP allows the growth of phytoplankton biomass and is a suitable environment for larval fish retention and survival.

A Miguel P Santos amsantos@ipimar.pt
Instituto Nacional de Recursos Biológicos (INRB)-IPIMAR
Av. Dr. Alfredo Magalhães Ramalho s/n
1449-006 Lisboa
Portugal

3-15

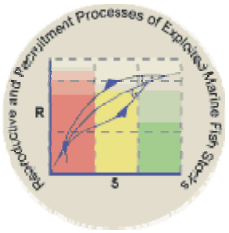
Effects of intra- and inter-annual variability in the prey field on feeding selectivity of larval Atlantic mackerel

Dominique Robert, Martin Castonguay and Louis Fortier

For about a century, the availability of adequate prey during the larval stage of marine fish has been considered a prerequisite for the emergence of a strong year class. Despite the importance of this assumption, field evidence of a relationship between prey density and survival or recruitment has remained elusive. This may be attributable to the generally insufficient taxonomical and temporal resolution in the definition of the effective prey field of fish larvae. The objective of this study was to identify to the lowest taxonomical level possible the preferred prey of Atlantic mackerel (*Scomber scombrus*) larvae from the Magdalen Shallows (Eastern Canada), and assess to what extent feeding selectivity varies within and between years. Mackerel larvae were captured along with their zooplankton prey during four consecutive years (1997-2000). The gut of 556 mackerel larvae was dissected and prey organisms, as well as potential prey found in plankton samples, were identified to the lowest taxonomical level possible. The nauplii of the calanoid copepod *Pseudocalanus* sp. strongly dominated the diet of larvae <7 mm both in terms of numbers and carbon content, while larvae ≥7 mm mainly fed on cladocerans. Piscivory occurred from the first-feeding stage and contributed to a large fraction of gut carbon content for larvae ≥ 7 mm long. Chesson's alpha index revealed strong selectivity in all years for Pseudocalanus sp. nauplii in first-feeding larvae. Selectivity shifted to cladocerans and fish larvae around a body length of 7 mm. Temporal and interannual differences in feeding selectivity mainly concerned alternative prey, during periods of low abundance of the preferred prey. These results underscore the importance of considering the availability of the main prey *Pseudocalanus* sp. nauplii (early larval stage) as well as cladocerans and fish larvae (late larval stage), rather than the entire prey field in the future assessment of the role played by prey availability on larval mackerel vital rates.

Dominique Robert
Québec-Océan
Université Laval
Québec, QC
Canada G1K 7P4

dominique.robert@giroq.ulaval.ca



SESSION 4 – ORAL

Stock Assessment and Management Implications

Session Convenor:

Rick Brodeur

USA

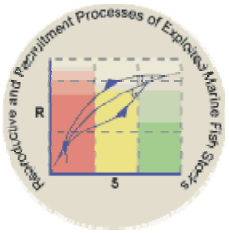
4-1 **Keynote Address**

Integrating reproductive biology into scientific advice for fisheries management

Morgan, M. Joanne

Understanding the reproductive biology of a species is central to providing sound scientific advice for fisheries management. It is reproductive biology that determines productivity and therefore a population's resiliency to exploitation by fisheries or to perturbation caused by other human activities. This paper provides an overview of variation in reproductive characteristics in commercial fish species. It examines the impact on perceived productivity and therefore on advice for fisheries management, of taking such variation into account. Some suggestions for possible future research directions are also given.

Joanne Morgan morganj@dfo-mpo.gc.ca
Science Branch
Dept. of Fisheries and Oceans
P. O. Box 5667
St. John's, NL
Canada A1C 5X1



4-2

Eastern Baltic cod recruitment depends on environment, can scientific advice on fisheries management ignore this ?

Köster, Fritz, Morten Vinther, Brian MacKenzie and Maris Plikshs

The decline of the Eastern Baltic cod from highest to lowest stock levels on record throughout the 1980's and early 1990's was caused by a combination of recruitment failure and increasing fishing pressure at declining stock sizes. The processes driving the reproductive success are largely understood, but the consequences of these changes for fisheries management are far less evident. This includes doubts about the adequacy of the biological reference points presently used by ICES to advice on the stock status, and the need of their revision given that environmental changes have affected the stock productivity. Medium- to long-term projections suggest that under present adverse environmental conditions for reproduction, harvesting at precautionary fishing mortality does not lead to a recovery of the stock to a precautionary biomass level. Thus, a revision of either the limit fishing mortality or the limit biomass reference point is indicated. However, an accepted methodology to determine these reference points in situations of changing stock productivity or carrying system capacity does not exist. In fact, it appears questionable that biomass reference points can be defined in these situations, questioning a cornerstone in the present ICES scientific advisory procedure. Environmental conditions affecting recruitment matter not only for the determination of limit reference points, but according to long-term simulations also for target fishing mortalities, being central part of harvest control rules in several management plans, such as the new multi-annual management plan for Baltic cod stocks adopted recently by the EU commission.

Fritz Köster fwk@difres.dk
Danish Institute for Fisheries Research
Technical University of Denmark
Department of Marine Fisheries
Charlottenlund Castle
DK-2920 Charlottenlund
Denmark

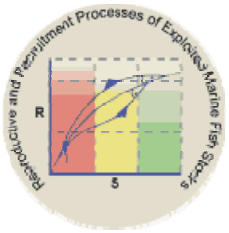
4-3

Evolutionary effects of fishing and marine reserves on size at maturation and movement

Miethe, Tanja, Calvin Dytham and Jon Pitchford

Size-selective fishing mortality may induce evolutionary changes to smaller size at maturation in fish stocks. Marine reserve can be a useful management tool dealing with the ecological and evolutionary effects of fisheries. We examine the effect of size-selective harvesting and the implementation of marine reserves on the evolution of size at maturation using individual-based models. The probability of an individual fish to move between protected and fished area is added as an evolving trait to account for behavioural changes in migration patterns. The results show that with increasing mortality of the largest individuals an evolutionary change from large to small maturation size may occur. This reduces spawning stock biomass and yield. With implementation of a protected area the evolutionary change in maturation size can be prevented inside the reserve leading to higher fish abundance there. Although the probability to move between the areas decreases for fish within the reserve, overall yield increases due to evolutionary effects of the reserve and spill-over.

Tanja Miethe tm518@york.ac.uk
Department of Biology
University of York
PO Box 373
York YO10 5YW
United Kingdom



4-4

Variations in proportions of lethal malformations observed in recently spawned eggs from North East Arctic Cod explained by population parameters

Korsbrekke, Knut, Valeri Makhotin and Per Solemdal

Studies on the frequency of lethal malformation during embryo development have demonstrated a higher mortality in embryos from small/recruit spawners compared to older/repeat spawners, the maternal effect. This phenomenon has been demonstrated in experimental work (Solemdal *et al.* 1998) and is confirmed in this study using field information.

The embryological method was used to study living recently spawned cod eggs during March - April, in the years 2000-2003 at the spawning sites of North East Arctic Cod off Vesterålen – Lofoten in Northern Norway. The frequencies of malformations in cod embryos show large variations between samples (vertical net hauls 0-100 m), but with a very clear downwards trend in the proportions of lethal malformation over the spawning season. The observed proportions shows differences between areas and years and this pattern can to a large extent be explained by the structure of the female spawning population in the different areas. Areas (or years) with a higher proportion repeat spawners, a higher mean length or age corresponds to lower proportions of lethal malformations. Parts of the spawning area are well known as upwelling areas and the hydrographical conditions are quite diverse, but with no apparent effect on the proportions of lethal malformations. Consequences for the estimation of reproductive capacity are discussed together with potential implications for the limit biomass reference point (B_{lim}).

Knut Korsbrekke knut.korsbrekke@imr.no
IMR
Norway

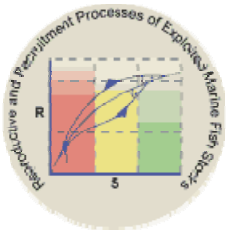
4-5 Keynote

Larval Dispersal and MPAs: Implications of the Distance Between Reproduction and Recruitment for Spatial Management

Louis Botsford

Consideration of explicitly spatial management of fisheries, such as through Marine Protected Areas (MPAs), requires an expansion of our quantitative description of the reproductive/recruitment phase. We need to explicitly consider the fact that these two processes can occur at different locations, and the specific type of density-dependence that occurs at each. To represent population persistence or sustainability, our calculations of lifetime replacement, as in Eggs-per-Recruit or Spawning Potential Ratio needs to be expanded to include replacement through all possible paths. This means that for every location, larval dispersal patterns that begin and end there, as well as lifetime replacement, Lifetime Egg Production (LEP), at other locations reached, become potentially important. Results of spatially explicit replacement calculations indicate that individual MPAs protect species with dispersal distances up to the width of the MPA, and that a network of MPAs covering a certain fraction of the coastline will protect species with all dispersal distances. This means that in any proposed network of MPAs, virtually all of the MPAs will have short distance dispersers persistent in them, while long distance dispersers will persist only where MPAs are clumped densely enough. Fishery yields possible through the use of MPAs are approximately the same as those possible through conventional management, but this depends critically on the whether the density-dependence in recruitment occurs before or after the larval stage, and whether it is intra- or inter-cohort. This approximation implies that the addition of MPAs will not increase yields in well-managed fisheries.

Louis W. Botsford lwbotsford@ucdavis.edu
Department of Wildlife, Fish, and Conservation Biology
University of California
Davis, California
95616 USA



4-6

Estimating Baltic cod (*Gadus morhua* L.) population sizes from egg production

Kraus, Gerd, Hans-Harald Hinrichsen, Rüdiger Voss, Jonna Tomkiewicz, Eske Teschner, Matthias Schaber, Friedrich W. Köster

Eastern Baltic cod (*Gadus morhua callarias* L.) has collapsed due to climate-driven adverse hydrographic conditions and overfishing, remaining on historically low level to date. Due to misreporting of landings, discarding and age reading problems the quality of the VPA-based stock assessments are weak at present. Since 1986, egg surveys have been carried out regularly in the Bornholm Basin, the presently most important spawning ground of Eastern Baltic cod. We use cod egg abundance estimates of the youngest egg stage in combination with information on ambient temperatures to calculate time series of egg production and apply the annual egg production method (AEPM) to estimate cod stock sizes in the Bornholm Basin. In addition, two alternative methods are tested, the daily fecundity reduction method (DFRM) measuring the daily decline in the standing stock of advanced, yolked oocytes and the fraction of females in spawning condition as well as the daily egg production method (DEPM) using batch fecundity and spawning frequency. Although some of the parameters required for the latter method fall back on assumptions, all three methods provided comparable results yielding population numbers in the same order of magnitude. Sensitivity analyses simultaneously varying input parameters up to 20% in both directions indicated that AEPM was especially sensitive towards changes in proportions of mature females, whereas changes in potential fecundity were less influential. Correspondingly, the DFRM was relatively robust against changes in daily fecundity, but especially decreasing the fraction of mature females strongly affected the estimated stock size. Batch fecundity as well as spawning frequency changes affected stock estimates from the DEPM equally with a simultaneous reduction in both parameters exerting a stronger effect than an increase.

Independent estimates from a spatially down-scaled multi-species stock assessment model applying fisheries statistics as well as hydroacoustics targeting the spawning pelagic cod in the Bornholm Basin confirmed the results of the egg production methods.

Gerd Kraus gkr@difres.dk
Technical University of Denmark
Danish Institute for Fisheries Research
Dept. of Marine Ecology and Aquaculture
Kavalergården 6 2920
Charlottenlund
Denmark

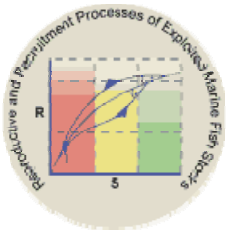
4-7

The influences of maternal age of spawning, recruitment variability, and life-history pattern upon harvest reference points and fisheries management

Spencer, Paul D. and Yasmin Lucero

For some stocks--i.e. Pacific rockfish (genus *Sebastes*) and Atlantic cod (*Gadus morhua*)--there is evidence that larval viability may be reduced for younger spawners, thus potentially complicating stock-recruitment relationships. These maternal effects can be viewed as redefining the units of reproductive output from spawning stock biomass (i.e., eggs) to "viable larvae". For Alaska Pacific ocean perch (*Sebastes alutus*), this redefinition results in estimates of F_{msy} that are similar but slightly reduced from those obtained using spawning stock biomass, and steeper reductions in sustainable yield with fishing rates higher than F_{msy}. We simulated "cod-like" and "rockfish-like" populations to further explore how estimates of management reference points such as F_{msy} may be affected by life-history pattern, recruitment variability, and exploitation. Under high fishing mortality rates the estimated slope at the origin of stock-recruitment curves (defined as "steepness") is generally larger when using viable larvae, rather than eggs, as reproductive output due to the truncation of age structure, reduction of reproductive output, and associating a given set of recruitments to a diminished measure of reproductive output. Use of viable larvae as reproductive output also generally increases estimated steepness when autocorrelated recruitment variability is applied to shorter-lived stocks such as cod. This is due to autocorrelated recruitment affecting the population size of shorter-lived species at a faster rate than longer-lived species such as rockfish, thus increasing the number of observations at low stock sizes and increasing the potential of associating observed recruitments at low stock sizes with diminished reproductive output. Finally, we use a management strategy evaluation to consider the consequences of managing under misspecified management reference points that may result from unrecognized effects of spawner age upon larval viability.

Paul Spencer paul.spencer@noaa.gov
NMFS - Alaska Fisheries Science Center
7600 Sand Point Way NE, Bldg 4
Seattle WA
98115 USA



4-8

Meta-analysis of anchovy egg production parameters

Somarakis, Stylianos, Eudoxia Schismenou and Athanassios Machias

Variability of parameters from worldwide applications of the daily egg production method (DEPM) to anchovy species/stocks is analyzed to highlight potential effects of ecosystem productivity. The California, Humboldt and Benguela current stocks are compared with European stocks (Bay of Biscay and Mediterranean Sea) and recently introduced empirical relationships among DEPM parameters are re-examined based on a larger data set. Spawning frequency estimates are generally much lower in the upwelling areas, which can be explained in terms of lower temperature regimes. Relative fecundity of mature females (eggs g-1) is, on average, significantly lower in the Mediterranean Sea and the daily specific fecundity (number of eggs produced per gram of spawning stock) is higher in the Bay of Biscay. Reproductive parameters are markedly variable in the oligotrophic Mediterranean Sea which has been attributed to the higher dependency of reproductive effort to direct food intake. Significant linear log-log relationships exist between estimates of daily egg production in the spawning ground (number of eggs produced per unit surface area, P0) and the daily specific fecundity (DSF). Also, between the spawning stock biomass (SSB) and the spawning area (SA) The P0-on-DSF and the SSB-on-SA relationships have the same slope for upwelling and European stocks but significantly different intercepts, indicating that, on average, the daily egg production and the SSB per unit surface area are 6 and 9 times higher respectively in the upwelling systems compared to the less productive European Seas.

Stylianos Somarakis somarak@biology.uoc.gr
Department of Biology
University of Crete
Vassilika Vouton
P.O. Box 2208
71409 Heraklion
Crete, Greece

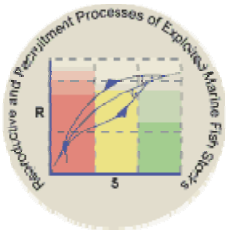
4-9

When recruitment regimes vary, can we still manage North Sea herring in a precautionary manner?

Simmonds, John (FRS), Mark Dickey-Collas (IMARES) and Richard Nash (IMR)

In recent years the recruitment of North Sea herring has declined, despite a large spawning biomass. This has been attributed to environmental change and the decline has the potential to cause serious problems for the sustainable exploitation of the stock. Over the available time series for North Sea herring, the stock to recruit relationship has shown shifts in terms of carrying capacity and productivity. We use medium term simulation techniques to investigate whether changes in carrying capacity, productivity or both are more influential in determining risk to the population due to exploitation both inside and outside a precautionary approach. To illustrate the robustness of this approach the simulations start from both a large "healthy" stock and a small collapsed stock. This study highlights which elements of the stock to recruit relationship are more influential in determining catching potential in either a healthy or overexploited stock. The overall objective of this work is to improve advice when responding to a changing environment, and to illustrate what criteria are most informative when considering precautionary management.

Mark Dickey-Collas mark.dickeycollas@wur.nl
IMARES
Haringkade 1 IJmuiden
P.O. Box 68, 1970 AB IJmuiden
The Netherlands



4-10

Using Life-History Models to Explore Environmental Effects on Stock Reproductive Potential of Several Cod Stocks

O'Brien, L., N. Yaragina ,Y. Lambert, G. Kraus, T. Marshall, G. Marteinsdottir, H. Murua, F. Saborido-Rey, J. Tomkiewicz and P.Wright

Any effect of environment on stock reproductive potential (SRP) will have implications in stock assessment projections of stock biomass and sustainability of commercially important species. Environmental influences on SRP were investigated using the intrinsic rate of population increase *r*, derived from life table analysis, that incorporates characteristics (e.g. growth rate, fecundity, etc.) which are also associated with SRP. Trends in *r* were compared among nine Atlantic cod *Gadus morhua* stocks (Northern Gulf of St. Lawrence, Northeast Arctic, Georges Bank, Gulf of Maine, Baltic, Icelandic, Irish Sea, Flemish Cap, and West of Scotland) with time series varying in length between 22 and 56 years for the time period 1946-2005. Cod west of Scotland had the highest *r* over the observed period while Northern Gulf of St. Lawrence cod had the lowest *r*. Tests for significant differences of mean *r* between stocks indicated five distinct groups, for example, cod from Northern Gulf of St. Lawrence and West of Scotland were significantly different from each other and the other three stock-groups. Stock specific environmental variables, including a global climatic variable (Northwest Atlantic Oscillation) and life history characteristics relative to r were analyzed to further investigate the environmental influences on SRP.

Loretta O'Brien lobrien@whsun1.wh.whoi.edu
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory
166 Water Street
Woods Hole, Massachusetts 02543
USA

4-11

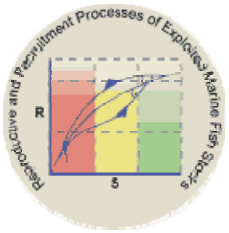
Managing fluctuating populations: what is the value of stock assessment?

Myrseth, Johanna, Øyvind Fiksen and Mikko Heino

Fisheries systems are subject to numerous uncertainties which complicate the management process and decision making. Stock abundance estimates utilized in regulating fisheries are subject to process-, observation- and model uncertainty. An increased effort in stock assessment is generally considered to decrease the uncertainty concerning the population estimate. Large resources are allocated to fish stock assessment, and it is therefore important to investigate how uncertainty in the estimates influences risk (low stock abundance) and long term yield. We have developed an age-structured population model resembling the Norwegian spring-spawning herring. The model contains 16 age classes, and a density-dependent (Beverton-Holt) and stochastic recruitment function. We explore how uncertainty about the stock abundance estimate affects factors like the mean annual yield and the risk of the population falling below a biomass limit reference point (B_{lim}), below which the stock status is considered unfavourable. We also investigate how variability in recruitment (stochasticity) influences the value of more precise abundance estimates. Finally, we study how an inherent tendency of over- or underestimation of spawning stock biomass changes the value of precise population estimates.

Johanna Myrseth
Rosenbergsgaten 6
5015 Bergen
Norway

johanna.myrseth@student.uib.no



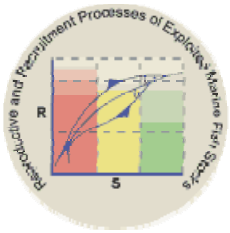
4-12

Reproduction patterns of commercially important flatfishes in Portuguese fisheries: implications for management

Cabral, H. N., C. M. Teixeira and M. I. Batista

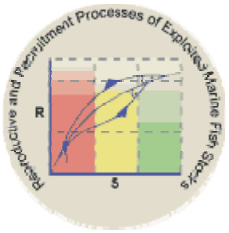
Flatfishes are extremely valuable resources in the Portuguese fisheries accounting for ca. 2% in weight and 10% in value of all landings. Despite their commercial importance, the knowledge on these species is scarce. From 2003 to 2005, seasonal sampling surveys were conducted along the Portuguese coast in order to study the reproduction patterns of the most important flatfish species: *Solea solea*, *Solea senegalensis*, *Solea lascaris*, *Microchirus azevia*, *Platichthys flesus*, *Lepidorhombus boscii* and *Citharus linguatula*. Maturity stages were assigned to each individual based on the macroscopic observation of gonads and the gonadosomatic index determined. Different reproduction patterns were found: *S. solea*, *P. flesus* and *L. boscii* were considered winter spawners; *S. senegalensis*, *S. lascaris* and *M. azevia* presented a wider spawning period, from winter to summer; and *C. linguatula* spawns in summer and autumn. Differences in the beginning and the duration of the reproduction period were found for these species in the Portuguese coast compared to other geographical areas from Northern Europe. For the majority of the species, the highest fisheries landings were recorded in the spawning period, since a behavioral pattern of fish concentration for reproduction is generally observed. The implications for management are discussed and some conservation measures proposed.

Henrique Cabral hcabral@fc.ul.pt
Departamento de Biologia Animal / Instituto de Oceanografia
Faculdade de Ciências da Universidade de Lisboa
Campo Grande, 1749-016
Lisboa, Portugal



SUMMING UP

Keith Brander
ICES


Reproductive and Recruitment Processes of Exploited Marine Fish Stocks
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POSTERS

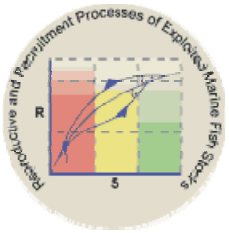
P1-1

Critical timing for reproductive allocation in an over-wintering capital breeder: experimental evidence from sandeels

Boulcott, P. and P.J. Wright

Field investigations of maturation schedules generally consider mature fish size long after the period when they have committed energy to mature. However, the decision to continue gametogenesis through to spawning is taken long before spawning actually happens. This paper presents experimental evidence from sandeels (*Ammodytes marinus*) that illustrates that resource accrual during their major feeding period is more important than size in their 'decision' to mature. To determine the proximate conditions which influence variation in reproductive investment, we recorded somatic growth, sexual maturation and fecundity in individually marked, first time maturing fish reared under ambient conditions. Cytological investigation revealed that the transition in gonad development from primary to secondary stages occurred during their main feeding period between June and August in both sexes. Using logistical regression, variation in maturation could be attributed to observed differences in resource accrual during this period, suggesting that if growth prior to this period is inadequate then maturation is physiologically switched off. For those females that did mature, potential fecundity positively correlated with final body size. The relevance of this work in explaining the large regional variability in maturity at age seen in the field is discussed.

Peter J. Wright P.Wright@marlab.ac.uk
Fisheries Research Services
Marine Laboratory
PO Box 101
375 Victoria Road,
Aberdeen AB11 9DB,
Scotland, United Kingdom



P1-2

Probabilistic maturation reaction norms of sockeye salmon spawning populations of Bristol Bay, Alaska

Kendall, Neala, Mikko Heino and Ulf Dieckmann

Humans can influence life history traits of domesticated and wild animals through selective processes. Fishing is often deliberately size-selective for economic and biological reasons. Size-selective fishing mortality has been associated with directional selection and changes in life history traits such as age and size at maturity. Norms of reaction show the ranges of potential phenotypes, such as different ages and sizes at maturation, that a given genotype could develop if an individual is exposed to different environmental conditions. Selection, due to many causes, may act on age and size at maturation and cause the reaction norm of an individual or population to change in position or shape. Maturation reaction norms may help to disentangle phenotypic plasticity associated with different growth and mortality conditions from genetic effects that influence maturation as a result of reaction norm evolution. Thus, they may reveal changes in maturation schedules associated with size-selective fishing. Bristol Bay, Alaska has some of the most diverse and abundant sockeye salmon (*Oncorhynchus nerka*) populations in the world. A large commercial gillnet fishery has exerted strong, size-selective fishing pressure on these salmon since 1884. I will use fishery catch and escapement and spawning ground data from 1946-present to calculate probabilistic maturation reaction norms (PMRNs) for length and age at maturation of multiple locally adapted sockeye spawning populations of the Wood River system of Bristol Bay. Fish from these populations exhibit different patterns of age and size at maturity, though they rear together in both freshwater and marine environments. While PMRNs have been developed for a number of fish species who spawn multiple times, little work has been done understanding PMRNs for semelparous species, such as Pacific salmon, who spawn only once before dying. With these PMRNs, in the future I can understand changes in sockeye salmon life history traits over time and will evaluate if this fishery selection has the potential to cause life history evolution in the sockeye populations.

Neala Kendall kendalln@u.washington.edu
University of Washington
School of Aquatic and Fishery Sciences
Box 355020
Seattle, WA
98195 USA

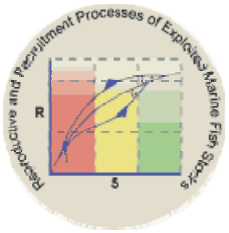
P1-3

Assessing the accuracy of macroscopically assigned maturity stages and the potential for skipped spawning in Northwest Atlantic Greenland halibut (*Reinhardtius hippoglossoides*)

Rideout, R.M., M.J. Morgan, A.M. Cohen and J.H. Banoub

Greenland halibut (*Reinhardtius hippoglossoides*) off Newfoundland and Labrador mature at greater size and age than other populations of this species. The cause of this late maturation has been difficult to ascertain, leading some to question the accuracy of macroscopically assigned maturity stages and raise the possibility of a non-annual maturation cycle. We are currently comparing macroscopically and histologically assigned maturity stages to evaluate the accuracy of maturity assignment. In addition, data are being collected on various histological characters (oocyte size, post-ovulatory follicles, atresia, ovarian wall thickness) as well as blood plasma vitellogenin levels in order to examine the possibility of non-annual spawning within this population of Greenland halibut.

Rick Rideout RideoutR@DFO-MPO.GC.CA
Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
P.O. Box 5667
St. John's, Newfoundland and Labrador
Canada A1C 5X1



P1-4

Spatial and temporal trends in condition of Atlantic cod (*Gadus morhua* L.) on the Icelandic shelf

Pardoe, Heidi, Gudmundur Thórdarson and Guðrún Marteinsdóttir

Interannual (1993 to 2006), spatial and bathymetric trends in the hepatosomatic index (H) of Atlantic cod (*Gadus morhua*) in Icelandic waters were investigated. Generalized additive models (GAMs) were used to test the effects of environmental covariates (latitude, longitude, depth, temperature) on data collected during annual spring (March) groundfish surveys. Individual stomach content data were analysed to assess the relationship between condition and consumption of capelin (*Mallotus villosus*). Liver condition was found to vary with region and depth, most probably as a result of capelin availability. Temperature appeared to act as a proxy for food supply rather than affecting condition directly. Mature cod were found to be in significantly better condition than immature cod of the same age. Such differences were also observed between mature female and male cod. H was found to be a dynamic index of condition. Our results illustrate the importance of investigating potential spatial and temporal variability in metrics such as liver condition when describing the productivity and reproductive potential of a stock.

Heidi Pardoe heidi@hafro.is
Marine Research Institute
Skulagata 4
121 Reykjavik
Iceland

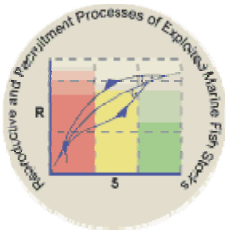
P1-5

Reproductive attributes of three exploited skate species on the Grand Banks and in surrounding Canadian waters

Kulka, D. W., C. Miri and M. Simpson

Skates, primarily thorny skate *Amblyraja radiata* are the target of an international fishery on the Grand Banks off Newfoundland and have only recently come under quota management in the NAFO Regulatory Area. In addition, 14 other species are frequently captured in substantial amounts as bycatch in demersal fisheries off Atlantic Canada. Unlike most teleosts, skates (Rajidae) have very low reproductive potential due to low fecundity and late maturity. This "k-selected" life history strategy results in a low intrinsic rate of population increase making them particularly vulnerable to fishing pressure. While reduction in fishing effort or improved environmental conditions can result in increased survival of offspring, the potential for a large recruitment event or quick recovery from an over-fished state is much lower than in more productive species. In spite of this, knowledge of the reproduction of any of the species off Canada is deficient. This study describes the reproductive processes of three ecologically different species, *Amblyraja radiata* (primarily shelf, widespread), smooth skate *Malacoraja senta* (shelf/trough, forming isolated aggregations) and spinytail skate *Bathyraja spinicauda* (slope), all presently being assessed for risk of extinction in Canada as well as being taken in a targeted fishery and as bycatch. Functional size at maturity, based on internal and external characteristics including clasper length/morphology, degree of coiling in the vas deferentia and gonad structure in males, and nidemental gland, yolk and egg production in females are used to describe reproductive stages. Management implications of the different reproductive strategies are discussed both in terms of commercial exploitation and extinction risk.

Dave Kulka kulkad@dfo-mpo.gc.ca
Fisheries and Oceans
Science, Aquatic Resources
Northwest Atlantic Fisheries Centre
St. John's, Newfoundland & Labrador
Canada A1C 5X1



P1-6

Comparative analysis of reproductive investment of Coastal cod (Gadus morhua) sampled along the Norwegian coast

M. Blom, A. Thorsen and O.S. Kjesbu

The Coastal cod along the long coast of Norway is considered to consist of many local stocks. An intense fishery through many years has led to significantly reduced stock size and recruitment of several of these stocks, which are now IUCN 'red-listed'. This has resulted in an increased focus on stock dynamics including stock-specific reproductive potential studies.

Samples of Coastal cod were sampled at different locations along the Norwegian coast during a two-year period: northern Norway (Lofoten), mid Norway (Verrabotn), western Norway (Bømlo) and south-east Norway (Langesund). Potential fecundity analyses were accomplished by means of the Auto-diametric method (Thorsen & Kjesbu, 2001).

Results indicated that potential fecundity was highest in the northern and mid parts of Norway, i.e., in Lofoten and Verrabotn, respectively, and lowest in southern Norway, in particular for Langesund. Both Fulton's K and hepatosomatic indices indicated a difference between north and south, with its highest value in Lofoten and the lowest in Langesund. The prespawning GSI appeared to be highest in Lofoten, followed by Verrabotn, Bømlo and finally Langesund. The intensity of atresia varied between locations, with a maximum in Verrabotn and a minimum in Bømlo. The prevalence of atresia showed its maximum in Lofoten and Bømlo and its minimum in Verrabotn and Langesund.

Martin Blom martin.blom@hials.no
Ålesund University College
6025 Aalesund
Norway

P1-7

Description and incidence of ovary cysts in two gadoids from the North Atlantic: *Merluccius merluccius* and *Gadus morhua*

Domínguez-Petit, Rosario, Alonso-Fernandez Alexandre and Saborido-Rey Fran

Spawning stock biomass (SSB) has been generally used as an indicator of spawning stock production but it is not exact because there are other factors like size, experience or condition that affect capacity of females to produce viable offspring that may eventually recruit to adult population or fishery. This ability is the Stock Reproductive Potential (SRP). Fish used to resorpt remanents oocytes prior or after batches release by atresia regulating its egg production. In some species oocytes are encapsulated in cystic structure that may remain in the ovary for several months, even years, without being reabsorbed, altering female reproductive potential in next spawning season. In the present work ovaries of Atlantic cod and European hake from Flemish Cap and Galician Shelf respectively, since 1999 to 2006, have been analysed. Prevalence and abundance of ovary cysts have been estimated by stereological methods. Results show a significant increase of cysts incidence with female size and age. Besides, presence of these structures is higher in recent years and it is related with female condition factor (K). Subsequently, influence of size/age structure of SSB, female condition and environmental factors like temperature could be affecting stay of cysts in ovaries which may reduce SRP.

Rosario Domínguez Petit rosario@iim.csic.es
Fisheries Group
Institute of Marine Research (CSIC)
C/Eduardo Cabello, 6. c.p. 36208
Vigo (Pontevedra)
Spain

P1-8

Energy allocation related to spawning season in a temperate fish, *Trisopterus luscus* (Linnaeus, 1758)

Alexandre, Alonso-Fernandez, Dominguez-Petit, Rosario and Saborido-Rey, Fran

Hepatosomatic index (HSI) quantifies seasonal changes in liver mass, principally due to lipid storage variations in relation to vitelogenin synthesis and is usually used as an energetic storage index. However, for reproductive studies purpose, this is relevant only to species for which the liver plays an important role in the energetic accumulation of reserves for gonad maturation. In previous studies, HSI and condition factor (K) changes presented an opposite temporal pattern of gonadosomatic index (GSI), indicating a likely mobilisation of energy reserves from the liver to gonad development during reproductive period. Based on this hypothesis, proximate composition in gonads, muscles and liver was estimated to describe the energy allocation during the spawning season in a temperate gadoid like pouting, *Trisopterus luscus*. Protein content in gonads and muscles, as well as lipid in liver, presented clear trends related to the spawning season. Besides, water content was calculated and high correlations with the main component of the three tissues were found. These results suggest that condition indexes and proximate composition could be good proxies of energy content and nutritional state of the female. This work highlights the need for further research in fish energy allocation mechanisms since they are likely to influence significantly the stock reproductive potential.

Alexandre Alonso-Fernández alex@iim.csic.es
Departament of Marine Ecology and Resources Fisheries unit Institute of Marine Research
CSIC c/ Eduardo Cabello 6
36208 Vigo (Pontevedra)
Spain

P1-9

Addressing the influence of environmental and density-dependence factors on juvenile growth and maturation of anchovy (*E. encrasicolus*)

Reglero, Patricia, Diego Alvarez-Berastegui, Magdalena Iglesias and Ana Giráldez

Juveniles of anchovy, *Engraulis encrasicolus*, inhabit waters of the continental shelf along the Spanish NW Mediterranean. The hydrographical features and the productivity of the nursery areas differ as they are influenced by the water discharge from the Ebra and the Rhone rivers and the existence of a major current from the Gulf of Lion to the Catalan Sea. Anchovy co-occurs with increasing number of other species of small pelagics as it moves southwards which together with the environmental fluctuations may have direct effect in juvenile growth rates and further length at maturity. In this study, we study if fluctuations in the environment and in the species abundances during the juvenile growth of anchovy lead to changes in length at maturation. Juvenile growth of mature and immature anchovy is examined through otolith analyses from research surveys conducted during 2003-2006. The analyses of satellite images provide temporal and spatial trends in the productivity and temperature regimes along the continental shelf during the same periods. The abundance of small pelagic species estimated from acoustic data collected in the research surveys is used as an input to describe density-dependent settings affecting juvenile growth. The study gives an insight of the interaction between the environment and maturation of anchovy within the pelagic fish ecosystem.

Patricia Reglero patricia.reglero@ba.ieo.es
I.E.O.- Centre Oceanogràfic de les Balears
P.O. Box 291
07015 Palma de Mallorca
Spain

P1-10

Size at sexual maturity in females in the introduced red king crab (*Paralithodes camtschaticus*) from Finnmark, Norway

Hjelset, A. M., J. H. Sundet and E. M. Nilssen

The aim of this study was to estimate the 50 % ovgerious length (OL_{50}) of female red king crab (*Paralithodes camtschaticus*) sampled from three fjords of Finnmark, Northern Norway. Morphometric data and egg status from 24,768 females have been analysed in the period 1994 - 2006. Females were defined as sexually mature based on presence of eggs or egg remnants. A logistic model based on the proportion of egg carrying females from 70-150 mm carapace length (CL) was fitted to estimate maturity. The results show variation between years and fjords. Mean OL50 at which female red king crabs were carrying egg was 109.1 ± 0.2 mm CL for a 13 year sampling period in Varangerfjorden. The mean OL50 for 8 and 5 year sampling periods in Tanafjorden and Laksefjorden respectively, were estimated to 109.6 ± 0.3 mm and 111.3 ± 0.6 mm CL. OL50 values are compared to size at maturity estimates from morphological changes. Size distribution for females in the three fjords is presented for every year. Russian scientist introduced the red king crab successfully into the Barents Sea in the period 1960-1969 with the aim to establish a fishery. The red king crab stock has increased in number and extended its distribution since the introduction. The Norwegian fishery started in 1994, and the harvest rate has increased proportionally to the stock growth. Red king crab females in the Barents Sea appear to mature at a larger size than red king crab in its native areas.

Ann Merete Hjelset
P.O. Box 6404
N - 9294 Tromsø
Norway
ann.merete.hjelset@imr.no

P1-11

Age validation of the European plaice (*Pleuronectes platessa* L.) from the Celtic Sea and the North Sea: Using stable delta 18O isotope in otoliths

Sheku, Sei

Accurate age estimation techniques are of crucial importance in fisheries research if the data collected is to support management policies. Apart from classical aging by interpretation of growth zones in fish otoliths, age validation studies can be enhanced by the use of stable isotopes in otoliths. This is useful when studying commercial fish species that are difficult to age with classical methods. The stable isotope approach presented here validates conventional aging of two plaice stocks (*Pleuronectes platessa* L.) from the Celtic Sea and the North Sea. Plaice saggital otolith samples (989 in total) selected for this study were obtained from the archived collection at the Sea Fisheries Department, Oostend, Belgium. Otoliths were sectioned via a labcut machine and ages obtained through image analysis system (AxioVision 3.1) by counting successive opaque and translucent growth bands in the otolith section. A total of 12 otoliths from the band count aging were selected for stable isotope analysis. These samples were analyzed at the stable isotope laboratory at the Department of Geology, Vrije Universiteit Brussel (VUB), Belgium. The Merchantek Micromill device permitted milling of time specific carbonate samples from otolith growth bands (1-3 samples per growth layer). The Kiel carbonate device coupled to the stable isotope mass spectrometer, allowed final analysis of oxygen isotope signals from the carbonate sample aliquots. The seasonal variations of the d18O signals were used to age the otoliths. In most cases, the d18O-aging coincided well with the band count ages except for one otolith from the North Sea, for which band counting produced an age of 8 years while the d18O technique indicated 7 years. This underlines the difficulty in the determination of ages of older fishes. The otolith-derived temperatures are very close to the temperatures in the ambient seawater inhabited by plaice, and have validated the timing of ring formation of the two plaice stocks. Characterizing the opaque zone with higher temperatures and the translucent zone with lower temperatures. Plaice otolith is therefore a faithful recorder of ambient seawater temperature and can be a valuable tool for ecosystem based fisheries management.

Sheku Sei seisheku@yahoo.com
Statistics and Research Unit
Ministry of Fisheries and Marien Resources
Jomo Kenyatta Road
New England, Freetown
Sierra Leone

P1-12

Assessment of the Red Seabream (*Pagellus bogaraveo*) off the Strait of Gibraltar: Sensitivity to the Application of Different Age Length Keys

Gil, J. and DEEPER Team (J.Baro, C. Burgos, J. Canoura, V. Díaz del Río, C. Farias, L. M. Fernández-Salas, Mª. C.Fernández-Puga, T. García, D. Palomino, V. Polonio, J.M. Serna-Quintero, M. Sayago)

Since the early 1980s an artisanal fishery targeted to the red seabream (*Pagellus bogaraveo*, namely "voraz"), have been developing along the Strait of Gibraltar area. Fishing is carried out taking advantage of the turnover of the tides in bottoms from 200 to 400 fathoms. The Instituto Español de Oceanografía (IEO) began the fishery monitoring in 1997, which includes: landings and effort data collection, length frequencies distributions, reproductive and growth studies, location of nursery and recruitment grounds, VPA assessment and projections.

The determination of age was done by observing and analysing whole otoliths (sagitta) from individuals sampling in the year 1998 and annually from 2003 onwards. From agreed readings it was created the respective Age Length Keys (ALKs) to estimate the growth parameters according to the von Bertalanffy equation and also obtain the catches at age matrices (in numbers) required for VPA assessments. The main aim of this work is analyse differences between the results from several assessment attempts of the *P. bogaraveo* of the Strait of Gibraltar.

Differences in von Bertalanffy growth curves and respective ALKs could be verified using Chow test. Several catches at age matrices obtained are consequence of the applying of annual and combined ALKs. In case of no differences between VPA results the use of combined ALKs seems to be more suitable because sampling problems and lack of data could be solved.

Within the DEEPER Project, we're trying to document scientifically the deep habitats of three neighbouring regions: Gulf of Cádiz, Strait of Gibraltar and the Alborán Sea. Thus, later and according to the ecosystem approach, our next goal must be to carry out research work in this area in order to learn more about the structure and workings of the ecosystem and the effect of human activities on it.

Juan Gil Herrera juan.gil@cd.ieo.es
Instituto Español de Oceanografía - Unidad de Cádiz
Institutos de Investigación - CACYTMAR
c/ República Saharaui, s/n.
Campus Universitario de Puerto Real
11510 Puerto Real, Cádiz
Spain

P1-13

The "Red Mullet", *Mullus barbatus* (Teleostei, Mullidae): Biological and fishing aspects (Coasts Atlantic and Mediterranean of the Andalusian littoral) -- Comparison with *M. surmuletus,* "Striped Red Mullet"

García Rebello, J. M., Velasco, E. and Hernanso, J. A

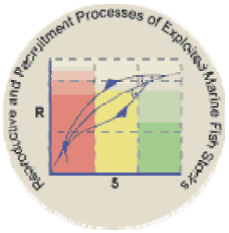
An additional problem to the over-exploitation of fisheries is the joint exploitation and commercialisation of different species that may present different biological characteristics. This is the case of the two species of red mullet, *Mullus barbatus* (L., 1758) and *Mullus surmuletus* (L., 1758), species that are very similar in their morphology and way of life, that appear jointly in the fishing statistics; one of the possible approaches to the monitoring and management of the fisheries should be to obtain more knowledge of their somatic and reproductive growth for the maintenance of the stock.

M. barbatus presents a growth in length and in significantly minor weight that *M. surmuletus* so much in an area as in other one as well as for sexes.

On comparing the structure by ages with that found for *Mullus surmuletus*, all the results indicate that the zone, and the Gulf of Cádiz in particular, is submitted to intense overfishing; the effect of this is that most of the individuals of this species are caught before completing two years of life, and so only very small percentages reach an age of two years, and those reaching three years of age are extremely rare. This symptom of over-exploitation is masked by the captures that are realized on *M. surmuletus* due to the joint exploitation of both species.

The reproductive cycle of both, red mullet and striped red mullet, is described on a macroscopid scale in terms of the GSI and K, and on a microscopid scale in terms of histological changes in the ovary and changes in the oocyte size frequency distribution. *Mullus barbatus* has its maturity and spawning season during spring and summer. In *Mullus surmuletus* maturity period would start in late winter, showing a maximum spawning in June.

José Miguel García Rebollo jmgarcia.rebollo@uca.es
University of Cádiz
Spain



P1-14

The analysis of age composition and growth of Greenland halibut *Reinhardtius hippoglossoides* of the Norwegian-Barents Sea population for the purposes of stock management

Kuznetsova, Elena N. and Mikhail V. Bondarenko

The comparison of age composition and growth rate of Greenland halibut for the Norwegian-Barents Sea population in the current period and the 1960s was made (before the beginning of the intensive fishery on this species).

The results of determination of Greenland halibut by otoliths and scale for fish with length of 60 cm (age of 12-13+ years) were similar. In assessments by scale there was an underestimation of fish age older than 13+ years.

The linear and weight growth of males and females of Greenland halibut was similar up to 8 years inclusively. For the older age the growth rate of females was slightly higher. The highest rate of the linear growth for halibut was observed up to 5 years. The relationship between age and length of Greenland halibut is close to linear. The coefficient of correlation for these parameters was 0.98. The rate of weight growth was relatively low up to 9-10 years. Since that when the larger part of males was withdrawn from the stock, the rate of weight growth increased.

The comparative analysis of the Greenland halibut growth in the present period and its growth in the 1960s showed the higher linear growth for the younger age groups in the former that indicated on the lower density. The mean age of Greenland halibut in the current trawl catches has been also essentially lower than during the 1960s.

Mikhail V. Bondarenko bondarenko@vniro.ru
Early Life History Laboratory
VNIRO
V. Krasnoselskaya 17
107140 Moscow
Russia

P1-15

Minimum Size at Sexual Maturation of Mediterranean Swordfish Stock (*Xiphias Gladius*): A Comparison With North Atlantic Swordfish Stock

Macías, D., Lema, L., Gómez-Vives, M.J., Ortiz de Urbina J.M. and de la Serna J.M.

Swordfish (*Xiphias gladius* L.) is a large, highly migratory mesopelagic species widely distributed in Mediterranean Sea and Atlantic Ocean. Genetic studies suggest that Mediterranean swordfish form a distinct stock, being reproductively isolated from the Atlantic stock. According to our results, every Mediterranean Swordfish female over 160 cm is sexually mature. The first maturity size (L_{50}) was estimated in 138 cm using GLM. All female smaller than 125 cm LJFL were sexually immature. Previous studies in Mediterranean swordfish reported mature female as small as 110 cm LJFL and the size at first maturity (L_{50}) was estimated in 142 cm. All these result are very similar and differ from those reported for the North Atlantic stock (L_{50} = 182 cm.).

A research cruise on board commercial fishing vessels was carried out from July to December 2005 in the Western Mediterranean. A total of 712 adult swordfish female with fork length ranging from 64 to 223 cm were sampled to study its reproductive biology. In addition to L_{50}, information on spawning period, ground (areas) and pattern based on development stages of gonads and gonadosomatic index, were also obtained from the histological analysis of ovaries. Developmental characteristics of oocyte maturation of swordfish are similar to those described for other species with asynchronous development. These results strongly support the hypothesis of a distinct reproductive pattern of Mediterranean swordfish that differ from those reported for Atlantic and Pacific stocks.

David Macías
C.O. de Málaga (IEO)
Pto. Pesquero s/n
aptdo: 285
29640 Fuengirola
Málaga, Spain

david.macias@ma.ieo.es

P1-16

Reproductive characterization of the Mediterranean Stock of albacore (*Thunnus alalunga*, Bonaterre 1788)

Macías, D., Lema, L., Gómez-Vives, M.J., Ortiz de Urbina J.M. and de la Serna J.M.

The estimated size at maturity of Mediterranean Albacore was very similar in both sexes: female reach L50 at 56.5 cm FL and male at 56 cm FL. Significant differences has not been found between albacore caught in 2004 and 2005.

A research cruise on board sport fishing vessels took place from July to September 2004 and 2005 in the Western Mediterranean. A total of 215 adult albacore (*Thunnus alalunga*, Bonaterre 1788) with a fork length ranging from 31 cm to 96 cm were sampled to study its reproductive biology. Information on spawning period, ground (areas) and pattern based on development stages of gonads and gonadosomatic index, were obtained from the histological analysis of gonads. In addition, information about maturity was used to assess size at maturity. Male albacore caught in western Mediterranean in the first fortnight of July were in active pre-spawning stage and the specimens caught in the second fortnight of July were spawning. Female albacore caught in the first fortnight were in active pre-spawning ripening stage, while the female caught in the second fortnight of July were fully ripe or spawning. All Albacore specimens caught in September were in mature post-spawning stage.

Laura Lema Varea – presented by colleague??? laura.lema@ma.ieo.es
C.O. de Málaga (IEO)
Pto. Pesquero s/n
aptdo: 285
29640 Fuengirola
Málaga, Spain

P1-17

Time - space reproductive differences of black hakes, *M. polli* and *M. senegalensis* off the NW African coast

Fernández, Lourdes, César Meiners and Francisca Salmerón

Black hakes from NW Africa include two hake species, *Merluccius senegalensis* and *M. polli* as in other hake stocks in other parts of the world. Both species are form part of commercial fisheries, especially by trawl fleets and to a minor degree by longlines in the area between Sahara and Senegal, primarily in Mauritanian waters. Due to their great resemblance and to their distribution overlap, both species are mixed in the landings and recorded in the fishery statistics as *Merluccius* spp. Geo-referenced data on maturity and development of gonads by weight of the two species from onboard scientific observations and from trawl and longline surveys carried out in 2003 and 2006 are analyzed in this work. Certain areas and depths are identified as probable spawning grounds together with their detected interannual variability and the predominating hydrographic conditions. Although both species inhabit intermediate depths (200-400 m), the distribution of the species is depth-dependent, in which *M. senegalensis* spreads over shallower waters while *M. polli* live in deeper waters. Nonetheless, a slight overlap of mature specimens of both species is observed. Both species show latitudinal and bathymetric migrations linked to cold water mass movements. During summer, the species are almost absent in the waters of Senegal while their abundance increase in the Mauritanian fishing grounds. In winter, the species concentrate further south, especially in the Senegalese waters. The fraction of specimens showing peak spawning activity is not too high but it may be caused by the inaccessibility of the species to the trawl and longline gear. Nevertheless, there are some indications as to their spawning potential. The observed bathymetric in the mature specimens of both species are related to their habitats and do not hinder considering the black hake fishery as a single-species entity for stock assessment and management purposes.

Lourdes Fernández Peralta lourdes.fernandez@ma.ieo.es
IEO
Málaga Spain

P1-18

Maturity of blue hake, *Antimora rostrata*, along the mid-Atlantic Ridge

Stene, Anne and Agnes Christine Gundersen

The maturity of *Antimora rostrata* distributed on the mid Atlantic Ridge (MAR ECO project in 2004) was determined visually, microscopically and histologically. Samples were collected in august. Females became more mature the further north samples were collected along the ridge. The most mature fishes had ovaries with very homogenous oocytes with respect to size. Little difference in oocyte size within a lobe was found. Females in maturing condition (stage 3) had oocytes with a diameter range from 700 - 1100 um. This might indicate only one spawning event in the autumn. Of the ovaries fixed, only 15 in maturity stage 2 (early maturing) and 3 (maturing) were possible to use for fecundity counting's. The potential fecundity ranged from 1 200 000 to 2 400 000 eggs pr female. *Antimora rostrata* belongs to the, genus Antimora with only to species represented. There are few comprehensive data on reproduction of this specie. The samples from the Mid Atlantic ridge therefore represent an important contribution to the understanding of reproduction of this specie.

Anne Stene aste@hials.no
Aalesund University College
N-6025
Ålesund, Norway

P1-19

Size at Maturity of Southern Hake Stock (ICES Div VIIIc and IXa)

Morgado, C., C. Chaves, E. Jardim, F. Cardador and C. Piñeiro

European hake shows a sexual dimorphism in growth and size at maturity (Piñeiro and Sainza, 2003). This work analyses the historic trends in size at maturity of males and females. Males' size at maturity is smaller than females. Data used are from the same used to estimate combined maturity ogives used in stock assessment (ICES, 2006) collected in surveys and commercial landings during the spawning season, from 1982 to 2006. Female's size at maturity is constant from the whole period, while males show that the size at first maturity had decreased.

Cristina Morgado
IPIMAR - DRM
Av. Brasilia,
1490-006 Lisbon
Portugal

cmorgado@ipimar.pt

P1-20

Age at 50% maturity and age structure as indicators of stock status of the Namibian horse mackerel *Trachurus trachurus capensis* stock

Wilhelm, M.R.

An alarming decrease of age at 50% maturity (a_{50}), from 4.5 to 1.5 years in the last 30 years, has been observed in the Namibian horse mackerel *Trachurus trachurus capensis* stock. In addition, the mean age has been decreasing drastically, indicating an increasing total mortality. These are clear signs over-exploitation, although this is not as clearly observed in the stock assessment performed on Namibian horse mackerel. A_{50} as well as the observed size structure of the stock (total mortality rate) should therefore be used as additional indicator- and limit reference points in the recovery plan for the stock.

The horse mackerel fishery consists of a mid-water trawler fleet and a purse-seine (pelagic) fleet and is the largest fishery (in volume) in Namibia. The stock is monitored by catches and length-frequencies of both fleets, and catch-per-unit-effort of the mid-water fleet. Annual acoustic biomass surveys serve as fisheries-independent indicators of stock abundance. The stock is assessed using an age-structured production model and managed by an annual total allowable catch (TAC).

Length at 50% maturity (L_{50}) for horse mackerel was 16.6cm (total length) in March 2007, calculated from survey data. This length translates to an a_{50} of about 1.5 years (calculated at 1.6 years from 2004 age data). Mean L_{50} from survey data from 1999 to 2005 was 20.1cm (2.5 years). A serious decrease in L_{50} as well as the mean age of the stock was already noticed when L_{50} decreased from 26.9cm (4.5 years) in 1977/78 to 23.5cm (3.5 years) in 1983.

Margit Wilhelm mwilhelm@mfmr.gov.na
National Marine Information and Research Centre
Ministry of Fisheries and Marine Resources
PO Box 912, Swakopmund
Namibia

P1-21

Influence of Growth on Maturity in Haddock (*Melanogrammus aeglefinus*)

Einarsdóttir, Sólveig Krista, Guðmundur Jóhann Óskarsson, Guðmundur Þórðarson, Gunnar Stefánsson and Guðrún Marteinsdóttir

Knowledge on the age at which fish become sexually mature and on the factors which determine this age within stocks is needed for management in order to avoid incorrect estimation of spawning stocks biomass. Growth rate is generally accepted as an important factor in the onset of maturity and a common response to a change that increases the growth rate of the fish is a decrease in the age of maturity. In this study we test the hypothesis whether a haddock that grows fast is more likely to mature earlier than a haddock with a slow growth rate. The state of maturity was determined from histological examination of gonads from haddock collected in early stages of maturity. Gonads were classified according to the presence of semi nuclear rings and cortical alveolus stages in the ovary. The presence of these stages give an indication of maturation but the appearance of cortical alveoli indicates that the oocytes will normally continue their development through the remaining stages within the current breeding season. Growth estimation was based on width of annual growth rings in otoliths. Overall, gonad status was estimated for 156 females of different lengths and ages from fifteen sampling areas south of Iceland in the autumn 2004. The results will be discussed in relation to growth and maturity status of fish of various condition, size and ages.

Sólveig Krista Einarsdóttir ske@hi.is
Institute of Biology
Askja, Sturlugata 7
101 Reykjavík
Iceland

P 1-22

Size at sexual maturity of male and female South African hakes, *Merluccius capensis* and *M. paradoxus*

Osborne, Renée Felicia, Yolanda Melo and Luyanda Anthony

The length at maturity for *Merluccius capensis* and *M. paradoxus* males and females was last estimated in 1991 from data collected from 1985 to 1990 during the tri-annual hake biomass surveys. The main criticism of this study was that the maturity analyses were based on macroscopic assessments that were not verified by a microscopic (histological) assessment of the male and female gonads. A recent histological assessment of the accuracy of macroscopic maturity staging of hake has shown that a high degree of error exists in all stages of classification. In addition, it is known that maturation parameters of marine resources may change in response to changes in abundance. Many years have elapsed since the maturity assessment, and in this time, there have been important changes in fishing pressure. Exploitation by longlining and handlining, with its significant selection of larger fish, was allowed in addition to trawling. The ensuing lucrative export market for large, whole hake caused a shift in fishing practice, with trawlers, longliners and handliners actively targeting large fish for a number of years. The general theory is that this targeting strategy has resulted in a reduction of the spawning population of hake. Therefore, new maturity ogives would need to be generated from histological analyses of *Merluccius capensis* and *M. paradoxus* gonads. It is also of interest to ascertain whether or not the estimates of hake maturity have changed in response to the increased fishing pressure on what is believed to be the most fecund part of the population.

Renée F. Osborne Rosborne@deat.gov.za
Department of Environmental Affairs and Tourism Branch
Marine and Coastal Management
Private Bag X2 Rogge Bay,
8012 Cape Town
South Africa

P1-23

Sexual maturity cycle and spawning of Greenland halibut, *R. hippoglossoides* Walbum, in the Davis Strait

Gundersen, Agnes C., Claus Stenberg, Inge Fossen, Bjarne Lyberth, Ole A. Jørgensen and Jesper Boje

Female sexual maturation cycle and identification of main spawning time of Greenland halibut (*Reinhardtius hippoglossoides*, Walbum) in the Davis Strait was studied through regularly collected samples during one year starting in spring 2003. Samples were collected from the southern slope of the Davis Strait Ridge between Canada and Greenland in the depth range 1000-1500m. Female sexual maturation was described using different approaches; gonadosomatic index, visual macroscopic maturity stage index, histological microscopic maturity index, and oocyte diameter measurements. A significant increase in gonadosomatic index was seen from September onwards February with a maximum estimated value of 18%. Proportion of mature fish increased in December - March. At the same time the proportion of females with low gonadosomatic index also increased in February - indicating that spawning had occurred and females were recovering. Oocyte diameter distribution revealed a leading cohort developing during autumn towards December - February. A coupling between sexual maturity and fish condition was seen for females in maturing condition indicating a steadily build up of energy storage in liver from June to November.

Agnes Chr. Gundersen agnes@mfaa.no
Moere Research
Aalesund
P. O. Box 5072, Larsgaarden
N-6021 Aalesund
Norway

P1-24

Gonadal maturation of herring (*Clupea harengus* L.) assessed by histological and macroscopic characteristics

Bucholtz, Rikke Hagstrøm, Jonna Tomkiewicz and Jørgen Dalskov

Gonads from herring (*Clupea harengus*) from the Baltic Sea were sampled in November (126 individuals), March (127 individuals) and May (66 individuals) during 2004-6 with the purpose to improve maturity staging of female and male herring. Sampling was conducted on research surveys or caught on the spawning ground by a fisherman. The female and male herring were sampled immediately after landing using a length-based random sampling design. Ovaries and testes were weighed and photographed together with the individual fish and samples of oocytes from the fresh ovary tissue were photographed under microscope. Afterwards, the gonads were preserved in formalin for processing and histological examination in the laboratory. Histological maturity stages were defined based on microscopic characteristics of oocyte and spermatocytes in the processed tissue and an illustrated histological maturity manual was established based stages gametocyte characteristics. Macroscopic characteristics and stages were established using the photographs of the histologically classified gonads, and an illustrated manual for visual determination of maturity class was elaborated. The manual also applies GSI and photographs of the fresh ovary tissue to assist the determination. The aim of the illustrated manual considering macroscopic and microscopic criteria is to improve the quality of herring maturity determination and thereby the estimation of the spawning stock biomass applied in stock assessment and management. The manual will also be useful enhancing estimates of egg production in studies of reproductive potential of herring populations.

Rikke Hagstrøm Bucholtz rhb@difres.dk
Technical University of Denmark
Danish Institute for Fisheries Research
Department of Marine Ecology and Aquaculture
Kavalergården 6
2920 Charlottenlund
Denmark

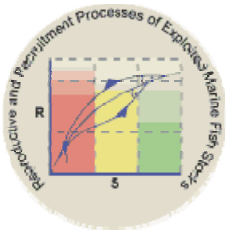
P1-25

Fecundity and growth-dependent mortality of Pacific anchovy (*Engraulis japonicus*): application of size-based theory

Sukgeun, Jung, Sun Do Hwang, Joo Il Kim, Young-Il Seo, Jin-Yeong Kim

To estimate size-dependent fecundity, growth and mortality of Pacific anchovy (*Engraulis japonicus*), the most abundant fish species in coastal waters off the Korean peninsula, we undertook a synthesis of results from past studies. Assuming that the growth coefficient k varies with water temperature, we derived a modified von Bertalanffy growth equation covering all life stages. Fraction of mature females spawning per day ranged from 0 to 0.32 and estimated mean total batch-spawning per female during the spawning period from March to September was 35. Preliminary estimate of mean egg number spawned by a female, based on the relationship between batch fecundity and body weight, was 157 x 103 yr-1. Accepting the 'bigger-is-better' hypothesis, we derived a theoretical mortality curve that assumes instantaneous natural mortality as an inverse function of anchovy body length. Assuming equilibrium status of stock, estimated annual instantaneous mortality of age-0 anchovy was 11.3 yr-1 and estimated size-specific mortality was 1.22 d-1 mm-1. Our theoretical mortality curve fit well the stage-specific mortalities, which were estimated based on ichthyoplankton surveys and catch data from commercial nets, but underestimated the egg mortality (0.89 and 0.82 d-1).

Jung Sukgeun sukgeun.jung@gmail.com
National Fisheries Research and Development Institute
South Korea



P1-26

Determination of size at first sexual maturation in Flemish Cap cod (*Gadus morhua*) using the otolith-fish size allometric relation

Pérez Rodríguez, Alfonso

A progressive decrease in fish age and size at maturity has been observed in many fish stokc during the last decades, as in Flemish Cap cod (*Gadus morhua*). Fishing is considered as the main cause in this process because of its size selective capacity and changes that produce in the ecosystem structure. The earlier sexual maturation combined with the decrease in the abundance of older mature cod have induced a decline in the mean spawning stock age and size affecting to the stock reproductive potential through a decrease in fecundity, offspring quality and survivorship chances, affecting population status recovery.It is necessary to understand the reasons behind these changes to design better management strategies. To estimate size and age at maturity is, thus, critical in the fisheries management. However, the estimation of this parameters requires the collection of ovaries and it is not possible to estimate in historical data. Otoliths, however, have been collected in regular basis in most of the assessed fish stocks. In this paper a modified method of Bervian *et al*, 2006, is applied to Femish cap cod. The variable allometric coefficient introduced in the classical allometric equation, allowed us to detect key period in the fish life history, such as the maturation proccess.Female size at maturity in Flemish Cap cod obtained with this methodology for the 1990-1997 period was highly correlated (r= 0.93) with the L_{50} values determined histologically from ovaries collected during the same period. Apart from low cost and reasonably time consuming, this method, opposite to others, would permit us to know the evolution in size at maturation over the past years, by means of use the available otoliths in long time series. It could be very useful to clarify the responsible factors of the early maturation process, via compensatory response and/or genotypic frequency variation. In the future, this method could collaborate in a more effective management together with other methodologies such the reproductive potential concept in the ecosystem approach view.

Alfonso Pérez Rodríguez fonsilei@iim.csic.es
Instituto de Investigaciones Marinas (CSIC)
Vigo (Pontevedra)
Spain

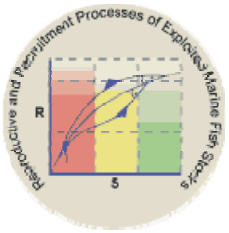
P1-27

Effect of body size, condition and growth on sexual maturation of Japanese flounder *Paralichthys olivaceus* off the Pacific coast of northern Japan

Yoneda, Michio, Yutaka Kurita, Daiji Kitagawa and Masaki Ito

The timing of sexual maturation can be largely affected by growth rates and energy storage during the pre-spawning season. However, the mechanism of the onset of sexual maturation in some fish species may differ between sexes, as males generally mature at a younger age and grow to a smaller size than females. We examined the effect of body size, condition and growth rates on sexual maturation of male and female Japanese flounder off the Pacific coast of northern Japan. Male flounder in these waters matured sexually at age 2 years. Total length during the spawning season and growth rates during the juvenile stages had significant influence on the probability of being mature of males. However, the growth rates explained a higher proportion of the variation than the body size. Spatial variation in the influence of growth rates on the probability of being mature was also found, as in 2-year-old males growing at similar levels during the juvenile stages northern fishes less mature than southern fishes. There was no significant effect of body condition during the spawni ng season on maturation of males. Females started maturation at age 2 years and the majority matured at age 4 years. In females at age 2 years faster-growing cohort showed a higher probability of being mature than slower-growing cohort. However, in females at age 3 years the combination of body size and liver condition during the spawning season explained a higher proportion of the maturation variability than the growth rates during the juvenile stages. This study showed the spatial and sex-specific variation in the influence of sexual maturation of Japanese flounder off the Pacific coast of northern Japan.

Michio Yoneda myoneda@fra.affrc.go.jp
Tohoku National Fisheries Research Institute
Shinhama, Shiogama 985-0001
Japan



P2-1

Relative fecundity of Atlantic cod (*Gadus morhua*) on Georges Bank and in the Gulf of Maine: using new methods for an old problem

Klibansky, Nikolai and Francis Juanes

The once massive cod stocks on Georges Bank and in the Gulf of Maine are now at near record lows and are not recovering well. Information regarding reproductive potential of these stocks is very valuable to their recovery. Despite the importance of these data, our study is the first to estimate relative fecundity for Atlantic cod in the Gulf of Maine for over 120 years, and is only the second study to ever estimate fecundity for Georges Bank cod. We used a low-cost age but ctive digital method to count and measure eggs. We found that the average Gulf of Maine cod produced more eggs per gram of body weight than Georges Bank cod. Using stepwise-selection to choose a model that best predicts fecundity based on physical characteristics of the fish, we found that somatic weight alone explained 87% of the total variation, when specimens were pooled. A model including total length and liver weight (an index of condition) only explained 83% of the total variation. Mean egg size increased with body size for both stocks. Our results will be valuable to managers estimating the reproductive potential of these stocks.

Francis Juanes
Department of Natural Resources Conservation
University of Massachusetts
Amherst, MA
01003-4210 USA

juanes@forwild.umass.edu

P2-2

The paternal contribution to the 'Stock Reproductive Potential' of North-East Arctic cod (*Gadus morhua*): are males important?

Nash, Richard D.M., Olav S. Kjesbu, Edward A. Trippel, Audrey J. Geffen & Heidi Finden

Over the years there has been a growing interest in determining the real stock reproductive potential (SRP) as a means of understanding the dynamics of a fish population. For the purposes of assessment the spawning stock biomass (SSB) is generally used, however, this is not a good descriptor for process types of population modelling. In general, the focus in SRP studies has, with a few notable exceptions, been on female fecundity and realised egg production. In North-east Arctic cod, potential egg production for the stock, over the years 1946 to 2005 has been estimated. In this paper we present preliminary data on the total viable sperm production, estimated for the same years. There have been large changes in the total sperm production, which to a certain extent reflects changes in the mature biomass of the stock. Since 1946 there have also been changes in mean length of mature males and females with a tendency toward smaller fish in the most recent time period. With the relatively large decline in mean size of mature females and the tendency to mature at a smaller size in the latter years the mature fish of both sexes are now of a similar mean size. The relationship between mean size of mature males and females is substantially different than when the stock was large in the early part of the time series. This could have implications for fertilisation success, a factor that is dependent on the dynamics of both sexes.

Richard D. M. Nash richard.nash@imr.no
Institute of Marine Research
PO Box 1870 Nordnes
5817 Bergen
Norway

P2-3

Long-term variability in maturation and fecundity of North Sea haddock and its implications to egg production

Wright, P.J. and I. M. Gibb

The use of spawning stock biomass as a proxy for egg production has been criticised in recent years due to known size, age and condition effects on fecundity and the importance of atresia. In addition, for many ICES stocks a constant maturity at age key is applied to estimate SSB. In the present study, annual sex stratified maturity-length ogives were calculated by logistic regression using data from ICES IBTS surveys. Mature female biomass was found to vary by up to 67% for a given spawning stock biomass. Observed maturity at age data were then combined with annually derived relative fecundity at age data for seven years (1976, 1977, 1978, 1985, 1996 1999 and 2007), in order to derive estimates of stock egg production. For the seven year data set, annual variations in mature female biomass differed from SSB by 37% whilst egg production per SSB varied by 76%. The differences in egg production per SSB arose because of age-specific and inter-annual variability in relative fecundity. Investigations of pre-ovulatory atresia over 4 years suggested that oocyte resorption would not have led to a significant reduction in the number of oocytes released following the onset of spawning. Hence, realised fecundity should have been similar to relative fecundity measured just prior to the onset of spawning in this deterministic serial spawning species. The importance of age to relative fecundity does mean that it should be possible to forecast some of the annual variability in egg production from projections of stock age structure alone.

Peter J. Wright P.Wright@marlab.ac.uk
Fisheries Research Services
Marine Laboratory
PO Box 101
375 Victoria Road
Aberdeen AB11 9DB
Scotland, United Kingdom

P2-4

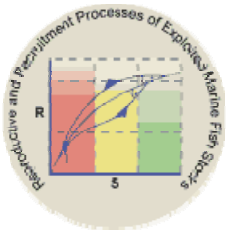
Spatial gradients in fat content of North Sea herring (*Clupea harengus*)

Davidson, Deborah, Christoph Konrad and C. Tara Marshall

The North Sea is a spatially heterogenous environment with respect to factors such as temperature, salinity, and plankton distribution. Due to these spatial gradients in extrinsic factors, it might be expected that similar clines exist in the biological characteristics of species at higher trophic levels. For example, the fat content of higher species might co-vary with any spatial variation in food abundance. Differences in fat content can also led to differences in various life history traits such as fecundity and maturation. In order to determine whether there was any spatial gradient in fat content present in the North Sea herring stock, the Distell fish fatmeter was used onboard the 2006 and 2007 ICES herring acoustic survey to generate fat content estimates of individual herring. Ordinary kriging was used on the data collected to generate a FATMAP (a visual representation of the spatial variation in fat content) of herring in different stages of maturity. There was a strong increasing gradient from south east to north west in both fat content and length of immature herring. When the covariation between the two was taken into account, the south east to north west gradient in fat content was still present. We hypothesise that the spatial gradient in fat content of immature herring may be caused by a combination of spatial changes in herring life history traits such as spawning time, temperature, and zooplankton abundance and assemblage.

Deborah Davidson
School of Biological Sciences
Zoology Building
Tillydrone Avenue
University of Aberdeen
Aberdeen, AB24 2TZ
Scotland

deborah.davidson@abdn.ac.uk



P2-5

Reproductive potential of multiparous female Tanner crab, *Chionoecetes bairdi*, mating or fertilizing eggs with stored sperm

Webb, J. B.

The ability of some crab species to fertilize successive clutches using sperm stored sperm is assumed to provide resiliency in population reproductive output for commercially exploited crab stocks with male-only harvest restrictions and complex mating behavior which may limit female mating opportunities on variable spatiotemporal scales. Contrasting results have been reported for the reproductive success of multiparous female Tanner crab (*Chionoecetes bairdi*) relying on stored sperm for fertilization. In this study multiparous female Tanner crab were collected and held in the lab in the absence of males through hatching and extrusion of a subsequent clutch or collected after hatching, mating, and extrusion in situ in Glacier Bay, Alaska an area closed to commercial fishing. Mean post-extrusion spermathecal load and sperm cell counts increased significantly ($p<0.05$) from 0.21 to 0.44 g and 2.00×10^7 to 9.35×10^7, respectively, between unmated and mated females. Both groups of females extruded clutches of normally developing, viable eggs (>99%), but a significant reduction in fecundity was observed for unmated females. Due to decreased sperm viability with increasing storage time and reduced fecundity, mating of multiparous females is likely to be important for maintenance of reproductive potential in this species. For fisheries management purposes monitoring of sperm reserves and egg production in exploited crab stocks may be valuable for understanding natural variability in reproductive potential and detection of recruitment overfishing.

Joel Webb joel.webb@alaska.gov
Alaska Department of Fish and Game
Comm. Fish. Div., Shellfish Research
PO Box 115526
Juneau, AK
99801-5526 USA

P2-6

Estimates of post-ovulatory follicle persistence time in Atka mackerel, *Pleurogrammous monopterygius*

Cooper, Daniel and Susanne McDermott

Post-ovulatory follicles (POFs) are structures formed within ovaries when ova are released for spawning. They are used as indicators of spawning in maturity, fecundity, and other reproductive studies. It is important to understand the reabsorption rate of POFs if they are used to differentiate spent from immature females. The duration of time that POFs remain identifiable in Atka mackerel, *Pleurogrammus monopterygius*, ovaries was indirectly estimated using two methods. In one method, POFs were classified into stages of degeneration. At least three stages of POFs were present in some ovaries. Using previous estimates of the time interval between batch spawning events, POFs were estimated to persist at least two to four weeks. In another method, population spawning dates and POF presence were compared. POFs were estimated to persist at least 30 days using this method. Estimates of POF persistence time from other studies are compared by latitude. Longer POF persistence times may be common in cold-water fishes which would enable sampling for maturity from expanded time periods. This is important in many remote, high latitude areas where sampling is costly and may be possible only during scheduled research cruises or temporally limited commercial fishing seasons.

Dan Cooper dan.cooper@noaa.gov
National Marine Fisheries Service
Alaska Fisheries Science Center
Alaska, USA

P2-7

Fecundity of Greenland halibut (*Reinhardtius hippoglossoides* W.) in the waters of Iceland

Gundersen, Agnes Christine and Einar Hjørleifsson

Greenland halibut (*Reinhardtius hippoglossoides* W.) in Icelandic waters are treated as a management unit along with Greenland halibut in the waters of East Greenland and Faroe Islands. Observations on Greenland halibut spawning in Icelandic waters were reported in the late 1970-ies, and since then spawning in Icelandic waters has been considered as a major contributor of recruits to the mentioned management unit. In October 1998 a study on fecundity on Greenland halibut in Icelandic waters was conducted. Data on gonad and liver weight were collected along with fecundity samples. Potential fecundity was in the range 8 000 to 152 000 oocytes for fish sized 57 to 99 cm total length. Fecundity (1000) - length relationship was F = 1.942 * 10-6 L3.93 (N=47). Confidence interval of parameter estimates as determined by bootstrapping showed that median bootstrap estimates are the same as those estimated by linear regression, indicating no bias in parameter estimation. The Icelandic fecundity relationship was in the same range as similar estimates for the Barents Sea. It seems, however, that Icelandic Greenland halibut may produce fewer eggs than Greenland halibut in East Greenland, and more eggs than Greenland halibut in Faroe Islands and West-Greenland.

Agnes Christine Gundersen agnes@mfaa.no
Moere Research, Aalesund
P. O. Box 5072
Larsgaarden
N-6021 Aalesund
Norway

P2-8

Evolution of fecundity along the spawning period for European Hake (*Merluccius merluccius*)

Gonçalves, P.; Morgado, C.; Chaves, C.; Cardador, F.; Jardim, E.

The European Hake is an indeterminate spawner, with females spawning all year.

However, the main spawning period is identified between January and March.

In fishes showing indeterminate fecundity, the potential annual fecundity is not fixed prior the onset of spawning, the production of pre-vitellogenic oocytes occurs in a continuous series of shorter cycles during the spawning season. Being the annual fecundity seasonally indeterminate the batch fecundity is the only useful measurement.

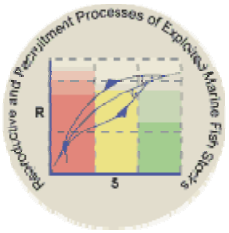
This study intends to contribute to a deep knowledge of the mean batch fecundity and its relation with the spawning stock biomass (SSB) for the Hake Southern stock (ICES div. VIIIc and IXa). Data collected during several years (2003 - 2006) on autumn (before the main spawning season) and winter (inside the main spawning season) surveys was analyzed.

Mean batch fecundity analyzed increases from autumn to the peak of the spawning season.

These results were compared with females SSB estimates for each surveys. SSB estimates are higher in March once all adults are active for reproduction.

Outside the spawning season some adults that are already mature are inactive and macroscopically classified as immature, not contributing to the spawning biomass estimates. Also, new recruits for maturation tend to start spawning later and only contribute for the SSB in the peak of the spawning period.

Patrícia Gonçalves patricia@ipimar.pt
IPIMAR
Lisbon, Portugal



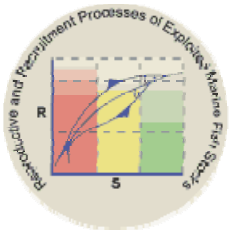
P2-9

A quick method for an easy identification of ovarian structures: the use of autofluorescence

Saborido-Rey, F., R. Domínguez-Petit and A. Alonso-Fernández

The easy and quick estimation of key reproductive parameters, as potential and batch fecundity, atresia etc has been one of the main topics on fish reproductive ecology recently. Few studies have been conducted on these parameters as the estimation of fecundity and atresia intensity is time consuming, and it may involves the use of stereology. The aid of image analyses has facilitated considerably this task, but still the use of this technique on histological sections is restricted by the lack of differentiation of ovarian structures with standard staining techniques. In this study we show a method based on the autofluorescence of eosin that build a pattern easy detectable by image analysis. This pattern allows to distinguish clearly among atretic and postovulatory follicles; also mature oocytes, including cortical alveoli, are easily separated from primary growth oocytes.

Fran Saborido-Rey fran@iim.csic.es
Institute of Marine Research
Eduardo Cabello 6
36208 Vigo
Spain



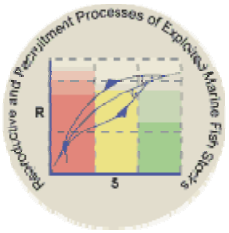
P2-10

Atypical dynamics during the 2001-2002 sardine spawning season off Portugal

Nunes, C., A. Silva, M.M. Angélico and Y. Stratoudakis

The sardine (*Sardina pilchardus*) DEPM survey off Portugal during January 2002 indicated an unusual reproductive behaviour. Biological observations from commercial catches in that year confirmed that the spawning season dynamics in 2001-2002 were atypical. Ichthyoplanktlon samples indicated a low daily egg production during the survey period, but also the adult parameters revealed a low daily specific fecundity, thus leading to a large estimate of spawning biomass off Portugal and the Gulf of Cadiz. Female relative fecundity during peak spawning was lower than all previous estimates available, irrespective of fish size/weight. Average spawning fraction presented the lowest value ever reported for sardine (around 3%, based on 1- and 2-day old postovulatory follicles). Microscopic examination of female gonads also showed a higher proportion of inactive females (post-spawners) than would be expected for the peak spawning period, and the ovaries presented a particularly high incidence of atresia, resulting in a lower mean gonadosomatic index. Female body condition factor during the preceding summer and autumn months showed a seasonal evolution similar to other years but the mean values were significantly lower, suggesting that food availability may have conditioned the amount of energy stored. The 2001-2002 spawning season took place in the context of an exceptionally high level of sardine biomass (dominated by a strong age 1-cohort) as a consequence of the unprecedented recruitment which occurred in 2000 off Northern Portugal. Density-dependent effects (limited food resources, slower maturation, lower fecundity) may have "shaped" this unusual spawning season that was dominated by first time spawners.

Cristina Nunes cnunes@ipimar.pt
INRB-IPIMAR
Fisheries and Sea Research Institute
Marine Resources Department
Avenida Brasília
1449-006 Lisboa, Portugal



P2-11

Determination of the daily spawning time of haddock

Katie Anderson, Rodney Rountree and Francis Juanes

Despite a history of monitoring and assessment of the southwestern Gulf of Maine commercially and recreationally valuable haddock stocks, limited information exists on their reproductive biology. The primary objective of this study was to determine if haddock spawn at a particular time of day. Macroscopic and microscopic differences were observed in ovaries collected from specimens over a twenty four hour period. The existence and percentage of hydrated oocytes in each ovary was especially noted. Difference in gonad somatic weight was also observed. Commercial fishing vessels were chartered for a total of 25 sea trips during February -June of 2006 and 2007. Fishing was conducted using long lines in locations where spawning haddock aggregations have been most commonly found in the southwestern Gulf of Maine through Northeast Fisheries Science Center surveys and personal communication with local fishermen. Long lines were set and hauled three times in the same location over a 12 hour period (every four hours) so that two contiguous trips would represent sampling over a twenty-four hour period of time. Sex, fork length and reproductive maturity of approximately 2000 haddock were recorded at sea. In the laboratory the ovaries of a subsample of female haddock selected from each haul were excised and weighed. An ovary tissue sample was taken from each and preserved in 10% buffered formalin for histological observation. Comparisons made between macroscopic predictions of maturity stage made in the field with histology analysis showed good agreement. Catches exhibited a pronounced daily pattern with low catches of females during the day and higher catches of males during the early evening hours. Nearly equal proportions of males and females were collected (ratio 0.92 males/females) in 2006 but, we observed a skewed sex ratio in 2007 with a ratio of males to females of 2 to l. Males did not exhibit daily peaks in maturation, with 77-94 % of the individuals ripe-and-running at any given time. This supports the idea that once male haddock mature for a spawning season they are capable of spawning milt at any given time in a day. In contrast, mature females are more likely to be in spawning-ready condition during certain hours of the day with 50 percent of the females in spawning condition between 2100h and 0500h and only 8 to 33 percent ready at other times. Preliminary histology analysis suggests that final oocyte maturation begins near midnight with spawning taking place during morning hours.

Katie A. Anderson
153 Summer Street
Rehoboth MA 02769
USA

kaanders@forwild.umass.edu

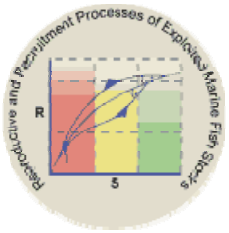
P2-12

Reproductive dynamic and strategy and oocyte recruitment process of European hake (*Merluccius merluccius*, L. 1758) in Galician shelf waters

Dominguez Rosario, Saborido-Rey Fran and Alonso-Fernandez Alexandre

Hake Reproductive Potential has been poorly studied. It shows indeterminate fecundity; hence it is not possible to estimate potential fecundity but number of developing oocytes (NDO) instead, and the batch fecundity (BF). Ovary development was assessed by histology. Energy density was estimated after analyze proximate composition in gonad, liver and muscle of 50 females. NDO and BF were estimated by image analyses. In histological analysis showed that hake population in Galician waters has a protracted spawning season with a peak of spawning from February to March and high synchronous both, at individual and at population level, was detected. Proximate composition of tissues considerably changes along spawning season although population spawning synchrony masks temporal patterns. Both NDO and BF are affected by maternal attributes; nevertheless NDO is modulated by energy intake. In other words, this work corroborates the importance of proximate composition as a short-term energy reserve for egg production in European hake from Galician shelf waters, but energy dynamic associated with egg production are different from those observed in cold water species in which traditional assessment and management models are based.

Rosario Domínguez-Petit rosario@iim.csic.es
Fisheries Group
Institute of Marine Research (CSIC)
C/Eduardo Cabello, 6. c.p. 36208
Vigo (Pontevedra)
Spain



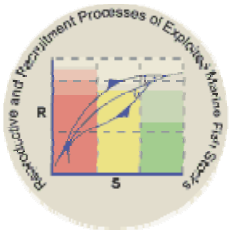
P2-13

Spatial and temporal variability in Baltic sprat (*Sprattus sprattus balticus* S.) batch fecundity

Haslob, Holger, Jonna Tomkiewicz and Hans-Harald Hinrichsen

Batch fecundity of Baltic sprat (*Sprattus sprattus balticus* S.) during peak spawning time was investigated in relation to fish length and weight applying the hydrated oocyte method. A series of ten years was established covering the main spawning areas in the Central Baltic Sea, i.e., the Bornholm Basin, the Gdansk Deep and for some years the Gotland Basin. Analysis of Covariance (ANCOVA) showed significant differences in batch fecundity of Baltic sprat between areas and years. To detect possible causes for this variation in batch fecundity environmental factors such as water temperature, salinity, oxygen content as well as fish and stock size were tested as explanatory variables. The data obtained in this investigation were used to develop a predictive model of Baltic sprat batch fecundity. Coupling these results with existing ichthyoplankton survey and stock structure data will allow to apply the daily egg production method. The suitability of utilizing this method in order to retrospectively estimate sprat stock development in the Central Baltic is discussed.

Holger Haslob hhaslob@ifm-geomar.de
Leibniz Institute of Marine Sciences
IfM-GEOMAR
FB3 Marine Ecology / Fishery Biology
Düsternbrooker Weg 20
24105 Kiel
Germany



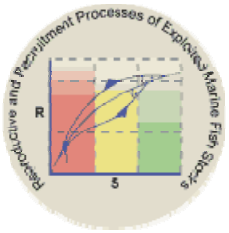
P2-14

Evidence of possible skipped spawning in Pacific halibut (*Hippoglossus stenolepis*) and its potential to impact effective spawning biomass

Loher, Timothy and Andrew C. Seitz

Pacific halibut (*Hippoglossus stenolepis*) are managed throughout the US and Canada via a management plan comprised of regional catch limits, exploitation rates scaled to biomass, and a provision to cease harvests if the stock declines to historically-observed minimum spawning biomass. The plan assumes that all mature individuals spawn annually, but while halibut are known to spawn on the continental slope in winter, electronic tagging demonstrates that some halibut fail to undertake the offshore migration. Recently, a behavior was observed in electronically-tagged halibut that is believed to represent active spawning: series of abrupt ascents, each of ~10 minutes in duration, regularly-spaced during mid-winter. Here, we examined the annual depth profiles of 74 Pacific halibut tagged with Pop-up Archival Transmitting (PAT) for evidence of spawning or the lack thereof. PAT tags collect depth every minute, release on a programmed date, and download data via satellite. Transmissions include daily minimum and maximum depths, and behavior can be reconstructed minute-by-minute if the tag is recovered. Spawning rises were observed from January 9 – March 19, but ~30% of halibut with detailed records failed to exhibit spawning rises and 20% of fish whose tags broadcast to satellites failed to conduct an offshore migration. These data suggest that some individuals either fail to spawn annually or utilize alternative spawning strategies, either of which could affect reproductive success. Results will be discussed in the context of evidence for regional variability in spawning frequency, size-at-maturity anomalies observed in survey data, and potential effects on accurately estimating effective spawning biomass.

Timothy Loher Tim@iphc.washington.edu
International Pacific Halibut Commission
PO Box 95009
Seattle, WA 98145-2009
USA



P2-15

The cod mating system and the risk of genetic introgression from farmed escapees

Skjæraasen, J. E., J. J. Meager, Ø. Karlsen, S. Løkkeborg, K. Michaelsen, I. Mayer, J. A. Hutchings, A. Fernø

Most farmed Atlantic cod (*Gadus morhua*) in Norway are produced in net-pens in sheltered coastal areas also used by wild coastal cod. As future expansion of the industry is expected, interactions between farmed escapees and local coastal stocks are inevitable. Genetic introgression from escapees has caused fitness depression in wild Atlantic salmon (Salmo salar) populations and similar effects may occur with cod. Wild coastal cod are currently subjected to over-exploitation and are at low population size throughout their range. It is, therefore, very important to examine the potential effect cod farming and escapees may have on wild stocks.

The cod mating shoal has been described as a lek which is an aggregated male display that females attend primarily for fertilisation. During spawning, males act aggressively towards each other and court females, using a combination of acoustic and behavioural displays. These behavioural interactions are directly correlated with male reproductive success. Behavioural divergence between farmed and wild populations may, therefore, limit the potential for hybridisation between them. Domestication may also influence the reproductive success of cod by affecting the development and expression of secondary sexual characteristics. We will present data from studies that tested for differences in both the morphology and the spawning behaviour of farmed and wild cod within mixed spawning shoals.

Jon Egil Skjæraasen
Department of Biology
University of Bergen
P.O. Box 7800
N-5020 Bergen
Norway
jon.skjaeraasen@bio.uib.no

P2-16

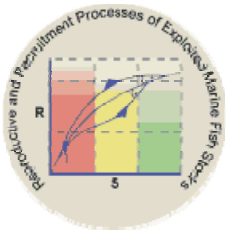
On the role of frontal systems of the Argentine Sea as spawning grounds for fishes

Macchi, Gustavo, Acha Marcelo, Pájaro Marcelo, Militelli María Inés and Rodrigues Karina

Most of the fishes inhabiting the Argentine Sea and adjacent waters show a wide spatial distribution. Nevertheless, their main spawning activity occurs in small areas inside this region. Selection of reproductive aggregation sites depends on the physical, chemical and biological properties of these environments. Therefore, we analyze physical and biological patterns searching for potential bio-physical couplings defining reproductive ground selection. Information about maturity of ten finfish species (*Merluccius hubbsi*, *Engraulis anchoita*, *Brevoortia aurea*, *Micropogonias furnieri*, *Cynoscion guatucupa*, *Percophys brasiliensis*, *Cheilodacthylus bergi*, *Ramnogaster arcuata*, *Micromesistius australis* and *Sprattus fueguensis*) representative of different ecosystems of the Argentine Sea was obtained from different research cruises carried out between 1991 and 2005. Macroscopic and histological ovarian analyses were used to assign the maturity stages. The criteria employed to estimate incidence of spawning individuals was the presence of hydrated oocytes or new postovulatory follicles. Salinity and temperature data were collected with a CTD in different oceanographic stations.

From the species analyzed, six showed the main spawning activity during spring and summer, one in midwinter, two at the end of this season and one in autumn. *M. hubbsi* showed two fishing stocks with spawning peaks in different seasons, one in spring- summer (Southern stock) and the other in autumn – winter (Northern stock). Oceanographic analysis in areas where gravid females aggregate evidenced that spawning was spatially coincident with maximum salinity and/or temperature horizontal gradient (frontal zones). This fact was associated with the physical and biological properties of these systems, characterized by high levels of chlorophyll, showing them as productive places suitable for larval feeding and growth. Moreover, frontal dynamics could act as retention mechanisms reducing egg dispersion after spawning, while in other situations, they may enhance larval movement from reproductive areas to the main nursery grounds.

Gustavo J. Macchi gmacchi@inidep.edu.ar
CONICET / INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero)
Paseo Victoria Ocampo N° 1
B7602HSA Mar del Plata
CC 175, Argentina



P2-17

Reproductive and Recruitment Processes of haddock (*Melanogrammus aeglefinus*) on the Rockall Bank

Filina E. A., Khlivnoy V. N., and V. I.Vinnichenko

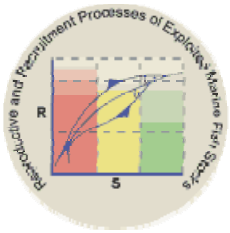
As microscopic examination showed, in the period of trophoplasmatic growth, the oocytes of Rockall haddock had the same development phases as those ones of the other cods. The expenditure supply of Rockall haddock oocytes forms synchronously. But further growth of oocytes is asynchronous. At the beginning of prespawning stage, in the ovaries, the oocytes at different development phases may be observed simultaneously: the start of vacuolization and accumulation of yolk, intensive trophoplasmatic growth, the yolk filled oocyte. Asynchronism in oocytes development conditions the batch character of spawning.

The data from histological examination of haddock gonad samples collected in March-May 2004-2006 mass sexual maturation occurs at the age of two years with the length of 25 cm. These data agree well with the results of recent Scottish research in compliance with which the majority of fish become mature at the age of 2 years. The haddock had the same sexual maturation rate before. So, the biological analyses made in April 1977 showed that practically all the fish as long as 24 cm and more were mature.

Absolute individual fecundity increased with age: it was 80x103eggs in first spawning fish aged 2 years, 216x103 eggs in four-year-olds, 1.0x106 eggs in eight-year-olds. The analogous results were obtained by the scientists of PINRO in the 1970s.

Rockall haddock group is an isolated population. The abundance of fecundity is mainly determined by the rate of survival of eggs and larvae at plankton development stage which basically depends on the environmental conditions in the period of spawning. Significant year-to-year fluctuations of recruit (the age is one year) abundance are noticed, at that, the link between adult haddock biomass and abundance of survived fingerlings and yearlings is absent. In the years when biomass is maximal poor year-classes are often observed. So, in 2001, when the stock was the lowest for recent years, one of the most abundant year-classes appeared. Strong year-classes appear one time in 4-5 year period. There are significant year-to-year variations of haddock year-class survival rate. Its maximal values were recorded within 8.9-9.4ºC water temperature range. The minimal values of survival rate corresponded to years with higher water temperature in the surface layer.

V.I.Vinnichenko vinn@pinro.ru
PINRO
Murmansk, Russia



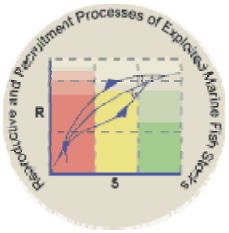
P2-18

Spawning pattern and size at first sexual maturity of European hake off NW Africa: A geographical and environmental comparative approach

Meiners, César, Lourdes Fernández and Ana Ramos

European hake (*Merluccius merluccius* L.) inhabits in a wide range of Eastern Atlantic waters, their southern distribution limit is located in NW Africa, where it is one of the most important commercial species. This area is under influence of strong upwelling process induced by the tradewinds. Knowledge of spawning dynamics and the mean size at which individuals reach sexual maturity is basic information for the control of exploitative fishing of young individuals, and when associated with other information aids in evaluation and prediction of fish stocks. We believe that environmental variability of wind induced upwelling, determines some of the reproductive dynamics differences between the NW African stock and the ICES area and Mediterranean sea commercial stocks of this species. To test this idea we analyzed a monthly time series of European hake female gonad landings of Spanish fleets, between 1989 and 1995 as a proxy of spawning pattern, and we determined the size at first maturity analyzing a total of 5639 individuals from commercial Spanish landings during 1989, 1990, 1991 and from Spanish-Moroccan scientific surveys during 2004, 2005, 2006. The female gonad landings took place during all year with maximum yields in winter and spring-summer season in order of importance, however the summer-spring peak became the most important during 1992-1995, at the same time that general trend increased. Females reached 50% maturity at 40.3-43.4 cm TL, while Males at 22.2 - 26.9 cm TL. Comparatively, the European hake of NW Africa showed the same pattern of first maturity than other stocks of the same species, males maturing at shorter sizes than females, however the amplitude of this relation showed a latitudinal gradient: larger sizes at North distribution areas (ICES stocks: 45.0 - 58.4 cm for females; 32.8 - 39.5 cm for males) and shorter ones in the South (Western Mediterranean and NW Africa). The dynamic shifting of seasonality spawning proxy, suggests that intensity and timing of this process is closely related with environmental variability of the regional system, which has been linked in previous works with the climatic system variability described by the North Atlantic Oscillation index.

Cesar Meiners cesar.meiners@ma.ieo.es
Centro Oceanográfico Fuengirola - IEO
Puerto Pesquero s/n Fuengirola
29640 Spain



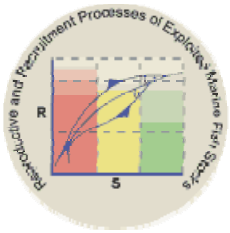
P2-19

Reproductive potential of the Argentine hake, *Merluccius hubbsi*, in Patagonian waters

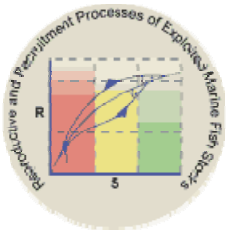
Gustavo, Macchi and Pájaro Marcelo

Batch fecundity, spawning frequency and size at maturity of the Argentine hake inhabiting the Patagonian waters, south of 41° S, were estimated by using samples collected during the spawning peak (January) in 2001, 2004, 2005 and 2006. Batch fecundity (BF) was fitted to a power function of total length (TL) and age, and to a linear function of ovary-free female weight, ranging from 100,000 (31 cm TL) to 2,900,000 (90 cm TL) hydrated oocytes. No significant differences (P>0.01) were observed between the coefficients of the relationship BF vs TL estimated for different years. Inter annual comparison of the relative fecundity showed similar results, with values ranging from 100 to 1000 hydrated oocytes per female gram (without ovaries). Spawning frequency, determined from the proportion of females with day-1 postovulatory follicles, was similar in January 2001 (0.15), 2005 (0.18) and 2006 (0.18), but lower in 2004 (0.08). At these frequencies, a female hake spawned once every 5 or 6 days in January 2001, 2005 and 2006, and every 12 days in January 2004. Argentine hake females reached sexual maturity at a higher size than males, but low variability between the L50% values estimated for different years was observed. This variable ranged from 27.78 cm to 28.41 cm TL in males and from 33.21 cm to 34.44 cm TL in females. In conclusion, the reproductive variables analyzed showed low annual variation at the main spawning peak, independent of changes in Argentine hake abundance or local oceanographic conditions during the period considered.

Gustavo J. Macchi gmacchi@inidep.edu.ar
CONICET / INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero)
Paseo Victoria Ocampo N° 1
B7602HSA Mar del Plata
CC 175, Argentina



Reproductive and Recruitment Processes of Exploited Marine Fish Stocks
1-3 October
Lisbon Portugal



P2-20

Annual fecundity, batch fecundity, and oocyte atresia of Atka mackerel (*Pleurogrammus monopterygius*) in Alaskan waters

Susanne F. McDermott (contact author)

Annual potential fecundity, batch fecundity, and oocyte atresia were estimated for Atka mackerel (*Pleurogrammus monopterygius*) collected in Alaskan waters during 1993-94. Atka mackerel were assumed to be determinate spawners on the basis of decreasing fecundity after batch spawning events. Histological examination of the ovaries indicated that oocytes in the vitellogenic stage and higher had been spawned in the current spawning season. For an average female of 40 cm, potential annual fecundity was estimated to be 41,994 eggs, average batch size (i.e., batch fecundity) was estimated to be 6689 eggs, and there were 6.13 batches per spawning season. Recent studies have shown that many fish species reabsorb a substantial number of their oocytes before spawning or at the end of the spawning season, a process known as atresia. Atresia was estimated by examining postspawning specimens and was found to be substantial. The average amount of atresia for a 40-cm fish was estimated to be 11,329 eggs, resulting in an estimated realized fecundity of only 30,664 eggs and 4.64 batches of eggs per spawning season.

Susanne F. McDermott
NOAA/NMFS/AFSC
Seattle, WA
USA

Susanne.McDermott@noaa.gov

P2-21

Fecundity assessment of pouting, *Trisopterus luscus* (Linnaeus, 1758) in Galician shelf

Alonso-Fernández, Alexandre, Dominguez-Petit, Rosario and Saborido-Rey, Fran

Traditionally, in terms of fecundity, stock assessment methods distinguish between two reproductive strategies: determined and indeterminate fecundity. To assess the annual fecundity accurately, it is necessary to identify the reproductive strategy of the species of interest. Until now, studies on reproduction of pouting are scarce. Though it has not been clearly demonstrated, it has generally been assumed that this species is a determinate spawner. Histological examination of its gonads revealed an asynchronous ovarian development organisation. Gonadosomatic index (GSI) and hepatosomatic index (HSI) presented significant difference between months. A continuous oocyte size-frequency distribution was found for every maturity stage except in hydrated ovaries. Relative number of developing oocytes (RNDO) shown a clear decrease throughout the spawning season and the ratio between NDO and batch fecundity was relatively high. Our results show enough evidences to consider pouting as determinate fecundity species with the consequences this has for future management purposes.

Alexandre Alonso-Fernández alex@iim.csic.es
Departament of Marine Ecology and Resources
Fisheries unit
Institute of Marine Research, CSIC
c/ Eduardo Cabello 6, 36208 Vigo (Pontevedra)
Spain

P2-22

Do Greenland halibut, *R. hippoglossoides*, spawn in inshore Disko Bay, West Greenland?

Fossen, Inge, Agnes C. Gundersen, Claus Stenberg, Bjarne Lyberth and Jesper Boje

In 2002 three sample sets were collected from the inshore fishery in the fjords of Disko Bay in May, October and December respectively, aiming to describe the maturity of Greenland halibut (*Reinhardtius hippoglossoides*)in the inshore areas of Disko. These sample sets completed a sample series conducted in 1998 involving monthly sampling of Greenland halibut ovaries from February - September (Simonsen and Gundersen, Journal of Fish Biology, 2005). In December gonad index ranged up to 8.8%. Oocyte modal diameter in the leading cohort was 2 300 µm, which is larger than previously reports for August and September (1 400 to 2 000 µm respectively). Individuals in maturing and late maturing conditions were seen in December indicating females are preparing for spawning. Previously it has been questioned if Greenland halibut in the inshore waters of West Greenland actually perform spawning inshore, migrates to the Davis Strait spawning ground or never ripe their gonads for spawning, constituting a dead end of the species.

Inge Fossen
Møre Research
Ålesund
Norway

inge@mfaa.no

P2-23

Fecundity and lipid content in autumn- and winter spawning North Sea herring (*Clupea harengus*)

van Damme, Cindy, Marcel Schouten, Jan Beintema, Deborah Davidson and Mark Dickey-Collas

Part of the energy reserves in herring *Clupea harengus* are stored as lipid in the body tissue. Throughout the maturation of the ovaries these lipid reserves and protein are used for the development of the oocytes. Not much is known about the relationship between the lipid content and fecundity in North Sea herring.

As shown by histological analysis, 'down regulation' of the number of oocytes in the maturing ovary occurs through atresia. This has been found before in cod, plaice and Norwegian spring spawning herring but has not been reported before in North Sea herring.

Throughout maturation and spawning the variation in lipid content is large for both spawning types. Lipid content of the winter spawners is higher compared to the autumn spawners, although the autumn spawners are on average larger both in length and weight, 28.3 cm, 221.5 gram and 26.0 cm, 158,2 gram respectively.

In 2006 lipid content was very low at the onset of maturation and spawning of both autumn and winter spawners was later in the year compared to earlier years.

For autumn spawners no clear relationship between lipid and fecundity is found. For winter spawners fecundity and lipid content are high at the onset of maturation and decrease through time, while oocytes are growing.

Mark Dickey-Collas mark.dickeycollas@wur.nl
IMARES
Haringkade 1 IJmuiden
P.O. Box 68, 1970 AB Ijmuiden
The Netherlands

P2-24

Advances in fecundity methodology applied to marine fish

Witthames, P.R., A .Thorsen, M. Fonn, L.N. Greenwood, F. Saborido-Rey, R. Dominguez, H. Murua, M. Korta and O.S. Kjesbu

Estimation of individual egg production is a key step either to understand the relationship between stock and recruitment or to carry out fisheries independent assessment of spawning stock biomass using egg production methods. The work is demanding on human resources and some times requires large quantities of toxic fixative because many fish are highly fecund and their ovaries may weigh over a kilogram. On the other hand, it has recently been shown for cod (*Gadus morhua*) that image analysis can automate estimation of fecundity determination using the Auto-diametric method. In this paper, we focus on the precision of the Auto-diametric method applied to a range of species with different spawning strategies caught in ripe or spawning condition. A new method using a solid displacement pipette to remove small (<25-200 mg mass) fecundity samples is evaluated as are the underlying assumptions to effectively sub-sample the ovary. Finally, we demonstrate the interpretation of dispersed formaldehyde fixed ovary samples to assess the presence of atretic and post ovulatory follicles to replace labour intensive histology and consider how to estimate down regulation (production of atretic follicles) of potential fecundity during maturation.

Peter Robin Witthames
CEFAS
Lowestoft Laboratory
Pakefield Rd
Lowestoft, Suffolk
England NR33 OHT
United Kingdom

peter.witthames@cefas.co.uk

P2-25

Spawning strategy of *Engraulis anchoita* (Pisces, Engraulidae) in the continental shelf waters off Argentine

Pájaro, Marcelo, Patricia Martos, Ezequiel Leonarduzzi and Gustavo J. Macchi

Abundance and distribution of *Engraulis anchoita* eggs were analyzed with the aim of describing the relation with the physical processes observed in the spawning area. Argentine anchovy is the most abundant fish resource in the Southwest Atlantic Ocean. South of 34°S at least two populations of *E. anchoita* exist separately at approximately 41°S. During spring the Northern stock is found in coastal sectors of the northern Argentine continental shelf (34-41°S), where massive spawning occurs. Southern stock spawns along the Patagonian coast (41-48°S) during late spring-early summer. From 1993 to 2004 a series of 16 surveys were carried out in order to assess the spawning biomass of argentine anchovy. Anchovy eggs were collected from 1681 vertical hauls using a Pairovet net. Temperature and salinity were recorded with a CTD sensor. Annual mean anchovy eggs density ranged from 660 to 2162 eggs m-2 for the Northern stock and from 425 to 1023 eggs m-2 for the Patagonian stock. The spawning area varied between 88516 and 148822 km2 for the Northern stock and between 39063 and 78440 km^2 for the Patagonian stock. In the Northern area, spawning was associated with several oceanographic regimes; the higher egg densities were mainly observed in relation to the 50 m isobath and to a near-shore area east of an estuarine system. On the other hand, spawning in the Southern area was coupled with the Patagonian tidal front system and the higher egg abundance were observed in both sides, homogenous and stratified waters, of the front.

Marcelo Pájaro mpajaro@inidep.edu.ar
INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero)
Paseo Victoria Ocampo N° 1
B7602HSA Mar del Plata
CC 175, Argentina

P2-26

Sexual Maturity and Fecundity of *Scyliorhinus canicula* (Linnaeus, 1758) in the Aegean Sea

Kousteni, V., Kontopoulou, M., Amorginos, G. and Megalofonou, P.

A total number of 325 small-spotted catsharks (*Scyliorhinus canicula*) ranging from 184 to 488 mm in total length (TL) and from 62 to 617 g in total weight (W) were sampled by the trawl fishery in the Aegean Sea during the two-year period 2005-2007. The overall ratio of males to females was 1.06:1. Sexual maturity was assessed by macroscopic observation of the reproductive organs and Gonadosomatic indices were estimated. Almost 60% of the specimens were mature (68% of males and 51% of females). Gonad observation revealed that females larger than 364 mm TL had mature ovaries with visible yolked oocytes. Ovary weight varied from 0.12 to 25.41 g and maximum oocyte diameter was 18 mm. Gonadosomatic indices ranged from 0.10 to 7.28 in female fish and from 0.18 to 5.90 in male fish. Males larger than 352 mm were all mature. Size-at-first-maturity L50 was determined using the logistic curve and males were found to be mature in a smaller size than females. Fecundity was assessed numbering the ripe oocytes in the ovary reaching 30 in a 460 mm TL female. In 27 mature females, one egg capsule in each of the oviducts was found.

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Persefoni Megalofonou pmegalo@biol.uoa.gr
University of Athens
Athens, Greece

P2-27

Batch fecundity, spawning frequency and size at maturity of the Argentine anchovy (*Engraulis anchoita*) in the southwest Atlantic Ocean

Leonarduzzi Ezequiel, Pájaro Marcelo, Macchi Gustavo and Hansen Jorge

The Argentine anchovy (*Engraulis anchoita*) is the most abundant pelagic species in the Argentine sea, with a extensive geographical distribution ranging 34° and 48°S. E. anchoita is batch spawner with indeterminate annual fecundity. Batch fecundity (BF), spawning frequency (SF) and size at maturity (L50%) of this species inhabiting waters off the Buenos Aires Province, from 34°S to 40°S, were estimated by using samples collected during the spawning peak (October) between 1993 and 2006. BF was fitted to a power function of total length (TL) and age, and to a linear function of ovary-free female weight (TW*), ranging from 1,034 (96 mm TL) to 34,505 (181 mm TL) hydrated oocytes. Significant differences ($P<0.05$) were observed between the coefficients of the relationship BF vs TL and BF vs TW* estimated from different years. Inter annual comparison of the relative fecundity estimates showed similar results, with values ranging from 128 to 1,111 hydrated oocytes per female gram (without ovaries). Spawning frequency for the different sampled years was similar, ranging from 0.09 to 0.15. At these frequencies, a female anchovy spawned once every 11 or 6 days. L50% values showed variability among years ranging from 84.4 mm to 106.8 mm TL. Fluctuations of BF and L50% could be associated to variations in the availability of food, temperature, eggs size or age-size composition of the stock. On the other hand, SF did not show statistical difference between years, but it may be consequence of the higher variation coefficients estimated for this variable.

Leonarduzzi Ezequiel eleonard@inidep.edu.ar
INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero)
Paseo Victoria Ocampo N° 1
B7602HSA Mar del Plata
CC 175, Argentina

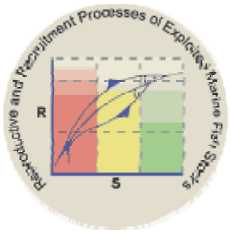
P2-28

Reproductive features of two Patagonian toothfish (*Dissostichus eleginoides*) aggregations in the Southwest Atlantic Ocean

Pájaro, Marcelo, Gustavo J. Macchi, Patricia Martinez and Otto C. Wöhler

Spatial distribution of maturity stages and estimates of length at maturity for two aggregations of Patagonian toothfish (*Dissostichus eleginoides*) in the Southwest Atlantic Ocean were analyzed. Samples (n=42,821) were collected from longline commercial fishery between 2003 and 2006. The northern group occurs over a wide latitudinal range from 36°S to 50°S while the southern group inhabits the area from 52°S to 60°S. Annual analysis of the maturity stage composition of the northern group showed that 24% of fish were juveniles, 54% were reproductively active individuals and less than 0.1% were males in spawning condition. The lack of running females suggested that spawning of D. eleginoides does not take place in the north area. With respect to the southern group, only 13% of fish were juveniles, 60% were reproductively active individuals and 4% were in spawning stage. Monthly analysis of maturity stage composition for this group suggested that main spawning activity occurs from June to October. On the other hand, spatial distribution of maturity stages showed that 85% of spawning individuals were observed in waters deeper than 1000 m. Length at maturity (L50%) for the northern and southern group was 84.7 and 81.7 cm total length, respectively; statistical differences between groups were observed ($p<0.001$). Nevertheless, no statistical differences ($p>0.28$) in length at maturity was observed between fish inhabiting deeper waters (>1000 m depth) and inshore waters (<900 m depth). Other aspects as reproductive behavior and environmental features in relation with the population structure of D. eleginoides are discussed.

Marcelo Pajaro mpajaro@inidep.edu.ar
INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero)
Paseo Victoria Ocampo N° 1
B7602HSA Mar del Plata
CC 175, Argentina



P3-1

Does Frontal Residence Help Larval Fish? Growth and Abundance of Larval Dab, *Limanda Limanda*, within a Developing Frontal System in the North Sea

Olbrich, R., Peck, M.A., Munk, P.and St. John, M.A.

The North Sea features a complex hydrographic situation with various frontal systems, some of which exist only seasonally. The impact of frontal activity on recent growth of dab, *Limanda limanda*, larvae was examined in April, May and July 2001 at transects that bisected a frontal system that was parallel to the Danish coast. Larvae examined in April, May and June had between 9 to 34, 10 to 43, and 14 to 46 otolith increments. The median otolith radii were 27.0, 43.3 and 51.3 mm, respectively, which translated to median standard lengths of 7.8, 9.2 and 9.8 mm as calculated by an otolith radius-length regression. Recent (three to six day) growth was determined separately for each month from increment widths that were standardized for differences in water temperature and fish size. Hydrographic measurements indicated a well-developed tidal front in July. During this period, growth during the previous six days was significantly elevated at the stratified side of the front relative to the neighboring mixed and stratified water masses. Stations with the highest growth were correlated with a five- to 10-fold increase in copepod biomass but also with a ~ nine-fold decrease in larval abundance (0.2 vs. 1.8 larvae 100m-3). In April and May the frontal system was comprised of a plume and a tidal front. Recent growth was significantly higher on the stratified side of the plume front relative to the neighboring water masses in May but copepod biomass was unrelated to frontal position. Fronts were not strongly developed in May and a storm prior to sampling may have advected larvae. In April, frontal development was very weak, and variability in growth rates was minimal. Overall, abundances in April and May were elevated at fronts, but a causal relationship seems questionable. Our findings suggested that well-developed frontal systems in the North Sea provided conditions that enhanced growth.

Roland Olbrich
Sustainability Economics Group
University of Lueneburg
Postfach 2440
21314 Lueneburg
Germany

roland.olbrich@uni-lueneburg.de

P3-2

Variations in Greenland halibut egg buoyancy during development at three temperatures

Ouellet, P., Lambert Y. and Bertolone, C.

Greenland halibut (*Reinhardtius hippoglossoides*) is found in the various deep channels of the Gulf of St. Lawrence (Canada), at depths greater than 200 m. These regions are characterized by conditions of temperature and dissolved oxygen that could significantly influence the reproductive success and growth of fishes. Moreover, since this fish reproduces during winter, when there is ice in the Gulf, little is know on the distribution of reproductive aggregations and the dispersion pattern of the eggs and larvae in relation to water mass circulation. Our project examined the initial specific density and the effect of water temperature on the development and density changes of Greenland halibut eggs. Density gradient columns (Coombs columns) were used to assess density and buoyancy of Greenland halibut eggs at different developmental stages when incubated at three temperatures (2° 4° 6°C). Newly spawned eggs have a specific density varying between 1.0268 and 1.0276 g°cm°-3 (26.8 to 27.6 sigma-t) that would confirm that Greenland halibut eggs are bathypelagic in the Gulf of St. Lawrence. Water densities equivalent to egg mean densities are typically found at depth greater than 200 m in the Gulf of St. Lawrence. Egg density remained relatively stable during development at all temperatures but a tendency toward reduced density in late egg stages (near hatching) was noted. The hatching of larvae at 4°C and 6°C occurred after approximately 31 and 22 days, respectively. Development times were about twice as long at 2°C than at 6°C. Since Greenland halibut spawn between January and March in the Gulf, a long egg development time in deep waters would represent an adaptation to existing environmental conditions where sea ice is present over much of the Gulf until April. Our results will provide information necessary for the use of numerical circulation models to propose specific hypotheses on potential Greenland halibut reproductive areas, timing of reproduction and egg and larval drift to nursery areas in the Gulf of St. Lawrence ecosystem.

Patrick Ouellet ouelletp@dfo-mpo.gc.ca
Direction des sciences océaniques et de l'environnement/Ocean and Environmental Sciences Branch
Pêches et Océans Canada/Fisheries and Oceans Canada
Institut Maurice Lamontagne/Maurice Lamontagne Institute
850 route de la mer
Mont-Joli, QC
Canada G5H 3Z4

P3-3

Predicting egg and larval dispersion in northeast Pacific flatfish stocks using a coupled biophysical model: Is it a Cadillac or an Edsel?

William T. Stockhausen, Janet T. Duffy-Anderson, Albert J. Hermann and Thomas K. Wilderbuer

In recent stock assessments, simulated trajectories of passive particles from a relatively simple wind drift model of ocean surface currents (the Ocean Surface Current Simulator, OSCURS) have been used to provide a qualitative indication of egg and larval dispersion (and potential recruitment) for several winter-spawning flatfish stocks in the eastern Bering Sea. However, the OSCURS model lacks somewhat in both physical and biological realism: vertical current structure is ignored and simulated particles are passive drifters. Also, the resolution of the OSCURS grid (~90 km) is inadequate to resolve mesoscale eddies, which can alter dispersal paths and affect horizontal dispersion rates. To incorporate more physical and biological realism into dispersion-based predictions of recruitment for these winter-spawning flatfish stocks, we have developed DISMELS, the Dispersal Model for Early Life History Stages. DisMELS is a coupled biophysical model that incorporates individual behavior and simulates egg and larval dispersal based on time series of 3-dimensional (3D) oceanographic salinity, temperature and current fields from the NEP ROMS model-an oceanographic model of the northeast Pacific Ocean using Regional Ocean Modeling System. Here, we compare trajectories from DISMELS and OSCURS for northern rock sole (*Lepidopsetta polyxystra*) and Alaska plaice (Pleuronectes quadrituberculatus) early life stages. In DisMELS, older rock sole larvae undergo diel vertical migration, whereas plaice larvae remain near the surface. At a gross scale, results from the two models are qualitatively similar. However, incorporating larval behavior and 3D current structure in simulations can lead to differences of over several hundred kilometers in final destination.

William Stockhausen
Alaska Fisheries Science Center, F/AKC2
7600 Sand Point Way N.E.
Seattle, WA
98115-6349 USA

william.stockhausen@noaa.gov

P3-4

Predation dynamics of mackerel foraging on populations of larval and juvenile anchovy: is survival of anchovy linked to growth?

Robert, Dominique, Akinori Takasuka, Sayaka Nakatsuka, Hiroshi Kubota, Yoshioki Oozeki, Hiroshi Nishida and Louis Fortier

Fast-growing marine fish larvae are considered to benefit from higher survival rates than their slow-growing conspecifics. This survival advantage would be attributable to the synergy of (1) a more efficient anti-attack behaviour at a given size, (2) a larger size at a given age, and (3) a shorter transit through the periods of high predation risk. Small pelagic predators constitute one of the most important sources of mortality of larval and early juvenile fish. In particular, species comprised in the gender Scomber are known for their active piscivorous behaviour starting from the larval stage. The objective of this study was to determine whether the predation dynamics of chub (*S. japonicus*) and spotted (*S. australasicus*) mackerel on young anchovy (*Engraulis japonicus*) is related to prey individual growth characteristics and could account for the growth-selective survival predicted by recruitment hypotheses. Juvenile and adult mackerel were sampled along with their larval and juvenile anchovy prey in 2004 (juvenile mackerel preying on larval anchovy) and 2005 (adult mackerel preying on juvenile anchovy) offshore Tohoku, Japan. Recent 3-day mean growth rate of larval and juvenile survivors and prey found in the stomach of mackerel was estimated from the otolith microstructure. No significant differences were found in the recent growth of larval survivors and prey, or between the recent growth of juvenile survivors and prey. We conclude that despite its relatively small size, the high level of activity and predation skills displayed by mackerel prevents fast-growing larvae and early juveniles from gaining a survival advantage compared to slow-growers. Selection for fast growth is more likely to appear under predation pressure from filter-feeding and particulate-feeding predators like small pelagic fish (e.g. herring, anchovy) specialized on zooplankton.

Dominique Robert
Québec-Océan
Université Laval
Québec, QC
Canada G1K 7P4

dominique.robert@giroq.ulaval.ca

Reproductive and Recruitment Processes of Exploited Marine Fish Stocks
1-3 October
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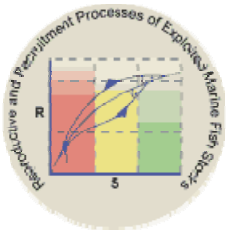
P3-5

Dispersion of eggs, larvae and pelagic juveniles of White Hake (*Urophycis tenuis*, Mitchill 1815) on the Grand Banks of Newfoundland in relation to subsurface currents

G. Han, D.W. Kulka and M. He

White hake (*Urophycis tenuis*, Mitchill 1815) is a temperate bottom dwelling fish with the northern extent of its distribution on the southern Grand Banks. There they are found at bottom depths from 50-800 m, associated with 4-8ºC ambient temperatures. They are restricted to a narrow band along the southwest edge and into the Laurentian and Hermitage Channels where local bottom temperatures are warmest (> 4ºC). We have examined potential dispersion patterns of eggs, larvae and juveniles under climatological monthly-mean circulation fields, M2 tidal currents and associated turbulent mixing, which were computed from a three-dimensional regional ocean circulation model. Effects of spawning locations (horizontal and vertical) and timing (monthly and yearly) are investigated. The results indicate a relatively high percentage of shallow drifters from the SW Grand Bank release can be available for settle-down in the nursery region at the end of summer whereas the availability from the SW slope deep release is low. Particles located nearer the surface are carried away to deep waters, more so earlier in the season. Spawning below the surface Ekman layer, on the SW Grand Bank and in the weaker Labrador Current year have higher chances for young juveniles to settle down in the southwest Grand Bank nursery area in fall.

Dave Kulka kulkad@dfo-mpo.gc.ca
Fisheries and Oceans
Science, Aquatic Resources
Northwest Atlantic Fisheries Centre
St. John's, Newfoundland & Labrador
Canada A1C 5X1



P3-6

Long-term association between fish recruitment and temperature in the North east Atlantic

Brunel, Thomas

Recently, an increasing number of studies have focused on the effects of climate change on marine populations. The response of fish stocks to climate change have been less studied than for other components of marine ecosystems, like the plankton. It is however of primary importance to know what changes in fish stock productivity can be expected in response to climate change, in order to design more appropriate management strategies. The long term changes in the recruitment of North Eastern Atlantic fish stocks are examined here, with the aim of finding common patterns of variation, that could reflect a common response to climate change.

The dominant pattern of recruitment variation extracted with a principal component analysis (PCA) was a long-term decline, with a stepwise change occurring in 1987. A majority of Baltic Sea, North Sea, West of Scotland and Irish Sea populations, especially the gadoids, have followed this decreasing trend. On the contrary, some herring populations, and the populations of boreal ecosystems have followed an opposite increasing trend. This pattern was strongly negatively correlated to the dominant signal in Northeast Atlantic sea surface temperature, also extracted by a PCA, which was, in turn, highly correlated with the global increase in temperature.

The analysis of correlations between populations recruitment and local temperature was also carried out. Most of the populations with a decreasing recruitment trend exhibited a negative recruitment-temperature correlation, and were populations living in the southern part of the species range. The opposite was observed for populations with an increasing recruitment trend.

Traditionally, changes in recruitment are attributed to variation of spawning stock biomass caused by fishing. This study suggests that climate change is also a factor explaining the long term changes in recruitment, probably acting in combination with the effect of fishing.

Thomas Brunel
Wageningen IMARES
PO Box 68
1970 AB IJmuiden
The Netherlands
Thomas.brunel@wur.nl

P3-7

Variations of the reproductive cycle of northern shrimp *Pandalus borealis* populations in the Estuary and Gulf of St. Lawrence

Savard, Louise and Patrick Ouellet

Northern shrimp females spawn in late summer or early fall in the Estuary and Gulf of St. Lawrence and carry their fertilized eggs on their pleopods until the larvae hatch eight to nine months later, in spring. Northern shrimp recruitment success seems favoured by oceanographic conditions that affect the initiation of the spring bloom and that can sustain high levels of production at the time of larval emergence. However, besides the annual variations in the timing of both events (larval emergence and spring bloom), it seems that shrimp populations in the EGSL exhibit differences in their reproductive cycle, ensuring that the release of larvae is synchronized with the spring bloom. A strong longitudinal gradient in the time of spawning and hatching has been observed in the EGSL, spawning and hatching being earlier in the eastern sector where earlier spring blooms occur. Although the duration of incubation seems similar between locations within the Gulf, it is longer in the Estuary indicating an effect of colder bottom temperatures. Variations over time in the timing of gonad maturation, spawning and hatching have also been observed suggesting that maturation and incubation are sensitive to temperature. Moreover, data series show trends over time in the initiation of maturation and in egg extrusion while hatching seems to fluctuate without a trend. Maternal characteristics and oceanographic conditions are examined to determine their effects on the variations of shrimp reproductive cycle in the EGSL.

Louise Savard savardl@dfo-mpo.gc.ca
Fisheries and Oceans Canada
Maurice Lamontagne Institute
850 route de la mer
Mont-Joli, QC
Canada G5H 3Z4

P3-8

Spatial recruitment patterns of fish larvae in a tropical coastal lagoon in the Mexican Pacific coast

Franco-Gordo, C., E. Godinez-Dominguez, C. Bernardez, B. Garcia-Calvo, J. Rojo-Vázquez, A. Filonov, I. Tereshchenko, D. Kosonoy, A. Hinojosa, and J. Freire

Weekly zooplankton samples were taken according to moon phases during a one-month period in one of the main hydroclimatic periods of the year (November-December 2004) in 5 sites in Barra de Navidad Lagoon, Jalisco, in the Pacific Coast of México. The fish larvae were collected by horizontal hauls of a conical net with a 200µm mesh size. A digital flowmeter was adapted to the net mouth in order to estimate the amount of water filtered. Previous to each tow, a profile of temperature and salinity was obtained using a CTD profiler SBE-19. Abundance data were standardized into number of larvae per 10 m². We describe the horizontal distribution and migration of fish larvae. The distribution patterns were examined in relation to temperature, salinity, day/night and tides. The distribution and abundance of fish larvae showed a dynamic pulse probably due to larval supply and was related with tidal amplitude patterns, and seems to be related to coastal dynamic events mainly represented by advective processes, a well-differentiated abundance gradient was observed.

Beatriz García-Calvo bgcalvo@udc.es
Departamento de Bioloxía Animal
Bioloxía Vegetal e Ecoloxía
Universidade da Coruña
Campus da Zapateira s/n
15071 A Coruña, Spain.

P3-9

Short-term settlement patterns and habitat selection of penaeids in a tropical estuary

Godínez-Domínguez, Enrique, García-Calvo, Beatriz, Bernárdez, Cristina1, Rojo-Vázquez, Jorge, Franco-Gordo, Carmen; Kosonoy, Daniel1; Flores, Juan Ramón, Hinojosa-Larios, A. and Freire, Juan

Weekly samples were taken according to moon phases during a one-month period in two main hydroclimatic periods of the year (November-December 2004 and April-May 2005) in 4 sites (mud, sand and two mangrove stations) in Barra de Navidad Lagoon, Jalisco, in the Pacific Coast of México. Newly settled shrimps were collected using sets of 50 cm side squares of a plastic mesh carpet. Collectors were deployed for 24 H periods starting the day previous to the moon phase and until a day after (3 days). The settlement showed a pulse dynamics probably due to variability in larval supply associated to tidal amplitude. Habitat use patterns were related to habitat selection processes, distance to the mouth of the lagoon and tidal circulation patterns.

Beatriz García-Calvo bgcalvo@udc.es
Departamento de Bioloxía Animal
Bioloxía Vegetal e Ecoloxía
Universidade da Coruña
Campus da Zapateira s/n
15071 A Coruña, Spain.

P3-10

Long-term changes in walleye pollock (*Theragra chalcogramma*) reproduction and stock abundance in the Tatar Strait (Japan Sea)

Velikanov A. Ya. and Luchenkov A.V.

The long-term monitoring of stock abundance of commercial fishes conducted by SakhNIRO in the Sakhalin Island seawaters showed a marked tendency to abundance decline that has been observed for walleye pollock, spawning in the Tatar Strait. During the last 15 years walleye pollock stock biomass decreased as much as almost 16 times. From 1995 to 2005 their recruitment abundance (four-year-old fishes) decreased as much as 19 times. At present, walleye pollock abundance near the western Sakhalin coast is at the extremely low level (less than 10.0 thousand tons). A tendency of decline in stock abundance has been accompanied by essential changes in some biological parameters of their reproduction. Results of trawl and ichthyoplanktonic surveys showed that between 1980th and 2001-2006 spawning grounds of this species again were shifted from the northern part of the Tatar Strait to the southwestern coast of Sakhalin Island, but to the deep-sea zone (100-600 m). There was observed a significant decrease in concentrations of the floating eggs in the years 1999-2005 comparing to 1960-1980. A size-age structure of walleye pollock aggregations is characterized by a large portion of young fish. The fishes from 31 to 50 cm long, which usually dominated among adult pollock and constituted 83.4% in the 1968-1972, decreased to less than 20 % in 2006. The revealed trend of stock dynamics of the western Sakhalin walleye pollock reflects a long-term decrease in abundance for this species that occurs all over the Sea of Japan during the last 30 years. A unidirectional long-term tendency to a significant decline in walleye pollock abundance and catches in all areas of their fishing in western and eastern parts of the Sea of Japan gives grounds to consider climatic and oceanological changes as a general reason for this phenomenon.

Anatoly Velikanov velikanov@sakhniro.ru
Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO)
196, Komsomolskaya Str.,
Yuzhno-Sakhalinsk, 693023
Russia

P3-11

Effect of climate and oceanographic conditions on sole larval transport towards the Tagus estuary, Portugal

Vinagre, C., M.J. Costa and H.N. Cabral

Spawning grounds of the soles, *Solea solea* and *Solea senegalensis*, are distant from the estuarine nurseries where juveniles concentrate. Recruitment of these species is highly dependent on the success of the larval migration towards the inshore nursery grounds. Unfavourable climate and hydrodynamic circulation may lead to high mortality rates at this stage. The relation between river drainage, NAO index and the North-South wind component intensity over the three months prior to the end of the estuarine colonization and the densities of *S. solea* and *S. senegalensis* in the nursery grounds were investigated for both species based on a discontinuous historical dataset (from 1988 to 2006) for the Tagus estuary. Multiple linear regression models were developed for sole density and environmental data (separately for each species). Results showed that river drainage is positively correlated with juveniles' densities of both species, possibly due to the existence of chemical cues used by larvae for movement orientation. NAO index and the North-South wind component intensity relations with soles densities were non-significant. It was concluded that the high complexity of the Portuguese upwelling system makes it hard to detect causal relations of the environmental variables tested. The importance of river flow for coastal ecosystems was stressed. Since climate change scenarios predict a strong decrease in rain fall over the Portuguese river basins, as well as a concentrated period of heavy rain in winter, it was hypothesized that future river drainage decrease over much of the year may affect soles' recruitment success, especially for *S. senegalensis*, which has a more prolonged spawning period.

Catarina Vinagre cmvinagre@fc.ul.pt
Centro Oceanográfico Fuengirola - IEO
Puerto Pesquero s/n Fuengirola
29640 Spain

P3-12

The embryos of *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809)

Vila, S.; Sequeira, V.; Serrano-Gordo, L. and Muñoz, M.

Helicolenus dactylopterus dactylopterus (Delaroche, 1809) embryos are extruded from the mother's body before or just after reaching the 16 somites stage, and they complete their development floating in the sea immersed in a gelatinous matrix that protects them.

H. d. dactylopterus is a zygoparous species with internal fertilization. Its particular mode of reproduction includes intraovarian sperm storage in which sperm remain within specialized cryptal structures. Ovarian fluid samples obtained at the spawning season of this species (from February to April) contains both oocytes and embryos at different stages of development. The samples were counterstained with DAPI and Hoescht. Fixation with formalin or paraformaldehid destroys the general morphology and organization of the embryos so the fresh samples were the ones that permit us to obtain the most reliable results. Embryos are characterized by a segmented yolk mass that occupies an important fraction of the egg and an evident lipid drop. When the amount of ovarian fluid was scarce almost all the embryos found immersed in it were at early segmentation, formed by some big cells or by smaller cells if the development was more advanced. If the amount of ovarian fluid was important, the stages of embryos found were some early segmentation embryos but almost all of them were at blastula and discoblastula stages.. Among all the females examined, only in one occasion we observed one embryo with 16 clear somites, the most advanced stage of development we could found.

Sílvia Vila Espuña silvia.vila@udg.es
Campus de Montilivi
Facultat de Ciències
Universitat de Girona
Dept. de Ciències Ambientals
17071 Girona
Spain

P3-13

Identification of *Ichthyodinium chabelardi* - a lethal parasitic dinoflagellate infecting pelagic eggs of marine fishes

Skovgaard, Alf, Maria Manuel Angélico and Isabel Meneses

Ichthyodinium chabelardi isolated from eggs of various fish species. *I. chabelardi* was first observed half a century ago infecting eggs of sardine (*Sardina pilchardus*) and bristlemouth (*Maurolicus pennanti*). Recently, Ichthyodinium has been found in eggs of several other fish species like Atlantic mackerel (*Scomber scombrus*), yellow fin tuna (*Thunnus albacares*), and leopard coral grouper (*Plectropomus leopardus*) in Europe and Asia. Ichthyodinium is responsible for a substantial mortality of pelagic fish eggs and larvae, yet our knowledge on the basic biology and distribution of this parasite is only scarce. We isolated Ichthyodinium from eggs of sardine and bogue (*Boops boops*) of which the latter has not previously been reported as host for this parasite. Sequences of the small subunit rRNA gene showed that sardine and bogue eggs from Portuguese waters were infected by the same parasite, indicating that *I. chabelardi* is not host-specific. This European *I. chabelardi* was, however, genetically different from Ichthyodinium of yellow fin tuna and leopard coral grouper from Asian waters. The phylogenetic position of Ichthyodinium in relation to other dinoflagellates was demonstrated through analyses based on rRNA gene sequences. The identification and classification of Ichthyodinium is an important step for understanding the biology of Ichthyodinium and assessing its significance for mortality of eggs of marine fishes.

Isabel Meneses imeneses@ipimar.pt
IPIMAR
Av. de Brasília s/n, Algés,
1449-006 Lisboa
Portugal

P3-14

Ichthyodinium chabelardi (Hollande et Cachon, 1952): an indiscriminate killer of pelagic fish eggs

Meneses, Isabel, Catarina Vendrell and Maria Manuel Angélico

Infection of eggs and larvae of commercially important fish species by the parasitic dinoflagellate *Ichthyodinium chabelardi* has been studied in the NE Atlantic, the Mediterranean Sea and the Indian Ocean. Although little is know about this parasite, it is certain that infection can give rise to high mortality rates, possibly overshadowing other sources of mortality at the transition phase into free-swimming larvae. Infected eggs die soon after hatching, since the parasite depletes the energy reserves necessary for larval survival, and the yolk sac bursts, releasing parasite cells to the seawater. Recent reports of mass mortality in cultured yellow fin tuna (*Thunnus albacares*) and leopard coral grouper (*Plectropomus leopardus*) in Indonesia and Japan, respectively, have been attributed to the same parasite. In Iberian waters occurence of infected eggs in different species such as sardine (*Sardina pilchardus*) since 1991 and more recently horse mackerel (*Trachurus trachurus*), scombrids (*Scomber* sp.) and bristlemouth (*Maurolicus pennanti*) were reported. Scombrid eggs have been also studied in NE Atlantic European waters. Results show temporal and spatial variability of infection, with greater incidence from the northern Portuguese coast to the Bay of Biscay. Recent morphological observations of the endogenous part of the life cycle of the parasite and images of parasited eggs from different species of fish illustrate the non-specificity of *Ichthyodinium chabelardi* as a potential source of mass mortality for pelagic fish eggs.

Isabel Maria Cardoso de Sousa e Meneses imeneses@ipimar.pt
INRB/IPIMAR
Av. de Brasília s/n, Algés,
1449-006 Lisboa
Portugal

P3-15

Tracking of chum salmon fingerling in stream and coastal area off the Korean Peninsula

Kang, Sukyung, Suam Kim, and Joo Kyung Kim

Though the catches of chum salmon have increased more than double during the past 20 years due to favorable oceanic conditions and artificial enhancement programs, the conspicuous low survival rate was found in Korean chum salmon compared to other stocks. To evaluate the environmental effects on chum salmon survival in Korean waters, a series of larval/juvenile surveys were conducted in Namdae Stream and coastal area during 2005~2007. Six locations in the stream were chosen, and fries were collected approximately every 10 days during March through May. Also, 10~12 ocean stations were occupied for juveniles sampling with about 2~3 week interval in late spring. In stream, fries seemed to be transported toward the estuary in March. The highest densities in April and May, however, were found in upper stream. Fork length and weight were increased with time, but those parameters decreased at mid May as fast growing fries moved downstream. In ocean, chum salmon juveniles stayed mostly closed to the coastal areas, and showed tendency of northward distribution with time. Furthermore, negative correlation between sea surface temperature near the coastal area and return rate of spawners to natal stream three years later was found ($p<0.01$).

Suam Kim suamkim@pknu.ac.kr
Dept. of Marine Biology
Pukyong Natinal University
599-1 Daeyeon3-dong
Nam-gu, Busan 608-737
Korea

P3-16

Vertical positioning of larval cod in experimental temperature gradients

Vollset K.W., Ø. Fiksen and A. Folkvord

Life in the pelagic is characterized by minor smaller-scale horizontal gradients in environmental variables. Vertically however, physical and biological parameters will change with depth in distances within reach of larval fish by directional swimming. Marine fish larvae are characterized by fast growth and high predation rates, but changes in vertical distribution may be one way to mediate drift, growth and predation risk over ontogeny. Furthermore, positioning according to temperature in the water column allow larvae to behaviourally regulate its own metabolism and thus utilization of energy and growth. We set up a controlled lab experiment with vertical temperature gradients (8-4 ?C) to investigate change in vertical distribution and temperature exposure of cod through early life stages. The observations of vertical distribution were done in transparent plastic bags (20 cm DM and 1 m depth) at 10, 26 and 47 days post hatch. Observation of vertical positioning was done after 5, 10 and 120 minutes, then the light was turned off and after two hours the middle of the water column was sealed off by pursing the plastic bag. Preliminary results indicate that at early stages larval cod are all found in the upper few cm when water are stagnant, also in the homogeneous water column. At 26 dph they seek down in the water column, and do not seem to actively avoid the water below the thermocline. At 46 dph the cod actively avoids the coldest water and this avoidance is tuned according to the strength of the thermocline. Obviously there is an ontogenetic shift in where the larvae position themselves in the water-columns.

Knut Wiik Vollset knut.vollset@bio.uib.no
University of Bergen
Bergen, Norway

P3-17

Climate change and variation of hatching onset in Baltic herring (*Clupea harengus*) - a long-time analysis of spring spawning in the Greifswalder Bodden (ICES area 24)

Stuermer, Ingo W., Friedrich Nast, Birgitt Klenz, Christopher Zimmermann

Climate change, specifically the global warming of sea temperatures, may affect distribution and reproduction cycles of marine organisms. The influence of climatic conditions on herring stocks in the Western Baltic Sea is well described and analyses have utilised data back to the medieval. While most analyses study recruitment strength, we investigated the timing of hatching onset as one crucial factor to reproduction success. In this work, we analysed long-term data on herring larval development in the main spawning area of Western Baltic herring near Rügen Island since 1937.

Spawning of Baltic spring spawning herring in the Greifswalder Bodden and costal waters around Rügen was sporadically recorded since 1937 (literature data), and closely monitored since 1977 in the framework of the Rügen herring larvae survey (RHLS). Thirty-five defined stations were sampled weekly during most of the potential spawning period (April to June). Frequency distribution of larvae of the first relevant sample within each season, water temperature and date of sampling were used to recalculate the date of first significant hatching for each year. This varied between February (1937) and early May (1979). Literature data for 1937 to 1976 indicate mean first hatching in early April. A change in the hatching onset was apparent during the last 20 years: date of first hatching shifts from late March / early April to the middle of April. The obvious contradiction between large scaled warming and later onset of hatching points to complex mechanisms between climate change and local herring recruitment.

Ingo W. Stuermer ingo.stuermer@ior.bfa-fisch.de
Institute for Baltic Sea Fisheries
Federal Research Centre for Fisheries (BFA für Fischerei) Alter Hafen Süd 2
18069 Rostock
Germany

P3-18

Body density of Conger eel larvae increase in the process of inshore migration

Hiroaki Kurogi, Noritaka Mochioka

Conger eel (*Conger myriaster*) larvae, termed as leptocephalus, are known to migrate from warm offshore Kuroshio areas (20-26°C) to colder coastal areas (<16°C) with their growth; however, the mechanism of the inshore migration is still unclear.

Generally, there is negative relationship between temperature and density of sea water; therefore, the leptocephali are predicted to experience decreasing environmental density during the inshore migration. However, it is not known whether the leptocephali, which are devoid of a swim bladder, regulate buoyancy. To examine the presence of buoyancy regulation of the leptocephali, the body density of live leptocephali caught from cold coastal areas in which sigma-t ranged from 25 to 26 (13-15°C) were measured.

Repetitive measurments of the same specimens (n=10) revealed that the mean body relative density was higher in the day (1.029) than in the night (1.026), indicating that the leptocephali actively regulate the body density diurnally. The body density of leptocephali at mid-night ranged from 1.025 to 1.028, and larger individuals had a higher density, indicating the increase in the body density with the body growth. The body density of the leptochphali is ascertained to be lower in the offshore areas before migration than in the coastal areas because sea water density in upper layer of the offshore Kuroshio in which the leptocephali maintain neutral buoyancy ranges from 1.023 to 1.024. Therefore, the leptocephali are considered to increase the body density through the inshore migration process.

Hiroaki Kurogi hkuro@affrc.go.jp
National Research Institute of Fisheries Science, FRA
6-31-1 Nagai, Yokosuka
Kanagawa
238-0316 Japan

P3-19

Maternal Effects of Egg Quality on Progeny Morphology, Survival and Growth in Larval Atlantic Cod (*Gadus morhua*)

Bachan, M.M., Trippel, E.A., Fleming, I.A.

The early life history of larval fish is influenced by the quality of egg from which they derive. For marine serial spawners, such as Atlantic cod (*Gadus morhua*), questions exist about how the production of several distinct egg batches during the spawning season affect egg quality and subsequent larval morphology, survival and specific growth rate. During the winter of 2006, pairs of cod were allowed to spawn naturally in holding tanks at St. Andrews Biological Station where egg batches were collected, allowed to hatch and larvae given a food challenge over a 15 day feeding trial. Larvae were fed one of two diets; a high food diet (mimic aquaculture conditions), which consisted of 4 rotifers/mL, and a low food diet (mimic wild conditions at times of low food supply), which consisted of 1.5 rotifers/mL. Lipid analyses are being used to determine egg quality and to assess whether lipid classes or fatty acid composition differ between the successive egg batches and can account for offspring growth and survival variability within or among females. Thus far, it has been determined that fecundity and egg diameter and dry weight decrease with each successive egg batch of a female. Larval morphological traits (standard length, myotome height, jaw length, eye diameter and yolk sac area) and larval dry weight results indicate that these traits are related to egg size. Standard length, myotome height, jaw length (usually absent in 0 day post hatch (dph) larvae) and eye diameter increases between 0 dph larvae and 5 dph larvae, while yolk sac area diminished between 0 dph and 5 dph larvae. Results from the feeding trial indicate there is variability in survivourship between the larvae from the two diets. Specific growth rates and condition factor for these individuals are still to be determined to conclude whether egg quality has an effect on survival and growth, and how the maternal effect may vary with environmental conditions (i.e. food availability).

Michelle M. Bachan michellebac@gmail.com
Memorial University of Newfoundland
St. John's, NL
Canada

P3-20

Abundance and Summer Distribution of *E. encrasicolus* and *S. aurita* Larvae Along of Atlantic-Medterranean Coastal Oceagraphic Gradient

Ramos, Gloria and Juan Perez de Rubín

The aim of this work was to analyze the larvae abundance, distribution and their interannual variability in two small pelagic species, Engraulis encrasicolus and Sardinella aurita, along the coastal gradient between two different oceanographic provinces: the Gulf of Cadiz and Alboran Sea (Western Mediterranean). We analyzed 79 ichthyoplankton coastal samples (10 m to 100 m deep) of three summer surveys ICTIO.ALBORAN carried out in July of 1994, 1995 and 1996, between Huelva (Gulf of Cadiz) and Malaga's Bay (Alboran Sea). During 1994 and 1995, the distribution pattern was similar for both species, more abundant by far in the Gulf of Cadiz and Gibraltar Strait compared to Alboran Sea, representing between 95% and 94% for E. encrasicolus, and 78% and 99% for S. aurita. In 1994 E. encrasicolus was more abundant (1453 individuals/10 m2) than S. aurita (1039 individuals/10 m2) over this area, however during 1995, the abundance of S. aurita increased threefold (3194 individuals/10 m2), doubling the E. encrasicolus abundance (1547 individuals/10 m2). In other hand, the survey of 1996 showed a sharply different scenario of abundance and distribution pattern of both species, E. encrasicolus increased its total abundance, twofold (3406 individuals/10 m2) in the Gulf of Cadiz and Gibraltar Strait, and sevenfold along the Alboran Sea (657 individuals/10 m2), meanwhile S. aurita declined markedly almost disappeared from samples along the whole study area, 229 individuals/10 m2 in Gulf of Cadiz and 32 individuals/10 m2 along Alboran Sea. The results of this study showed the highly dynamic recruitment behavior of studied species. It is likely that interannual abundance variability is closely linked with oceanographic-environmental variability along the area, which is under strong influence of river run off and wind induced coastal upwelling belts, both of them in phase with atmospheric system.

Gloria Ramos Viera venade8@hotmail.com
Instituto Español de Oceanografía
Centro Oceanográfico de Málaga
Puerto pesquero s/n, Fuengirola (Málaga)
29640 Spain

P3-21

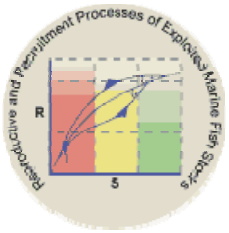
Interannual variability of length distributions patterns of anchovy and gilt sardine larvae in coastal waters of Gulf of Cadiz and N.W. Alboran Sea

Ramos, Gloria and Juan P. Rubín

The study area, along the coastal zone of S.W. Spain, are located in the Atlantic-Mediterranean frontier area. This study set about to investigate the time-space interannual variability of the length frequency patterns for the anchovy (*Engraulis encrasicolus*) and gilt sardine (*Sardinella aurita*) larvae shoals.

A total of 986 larvae of E. encrasicolus and 595 of S. aurita are measured from ichthyoplanktonic samples from three consecutive surveys (July 1994, 1995 & 1996). The widest length interval for both species comprised between 2-12 mm, nevertheless it was skewed to short lengths and with a trend, in both species, to increase the relative contribution of larger sizes during the last years. Particularly, the year 1994 was characterized by: 1) less larvae of both species as a whole, but equilibrated larvae abundance between Engraulis:Sardinella (?= 351 larvae / 1:1), 2) the widest spatial distribution for both (including Straits of Gibraltar) and 3) coincidence in the maximum larvae percentage (>80%) in the shortest sizes (2-3 mm). During the two subsequent years, the total abundance of larvae grew up gradually, nevertheless there were registered opposite dominance between the species: during 1995 (?= 548 larvae / Engraulis:Sardinella = 1: 2) and during 1996 (?= 682 larvae / 11: 1). In the other hand, during both years the larvae distribution of *E. encrasicolus* were wider (being dominant the largest sizes in Alboran Sea during 1996) than Sardinella (concentrated along the medium sector of Gulf of Cadiz).

Gloria Ramos Viera venade8@hotmail.com
Instituto Español de Oceanografía
Centro Oceanográfico de Málaga
Puerto pesquero s/n, Fuengirola (Málaga)
29640 Spain



P4-1

The evaluation of reference points and stock productivity in the context of alternative indices of stock reproductive potential

Morgan, M. J., H. Murua, G. Kraus, Y. Lambert, G. Marteinsdóttir, C. T. Marshall, L. O'Brien, J. Tomkiewicz

In this study we explore the impact of alternative indices of reproductive potential (RP) on perceptions of population productivity for eight populations across the north Atlantic, each with four different indices of RP. We examine how productivity measures differ when using different indices of RP, as well as impacts on limit reference points and estimates of population growth. Population status relative to reference points, RP per recruit and projections of population size were all affected by using alternative indices of RP. There was no consistency in which index of RP gave the highest or lowest estimate of population productivity. There are clear implications for estimating sustainable harvest levels and recovery time for depleted populations. Research should continue on producing and validating alternative indices of RP and on their incorporation into advice for fisheries management.

Joanne Morgan morganj@dfo-mpo.gc.ca
Fisheries and Oceans
Science, Aquatic Resources
Northwest Atlantic Fisheries Centre
St Johns, Newfoundland & Labrador
Canada A1C 5X1

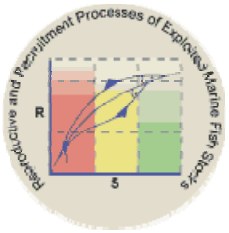
P4-2

Yield-per-recruitment analysis for Pacific anchovy (*Engraulis japonicus*) in Korean coastal waters

Sukgeun, Jung

Commercial catch of Pacific anchovy (*Engraulis japonicus*) in Korean coastal waters has steadily increased since the 1950's. To evaluate consequences of fishing activities on anchovy production and economic yield, I undertook daily simulations for the yield-per-recruit (Y/R) analysis by applying the derived growth function and size-dependent natural mortality. I evaluated consequences of changes in fishing activity by varying: 1) fishing mortality, 2) the length at first capture (Lc), and 3) the range of target lengths of fishing nets (Lr). Outcomes of Y/R analysis by varying Lc suggested that potential yield could be maximized when Lc ranges between 40-80 mm fork length (FL), while contribution to predators and reproductive capacity were maximized when Lc > ca. 85 mm. However, economic yield was relatively stable against varying Lc, because the price per weight of anchovy differs among the size classes in Korean markets. Although results suggested that reproduction capacity could be maximized when Lc and Lr > 95 mm, annual fluctuations in anchovy catch have been relatively stable, suggesting that strong density-compensatory recruitment processes must occur to maintain the long-term equilibrium of stock size and that a larger spawning stock size would not necessarily guarantee higher yield of anchovy.

Jung Sukgeun sukgeun.jung@gmail.com
National Fisheries Research and Development Institute
South Korea



P4-3

Temporal Changes in Size at Maturity and Their Implications for Fisheries Management for Eastern Bering Sea Tanner Crab

Zheng, Jie

Tanner crabs (*Chionoecetes bairdi*) in the eastern Bering Sea are primarily distributed in Bristol Bay and around the Pribilof Islands. Summer trawl survey data in these two areas were used to estimate mean sizes at maturity for female Tanner crabs from 1975 to 2006 and sizes at 50% morphometric maturity for male Tanner crabs from 1990 to 2006. Estimated mean sizes at maturity for females in both areas show a statistically significant downward trend during this period. Sizes at 50% morphometric maturity for males have declined significantly in Bristol Bay only. In Bristol Bay, the distribution centers of female Tanner crabs have shifted to southwest over time and the decrease in female mean size at maturity is statistically significantly related to changes in longitude and bottom depths. Because of terminal molt at maturity, the decrease in size at maturity has important implications for fisheries management: a smaller proportion of males grow to legal size and therefore a higher proportion of large-growing males are removed by the fishery before they have a chance to participate in reproduction under the current size limit. The size limit for male Tanner crabs in these two areas needs to be re-evaluated with respect to biological conservation and economic objectives of the fishery management plan.

Jie Zheng
P.O.Box 115526
Juneau, Alaska
99811-5526 USA

jie.zheng@alaska.gov

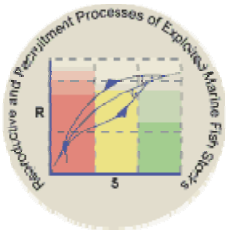
P4-4

Rebuilding the stock of Northeast Arctic Greenland halibut

Høines, Åge S. and Agnes C. Gundersen

In recent years a rapid increase in juvenile abundance of Greenland halibut (*Reinhardtius hippoglossoides* W.) in the Barents Sea has been observed. At the same time spawning stock biomass has increased. The swept area index of females larger than 70 cm, which means the main contributors to the egg production of the stock, has tripled since 1996 now reaching a level of 12 000 tons. This is seen after years of strong regulations, introduced in 1992. Regulations included allowance of only a very limited directed fishery for the species and strict bycatch regulations. Regulations were introduced after a dramatic change in stock situation for the NEA Greenland halibut during the 1980ies. In the 1960s and 1970s NEA Greenland halibut became an important species for the fleet fishing in the area. Catches increased rapidly from about 10 000 tons in the 1960s to 90 000 tons in 1970. In the 1980s fishing pressure was still high but the stock size declined, CPUE dropped, year class indices derived from regular 0-group and juvenile surveys dropped and that the spawning stock size reached historical low levels. In 1996 a survey programme started to map juveniles in previously not surveyed waters north and east of Svalbard. Nursery grounds were found and after rather stable indices in the first years the recruitment indices have increased with a tenfold from 2001 to 2006. It is therefore evident that rebuilding Greenland halibut takes time and that at least 12-15 years with restrictions are needed to recover from the low levels observed in the Barents Sea in the 1980s.

Agnes C. Gundersen agnes@mfaa.no
Moere Research, Aalesund
P. O. Box 5072
Larsgaarden
N-6021 Aalesund
Norway



P4-5

Recruitment and spawning stock in spring spawning Norwegian herring, North-east Arctic cod and haddock

Bondarenko, Mikhail V. and Valery P. Serebryakov

The precautionary approach dictates that unless it is scientifically demonstrated that there is no relationship between the parent stock and subsequent recruitment, such a relationship should be assumed to exist, even if the data are ambiguous.

Since abundance and biomass of the spring spawning Norwegian herring stock are dominated by only a few outstanding year-classes it was considered of interest to find out an existence and a form of such a relationship. Popular "stock-recruitment" models, which include density-dependent factor of mortality in early life, have been traditionally applied to the North-east Arctic cod and haddock populations. It is commonplace to believe that by means of these models it is possible to predict year-classes strength when spawning stock biomass and abundance are known.

The data set on spawning stock biomass, population fecundity and year-class abundance of herring at age 3 in the period of 1907-2002, and the same data set for cod in the 1946-2002, and for haddock in the 1950-2002 time series were used to make theoretical retrospective predictions of year-classes strength employing models developed by Beverton and Holt's, Ricker, Cushing and Shepherd.

Figures obtained with these models proved to be significantly different from the actual ones. The deviations from the observed figures exceeded 100% on the average, which precluded considering the models tested as perfectly adequate descriptions of recruitment dependency on spawning stock size.

An alternative method, which incorporates environmental impact on survival during early life history, was also used in attempts to reveal the stock-recruitment relationship existence and the form of it in the above-mentioned species. For a generalized environmental conditions factor a survival index was taken of a year-class, which is a ratio of the year-class abundance at age 3 to the spawning stock biomass or population fecundity.

Three types of recurrent in different years survival conditions were revealed, i.e. propitious, moderate and unfavorable conditions. Within each of these types of conditions dependence of recruitment on spawning stock can be described by means of regression equation with the determination coefficients 0.756 - 0.959.

A comparison was made by means of principal component analysis of survival index fluctuations with North Atlantic Oscillation (NAO) Index that is one of the main factors of climatic variations in the North Atlantic. The comparison showed than propitious survival conditions are associated with positive phase of NAO.

Mikhail V. Bondarenko bondarenko@vniro.ru
Early Life History Laboratory
VNIRO
V. Krasnoselskaya 17
107140 Moscow
Russia

P4-6

Adult parameters estimates of the European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) from the Gulf of Cadiz obtained during a June 2005 Spanish DEPM survey

Vila, Y., Millán, M., Ramos, F., Bernal, M., and Tornero, J.

Egg Production Method (DEPM) survey aimed at the Gulf of Cadiz anchovy spawning stock biomass (SSB) was conducted for the first time in June 2005. DEPM-based adult parameters estimates (i.e., mean female weight, W, sex-ratio, R, batch fecundity, F, and spawning fraction, S) from this survey are given in the present work. An exploratory analysis of the mean estimates of these parameters from individual samples evidenced the occurrence of a consistent spatial pattern in the mean female weight (W) and batch fecundity (F) per haul, which was characterised by a westward increasing gradient in the value of these parameters. The daily egg production in this survey also showed such a spatial structure. These evidences led to consider the possibility of a spatial modelling of both the egg and adult parameters. The suitability of a (geographic) post-stratification of the individual samples of DEPM adult parameters was accordingly tested by GLM and independent estimates for each of the two resulting spatial strata (Spanish and Portuguese waters) were computed.

Yolanda Vila Gordillo yolanda.vila@cd.ieo.es
IEO
Spain

P4-7

Regulatory assessment of fishing gear impact on non-target fish populations of Sierra Leone IEZ

Sheku Sei

Sierra Leone has a coastline of approximately 560 km, a continental shelf area of about 30,000 km2 and an EEZ of about 155,700 km2. The Sierra Leone coast enjoys a coral reef bounty of about 0.03% of the world and a primary production rate of about 643mgC.m-2.day-1. Illegal fishing gears and methods were introduced into the country's fisheries mainly as a result of a ten-year civil war, during which time the laws governing the fisheries were not fully enforced. Fish breeding grounds have been perturbed and juvenile stocks targeted. The industrial fishery is dominated by shrimpers that usually fish in the IEZ, taking substantial bycatch of finfish and other shellfish species, mostly juveniles, resulting into high discards rates. A decline in fish production figures from 1991-2002, shortages of fish at local markets, high level of juvenile fish in both industrial and artisanal landings and persistent net destruction conflicts, justified a regulatory assessment of fishing gears operating in the IEZ of Sierra Leone -mainly to evaluate impact of trawl fishing on inshore fish populations. Juvenile species occurring in discards include: *Panulirius* spp (spiny lobster), *Scyllarides herklotsii* (red locust lobster), *Illex coindetti* (squid), *Pseudotolithus epipertus* (gwangwa), *Dentex congoensis* (Snappers), *Sphyraena guachancho* (kinny), and other valued demersal species. The assessment targeted both industrial and artisanal fishing gears. For the industrial gears, shrimpers were targeted during transshipment exercises and data from Fisheries Observer logbooks were used to estimate bycatch and discards levels in shrimp and demersal trawl fisheries, using CPUE model. The targeted species in the shrimp fishery of Sierra Leone are: *Penaeus notialis* (pink shrimp), *Penaeus kerathurus* (caramote prawn) and *parapenaeus longirostris* (deep water rose shrimp). Mesh sizes of all shrimp trawl nets were measured. Gear designs were also assessed. The shrimp vessels are mostly of double-rigged trawler type. They are between 23-26m long with GRT ranging from 80 to 130. An EEC mesh-measuring gauge was used for cod end measurements using stretched mesh diagonal lengths. In the artisanal sector, fishing gears were assessed at major landing sites. Results of the study show that undersized nets are in use in both sectors. In the industrial sector, results were far below the 42 mm stretched mesh diagonal length used as standard for shrimpers, and far bellow the 25mm standard allowed for the artisanal sector. Average fish bycatch rates estimated for shrimpers range from409.73kg/vessel/day in 1991 to 721.94kg/vessel/day in 2002. In the demersal finfish trawl fishery, average bycatch rates range from 1132.11kg/vessel/day in 1991 to 2772.76kg/vessel/day in 2002. More than 20% of total bycatch landed in the shrimp fishery is discarded, while over 10% bycatch is discarded in the demersal finfish trawl fishery. The use of undersized mesh nets can have a negative impact on the population dynamics of a fishery, with severe consequences of growth overfishing. High level of juvenile fish in catch landings, production declines, high bycatch and discard levels are ecosystem indicators for fisheries management. Subsequent effect on spawning stock biomass will be the case if these indicators are not quantified. A more robust assessment work is ongoing and it is hoped that the results will be useful in suggesting management options for bycatch and discards reduction in Sierra Leone.

Sheku Sei seisheku@yahoo.com
Statistics and Research Unit
Ministry of Fisheries and Marien Resources
Jomo Kenyatta Road
New England, Freetown, Sierra Leone

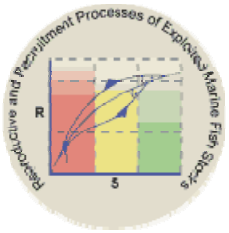
P4-8

Environmental variability and stock-recruitment relationships for European hake (*Merluccius merluccius* L.) off NW Africa

Meiners, César, Lourdes Fernández and Ana Ramos

Recently it was stated a strong dependence of European hake abundance with climatic and environmental variability in NW Africa This fact was related with changes in upwelling timing and its geographic coverage forced by the North Atlantic Oscillation (NAO), which probably affects the survival rate during early life stages of this species. In order to contribute to build predictive tools for stock management, the aim of this work was to analyze the environmental forcing described by NAO over the stock-recruitment (S-R) relationships of European hake fished in NW Africa during the last two decades. A classical density dependence hypothesis and an density-environmental-dependence hypothesis were considered. For the first case we used the classical Ricker and Beverton-Holt models. For the latter case we used a modified Ricker-NAO model. The explained variability of the models varied between 35% and 45%. However, the cross-validation analysis showed that the modified Ricker-NAO model showed the best fit in accordance with the Akaike information criterion (AIC). This model detected a direct effect of the North Atlantic Oscillation (NAO) on recruitment, during the favorable conditions (NAO+) the hake recruitment increased. The NAO variable determined the recruitment maximum at the same spawning stock biomass level acting as a carrying capacity proxy, maximizing the dispersion around the optimum spawning stock biomass (450 kg/fishing day) and minimizing the recruitment differences in the overcompensation area of the recruitment curve. We suggest that NAO index could be a robust proxy of environmental scenario which determines the amplitude of direct correspondence between the spawning stock biomass and recruitment of European hake in NW Africa. Unfortunately, there was impossible to get data from minimum spawning stock biomass period, which had allowed us to reduce the methodological limitations on this type of procedures.

Cesar Meiners cesar.meiners@ma.ieo.es
Centro Oceanográfico Fuengirola - IEO
Puerto Pesquero s/n Fuengirola 29640
Spain



P4-9

Regional variations of hogfish life history (Labridae: *Lachnolaimus maximus*) in Florida: consequences for spawning biomass and egg production models

McBride, Richard S., Paul E. Thurman, and Lewis H. Bullock

Life history traits of hogfish, a hermaphroditic reef fish, varied between samples from the Florida Keys (south Florida) and the eastern Gulf of Mexico (eastern gulf). Differences in female survivorship were associated with a high spawning stock biomass-per-recruit (SSB/R) in the eastern gulf (38% relative to a virtual, unfished population) and a low SSB/R in south Florida (16%); male SSB/R values were similar in each region even though there was a several year difference in the age at 50% maturation between sexes. In addition, differences in batch fecundity resulted in much higher lifetime fecundity in the eastern gulf compared to south Florida (9.7 vs. 2.1 million eggs). Relative to a virtual, unfished population, lifetime fecundity was still about 38% in the eastern gulf but only 8% in south Florida. Lifetime fecundity is not easy to measure, but the results here demonstrate how the SSB/R model can overstate the resiliency of fish stocks to recruitment overfishing. Both models, along with a previously published yield-per-recruit model, demonstrate the potential benefits to yield and recruitment that could result from an increase in the minimum size limit for hogfish.

Richard S. McBride richard.mcbride@noaa.gov
NOAA Fisheries
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543
USA

P4-11

Genetic population structure of Pacific cod over broad and local geographic scales

Canino M. F., Cunningham K. M., Spies I. B. , Hauser, L.

Genetic variation was screened in Pacific cod from seven geographic locations covering most of its demographic range using 11 polymorphic DNA microsatellite loci. There was a large genetic division between Asian and North American populations of Pacific cod, possibly resulting from vicariant separation during Pleistocene glaciation, indicating an absence of effective trans-oceanic migration in this species. Genetic distances were highly correlated with geographic distances in an isolation-by-distance (IBD) pattern in the northeastern Pacific, suggesting limited dispersal along contiguous coastal locations in North America. Exceptions to this IBD pattern were found in samples taken from the Strait of Georgia and Puget Sound, WA, which were differentiated from other North American coastal cod, inferring that more localized, and perhaps transboundary, stocks may exist. These results are consistent with what is known of population structuring in the congeneric Atlantic cod (Gadus morhua) and reveal population subdivision at spatial scales relevant to international and regional fisheries management practices.

Mike Canino
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA
98115 USA

Mike.Canino@noaa.gov

P4-12

Spawning biomass and production of Pacific anchovy, *Engraulis japonicus*, in the southern coastal area of Korea

Kim, Joo Il Young-Il Seo, Sukgeun Jung

Based on size-based theory and a cohort analysis, we estimated daily standing stock biomass and production of Pacific anchovy, *Engraulis japonicus*, in the southern coastal areas off the Korean peninsula. To apply the daily egg production method, we conducted 15 ichthyoplankton surveys from May to July 2005 and deployed a KOB 80 net obliquely for 5min from 10-m water depth to the surface layer at speeds of 1-2knots in the research vessel. Eggs were classified into the 9 developmental stages to estimate their mortality. The estimated daily egg production was 3,906 m-2 d-1 and mortality rate during the embryonic stages was 1.425 d-1. The average batch fecundity per female weight was 431 eggs g-1. Estimated female biomass of anchovy for the May-July period was 103 x 104 mt, but the cohort analysis indicated that the total anchovy biomass is seasonally-variable and could reach 980 x 104 mt in early November. Estimated potential production of age-0 anchovy was 40 x 106 mt yr-1, which peaked in September. Estimated fishing mortality derived from the catch statistics was 0.067 yr-1, which was marginal compared with the total mortality = production to mean-biomass ratio of age-0 anchovy, 11.3 yr-1.

Jung Sukgeun sukgeun.jung@gmail.com
National Fisheries Research and Development Institute
South Korea

P4-13

Factors affecting the recruitment on Horse-Mackerel (*Trachurus trachurus*)

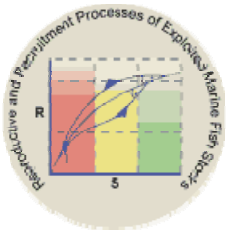
Costa, A.; Gonçalves, P.; Palma, S.; Murta, A.

Studies applied to different species reveals that the recruitment is positively correlated with spawner biomass. The assessment models to estimate fish biomass use information about reproductive variables such as age or length at maturity, fecundity and spawning frequency. Changes of these variables could affect the stock productivity and produce variability on the recruitment of fishes.

This study intends to contribute to a deep knowledge of the factors affecting the recruitment on horse-mackerel. Focused on the correlation between recruitment and the following relations: diameter of the yolked oocytes versus length composition of the females; fecundity versus length composition of the females; egg quantity versus egg quality.

The results of these intrinsic relations were compared with the productivity indexes in order to show the effect of extrinsic factors on the recruitment for this species.

Ana Maria Costa amcosta@ipimar.pt
INRB / IPIMAR - Instituto Nacional dos Recursos Biológicos
Instituto de Investigação das Pescas e do Mar
DAA - Departamento de Ambiente Aquático
Av. Brasília, 1449-006
Lisboa, Portugal



P4-14

Can a single-transect sampling strategy be reliable in monitoring sardine and anchovy spawning and recruitment off South Africa, in the southern Benguela Current region?

Tsotsobe, Sakhile and Jenny Huggett

South Africa's commercially important sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* spawn mainly during austral spring and summer on the Agulhas Bank (particularly sardine) and on the west coast (particularly anchovy) of South Africa. Eggs and larvae are then transported along a shelf edge Benguela jet current into nursery grounds on the west coast. The Sardine Anchovy Recruitment Programme was initiated in August 1995, with the aim of investigating the transport of early life stages of the two species by the jet current. This study elucidates long-term temporal distribution patterns of eggs and larvae along the SARP Monitoring Line - a transect crossing the jet current. Biweekly sampling from August to July already shows different seasonal patterns in the eggs and larvae of sardine and anchovy, with anchovy showing a strong preference for spawning between October and February (with peak egg/larval abundances in November-December), whereas sardine spawning is at best uniformly distributed throughout. This paper intends to make use of 12 years of data to investigate whether the SARP Line is still useful in monitoring spawning and recruitment of sardine and anchovy, especially in light of the recently observed eastward shift in sardine spawning. Also, it will be investigated if there have been any changes in the behaviour of the jet current, which possibly resulted in the eastward shift of sardine spawning.

Sakhile Tsotsobe stsobs@deat.gov.za
Marine & Coastal Management
Private Bag X2
Rogge Bay
8012
Cape Town, South Africa

Northwest Atlantic Fisheries Organization
P. O. Box 638 • Dartmouth Nova Scotia B2Y 3Y9 Canada
Telephone (902) 468-7542 Fax (902) 468-5538
E-mail: journal@nafo.int

Reproductive and Recruitment Processes of Exploited Marine Fish Stocks

Manuscripts will be published in a special symposium issue of *JNAFS* and should be submitted to the General Editor by 30 November 2007. The symposium Convenors will act as Editors and arrange for peer review to normal scientific journal standards. Accepted MS will be published electronically, in fully citable format, on the journal's webpage soon after final acceptance. The bound volume will be printed in April 2009 as Volume 41 and distributed at cost to the participants.

Information for Preparing Manuscripts for NAFO Scientific Publications

Journal of Northwest Atlantic Fishery Science

JNAFS is for the primary publication of original practical and theoretical research that is unpublished and is not being submitted for publication elsewhere. It is intended to be regional in scope, although papers of general applicability and methodology will be considered. Space is also provided for notes, letters to the editor and notices. Each MS is assigned to an Associate Editor of the Journal's Editorial Board, and is normally reviewed by two referees.

Content of Paper

The MS should be concise and in English. The inclusion of excessive data and statistics should be avoided.

Title

The MS should start with the title, followed by the name(s), address(es) and emails of the author(s) including professional affiliation, and any related footnotes. A running-header should also be provided.

Abstract

An informative concise abstract should be provided along with key words listed alphabetically.

Text

In general, the text should be organized into Introduction, Materials and Methods, Results, Discussion, and Acknowledgements. Authors should be guided by the organization of previously published *JNAFS* articles.

Introduction should be limited to the purpose and rationale of the study.

Materials and Methods should describe in sufficient detail so as to enable other scientists to evaluate or replicate the work.

Results should answer the questions evolving from the purpose of the study in a comprehensive manner and in an orderly and coherent sequence, with supporting tables and figures.

Discussion should explain the main contributions from the study, with appropriate interpretation of the results focusing on the problem or hypothesis. Comparisons with other studies should be included here.

Acknowledgements should be limited to individuals who provided significant scientific and technical support, including reviewers, during the preparation of the paper, and the names of agencies which provided financial support.

References

The references cited in the text should be listed alphabetically. References should be mainly restricted to significant published literature. Unpublished documents and data, papers in preparation, and papers awaiting acceptance to other journals, may be cited with full contact addresses as unpublished or personal communications.

Examples:

KING, M. 1995. Fisheries biology, assessment and management. Fishing News Books, UK, 341 p.

CROWDER, L. B., and S. A. MURAWSKI. 1998. Fisheries by-catch: implications for management. *Fisheries*, **23**: 8-16.

ÁVILA DE MELO, A. M., D. POWER, and R. ALPOIM. MS 2005. An assessment of the status of the redfish in NAFO Division 3LN, *NAFO SCR Doc*., No. 52, Serial No. 5138, 19 p.

Text citations of the above would be (King, 1995; Crowder and Murawski, 1998; Ávila de Melo *et al*., MS 2005) with *et al.* being used for more than two authors. The citation of mimeographed reports and meeting documents should contain the abbreviation "MS". Abbreviations of periodicals can be found ftp://ftp.fao.org/fi/asfa/Monitoring_List/MASTER.txt The Digital Object Identifier (doi) should be included if available. http://www.crossref.org/freeTextQuery/ can be used to checked this.

Tables and Figures

Tables and Figures must be cited in the text, and numbered consecutively and correspond with the order of presentation in the text. Figure captions should be included as a separate page. Each table and figure should have a complete concise descriptive caption. Figures should be submitted in black and white. Color plots and photographs are acceptable only if color is essential to the content. Preferably, all figures should be submitted as separate files in .eps or .ps format. Under certain circumstances, .doc format may be acceptable. Photographs, maps and contour plots can also be submitted in high quality .jpg format.

Paper Submission

Papers should be submitted in MS WORD, or similar, format by email to Dr. A.B. Thompson, General Editor, at **journal@nafo.int**