



BASIN: Basin-scale Analysis, Synthesis, and INtegration

**Resolving the impact of climatic processes on ecosystems of the North Atlantic
Basin and shelf seas**

Report of the first BASIN Specific Support Action (SSA) meeting held at the University of
Hamburg's Institute for Hydrobiology and Fisheries Science,
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Abbreviations

ACSOE - Atmospheric Chemistry Studies in the Oceanic Environment
AMO - Atlantic Multidecadal Oscillation
AMT - Atlantic Meridional Transect
AUV - Autonomous Underwater Vehicle
BASIN - Basin-scale Analysis, Synthesis and INtegration
BATS - Bermuda Atlantic Time Series Station
CAVASOO - Carbon Variability Studies by Ships of Opportunity
CPR - Continuous Plankton Recorder
EDDIES - Eddies Dynamics, Mixing, Export, and Species composition
GLOBEC - Global Ocean Ecosystem Dynamics
IBM - Individual-based modelling
IFREMER - Institut français de recherche pour l'exploitation de la mer
IMBER - Integrated Marine Biogeochemistry and Ecosystem Research
JGOFS - Joint Global Ocean Flux Study
LOICZ - Land-Ocean Interaction in the Coastal Zone
NAO - North Atlantic Oscillation
OMEX - Ocean Margin Exchange
PAP - Porcupine Abyssal Plain
PFT - Plankton Functional Type
POLCOMS - Proudman Oceanographic Laboratory Coastal-Ocean Modelling
POMME - Programme Océan Multidisciplinaire Méso Echelle
PRIME - Plankton Reactivity in the Marine Environment
SeaWiFS - Sea-viewing Wide Field-of-view Sensor
TASC - Trans-Atlantic Study of *Calanus finmarchicus*
WHOI - Woods Hole Oceanographic Institution

I. EXECUTIVE SUMMARY

The justification for the BASIN program is the scale of influence of global change and the added value of co-ordinating the scientific activities of the EU and North American countries to assess, predict, and mitigate the impact of climate and anthropogenic forcing on marine ecosystems and services of the North Atlantic. A crucial step towards such a co-ordinated approach is the development of an implementation plan whereby jointly funded international projects can be supported. The development of such a plan is the first key goal of BASIN. The second goal of BASIN is to develop an integrated basin scale North Atlantic science plan. The BASIN program will seek

- “to understand and simulate the population structure and dynamics of broadly distributed, and trophically and biogeochemically important plankton and fish species in the North Atlantic ocean,
- to resolve the impacts of climate variability on marine ecosystems and the feedbacks to the climate system, and
- to develop understanding and models that will advance ocean management.”

The development of the program goals began at the meeting in Hamburg and will continue at a second meeting to be held at the beginning of May in North Carolina. These meetings involve open discussion in working groups with experts from both the EU and North America. The approach taken towards the development of a science plan for BASIN begins with

- the assessment of the status of climate-related ecosystem research in the North Atlantic Basin and associated shelf seas,
- identification of the gaps in systematic observations and process understanding of atmospheric and oceanic parameters, and
- identification of the potential for consolidation of long-term observations from EU and international databases for modelling and prediction.

The BASIN science plan will focus on resolving the natural variability, potential impacts and feedbacks of global change on the structure, function, and dynamics of ecosystems. The program will also seek to improve the understanding of marine ecosystem functioning. Improved understanding and modelling will be applied to the development of new and improved approaches to ecosystem-based management.

BASIN will contribute significantly to the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan via the development of comprehensive, coordinated, and sustained observations of the earth system, improved monitoring of the state of the earth, increased understanding of earth processes, and enhanced prediction.

This report, from the Hamburg meeting, summarizes the activities and discussions from the first of four BASIN meetings to be held during 2007. These meetings are supported by the EU Specific Support Action BASIN and the NSF. The purpose of this European meeting was to start the process leading to the development of a Science Plan that would enable the integration and advancement of observation, monitoring, and prediction of ecosystems of the North Atlantic basin and shelf seas in order to assess the impact of climate variability and change on their processes.

A number of questions for potential further development were identified during the Hamburg Workshop. These include:

- How will climate change, as manifested through changes in, e.g., temperature, stratification, transport, etc., influence the phenology of features such as the spring bloom, the flux of carbon to the deep ocean, and interactions between trophic levels? How do these dynamics differ from the shelf to the open basin? What are the potential feedbacks to climate?
- Has the harvesting of resources such as fish stocks resulted in a restructuring of marine ecosystems? How do these changes in ecosystem structure influence the sequestering of carbon in the deep ocean and on the continental shelves as well as the resilience of these ecosystems?
- How are the populations of phytoplankton, zooplankton, and ichthyoplankton influenced by the present large-scale basin circulation and what is the influence of changes of the oceanic and atmospheric climate on their population dynamics?
- How do the overwintering strategies of organisms, involving both vertical and horizontal migration, lead to the observed patterns of community structure?

II. INTRODUCTION

This meeting was the first of four BASIN meetings to be held during 2007, and was supported by the EU Specific Support Action BASIN and the NSF as well as the FP 6 European Network of Excellence EUROCEANS. The purpose of this European meeting was to start the process leading to the development of a Science Plan that would enable the integration and advancement of observation, monitoring, and prediction of ecosystems of the North Atlantic basin and shelf seas in order to assess the impact of climate variability and change on their processes. Three other meetings will follow: one with a focus on the North American research community, one with program managers to explore joint funding mechanisms, and finally a fourth meeting to write the Science Plan.

This meeting was held at the Institute for Hydrobiology and Fisheries Science in Hamburg and hosted by Dr. Michael St. John, Vice-Director of the Center for Marine and Climate Research. Thirty two scientists attended this first meeting, with twenty-seven from Europe and five from North America.

The steering committee for the BASIN SSA consisted of Mike St. John, Roger Harris, Cisco Werner, Peter Wiebe, and Brad de Young. Most of these individuals met the day before the official start of the meeting to review the agenda and to make final adjustments to the charge to the meeting's working groups.

III. NARRATIVE OF THE WORKSHOP

The meeting opened at 0900 on 23 January (Tuesday) with welcoming remarks by Mike St. John and Peter Wiebe. This was followed by a presentation by M. St. John describing the rationale for the SSA workshop series and the ultimate goal of developing a BASIN Science Plan. He described what this workshop was intended to accomplish. Dr. Ana Teresa Caetano, a program manager from the EU (research DG) described elements of the EU 7th Framework (2007-2013) structure and programs, and highlighted ones that were relevant to the BASIN initiative. P. Wiebe provided a description of the report of the March 2005 Iceland BASIN meeting (Wiebe, P.H., R.P. Harris, M.A. St. John, F.E. Werner and B. de Young. (Eds.). 2007. BASIN. Basin-scale Analysis, Synthesis, and INtegration. GLOBEC Report 23 and U.S. GLOBEC Report 20. 1-56pp), which provides a basis upon which the current series of workshops can build.

Following morning coffee, a series of 30 to 45 minute talks were presented during the last half of the morning (See Appendix 1). These talks were intended to provide background information related to the effects of climate on marine ecosystems of the North Atlantic and their services both biogeochemical and the production of exploited resources such as fish stocks. In the early afternoon after lunch there was another series of shorter talks to enable meeting participants to present issues they felt were important to the generation of the BASIN Science Plan.

In the late afternoon, the three working groups were formed to discuss a series of key issues associated with “Biogeochemistry” (Chair, Frede Thingstad; Rapporteur, Tom Anderson), “Ecosystems” (Svein Sundby, Chair; Icarus Allen, Rapporteur), and “Exploited Resources” (Fritz Köster Chair; Richard Nash, Rapporteur). While the working groups had a “disciplinary composition” the intention was to ensure good cross-fertilization and effective integration of these communities which was perceived as key to the BASIN concept. The groups were asked to:

1. Survey and report on the status of climate-related ecosystem research in the North Atlantic Basin and associated shelf seas;
2. Identify the potential for integration of long-term observations/data (available and otherwise) for the modelling and in particular prediction of the dynamics of North Atlantic and associated shelf ecosystems and their services (biogeochemical and exploited resources); and,
3. Identify and document gaps in systematic observations and process understanding of atmospheric and oceanic parameters, including those of climate, necessary to improve forecasting of ecosystems in the North Atlantic and associated shelves.

Specific sub-topics were posed under each over-arching theme.

The day’s sessions ended at 1815. The evening was highlighted by a special wine tasting event with the wines and informed discourse about them provided by Jürgen Alheit.

On Day 2 (Wednesday, 24 January), the meeting started at 0900 with a plenary session (chaired by M. St. John) in which an additional series of four talks were given that focused on aspects of ecosystem and biogeochemical modelling.

During the last hour of the morning session, the working group leaders presented reports on their group's progress in addressing the three topics. T. Anderson presented for the "Biogeochemistry" group, I. Allen presented for the Ecosystem group, and F. Köster presented for the "Exploited Resources" Group.

Immediately after lunch, the working groups went into separate rooms to continue their deliberations. In the late afternoon, the groups again met in plenary session (chaired by R. Harris) for a short time to review the questions that each group had come up with and discussion focused on how to make some of them more basin-scale oriented.

A group dinner was held at a popular restaurant in the center of Hamburg, the Gröninger Braukeller, where traditional German food and drink was enjoyed.

The Groups started day three (Thursday, 25 January at 0900) in separate sessions working on topics they had not yet completed. At 1145, R. Harris chaired a plenary session to discuss working group reports. T. Anderson presented on "Biogeochemistry" and reviewed their product; F. Köster talked about "Exploited Resources", and I. Allen reviewed the "Ecosystem" group's product. Following the group reports, discussion then turned to the next SSA meeting, now scheduled for the week of 30 April in Chapel Hill, North Carolina.

The meeting ended about 1300 on 25 January with a show of appreciation to Mike St. John and his staff for the fine meeting support.

The Steering committee met for an afternoon session where the details for preparing the meeting report and logistical aspects for the next meeting were worked out.

IV. SYNTHESIS OF WORKING GROUP REPORTS

Three working groups were formed by the themes of “*Biogeochemistry*”, “*Ecosystems*”, and “*Exploited Resources*”. They were asked to address the same three topics. The following is the integration of the information developed by the groups.

Topic 1: Survey and report on climate-related ecosystem research from the North Atlantic Basin and associated shelf seas;

Biogeochemistry

Programs: JGOFS, CPR, BATS, AMT, PAP, CAVASOO, POMME, BICEP (FISHES), Marine Productivity, TASC, PRIME, ACSOE, SeaWiFS and associated programs, OMEX, LOICZ, EDDIES.

a) What topics were addressed?

Open Ocean Biological pump (including export); spring bloom dynamics (including pre-bloom); variability of zooplankton populations in time and space; seasonal succession; biogeochemical provinces; CO₂ fluxes; eddy dynamics; food web structure; life history of targeted zooplankton species; trends in surface chlorophyll; shelf-sea exchanges.

b) What were the key findings of previous programmes?

- Meridional gradients in export are smaller than gradients of primary production.
- Primary production over winter is larger than expected in the northern N Atlantic.
- Diatoms contribute less to spring blooms than had been thought.
- Carbon and nutrients often show net consumption that deviates from Redfield stoichiometry.
- Export to the deep ocean can occur in sporadic events.
- DOM accumulates seasonally and has a vertical gradient; varying lability.
- Unique ecosystem structure in oligotrophic gyres.
- Role of the microbial food web as a source of nutrition for copepods.
- Importance of mesoscale/sub-mesoscale in biogeochemical cycles.

c) What are the knowledge gaps?

- Roles of multiple limiting nutrients in controlling community structure.
- Differential dissolution/remineralisation; twilight zone processes.
- Factors controlling export flux, e.g., ballast.
- Roles of different plankton functional types in controlling fluxes and structuring phytoplankton communities, e.g., jellies, salps.
- Role of biophysical interactions at small scales.
- Overwintering strategies for phytoplankton and zooplankton.
- Shelf-open ocean exchange processes.
- Cycling and remineralisation of DOM.

- Amount and controls of N₂-fixation.
- Amount and ecology and ecophysiology of calcification.

d) What questions are now pertinent?

- What is the role of different nutrients in controlling ecosystem structure throughout the N. Atlantic basin, and how might this change in future? How might changes in the elemental stoichiometry of organisms affect trophic transfer and biogeochemical cycles? (The N. Atlantic is ideal for this because of the contrasting regimes – dust from Sahara leading to potential P-deficiency in gyres, N-deficiency in north, etc).
- What influence do overwintering stocks of zooplankton and phytoplankton have on processes in spring? What strategies do organisms employ to survive over winter, and what is the resulting community structure at the end of the winter? (Again, contrasting regimes – deep winter mixed layer in northern N Atlantic vs. oligotrophic gyres; spring bloom very large in north, unlike southern gyre).
- Are continental shelves a significant source or sink of inorganic nutrients and/or C to the deep ocean? (e.g., N. Atlantic may have significantly increased runoff, with implications for exchange across the shelf).
- What is the importance of climate variability (interannual to decadal) on ecosystem structure, export flux and for higher trophic levels?
- Given that the potentially important processes of climate change as regards the N. Atlantic and shelf seas during the 21st century (e.g., temperature, atmospheric composition, hydrological cycle), what are the resulting biogeochemical feedbacks in the ocean (e.g., changes in supply of nutrients to the euphotic zone, acidification, leading to changes in species or functional groups)?
- How might export across the base of the thermocline change with climate change? What is the role of the mesopelagic zone in processing nutrients and C and so influencing this export?

e) What kinds of models are required to address these questions?

Given the current state-of-the-art (with no current consensus), a variety of models must be employed.

Physics: existing GCMs provide the structure upon which to build model frameworks however advances are needed. In particular these are:

- Increased spatial and temporal resolution, together with things like mixed layer schemes and parameterizations are of great importance in order to adequately capture the scales of biological and or biogeochemical interest;
- realistic diapycnal mixing;
- realistic forcing;
- improved sea ice models;
- shelf-open ocean coupling;
- benthic boundary layer;
- tidal mixing;
- unstructured grid models;
- Forecasting models to design experiments;
- Variety of approaches for ecosystem models, e.g., targeted complexity; documented

- validation; size structure vs. functional types;
- It's important to emphasise that a range of ecosystem models is needed. NPZD models appear to do a reasonable job at getting first order properties such as chl, primary production and nutrients right;
- A priori more complexity is needed in order to get more subtle climate feedbacks but, given the difficulties in adequately parameterising this extra complexity, a range of models should be explored at this stage rather than just opting all-out for complexity;
- Validation is of critical importance;
- The rhomboid approach – targeting complexity at particular trophic levels of interest presents a potentially promising way forward.

Ecosystems

Programs: Ecosystem research with international cooperation. Work started in 1990; ICES Cod and Climate Change program Small Pelagic fish and Climate Change (international GLOBEC); ECOMON, CPR... (national monitoring); TASC, Trans-Atlantic Study of *Calanus finmarchicus*; ICOS, LIFEKO - linking hydrography, ecosystem dynamics and fish recruitment etc.

a) What questions were addressed?

- Effect of temperature on processes (prior to 80's).
- More mechanistic approach – NAO – correlation but what's the mechanism?
- Bottom up effects as the controlling factors (consensus) e.g., circulation on zooplankton and hence fish?
- Top-down control in shelf systems? (longer time scale).
- Climate acts independently on different trophic levels (wasp waist controls).
- Focus on zooplankton and larval fish trophic levels and influence of climate.
- What are the underlying multi-scale biological physical mechanisms controlling recruitment of cod and haddock and the dominating prey species on Georges Bank, in relation to global climate change?
- Effects of frontal processes on ecosystem dynamics.

b) What were the key findings?

- Climate influences all trophic levels, individual levels and interactions, i.e., climate acts on the whole ecosystem.
- New advances about fish recruitment and zooplankton but mechanisms controlling population dynamics were not sufficiently resolved.
- Move from bulk energy flow approach to individuals and species.
- Most influential physical process is the NAO – lots of insights but caused confusion as mechanisms were not clarified.
- Revealed linkage between zooplankton populations and fish recruitment.
- Georges Bank - link between physics (salinity), phytoplankton, zooplankton and larval fish (cod and haddock).
- German GLOBEC – link with physics and sprat.
- Norway – No obvious link between phytoplankton production and production of

zooplankton. Link between stability of water column and timing of the bloom, an early bloom is good for *Calanus*.

- Different ecosystems (diatom: dinoflagellate balance changing) what are the ecosystem consequences?
- Physical forcing acts at the individual level.
- Hydrodynamic models don't have enough resolution to model advective processes.
- Necessary for the model to address the relevant spatial and temporal scale of the process, population or individual.

c) *What are the knowledge gaps?*

- NAO a proxy for something we don't understand.
- Relationship between recruitment and zooplankton dynamics.
- Lack of knowledge of what really controls diapause and boundary conditions (*Calanus finmarchicus* – basin scale).
- *Pseudocalanus* – cod and haddock feed on them (coastal – need to look at genetics?) and are important for larval fish.
- *Calanus helgolandicus* – what is its overwintering strategy? Close the life cycle, why is it not found in the Western North Atlantic when it's in the deep ocean?
- C. fin./C. helgo. Balance and implications for changes with changing climate.
- What is the link between biogeochemically important groups such as coccolithophores and key species such as *Calanus*?
- Other zooplankton? – Pteropods?
- What is the importance of *Calanus* feeding on microbial loop (micro zoo)?
- How important is trophic upgrading in controlling the populations of higher trophic levels?

d) *What questions are now pertinent?*

Lower trophic level (phytoplankton, bacteria, micro zoo)

- What is the basin scale variability in primary production?
- What is the food quality and how is this transferred up the food chain?
- What are the causes and consequences of changes in the phytoplankton community (diatoms vs. dinoflagellates) on biogeochemical cycling and recruitment (food-chains, food quality).
- What is the basin scale variability of the impact of top down (grazing) control on phytoplankton community composition?
- How will climate change affect basin-scale spring bloom dynamics and what are the consequences for zooplankton and implications for the survival of fish populations?
- Is an early spring bloom required for good trophic transfer and successful recruitment?
- What changes occur in biogeochemical cycling between and early spring bloom and a late one – how does this propagate up the food chain?
- What are the consequences of large-scale changes in the fluxes (transport of salt, heat, IOP, nutrients, etc...) of Atlantic and Arctic water on ecosystem productivity and function?
- How will changes in stratification change the different phytoplankton community (lower foodweb structure), what are the consequences for the ecosystem?

Mesozooplankton level (population dynamics of key species)

- How do pan-Atlantic population exchanges between shelf and ocean control ecosystem dynamics? How are these exchanges influenced by climate change?
- How will biogeographic regions be maintained in the N Atlantic and how will they change with climate change? What are the consequences for biodiversity?
- What maintains the biogeographic boundaries between con-generic species?
- What are the mechanisms causing and ending diapause in different parts of the basin?

Larval fish and planktivore levels (separate or with meso-zoo?)

- How will climate change affect basin scale spring bloom dynamics and what are the consequences for zooplankton prey and implications for the survival of fish populations?
- Role of horizontal migration on a basin scale and basin scale interconnectivity, interaction with advective transport of prey.
- Nonlinearities in biological cycles (e.g., long-lived fish), what are the interactions with climate cycles?

Other questions and relevant topics

- Do human-introduced invasive species from one side of the basin to the other occupy similar niches. If so, what will be the ecological and biogeochemical implications?
- How does climate change modify the success of invaders? Are there basin-wide differences and are they influenced by biodiversity/ecosystem structure?
- What is the best climate proxy and why? AMO vs. NAO? What is the spatial extent of these proxies (AMO much larger spatial scale, equal on both sides of the Atlantic)?
- Larval loss driving recruitment variability (e.g., storms wash larvae for GB). Effects of on/off shelf transport (zooplankton, larvae etc.).
- What eats *Calanus* (other than fish larvae) – is predation by deep water fish species important for the over wintering population or is predation not that important?
- Predation on fish larvae – big black hole (DNA probes).
- Advection – shelf-basin communication.
- Do zooplankton control biogeochemical flux by restructuring phytoplankton communities?
- Do zooplankton mediate the continental shelf carbon fluxes around the basin?
- How does zooplankton distribution and species composition affect the C flux to the deep ocean?
- How and when does the microbial loop contribute to higher trophic level production?
- Why don't many deep ocean species overwinter on the continental shelf (eaten or exported)?
- What is connectivity between shelf populations of zooplankton?
- What are the causes and consequences of drastic changes in community composition
- What is the impact of timing of the spring bloom on higher trophic levels? (Example: early bloom better haddock recruitment Scotian shelf).

e) What kinds of models required?

- High resolution.
- Model frontal distributions? Modelling shelf slope front dynamics. Shelf edge currents.
- Individual Based Models (IBMs) linked to realistic physical forcing.
- Hydrographic models – need good meteorological forcing that resolves climate forcing, but is also at a spatial and temporal resolution to capture key biological and biogeochemical processes.
- Modelling light climate.
- Sub-grid scale physics.
- Regeneration of production is poor - microbial.
- Are feeding links defined properly?
- Individual species vs. bulk properties.
- Intermediate complexity models to encapsulate complex adaptive systems.
- Implementation of trophic couplers with two way feedbacks.

Exploited Resources

a) What questions were addressed?

- Key population dynamic rates (F, M, growth, maturation including bioenergetics, etc), recruitment addressed for most commercially exploited species. Distributions also covered for a number of species. These studies covered different life stages, but only few cases of all life history stages within one stock.
- Studies addressing the effect of climate change on a species or stock in an ecosystem context, considering also their prey (e.g., zooplankton, benthic invertebrates, and small benthic fish) and predators (e.g., birds) are more seldom. Likewise studies on guilds or communities are seldom, but important, as fluctuations/variability in single exploited stocks are much more pronounced than in guilds or communities.

b) What were the key findings?

- The responses of fish populations to climate forcing are non-linear and non-stationary.
- Biological reference points presently used are not robust against global change. Nevertheless, there are surprisingly good correlations with large-scale atmospheric indicators and there is an apparent overall stability in the production of resources. Result of feedbacks in complex adaptive systems?

c) What were the knowledge gaps?

- Whole life cycle for many stocks/species, especially the late larvae/early juvenile stages.
- Knowledge on key turning points in mortalities of early life stages.
- Factors that regulate mortalities in critical phases of the life history.
- Even in well investigated species (e.g. North Sea herring) the factors causing extremely high or low reproductive success are not well understood.

- The prey species and community dynamics associated with target species is normally not well known.
- Limits to our knowledge of the spatial distributions of fish species.
- Of great importance is a lack of understanding of temporal and spatial variability in key vital rates (note that present stock assessment models are based on a homogeneous stock dynamics).
- The ability to disentangle fishing and climate (forcing functions) (note that the interaction between both is more important for management).
- Models to adequately predict into the future (note that our present assessment and management system account for this by relying on monitoring most recent stock development and, based on abundances of prey-recruit stages, prediction is short-term i.e. (2 years) ahead only).
- All existing methodology for medium predictions (beyond 2 to 3 years) is highly unrealistic and cannot be used for management, which affects in the present system biological reference points.

Topic 2: Identify the potential for integration of long-term observations for the modelling and in particular prediction of the dynamics of the North Atlantic and associated shelf ecosystems and their services.

Biogeochemistry

a) What data sets exist?

- Data sets for programs listed under (1).
- EU FP data; data “rescue” from previous EU programs.
- Model output.
- Station data, e.g., “M”, PAP, India, BATS.
- Ferrybox.
- Laboratory data?
- Mesocosm data.

b) How should data be shared and managed?

- See Glover et al (2006): DSR II [Glover, D.M., C.L. Chandler, S.C. Doney, K.O. Buesseler, G. Heimerdinger, J.K.B. Bishop, and G.R. Flierl, 2006: The U.S. JGOFS data management experience, *Deep-Sea Res. II*, 53(5-7), 793-802.].
- Openly Common formats where possible. Ensure user-friendly interfaces, e.g., web-based, for automatic download of data. Data should be made available within the program at the earliest opportunity to the public, e.g., 2 years.
- Model output and codes to be made freely available.
- European data centre; metadata held centrally?
- BASIN should have its own web server – metadata can go there.

c) What models do we have?

- Physics: Various GCMs: z-level, isopycnic or some mixture of the two; POLCOMMS; nested grids; very high resolution, local-domain models, e.g., HOPS.
- Ecosystem: Everything from NPZD to complex PFT models such as ERSEM and DGOM. Stage-structured zooplankton models linked to NPZD or food fields. Size-structured models. Adaptive models. Lagrangian models.

Ecosystems

a) What data sets exist?

- See appendix A of the Reykjavik report for additional information.
- ICES Cooperative Research Report No 281 2006.
- CPR – SAHFOS (phyto and zoo), ARGO, Ferrybox, Coastal Obs (Station L4, POL, Helgoland), Ocean Obs (BATS, PAP, station M etc), AMT, CAVASOO (pCO₂), Global Plankton data base, Fisheries data holdings, BODC, ICES, Icelandic zooplankton time series, Norwegian data holdings, Russian Data.
- GMES – Thematic data portals (satellite data and operational *in situ*).

b) How should data be shared and managed?

- Freely and openly available. Requires accessible and inter-operable distributed data base with web-based data delivery. Extant data needs to be brought together so they can be accessed in a holistic manner.
- Where does new data go? How is it stored and managed?
- How do we make data available in a coherent way? (Key players BCO_DMO (US, Wiebe), CDATA NET (BODC, etc....), GMES TEPS, ICES data management office, NERC data grid, etc.
- Some Data archaeology is required. See Table below which lists some data sources and a preliminary assessment of availability.

Data Source	Freely Web accessible	Web accessible on request	On request	Not available
Georges Bank GLOBEC	X			
GMES satellite (ocean colour, SST, SSH, Ice) from 2008	X			
GMES (in –situ) from 2008	X			
Helgoland roads	X		X	
Canada GLOBEC	BIO/MEDS			
UK GLOBEC		X (BODC)		
TASC			X (CD)	
ICOS				X
German GLOBEC		X (password)		
L4	X			
Icelandic				
CPR	X	X		
Labrador Sea transect				
Mare Cognitum				X
ICES WGZE Storfjorden gear intercomparison			CD from ICES	
Atlantic Meridional Transect		X (BODC)		
POMME				
PANGEA		X?		

c) What models do we have?

- Basin scale physics (NEMO, OPA, FOAM, TOPAZ etc...).
- Shelf seas physics (POLCOMS, ROMS etc...).
- Basin scale NPZD (NOCS, PISCES etc).
- Basin PFT (BFM, Planktom etc).
- Shelf, Benthic –Pelagic (ERSEM, etc).
- Zooplankton models (Carlotti, Fennel, Neumann Moll, Spiers,).
- IBM’s larval fish (Norwegian, Georges Bank, North Sea, Baltic).
- Single and multi species VPA (ICES).
- Fisheries (GADGET; FEMS; ECOPATH, ECOSIM etc.).

Exploited Resources

a) What data sets exist?

- Fish surveys (incl. biol./physical data): ICES in Europe in most cases, West-Atlantic from the NMFS and DFO.
- Fisheries data: Nations restricting the availability of area/time dis-aggregated data, refers to catch composition, effort etc.
- Suggestion: Agreement within BASIN that all databases available in participating institutes be available to the project.
- Practical approach: to ally with projects compiling necessary data (CLIOTOP: tuna, PROTECT: Baltic, STECF: North Sea etc).
- Aggregated data available at ICES, ICCAT, NAFO and non NAFO stocks: NMFS, DFO, may also be approached for disaggregated data.
- Tendency: to create national databases holding raw data and web-based access tools to draw aggregated data out (EU, JRC).
- Fish surveys (incl. biol./physical data): ICES in Europe in most cases, West-Atlantic from NMFS and DFO.
- Biological data in relation to fish (and related biological environment) from dedicated studies: scattered among a variety of research scientists (even for larger scale international projects) (note there is an FP7 SSA topic published for procedures to handle historic and future data from EU projects). US/Canada have obligation to make data publicly available if funded from government sources.
- Physics: in contrast freely available, when archived, but entirely clear what each database contains. Danger may be: different datasets originating from one data source.

b) How should data be shared and managed?

- Problems in all areas (but important in our data categories).
- Availability: none existence, del. restricted availability, none accessible due to technical and/or political limitations, completely freely available.
- Biol. data in relation to fish (and related bio. environment) from dedicated studies: scattered at each scientist even for larger scale international projects → FP7 SSA topic published for procedures to handle historic and future data from EU project. US/Canada have obligation to make data publicly available if funded from government sources.
- Physics: in contrast freely available, when archived, but clear what each database contains. Danger may be: different datasets originating from one data source.
- Action for BASIN, building meta-databases (using presently ongoing similar activities, e.g. UNCOVER) and for specific target species and related environment also creation of databases.

c) What models do we have?

- Fish stock assessment models, well understood, but normally not spatially explicit. There are a few examples of spatially explicit models: ISIS, Tuna, and North Sea.
- Fisheries distribution modelling (human behaviour) in progress, but not BASIN focus.

- BASIN work would provide key results for later collaboration on such work.
- Fish distribution (behaviour): Modelling fish distribution mostly available as statistical approaches. Predictive models need functional relationships on environmental forcing.
 - Metabolism, bioenergetics models to understanding productivity, specifically growth, maturation, egg production: coupled models seldom, but check e.g. Walleye Pollock. Needed also for food consumption models.
 - Recruitment: statistical relationships between recruitment (mostly to fishery) and environmental forcing available. Life stage process models (very diverse, challenge to get an overview). Life cycle models either rather crude (SRR in medium-term projections), or non existent. Available are however models coupling two life stages (e.g., eggs/larvae, larvae/settled juveniles, settled Juveniles/adults).
 - Attempts to close life cycle in Multispecies models (e.g., GADGET), e.g. linking food consumption to growth, maturation, egg production on one side and juvenile mortality (predation) on the other. Models address spatial differences on large scale, but far away from closing mismatches between scales on which processes act and are modeled. Prey selection sub-models of importance.
 - Progress in integrating fish early life stages into 3-D physical/biological models (covering stages with limited behaviour).
 - Suggestion for BASIN: Integration of both schools is one goal.
 - Size structured population to ecosystem models.
 - Mass balance models (→ Ecosystem model)?
 - Dynamic energy budget models (RECAIM).
 - Ensemble modelling approaches may be an option.

Topic 3: Identify and document gaps in systematic observations and process understanding of atmospheric and oceanic parameters, including those of climate, necessary to improve forecasting of ecosystems in the North Atlantic and associated shelves.

Biogeochemistry

a) What are the data gaps?

- Data gaps link to knowledge gaps (1c).
- Plankton functional types; organic nutrients and carbon (including lability).
- Zooplankton, particularly microzooplankton and mesopelagic zone zooplankton.
- N₂-fixation.
- Flux rates.
- Ballasting.
- Micronutrient biogeochemistry, e.g. Fe.

b) What new information should be collected?

- Physiological indicators for limitation by different substrates in phytoplankton and bacteria.
- Characterization of twilight (mesopelagic) zone, e.g., sedimenting and suspended particles (including ballasting properties).
- Describe distribution and amount of calcifying organisms (e.g., coccolithophores and forams). Impact of acidification on these and other organisms.
- Impact of changes in pH on calcification and the Redfield ratio.
- Benthic measurements (?) in shelf areas.
- Balance between isopycnal transport and diapycnal mixing in terms of vertical fluxes.
- Not new, but need to emphasize need for high-resolution survey work with measurement of many variables of interest, as well as time series studies. But need to be able to scale up to basin scale using framework of basin-wide observations. Also, need to sustain existing measurements, both *in situ* and remotely sensed.
- Characterisation of export flux, particularly in terms of ballasting minerals as well as organic matter.
- Characterisation of the phytoplankton, and indeed zooplankton, community in terms of functional types.

c) What models do we need?

- Unstructured grid models; two-way nesting; interfacing between open ocean and shelf seas models; non-hydrostatic.
- Data assimilation.
- Intermediate complexity ecosystem models – that compromise between simplicity and additional complexity in order to be able to give realistic predictions, given the problems inherent in complex models. Variety of ecosystem models to be subjected to rigorous validation. We can't say right now what level of biological complexity is ideal.

- Ecosystem models do nevertheless need sufficient complexity to address important system features and feedbacks, e.g. multiple nutrients, or particular PFTs. Targeted complexity.
- Need to consider carefully whether, given limited computing resources, to crank up the resolution, go for extra complexity, or do multiple runs.

d) What new observational tools are required?

- Advanced sediment traps, e.g. neutrally buoyant.
- Genomics tools for specific biogeochemical functions.
- New AUVs.
- New tools for automated characterization of community structure.
- Methods to handle much more water at sea.

Ecosystems

a) What are the data gaps?

- Mixed layer dynamics, entrainment across the thermocline.
- Lots of qualitative data (e.g., CPR) but big lack of quantitative data (biomass, fluxes, vital rates).
- Knowledge of measurement error is crucial!
- Basin scale spatial distributions of most species.
- What are the mechanisms causing and ending diapause in different parts of the basin?
- Spatially and temporally resolved predation estimates.
- Zooplankton influence on flux rates.
- Influence of top down and bottom up controls on trophic structure.

b) What new information should be collected?

- Food quality.
- C requirements of planktonic predators (respiration) essentially scope for growth.
- N, P requirements.
- Basin-scale distribution of predators.
- Better boundary conditions.

c) What new models do we need?

Physical

- Better ice models.
- Frontal resolving models.
- Improved light climate.
- Finer spatial scales.
- Unstructured grids (the future, basin scale within 5 years).
- High resolution physics.
- OSSE (Observing System Simulation Experiment) – to help design experimental setup
- Basin scale re-analysis – physics. We can get started with what we have got (coupled

- basin/shelf physics).
- Eddy resolving, resolve the Rossby radius.
- Basin scale models to provide fluxes (volume, heat) from the Arctic and equatorial regions correctly and to drive basin scale re-analysis of ecosystem and provide good boundary conditions.
- 2-way nesting.
- Clean assimilation over nested grids.
- Better mixing parameterizations.
- Improved resolution of atmospheric forcing – liaise with national met services.

Biological models

- Zooplankton models: Intermediate Complexity and two way coupling.
- Currently full age structured individual species (Pseudocalanus, Cal. fin, etc.) coupled to NPZD – quasi 3D resolved.
- One-way coupling – P to Z. Need two way coupling. Big issue with numerical diffusion: one solution tracking mean age of stage.
- Big issue: lack of data to parameterize species-specific functional curves. Need information on feeding on phytoplankton and protozoa.
- Big challenge: to link correctly to microbial loop.
- What is the role of food quality? Do we need to model cellular fatty acid content, essential amino acids, toxins?
- What is the transfer efficiency of food quality from the microbial loop to zooplankton. How do we build this into intermediate-complexity?
- PFT's must contain a measure of food quality.
- PFTs (functional for zooplankton – this is the key group for this system).
- IBM (larval fish): Correct parameterisation of current models big challenge but need data/process understanding. What questions contribute to recruitment or process understanding? Big black hole is mortality. Who is feeding on whom? Models require predators. What are the predator fields (other than planktivorous fish)? Better models of the predators. Lack of knowledge of the vertical behavior of larvae. Observations can provide a predator field.
- Benthic models – crucial for shelf sea “Biogeochemistry” and demersal fish. Existing models require new data for validation. New models needed (what is the complexity needed, chemistry vs biology?).
- Other issues: Mixing by biota? Bio-feedback. Mucus changing viscosity, affecting mixing and vertical movement, settling. Effect of blooms concentrating heat in the upper layer.

c) What new observational tools are required?

- Use of observing system simulation experiments (OSSEs).
- Build on existing data collections (e.g., satellite EO, *in situ* buoys, VOS, ARGO, CPR, coastal observing systems, long term time-series, etc.... GMES should deliver a lot of this).
- New sensors, Flow cytometer, optical plankton, acoustics, DNA/Fish analyses, metabolomics.

- Gliders – with biological measurement.
- Undulating Video Plankton Recorder – towed.

Exploited Resources

What are the data gaps?

- Accurate catch information.

What new information should we collect?

- Natural mortality rates (predation rates).
- Process information for input to scenario testing models.

a) What new models do we need

- Integration of modelling suites, geochemical, ecosystem and fishery in to one cohesive and workable unit.

b) What new observational tools are required

- Platforms e.g. drifters, autonomous vehicles (including the animals themselves e.g. tuna, large cod etc).
- Sensor development, i.e. acoustics.
- Matrix of platforms and sensors e.g. Biological Markers, tags; Argo float program; Argos III dual way system (communication to the platform/sensor).

V. APPENDICES

Appendix I.

Agenda

BASIN SSA Hamburg meeting Agenda

Tuesday January 23rd

0900-0915

Welcome: Michael St. John and Peter Wiebe

0915-0945

Goals of the BASIN Specific Support Action: Michael St. John

09:45-10:15

The EU Seventh frame work Program and BASIN Expectations: Ana Teresa Caetano

1015-10:45

Synopsis of the Iceland Meeting in 2005: Peter Wiebe & Roger Harris

1045-1100

Agenda and goals for the working groups: Michael St. John

11:00-1130

Coffee

Plenary Talks

11:30 –12:00

Regime Shifts In Marine Ecosystems: A European Perspective: Jürgen Alheit

12:00 -12:30

Climatic forcing on Calanus and fish populations in the NA BASIN: Svein Sundby.

12:30-13:00

Climate Change Impacts, and Climate-Fishing Interactions: Benjamin Planque

13:00-13:30

Deep convection. Implications for phytoplankton and Zooplankton Dynamics: Jan Backhaus

13:30-15:00

Lunch

15:00- 16:15

Presentations by participants: Each Participant will have the opportunity to present 4 slides on topics or issues they feel are of importance for the generation of the BASIN Science plan.

- Dale Haidvogel - Pan Regional Synthesis in US GLOBEC program.
- Nils Tøkle- Trondheimsfjord sampling and field work with Temora and Calanus
- John Allen - why is he interested in BASIN.

- Wilfred Kühn - Ecosystem modelling
- Andreas Moll – Structured Population Modelling
- Webjorn Melle - Norwegian Sea Sampling
- Justus van Beusekom – Helgoland Time Series

16:15- 1630

Coffee

1630-1800

Three breakout groups (initially “Biogeochemistry”, “Ecosystems”, and Exploited Resources) to address the following Action Topics:

(1) Survey and report on the status of climate-related ecosystem research in the North Atlantic Basin and associated shelf seas;

- a. What questions were addressed?
- b. What were the key findings?
- c. What were the knowledge gaps?
- d. What questions are now pertinent?
- e. What kinds of models are required to address these questions?

(2) Identify the potential for integration of long-term observations/data (available and otherwise) for the modelling and in particular prediction of the dynamics of North Atlantic and associated shelf ecosystems and their services (biogeochemical and exploited resources);

- a. What data sets exist?
- b. How should data be shared and managed?
- c. What models do we have?

(3) Identify and document gaps in systematic observations and process understanding of atmospheric and oceanic parameters, including those of climate, necessary to improve forecasting of ecosystems in the North Atlantic and associated shelves;

- a. What are the data gaps?
- b. What new information should be collected?
- c. What new models do we need?
- d. What new observational tools are required?

Working Group Products

WG reports contributing to the development of the BASIN science plan. Contributions should comprise 2 pages per topic in a bulleted form with brief explanations containing relevant references. These should be available at the close of the meeting.

18:00 Break for the evening.

18:30 Get Together at IHF.

Wednesday, January 24th

09:00-09:30

Perspectives in Ecosystem Modelling: Tom Anderson

09:30- 10:00

Biogeochemical modelling in the North Atlantic: Andreas Oschlies

10:00-10:30

Ecosystem modelling on the European Shelf: Icarus Allen.

10:30-11:00

Coupling lower trophic levels and fish: Patrick Lehodey

11:00-11:300

Coffee

11:30-13:00

Plenary Session - Working Group Reports

13:00-14;30

Lunch

14:30- 16:00

Reassemble in Breakout Groups to continue discussion and documentation of Action Topics.

15:30-16:00

Coffee

16:30- 18:30

Plenary Session - Working Group Reports

19:00

Group dinner at local restaurant.

Thursday, January 25th

0900- 1115

Breakout Groups to continue discussions and documentation of Action Topics

11:15-11:45

Coffee

11:45-13:00

Plenary report and submission of written reports

Discussion of topics to be specifically addressed in the following workshops.

Timeline for future workshops.

Adjournment 13:00

14:00-18:00 Steering committee's collation and synthesis of report.

Appendix II.

Breakout groups: Chairs and Rapporteurs

“Biogeochemistry” (Frede Thingstad, Chair; Tom Anderson, Rapporteur),

“Ecosystems” (Svein Sundby, Chair; Icarus Allen, Rapporteur),

“Exploited Resources” (Fritz Köster Chair; Richard Nash, Rapporteur).

Appendix III.**BASIN SSA Hamburg Meeting Participants**

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