Workshop on History of Marine Animals (H-MAP)

February 19-22, 2000

Center for Maritime and Regional History, Esbjerg, Denmark

Tim Smith and Poul Holm

Appendices to the Workshop Report

Appendices

Appendix 1: H-MAP Workshop Agenda

Saturday

19:00: Dinner at Hotel Hjerting

Sunday

9:00-10:00: Presentation of Census of Marine Life: Ausubel
Workshop agenda: Smith and Holm

10:00-11:00: Case study 1: Implications from history on ecological effects of fishing on the Grand Banks

* Historical Perspective
    - European Perspective: Starkey, Barkham and Lopez
    - North American Perspective: Hutchings
* Ecological Perspective: Myers

11:00-12:00: Case study 2: Effects of aperiodic environmental fluctuations in the Skagerrak, western and eastern Baltic

* Ecological Perspective: Conley, Alheit, MacKenzie
* Historical Perspective: Jahnke, Holm and Bager

14:00-16:00: Identification of potentially testable ecological hypotheses: Smith, Steele, Hutchings, Myers

16:00-18:00: Research agenda of H-MAP (first session)

Monday

9:00-10:00: Status and potential
    Status and potential for reconstruction of cetacean populations: Smith
    Status and potential for reconstruction of ecosystems, the Strait of Georgia case study: Christensen
    Status and potential of the N California current ecosystem: Francis

10:00-11:00: Status and potential for historical and ecological studies of Barents Sea fisheries: Lajus
    Status and potential for paleo-ecological studies: Francis, Finney

11:00-12:00: Status and potential for historical and ecological studies of Japanese fisheries: Kalland, Matsuda
    Status and potential for historical studies of Latin American fisheries: Reid

12:00-13:00: Lunch

13:00-14:00: Status and potential for historical studies of South African fisheries: van Sittert
    Status and potential for historical studies of Australian fisheries: Tull

14:00-15:00: Overview of status of ecological knowledge of large marine ecosystems: Smith

15:00-16:00: Overview of state of selected historical archives: Holm

16:00-18:00: Research agenda of H-MAP (second session)

Tuesday

9:00-12:00: Research agenda of H-MAP (third session)

Appendix 2: Participants

Alheit, Jurgen - Baltic Sea Research Institute, Warnem nde, Germany

Ausubel, Jesse - Alfred P. Sloan Foundation, New York, USA

Bager, Maibritt - Center for Maritim og Regional Historie, Esbjerg, Denmark

Christensen, Villy - University of British Columbia, Vancouver, Canada

Collie, Jeremy - University of Rhode Island, Rhode Island, USA

Conley, Daniel - National Environmental Research Institute, Roskilde, Denmark

Decker, Cynthia - National Oceanographic Partnership Program, Washington D.C. USA

Fisher, Lewis - Memorial University of Newfoundland, St. John's, Canada

Francis, Robert - University of Washington, Seattle, USA

Holm, Poul - Southern Denmark University, Esbjerg, Denmark

Jahnke, Carsten - Staffelde/Altmark, Germany

Kalland, Arne - University of Oslo, Oslo, Norway

Kinze, Carl - University of Copenhagen, Copenhagen, Denmark

Lajus, Julia - Russian Academy of Sciences, St. Petersburg, Russia

Lassen, Hans - International Council for the Exploration of the Sea, Copenhagen, Denmark

Markham, Michael - Bilbao, Spain

Matsuda, Hiroyuki - University of Tokyo, Tokyo, Japan

McKenzie, Brian - Danish Fisheries Research Institute, Copenhagen, Denmark

Myers, Ransom - Dalhousie University, Halifax, Canada

Polacheck, Tom - CSIRO, Hobart, Australia

Reid, Chris - University of Portsmouth, UK

Rozwadowski, Helen - Georgia Institute of Technology, USA

Smith, Tim - Northeast Fisheries Science Center, Woods Hole, USA

Starkey, David - University of Hull, Hull, UK

Steele, John - Woods Hole Oceanographic Institution, Woods Hole, USA

Tull, Malcolm - Murdoch University, Perth, Australia

van Sittert, Lance - University of Capetown, Capetown, South Africa

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Appendix 3: Southern Hemisphere Working Group

Participants: Tull (rapporteur), Polacheck, van Sittert, Reid, Ausubel

Question 1. Define Candidate ecosystems/fisheries

For the Southern Hemisphere, six possible candidate ecosystems/fisheries were identified. These were the marine mammal fisheries (i.e. whaling and sealing) in the Antarctic, the Southeast Australian shelf and slope ecosystem, the Humboldt Current ecosystem, the Benguela Current ecosystem, the Bay of Bengal ecosystem, and the Northern Australian pearl fishery.

The Antarctic marine mammal fisheries were included because the history of these fisheries should provide the basis for examining how large was the biomass of megafauna in this system and what was the effects of its removal on community structure and species composition.

The Southeast Australian shelf and slope ecosystem was included because it is an example where there is a good prospect of reconstructing the complete history of exploitation from a locally important multi-species trawl fishery with high levels of fishing mortality and where scientific survey data exist prior to the commencement of exploitation.

The Humboldt and Benguela current systems were considered because there has been extensive controversy about the extent to which exploitation versus environmental forcing has been the dominant factor in the observed changes in abundance and community structure in these ecosystems. Both of these are important upwelling systems and would provide the potential for comparative analyses.

The Bengal ecosystem was included because it is an important artesianal and commercial fishery serving the needs of a densely populated region and it was considered important to include a system from the Indian Ocean. Issues to be explored include the interaction of pollution and heavy levels of exploitations on community structure in a multi-species fishery.

The Northern Australian pearl fishery was included because it is an example of an important sedentary invertebrate benthic fishery with a long history of exploitation. It provides a basis for comparison of the impacts of wild and aquaculture fisheries on the habitat.

Questions 2 and 3. Identify State of knowledge and expertise

For the Antarctic marine mammal fisheries there exists an extensive body of information on the ecology of the exploited stocks and the overall system. There are also extensive historical catch and recent scientific survey data, much of which exists in computerized form, particularly for whales. There are needs to fill in gaps relative to seals, early period of exploitations and mis-reporting of catches. If this were to be an H-map case study there would need to be close collaboration with IWC and CCAMLR.

For the Southeast Australian shelf and slope ecosystem extensive information exists on the ecology of the fish species. There are detailed historical fishery data from the commencement of exploitation as well as survey data. There is a need to reconstruct the total level of removals, but extensive relevant historical data exists.

The Humboldt Current ecosystem has been well documented since the 1970s and it has been the focus of biological/ecological and physical oceanographic studies. The extent of the historic data is uncertain but extensive trade data exist, particularly with respect to the guano trade. This should allow reconstruction of the fluctuations in this system.

The Benguela ecosystem has been the focus of extensive scientific study since the 1950s both with respect to exploitation and the ecology of the system. There exist historical data (including survey information) going back to the 1800s. There is also pale-archaeological information that may provide information on centennial scale fluctuations.

For the Bay of Bengal ecosystem, there has been extensive research in recent years. Information on the historical data was not available at the meeting, but given the British colonial influence it is likely that there is a substantial archive.

The Northern Australian pearl fishery has been the focus of extensive biological research. Historical data are available on the fishery from the commencement of exploitation, though there is uncertainty about the spatial resolution of these data. Relatively fine scale resolution may be important for examining ecological hypotheses for sedentary species.
Question 4: Ecological Hypotheses

This question was discussed but the working group felt that at this stage it was premature to specify them in detail as more research is needed.

Candidate Ecosystems for Initial Study

The working group identified two priority studies, one the Southeast Australian shelf and slope ecosystem and the other a comparative study of four eastern boundary currents.

Candidate 1: Southeast Australian shelf and slope ecosystem

Detailed catch and effort data exist for the trawl fisheries that have exploited this system. This provides information on catch weight, composition and location on a haul by haul basis from the start of exploitation in the early 1900s. The existence of the scientific survey data that pre-dated exploitation plus additional survey data which have been collected at various times subsequently can provide important snapshots of the system. Some preliminary results shown at the workshop demonstrated a range of important ecological questions that could be readily addressed.

Historical research is needed to reconstruct the entire time series of catches and, as far as possible, the effort series. This would entail archival research into fish market statistics and fishery department records. Also, oral interview of fishers and related material on the socio-economic aspects of the fishery are needed to ensure meaningful interpretation of the archival material. There is also the likelihood that additional personal records (e.g. skipper logbooks) could be obtained and this should be pursued. It was judged that this could be achieved in a reasonable time frame with a modest amount of resources

Candidate 2: Comparative study of four eastern boundary current ecosystem:

The four boundary currents at the east coast of the Americas, Africa and Europe (California, Humboldt, Benguela and Canary Current) are very similar ecosystems. They are characterized by strong upwelling generating high plankton production which supports large pelagic fish populations. It is argued here that a comparative study would be of great benefit as the data from the four systems are of mutual support to each other as:

The four systems have the highest productivity when compared to other ecosystems all over the world, The fish species mix in the four systems is the same: sardine, anchovy, jack mackerel, mackerel and hake populations most of which are under heavy exploitation at present,

The four ecosystems are under strong external forcing by the coupled ocean/atmosphere system,

There are clear teleconnection patterns (sardine and anchovy populations in the Pacific exhibit synchronous population swings and their periods of high and low biomass alternate with those in the Benguela Current),

The high plankton production caused anaerobic sediments which are excellent archives of past production regimes.

Outline of a comparative study of the eastern boundary current ecosystems

To illustrate this study, the group described the state of ecological knowledge, the nature of the archives, and the potential ecological hypotheses and expertise in greater detail.

State of Ecological knowledge

Fish population dynamics in the four systems are well known because of long-time research activities of the governmental fisheries agencies of all countries bordering the eastern boundary currents. The dramatic changes in biomass of sardines and anchovies, the so-called regime shifts, appear to have been caused largely by external physical forcing. Over fishing seems to have played in many cases only a secondary role. The nature of this external physical forcing and the causal relationships between the dynamics of the coupled ocean/atmosphere system and the reactions of fish populations are obscure. The regime shift between sardine and anchovy periods seem to re-structure entire ecosystems including phyto- and zooplankton communities. Large collections of zooplankton sampled over several decades are stored in laboratories of all four ecosystems. The analysis of these zooplankton long-term time series would yield important information on regime shifts. However, due to lack of funds, the samples have not been analyzed.

Historical and paleo archives

Social scientists are needed to disentangle environmental impacts from anthropogenic impacts on the exploited fish populations. They can provide (1) data on the onset of the fishery, i.e. the threshold between sampling and exploitation phases, (2) historical catch and effort series data for whale, seal, fish and guano harvesting as well as historical survey data, (3) qualitative data to provide additional "soft" indicators of environmental conditions and population levels, and (4) critical appreciation of discourse between science, agencies and practitioners, especially with respect to debates surrounding the importance of environmental forcing against human intervention, i.e. analysis of documentation.

Fish catch and effort data exist for the last 50 years and for the California Current for an even longer period. There are extensive sets of long-time environmental data which have not been analyzed to a large extent in the Benguela and Canary Current. Sites of anaerobic sediments containing a wealth of information on fish population dynamics (fish scale abundance in sediments) and past environmental regimes have been identified in the California, Humboldt and Benguela Currents and are likely to be found in the Canary Current. Research projects analyzing sediment cores in the California and Benguela Currents are on-going and planned for the Humboldt and Canary Currents.

Ecological Hypotheses

Main hypothesis: The dramatic changes in productivity (regime shifts) on the decadal to centennial scale in eastern boundary currents are due to physical forcing. This has to be investigated by a combined effort of scientists of the four ecosystems using data from long-term time series of existing collections (fish, plankton, physical data) and paleo studies (over the last 500 years).

Goals: (1) to understand the dynamics of past productivity systems eventually to predict future scenarios and (2) to give sound advice to improve fisheries management.

Expertise and Organization of Study

Research laboratories of the countries bordering the eastern boundary currents are already waking on the issues presented here. What is needed is an international co-ordinated effort to combine research results from the four different ecosystems.

Local expertise: (list is not complete)

South Africa	Rob Crawford, Cape Town (fisheries) Hans Verheye, Cape Town (plankton) Lance van Sittert, Cape Town (social sciences)
Namibia	E. Klingelhoeffer, Swakopmund (fisheries, plankton)
Portugal	M. Rios, Lisbon (fisheries, physics)
Spain	C. Porteiro, Vigo (fisheries)
US	B. Francis, Seattle (fisheries, paleo) P. Smith, La Jolla (plankton) M. Ohman, Scripps (plankton) M. Glantz, Boulder (social sciences)
Mexico	T. Baumgartner, Esenada (paleo)
Peru	S. Carrasco, Lima (plankton) J. Zuzunaga, Lima (fisheries)
Chile	R. Serra, Valparaiso (fisheries, plankton)

Outside expertise (list not complete):

Germany	J. Alheit, Warnem nde (plankton, fisheries) G. Wefer, Bremen, (paleo) V. Struck, Munich (paleo)
UK	C. Reid, Portsmouth (social sciences) C. P. Reid, Plymouth (plankton)

Potential partners for co-operation and funding:

BENEFIT program in Benguela region
World Bank project in Benguela current
French aid project in South Africa
German aid project in Namibia
IAI projects in Mexico, Peru, Chile
GLOBEC project of IGBP

<u>Main Steps in development of project</u>:

1st step Organization of regional workshops to identify research needs

2nd step Organization of workshop with representatives of all regions to identify gaps and common goals

3rd step Research (including funding of technicians and students to process samples and data)

4th step Joint analysis of data from all four ecosystems in regional and "global" workshops

Training and capacity building should be integral parts of project.

Appendix 4: North Pacific Working Group

Participants: Christensen, Kalland, Matsuda, Reid, Francis (rapporteur)

Question 1: Define Candidate Ecosystems/Fisheries

Identified 4 candidate ecosystems

- British Columbia and Washington State coast and inland seas
- Bering Sea & Aleutian Islands
- Sea of Japan and Inland Sea
- South China Sea Shelf

Identified several overarching issues

- Role of megafauna in ecosystem structure and dynamics
- Historical phases or regimes of human impacts (e.g. pre-exploitation; harvest of megafauna/mammals primarily; harvest of fish)

Question 2: State of ecological knowledge

British Columbia / Washington	Bering Strait / Aleution	Japan	S. China
Good data	Good data back to 1950s, 60s	Good on Japanese side	Excellent surveys in Gulf of Thailand since 1960s
Better ecological data for Strait of Georgia, Hecate Strait, than Puget Sound	Food habits		

Question 3: Identify historical & paleo archives

British Columbia / Washington	Bering Strait / Aleution	Japan	S. China
Paleo-Effingham, Saanich Essentially same as BS/Aleut.	Few paleo archives. Info - voyagesof discovery, Russian settlement. Climate ~ 100 yrs. Trawl survey since mid 1970s. MM harvest - Russia, Japan.	Catch data since 1905. Time series of sardine trade in Osaka. Archival data for snapshots.	Fishery starts very recent. Not much environmental data. No paleo data.

Question 4: Identify ecological hypotheses which might be tested (numbers refer to report text).

British Columbia / Washington	Bering Strait / Aleution	Japan	S. China
Essentially same as BS/Aleut. Terretsrial input 3, 5 Aquaculture impacts	MM/Fishing 5, 5.7 Ecosystem Structure under 3 regimes. 5	Effects of fishing 4, 5 Eutophication Aquac. 5.5, 5.6 Demersal, shellfish,	Effects of fishing on high diversity/low productivity tropical system: 4, 5, 6

5.5		vs. pelagic	Ecosystem restructuring in response to fishing: 4

Question 5: Identify historical / ecological expertise (PICES connection for all)

British Columbia / Washington	Bering Strait / Aleution	Japan	S. China
Ecological expertise very high Not sure about historical Ongoing St. Georgia and Hecate Strait UBC	Ecological expertise very high Not sure about historical Ongoing BS modeling efforts - NMFS	Local Historical interest Few professional historians Fisheries / ecological expertise very high	Excellent German resource surveys Otherwise unknown

Candidate Ecosystems for Initial Study

The group did not select a specific ecosystem, but rather identified how such a study might be initiated in general, considering especially the Inland Seas in Japan and British Columbia. The following steps were identified.

Step 1: Select ecosystem(s).

Because of the expertise of our group, we selected the Inland Seas of Washington, British Columbia and Japan, and then discussed how we might undertake the initial part of an HMAP.

Step 2: Identify key expertise required:

- Professional historians
- Economists
- Sociologists
- Anthropologists _ bridge gap between practical and scientific knowledge
- Archaeologists _ bridge gap between practical and scientific knowledge
- Ecologists
- Climatologists (atmosphere and marine)
- Modelers

Step 3: Establish a lead institution or center.

Step 4: Initial activities.

Determine time frame for the study: WA / BC _ 500 years; Japan 1500-2000 years

What are the historical phases or regimes of human impacts?

What is the history of physical forcing?

Construct a present day model of the system (social, ecological, climatological) and do this collectively among all participants.

Based on b) and c) above, develop detailed snapshots of the system, starting before significant human influences and trying to represent aspects of all human impact phases.

Appendix 5: North Atlantic - West Working Group

Participants: Starkey (rapporteur), Fischer, Myers, Collie, Barkham, Smith, Rozwadowski)

Question 1: Define candidate ecosystems/fisheries

The group defined four candidate case studies. Three of the candidates were identified as ecosystems spatially and ecologically coherent areas of the North Atlantic. These were:

The Newfoundland Fishery, i.e. from the Davis Strait to the Scotian Shelf, embracing the inshore waters of the island of Newfoundland, the Labrador shore and including the Grand Banks.

The Georges Bank/Gulf of Maine ecosystem, embracing the inshore waters of New England and the waters covering Georges Bank.

The Iceland/Greenland ecosystem.

It was noted that these ecosystems contained a diversity of species, including walruses, whales, cod, halibut, salmon, haddock & sea birds.

The fourth candidate was identified on the "fishery" criteria. This was the baleen whale fishery throughout the North Atlantic. Although knowledge of whale abundance will be required for each of the other three ecosystems identified, the nature of the species involved and the movements of the fishery over the North Atlantic suggest that an ocean-basin wide approach will be more efficient.

Question 2: Identify the state of ecological knowledge

The group divided ecological knowledge into nine species-determined categories:

phytoplankton, zooplankton, benthic invertebrates, pelagic invertebrate carnivores, pelagic fish, demersal fish, seals, whales, sea birds.

The state of knowledge in each of the three defined ecosystems was considered against these nine categories and graded as good, average and weak. The number of the nine categories in each category were summarized, suggesting that knowledge of the Georges Bank/Gulf of Maine ecosystem was particularly strong.

Table: The number of the nine categories grades Good, Average and Weak for three ecosystems.

Ecosystem	Good	Average	Weak
Georges Bank/Gulf of Maine	7	2	0
Iceland/Greenland	3	4	2
Newfoundland	3	2	4

Question 3: Assess the availability of historical & paleo data

The extent of historical & paleo was assessed according to four criteria:

- snapshots
- catch time series
- effort time series
- environmental time series.

The four candidates rated as follows:

Newfoundland: while incidental evidence of fishing effort and catches date back to the 1490s, time series relating to catches and fishing effort commence in 1675, and environmental time series of ice cover and air/sea temperature run from c.1800.

Iceland/Greenland: snapshots relating to harvesting activity can be gleaned from the sagas from c.1000 AD. Catch and effort time series commence in c.1700 and data pertaining to ice cover date back to 1650.

Georges Bank/Gulf of Maine: snapshots are available from the early colonial period (c.1600), and time series relating to catches and effort run from c.1630. Environmental data relating to air/sea temperature are available in time series from c.1800.

Whales: while snapshots of whaling activity are available from c.1200, catch and effort series run from the early seventeenth century.

Question 4: Identify the ecological hypotheses that might be tested by the our candidates

Using the ecological hypotheses listed in the workshop report, the group judged that the following were relevant for the four systems identified.

Whales	1.2, 2, 3.1, 4.2, 5.5-5.7, 6.1, 6.2

Newfoundland	1.2, 2, 3.1, 3.2, 4.2, 4.2, 5.1-5.6
Iceland/Greenland	1.1, 2, 3.1-3.4, 4, 5.1-5.5
Georges Bank, GM	1.2, 2, 3.1-3.4, 4, 5.1-5.5

Question 5: Assess the quality of historical and ecological expertise in relation to the candidates

Historical expertise was considered to be "excellent" in respect of the Newfoundland, Iceland/Greenland, and whales candidates. It was rated "good" on the Georges Bank/Gulf of Maine candidate.

Ecological expertise was considered to be "excellent" for the Whales and Georges Bank/Gulf of Maine candidates, and good/excellent with regard to Newfoundland and Iceland/Greenland.

Candidate Ecosystems for Initial Study

The Newfoundland fishery (including baleen whales) was selected as the candidate ecosystem.

The best scope was thought to be:

Temporal - since 1500

Spatial - from Davis Strait to Scotian Shelf, including inshore waters of the island of Newfoundland and the Labrador shore.

Species - cod, halibut, seals, walruses, salmon, seabirds, whales.

It was felt that the information required to address whaling would best be obtained from an Atlantic-wide study, one of the other three candidate systems. The specifics of that study are not developed here.

The aim of such a study would be to assess the impact of human intervention on marine ecosystem. The project would:

Assess the extent and quality of the historical data relating to human harvesting in this ecosystem;

Measure catch levels and fishing effort over time;

Test ecological hypotheses with historical data assembled;

Using data gathered throughout the project, establish the structure of the pristine ecosystem. The main research issues for each of the systems would be the ecological and anthropogenic hypotheses indicated above.

The first stage would entail the conduct of a pilot study to assess the feasibility of the project and to establish a research agenda and project management structure. This study would:

Assess the state of existing historical and ecological knowledge;

Evaluate the quality of data;

Identify gaps in knowledge (e.g. in Portuguese, French, Spanish records; in evidence before 1650);

Prioritize research areas _ allowing focus on areas where knowledge is limited but where sufficient sources exist;

Assemble and analyze sample data for discussion at workshop;

Identify desirable outputs and means of dissemination of findings.

Appendix 6: North Atlantic - East Working Group

Participants: Alheit, Bager, Conley, Holm, Jahnke, Kinze, Lajus, MacKenzie (rapporteur)

The working group participants identified that they were from a limited geographical area (i.e., Baltic Sea, White Sea/Barents Sea/Norwegian Sea) within the entire region of interest. As a result, the evaluations of some criteria associated with some of the ecosystems may not be accurate and should be reassessed by local regional experts.

Question 1. Definition of candidate ecosystems/fisheries.

The working group chose 11 candidate sites and added 1 more after plenary discussion. The sites chosen are listed in Table 1.

Question 2. Identification of states of ecological knowledge.

The state of ecological knowledge within each candidate ecosystem was estimated (Table 1). In this context the "state of ecological knowledge" was interpreted to mean all aspects related to fish production, fisheries and the structure/functioning of the given marine ecosystem.
The working group expanded the subheading by including two additional criteria to evaluate ecosystems:

i) existence of historical knowledge
ii) state of historical research.

Results are given in Table 1.

Question 3. Identification of historical and paleoecological archives.

- chronological snapshots?
- catch time series?
- effort time series?
- relevant time series of environmental data?

These criteria were evaluated by estimating the dates and time periods for which each ecosystem had information corresponding to the given topic (Table 1).

Question 4. Identification of ecological hypotheses which could be tested.

The list of ecological hypotheses compiled before and during the workshop was used as a guideline to identify those potential hypotheses which could be evaluated within each system. Due to the strong geographic representation of the working group within the areas of Central and North Europe and the group's limited expertise on the Southern Europe ecosystems, it was decided to focus on the White Sea/Barents Sea/Norwegian Sea and Baltic Sea. Hypotheses suitable for other ecosystems can be identified at a later date.

The working group concluded that hypotheses 1 and 2 could be evaluated for *all* ecosystems for which good or excellent historical records were available.

Regarding hypotheses 3-6, the working group considered these for the main fish and marine mammal species that are (were) present in the White Sea/Barents Sea/Norwegian Sea and Baltic Sea ecosystems. Those hypotheses chosen are given in Table 2. Additional background related to these hypotheses are given in the working papers by Lajus (WP 13) for the White Sea and Barents Sea), and Holm and Bager (WP 8), Jahnke (WP 7), Kinze (WP 10), and by MacKenzie et al. (WP 6) for the Baltic Sea.

Question 5. Identification of historical / ecological expertise.

Expertise required to test the selected hypotheses was present within the working group. Substantial expertise (historical, scientific) for both areas is available in the broader historical and ecological/fisheries communities.

Candidate Ecosystems for Initial Study

The working group nominated two ecosystems for initial investigation, the White and Barents Sea Ecosystem and the Baltic Sea Ecosystem. A more detailed description of the former is provided below but time precluded further discussion. Preliminary ideas of how to proceed with a Baltic study were developed and are described in greater detail below.

Candidate 1: The White and Barents Sea Ecosystem

The ecosystem of the White and the Barents Seas need to be discussed simultaneously because of very close historical connections of the fisheries in these seas and also because some of their objects (Atlantic salmon, Atlantic herring, Greenlandic seals) are distributed in both these seas. Although some unique environmental and biological features characterize the White Sea as the inner sea, both seas are influenced by the processes occurring in the Northwest Atlantic.

The reduction of fish biomass relative to pre-exploitation level is considered to be evident (4.4.1). The intensive development of the trawl fishery from the beginning of the 20th century and especially in 1950s -1970s led to a significant decline of catches of cod and herring and a depression of population of capelin. Environmental changes also added their impact to this decline. The cod - capelin relations are good examples of hypothesis 4.2.2 - declines in predators' carrying capacities due to the harvest of prey.

The peculiarity of the Barents Sea fishery is its dependence on migrations of fishes. Cod, haddock and herring migrate to the Barents Sea from their spawning grounds near Norwegian coasts, so knowledge of the fluctuation of catches in this sea is necessary for an understanding of processes in the Barents and partly in the White Sea. One of the set of hypotheses which needs to be measured against historical data is the presence of decadal shifts, inter-annual fluctuations of fish abundance, and maybe centennial climate shifts for this ecosystem for the period before over-fishing (3.1.1, 3.2.1,.3.2.2).

It is well known that migrations depend on two factors: the size of the population and the water temperature. Time and patterns of cods' migration toward the shore is caused by the temperature, but intensity is determined by the size of the population. When analyzing fluctuations of intensity of cod inshore migrations, it is necessary to take into account seasonal and spatial fluctuations of catches. The warm periods of the Barents Sea can be traced also by mass inshore migrations of non-mature Atlantic herring to the Murman.

The Atlantic herring migrates fairly regularly also to the White Sea, but never spawns there. The White Sea herring (a subspecies of the Pacific herring) lives in the White Sea throughout its life cycle. It is divided into many stocks. The main tendency in the development of the White Sea herring fishery has been the decline of catches during the last 200 years. During the 19th and 20th centuries the fishing area also decreased. This general decrease was accompanied by high fluctuations of catches. In different parts of the sea the fluctuations of catches have their own pattern. Fluctuations of populations of the White Sea herring as well as of the other herring species are especially caused by the fluctuations of the strength of the year classes (hypothesis 3.2.1, see report text). The question of the cause of these fluctuations, either environmental changes or over-fishing, especially on the spawning grounds, is still open. Some authors considered the tendency of Arctic warming as the main factor of decreasing productivity in the White Sea fishery.

Fluctuations in different locations can be asynchronous. Thus more perspective will be obtained by focusing on particular areas for which the historical records are the most abundant. Another problem is the necessity to separate catches of Atlantic herring from total herring catches in the White Sea. Atlantic herring enters from the Barents Sea, and in some years constitutes a large part of the autumn herring catches. To separate the two species in cases where there is no direct evidence, one needs to compare carefully the herring catches in the White and in the Barents Sea.

The biomass of salmon, one of the most commercially important fish species, significantly decreased from 1930s. The stable level of salmon catches in recent decades was maintained (in spite of the great reduction of its area) only at the expense of the significant increasing of fishing efforts on the most productive grounds. So for this species it is necessary to point out the hypotheses of the changes of its population richness (6.2). The influence of the recent introduction of Pacific salmon and escaping of domestic salmon (6.4) is also significant. The decrease of the abundance and spatial distribution of salmon was accompanied by the changes in age and size composition (4.1.3).

The role of megafauna in the ecosystem (5.7) can be investigated by an analysis of hunting, especially of seals. The hunting yield declined during the last 400 years, as did the range of species. Walrus hunting took place in the White Sea in 16th-17th centuries. For both species, hypotheses of overexploitation or (and) climatic change need to be investigated in order to understand significant changes in abundance and spatial distribution.

Candidate 2: The Baltic Sea Ecosystem

In order to initiate HMAP activities for the Baltic Sea, it is proposed that a workshop be held to identify people and resources that could assist in developing a history of the marine animal populations and environment of the Baltic Sea. Participants recognized that much historical material related to fishes and marine mammals of the Baltic was available in their national archives (Table 1) but that a large amount of additional material was available in archives of other countries (e.g., Sweden, Finland, Estonia, Latvia, Lithuania, Poland) and through institutions which were not represented at the meeting. The proposed workshop would draw on this expertise and have the goals listed below. The workshop would therefore be a mechanism to initiate a series of ongoing activities that would lead to a full description of the history of marine animal life and the environment in the Baltic Sea during the last 5-7 centuries.

Primary goals would be:

1) Identify major sources of historical information in all Baltic countries that could be used to describe changes in fish and marine mammal abundance in the Baltic during the last 5-7 centuries.

2) Establish a network of experts (e.g., historians, fisheries ecologists, oceanographers) interested in multi-disciplinary investigations of long-term variations (decadal-century scale since *c*1300) in the fish, fisheries, marine mammals and environment of the Baltic ecosystem.

3) Outline a plan of activities by historians, ecologists and oceanographers that will result in a description of the history of the marine animal life in the Baltic during the last 5-7 centuries.

In preparation of such a meeting, experts should be invited to prepare four reports to address the following topics:

1) state of historical archives in all Baltic countries which could contribute to HMAP;

2) application and potential utility of paleoecological approaches for detecting long-term variations in fish abundance and environmental change;

3) archeo-faunal evidence of fishing and marine mammal hunting;

4) climatological evidence of environmental change in the Baltic region

Both historical and ecological/oceanographic considerations make the Baltic Sea a potential candidate for H-MAP investigation.

Brief descriptions of (1) the historical material available for studying trends in the abundance of fish and marine mammals over century scales and (2) the environment and upper trophic levels (fish, marine mammals) in the Baltic are given below.

The hypotheses that the historical and ecological/oceanographic data can be used to test are given in Table 1. However, two overall goals would be the following:

1) describe the state of historical fisheries (e. g., effort, landings, gears) for cod, herring, sprat, and salmon, and also describe the hunts of marine mammals (e. g., seals, porpoises);

2) use the information from (1) together with modern scientific studies to identify how exploitation, predation/cannibalism and climate variability (e. g,. inflows of water from the North Sea, North Atlantic Oscillation) affect marine life at high trophic levels in the Baltic.

Historical sources relevant to an HMAP-Baltic project

There are presently few known records which can provide information relevant to the history of marine life in the Baltic Sea. In general historical tax accounts that exist in the archives of many countries will be able to give information about *fishing effort* in various medieval and Early Modern Baltic fisheries whereas customs accounts can give information about the *quantities of fish landed*. Both types of information are necessary for developing a complete perspective of the extent of fishing and marine mammal hunting activities in previous centuries. This information will therefore be essential for quantifying the influence of fishing and hunting effort on changes in abundance and distribution of fish and marine mammals.

One of the best sources of information presently known are tax accounts from Danish archives for Jutland, Blekinge and Bornholm starting in the 16th and continuing to the 18th centuries and tax accounts such as the flresund tax lists (Holm and Bager, this workshop). In addition to these, the customs rolls from German archives since 1368-1600's can give important information to H-MAP researchers (Jahnke, this workshop). Furthermore archives from England and the Netherlands can be useful for obtaining data on Baltic Sea fisheries.

The archives which have to date received most attention in terms of fisheries history seem to be those in Denmark and Germany (e. g., Holm and Bager, this workshop; Janke, this workshop); large Russian archives containing raw material related to Baltic fisheries exist, but have not yet been compiled in ways that allow the extent of the Russian fishery to be described (J. Lajus, pers.

comm.). However in order to obtain a complete (i.e., Baltic-wide) perspective of Baltic fisheries, archives in all Baltic countries will have to be investigated. This will require that contact be established with colleagues in all Baltic countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden) and a network of collaborators established. Furthermore archeologists working with fishery-oriented problems should be invited to take part in the program.

Extraction, compilation and interpretation of historical archival material will extend the known commercial catch time series for fish and marine mammals back several centuries. This extension backwards in time will enable statistical analyses of fluctuations in abundance and distribution under different combinations of predators/prey, exploitation and environmental conditions (see below for details) than are presently possible with the existing time series (1900+; Sparholt 1994).

Baltic Sea - ecological overview:

The Baltic Sea is a semi-enclosed brackish-water body which is characterized by horizontal and vertical salinity gradients. The water exchange between the Baltic and the North Sea involves many processes and is rather complicated (Gustaffson 1997). Stratification in the Baltic Sea is controlled both by occasional salt water intrusions and river runoff. Dramatic changes can occur in the haline stratification after major inflow events (Matth us and Franck 1992). It is not clear at present whether (and if so, how strongly, these) salt water intrusions are controlled by climate variability, e.g. by the North Atlantic Oscillation. Anoxic conditions can develop in the deep basins due to degradation of organic material during periods of restricted circulation. The aperiodic intrusions of the saline, well oxygenated water from the North Sea and the Skagerrak can drastically change the hydrography of the Baltic Sea and even allow benthic settlement in the usually anoxic basins for short periods. Species diversity in the Baltic Sea is relatively low: many species are under permanent physiological stress because of the strong vertical salinity and oxygen gradients and the generally low salinity in the geologically young Baltic. There are indications that increased use of fertilizers after 1900 and particularly since 1950 has increased biological production due to eutrophication (Larsson et al. 1985; Elmgren 1989), also contributing to prolonged periods of anoxia in the deep basins.

The three most important fish species in the Baltic Sea are cod, herring and sprat and all three species are exposed to heavy fishing pressure. Their dynamics and those of their major prey, crustacean copepods, are governed by external physical forcing, biological interactions (mainly predation) and anthropogenic influences, particularly fishing activities and habitat alteration (Alheit et al, 2000). Marine mammals (mainly seals and a small number of harbour porpoises) are also present but their abundance is much lower than in 1900 due mainly to hunting (Durant and Horwood 1986; Helle et al. 1990; Kinze 1995, this workshop).

Trends in abundance of fish and marine mammals and their exploitation in the Baltic:

Bohusl n and flresund herring fisheries:
Fish populations in the Skagerrak and Baltic Sea have undergone major fluctuations over the past 5 centuries. In the Bohusl n region of the Skagerrak alternating periods of strong and weak

herring fisheries have been observed. Each good or bad period lasts several decades and the initiation and fall of these fisheries is believed to be at least partly related to large-scale climate variability (North Atlantic Oscillation). In the flresund, herring supported a major fishery lasting several centuries but then this fishery declined mainly due to changing economic conditions (e. g., taxation, alternative supplies). These fisheries were key mechanisms in the development of the economies of Baltic towns during the medieval and Early Modern period (ca. 1300-1600). The historical records related to this fishery have therefore been particularly valuable and have been able to reveal some of the causes of the fluctuations in herring landings (Alheit and Hagen 1997, 2000). The data have also been used to suggest ways in which climate affects fish landings in other European waters because periods of strong and weak herring and sardine fisheries appear to be correlated across large space-time scales (Alheit and Hagen 2000). However, several fisheries and oceanographic issues related to the Bohusl n and flresund herring fisheries remain unclear and will require input of historical expertise and data.

Fish, fisheries and marine mammals in the eastern Baltic Sea:
In the main part of the Baltic Sea, the biomass and landings of three fish species (cod, herring, sprat) have all increased since 1900 (Sparholt 1994) while the biomass of marine mammals (seals, harbour porpoises) has decreased (Durant and Horwood 1986; Helle et al. 1990). Prior to 1900 and even up to the 1950's, little information is available concerning the magnitude of fisheries in the Baltic.

Marine mammals (seals, porpoises) have greatly declined due to hunts from at least the mid-1700's (Durant and Horwood 1986, Helle et al. 1995; Kinze 1995, this workshop). These marine mammals were predators of fish in the Baltic (Elmgren 1984, 1989; Thurow 1997) and it has been suggested that their decline has contributed to the major increase in fish biomass in the Baltic during the 20th century (Thurow 1997). If this suggestion is true, predation by marine mammals may have been a key factor controlling the abundance of Baltic fish populations in previous centuries. This hypothesis could potentially be evaluated with historical catch and effort data from previous centuries.

However, major long- and short-term environmental changes (e. g., eutrophication) have also taken place in the Baltic during the 1900's (Larsson et al. 1985; Helcom 1996). The abundance of two fish species is believed to have increased partly because of intensifying eutrophication during the 1900's (herring, sprat; Thurow 1997). At shorter time scales (semi-decadal), the abundance of at least two (cod, sprat) fish species in the 20th century depended on hydrographic and climate variability (cod: Pliksh s et al. 1993, Sparholt 1996, Jarre-Teichman et al. 2000; sprat: Kalejs and Ojaveer 1989). In the case of cod, reproductive success is related to oxygen content in the deep layers of the Baltic, which in turn depends on inflows of water from the North Sea (Helcom 1996; Schinke and Matth us 1998). Sprat recruitment appears to be lower in cold years than in warm years (Kalejs and Ojaveer 1989)

These observations of variability in fish abundance and the environment during the 1900's make it difficult to identify what their main causes are (ie., predation, fishing, environmental variability), and to establish the relative abundance of species at the upper trophic levels before the intensification of fishing effort in the mid-1900's (Bagge et al. 1994). As a result, it is necessary to evaluate how fish populations varied in previous decades and centuries when different combinations of predation, fishing effort and environmental conditions existed compared to those present in the 1900's.

Estimation of fluctuations in fish abundance in the pre-1900 era will require the extraction and compilation of historical information about fisheries and marine mammal hunts. Fortunately, a wealth of such information appears to exist in raw form in various archival records around the Baltic (e. g., Holm and Bager, this workshop; Janke, this workshop).

Historical information such as this has given useful information about the relative abundance of fish and fishing effort in other marine ecosystems (e. g., Bohusl n: Alheit and Hagen 1997; Newfoundland; Hutchings and Myers 1995). The working group feels that such information can do the same in the Baltic for both fish and marine mammals, and can indicate major changes in the structure and functioning of the Baltic ecosystem long before the onset of intensive fishing, eutrophication and global warming. Collaborative investigation by historians, fisheries scientists and oceanographers will be a promising way to document the history of the Baltic marine environment and to identify the roles of man and nature in its changes.

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Table 1. Summary information compiled by the working group on Northeast Atlantic, Baltic Sea and White Sea related to five topics on historical/ecological information. (See above for list of topics.)

	White-Barents Sea	Skagerrak / Baltic	North Sea	Bay of Biscay	Irish Sea	NW Spain / Portugal	Western Medit.	Eastern Medit.	Adriatic	Black Sea / Azov	Greenl. / Iceland / Faroes
State of ecological knowl.?	high	excell.	excell.	good	excell.	good	good	fair	good	good	excell.
State of historical records?	excell.	excell.	excell.	very good	good	very good	excell.	excell.	excell.	good	excell.
State of historical research?	poor	good	good	miserable	poor	miserable	very good	poor	good	poor	good
Historical and paleo archives:											
Chronol. snapshots?	1600+	1400+	1300+	1600+	1500+	1600+	1250+	?	1300+	1800+	1400+
Catch time series	1700+	1580+	1500+	1600+	?	1600+	?	?	?	1800+	1500+
Efort time series?	1800+	1580+	1500+	1600+	?	1600+?	?	?	?	1800+	1500+
Relevant environ. variables?	1700+	6000 BC+	6000 BC+	1850+	1850+?	1850+?	?	?	1400+	1800+	6000 BC+

Table 2. Ecological hypotheses that may be tested for the two selected candidate ecosystems, with key species indicated for each.

	White-Barents Sea	Skagerak and Baltic Sea
Cod	1, 2, 3.1.1, 3.2.1, 3.2.2, 4.1.1, 4.1.2, 4.1.3, 4.2.2, 5.5, 5.6, 5.7, 6.2	1, 2, 3.1.1, 3.2, 3.2.2, 3.3, 4.1.1, 4.1.2, 4.2.2, 4.2.3, 5.3, 5.4, 5.5, 5.6, 5.7, 6.1
Herring & capelin	1, 2, 3.2.1, 3.2.2, 4.1.1, 4.1.2, 4.2.3, 6.2	1, 2, 3.1, 3.2, 3.3, 3.4, 4.