PICES Scientific Report No. 11
1999

PICES-GLOBEC INTERNATIONAL PROGRAM ON CLIMATE CHANGE AND CARRYING CAPACITY

SUMMARY OF THE 1998 MODEL, MONITOR AND REX WORKSHOPS, AND TASK TEAM REPORTS

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September 1999
Secretariat / Publisher
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EXECUTIVE SUMMARY

This volume summarizes the results of three workshops organized by the PICES-GLOBEC Climate Change and Carrying Capacity Program that were held just prior to the PICES Seventh Annual Meeting in Fairbanks, Alaska, in October 1998. These workshops represent the efforts of the REX, MODEL, and MONITOR Task Teams to integrate the results of national GLOBEC and GLOBEC-like programs to arrive at a better understanding of the ways in which climate change affects North Pacific ecosystems. The BASS Task Team published the results of their Science Board Symposium 1997 in a refereed journal (Progress in Oceanography, 1999. 43:2-4). The detailed reports and recommendations for the future work of each of the Task Teams from their last meeting in 1998 can be found in the PICES Annual Report 1998, pages 129-138.

The REX Workshop on "Small Pelagic Species and Climate Change" reviewed the status of national efforts on small pelagic fish and climate research. The workshop participants presented research results from seven different regions around the North Pacific Rim, and identified key hypotheses that link climate variability and small pelagic fish response. These hypotheses will be used in future cooperative research.

A “Lower Trophic Level Model” Workshop was sponsored by the MODEL Task Team, in collaboration with researchers involved in the Joint Global Ocean Flux Study Program (JGOFS). The goal of this workshop was to deal with model comparison issues related to the lower trophic level and to gather information for nutrient databases. This activity provides a crucial link between the JGOFS synthesis and modeling efforts and the application of those results to GLOBEC research. The Task Team is planning activities that relate to upper trophic level models. However, the lower trophic level model efforts will remain a key activity in the near future. Several recommendations about lower trophic level models were made at the workshop that will be followed up on in the next two years. These include building a prototype model that will be executable on the web and holding another lower trophic level model workshop in the year 2000 for comparison of different marine ecosystems using the prototype model.

The MONITOR Task Team is the most recently formed component of the CCCC Program. They report here on the results of their first workshop, held to outline the present monitoring activities of PICES nations and to identify future monitoring needs and intercalibration experiments that might be conducted. The workshop resulted in several recommendations, particularly with regard to zooplankton monitoring efforts. The focus of the Task Team's future work will likely be on intercalibration experiments to facilitate comparison of zooplankton time series, design of a monitoring system for zooplankton production, and discussion of Continuous Plankton Recorder (CPR) use in the PICES region.

Although the BASS Task Team did not hold a workshop in 1998, it was occupied with review and publication of papers from their 1997 symposium. The Task Team is now proposing to identify new BASS members to assist in the development of a long-term work plan for BASS. They will also be holding a special workshop just prior to the PICES Eighth Annual Meeting in October 1999, in which they will develop a conceptual model of how the subarctic gyres work and how they change with regime shifts. This workshop will provide a basis for future comparative work by the Task Team.

Patricia Livingston
Chairman, Science Board

MODEL TASK TEAM REPORT

The MODEL Task Team is concerned with advancing the development of conceptual/theoretical and modeling studies needed for both regional and basin scale components of PICES/GLOBEC Climate Change and Carrying Capacity (CCCC) Program.

The MODEL workshop in Nemuro, Japan in 1996 was a step toward the goal of promoting MODEL activities, one of five "Key Research Activities" defined in the CCCC Implementation Plan. Lower Trophic Level (LTL) modeling aims to understand how a change in physical forcing is translated into a change in the structure and productivity of lower trophic levels and subsequently moves through foodweb to higher trophic levels. To make progress on this issue, it was recommended at the LTL modeling discussion in Nemuro to hold a workshop that focuses on model inter-comparison.

One way to start to deal with diverse process formulation problem is to reduce the possible combinations for a particular structure. M. Kishi gave an example of such effort for NPZD model (Appendix A). He examined the stability of different combinations of possible process formulations. Among the 2,400 combinations, about half were unstable. He also checked the sensitivity of the stability to the initial values. Three types of combinations were found stable.

Unfortunately, several participants were unable to attend the Fairbanks meeting on short notice so the workshop scope was reduced accordingly.

Assembling an inventory of nutrient data in the North Pacific region was also identified as an immediate action item to advance the CCCC LTL modeling activities.

I. WORKSHOP ON LOWER TROPHIC LEVEL MODELING OCTOBER 14, 1998 (Convenor: Sinjae Yoo)

Review of JGOFS/GLOBEC modeling activities

S. Yoo (KORDI) gave a brief summary of JGOFS 1995 modeling workshop report (JGOFS, 1997). The workshop aimed to produce a systematic comparison of the diverse JGOFS models, comparing both how they were formulated and how well they reproduced observations. Ten models with variable numbers of compartments (3 - 7) were planned to be run on four data sets to compare the model behavior with observations at different locations. Most of the runs succeeded only with the Station P data set. Despite significant efforts before and after the workshop, no conclusions about the intercomparisons were drawn and there appeared to be no further advances after the workshop. Presumably, the 1995 JGOFS model workshop was too ambitious in addressing the comparison issue by compounding differences in structure, formulation, and data sets.

R. Brown gave a summary of the recent JGOFS synthesis workshop with particular reference to data management. The goals of CCCC models are somewhat different from those of JGOFS models in that not only the material flux but also the structure of the foodweb is among the target properties.

R.C. Dugdale pointed out that JGOFS models lack silicate and iron and presented a model that incorporated these components.

M. Kishi briefly reviewed GLOBEC modeling activities. A workshop on numerical modeling was held in 1993, where the model inter-comparison was not included in the agenda. Since then, no subsequent workshops concerning modeling have been held. Nevertheless, the draft implementation plan (GLOBEC, 1998) identifies model inter-comparison as an important issue.

Group discussion on model intercomparison

Model inter-comparison was identified as one of the major technical issues to be resolved. Model inter-comparison issues arise from two main sources: different model structure and different submodel formulation. Different model structures means that models have different numbers of state variables and the links between them. For process models, there could be a variety of different formulations. For example, a number of different formulations have been proposed for the light-photosynthesis relationship. When the outputs from two different models are compared, a portion of the differences must be due to the differences in structure or formulation. Therefore, it is of utmost importance to judge whether the crucial differences are not due to idiosyncrasies in model structure or process formulation. When these two sources of variation are compounded, the judging would become even more difficult. Since comparison of the behavior of 12 different ecosystems is the core of the CCCC, models should have similar structures as long as they correctly represent the characteristics of each system. There may not be a single consensus model but a small set of models can be consented upon. The same can be said to process formulation. Thus a prototype model could facilitate the development of comparison protocols.

B. Megrey pointed out that well-established methods of model comparison exist for higher trophic levels, it seemed that this was not the case for lower trophic modeling. Model structure and process formulations might be more diverse for lower trophic level than those of higher trophic level. For model inter-comparison to be successful, compounding structural differences and formulation differences must be minimized. If the variability of model structure and formulation could be reduced, systematic comparisons would be easier.

The CCCC LTL models aim to model the change in the trophic structure as well as material flux. In the Nemuro workshop, a model structure with twelve compartments was recommended to model such change. For example, diatoms and non-diatoms should be separated to incorporate changes in trophodynamic linkages.

A prototype model on which variations can be made will serve as a base where model inter-comparison protocols are developed. M. Kashiwai suggested a follow-on workshop in that direction.

II. WORKSHOP ON SOURCES OF HIGH QUALITY NUTRIENT DATA FOR MODELING LOWER TROPHIC LEVELS OCTOBER 15, 1998 (Convenor: R.C. Dugdale)

The objective was to provide information about nutrient databases suitable for initiating and validating ecosystem models as part of the LTL Modeling Workshop. The results are summarized in Table 1.

Cruise level summary based on NODC holdings for the region of the open Pacific and adjacent Bering Sea.

R.M. Brown
Institute of Ocean Sciences, Sidney, Canada

The cruise level data available for the North Pacific from the U.S. NODC was presented along with a discussion of quality control problems that culminated in retraction of a published article. The U.S. NODC personnel are eager to receive help on the design of algorithms to detect bad data. From the data represented geographically it was clear that a considerable amount of data known to the participants of the workshop was not present in the NODC archives. These considerations demonstrated the importance of gathering information on the major programs carried out in the North Pacific and Bering Sea that measured nutrients.

Ocean Station 'P' region

C.S. Wong[1] and P.J. Harrison[2]
[1]*Institute of Ocean Sciences, Sidney, Canada*
[2]*University of British Columbia, Vancouver, Canada*

The extensive time series of nutrients obtained from 1970 onward at Station P during and after the weathership occupation will soon become available as a series of papers are published. Large variations in nitrate and silicate were observed and some appeared to be related to El Niño conditions. A trend of increasing temperatures, decreasing salinities, decreasing nitrate and increased stability was also evident tha may be related to increased productivities that have been observed in recent years. The region of low nitrate concentration in summer has expanded westward in recent years and now includes Station P.

Ships of opportunity (SOO) program

C.S. Wong[1] and Y. Nojiri[2]
[1]*Institute of Ocean Sciences, Sidney, Canada*
[2]*National Institute for Environmental Studies, Tsukuba, Japan*

This data comes from the container ship *Skaugran* that crosses between Japan and Vancouver, B.C ten times each year. To date, the data comprise 43 crossings since 1995. A new container ship program has been initiated between Japan and Australia. The ship tracks vary depending upon weather and destinations, but generally move south of the great circle route in winter. The data show regions of undetectable nitrate along the west coasts of the U.S. and Canada with values of 5 mmol•m^{-3} just south of the Aleutians. The data reside at IOS and are on a migration path to Data Center A of the U.S. NODC. SOO data were used to obtain temperature/nitrate regressions and maps of the surface distribution of nitrate obtained using these regressions and OCTS satellite temperature and color data were presented.

Bering Sea-PROBES and ISHTAR

T. Whitledge and J.J. Goering
University of Alaska, Fairbanks, U.S.A.

The major programs of the Bering Sea that contained nutrient data sets were reviewed. They include PROBES which occupied a cross shelf line in the southern Bering Sea 55 times in five years, providing an excellent seasonal view of nutrient and production processes in that area. Nutrient budgets are well constrained from annual measurements and uptake rate measurements. The strongest data collection years were 1979, 1980 and 1981. The ISHTAR program obtained data in the southern Bering Sea, often on about the same line occupied by PROBES, but extending also to the North Bering Sea and the South Chukchi Sea. ISHTAR data were obtained in 1986, 1987 and 1988. Nutrients, chlorophyll and zooplankton collections were obtained on every station in both PROBES and ISHTAR programs. The PROBES data show very rapid spring blooms and reduction in nutrients but these clear patterns appear to have changed significantly in recent years. The PROBES, ISHTAR data sets are particularly useful for modeling lower trophic levels since they include ammonium, one of the nutrients needed in a 3 nutrient (nitrate, ammonium and silicate) model. The PROBES and ISHTAR data sets were migrated to U.S. NODC. Beginning in 1997 a GLOBEC line has been established from Resurrection Bay southward into the Gulf of Alaska. The full nutrient set including ammonium is being measured.

Japanese National Database

T. Saino
Nagoya University, Nagoya, Japan

A thorough review of the available data (See Table 1) collected by Japanese scientists, some of which is archived at JODC (Japan Ocean Data Center) was given.

Bering Sea-NOAA COP (Coastal Ocean Program) Bering Sea ecosystems program.

B.A. Megrey
Alaska Fisheries Science Center, Washington, U.S.A.

The SEBSCC (South East Bering Sea Carrying Capacity) program of U.S. NOAA (National Oceanic and Atmospheric Agency) COP collected nutrient and other data beginning in 1995 from approximately the same location as the PROBES line providing a post-PROBES view of the southern Bering Sea. Recently NSF sponsored studies of fronts have provided local, high density data. The Bering Sea Ecosystem Biophysical Metadata Base project was reviewed. This system does not hold data. It is a catalog with pointers to locations where the data are available or held, and gives ways to access the SEBSCC and FOCI (Bering Sea Fisheries Oceanography Coordinated Investigations) data. Some nutrient data is included and the system may be a model for a smaller project on data sources for modelers, the objective of the workshop.

Group Discussions on approaches to quality assessment and developing and assembling an iron database

The nutrient workshop finished with group discussions that noted the need for reliable iron data since a strong link between iron, silicate and diatom productivity is now well established. However, iron data are extremely sparse and cannot, at the present time, be included explicitly into lower trophic level models. The workshop also observed a good congruence between strong modeling programs in some of the 12 CCCC model regions and the availability of nutrient data likely to be of high quality.

Workshop References

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GLOBEC. 1998. Draft Implementation Plan.

PICES. 1997. Workshop on Conceptual/ Theoretical Studies and Model Development. R.I. Perry, S. Yoo, and M. Terazaki [eds.] *PICES Scientific Report No. 7, 93p.*

Table 1 Available nutrient data and sources for the North Pacific.

Data Source	Geographical Area	Type of Data	Contact
U.S. NODC (World Ocean Database 1998)	N. Pacific	26000 profiles since 1929	
US NODC/IOS	Station P Line P		brownro@pac.dfo-mpo.gc.ca wongc@pac.dfo-mpo.gc.ca
UBC (University of British Columbia)	Station P Line P		pharrisn@unixg.ubc.ca
US NODC/IMCS (Inst. Mar. Sci.) Univ Alaska	Bering Sea	PROBES Program ISHTAR Program	whitledge@ims.uaf.edu goering@ins.alaska.edu
Bering Sea Biophysical Metadatabase Project	Bering Sea	Data Index	bmegrey@afsc.noaa.gov macklin@pmel.noaa.gov
SEBSCC (SE Bering Sea Carrying Capacity Program) and FOCI (Bering Sea Fisheries-Oceanography Coordinated Investigations	Bering Sea	5 cruise/year since 1995	napp@afsc.noaa.gov
NOAA-COP (Coastal Ocean Program)	Bering Sea		coastalocean@cop.noaa.gov
GLOBEC Monitoring Project	Ressurection Bay south to Gulf of Alaska,	4 lines, 20 stas, 1997-2001, 300 samples/cruise	whitledge@ims.uaf.edu
Skaugran - Ship of Opportunity JEA (Japan Env. Agency)/IOS	N. Pacific (Japan-Vancouver)	10 cruises/year 43 crossings since 1995	wongc@pac.dfo-mpo.gc.ca Nojiri
JODC (Japan Ocean Data Center)	137 E line (35°N-0°N)	From 1964- 4 cruise/yr, 5 regions	tsaino@ihas.nagowya-u.ac.jp
Japan Meteorol. Agency, JODC	E line, 165°E	1996-	tsaino@ihas.nagowya-u.ac.jp
Japan Fish. Agency/JAFIC (Japan Fish Info Ctr), JODC	Local fish stations		tsaino@ihas.nagowya-u.ac.jp

Table 1 (continued) Available nutrient data and sources for the North Pacific.

Data Source	**Geographical Area**	**Type of Data**	**Contact**
ORI (Ocean Research Inst.)/UT (U. Texas) Vessel *Hakuho Maru*	48°N, 165°E Bering Sea	1975 on 5-6 cruises	tsaino@ihas.nagowya-u.ac.jp
Hokkaido University Vessels, *Oshoro Maru* and *Hokusei Maru*	NW Pacific, 155 line 180 line, Bering Sea	1950-- summer some nutrients	tsaino@ihas.nagowya-u.ac.jp
Hokkaido National Fish. Lab. Vessels, *Hokko Maru* and *Tankai Maru*	Okhotsk Sea Line A (SE Hokkaido)	1992-- seasonal	tsaino@ihas.nagowya-u.ac.jp
NOPACCS (North Pacific Carbon Cycling Study)/NIRE (National Inst.Resources and Environment) Vessels-*Hakurei Maru I*	E line 175°E (48°N-10°S)	1991-6, onboard nutrients	tsaino@ihas.nagowya-u.ac.jp
KNOT(Kyodo North Pacific Ocean Time Series)	44°N, 155°E	1998	tsaino@ihas.nagowya-u.ac.jp
JAMSTEC (Japan Marine Sci.Technology Center), Vessel *Mirai*	NNWP some Artcic, include Bering Sea	1997	tsaino@ihas.nagowya-u.ac.jp
MasFLEX	E. China Sea	1994-96 on CD Rom	tsaino@ihas.nagowya-u.ac.jp
NIRE COSMIC (Carbon Dioxide Ocean Sequestration for Mitigation of Climate Change) Vessel *Hakurei -Maru II*	5-10°N, 130, 135 140,155,165, 175°E	1997-2001	tsaino@ihas.nagowya-u.ac.jp

Task Team Recommendations

The participants agreed that (i) models with too diverse structures might be difficult to compare, and (ii) comparison protocols are necessary to tackle the problem.

Long-term
Development of prototype models and comparison protocols.

Short-term
To achieve advances toward long term objectives, following activities were recommended:

1. Develop an executable prototype model with 12 compartments (1996 Nemuro Workshop) on web by June, 1999 (Dr. Kishi).
2. Apply the model to more than two sites, including Bering Sea and Sanriku area and compare with the Bering Sea ecosystem model.
3. Expand MODEL web page to include more regional circulation models.
4. Add nutrient database directory to the PICES home page.
5. Facilitate interactions with JGOFS/GLOBEC modeling activities.
6. Convene a workshop on the development of prototype model and comparison protocols as follows (See Appendix B).

APPENDIX A: STABILITY ANALYSIS OF DIFFERENT PROCESS FORMULATIONS (MICHIO J. KISHI)

Introduction
During the 6th Annual Meeting in Pusan, our Task Team discussed the stability of lower trophic ecosystem models. It was my task to evaluate the stability of some ecosystem models before the 7th Annual Meeting. There are many kinds of lower trophic ecosystem models which have been applied to open ocean ecosystems. If we limit them to Pacific ecosystems, still many models have been applied to the Ocean Station Papa and HOTS time series data and so on (Evans and Garcon 1997, Glover et al. 1994, Kawamiya et al. 1995, 1997, Kawamiya et al. 1999 a, b, Yoshimori et al. 1995).

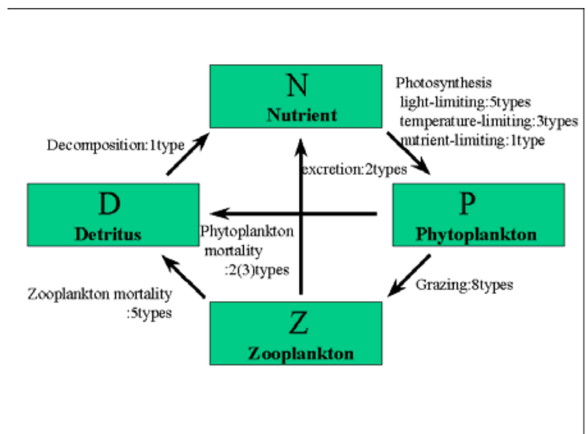

Fig. A1 Tested ecosystem model. Kinds of equations which were referred here are shown beside the arrows.

Here the most simple and common NPZD model (Fig. A1) is treated. Even for this simple model, there have been proposed many kinds of equations which describe the material flows among compartments. In Figure A1, the different kinds of equations are shown beside the arrows, and all equations and their references are shown in Table A1.

If all equations are combined, there are 2400 combinations (5*3*1*8*...). So, I calculated the time dependent features of four compartments with all combinations by fourth order Runge-Kutta method under the following four conditions. (1) Using normalized parameters i.e. parameters are selected such that all processes are ≤1.0, (2) giving daily oscillations of light intensity to case (1), (3) using real parameter values from each referenced paper, (4) giving daily light oscillation to case (3). After calculations are carried out for 300 days for each combination, the stability of the solutions is examined. *Stable* refers to a case where there is no oscillation without a daily oscillation corresponding to the light change, and *unstable* is a case where there is an oscillation in the solution and/or a divergence.

Results

<u>Percentage of stable cases</u> - In Figures A2-A5, the percentage of stable cases and unstable cases are shown. Solutions of almost half of the combinations of process equations are unstable. For example, in the table under Figure 2A the row of A-1 shows that if we use A-1 for light limitation, there are 6 cases in which the solution diverges, 255 cases in which the solution shows unstable oscillations, and 517 cases stable solutions with all combinations except light limitation.

<u>Stability to initial conditions of 4 compartments</u> In order to investigate the stability due to initial conditions, the initial values were changed to 0.5, 0.8, 1.2, 1.5 times the standard case. The stable cases are shown in Table A2. We selected the most stable of these (Fig. A6-A8) named Patterns P1, P2a and P2b together with their equivalent equations. I suggest that these three stable combinations be used for the NPZD model.

Acknowledgement

I would like to thank my student, Nobuyuki Imamura for his help of calculations and preparation of figures.

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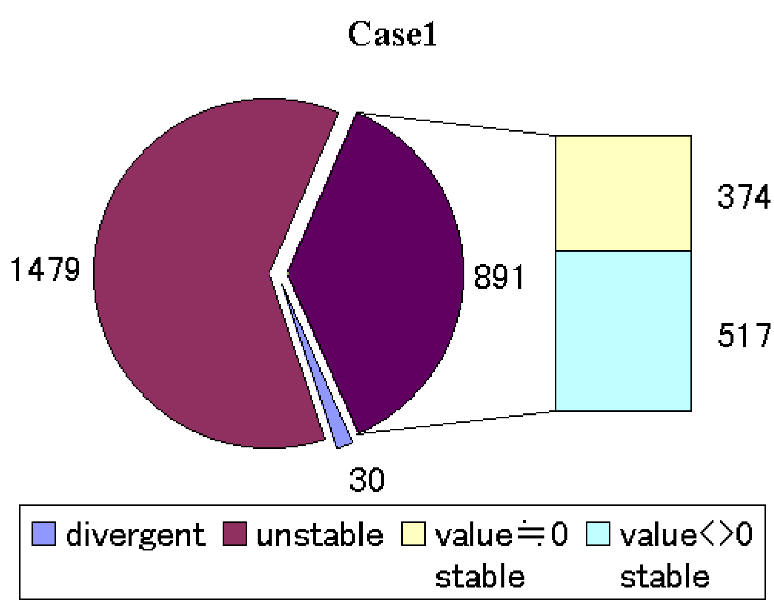
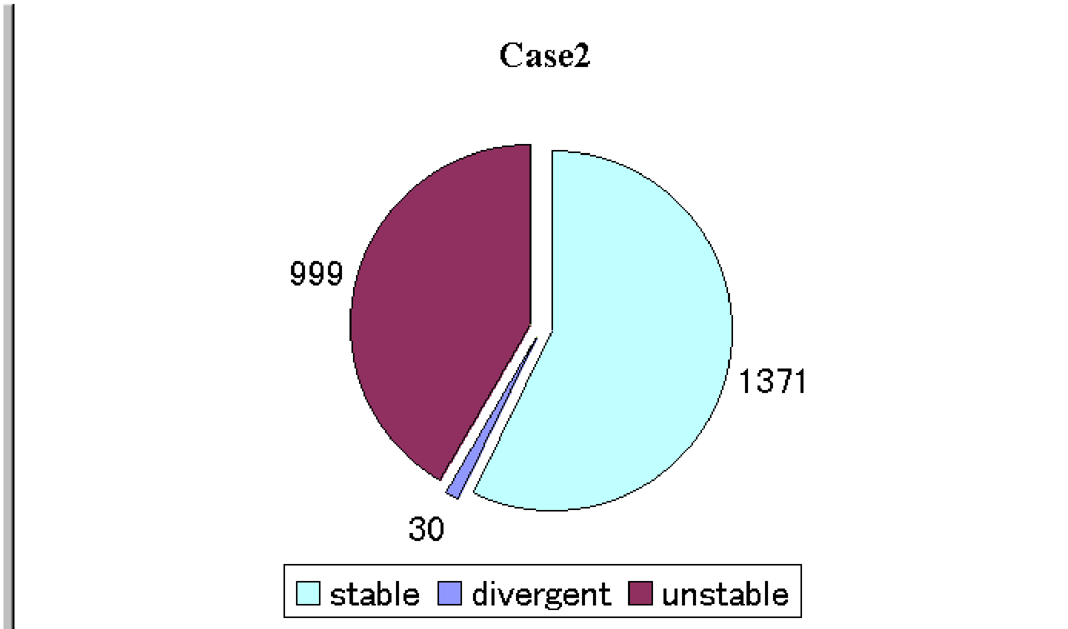


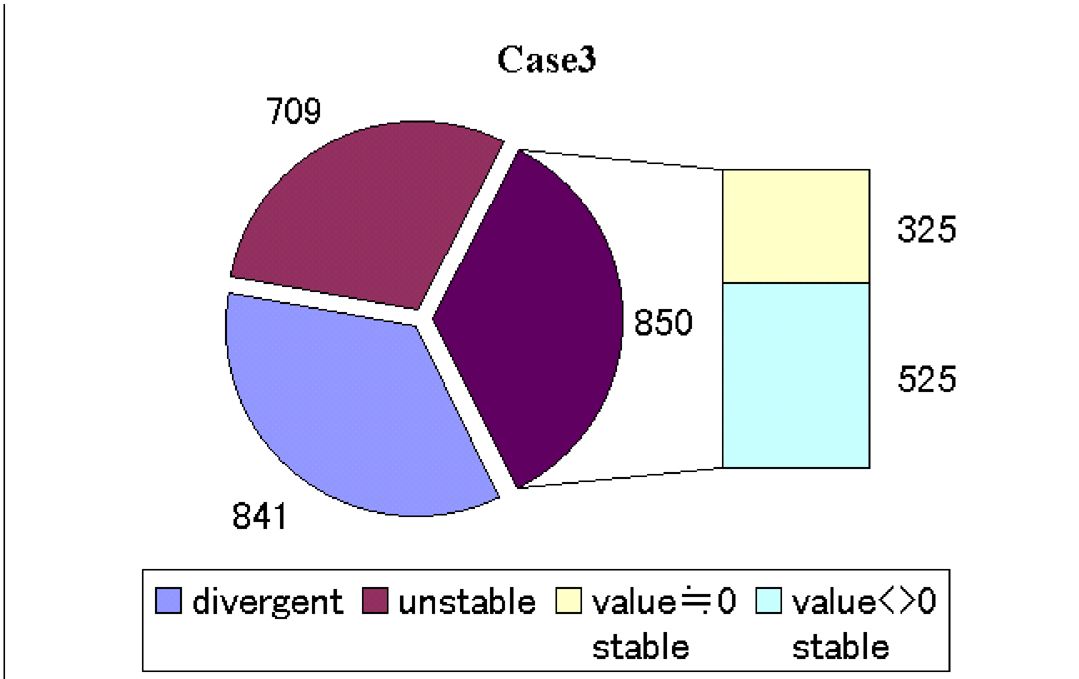
	divergent		unstable		stable		stable		total
		rate(%)		rate(%)	value≒0	rate(%)	value<>0	rate(%)	
total	30	1.25	1479	61.63	374	15.58	517	21.54	2400
A-1	6	1.25	255	53.13	87	18.13	132	27.50	480
A-2	6	1.25	255	53.13	87	18.13	132	27.50	480
A-3	6	1.25	429	89.38	26	5.42	19	3.96	480
A-4	6	1.25	285	59.38	87	18.13	102	21.25	480
A-5	6	1.25	255	53.13	87	18.13	132	27.50	480
B-1	10	1.25	493	61.63	125	15.63	172	21.50	800
B-2	10	1.25	493	61.63	124	15.50	173	21.63	800
B-3	10	1.25	493	61.63	125	15.63	172	21.50	800
D-1	0	0.00	183	61.00	39	13.00	78	26.00	300
D-2	0	0.00	96	32.00	38	12.67	166	55.33	300
D-3	30	10.00	234	78.00	36	12.00	0	0.00	300
D-4	0	0.00	102	34.00	45	15.00	153	51.00	300
D-5	0	0.00	225	75.00	60	20.00	15	5.00	300
D-6	0	0.00	207	69.00	48	16.00	45	15.00	300
D-7	0	0.00	207	69.00	48	16.00	45	15.00	300
D-8	0	0.00	225	75.00	60	20.00	15	5.00	300
E-1	15	1.25	915	76.25	11	0.92	259	21.58	1200
E-2	15	1.25	564	47.00	363	30.25	258	21.50	1200
F-1	0	0.00	276	57.50	204	42.50	0	0.00	480
F-2	0	0.00	324	67.50	9	1.88	147	30.63	480
F-3	0	0.00	318	66.25	2	0.42	160	33.33	480
F-4	0	0.00	270	56.25	159	33.13	51	10.63	480
F-5	30	6.25	291	60.63	0	0.00	159	33.13	480
G-1	30	2.50	717	59.75	161	13.42	292	24.33	1200
G-2	0	0.00	762	63.50	213	17.75	225	18.75	1200

Fig. A2 Percentage of stable and unstable results for Case 1. Value=0 means stable but P=Z=D=0 and N=NT, and value<>0 means all of NPZD have non-zero stable solutions. See text for description of the table.



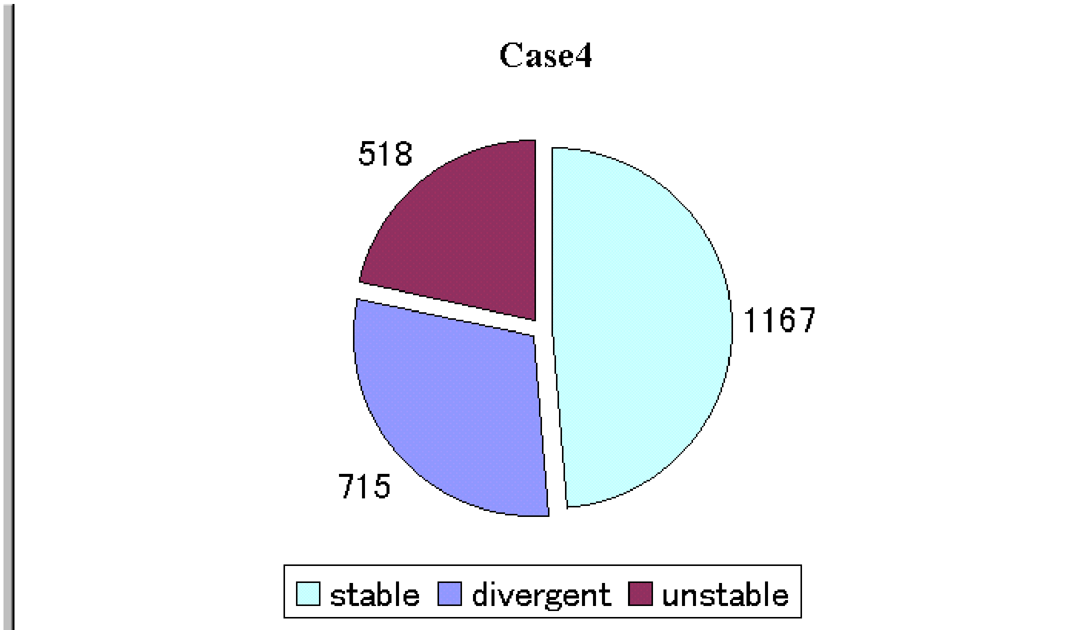
	divergent		unstable		stable		total
		rate(%)		rate(%)		rate(%)	
total	30	1.25	999	41.63	1371	57.13	2400
A-1	6	1.25	143	29.79	331	68.96	480
A-2	6	1.25	177	36.88	297	61.88	480
A-3	6	1.25	290	60.42	184	38.33	480
A-4	6	1.25	214	44.58	260	54.17	480
A-5	6	1.25	175	36.46	299	62.29	480
B-1	10	1.25	332	41.50	458	57.25	800
B-2	10	1.25	335	41.88	455	56.88	800
B-3	10	1.25	332	41.50	458	57.25	800
D-1	0	0.00	112	37.33	188	62.67	300
D-2	0	0.00	56	18.67	244	81.33	300
D-3	30	10.00	234	78.00	36	12.00	300
D-4	0	0.00	45	15.00	255	85.00	300
D-5	0	0.00	38	12.67	262	87.33	300
D-6	0	0.00	216	72.00	84	28.00	300
D-7	0	0.00	215	71.67	85	28.33	300
D-8	0	0.00	83	27.67	217	72.33	300
E-1	15	1.25	495	41.25	690	57.50	1200
E-2	15	1.25	504	42.00	681	56.75	1200
F-1	0	0.00	158	32.92	322	67.08	480
F-2	0	0.00	211	43.96	269	56.04	480
F-3	0	0.00	211	43.96	269	56.04	480
F-4	0	0.00	223	46.46	257	53.54	480
F-5	30	6.25	196	40.83	254	52.92	480
G-1	30	2.50	469	39.08	701	58.42	1200
G-2	0	0.00	530	44.17	670	55.83	1200

Fig. A3 Same as in Figure A2, except for Case 2.



	divergent		unstable		stable		stable		total
		rate(%)		rate(%)	value ≒0	rate(%)	value<>0	rate(%)	
total	841	35.04	709	29.54	325	13.54	525	21.88	2400
A-1	6	1.25	218	45.42	95	19.79	161	33.54	480
A-2	6	1.25	234	48.75	63	13.13	177	36.88	480
A-3	480	100.00	0	0.00	0	0.00	0	0.00	480
A-4	6	1.25	216	45.00	98	20.42	160	33.33	480
A-5	343	71.46	41	8.54	69	14.38	27	5.63	480
B-1	278	34.75	235	29.38	102	12.75	185	23.13	800
B-2	285	35.63	239	29.88	121	15.13	155	19.38	800
B-3	278	34.75	235	29.38	102	12.75	185	23.13	800
D-1	106	35.33	47	15.67	48	16.00	99	33.00	300
D-2	98	32.67	39	13.00	52	17.33	111	37.00	300
D-3	133	44.33	121	40.33	33	11.00	13	4.33	300
D-4	98	32.67	39	13.00	52	17.33	111	37.00	300
D-5	120	40.00	144	48.00	36	12.00	0	0.00	300
D-6	60	20.00	131	43.67	24	8.00	85	28.33	300
D-7	106	35.33	44	14.67	44	14.67	106	35.33	300
D-8	120	40.00	144	48.00	36	12.00	0	0.00	300
E-1	459	38.25	455	37.92	67	5.58	219	18.25	1200
E-2	382	31.83	254	21.17	258	21.50	306	25.50	1200
F-1	164	34.17	150	31.25	166	34.58	0	0.00	480
F-2	165	34.38	143	29.79	32	6.67	140	29.17	480
F-3	164	34.17	91	18.96	38	7.92	187	38.96	480
F-4	183	38.13	182	37.92	57	11.88	58	12.08	480
F-5	165	34.38	143	29.79	32	6.67	140	29.17	480
G-1	419	34.92	416	34.67	155	12.92	210	17.50	1200
G-2	422	35.17	293	24.42	170	14.17	315	26.25	1200

Fig. A4 Same as in Figure A2, except for Case 3.



	divergent		unstable		stable		total
		rate(%)		rate(%)		rate(%)	
total	715	29.79	518	21.58	1167	48.63	2400
A-1	0	0.00	109	22.71	371	77.29	480
A-2	0	0.00	146	30.42	334	69.58	480
A-3	480	100.00	0	0.00	0	0.00	480
A-4	0	0.00	173	36.04	307	63.96	480
A-5	235	48.96	90	18.75	155	32.29	480
B-1	240	30.00	171	21.38	389	48.63	800
B-2	235	29.38	176	22.00	389	48.63	800
B-3	240	30.00	171	21.38	389	48.63	800
D-1	84	28.00	42	14.00	174	58.00	300
D-2	84	28.00	15	5.00	201	67.00	300
D-3	76	25.33	156	52.00	68	22.67	300
D-4	84	28.00	15	5.00	201	67.00	300
D-5	119	39.67	18	6.00	163	54.33	300
D-6	66	22.00	144	48.00	90	30.00	300
D-7	83	27.67	104	34.67	113	37.67	300
D-8	119	39.67	24	8.00	157	52.33	300
E-1	387	32.25	301	25.08	512	42.67	1200
E-2	328	27.33	217	18.08	655	54.58	1200
F-1	186	38.75	65	13.54	229	47.71	480
F-2	134	27.92	128	26.67	218	45.42	480
F-3	132	27.50	43	8.96	305	63.54	480
F-4	129	26.88	154	32.08	197	41.04	480
F-5	134	27.92	128	26.67	218	45.42	480
G-1	331	27.58	242	20.17	627	52.25	1200
G-2	384	32.00	276	23.00	540	45.00	1200

Fig. A5 Same as in Figure A2, except for Case 4.

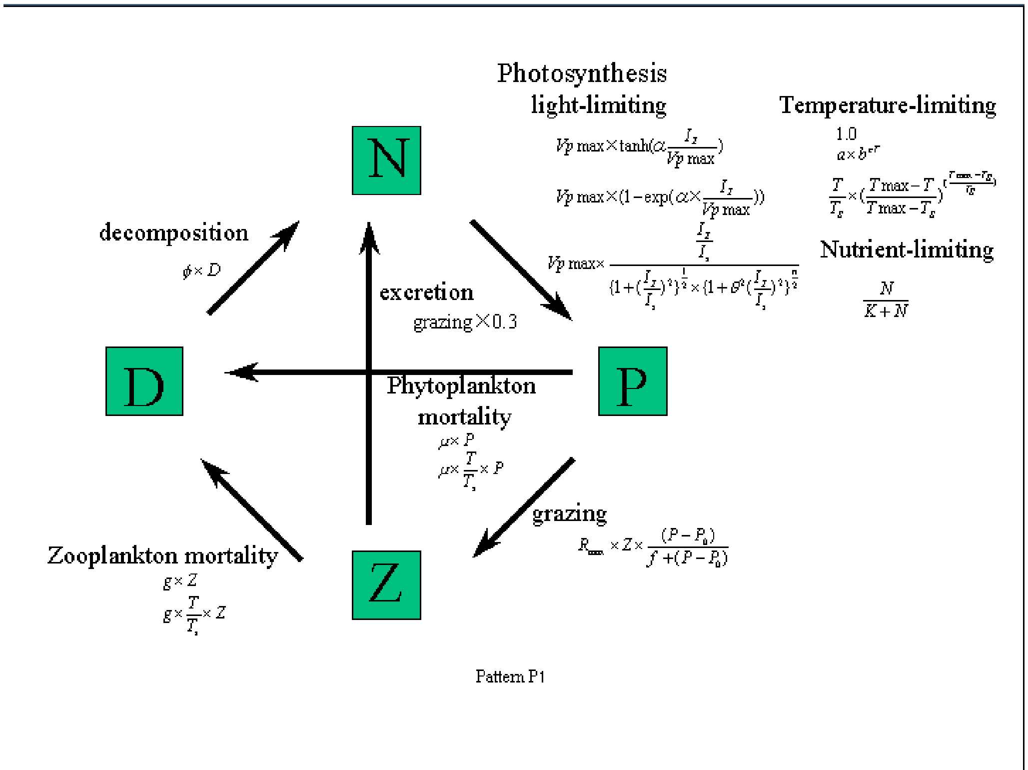


Fig. A6 Most stable combination pattern P1.

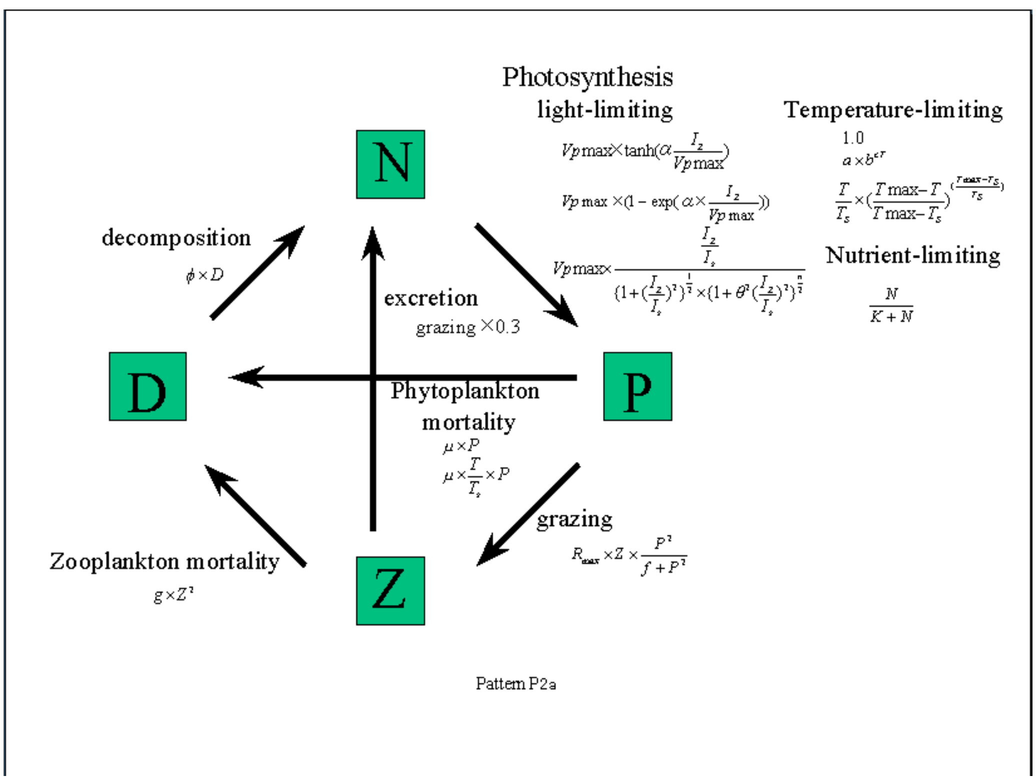


Fig. A7 Most stable combination pattern P2a.

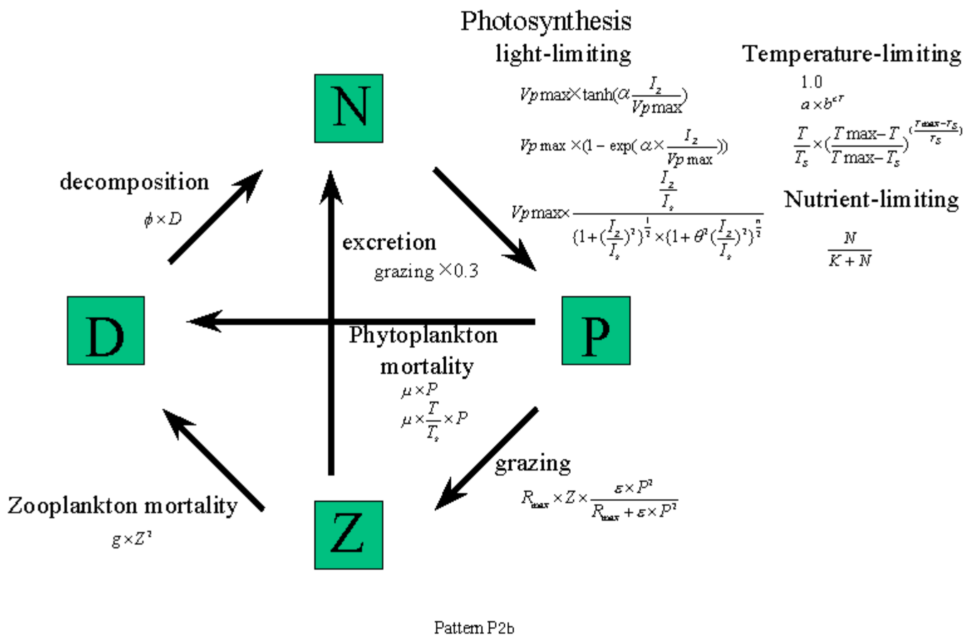


Fig. A8 Most stable combination pattern P2b.

Table A1 Parameters and biological equations.

P-I curve

Eq. No.	Symbol	Parameter	value	reference	Equation form
A-1	Vpmax	Max. phtosyn. rate	1.38 (/day)	Frost(1993)	Vpmax*tanh(αI/Vpmax)
	α	initial splope	3.7 (/ly)		
A-2	Vpmax	Max. phtosyn. rate	1.25 (/day)	Fasham(1995)	Vpmax(1-exp(αI/Vpmax)
	α	initial splope	0.29 (/ly)		
A-3	Vpmax	Max. phtosyn. rate	2.0 /day	Evans and Parslow(1985)	Vpmax* α*I/sqrt(Vpmax**2+(αI)**2)
	α	initial splope	0.17 (/ly)		
A-4	Vpmax	Max. phtosyn. rate		Vollenweider(1965)	Vpmax*(I/Is)/(sqrt(1+(I/Is)**2)*(sqrt(1+θ(I/Is)**2))
	θ	–	0.175		
	η	–	4.3		
	Is	Optimum light intensit	103.7 ly/day		
A-5	Vpmax	Max. phtosyn. rate	2.0 /day	Steel(1962)	Vmax*I/Is*exp(1-I/Is)
	Is	Optimum light intensit	103.7 ly/day		

Temperature

Eq.No.	symbol	Parameter	value	reference	Equation form
B-1	–	–	–		1
B-2	a	–	0.409	Eppley(1972)	a*b**(c*T)
	b	–	1.07		
	c	–	1.0 /℃		
B-3	Ts	Optimum temperature	13 ℃	Parker(1975)	(T/Ts)*((Tmax-T)/(Tmax/Ts))**((Tmax-Ts)/Ts)
	Tmax		20 ℃		

Nutrient Limitation

Eq.No.	Symbol	Parameter	value	reference	Equation form
C-1	K	half saturation const.	0.5 mmol/m^3	Many	N/(K+N)

Excretion of Zooplankton

Eq.No.	Symbol	Parameter	value	reference	Equation form
G-1	–	–			0.3*Grazing
G-2	g2	Excretion rate	0.1 /day	Fasham(1995)	g2*Z + 0.3*Grazing

Decomposition of Detritus

Eq.NO.	symbol	Parameter	value	reference	Equation form
H-1	φ	Decomposition rate	0.05 /day	Frost(1993)	φ*D

Table A1 (continued) Parameters and biological equations.

Grazing

Eq.No.	symbol	Parameter	value	reference	Equation form
D-1	Rmax	Max. grazing rate	1.0 /day	Evans and Parslow(1985)	Rmax*Z*(P-P0)/(f+(P-P0))
	f	half saturation const.	1.0 mmol/m^3		
	P0	lower limit of grazing	0.1 mmol/m^3		
D-2	Rmax	Max. grazing rate	1.0 /day	Holling(1965)	Rmax*Z*(P^2/(f+P^2))
	f	half saturation const.	1.0 mmol/m^3		
	Rmax	Max. grazing rate	1.0 /day	Holling(1965)	Rmax*Z*(ε*P)/(Rmax+ ε*P)
D-3	ε	const.	3.0		
D-4	Rmax	Max. grazing rate	1.0 /day	Holling(1965)	Rmax*Z*(ε*P^2)/(Rmax+ ε*P^2)
	ε	const.	1.0		
D-5	Rmax	Max. grazing rate	0.5 /day	Ivlev(1945)	Rmax*Z*(1-exp(-Λ*(P-Pt)))
	Λ	Ivlev const.	0.02 /(mmolN/m^3)		
	Pt	lower limit of grazing	0.0 mmol/m^3		
D-6	Rmax	Max. grazing rate	1.0 /day	Parker(1975)	Rmax*Z*P*(T/Ts)
	Ts	Standard temp.	13 ℃		
D-7	Rmax	Max. grazing rate	1.0 /day	Armstrong(1994)	Rmax*Z*P/K (P<K)
	K	half saturation const.	2.0 mmol/m^3		Rmax*Z (P>K)
D-8	Rmax	Max. grazing rate	0.5 /day	Dubois and Mayzaud(1975)	Rmax*Z*P*Λ*(1-exp(-Λ*(P-Pt)))
	Λ	Ivlev const.	0.02 /(mmolN/m^3)		
	Pt	lower limit of grazing	0.0 mmol/m^3		

Death of Phytoplankton

Eq.No.	symbol	Parameter	value	reference	Equation form
E-1		–	0		0
E-2	μ	death rate	0.07 /day		μ*P
E-3	μ	death rate	0.07 /day	Parker(1975)	μ*P*(T/Ts)
	Ts	Standard temp	13 ℃		

Death of Zooplankton

Eq.No.	symbol	Parameter	value	reference	Equation form
F-1	g	Max. death rate	0.4 /day	Frost(1993)	g*Z/(h+Z)
	h	half saturation cons.	0.44 mmol/m^3		
F-2	g	Death rate	0.05 /day	Wroblewski and Richman(1987)	g*Z
F-3	g	Death rate	0.25 /day	M.J.FASHAM(1995)	g
F-4	g	Death rate	005 mmol/m^3 /day	Steele and Henderson(1992)	g*Z^2
F-5	g	Deathrate	0.05 /day	Parker(1975)	g*Z*(T/Ts)
	Ts	Standard temp.	13 ℃		

Table 1 : Parameters and biological equations

Table A2 Combinations which are considered to be the most stable.

Patern No.	A	B	C	D	E	F	G	H
242	2	1,2,3	1	1	1	2(5)	1	1
256	1	1,2,3	1	2	1	2(5)	1	1
257	2	1,2,3	1	2	1	2(5)	1	1
286	1	1,2,3	1	4	1	2(5)	1	1
287	2	1,2,3	1	4	1	2(5)	1	1
○ 361	1	1,2,3	1	1	2	2(5)	1	1
○ 362	2	1,2,3	1	1	2	2(5)	1	1
○ 364	4	1,2,3	1	1	2	2(5)	1	1
376	1	1,2,3	1	2	2	2(5)	1	1
377	2	1,2,3	1	2	2	2(5)	1	1
406	1	1,2,3	1	4	2	2(5)	1	1
407	2	1,2,3	1	4	2	2(5)	1	1
496	1	1,2,3	1	2	1	3	1	1
497	2	1,2,3	1	2	1	3	1	1
526	1	1,2,3	1	4	1	3	1	1
527	2	1,2,3	1	4	1	3	1	1
601	1	1,2,3	1	1	2	3	1	1
● 616	1	1,2,3	1	2	2	3	1	1
● 617	2	1,2,3	1	2	2	3	1	1
● 619	4	1,2,3	1	2	2	3	1	1
△ 646	1	1,2,3	1	4	2	3	1	1
△ 647	2	1,2,3	1	4	2	3	1	1
△ 649	4	1,2,3	1	4	2	3	1	1
1697	2	1,2,3	1	2	1	3	2	1
1727	2	1,2,3	1	4	1	3	2	1
1816	1	1,2,3	1	2	2	3	2	1
1846	1	1,2,3	1	4	2	3	2	1

Table 2 Combinations which are considered to be most stable

○:P1, ●:P2a, △:P2b

APPENDIX B. MODEL WORKSHOP 1999: INTERNATIONAL WORKSHOP ON PROTOTYPE OF LOWER TROPHIC LEVEL ECOSYSTEM MODEL FOR COMPARISON OF DIFFERENT MARINE ECOSYSTEMS IN THE NORTH PACIFIC

Title	CCCC Workshop on Lower Trophic Level Modeling
Date	January 24 - 27, 2000
Place	Nemuro Cultural Center, Nemuro, Hokkaido, Japan
Convenors	Michio Kishi, Dan Ware, and Makoto Kashiwai
Steering Committee	S. Yoo, M. Kishi, D. Ware, M. Kashiwai, B. Megrey, D. Dugdale, J. Napp (to be confirmed or modified based on Workshop program)

Objectives

1. to develop lower trophic level models with common structure for study areas of CCCC program, by applying prototype model developed by M. Kishi;
2. to compare dynamics of lower trophic level models for study areas of CCCC program;
3. to identify necessary data for validation and comparative studies;
4. to develop strategy how to apply lower trophic level model to GCMs; and
5. to develop strategy how to connect lower trophic level model to higher trophic level models.

Tentative Schedule

1st day: Jobs on Objective 1) by modelers of component programs
2nd day: Jobs on Objective 2) by modelers of component programs;
3rd day: Presentation on results of Jobs on Objectives 1), 2) and 3);
4th day: Presentation and discussion of objectives 4) and 5).

Reports

1. Workshop Report in PICES Scientific Report Series
2. Scientific papers to be submitted to Fisheries Oceanography or to another Journal proposed by Publication Committee.

Invitation list

(to be identified)

1. modelers to work on objectives 1, 2, and 3 from day 1 to day 4
2. scientists to work on objectives 3, 4 and 5 from day 3 to day 4.

Public Lecture

Programs to be decided by Nemuro Supporting Committee.

MONITOR TASK TEAM REPORT

The MONITOR Task Team was formed in 1998 and held its first meeting from Oct. 16-17, 1998, immediately prior to the PICES Seventh Annual Meeting in Fairbanks, Alaska.

The format of the meeting was a workshop (Co-convenors: Drs. Yasunori Sakurai and Bruce A. Taft) on the design of a monitoring system for PICES. The first day was devoted to presentations by Task Team members and invited speakers. The speakers were asked to review present and planned long-term monitoring programs in the North Pacific that contribute to the attainment of the goals of PICES, and to suggest ways to improve the state of monitoring. The papers would be used to focus future discussions of how to design a more effective monitoring system.

A discussion of issues raised in the papers took place the on second day and a set of recommendations was drafted for forwarding to the CCCC Implementation Panel.

This report summarizes presentations given at the meeting and the proposed future activities. It is organized into 4 sections: (I) Introduction, (II) Components of Monitoring System, (III) International Planning for Ocean Climate Monitoring, and (IV) Task Team Recommendations. Appendix A contains a plan for using the Hardy Continuous Plankton Recorder to monitor zooplankton in the subarctic Pacific. The scientific proposal "A Continuous Plankton Recorder Monitoring Program" has been submitted recently to the North Pacific Marine Initiative and funded for a period of two years.

I. INTRODUCTION

<u>CCCC Expectations of the Workshop</u>

Patricia Livingston
Alaska Fisheries Science Center, Seattle, U.S.A.

The intent of this first workshop of the MONITOR Task Team of the PICES/GLOBEC Climate Change and Carrying Capacity Program (CCCC) is to review existing monitoring activities of PICES member nations and to suggest improvements in the monitoring of the subarctic Pacific to further understanding of the effects of climate variations on the subarctic marine ecosystem.

The first day is devoted to a series of lectures on various aspects of monitoring. On the second day discussions will be held, both in small break-out groups and in plenary session, to determine important gaps in existing monitoring activities and provide suggestions for improvement. A set of workshop recommendations will be prepared and forwarded to the CCCC Implementation Panel.

The following terms of reference for the MONITOR Task Team were the guiding force in designing the format of the workshop and should likewise guide the discussions and types of recommendations that will be made.

1. Review existing activities of PICES member nations and to suggest improvements in the monitoring of the subarctic Pacific to further the goals of the CCCC Program.

2. Consult with REX, BASS and MODEL Task Teams and TCODE on the scientific basis for designing the PICES monitoring system. Questions of standardization and intercalibration of measurements, particularly in the area of biological collections, should be addressed.

3. Assist in the development of a coordinated monitoring program to detect and describe events, such as El Niño, that strongly affect the subarctic Pacific.

4. Report to CCCC IP/EC on the monitoring in the subarctic Pacific to be implemented in the international Global Ocean Observing System (GOOS) or other related activities.

The overarching goal of the CCCC Program is to integrate and stimulate national activities on the effects of climate variations on the marine ecosystems of the subarctic Pacific through a coordinated implementation plan and oversight of the plan. It is thus important to hear from the national representatives about the status of monitoring various ecosystem components in their region and, in particular, the status of monitoring in national GLOBEC programs. We also hope to coordinate our activities with other international efforts such as the Joint Global Ocean Flux Study Program (JGOFS) and the Global Ocean Observing System (GOOS), so we have provided time on the agenda to hear from representatives of those organizations.

An overview of the CCCC Program and the present activities of the other Task Teams was provided. This overview gave workshop participants and the MONITOR Task Team representatives a more complete understanding of the role of monitoring in the science and implementation plans of the CCCC Program and also provided guidance on the kinds of activities that the Task Team could undertake.

Monitoring Planning in PICES

Bruce A. Taft
MONITOR Task Team Co-Chairman, U.S.A.

General aspects of ocean monitoring

A monitoring system is a systematic (regular) set of measurements collected over a period of time long enough to encompass several representations of the phenomena of interest. Because climate variability typically has long time-scales (for example N. Pacific regime shifts) the climate time series need to be long (several decades). Because the background high-frequency variability is often of large amplitude, the density of measurements must be adequate to resolve the time scales of the significant background variability so that it can be averaged out. The same considerations apply to the space scales. Often the background variability is unknown and must be estimated by initially over-sampling and then choosing an adequate sampling scheme. Ultimately the final design must lead to reliable estimation of the climate signals.

There are two main approaches to designing monitoring schemes. If data have been collected and analyzed, there may be an hypothesis that has been proposed and needs to be tested. In this case the design is guided by the nature of the hypothesis. An example of an hypothesis-testing monitoring scheme, which is highly relevant to PICES, is found in the proposal of Gargett (1997) that there is a link between size of the eastern North Pacific salmon stocks and the strength of the Aleutian Low. The link proposed by Gargett is the variation of the hydrostatic stability in the coastal ocean. The basic monitoring scheme would involve CTD sections across the coastal regime at several latitudes over several decades.

The other approach applies in cases where the ocean variability needs to be described before hypotheses can be developed. The collection of basic time-series data will lead to insights into the structure of the system and the formulation of hypotheses on the dynamics of the system. The preliminary monitoring data set will guide the design of future hypothesis-testing monitoring schemes.

Previous discussions of monitoring in PICES

a. PICES-STA Workshop on Monitoring Subarctic Pacific Variability - In October 1994, a two-day workshop on monitoring was held in conjunction with the PICES Third Annual Meeting in Nemuro, Japan. The results (six papers) of the workshop were published (in 1995) as PICES Scientific Report No. 3. The papers covered physical conditions (temperature, salinity, currents, ice cover) and lower trophic level variability in the subarctic Pacific. The emphasis was on the status of knowledge of the region but a few suggestions were made on the need for improved monitoring of certain parameters. The paper by Riser (1995) was particularly noteworthy because it treated in depth the statistical principles of design of monitoring arrays.

b. PICES Working Group 9 on Subarctic Pacific Monitoring - Working Group 9 held three meetings (1995, 1996, 1997). These discussions led to the recommendation of three new initiatives and the enhancement of two existing programs.

New initiatives

1. Ecological moorings. A high priority is the determination of response of primary and secondary production to atmospheric forcing and physical and chemical water-column structure in subarctic gyres. Understanding the relationship between forcing and response requires well-resolved time series of the physical, chemical and biological variables. Neither occasional shipboard (subject to aliasing) or satellite (infrequent surface data) measurements provide a sufficient data base to clarify the relationships. Technological developments suggest that ecosystem moorings can be used to obtain the needed data set. Many of the required sensors exist and others are under development that could be mounted on a moored buoy. As a start moorings should be deployed near the centers of the eastern (near Station P) and western (east of Kamchatka Peninsula) subarctic gyres.

2. East Kamchatka Current transport cable measurement. The general circulation of the subarctic Pacific is thought to consist of two clearly separated cyclonic gyres with the Alaskan Stream flowing westward south of the Aleutians. Flow into the Bering Sea occurs through a series of passages in the Aleutian Arc. The primary Bering Sea outflow occurs through the Kamchatka Strait (East Kamchatka Current) and is the source of water in the Oyashio Current. Variations of transport of Pacific water into the Bering Sea can be monitored by measuring East Kamchatka Current transport flucuations. Long-term measurements of East Kamchatka Current transport can be economically measured by means of an undersea cable laid across the Kamchatka Strait.

3. CTD measurements along eastern boundary. Gargett (1997) has proposed that survival of young salmon may be related to changes in the stability (vertical mixing) of eastern subarctic boundary coastal water. These changes may be related to atmospheric forcing (movement and strength of the Aleutian Low). A coordinated series of long-term CTD sections should be initiated to measure the stability of the coastal regime. Some elements of the needed measurements already exist.

Enhancement of existing programs

1. Surface measurements from VOS. At present there is a joint Japan-Canada ship-of-opportunity program in the North Pacific measuring surface values of temperature, salinity, pCO_2, pH, Chl *a*, NO_3, SiO_4, and total

CO_2. These valuable zonal measurements should be extended to include north-south sections as well as selected subsurface measurements (XBT and XCTD) along the tracks.

2. Heat and freshwater content. XBT coverage of the subarctic Pacific has dropped by 50% over the last five years. Sampling of the region is below the density required to map the thermal field, and should be enhanced. Appropriate new techniques, such as the PALACE float, should be employed as soon as possible to provide adequate coverage of temperature as well as provide badly-needed salinity measurements.

References

Gargett, A.E. 1997. The optimum stability 'window': a mechanism underlying decadal flucuations in North Pacific salmon stocks. *Fish. Oceanogr. 6(2)*: 109-117.

Riser, S.C. 1995. Space and time scales of variability in the subarctic N. Pacific: implications to monitoring the system. *PICES Scientific Report No. 3,* 41-65.

II. COMPONENTS OF MONITORING SYSTEM

Physical Oceanography Monitoring Systems

Phyllis J. Stabeno
Pacific Marine Environmental Laboratory, NOAA, U.S.A.

Ocean monitoring of the physical forcing falls into four categories: (1) satellite measurements; (2) shipboard measurements; (3) Lagrangian (drifting) measurements; and (4) Eulerian (moored) measurements.

Satellite measurements

Satellites provide a variety of surface variables including sea-surface temperature, ocean color and sea-surface height. Data is collected along track lines of the satellite and provides information on the horizontal variability of a variety of parameters. Satellite data are invaluable in placing data collected from ships or moorings in a large-scale context, although direct observations are necessary for calibration. For satellite data to be used as a monitoring tool, it is necessary that it be carefully archived and stored for future use. Historically, this has not always been done and significant portions of older data have been lost.

Shipboard measurements

Oceanographic research vessels provide both a platform for deployment of moorings and measurement of many physical parameters (temperature, salinity, currents, atmospheric variables). In addition, ships-of-opportunity have been used extensively to measure both atmospheric and oceanic variables. The number of long-term monitoring locations or lines in the Northeast Pacific and Bering Sea is limited. The most intensely measured location is Ocean Station Papa, where measurements of a variety of ocean and atmospheric variables have been made regularly over the last 40+ years. There are also a number of locations where conductivity-temperature-salinity (CTD) sections have been repeated more sporadically. The longest record (>20 years) is at GAK-1 maintained by the University of Alaska off Seward, Alaska. In addition a line of seven CTD stations has been repeated about three times a year between Kodiak Island and the Seward Peninsula for the last 15 years. Data have been collected in the Bering Strait sporadically over the last two decades.

These data provide information on transport, water properties (particularly changes in temperature and salinity) and atmospheric variables. While acoustic Doppler current profilers (ADCP) have been mounted on ships for more than 20 years, regular processing of this data has not been common. To obtain currents from the shipboard ADCP requires removal of ship motion which requires careful processing. Changes in heading cause oscillations in the compass heading that impair ability to measure currents. In addition, success has been limited in removing tidal currents from the records to look at low-frequency flow, especially in regions where the tidal currents are strong and the low-frequency currents are weak.

Lagrangian measurements

Most Lagrangian measurements are done via satellite-tracked drifters. These instruments are easily deployed from ships or even from aircraft. They consist of a surface float with transmitter that communicates its location to a satellite or a receiver aboard a ship or on land. There is a long tether beneath the buoy with a large drogue attached at its termination. The drag upon the drogue should be sufficient so that the drifter follows the current at drogue depth. The most common drogue design at the moment is a "holey sock". There is considerable stress put on the tether connecting the drogue to the surface float and the tether often fails. Most drifters test for this and indicate drogue loss in the data stream. Presently, there are drifters designed to measure a variety of variables including temperature, salinity, and chlorophyll *a* in addition to providing drifter position. Large numbers of drifters have been deployed in the North Pacific and Bering Sea to measure open-ocean currents and cross-shelf flows. New technology in the form of PALACE floats is promising. These floats are designed to operate in a mode that differs from surface drifters. After deployment they sink to a depth of 800-1500 m where they remain for a week or longer. They then rise to the surface, measuring temperature and conductivity (salinity). At the surface they transmit, via ARGOS, their location and the temperature and conductivity measured on ascent. They then sink to begin the cycle again. These instruments have been deployed extensively in the Atlantic and to a lesser degree in the North Pacific. The conductivity cells on the earlier instruments fouled, but newly designed floats have not had this problem and appear to measure temperature and conductivity reliably. There are plans to deploy a large number of PALACE floats in the world ocean, and the data then will be assimilated into models. These are the type of measurements that traditionally have required a ship or a mooring; the ability to do so with floats will markedly change monitoring techniques. A drawback for all types of Lagrangian measurements is that it is very difficult to calibrate the instrument performance after deployment.

Moored measurements

Moorings have played an important role in understanding ocean dynamics. While a single mooring can provide information on temporal variability at a given site, several moorings together are needed to differentiate between spatial and temporal variability. The most extensive mooring array today is in the equatorial Pacific (TOGA-TAO). More than 70 moorings have been deployed and provide data that have led to the diagnosis of the dynamics of ENSO. Current meters and thermistors are the most common instruments deployed on moorings. Modern current meters often use acoustics to measure currents over a depth range (Acoustic Doppler profilers). Currents can typically be resolved to 2 cm/s and 5 degrees in direction. A wide range of temperature recorders are available that provide high quality data.

Salinity continues to be a problem, especially in regions of high biological activity. Conductivity cells in such regions often foul within a month of deployment. Calibration by visiting ships in regions of high biological activity is very useful in resolving drift. Surface moorings typically measure a variety of atmospheric variables including wind, solar radiation, rainfall and barometric pressure. A major problem that continues to plague wind measurements in heavy seas is that the surface buoy spends a significant time in the troughs and so that the wind speed is underestimated. Ocean technology has now advanced to the point where many measurements can be made remotely. This technology will continue to develop and provide scientists with needed tools to resolve a variety of oceanographic measurement needs.

Pacific CO_2 Monitoring

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Pacific CO_2 monitoring activities are being carried out mainly in the North Pacific Ocean. The time-series approaches are: (1) ship-of-opportunity; (2) time-series stations and sections; and (3) bio-optics moorings. The cruise tracks (1) are shown in Fig. 1 and the locations of (2) and (3) are shown in Fig. 2.

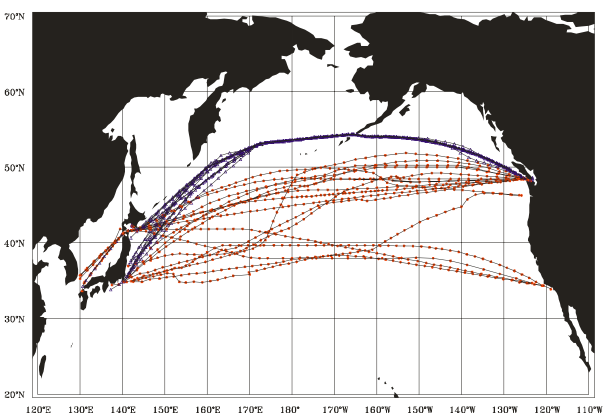

Fig. 9 Cruise tracks of the ship-of-opportunity, M/V *Skaugran*, from March 1995 to April 1997.

Ship-of-opportunity

A ship-of-opportunity program is being conducted as a bilateral cooperation between Canada's Climate Chemistry Laboratory at the Institute of Ocean Sciences (IOS) and Japan's Global Warming Mechanism Laboratory of the National Institute of Environmental Studies (NIES). The program was started in March 1995, using the lumber/cargo carrier *M/V Skaugran* running between Vancouver, B.C., Canada, and ports near Tokyo, Japan. The objective is to monitor the CO_2 parameters in the surface ocean and physical, chemical and biological parameters necessary to describe the seasonal and interannual changes. Continuous measurements, conducted by NIES personnel on board, include (a) surface seawater pCO_2, i.e. partial pressure of CO_2 in seawater, (b) atmospheric pCO_2, (c) sea-surface temperature (SST), (d) conductivity from a CTD and (e) fluorescence. The sea-water sampling program is being conducted by the Climate Chemistry Laboratory at IOS. Seawater samples are collected three times a day from a seawater loop for measurement of (f) DIC, dissolved inorganic carbon, (g) chlorophyll *a*, (h) TA, total alkalinity, (i) dissolved nitrate, phosphate and silicate and (j) salinity.

The west-bound routes from Vancouver always follow the great-circle route and are quite consistent over the year whereas the east-bound routes from Tokyo shift south in winter to avoid storms, or to transport cars from Japan and Korea to California and Oregon. This ship-of-opportunity program produces important data sets for the description of seasonal and interannual changes of CO_2, nutrients and pigments (Chl *a*), as well as other oceanographic properties in the subarctic waters of the Alaskan Gyre, Central Bering Sea, east of of the Kamchatka Peninsula and coastal region off the Kuril Islands. Other products are seasonal maps between 35ºN and 55ºN for the above parameters.

Time-series stations

Ocean Station P started as a weathership program, occupied in the beginning by naval ships (1956-1967), with the emphasis on physical measurements, then by weatherships (1967-1981), with the addition of chemical measurements (nutrients, Chl *a* and atmospheric CO_2 and surface water pCO_2). Since the termination of the weathership program, Station P has been occupied six times a year, now decreasing to three times a year, with short periods (3 days) on station. In recent years since 1990, full oceanographic profiles were obtained for DIC, TA, ^{13}C, nutrients and freons, so that penetration of anthropogenic CO_2 into the interior of the subarctic Pacific can be assessed.

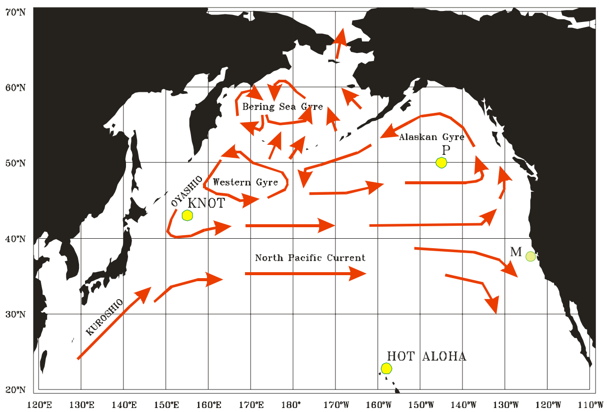

Fig. 10 Long-term monitoring stations and sections and bio-optics moorings superimposed on the general circulation in the North Pacific Ocean.

Japan initiated another subarctic time-series station, Station KNOT (Kyodo North Pacific Ocean Time-Series), in June 1998, at 44°N, 155°E as a joint effort of Japanese national institutes and universities, coordinated by Dr. Y. Nojiri of NIES. Research ships from institutions will visit KNOT during survey cruises in the western North Pacific. The core measurements include underway pCO_2 measurements of air and surface seawater, DIC, TA, nutrients, pH, pigments and productivity.

The U.S.A. initiated a subtropical time-series station, ALOHA (22°45'N, 158°00'W) in October 1988 as the open ocean time-series station HOTS (Hawaii Ocean Time Series). The emphases of HOTS are on the seasonal and interannual variability in the rate of primary and new production and particle export from the upper ocean, nutrient input and recycling, and the time-varying concentrations of CO_2 in the upper water column and the estimation of annual air-sea gas flux. CO_2 parameters DIC, TA and pH were measured in the water column (0-4800 m) on cruises at approximately monthly intervals.

Bio-optics moorings and sediment traps

Bio-optics moorings have been initiated or planned at several sites in the North Pacific: Station P; KNOT; and Monterey Bay (coastal). Sensors mounted on weather buoys provide continuous measurements of pCO_2, SST, air temperature, PAR, fluorescence and nitrate.

Sediment traps moored in the deep ocean is a way to assess the amount of CO_2 in the upper ocean being removed by biological processes. Long time-series have been established at Station P (since 1982) at 3,800 m, and Station ALOHA at 5,000 m (since 1992). At KNOT, sediment traps at 1,000, 3,000 and 5,000 m were deployed by the Japan Marine Science and Technolocogy Center (JAMSTEC) in November 1997. Moored traps are powerful tools to assess the biogenic fluxes of C, N, Si and $CaCO_3$ raining down into the deep ocean and provide a record of climate events, such as the El Niño, on CO_2 uptake.

Calibration of CO_2 measurements

The measurements of DIC and TA are all traceable to the reference seawater from the calibration laboratory at the Scripps Institution of Oceanography (Andrew Dickson), maintained as part of JGOFS' effort to ensure compatibility of data for the Global CO_2 Survey on WOCE cruises. The atmospheric CO_2 measurements are traceable to the WMO primary standard calibrated to the global scale determined by manometer at the CO_2 laboratory at the Scripps Institution of Oceanography (Charles Keeling).

CO_2 and carbon flux monitoring in the North Pacific is being developed as a national and international effort, under the guidance of the JGOFS North Pacific Task Team (NPTT) and PICES. These activities will form the important building blocks for LMR-GOOS in the future.

Phytoplankton Monitoring in the Western Subarctic North Pacific - Present Status and Recommendations

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Phytoplankton monitoring is essential to clarify the effects of climate change on the marine ecosystem because phytoplankton is the main primary producer in the system. In the eastern subarctic Pacific, plankton monitoring at Station P and Line P began in 1956. This data set, including phytoplankton biomass, is one of the few time series which is of sufficient quality and length that it is suitable for study of low-frequency variability in the ocean. There are no time series in the western Pacific of comparable length. In this study, we describe the present status of phytoplankton monitoring in the western subarctic North Pacific and consider aspects of the design of a program to measure subarctic phytoplankton variability on climate-change time scales.

Present status of phytoplankton monitoring in the subarctic western North Pacific

Chlorophyll-*a* concentration, an index of phytoplankton biomass, has been measured in the open ocean since the fluorometric method (Yentsch and Menzel, 1963) was introduced. In the subarctic western North Pacific, Japan Meteorological Agency (JMA) started phytoplankton monitoring in 1972 at stations along PH Line (41°30 N, 142-147°E). Since 1972 JMA has conducted four monitoring cruises per year along the line; the data collected include vertical distribution of chlorophyll-*a* and cell abundance of the key phytoplankton species specific to the water masses of the region. Japan Ocean Data Center (JODC) has archived these data and members of institutes contributing data to JODC can download these data sets from the JODC web site.

Hokkaido University established three transects in the central North Pacific in 1979; along 180ºE (between 35°N and 50°N), and 175°E and 155°E (between 38°N and 50°N). Chlorophyll *a* data have been collected in summer, using the two training ships *Oshoro Maru* and *Hokusei Maru*. These data were published in the Data Record of Oceanographic Observations and Exploratory Fishing (No. 23-41).

In the 1990s, the Japanese Fisheries Agency started phytoplankton monitoring in the subarctic North Pacific. The National Institute of Far Seas Fisheries has been accumulating summer surface chlorophyll *a* data at two transects: along 175°30'W between 38°30'N and 58°30'N (21 stations) and 155°E between 41°N and 51°N (11 stations). The Hokkaido National Research Institute of Fisheries occupied the A-line between 43°N, 145°E and 39°N, 147°E in 1990, and they have conducted 7 cruises per year to investigate changes in hydrography and plankton in the Oyashio Current in relation to climate change. On these cruises transparency, total and size fractionated chlorophyll *a* and profiling reflectance radiometer measurements of spectral distributions of upward and downward irradiance have been measured routinely.

Aspects of the design of a program to measure subarctic phytoplankton variability

According to Furuya and Marumo (1983), the biomass level of smaller size phytoplankton (smaller than 8 micrometer) is relatively uniform, about 10 mgC m^{-3}, in the Pacific Ocean. In contrast, the biomass of the larger size phytoplankton is highly variable and therefore most of the changes in the biomass of phytoplankton are due to variations of larger species. There are differences in the physiological response to light, nutrients, temperature and fundamental factors between the nano- and the micro-phytoplantkon which influence primary productivity. For example, the light and nutrient levels at which growth rates of larger size phytoplankton saturate are higher than those for nano- and micro-flagellates (Parsons and Takahashi, 1973). A high growth rate of diatoms can be found at relatively low temperatures, but growth rates of nano-flagellates are often positively related with temperature (Malone and Neale, 1981).

Environmental factors have probably influenced the biomass level through size or taxonomic composition of the phytoplankton. In the marine ecosystem, the body size of zooplankton predators is larger than their prey (Mullin, 1963; Hargrave and Geen, 1970) and zooplankton tend to select larger available prey (Sheldon et al., 1977). In an ecosystem where the primary producers are mainly pico- and nanno-phytoplankton, the number of trophic levels from the primary producers to fish is larger than those in the systems where larger phytoplankton such as diatoms are dominant. Accordingly, size or species composition of the primary producer is one of the important factors determining not only the biomass level of phytoplankton but also the ecosystem structure and the fish resources carrying capacity. Data on size or taxonomic composition of phytoplankton as well as total chlorophyll *a* are needed to clarify mechanisms of changes in the ecosystem structure in relation to climate change. To measure size-fractionated chlorophyll *a*, water is generally filtered through a sequence of nucleopore filters with adequate pore size (for example, 0.2, 2.0, 10 and 20 micrometer), and then chlorophyll *a* concentration on the filters is measured by the fluorometric method. Although this method involves errors due to the covering of the pores by phytoplankton cells, information about size-fractionated phytoplankton biomass can be measured easily.

All phytoplankton have chlorophyll *a*, beta carotene, and other photosynthetic pigments, called antenna pigments which are specific to taxonomic classes of algae. For example, diatoms have chlorophyll-*c* and focoxanthin and dinophyceae have chlorophyll-*c* and peridinin as antenna pigments. Pigment compositions can provide taxonomic composition information, and the pigment compositions of *in-situ* water can be measured with HPLC. Recently, the profiling reflectance radiometer, which can clarify the vertical distributions of upward and downward irradiance at various wave lengths, has been developed. In the future, taxonomic composition data may be taken automatically and easily by collecting data on the vertical distribution of pigment composition and patterns of absorption spectrum obtained by the profiling reflectance radiometer and constructing algorithms.

Measurement of primary productivity is another kind of data to be incorporated into ecosystem models. Because usage of the ^{14}C isotope is seriously limited in Japan, monitoring programs mentioned above have not included primary productivity data. Chamberlain et al. (1990) measured vertical distribution of natural fluorescence in the sea, which is solar stimulated emission of chlorophyll *a* in a narrow band centered at 683 nm, by profiling natural fluorometer, and revealed the relationship between the natural fluorescence of chlorophyll-*a* and primary productivity measured with ^{13}C. Measurement of natural fluorescence is instantaneous and can be performed without incubating a water sample, therefore natural fluorescence might prove useful in mapping photosynthetic rates during hydrocasts or in continuous monitoring from moorings and drifters (Chamberlin et al., 1990). The technique is promising for future monitoring of phytoplankton.

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Zooplankton Monitoring for the PICES Climate Change and Carrying Capacity (CCCC) Program

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Rationale

There are many well-documented cases that demonstrate zooplankton biomass and species composition response to large-scale changes in the physical environment (e.g. Russell Cycles; Cushing, 1982). The CCCC Program acknowledges that long-period changes occur in the PICES region and assumes that changes in zooplankton biomass, productivity and species composition will lead to changes in the carrying capacity of the subarctic Pacific. For this reason, zooplankton have been chosen as one element of the ecosystem to be monitored as part of the CCCC Program. Monitoring zooplankton during periods of large-scale change in the ecosystem may provide PICES scientists increased understanding of the mechanisms by which change occurs, and a way to predict changes in carrying capacity.

Building zooplankton monitoring systems

The PICES CCCC Program proposes comparative studies among coastal regions (REX) and between the open ocean subarctic gyres (BASS). These studies require comparable zooplankton sampling and analysis methodologies. Data archival systems that allow easy access and exchange are also necessary. National CCCC-type programs are encouraged to design and build zooplankton monitoring systems that address these elements so that comparative studies are possible.

Target organisms

PICES Scientific Report No.4 (1996) states that the CCCC Program will examine how secondary producers respond in productivity, biomass, and species composition to climate variability in different ecosystems of the subarctic Pacific. Secondary producers are found among three different size groups of the zooplankton community: microzooplankton (2-200 µm); mesozooplankton (200-2000 µm); and macrozooplankton (>2000 µm). CCCC monitoring studies should include key taxa or functional groups.

Program scope

Two critical elements of monitoring programs are duration and frequency of sampling. The North Pacific Ocean and Bering Sea ecosystems are known to exhibit decadal and longer-term oscillations (e.g. Chelton et al., 1982; Brodeur and Ware, 1992; Hare and Francis 1995; Mantua et al., 1997; Sugimoto and Tadokoro, 1997). In addition, recent attention has been given to slow secular changes in the North Pacific Ocean (Roemmich and McGowan, 1995; Veit et al., 1997). To resolve long-period periodicities and slow secular change in ecosystem form or function requires a sustained effort with secure funding (i.e. long-term observations). Sustained, long-term observation must be a priority of the PICES CCCC Program.

At the other end of the temporal spectrum are events that determine year-class strength of living marine resources. Sampling must be matched to the life history of the target species. For example, many fisheries target long-lived species (e.g. pollock or crab). In these populations the success of a single year-class may carry the fishery for many years. Therefore sampling must also be frequent enough to detect when recruitment-favorable or recruitment-unfavorable events occur. Another example is shifts in the timing of particular events (analagous to match/mismatch hypothesis of Cushing, 1990). For example, the timing of the biomass maximum of zooplankton (dominated by a single species) at Ocean Station Papa has become increasingly earlier over the last 15 years (Mackas et al., 1998). This demonstrates that sampling must be frequent enough so that changes in the timing of events do not alias the data leading to false conclusions (in this case that the zooplankton biomass is changing).

To design optimal sampling strategies for opposite ends of the temporal spectrum will be difficult. Observational programs often have tight financial constraints – CCCC-type programs from individual member countries must remain simple, using equipment with a high degree of reliability. Selection of target taxa must be judicious, relying on taxa that have demonstrated or suspected sensitivity to environmental change. Lastly, the CCCC Program assumes that zooplankton are responding to their physical and biological environment, therefore measurement of environmental variability is also necessary compounding the complexity and cost of these programs.

Adequacy of present technology

An exhaustive treatment of the technology available for measurement systems is beyond the scope of this report. The following discussion will highlight only a few aspects of this problem. In general, measurement of zooplankton biomass and species composition is more sophisticated (and applied more often) than measurement of zooplankton productivity. Recent advances in digital and optical technology are being applied to zooplankton measurement systems. Carrying capacity implies a system's ability to sustain and support production. Adequate measurements of secondary production are therefore also necessary. Reviews of accepted methods in zooplankton ecology can be found in Omori and Ikeda (1984) and the forthcoming ICES Manual on Zooplankton Methods (Harris, in press).

<u>Ocean Observatories</u> -At present, mooring systems are often stand-alone platforms that must be visited frequently for instrument servicing and data retrieval. This is because of instrument biofouling and because the band width/data transfer rates of satellite systems are limited (and expensive). Future ocean observatories envision single moorings, mooring arrays or sea-floor platforms connected to the shore via fiber optic cables. While this improves the spatial coverage and data transmission problems, more development is required to improve the suite of available sensors appropriate for long-term deployments with infrequent instrument service.

<u>Biomass and species composition</u>- **S**ample collection once meant retrieval of a physical sample of organisms from the sea for later analysis in the laboratory. Today it is possible to determine much (but not all) of the same information by collecting optical or acoustical data *in situ* (U.S. GLOBEC, 1991). Instrument development is taking advantage of the revolution in digital and optical technology. Instruments such as the Video Plankton Recorder (VPR; Davis et al., 1992; 1996), Flow Cytometer (Sieracki et al., 1998), Optical Particle Counter (OPC; Herman, 1992), and Tracor Acoustic Profiling System (TAPS; Holliday and Pieper, 1995; Barans et al., 1997) are good examples. The instruments

have demonstrated their utility in process-oriented research. Adaptations of these instruments for long-term observations are possible.

Secondary production - There are no instruments to directly measure secondary production. This quantity often must be calculated from physiological measurements made on experimental animals removed from their environment. Thus it presents a greater challenge for CCCC scientists. Two new promising techniques employ calculations of population dynamics parameters. Recently biomass spectrum theory has been developed to provide individual and population growth rates from closely spaced (in time) surveys using OPCs (Zhou and Huntley, 1997). Another technique, Vertical Life Tables (Asknes and Ohman, 1996), provides a method to estimate mortality without repeated sampling of a distinct population.

Conclusion

"The reason a lot of people do not recognize opportunity is because it usually goes around wearing overalls and looking like hard work." *Thomas Edison*

The PICES CCCC MONITOR Task Team has a difficult job. Our role is to offer advice to PICES member countries on direction and techniques. We can only advise, and have no authority to require that our advice be adopted into programs under the BASS or REX umbrella. The rewards, however, for implementing a cohesive, efficient, trans-North Pacific Ocean, long-term observational program are great. A well designed system will increase our understanding of natural system variations, describe important forcing functions and mechanisms, and may potentially allow accurate prediction of events that have a socio-economic impact on countries that rim the North Pacific Ocean.

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Potential use of the Continuous Plankton Recorder in the subarctic Pacific

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Introduction
The Continuous Plankton Recorder (CPR) has been deployed in the North Atlantic and North Sea since the 1930s providing a multi-decadal time-series of plankton abundance and distribution data. Correlations have recently been described between the plankton recorded by the CPR and indices of climatic variability in these regions. The CPR could be a potential monitoring tool for the plankton (particularly mesozooplankton) in the subarctic Pacific Ocean. A trial tow was conducted in the summer of 1997 to demonstrate the feasibility of operating such a survey from the CPR base at the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in the United Kingdom. Strengths and limitations of the CPR methodology, results from the trial tow in 1997 and examples of the climatic relationships recorded in the North Atlantic were presented to allow discussion of its application in the North Pacific.

CPR methodology
CPRs are towed in the surface mixed layer at a depth of about 7 m (Hays and Warner, 1993) by commercial 'ships of opportunity' on their regular routes of passage. The use of commercial ships is economical and ensures that sampling is evenly spread throughout the year and is not biased towards the more clement months, as is often the case with research ship programmes. Water enters the front of the CPR through a 1.27 cm square aperture, passes along a tunnel and through a silk filtering mesh (mesh size 270 micrometer) before exiting at the back of the machine. The movement of the CPR through the water turns an external propeller which, via a drive shaft and gear-box, moves the filtering silk across the tunnel at a rate of approximately 10 cm per 18 km of tow. As the filtering silk leaves the tunnel it is covered by a second band of silk so that the plankton are sandwiched between these two layers. The silk and plankton are then wound on into a storage chamber containing formaldehyde. On return to the laboratory, the silks are processed in a set manner (Colebrook, 1960). The deployment and recovery positions of the recorder are used to determine and mark the 18 km samples and alternate samples are analysed for the presence of plankton.

Phytoplankton colour, a visual estimate of the greenness of the sample (a proxy for chlorophyll), is first assessed by reference to standard colour charts. Phytoplankton are then semi-quantitatively determined by viewing 20 fields of view and recording the presence of all taxa in each field. Small zooplankton are identified and enumerated into categories of abundance from a subsample (1/50 of the sample) whilst all zooplankton larger than about 2 mm are counted with no subsampling. Identification is carried out to the highest practicable taxonomic level. Although CPR sampling is continuous, individual samples are allocated a position according to the latitude and longitude of the mid-point of the sample.

The most limiting factor regarding CPR data is that it is collected from a fixed depth. Diel vertical migration of zooplankton means that for some species true abundances are not recorded in day collected samples. Comparisons between zooplankton biomass derived from CPR samples and from the depth resolving.

Longhurst-Hardy Plankton Recorder have shown, however, that depth-integrated samples from the surface mixed layer and down to 200 m are not significantly different between the two devices, at least in the Celtic Sea (Batten et al., 1999). Development of an undulating plankton recorder (the U-Tow) is underway, however, it has not yet been proven to undulate at the high speeds a ship-of-opportunity programme requires. Both the existing CPR and the proposed undulator can carry instrumentation to record the physico-chemical environment as an invaluable supplement to the biological data. Temperature sensors are routinely fitted to several CPR routes and selected tows carry a CTD and fluorescence instrumentation package. Satellite images, which have a similar synoptic coverage, can also provide data to place the plankton information into hydrographic context.

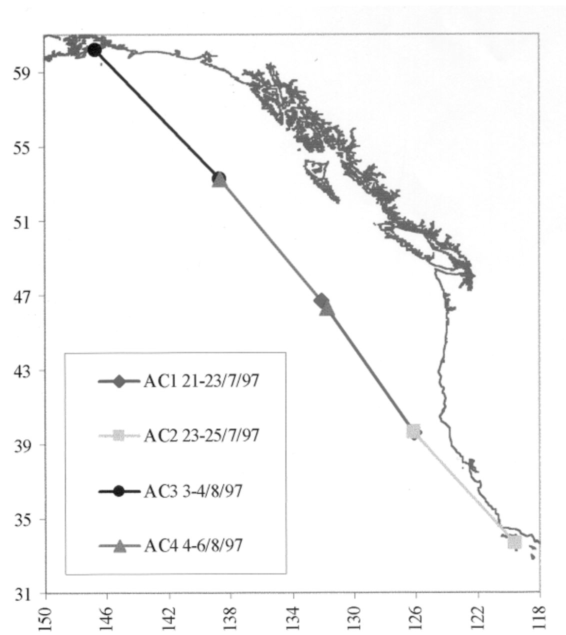

Fig. 11 The location of the CPR tows in the North Pacific Ocean, together with the dates of each tow.

Trial Pacific tow

In July and August 1997, a 3600 km tow was undertaken from Valdez, Alaska, to Long Beach, California (Figure 1), on the ARCO Alaska. This tow utilised four CPR internal mechanisms and resulted in 194 samples, of which every fourth (and always the first and last sample) were analysed for plankton abundance to give a total of 54 analysed samples. Excellent cooperation was achieved with the ship's Master and operating company (ARCO Marine Inc).

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Monitoring of Changes in Spawning Sites of Ommastrephid Squid *Todarodes pacificus* Related to Stock Fluctuations and Climate Change

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Most commercially exploited squid live for a year or less. Reproductive success will depend on the physical and biological environment at the spawning and nursery grounds. Possible causes of the "failures" of *Todarodes pacificus* (Steenstrup, 1880) and *Illex illecebrosus* (Lesueur, 1821) fisheries in the 1980s include changing environmental conditions and heavy fishing pressure (Lipinski et al., in press).

T. Pacificus migrates seasonally near Japan and Korea and spawns at the southern end of its distribution (Murata, 1989). Three spawning groups (winter, fall and summer) occur with overlapping spawning grounds. Catches have fluctuated during the 20th century; during 1986-96, annual catches near Japan have increased from 99,000 to 444,000 tons. Episodic "regime shift" changes involving entire biological community structures occur worldwide (Lluch-Belda et al., 1992). In the western North Pacific, interdecadal regime shifts in water temperature have occurred from a warm regime beginning in the late 1940s, to a cool regime in the late 1970s, and back to a warm regime in the late 1980s (e.g. Kodama et al., 1995). These regime shifts appear to affect the catches of *T. pacificus*, in particular, the early 1980s' catch decreased and the late 1980s' catch increased. Fall paralarval abundances since the late 1980s have been higher than during the late 1970s to the mid-1980s. This increase corresponds to the increase in adult squid catch that has occurred since the late 1980s (Goto and Kidokoro, pers. comm.). These stock fluctuations may be related to the effects of regime shifts on spawning and paralarval survival.

A possible scenario is proposed for this recent stock increase based on changing environmental conditions. First, trends in the annual variations of stock and larval catches are reviewed, and possible spawning sites around Japan are inferred, assuming that egg masses and hatchlings occur at temperatures between 15 and 23°C, and above the continental shelf (JODC, 1978; Sakurai et al., 1996; Bower and Sakurai, 1996). Possible changes in the spawning sites of *T. pacificus* during 1984-95 are inferred based on GIS data. The conclusion is that as stock size has increased since the late 1980s, the fall and winter spawning sites have overlapped in the Tsushima Strait and near the Goto Isands, and that winter spawning sites have expanded above the continental shelf and slope in the East China Sea. However, the inferred spawning sites varied annually (e.g. 1992 in a warm regime), which might be a cause of the historical catch fluctuations of *T. pacificus*.

It has been shown that GIS can be used to monitor and forecast the stock fluctuations of *T. pacificus* related to climatic regime shift, by examining temporal and spatial distributions of the optimum spawning sites. GIS will become an important tool in future monitoring studies of stock fluctuations in exploited squid species.

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Monitoring Fish Responses to Ocean Climate

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Pacific salmon are an especially tractable animal for use in monitoring ocean conditions, because they return with very high fidelity to their natal river. As a result, it is possible to consider all adult animals collected on their return to freshwater as being from a particular source population, with individual animals being replicate observations, and to consider differences between populations as measuring differences in the average conditions each population was exposed to.

The general conclusion from the overview presented below was that it was important to distinguish between effects of the ocean on survival from effects on growth. In general, oceanographic influences on survival and growth are likely not the same. Overall, survival is likely largely determined during the first year of life in the ocean (during the coastal phase of the life history). Size is likely determined later in the life history (during the second or later years of life, during the offshore, pelagic, phase of the life history). As a result, studies of how Pacific salmon growth and survival change over time are likely to provide information about a wide range of ocean regions.

The ocean distribution of Pacific salmon differs between species, but primarily in terms of the extent of their ocean migrations. In general, those species of salmon that have the most extended life histories in the ocean also have the most extensive ocean distributions. Sockeye (Fig. 1) have an intermediate level of distribution, with fish from different source regions being found about as far as half-way across the Pacific Ocean. Depending on the source population being studied, salmon returning from the ocean will therefore have sampled different parts of the ocean.

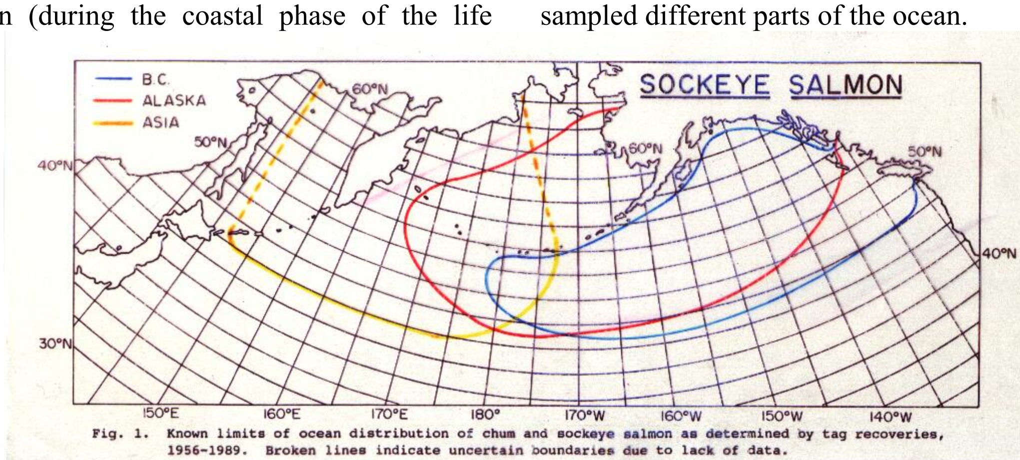

Fig. 1 Known limits of ocean distribution of sockeye salmon as determined by tag recoveries from 1956-1989. Broken lines indicate uncertain boundaries due to lack of data.

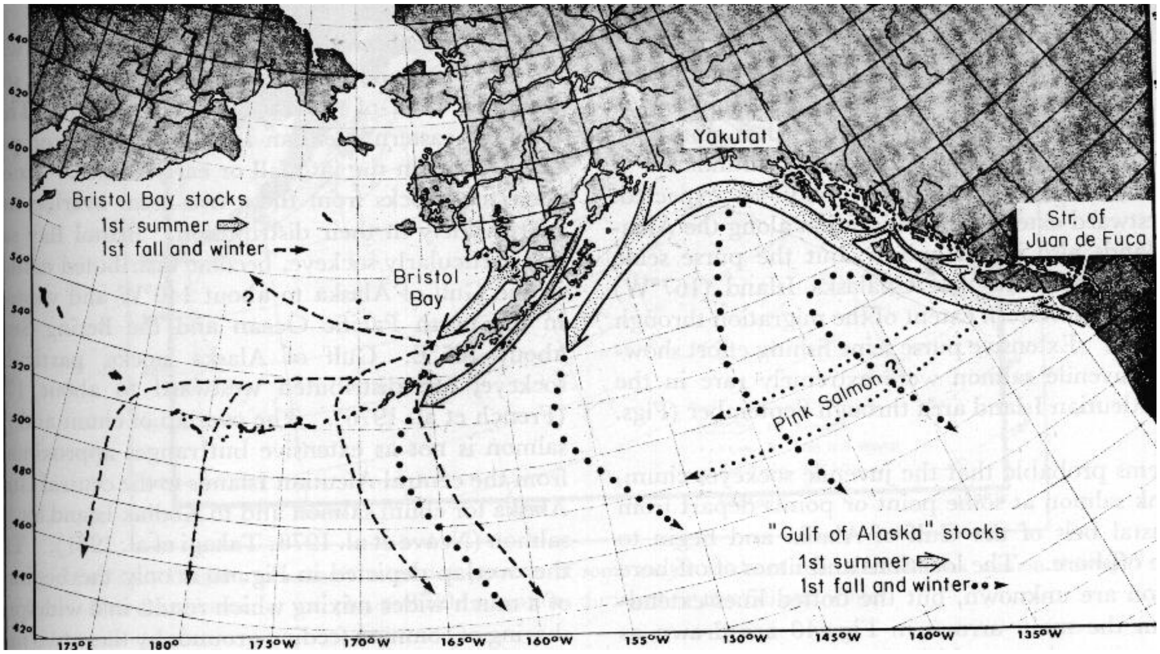

Fig. 2 Migration pathways of juvenile salmon along the west coast of North America (Hart and Dell 1986). The offshore migration paths in the fall were hypothesized, but not established by sampling.

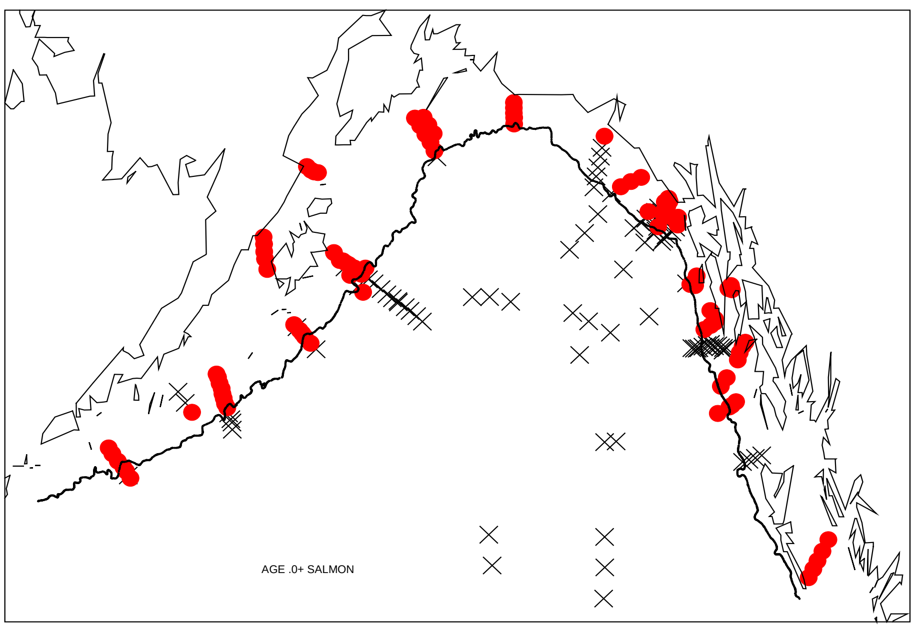

Fig. 3 Results of Canadian surveys of the migration pathways. Juvenile salmon were restricted to continental shelf waters until early December, and to migrate much greater distances along the shelf before moving to the offshore.

The migratory pathways of juvenile salmon in the first summer and fall after entry into the ocean are apparently the same for the different species of salmon (steelhead being the single possible exception). The general pattern of movement was established from work completed in the 1960s (Hartt and Dell, 1986). After leaving North American rivers in the spring, the juveniles turn right and move rapidly north and west along the coast (Fig. 2).

A striking feature of recent ocean surveys from 1995-97 is that even as late as the beginning of December no juvenile salmon have been found off the continental shelf (Fig. 3). Given the rapid rates of measured movement and the confinement of the young salmon to the surface waters over the shelf as far as the start of the Aleutians in early December, it is clear that the growth and survival of the vast majority is determined in the coastal zone, as opposed to the pelagic offshore.

These same surveys show an equally remarkable demarcation in the distribution of immature salmon, with no salmon in their second or later years of ocean life being found in continental shelf waters. (One species, chum salmon, is found in appreciable numbers in the slope region as immature individuals, but not in waters shallower than roughly 200 m).

As a result, there is a sharply delineated geographic and temporal separation between the ocean environments salmon are exposed to. During their first year of life in the ocean, juvenile salmon growth and survival is determined by conditions experienced in the coastal ocean off North America, while it is conditions prevailing in the offshore, open ocean, region that determine growth and survival during subsequent years of life in the ocean. This allows a relatively sharp delineation of the impacts of growth on salmon over their life in the sea, because the extensive archives of salmon scales that have been collected since the 1950s allow us to build up a picture of growth for different calendar years.

The next question that must be answered in assessing the use of fish such as Pacific salmon as useful monitors of ocean conditions is whether or not there is useful variation in the measured growth rates that can be used as indications of oceanographic change. The answer is that there is. The interannual variation in measured growth by year at sea is much larger than the variability between individuals (Fig. 4), indicating that changes affecting growth in the ocean can be reliably identified. Furthermore, as this particular example indicates, there is a qualitative difference in the nature of the growth response. The first (M1) and last (M3) years of life in the sea, when sockeye transit the continental shelf zone, show a significant trend to smaller average size since 1977. In contrast, growth during the exclusively open ocean phase (M2), when sockeye do not forage on the continental shelf region, shows no systematic decline in mean growth rate.

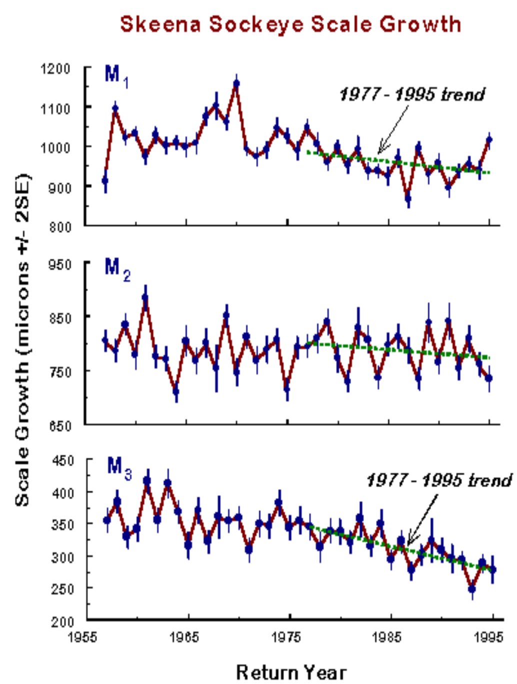

Fig. 4 Patterns of growth of Skeena River (B.C.) sockeye salmon.

The survival of all species of Pacific salmon also seems to have been negatively affected as a consequence of these climatic changes. Starting in 1990, one year after the drop in mean size of adult salmon was observed, the survival of juvenile salmon entering the ocean off southern and central British Columbia also decreased. Direct measurements of the ocean survival of several stocks of coho showed this drop (Beamish et al., 1999), and the ocean survival of steelhead trout

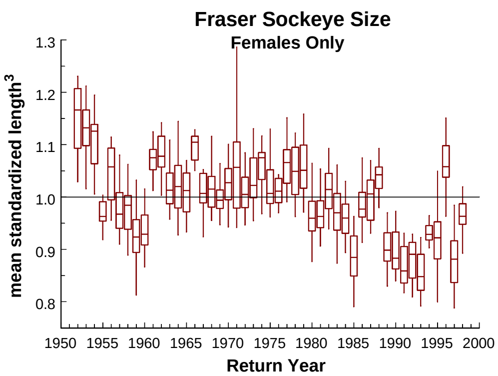

Fig. 5 Changes in adult size of Fraser River sockeye salmon.

The ability to identify the spatial and temporal location of these changes in growth is important, because there is good evidence that large changes in the ocean are now occurring. Beginning in 1989, the average size of adult British Columbia salmon returning from the sea dropped quite sharply (Fig. 5). This was also the year when a large-scale change in the northern hemisphere's atmospheric circulation occurred (Watanabe and Nitta 1998; 1999; submitted).

collapsed from roughly 16% to less than 4% (Welch et al., 1988, 1999). More recent findings support these direct observations of changes in marine survival. Once lagged back to the year of ocean entry as juveniles, all species of salmon in British Columbia show that a sharp reduction in adult recruitment began in 1990 (Fig. 6).

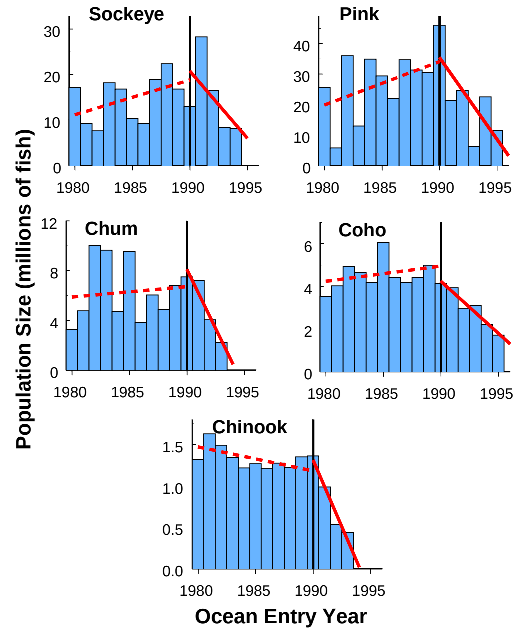

Fig. 6 Changes in total salmon returns to British Columbia. After 1989/90 all species show sharp declines.

Summary

Although relevance to fisheries has often been cited as one important reason for running oceanographic monitoring programs, the changes in the fish population themselves may be novel candidates relevant to studying the oceans. The rather detailed knowledge of the life history of Pacific salmon that has developed in the last few decades make them a particularly attractive example. Individual populations return with strong site fidelity to their rivers, making it possible to identify individuals from a range of populations. Large archival scale collections already exist for many of these populations. And as I have demonstrated with the examples above, both the growth variations contained in the scales and the survival trends reflected in the recruitment data indicate that large-scale impacts of changes in the ocean environment are affecting these records and likely have consistent and reliable interpretations.

The changes in fish populations may then be as relevant to oceanography as the changes recorded in glacial ice cores in reconstructing past climates. Although ice cores are capable of reconstructing aspects of past climates going back much farther in time than can modern fish records, detailed reconstructions breaking out coastal from offshore processes on an annual basis for salmon populations situated at different locations along the West Coast may make up for the relatively short (50 yr) time series that are available. Changes in Pacific salmon growth and survival may therefore make attractive candidates for part of a Pacific monitoring program.

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III. INTERNATIONAL PLANNING FOR OCEAN CLIMATE MONITORING

Status of Monitoring Discussion in LMR Module of GOOS

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The Living Marine Resources Panel of the Global Ocean Observing System (LMR GOOS) held its first meeting at UNESCO, Paris, on March 23-25, 1998.

Agreement was reached on the following statement of goals and objectives. The goal of LMR GOOS is to provide operationally useful information on changes in the state of living marine resources and ecosystems. The objectives are to obtain from various sources relevant oceanographic and climatic data, along with biological, fisheries, and other information on the marine ecosystems, to compile and analyze these data, to describe the varying state of the ecosystems, and to predict future states of the ecosystems, including exploited species, on useful time scales. A consequence of these efforts should be the identification and development of the more powerful and cost-effective means for monitoring marine ecosystems required to meet the LMR GOOS goal.

GOOS also has a Coastal Panel, with which there is potential for overlap. Initially the LMR Panel will focus on deep ocean and shelf sea conditions dominated by oceanic processes. Eventually the panels may be merged.

After a review of existing international monitoring programs, the Panel decided that its assessment was incomplete and therefore directed the following request to IOC: Several national, regional, and other international organizations have conducted, or now conduct, repeated observations designed to monitor the status of marine ecosystems or selected biological or physical components thereof. While some of these programs are well known, e.g., California Cooperative Oceanic Fisheries Investigations (CalCOFI), others are known only locally. In addition, some programs periodically assess the changing state of local ecosystems. An integrated set of these assessments could improve the understanding of marine ecosystems globally, as well as indicating areas whose present monitoring is inadequate. The Panel therefore requests that IOC compile and make available information on significant monitoring and assessment programs of its member states.

An analogous request was made to FAO: A number of national and regional bodies collect and analyze fishery statistics and make fishery assessments. An aggregation of these analyses would be invaluable in assessing population changes in the upper trophic levels of marine ecosystems. The Panel therefore requests FAO, the global centre for fishery statistics, to identify on a global scale the existing fishery analyses that could contribute to the desired meta-assessment and to advise on how it could best be organized and carried out.

A generic table was prepared of the ecosystem components and conditions for which information is desired:

Ecosystem components: Top predators, commercial finfish, forage and nekton, benthos, zooplankton, phytoplankton. Desired information: Abundance and distribution, reproduction, recruitment, growth, ecosystem role, causes of mortality.

Ecosystem conditions: Nutrient chemistry, temperature, salinity, dissolved oxygen, ocean velocity field, atmospheric forcing. Desired information: Magnitude and distribution, causes of variations.

The scope of an actual monitoring program will depend on which of these classes are already adequately monitored regionally, which are most salient for the recognized problems of the region or system, and which can be incorporated in a designed monitoring program at acceptable cost and using available technology. A vital monitoring base should be in place in all coastal states to which selected measurements can be added as appropriate. This base should include: coastal station measurement of sea level, surface temperature and salinity, winds, and atmospheric pressure, general knowledge of occurrence and life history of major marine species measures of catch, effort, and size frequency distribution of major commercial species.

Panelists are to provide more detailed specification of monitoring needs in regions with which they are most familiar.
It was proposed to test the concept of monitoring, analysis, and prediction in several well-sampled regions where significant ecosystem changes such as regime shifts have been observed. In such regions one could ask to what extent ecosystem changes could have been predicted from the observed variables. Could predictability have been improved if additional or different variables had been monitored? Was inadequate predictability a consequence of inadequate monitoring, inadequate analysis, or inadequate understanding? Proposed locations for these retrospective experiments include: Baltic Sea, CalCOFI area, Japan Sea/East Sea, Northwest Atlantic demersal stocks, Northeast Atlantic, Benguela Current, Black Sea.

The Panel will meet again in Montpellier in March 22-23, 1999. Members from the PICES area include Michael Laurs (Hawaii), Daniel Lluch-Belda (Mexico), Takashige Sugimoto (Japan), Chang-Ik Zhang (Korea) and Warren Wooster (U.S.A.).

GLOBEC International - Perspectives on Monitoring

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The PICES CCCC Program is a regional contribution to the international GLOBEC effort. The GLOBEC International planning focus is on the completion of an implementation plan. Aspects of monitoring are discussed in the draft implementation plan. The purpose of this paper is to provide an overview of monitoring activities outlined in the implementation plan, particularly those types of activities that regional programs would most likely undertake.

The GLOBEC International implementation plan has four research foci (retrospective analyses and time series studies; process studies; predictive and modelling capabilities; and feedback from changes in marine ecosystem structure), various activities defined under each research focus, and particular tasks identified within an activity. Extracted below from the implementation plan are the foci activities and tasks that most relate to monitoring.

FOCUS 1. Retrospective analyses and time series studies. The objective of this focus is to identify and understand the characteristic, natural modes of physical forcing and marine ecosystem variability over a range of temporal scales (interannual and longer) and including spatial scales from large marine ecosystems, to basins, and global systems. The approach is to develop and examine historical information on marine ecosystems from a variety of sources (including other global change programs) and the outputs will be the foundation for the structure and parameter estimates of ecosystem models, process studies, comparative ecosystem analyses, and future time series and monitoring programs.

Two activities under this focus that particularly relate to monitoring are: (a) the preservation of existing long time series data; and (b) the development of new data sets for future comparisons.

The tasks that are envisioned under (a) are: evaluate existing long time series data collection activities to determine if they are in the best locations and sampling the key variables at appropriate frequencies using the best available techniques; recommend continuation and/or modifications to time series to improve their utility to future monitoring, while ensuring continuity with past measurements and broad spatial distribution of monitoring sites; analyze, preserve, and disseminate samples and data collected in existing and previous time series studies but that are not widely available or are in danger of being lost.

Tasks to be accomplished under (b) are: develop new long-term time series study locations and variables based on results from present GLOBEC and other programs, in order to supplement and complement existing long-time series data collection activities; and coordinate and collaborate closely with GOOS in the continuation and development of these time series activities.

FOCUS 3. Predictive and modeling capabilities. The approach under this focus is to develop models that interface with interdisciplinary observational systems such that the coupled model-observation system has the capability to examine the responses of selected marine ecosystems, up to the level of zooplankton and fish populations, to physical forcing and biological interactions.

Key activities important to monitoring are: (a) the design and testing of relevant sampling and observational systems and (b) the development of coupled modeling-observational capabilities and applications.

Important tasks under activity (a) are: design testbed experiments to compare performance of new instruments and to intercalibrate existing technologies; capitalize on new technologies and modeling capabilities for the experiments; and establish optimal sampling designs for each region.

In order to make progress under activity (b), the following tasks have been identified: coupled model/observational systems need to be developed using testbeds (comprehensive arrays of sampling platforms, including *in situ* and remote systems); observational system simulation experiments should be conducted prior to process studies and deployment of large-scale sampling arrays; and observational and modeling methodologies should be made available for development of the Global Ocean Observing System.

Summary

Clearly, there are many monitoring activities envisioned in the GLOBEC International implementation plan that a regional program such as the CCCC should be undertaking. The tasks above give us direction to focus our attention. These tasks must be undertaken in order to ensure that a global synthesis of the results from the regional studies and national programs can be performed.

Long-Term Observations Carried out off the Washington, Oregon and Northern California Coasts

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A number of monitoring activities are focused on the ocean off the west coast of the U.S. through funding from the National Marine Fisheries Service, the U.S. GLOBEC program, the Bonneville Power Administration and the Office of Naval Research. This report summarizes these activities.

1. Bi-weekly cruises off Newport, Oregon (44°40'N). W.T. Peterson conducts cruises twice each month along the Newport Hydrographic Line from a small research vessel (40 foot). Sampling stations are located at offshore distances of 1, 3, 5, 10 and 15 miles (2, 5, 9, 18 and 28 km). The sampling routine includes a CTD profile at each station using a Seabird SBE-19 CTD, secchi disk measurement, continuous sea-surface temperature measured with an internally recording Onset Stowaway thermistor, surface seawater sample with a bucket for measurement of chlorophyll and nutrients, a vertical zooplankton tow with a 0.5 m mouth diameter net fitted with a 200 micrometer mesh net towed from near the bottom to the surface and an oblique tow over the upper 20 m with a 1 m mouth diameter and 333 micrometer mesh net. Cruises have been conducted since May 1996 and are supported by the National Marine Fisheries Service and the Office of Naval Research. Point of contact for this work is Bill Peterson: bpeterso@sable.nwfsc-hc.noaa.gov; phone (541) 867-0201; fax (541) 867-0389.

2. Bi-monthly cruises along four transect lines. The lines intersect the coast at Newport, Oregon (44°40'N), Coos Bay, Oregon (43°13'N), Crescent City, California (41°53'N) and Eureka, California (40°53'N). These cruises are part of the U.S. GLOBEC Long-Term Observation Program and are conducted by oceanographers from Oregon State University and NOAA. Principal Investigators include Bob Smith, Jane Huyer, Mike Kosro, Jack Barth, Pat Wheeler and Bill Peterson. Stations extend 156 km offshore off Newport, 63 km off Coos Bay, 93 km off Crescent City and 100 km off Eureka. Measurements taken at each station include profiles of CTD (Seabird 9/11), fluorometer, transmissometer and dissolved oxygen, particulate organic carbon and nitrogen, chlorophyll and nutrients from the euphotic zone from rosette samples, zooplankton by vertical tows over the upper 100 m with a 0.5 m diameter, 200 micrometer mesh net, oblique tows over the upper 20 m with 1 m diameter, 333 micrometer mesh net, neuston tows with a 333 micrometer mesh nets and oblique bongo tows (70 cm diameter, 505 micrometer mesh nets). Satellite-tracked WOCE drifters are launched at five stations; continuous underway measurements are made of fluorescence, temperature and current profile (acoustic doppler current profiler). Cruises are made in February, April, June, August, September and November. The program was initiated in July 1997, and will continue through 2002. Point of contact for this work is Bob Smith: rsmith@oce.orst.edu; phone (541) 737-2926; fax (541) 737-2064.

3. Rope trawl stations. Three times per year (May, June and September), pelagic nekton are sampled with a rope trawl (20 m x 30 m mouth, 185 m length) that is fitted with light foam-filled doors such that the net samples the upper 10-15 m of the water column. The purpose of this work is to monitor the abundance of juvenile salmonids in the vicinity of the Columbia River off the Washington and Oregon coasts. A total of 40-50 stations are sampled during the eight day

cruises, from nearshore to just beyond the shelf break, along eight transect lines extending from Gray's Harbor, Washington (47°N) to just south of Newport, Oregon (44°10'N). Ancillary data taken at each station include CTD profiles using a Seabird SBE-19, surface chlorophyll and nutrients, Secchi depth, and zooplankton tows with 0.5 m diameter, 200 x 10^{-6}m mesh net (vertical tow), 1 m 333 x 10^{-6}m mesh net (oblique tow over the upper 20 m) and a neuston tow. Support for this work is provided by the Bonneville Power Administration.

4. Moorings. Currents are measured at a mooring 10 miles off Newport from an upward-looking acoustic doppler current profiler that is mounted on the sea floor. The mooring has been in place for approximately one year and is retrieved at six month intervals. In addition, hourly observations on sea-surface meteorology and sea-surface temperature are available from NOAA Buoy 46050, located 17 miles off Newport.

5. Coastal Radar. A coastal radar array (CODAR) is operated by oceanographers at Oregon State University off the central Oregon coast. The system is still in the testing phase but will soon be operational and will produce hourly charts of surface currents in 1 km bins out to 40 km to sea. Point of Contact for the radar and mooring work is Mike Kosro: kosro@oce.orst.edu; phone (541) 737-3079; fax (541) 737-2064.

Ecosystem Monitoring on On-going and Planned Programs in Russia

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Pacific Oceanological Institute, Vladivostok, Russia

The Russian national GLOBEC plan is not completely designed and approved yet, however GLOBEC-like ecosystem studies of various agencies are included in the list of priority science and development programs adopted by the Ministry of Science and Technologies for the post-perestroika period. One of the major programs is the Ecosystem Dynamics project that is being implemented mostly by the institutes of the Russian Academy of Sciences. Other agencies, such as the Hydrometeorological Committee, Committee on Fisheries, Naval Hydrographic Service and Ministry of Education (universities) carry on ecosystem studies in accordance with their ministry programs. Because of insufficient and unstable funding, the number of monitoring programs decreased considerably over the last few years, in particular those funded by the last two agencies.

The Hydrometeorological Committee is officially responsible for monitoring and assessment of environment quality including marine environment. It maintains a net of meteorological stations and observations along standard hydrographic sections located in the Okhotsk and Japan Seas. Field work and preliminary analyses in the Pacific area are carried out by Primorye, Khabarovsk, Kolyma, Sakhalin and Kamchatka Regional Hydrometeorological Administrations. Data holding and methodological support is provided by the Far Eastern Regional Hydrometeorological Research Institute (FERHRI) (contact - Dr. Yuriy Volkov, Director, hydromet@online.ru). The Hydrometeorological system provides data on physical forcing related to the oceanic and atmospheric conditions. Observations of temperature, salinity, hydrochemistry at standard levels from the surface down to 1000-1500 m and marine meteorology were repeated along the fixed sections since the late 50s, however, by the end of the 90s, the number of operational coastal stations was reduced and the hydrographic sections program is practically canceled because of funding limitations.

Ecosystem studies by the Committee on Fisheries are focused mostly on higher trophic level organisms and physical forcing. The main organizations dealing with monitoring programs in the North Pacific are Pacific Research Fisheries Center (TINRO-Center), Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO) and Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO). Since the 80s, TINRO-Center (contact - Dr. Lev Bocharov, Director - root@tinro.marine.su) started regular assessment of demersal/pelagic fishes and invertebrates, zooplankton and ichthyioplankton distribution as well as hydrographic and hydrochemical conditions in the Bering, Okhotsk and Japan Seas and the Kuril Islands area. Some cruises also sample nekton, primary production, bacteria and protozoa. CTD measurements are typically done down to 500 m, trawl and acoustic sampling is used to obtain fish distribution data at a 30-mile spacing. The surveys cover quite large areas and are repeated annually at particular seasons: March-May - northwestern shelf of the Okhotsk Sea (pollock survey); May-July - western Kamchatka shelf (crab survey); July-September - western Bering Sea (pollock survey); and July-October- Okhotsk Sea (salmon survey). Hydrographic observations are carried out along fixed sections through the Japan Sea (0-200 m) and along a section across the Kamchatka Strait (0-1500 m).

Observations and sampling by SakhNIRO (contact - Dr. Felix Rukhlov, Director - okhotsk@tinro.sakhalin.ru) are similar to those done by TINRO. The principal area of monitoring covers waters within 100 miles of Sakhalin Island in the Okhotsk Sea and Tatar Strait. Hydrography and plankton are observed two times a year along the standard sections down to 500-1500 m depth. A once-a-year survey of fishery resources includes observations of juvenile distributions of pollock, herring and cod. Monitoring of salmon is also implemented at fishery plants.

At least three institutes of the Russian Academy of Sciences are engaged in the ecosystem monitoring: the Pacific Oceanological Institute (POI), Institute of Marine Biology (IMB) and Institute of Automation and Control Processes (IACP). POI (contact - Prof. Victor Akulichev, Director - poi@eastnet.febras.ru) conducts studies of physical forcing and lower trophic levels in various areas of the North Pacific. Long-term monitoring of the water mass and current structure of the western boundary of the subarctic gyre (Kuril-Kamchatka area) began in 1990 as the INPOC project and then was followed by joint surveys with TINRO (1994) and SakhNIRO (1996). The results indicate a tendency of circulation changes in the area over the 90s which should cause notable response of higher level organisms. The survey will be expected to continue on an annual basis.

Another area of planned monitoring is the Peter the Great Bay and adjacent northwestern part of the Japan Sea. Circulation and water exchange at the coastal area, mesoscale eddies and their effect on fluxes and ecosystem dynamics are main topics of the POI studies that are to be conducted as a part of the CREAMS-II program.

Institute of Marine Biology (contact - Dr. Vladimir Kasiyanov, Director -inmarbio@mail.primorye.ru) conducts monitoring of both lower and higher trophic levels of the Peter the Great Bay ecosystem. This study is limited to the Tuman river mouth areas (Tumangan project) and Amursky Bay.

The Inter-Institute Center for Satellite Monitoring of Environment has been recently established by IACP (contact - Dr. Emil Herbeck - herbeck@iapu2.marine.su), POI and TINRO. This center maintains monitoring of the Japan and Okhotsk seas based on the NOAA AVHRR and SeaWiFS thermal and ocean color imagery.

In relation to Russian plans for ecosystem monitoring the following items should also be discussed: feasibility of implementation, methods of observations, quality control and data accessibility. In many cases, even when the project is approved and judged to be feasible, its implementation depends on funding availability and the economic situation in the country. Even if the allocated fund does not allow the project in full to be completed it may be implemented partially. Special attention should be given to the methods of measurement, sampling, analysis and data quality control. This is especially critical in constructing long time series. Data availability for the international oceanographic community may also be a serious question. Information on physical and hydrochemical variables of some areas of marginal seas may be restricted for international exchange.

Besides national plans Russia is already involved in international projects related to monitoring of the North Pacific such as NEAR-GOOS and NOWPAP (contact - water@unep.org). The NEAR-GOOS project is a North-East Asian Regional component of the Global Ocean Observing System (GOOS) initiated by the IOC Sub-Commission for Western Pacific (WESTPAC). Participating countries are China, Japan, Korea and Russia. The area of interest covers Japan, East-China and Yellow Seas. The scope of the project is to facilitate the exchange of marine environmental data through a system of real-time and delayed-mode data bases that would provide free access through the Internet. The environmental parameters included in the system are so far focused on some physical characteristics, in order to ensure the successful initiation of the operation. With the operation of the system well underway and given the requirements of the user community, it is necessary to extend the system to a wider range, in particular to include chemical and biological parameters.

At the present stage, the Russian contribution to the NEAR-GOOS data exchange system includes marine meteorological data which are being contributed to the Real Time Data Base by FERHRI. POI has made available previously classified data from 13,628 oceanographic stations for international data exchange under the IODE/GODAR project. These data may now be contributed to the NEAR-GOOS Delayed Mode Data Base. For further development of the NEAR-GOOS program in Russia, it is required (a) to determine the regulations for international data exchange for the NEAR-GOOS program at the national level; (b) to provide necessary funds for the NEAR-GOOS activities; and (c) to improve telecommunication system in the country. The last one is extremely important in order to involve more users and contributors to the NEAR-GOOS data base. (NEAR-GOOS contact http://www.unesco.org/ioc/goos/ neargoos.htm).

Another international project which has similar objectives as NEAR-GOOS, covering a similar geographic area and involving the same countries, but covering a much wider range of marine, coastal and associated fresh water environments, is the Action Plan for Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (Northwest Pacific Action Plan - NOWPAP). It was established in 1994 under the United Nations Environment Program as one of the components of its Regional Seas Program. NOWPAP includes a sub-project focused on establishment of a collaborative, regional monitoring program which is developed jointly with IOC/WESTPAC. The last Inter-governmental Meeting on NOWPAP suggested the establishment of a regional monitoring center to coordinate activity of participating countries (contact - water@unep.org).

In conclusion, it should be pointed that Russia still has plans for a large-scale ecosystem monitoring of the North West Pacific and marginal seas. Its feasibility, which depends on the economic situation in Russia, will be determined by the availability of national research funds. Russia has a high potential for cooperation with the international community because of the experience of its research groups and individual scientists as well as a large fleet of research vessels which are available for cooperative studies.

Contributions to this report by Drs. Yury Zuenko and Gennady Khen of TINRO, and Gennady Kantakov of SakhNIRO, are gratefully acknowledged.

<u>**North Pacific GLOBEC Monitoring South Korea**</u>

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The Korean GLOBEC Science committee was formally set up in the fall of 1998. Experts in the field of marine ecology, fisheries, and meteorology take part in the preparation of the science program mainly controlled by the Korean Ocean Research and Development Institute (KORDI). This program, composed of six sub-programs, is going to be funded by the Korean Ministry of Maritime Affairs and Fisheries for three years (Nov. 1998 - Oct. 2001).

1. The sub-program "Climate change, methodology, and data management", will be in charge of overall control of the science program and international cooperation. The principal investigator is Dr. Suam Kim of KORDI. Subsequent research programs and fund raising will also be done by this team.

2. The project entitled "Pattern of climate change around the Korean Peninsula", will analyze past climate data. Spatial and temporal scales of climate change and underlying mechanisms of the changes will be studied by this team under the leadership of Dr. J.H. Oh of the Korean Meteorological Research Institute.

3. The sub-program "Impact of climate change on physical properties of the marginal seas" will address long-term variations in physical properties such as seawater temperature, salinity, dissolved oxygen, etc., as well as sea level. Prof. Im Sang Oh of the Seoul National University is the leader of this project.

4. The impact of climate changes on marine ecosystem of the marginal seas will be investigated by the team led by Dr. Sinjae Yoo from KORDI. This will include the studies on long-term variations in plankton biomass and planktonic production. The microbial loop is one of the major themes of this sub-program.

5. The project "Impact of climate changes on fisheries of the marginal seas" led by Dr. J.Y. Kim from National Fisheries Research and Development Agency (NFRDA), will cover the population dynamics of the major fish stocks around the Korean Peninsula.

6. The last project is "Impact of climate changes on the interactions among the components of the marine ecosystem". Trophodynamics will be the major concern of this team led by Dr. Chang-Ik Zhang of Pukyong National University.

Provided funding is not held up, the proposed research plan will be in progress soon with governmental funding of about $400,000 for three years although the amount of money is somewhat uncertain at this moment.

North Pacific Monitoring in Japan GLOBEC

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Japan GLOBEC has been organized through the coordination of university and national institution scientists, to contribute to the SCOR/IOC International GLOBEC since 1992 and the CCCC (Subarctic Pacific regional program under PICES) since 1993. The major emphases of Japan GLOBEC are the following aspects of the ecosystem dynamics of the Kuroshio and Oyashio regions:

1. Dynamics of the food chain through zooplankton and micronekton;
2. Dynamics of marine ecosystems in response to climate change;
3. Development and application of new technologies for measurement and modeling in marine ecosystems.

Funding has been proposed to the MESCS (Japanese Ministry of Education, Science, Culture and Sport) and STA (Science and Technology Agency). The MESCS funding of individuals for preliminary scientific studies and bilateral international cooperative research has begun. Details of the MESCS university program may be found in PICES Scientific Report No. 7 (1997).

The STA program was funded in 1997 for a six-year period under the Agriculture, Forestry and Fisheries Agency Research Council (AFFRC). The title of the program is "Multidisciplinary study of the environmental variation influencing the fisheries resources in the northwestern Pacific". The Japanese government is responsible for regulating the available catch based on scientific information, and managing and sustaining the fisheries resources in the 200 nautical mile Exclusive Economic Zone (EEZ) around Japan. The variability of the fishery resource has been forecast mainly from historical catch and body length data. Accurate forecasts could not be made because of the large interannual variations. Recent studies have demonstrated that the abundance of saury and walleye pollock depends on the biomass variations of zooplankton and phytoplankton, which depend on oceanic environmental fluctuations. Therefore the ecosystem dynamic approach must be taken to accurately forecast the stock size of important commercial fish species. The Kuroshio/Oyashio and the Transition Area south and east of Japan have been selected for study because they are the regions where the large fishery grounds of commercially important fish occur. The representative target species are saury and walleye pollock. The program goal is to clarify the influence of the oceanic environment and phytoplankton and zooplankton abundance on stock size of these two fish species by developing ecosystem dynamic models.

IV. TASK TEAM RECOMMENDATIONS

Geographic Coverage

In general, sampling in the northwestern Pacific is more dense than in the northeastern North Pacific. Much of the sampling in the west is carried out by Japan and it appears that this sampling will continue to be supported. The first priority is to increase coverage in the eastern North Pacific while maintaining the present level of sampling in the west. A number of valuable sampling programs have been initiated under the GLOBEC banner and it will be important to make a strong case for their continuation into the future to contribute to the description of climate change variability.

Action (inter-sessional): Construct up-to-date time (monthly) and space coverage of shipboard observations to clearly reveal gaps in the monitoring. Resulting document will be used to guide the MONITOR Task Team in designing an improved subarctic Pacific monitoring system.

Recommendation: Present time series in PICES area must be maintained. Their scientific value increases dramatically with increased duration. For example, the vital central Pacific sampling lines now occupied by the research ships *Oshoru Maru* and *Hokusei Maru* must be continued with replacement ships, if these ships are pulled out of the program.

Continuous Plankton Recorder

There are very few large-scale zooplankton data sets being collected in the PICES area. The resulting gap in our knowledge of climate variability of zooplankton abundance and species composition can be addressed by initiating a ship-of-opportunity (SOP) continuous plankton recorder (CPR) observation in the subarctic Pacific. Measurements in the North Atlantic have demonstrated that the SOP/CPR is capable of measuring the annual cycle by sampling long tracks in the summer and winter and that it efficiently samples a part of the zooplankton community that responds to climate variability.

Action (inter-sessional): Prepare a white paper on the design of a SOP/CPR program in the PICES region.

PALACE float array

The U.S.A. is planning to deploy an array of PALACE floats (ARGO) in the North Pacific as part of a global measurement program. These floats will measure temperature and salinity profiles in the upper kilometer of the water column and horizontal velocity at 1,000 m.

The resolution is 300 km in space and 10 days in time. Deployments are planned to commence in late 2000. The ARGO temperature/salinity profiles will provide a vital data set in describing the long-term, large-scale variability of the thermal and haline structure in the subarctic. At present neither the temperature nor salinity variations are being measured adequately. In the past the thermal structure was measured by the SOP XBT program but that program has been drastically cut back so that it no longer resolves the thermal variability.

Recommendation: PICES must strongly support the ARGO plan to begin Subarctic Pacific float deployment in 2000.

Zooplankton time series

Many types of sampling gear have been used to collect zooplankton data in the subarctic Pacific. Adequate intercalibration data for many of these sampling systems do not exist and time series are seriously flawed by systematic errors.

Action (inter-sessional): Prepare a report on sampling gear used in the North Pacific and the status of the calibration data. Develop a plan for obtaining needed calibration.

Biophysical mooring observations

In September 1998, an ATLAS mooring, modified for long-term deployment in the subarctic, was deployed at staion PAPA to test its survivability in the harsh environment at PAPA. It will be replaced in September 1999. The test mooring has only meteorological and subsurface physical sensors. A well-instrumented mooring will provide vital data on the response of the subarctic biological systems to physical forcing.

Action (inter-sessional): Prepare for a discussion of the optimum set of biological and chemical sensors that should be deployed on subsequent monitoring moorings.

Recommendation: At the completion of the engineering studies, moorings with a complete suite of state-of-the art meteorological, biological, chemical and physical sensors should be designed and deployed near the centers of the Alaska Subarctic Gyre and the Western Pacific Subarctic Gyre.

Zooplankton production

At the present time there is very little subarctic Pacific data being collected on the variability of zooplankton production.

Action (inter-sessional): Prepare for a discussion of the need for an expanded measurement program of zooplankton production in the subarctic Pacific. Specific suggestions for the design of a monitoring system will be addressed.

Regime-shift description

There was a substantial delay between the timing of the 1976-1977 regime shift and its recognition by scientists and assessments of its impact. An interesting question is whether there were precursors of the shift that were overlooked. Analysis of the data preceding and during the 1976-77 shift will provide insight into what type of monitoring will improve our description of future regime shifts.

Recommendation: PICES should sponsor a workshop to review physical and biological characteristics of regime shifts and the extent to which various elements of the ecosystem were affected.

Next Task Team meeting

The 1999 meeting of the Task Team will address the above items as well as others that will be suggested during the year. The venue would ideally be in Hakodate, Japan, before the Eighth Annual Meeting. Hakodate is an attractive choice because it will avoid the divided loyalty syndrome which occurs if it is held immediately prior to the Annual Meeting. In addition it will allow the Task Team to interact in the meeting with many Japanese scientists outside the Task Team who are working on subarctic climate change research. Funds will be solicited from PICES to bring an outside expert to the meeting to extend the scientific expertise of the participants. (*The location of the 1999 MONITOR Task Team meeting was changed to Vladivostok, to be held just prior to the Eighth Annual Meeting.*)

APPENDIX A: A PLAN FOR USE OF THE HARDY CONTINUOUS PLANKTON RECORDER IN MONITORING THE SUBARCTIC PACIFIC OCEAN

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Preamble
The Hardy Continuous Plankton Recorder (CPR) is a device that is designed to be deployed from ships-of-opportunity to obtain long-term information on the changes in the abundance and species composition of the animal plankton. The CPR works by slowly drawing a silk mesh through a small column of seawater flowing through the device while it is towed behind a ship. Use of the CPR would provide a broad-scale measure of the plankton distribution across the North Pacific in regions where it is deployed.

Statement of priorities
The PICES MONITOR Task Team (October 1998) discussed several possible routes for deployment of a CPR for long-term monitoring of zooplankton in the North Pacific. These routes were:

a. Deployment on ships of opportunity running an east-west route between Vancouver and Tokyo.
b. Deployment on ships of opportunity running an east-west route between San Francisco and Tokyo.
c. Deployment on ships of opportunity running a north-south route between Prince William Sound and Hawaii.
d. Deployment on ships of opportunity running a north-south route between Prince William Sound and San Francisco.

The Task Team preferred the east-west route from Vancouver to Japan over the route starting in San Francisco, because it passes near the existing long-term monitoring station (Station P), and because the cruise track would run parallel to Line P. For similar reasons, the north-south route from Prince William Sound to Hawaii was preferred because that line would run close to Station P. In the case that only one route could be funded, the route from PWS to Hawaii is probably preferable because some limited east-west sampling is possible along Line P and near the Japanese coast.

Issues
The early stages of the deployment of the Hardy CPR should be considered as a scientific experiment, the results of which will determine the final decision on the sampling strategy to be used for the long-term monitoring program. There is a need to establish the correct sampling frequency on each route, because over-sampling will limit the extent of the region that can be surveyed. A team should be identified in the early stages to work with the experts at the Sir Alister Hardy Foundation to design this initial survey and to identify the appropriate sampling frequency (Table A1). In essence, this will be an experiment to determine the spatial decorrelation length scale for different species of zooplankton, and the temporal frequency needed to resolve important aspects of the annual production cycle. Based on these results and the financial resources devoted to the program, appropriate sampling frequencies for the large-scale monitoring program will need to be determined.

Value of a Pacific survey
The multi-decadal survey in the North Atlantic demonstrates convincing correlations between climatic indices and changes in the plankton. A regime shift in the late 1980s in the North Sea is also evident for CPR data and is revealed in both changes in abundance of both the phytoplankton and zooplankton, as well as the species composition.

We advocate one north-south and one east-west route (as indicated under the priorities section) 6 times annually for a period of three years as the experimental phase of the Pacific survey.

Prior uses of the Hardy CPR

Hardy CPRs were used to routinely monitor the Irish Sea where the Sea Empress went aground, causing a major oil spill. The plankton data collected formed an essential baseline which was used to compare the plankton community after the oil spill (Batten et al 1998). In addition, the results from long-term CPR monitoring programs in the North Atlantic provide convincing evidence for the effects of decadal scale climate forcing of the plankton communities in the ocean, information which would otherwise simply be unavailable (Gamble 1994; Planque and Taylor, in press; Reid et al 1998; Reid et al, 1999).

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Table 1. Approximate budget (in pounds Sterling) for the cost of deploying the Hardy Plankton Recorder for a single tow, and the annual cost. Annual costs have been estimated by multiplying by the assumed number of tows per year, which is likely to be on the order of 6 (assuming bi-monthly sampling). Costs per tow are based on the assumption that every second sample is counted. Fixed costs per tow (see footnote) do not vary with the number of samples analyzed, so overall costs per tow when assuming different sampling frequencies are only approximate. Note that the costs of including a towed CTD package on the CPR are not included, but should be considered an essential part of the sampling program. Electronic flow meters could also be fitted.

LINE	***Distance (D, kms)***	***# Samples (D/18 kms)***	***Cost per Sample***	***Sampling Frequency[a]***				***Total Costs per Year[b]***
				18 KMS (ALL)	***36 kms (Every 2nd)***	***56 kms (Every 3rd)***	***72 kms (Every 4th)***	
Alaska-Hawaii	4,000 kms	222	£100	£22,200	£11,500	£7,500	£5,700	
Annual Cost (6 tows)				**£133,000**	**£69,000**	**£45,000**	**£35,000**	**£83,800**
Vancouver-Japan	6,000 kms	333	£100	£33,300	£17,000	£11,100	£8,500	
Annual Cost (6 tows)				**£200,000**	**£100,000**	**£66,000**	**£51,000**	**£115,800**

£ - Pounds Sterling

[a] Hardy CPR costs have to be divided into fixed costs invariant with the number of samples analyzed, and labour costs associated with analyzing each sample. The initial set-up on the vessel requires installation of a davit (ca. £5,000) plus fixed costs associated with each tow. These include: Rental of Hardy CPR (£500), Silk rolls (£112//800 km unit), crew gratuity (£40), and freight charges to and from the UK (£1,000).

[b] Includes Fixed Costs, assuming every second sample is enumerated (36 km spacing), and a total of 6 tows analyzed per year.

REX TASK TEAM REPORT

The REX Task Team is concerned with intercomparisons of regional scale studies, as proposed in the PICES/GLOBEC CCCC Implementation Plan.

Activities in 1997/98

1. The PICES Climate Change and Carrying Capacity Workshop on "The Development of Cooperative Research in Coastal Regions of the North Pacific" was published as PICES Scientific Report No. 9 in 1998.

2. A workshop on climate effects on small pelagic species was convened prior to the Seventh Annual Meeting in Fairbanks, Alaska.

    3. A scientific session highlighting research findings of GLOBEC and GLOBEC-like programs was convened in the Seventh Annual Meeting.

<u>**Task Team Recommendations**</u>

Short-term

1. REX recommends that Dr. W. Peterson replace Dr. A. Hollowed as REX Co-Chairman.

2. REX recommends the collation and synthesis of small pelagic species data for comparative studies. Initially, this could involve the exchange of scientists (or open workshop), data assembly, and development and application of analysis tools. The purpose of exchanging scientists is to facilitate a comparative analysis of larval and juvenile vital rates of Pacific herring from different regions of the North Pacific and its adjacent seas, and to facilitate comparative studies of the life pattern of dominant zooplankton species (especially euphausiids and calanoids (*Calanus, Neocalanus*)).

   REX proposes to conduct a two-day workshop for these purposes at the Eighth Annual Meeting in Vladivostok, Russia (See Appendix A). We anticipate that 12-15 scientists would participate in the workshop. We expect that PICES will provide funds (for 2 scientists from North America, 1 from China, 1 from Korea, and 1 from Japan) to facilitate this exchange.

3. REX recommends that the report of REX workshop "Small Pelagic Species and Climate Change" should be published in the PICES Scientific Report Series.

4. Compile a summary of the sampling strategies and methods used to assess the stocks of small pelagic species.

5. Continue to encourage discussions of small pelagic species through REX Task Team. Conduct a CCCC symposium on small pelagic species for the year 2000.

6. REX endorses the proposal for an inter-sessional meeting to review the 1976/77 and 1988/89 regime shifts. We will assist in preparing for this symposium.

7. REX encourages a review of the relationship between El Niño events and regime shifts.

Long-term

1. PICES Scientific Report No. 9 provides long-term research questions and activities.

2. REX highlights the recommendation for compiling a catalogue of historical samples and data sets, which are not yet analyzed or readily available as a high priority activity. Initially, this could be done for egg and ichthyoplankton samples and catch data by research vessels.

I. WORKSHOP ON SMALL PELAGICS AND CLIMATE CHANGE IN THE NORTH PACIFIC OCEAN, OCTOBER 16-17, 1998 (Convenors: D. Hay, Q. Tang, T. Wada, J. Kim, V. Radchenko and L. Jacobson)

Objectives

1. To compare the present findings on the response of small pelagic species to ocean climate changes in the PICES areas.

2. To encourage research collaboration among member countries through identifying key hypotheses and research methods suitable for testing the hypotheses.

Summary of papers

A Population Dynamic Model for Japanese Sardine - Why does the Sardine Show Such a Large Population Fluctuation

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In the population fluctuation of Japanese sardine, *Sardinops melanostictus*, periods of high and low abundance last for several decades, respectively. With the fluctuation of population, various ecological changes have been observed such as shift of spawning ground, expansion or reduction of the geographical area of nursery ground, and changes in the relative fecundity, or fecundity per unit of biomass. In addition, a significant relationship has been pointed out between the survival rate from egg to one-year-old fish and the SST of the Kuroshio Extension in winter. As a mechanism of the fluctuation, we supposed a positive feedback loop and that was driven by density-dependent changes in the range of distribution and food availability under the observed ocean climate change, and we tested the hypothesis by developing a simple population dynamic model. Assumptions for modeling are as follows:

1. the life history of sardine is divided into egg, juvenile, and adult stages;
2. egg production is linearly proportional to the number of adults, but the regression coefficient increases during the high abundance period;
3. survival rate from egg to juvenile is proportional to the food availability (food density x feeding efficiency x area of nursery ground / egg production), and the feeding efficiency is proportional to the food density;
4. area of nursery grounds approaches asymptotically to the maximum with increasing egg production;
5. food density in nursery ground fluctuates periodically corresponding to the SST of the Kuroshio Extension in winter.

Under these assumptions, model outputs showed cyclic changes in the numbers of recruits and adults and an abrupt increase and decrease of the survival rate. The relationship between egg production and number of recruits corresponded well to the observed stock-recruitment relationship. These results suggest that changes in food availability cause the recruitment success or failure, and a positive feed back loop sustains the population abundance at either high or low levels.

Biological Production, Variability, and Standards for Sustainable Yield in the Great Sardine and Anchovy Stocks

Larry Jacobson (presented by Tokio Wada)
Southeast Fisheries Science Center, La Jolla, U.S.A.

Introduction

This study is a part of the first co-operative work under the GLOBEC-SPACC (small pelagic fishes and climate change) program. A total of 14 scientists from 12 countries contributed data for catch, biomass, and area of spawning grounds for 9 stocks of 5 sardines and 7 stocks of 5 anchovies. The purpose of this work is to measure annual surplus production in sardine and anchovy stocks using only biomass and catch data, and then to compare the characteristics of population fluctuation between stocks, species groups (anchovies vs. sardines) over time based on the annual surplus production. The purpose also was to link climate research and fisheries management.

Methods

Calculations are very simple. Annual surplus production in year t (P_t) is calculated as the difference in biomass between successive years with a correction for catch:

$$P_t = B_{t+1} + \delta C_t - B_t$$

where B_t is biomass at the beginning of year t, C_t is catch in year t, and δ adjusts catch in year t to the corresponding biomass at the beginning of year t+1 if there had been no fishing. The annual instantaneous production rate $\rho_t = \ln[(B_{t+1}+\delta C_t)/B_t]$, and production per unit spawning area is calculated as P_t/A_t where A_t is the area of spawning grounds in year t.

Results

Production rates respond more quickly to climate change than biomass, catch or production. Results for Japanese sardine and other stocks with regime shifts show that changes in catch, biomass and production lag changes in production rates by 5 to 10 years. Where the regime shift means discontinuous changes in production rate or reproduction rate with climate change. This suggests that we should not use catch, biomass or production to identify onset of climate effect. We should use production rates.

Other interesting results

Many years of data (i.e. long time series of data) are required to measure variation in production and production rates. Plots of CV for annual production to Years of Data show a positive correlation. Extreme (maximum and minimum) production rates measure how fast a stock can increase or decrease in abundance. The minimum and maximum production rates were more extreme for five anchovy stocks than for nine sardine stocks although mean production rates for two groups were similar.

Production rates in consecutive years are positively correlated for long lived sardines and uncorrelated or negatively correlated for shorter lived (mostly anchovy) species.

Natural mortality rate is negatively correlated to life span. Thus, biological effects on favorable and unfavorable conditions last longer in sardine and effects of environmental variation appear to be mediated by longevity.

Average annual production per unit spawning area ranged from 1.2 to 16 mt/km^2 for four anchovy and six sardine stocks and the median was 3.8 mt/km^2. The range and median of production per unit spawning area for sardine and anchovy are similar in both species.

Comparisons of production rate and production per unit area between stocks suggests temporal differences in the effect of environmental variation. For instance, production per area of California sardine was much smaller than Japanese sardine in the Pacific Ocean although they had similar ranges and medians of production rate. This corresponds to actual observations of changes in spawning and nursery grounds of both species. The spawning ground expands along the coast with population increase in California sardine. On the contrary, changes in the area of spawning ground are relatively small but nursery grounds expand extremely with population abundance in Japanese sardine. Therefore the result of the comparison suggests that California sardine will be more sensitive to local (and probably short-term) environmental fluctuation in earlier life stages than Japanese sardine.

This approach is very simple. However it gives valuable information about the range and variability of biological production and fishery yield in small pelagic stocks. It may be useful to expand the approach to consider other small pelagics in the North pacific as a standard method for comparative retrospective studies in the CCCC Program.

Carrying Capacity Changes of Oyashio Shelf Ecosystem with the Disappearance of Japanese Sardine

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Introduction

Ecosystem models sometimes are referred to as works of art or fiction. Models, however, can assist with understanding a system as a whole. Important matters for ecosystem models are validation and analysis of model behavior. In this paper, we develop a method to analyze behavior of an ecosystem and natural populations from field data.

Scientific question

How does the large biomass of Japanese Sardine that migrates into the Oyashio Shelf Region change the structure and function of the ecosystem?

Model

We use a Trophodynamic Model developed for the Oyashio Shelf Region through collaboration with the Pacific Biological Station, Fisheries and Oceans, Canada and Hokkaido National Fisheries Research Institute, Japan. The main components of the model are phytoplankton (diatoms), zooplankton (copepods), euphausiids, Japanese sardine, pollock and the pollock fishery. The model is driven by nutrient supply, depth change of the surface mixed layer and mixing and by excretion by animals. In this model, zooplankton and euphausiids make seasonal or ontogenetic vertical migrations and sardines make seasonal horizontal migrations. The eco-physiological parameters for each ecosystem component are tuned within the range of values appearing in published literature. Initial biomass levels are determined from the results of time course observation of model output, including sudden termination of sardine migration.

Method for analysis

We use the relation between P/B ratio and Biomass, derived by Wada and Kashiwai (1989) from Nicholson-Bailey type host-parasite or predation model for analysis of individual growth of Japanese sardine from field data, as follows:

$$P/B = EgC\,(at/A)\{1-(at/A)\,(B/2)\},$$

where P = growth (production), B = biomass, Eg = growth efficiency, C = food abundance, a = area searched during unit time, t = searching time, and A = habitat area.

This relationship describes the density effect on individual growth under given food abundance, or the carrying capacity for the population for a given structure of the ecosystem.

Results

The transient responses of the model diminish within 2 or 3 years. After the disappearance of sardine migration, the biomass level of euphausiids exceeded the biomass level of copepods, but when sardine migrate, copepods decrease while diatom increase. A similar phenomenon appears in the La Perouse Bank ecosystem with change in Hake biomass (Robinson, 1994). The P/B - B relation for copepods, euphausiids and pollock show linear relation with negative slope within initial biomass change of ± 20 %. EgC (at/A), i.e. the maximum P/B ratio when B=0, show linear decrease with trophic level. The relative size of individual habitat (at/A), or relative share of food resources, decreases with trophic level.

The P/B - B relation for sardine shows that the historical maximum biomass is the limiting level beyond which density effect increase significantly and causes decrease in individual growth.

Conclusions

1. The P/B - B relationship is important in the analysis of ecosystem function (i.e., change in carrying capacity);
2. The P/B - B relationship depends on the structure of the ecosystem. If a major ecosystem element changes its biomass level drastically, the P/B - B relationship has different characteristics.
3. The P/B - B relation for Japanese sardine shows that the historical high biomass level is the limiting level of biomass that cause structural change on ecosystem.

Acoustic Estimation of Biomass of the Small Pelagic Fishes in the East China Sea

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Introduction

In the East China Sea, biological productivities are considered to be very high. The high productivity in this region supports various fisheries of China, Korea and Japan. Japanese fisheries caught over 300,000 tons of demersal fishes such as yellow croaker (*Larimichthys polyactis*) by bottom trawl net in 1960s, but landings of these fishes landing has decreased because of overfishing (Tokimura 1998). Tokimura (1998) also suggested the necessity of cooperative resource management of demersal fishes by China, Korea and Japan.

On the other hand, commercial landings of pelagic fishes by the Japanese (large powered) purse seine fleet were kept at a level of about 500,000 t from the 1970s to the 1990s. However, these pelagic fish stocks may be overfished, because their body size became smaller and the age of the beginning of reproduction shifted to younger ages. Therefore, pelagic fishes in the East China Sea also should be managed cooperatively by China, Korea and Japan. For rational management of the pelagic fish stocks, knowledge of the basic biological characteristics, including stock structure or distribution pattern of subpopulations, stock assessment and population dynamics are essential. However, for a variety of economic, political and biological reasons, much basic biological knowledge is not available. In addition to these commercially important species, it is important to understand the biological information of non-commercial animals, because they have a very large biomass and play important roles in the ocean ecosystem. However, stock assessment of non-commercial fishes is very difficult from the commercial fishery's data. Therefore, research vessel surveys, such as acoustic surveys, are necessary to understand the ecosystem in the ocean. In the present study, I show the biomass estimation not only for commercial fishes but also for non-commercial fishes using acoustic method in the East China Sea and adjacent seas.

Methods

1. Acoustical instruments

We used two acoustical instruments: the Furuno FQ-70 (50kHz) and the Simrad EK500 (38kHz). The biomass of anchovy (*Engraulis japonicus*) in the East China Sea and Yellow Sea, micronekton (*Maurolicus muelleri*) in the Sea of Japan and Japanese sardine (*Sardinops melanostictus*) spawners in the waters off western coast of Kyushu were estimated by the FQ-70. The biomass of several pelagic fishes in the outer rim of continental shelf, and several fishes in the waters off western coast of Kyushu were estimated using an EK500.

2. Fish identification

We used midwater trawling, Issacs-Kidd midwater trawling (IKMT), and fisheries statistics for fish identification. A cover net (20 mm mesh) was attached to the midwater trawl on outside of cod end (60 mm mesh). The midwater trawl net was towed for from 30 minutes to 1 hour. The warp length of the trawl net and towing speed were adjusted in order to aim the net opening at the strata of fish schools. The towing speed ranged from 2 to 3 knots during trawling. Trawl catches were frozen immediately on the vessel. When the catch was numerous, about 30 kg subsamples were picked up after the measurement of total weights of the catch. Samples were weighed by species at land laboratory after the survey. We used IKMT trawls (2 mm mesh) for identifying the organisms in deep scattering layers. The IKMT trawls were towed for 10 minutes, and towing speed was about 2 knots during trawling. All of samples were fixed in 10% formaldehyde. Annual landing data of the pelagic fishes were quoted from the fisheries statistics of the Ministry of Agriculture, Forestry, and Fisheries, Government of Japan.

3. Biomass estimation

3.1 Furuno FQ-70

Biomass (S) was calculated with the mean of volume back-scattering strength in each integration interval value (SV: dB), target strength value (TS: dB) and water volume (m^3) in the each integration interval, as follows:

$$S=V\Sigma 10^{(SV-TS)/10}$$

The SV values were logged on computer for each 0.5 mile. The TS value for anchovy and Japanese sardine was -31.4 dB/kg and -31.5 dB/kg, respectively. The TS value for *Maurolicus muelleri* was calculated as TS=17.4BL-69.6 (Hamano, 1993), where BL is body length in cm.

3.2 Simrad EK500

The SA (m^2/nm^2) values were logged on the workstation computer (software: BI-500) for each 5 nautical mile, and given by the equation.

$$SA=\sigma\ 1852^2/(\psi z^2)$$

where σ is the back-scattering cross-section of the target, z (m) is the sphere depth, and ψ is the solid angle covering the equivalent beam. For biomass estimation, the area density (ρ) is calculated as $\rho=SA/\langle\sigma\rangle$, where $\langle\sigma\rangle$ is the mean of σ. The relationship between TS and σ is calculated as $\sigma=4\pi 10^{(TS/10)}$. We estimated the biomass using the target strength of fishes as follows:

Jack mackerel (*Trachurus japonicus*):
TS=20logBL-71.70
Round scad (*Decapterus maruadsi*):
TS=20logBL-67.50
Chub mackerel (*Scomber japonicus*):
TS=20logBL-71.90
Anchovy:
TS=20logBL-71.90
Round herring (*Etrumeus teres*):
TS=20logBL-71.90,
Black Scrapper (*Thamnaconus septentrionalis*):
TS=20logBL-65.80,
Lanternfish (Myctophidae):
TS=20logBL-67.50, and
Maurolicus muelleri:
TS=17.4BL-69.60.

The equations of the target strength of jack mackerel, chub mackerel and black scrapper were quoted from Mukai et al. (1993), and anchovy, round herring and lantern fish were recommended by Simrad.

Results and discussion

Five acoustic surveys we carried out for biomass estimation of small pelagic fishes in the East China Sea and adjacent seas. They were as follows:

1. anchovy in the East China Sea;
2. micronekton in the Japan Sea;
3. Japanese sardine spawners of western Kyushu;
4. several different species of fishes in the edge of continental shelf;
5. several different species of fishes of western Kyushu.

The biomass of anchovy was estimated as about two million tons in the East China Sea and Yellow Sea (Ohshimo, 1996). A China-Norway cooperative acoustic surveys also indicated about three million tons of anchovy in the East China Sea, Yellow Sea and Bohai Sea (Iversen et al., 1993). The biomass estimates of both surveys in the East China Sea (Iversen et al., 1993; Ohshimo, 1996) are similar. However, Japanese fisheries have not caught the anchovy in this region, because the price of anchovy is lower than other species. Therefore, fishery catch statistics may not be accurate as indicators of biomass for this species. In contrast, the acoustic survey is useful for estimating anchovy's biomass. This estimate also is important, because anchovy is a key species in the midwater ecosystem in the East China Sea.

The mesopelagic fish (*Maurolicus muelleri*) in the Japan Sea is also a key species in the midwater ecosystem. *Maurolicus muelleri* feeds on the zooplankton (Ikeda et al., 1994), and are preyed upon by larger carnivorous animals such as mackerel, tuna and squid (Nishimura, 1959). It is generally believed that the biomass of micronekton such as *Maurolicus muelleri* is very large, but there are few studies on biomass estimation of micronekton in the East China Sea and adjacent sea. Ohshimo (1998) estimated the density of *Maurolicus muelleri* in the southwestern part of the Japan Sea as about $30g/m^2$. This value is nearly equal to previous papers in Japan Sea (Hamano, 1993), and that in fjords (Gjøsæter, 1978; Lopes, 1979), but larger than that in the Red Sea (Armstrong and Prosch, 1991). The biomass estimation of micronekton like this study would be helpful for understanding of the midwater ecosystem, because it has been difficult to estimate the abundance of these non-commercial fishes.

The acoustic survey of Japanese sardine spawners has been carried out since 1984 in the waters off west of Kyushu. Temporal variation in biomass from these surveys (Ohshimo et al., 1998) was similar to the stock fluctuation calculated from VPA methods (Hiyama et al., 1995). Therefore the acoustic survey is also an important method for assessing the stock level of small pelagic fishes, and it also can be useful for monitoring changes of distribution pattern with stock fluctuation (Ohshimo et al., 1998).

With the development of the post-processing software (Simrad BI-500; Foote et al., 1991), we could estimate the biomass of multi-species on computer. We estimated the biomass of anchovy (96,000 t), black scrapper (199,000 t), jack mackerel (392,000 t) and round scad (163,000 t) in the offshore area of continental shelf in the East China Sea. Many pelagic fishes are found in the East China Sea and the productivities of pelagic fishes is very high in this area. The acoustical survey was suggested to be a powerful method to estimate the biomass in this area, and should be continued for rational management and prediction of population dynamics.

Four acoustic surveys were conducted, two in the summer and two in the winter, in the waters off western coast of Kyushu. We estimated the biomass of seven species of pelagic fishes: anchovy, round herring, jack mackerel, round scad, chub mackerel, lantern fish and *Maurolicus muelleri*. All biomass estimates in winter were smaller than those in summer. The largest biomass was anchovy, at about 20,000 t in summer in 1997 and 1998. Lanternfish biomass was also large, and the ranged from 3,000-18,000 t in 1997 and 1998.

We conclude that the acoustic survey is a useful method for biomass estimation in the midwater habitat. However, there are major two problems to be solved in the future. One is fish identification, and the other is target strength. Since there are over 600 species of fishes in the East China Sea, fish identification on echogram is difficult. In the present study, midwater trawlings were mainly used for fish identification. However, there are some problems of midwater sampling, because vulnerability to midwater trawl nets varies with species and extensive midwater sampling require a lot of time. The problems of target strength are also caused from fish species diversity in the East China Sea. The target strengths of many fishes have not yet been measured. These measurements should be made and the results made available on the internet.

Generally speaking, the population size of pelagic fishes has fluctuated from both overfishing and environmental factors. However, the population decline of Japanese sardine was caused by recruitment failures, not by overfishing (Watanabe et al., 1995). This was demonstrated by research vessel surveys, so we should use the data from such research vessel surveys, such as egg surveys and acoustic surveys, for predicting the population dynamics of small pelagic fishes. In addition, acoustic surveys can estimate the biomass of non-commercial fishes such as lantern fish and micronekton which have important roles in the ecosystem. So, acoustic surveys should be used for studying the midwater ecosystem in the future. Since the abundance of zooplankton could be estimated by IKMT nets combined with and high frequency echo sounder (unpublished data), entire mid-water ecosystems, from zooplankton to fishes, might be clarified in the future.

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General Observations of Changes in Abundance of Small Pelagics and Specific Observations on Changes in Timing and Distribution of Herring Spawn in British Columbia: Impacts of Climate Change?

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OVERVIEW

In the 1990s several small pelagic species increased in abundance in British Columbia. Sardines, mackerel, capelin, anchovy are now commonly encountered in local waters but two of these species (sardines and capelin) were rare or unknown in the previous decade, although both were present in the 1940s and 1950s. Except for herring, biomass estimates are not available, but the high incidental capture rate in commercial catches and research fishing samples is strong evidence of a widespread increase in abundance of these small pelagic species. Herring abundance is estimated annually and in most areas of the BC coast herring abundance is high, and at historically high levels in some areas. Remarkably however, the spatial range and temporal duration of spawning of herring has decreased. Further, the size at age of herring has decreased. There is another observation that may have relevance: that is, in contrast to the apparent increases in pelagic species, the abundance of many demersal species has declined in recent years. We cannot demonstrate that these interspecific changes are related, nor can we prove that any of the changes are caused by, or related to, concurrent changes in ocean climate, although we take it for granted that climate change does occur and can be described (e.g. Wooster and Hollowed 1995). On the other hand, we have no evidence to falsify the hypothesis that these changes, either the increases in small pelagics or decreases in demersal fishes, are caused by climate change. There are many examples of probable effects of climate change in fish populations and communities (see Beamish 1995) but few where the linkage between climate change and biological impact are shown definitively. This conundrum has been discussed by Bakun (1996), mainly with respect to the dilemma of correlation analyses between biological indices and environmental signals, such as sea-surface temperature. Probably, the solution will require the elucidation of some of the complex bio-physical process and may new international and inter-disciplinary studies are in progress, many with PICES connections. In the meantime, the documentation of biological observations is important, and that is the objective of this brief report.

OBSERVATIONS ON SMALL PELAGICS

Sardines (*Sardinops sagax*) are common on the BC coast in the late 1990's, but they were unknown from the mid-1950's to the late 1980's. This change is part of a major change in sardines that occurred mainly in more southern waters off the USA and Mexico (Lluch-Belda et al. 1992). Sardines were common in BC during the 1930's and 1940's although spawning was thought to be limited to southern waters (Hart 1973). In general, sardines in BC consisted mainly of larger, older fish moved north in the summer to feed in BC waters (Hart 1973). There were suggestions that there was a spawning population in an inlet in the west coast of Vancouver Island, but that was not confirmed. In recent years, however, some sardine has been captured in the winter and some juvenile sardines also have been captured.

Mackerel (*Scomber japonicus*) abundance in BC waters fluctuates with long periods when it is rare and other times when it is common (Hart 1973). In the last several years, mackerel have been noticed more frequently and there have been concerns about the impact of these piscivores on juvenile salmon. In the last 2 years, their abundance has increased to the point where commercial fisheries have been initiated (A. Thomson, Pacific Biological Station, Nanaimo BC, personal communication).

Anchovy (*Engraulis mordax*) have always been present in southern BC waters, and there are indications that in some years they are more abundant than others, but there are no biomass estimates available. Mainly anchovy are found in more southern waters (Richardson 1981). Anchovy are known to spawn in inshore waters during mid-summer in southern Vancouver, and perhaps elsewhere. It is uncertain if their abundance has increased substantially in recent years, but it is known that they are now commonly found as part of the incidental capture of fishing efforts directed at other species. For instance, anchovy were captured incidentally in 1998 in Georgia Strait during surveys for juvenile herring (Haegele and Armstrong, ms 1999).

Although capelin (*Mallotus villosus*) are not and have never been abundant in BC waters, they were known to spawn every year, in the fall, at a number of different areas on the southern BC coast. Their spawning sites, in inter-tidal pebble beaches, were well known to local people and supported small recreational fisheries in certain areas (Hay 1998). Total catches were small, however, and would not have accounted for the apparent disappearance of capelin about 20 years ago, in the mid- to late 1970's. In 1993 and 1994, capelin reappeared in BC, mainly as spawning aggregations at the heads of inlets joining to the Strait of Georgia. In 1998 capelin were captured in research seine hauls in the northern part of the Strait of Georgia (Haegele and Armstrong 1999). In the north Atlantic the distributions of capelin are known to change over time, presumably in response to some sort of environmental change (Vilhjalmsson, 1994) but this has not been described before for the eastern Pacific.

Herring (*Clupea pallasi*) have been fished commercially since the turn of the century. Annual estimates of abundance are made, based on analyses of age and estimates of spawning biomass based on egg deposition. Herring stocks collapsed in the mid-1960's following a period of intense fisheries with high annual catches. In the 1970's the spawning stocks appeared to recover and a new fishery for roe was opened. Since then, biomass estimates are made on 5 different components, or stocks, on the BC coast Schweigert et al. 1998). Although all vary in time, and not always in synchrony, nearly all of the 5 major stock groupings are at historical high levels in the late 1990's (compared over the period from 1930 to 1998).

Herring spawning has been documented in BC since the 1930's. Over that time over 26,000 records have been collected on the location, date and approximate size of the spawn, from which indices of egg abundance have been estimated (Hay and Kronlund 1987, Hay and McCarter 1998). Probably, most of the spawning has been documented. Records of the timing and distribution of spawning areas of in BC have been collected since the 1930's. Major changes have occurred in the last two decades (Hay and McCarter 1997, 1998). In all locations the total amount of spawn has fluctuated throughout the last 65 years, but total spawn deposition, which is a function of abundance, is very high in the 1990's. In many areas, however, the distribution of spawning sites has changed. In general, present spawning areas are more spatially concentrated, with fewer, larger spawning sites especially in the Strait of Georgia and the west coast of Vancouver Island. Within parts of the BC coast, spawning has stopped in some areas and started in others. Also, the duration of the spawning season has decreased in all areas since 1970. The first spawns are later and the last spawns are earlier, although the mean time has not changed.

Another recent change has been noted in pacific herring: size at age is decreasing in recent years. Recruiting herring are smaller and the sizes of the oldest herring also smaller. The sizes are not unprecedented but size at age is now the smallest, for all age groups, since the 1930's. (Tanasichuk and Schweigert 1998).

Other observations: low abundance of demersal species

The recent changes – or increases - in theses 5 pelagic species, all of which are usually found in near-surface waters during some period within the diurnal cycle, are in contrast to what appears to be a general decline in many demersal species. This is especially apparent in a small species smelt, the eulachon (*Thaleichtys pacificus*) which, like capelin, herring and anchovy, is a small silver fish, but it is found mainly in benthic habitats, often in close proximity to shrimps (*Pandalus sp*) (Hay et al. 1997). The abundance of a number of other demersal species has declined in recent years, including some rockfish species (*Sebastes*), Pacific cod (*Gadus macrocephalus*) and others.

Implications: what is happening and what is the explanation?

Is there a 'pelagic outburst'? If the observations above are accurate, then the present relationship between pelagic and demersal fishes in BC, and perhaps in other parts of the northeast Pacific is almost the opposite of that described by Cushing (1979) for the North Sea. At that time Cushing showed that the abundance of North Sea herring and mackerel was low whereas the abundance of gadoid species (i.e. cod and haddock species) was high. He referred to the situation as a 'gadoid outburst'. Gadoids are demersal species but herring and mackerel are pelagic species. Cushing reviewed several potential explanations for the gadoid outburst, and climate change was one of them. He suggested that if climate were affecting gadoids, it may have been a trophic effect, by an effect on zooplankton availability as food. At the present time in British Columbia, and perhaps elsewhere in the North Pacific, we appear to have an ecosystem that favors small pelagics, which may be a sort of 'pelagic outburst'. Although this is the antithesis of the Cushing's observations, similar mechanisms may be operational (perhaps trophic impacts from climate change.

Changes in herring spawn. For the purposes of herring management, the BC coast is divided into 108 small geographic units called sections, of approximately equal size. In the last decade, the numbers of sections receiving spawn declined (Hay and McCarter 1998). This indicates that the geographic spawning range of herring has concentrated into a fewer number of larger spawning sites, that are distributed in all parts of the BC coast. Further, the duration of the spawning season is now shorter in all areas. In general, in the 1990's, compared to previous decades, the first spawns are later and the last spawns are earlier, although the mean spawning time has not changed. These changes have occurred during a period when total spawn deposition is relatively high in most areas. Therefore it seems counter-intuitive to observe decreases in spawning range and duration when total spawning is increasing. Ordinarily, we would probably expect that both the geographic range of spawning areas, and the duration of spawning times to expand, as a function of increasing spawning biomass. The simple observation presented here, however, does not appear to support this. Rather, the increase in herring biomass is associated with a concurrent reduction in spawning range, spawning duration and decreasing size at age. *(Note: during later discussions in the PICES workshop, Evelyn Brown noted that the same pattern appears to have occurred in Pacific herring spawning in Prince William Sound Alaska. Also Tokio Wada indicated the spawning range of Japanese sardine seems to be decreasing as the stock is increasing.)* It is interesting to speculate that the Baltic herring (*Clupea harengus membras*) have also decreased their spawning duration, by the loss of fall spawners, during the same period that total biomass has increased sharply. There are, however, other interpretations for the changes in Baltic herring (Aneer 1985, Anon 1996).

The main point of the observations on spawning, however, is to point out that if they are related to biomass, and if biomass is affected by changes in ocean climate, then we can see that the impact of climate change is far reaching, affecting all aspects of the biology of herring. In the instance of BC herring populations, the changes in spawning populations have been a source of great concern to many local communities and environmental groups. Specifically there are concerns that he reductions of spawning areas represent losses of discrete herring stocks. This point is under investigation and new research initiatives have been launched to examine this. Perhaps these concerns will be shown to be correct, and we should know within a few years, but in the meantime fishery management has been difficult. On the other hand, the results may also show that the changes in spawning distribution are not associated with loss of discrete stocks, or any loss of genetic variation. If so, we probably will conclude that the changes in spawning duration and geographic ranges are related to stock abundance, but in a complex way that we do not fully understand. If climate change is a causative factor for changes in abundance, then will then understand that the ramifications on other aspects of herring biology – specifically spawning biology – also is affected.

Climate change – and other explanations. Most of the observations in species abundance, and the changes in herring spawning patterns coincide with changes in sea-surface temperature or other indices of climate change. Such covariance, however, cannot be considered as proof of the role of climate, or even strong evidence, because other factors may be involved. The sardine fluctuations in California are well documented, and it is not clear that temperature or climate change can be identified as a prime causal factor regulating these changes. Similarly, throughout their entire northern circumpolar range, capelin are known to have occasional excursions into southern waters, and it is not clear if these are related to climate change. It is interesting, though, that the new appearance of capelin in the Pacific seems to coincide with a movement of capelin to the south in Atlantic Canadian waters.

Summary

We observed a general increase in the abundance of 5 pelagic species, decreases in a number of demersal species and changes in ocean climate. If climate change is the causative agent for observed changes in the fish populations, we acknowledge that we do not understand the mechanisms. Also, we recognize that there are other possible explanations, including effects of fishing, or other factors, usually of anthropogenic origin that could produce some of these changes. These other factors, however, may not necessarily result in synchronous changes in fish populations, especially in a number of different species. Therefore we tentatively conclude that the *synchrony* of change among different populations, specifically the increase in abundance of 5 different small pelagic species in BC in the 1990's, is an important observation that constitutes evidence of broad effects on marine ecosystems. These changes are consistent with the hypothesis that climate changes is a major causative agent affecting the distribution, abundance and biology of the 5 small pelagics species discussed in this report.

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Scale and Causes of Growth of the Pacific Herring Abundance in the Western Bering Sea in the 1990s

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The Korf-Karaginsky population is a basic component of the herring stock structure in the western Bering Sea. Several small groupings (so called "lake herrings") dwell the northwestern region. During summer some herring migrate there from the eastern Bering Sea.

In the early 1990s, a drastic decrease of walleye pollock biomass and growth of herring population took place in the western Bering Sea in conditions of regime shift. The Korf-Karaginsky herring exploitable biomass doubled by 1996 (up to 420,000 t) compared to estimations in 1986-1987. This stock has further opportunities to increase due to high recruitment of the 1993 and 1994 brood years. The success of these brood years was determined at under-yearling stage. Survival rates have likely increased for early life stages.

Herring distribution during feeding migrations, in particular terms of eastward migration behind the Olyutorsky Cape depend from water circulation pattern features and intensity of water inflow on the shelf. Eastward from the Olyutorsky Cape herring are mostly aggregated near the Central Bering Sea Current (CBSC) divergence. In the 1990s the area suitable for the herring feeding route was expanded due to a northeastern shift of the CBSC divergence zone.

Environmental changes were favourable for survival of early stages as for feeding route of adult herring in the western Bering Sea. Opposite trends of herring and walleye pollock stock dynamics are determined by distinctions in ecology and feeding habits of these species. Decline of zooplankton biomass in the offshore waters effects herring to a lesser degree since fish feed mostly on plankton concentrations at ocean fronts.

Forage Fishes in the Bering Sea: Distribution, Species Associations and Biomass Trends

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Relatively little is known about distribution patterns and species associations of forage fishes in the Bering Sea, despite their importance as major prey of many higher trophic level organisms, such as seabirds, marine mammals, and predatory fishes. In this study, we examined survey data on some dominant pelagic forage fishes (herring *Clupea pallasi,* capelin *Mallotus villosus,* and eulachon *Thaleichthyes pacificus)* and the juvenile stages of major commercial groundfish species (walleye pollock *Theragra chalcogramma* and Pacific cod *Gadus macrocephalus).* We analyzed two main data sets: 1) a 1987 Russian survey that covered most of the Bering Sea, and 2) National Marine Fisheries Service (NMFS) summer surveys (1982-95) in the eastern Bering Sea which sampled the same grid of stations each year. In the Russian survey, age-0 pollock had the highest biomass and were the most widely distributed forage fish, although jellyfish and age-2+ pollock dominated the biomass overall. Several geographically distinct assemblages were recognized in both the eastern and western Bering Sea. Age-0 pollock were associated with warmer bottom temperatures and capelin with colder bottom temperatures compared with other species. Distributions of all species from the NMFS surveys during a cold year (1986) were more widespread and overlap among species was greater than during a warm year (1987). Pacific herring showed the most dramatic fluctuations in their biomass index over 14 years of NMFS trawl surveys and was the dominant forage fish caught in most years, although when their biomass index was low, they were exceeded by age-1 pollock, eulachon, and capelin.

Effect of Short-Term Fluctuations of Water Temperature on Fish Catch by Set-Net Fishing Around Awa-Shima Island in the Sea Of Japan

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Background and objective

During the last 10 years, the catch level of yellowtail and jack mackerel migrating in the Tsushima Warm Current area of the Sea of Japan has increased. Catch data by coastal set-nets are useful for analyzing temporal variation in migrations of this species. Fluctuation in daily catch efforts of set-nets among each operating days is not as large as other similar fisheries. Also, there are many set-nets operating everyday along the coastal region of the Sea of Japan side of Japan mainland. However, often unexpectedly good catches are found in the set-net catch data. This study examined the relationship between short-term fluctuation of water temperature and these unexpectedly good catches.

Material and methods

Awa-shima Island is located at the eastern part of the Sea of Japan (38°28' N 139°15' E). This area is influenced by the Tsushima Warm Current and has a large coastal set-net fishery.

The analysis was made for the data on fish-landing by the set-net twice a day in the morning and evening and water temperature measured at the mouth of set-net at 1-hour interval from May to July in three successive years, 1995-1997. Among various fishes landed, the landing records of marketable-size tuna, yellowtail, jack mackerel and sea bream were compared with fluctuation of water temperature.

RESULTS AND DISCUSSION

Each year, the water temperature rose from 11-12 to 18-20°C by the end of July. The daily fluctuation was small at the beginning, then increased about 3°C at the end of May, and again became less. The main observations are:

1. Occasional catches of tuna and constant landings of yellowtail start after the water temperature exceeds 14°C (Fig. 1).
2. Good catches of yellowtail, over 1000 individuals per day, are observed when daily fluctuation of water temperature becomes 2-3°C (Fig. 2).
3. Catches of spawning adults of both jack mackerel and sea bream do not correspond to daily change of water temperature. The results on sea bream in 1996 is shown in Figure 3.

Therefore the movement or migration of tuna and yellowtail was considered to be under the influence of short-term fluctuation in the surrounding water condition. In contrast, the movement of spawning adults of jack mackerel and sea bream was considered to be a normal part of their spawning behavior rather than an effect of short-term fluctuation of water temperature.

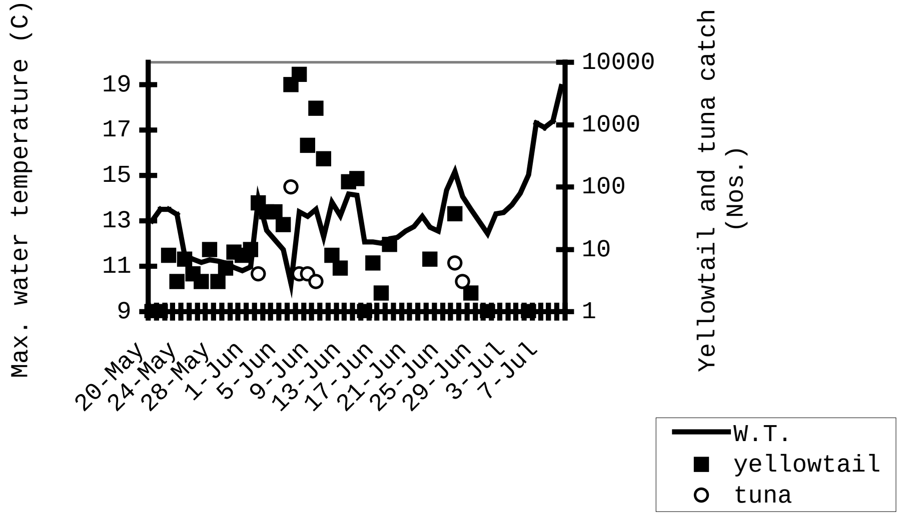

Fig. 12 Daily fluctuations in maximum water temperature and catches of yellowtail and tuna.

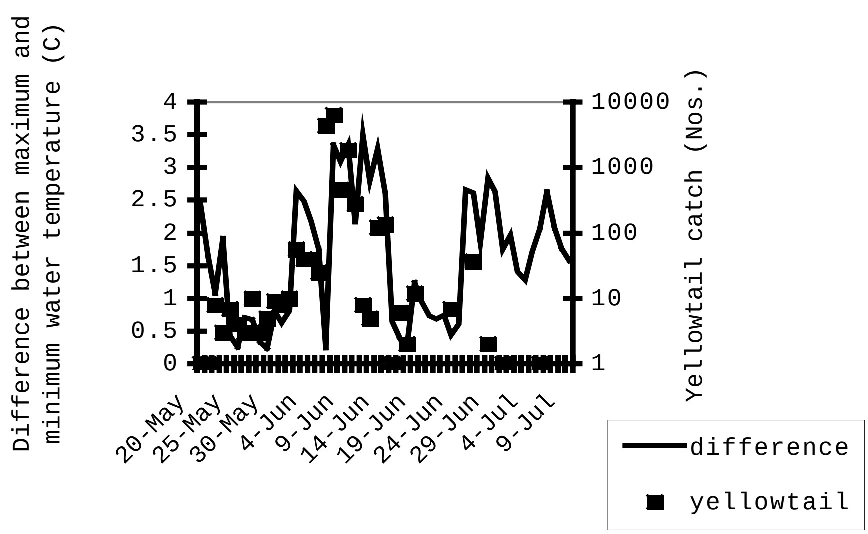

Fig. 13 Daily fluctuations in water temperature and catch of yellowtail

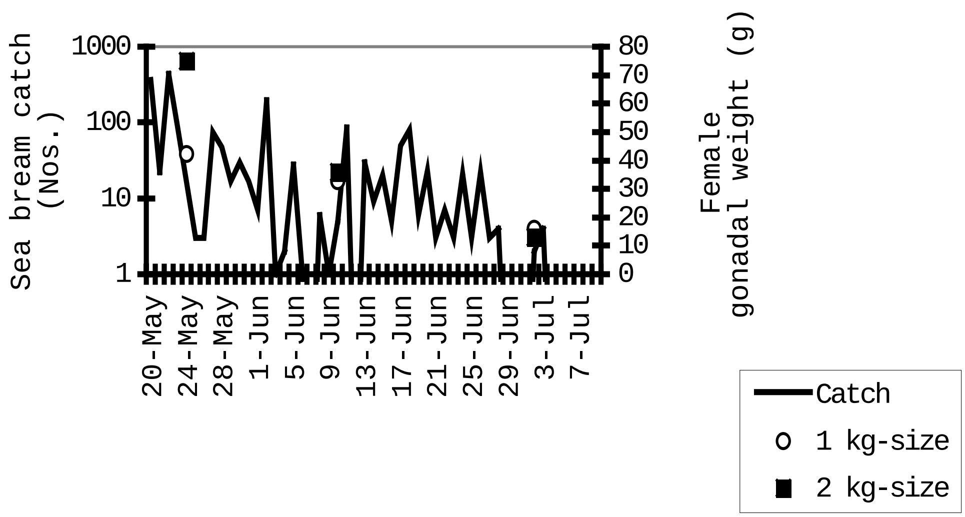

Fig. 14 Daily fluctuations in catch of sea bream and monthly change of mean gonadal weight of adult females in each kg size category.

Which is Responsible for Fluctuating Squid Catch Rates - Fishing or Climate Change?

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Most exploited squid species have a very short life span (annual or sub-annual); thus the only manners in which catch levels and the reproductive success effected by environmental conditions at the spawning grounds in one year affect the abundance the following year is through the stock-recruitment relationship. We will present some examples of recent stock fluctuations for two Japanese squids, the ommastrephid *Todarodes pacificus* and the loliginid *Loligo bleekeri,* in relation with climate regime shifts in waters around Japan after the 1980s.

Todarodes pacificus catch rates have fluctuated during the 20th century. It has been suggested that the stock reduction that occurred during the 1970s and 1980s was caused by both changing environmental conditions and fishing pressure. However, annual catch rates have gradually increased since 1987, despite the lack of catch regulations. In addition, paralarval catch rates since 1989 have been higher than during the late 1970s and the mid-1980s. On the other hand, *Loligo bleekeri* catch rates in northern Japan have fluctuated annually, with a large drop from 1984 to 1988 and a gradual increase since 1989. The recent stock increases of both species appear to be related to a regime shift to warmer temperatures around Japan that occurred in the late 1980s. Both squids recruitment were related mainly to the area of their spawning grounds. Recruitment in both species may have increased due to a warming and resulting expansion of the spawning grounds.

Identifying Seasonal Spatial Scale for the Ecological Analysis of Herring and Other Forage Fish in Prince William Sound, Alaska

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Recently there has been increasing interest in the distribution, abundance and ecology of forage fish because of their role in nearshore and pelagic ecosystems. In Alaska, however, relatively little is know about forage fish species. From 1995 to 1997 extensive ecosystem studies were conducted in response to the 1989 *Exxon Valdez* oil spill. Monthly aerial surveys were made to determine the distribution and abundance of juvenile Pacific herring (*Clupea pallasi*) and other surface schooling forage fish (Brown and Norcross 1997). Physical and biological data, useful for ecological analyses of forage fishes were also gathered concurrently. Before we could comment on ecosystems, we recognized that basic descriptive life history parameters and the spatial overlap with other ecological parameters needed to be documented first. The first general goal of the research was to conduct ecological analysis of forage fish distribution and abundance using appropriate temporal and spatial scales. The objective of this report is to use a Geographic Information System (GIS) to identify and define the appropriate seasonal and spatial scale. A starting place to define spatial scale is to examine processes for each species of interest. A fish such as herring, may be affected by one scale during spawning, another during the larval stage and yet another during the juvenile stage. Therefore seasonal affects on spatial scale should be defined first. In addition, traditional nested quadrat analyses may not truly reflect the scale of bottom forcing events. We therefore chose to start by looking at the spatial distribution of forcing events. For this examination of scale, we evaluated some of the available spatial data by season and removed interannual variability by pooling all years for which data were available. In order to gain a better understanding of the timing of physical and biological processes affecting forage fish, we plotted events along a linear time scale pooled over the years of data availability (Fig. 1).

Timing of events

Most of the ecological activity associated with the timing of forage fish activities in the surface waters (upper 100 m) occurred during the spring and summer months from April to August. In addition, we found that biological processes affecting forage fish during this period were concentrated in the upper 20 m of the water column. The activity was initiated by the formation and strengthening of the stratified layer (Data source CLAB Buoy 1991-1997; Eslinger 1997; Central PWS); this is accompanied by a steady increase of temperature in the upper 20 m of the water column (Fig.1, panel 1).

The phytoplankton bloom peaked in April during the formation of the stratified layer at approximately 20 m at a temperature of approximately 5°C (Chlorophyll *a* CFOS Buoy and southwestern PWS, 1994-1997; D. Eslinger, unpublished data, University of Alaska, Fairbanks; Eslinger 1997; McRoy et al. 1997; Fig.1, panel 2) the offshore zooplankton bloom began in April and peaked in June (mid-sound and southwestern PWS, 1981 to 1997; Cooney 1997 and 1998; T. Cooney, unpublished data, University of Alaska, Fairbanks). The inshore zooplankton bloom (near the juvenile herring rearing sites; Stokesbury et al. 1998) followed similar timing to the offshore bloom but was apparently more highly concentrated (1996 data; R. Foy, unpublished data, University of Alaska, Fairbanks; Fig. 1, panel 2).

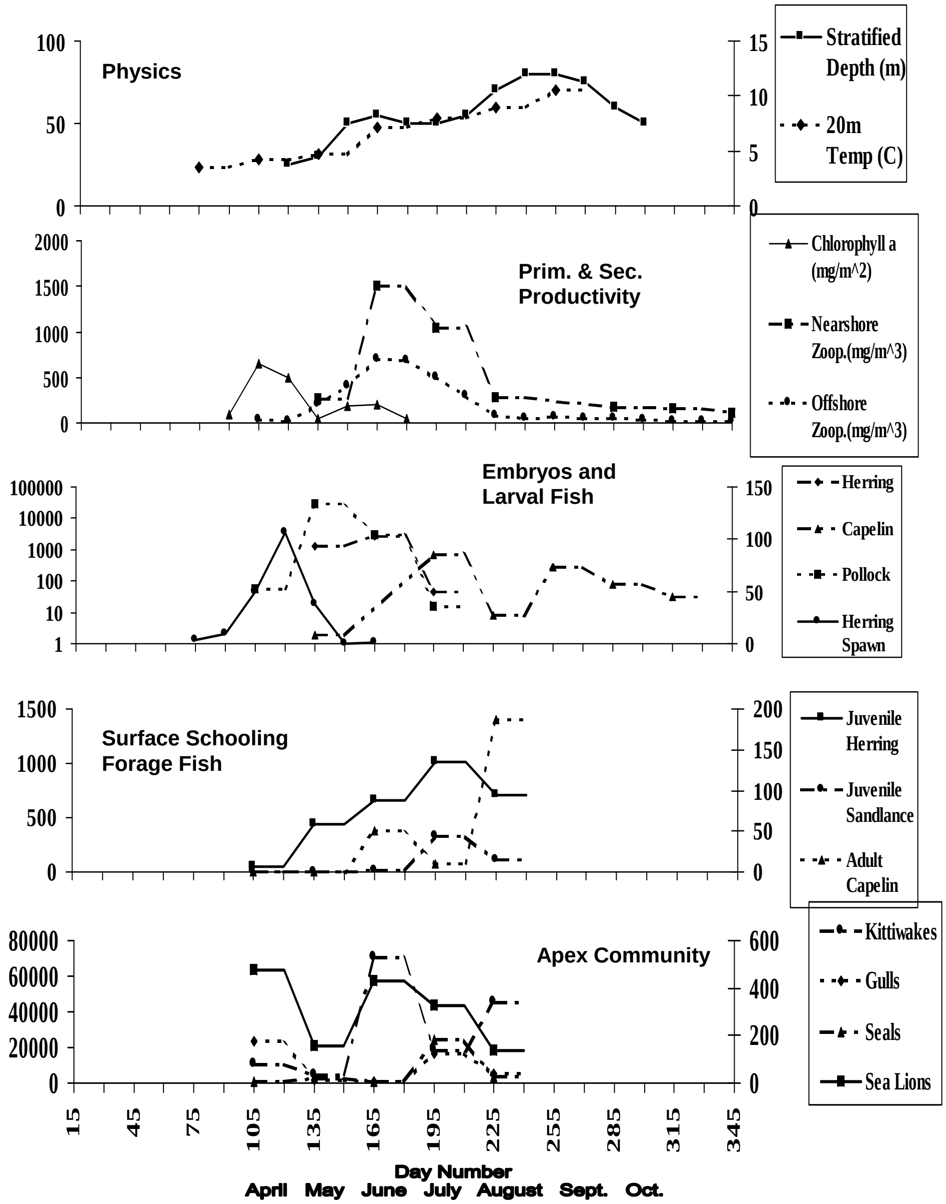

Fig. 1 The timing of key ecological events in Prince William Sound, Alaska including: the formation of the stratified layer (depth in m left axis) and ocean temperatures at 20 m depth (C, right axis); primary and secondary production (mg/m^2 or mg/m^3); herring spawning (cumulative miles of spawn, right axis) and larval fish (no. larvae/m^3, left axis); surface schooling forage fish (total m^2 school surface areas; capelin on right axis, sandlance and herring on the left); and apex predators (total no. of individuals, kittiwakes on gulls on left axis, sea lions and seals on the right).

Pacific herring spawning commenced after temperatures started rising (>4°C) and peaked when the stratified layer first formed (15 d cumulative estimates of miles of spawn, 1985-1997; ADF&G, Cordova Office, unpublished data; Fig.1, middle panel). From a single larval fish survey in 1989 (Norcross and Frandsen 1996), peak densities of larval pollock (*Theragra chalcogramma*) and Pacific herring (the second and fourth most abundance larval fish species found in PWS) roughly coincided with the peak of the zooplankton bloom (Fig. 1, middle panel). Capelin

(*Mallotus villosus*; the third most abundant larval fish species) showed a bimodal trend in abundance peaking later in July and then again in early fall, remaining abundant into October.

During 1995-1997, the most abundant surface schooling forage fish species observed from the air were juvenile Pacific herring, juvenile sandlance (*Ammodytes hexapterus*), and adult pre-spawning capelin (Brown 1998) (Fig. 1, panel 4). Juvenile herring (mainly age 1; E. Brown, unpublished data) appeared in the surface waters beginning in May after the stratified layer formed, temperatures had increased to at least 5°C, and coinciding with the onset of the zooplankton bloom. Their abundance steadily climbed, peaking in July and August after the age 0 herring joined the age 1 juveniles in the nursery bays. The appearance of sandlance in the surface waters coincided with a recruiting event (E. Brown, unpublished data) of age 0 fish in the nearshore zone in July and August well after the peak of the bloom. The occurrence of large pre-spawn schools of capelin showed two peaks, one in June and one in August (E. Brown, unpublished data) possibly indicated bimodal spawning events in PWS.

Information on aggregations of foraging predators was collected as auxiliary data during aerial surveys from 1995 to 1997. Those results indicated Stellar sea lions and glaucous-winged gulls were abundant in aggregations in April, coinciding with the herring-spawning event (Fig. 1, bottom panel). Black-legged kittiwake and sea lion aggregations peaked in June coinciding with increases in surface schools of herring and capelin. The appearance of harbor seals peaked while sea lions continued to be abundant during July and August likely due to the return of large numbers of spawning salmon in PWS.

SPATIAL OVERLAYS BY SEASON

Monthly overlays from April through August of physical and biological data were produced using a GIS. In April, the stratified depth is ~25 m in the central sound with a mean temperature of 4.2°C at a 20 m depth. Over the 20 year hydrographic data set available, the warmest regions occurred in northeast, north and northwest PWS (≥5.7°C); the coolest (2.9°C) occur in the central sound associated with anti-cyclonic gyre and at the entrances and exits to PWS from the Gulf of Alaska (GOA) (Fig. 2). The densest water was associated with the central gyre and the least dense water was associated with warmer regions and downstream from western glacial-filled fjords. The residual currents were generally low ranging from 0.001 to 0.210 $m \cdot s^{-1}$ with a mean flow of 0.04 $m \cdot s^{-1}$ (Fig. 2). The flow to and from PWS during this month was minimal. Herring spawning regions occurring during the 80s were generalized. Spawning regions occurred adjacent to, south, north and east of the central gyre, but never west; all spawning occurred well inside the "oceanographic boundaries" of PWS. During this month all the surface schooling fish (all herring), gulls, and aggregations of sea lions were associated with the herring spawn. Larval fish abundance was generally low and only pollock larvae were observed (1989; Fig. 2).

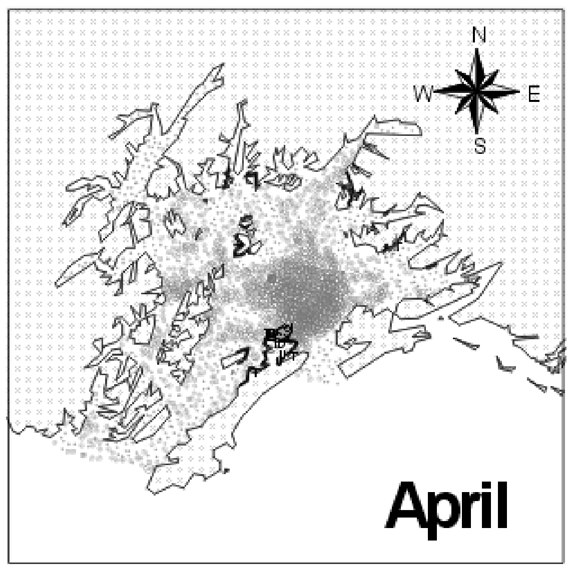

Fig. 2 Ecological features within Prince William Sound, Alaska during the month of April.

In May, the stratified depth had increased to 30 m with an average temperature at 20 m of 5.5°C. The temperatures all over PWS showed a large increase from April (not shown), but the northeastern region of PWS remained the warmest (up to 6.9°C) and the regions associated with high flow and gyres the coolest (down to 4.2°C). Some of the "hot spots" in

PWS were now associated with exchange of GOA water at the entrance and exits. The overall density of the water was lower during May with the least dense water still associated with higher temperatures. Ocean flow increased from April to a range of 0.004 to 0.284 $m \cdot s^{-1}$ with a mean flow of 0.042 $m \cdot s^{-1}$ (Fig. 3).

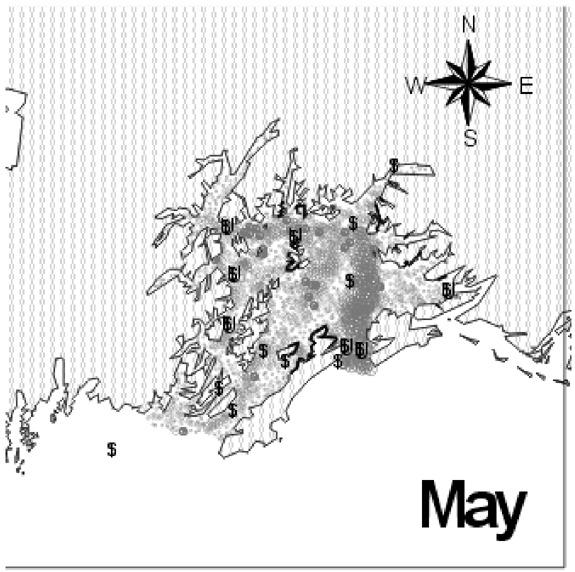

Fig. 3 Ecological features within Prince William Sound, Alaska during the month of May.

The central gyre intensified, reversed direction (now anti-cyclonic) and extended farther north. In addition, the net flow into and out of PWS greatly increased during this month. Topography steered cross sound flow was also observed in the north region of PWS. Larval fish peaked in abundance during May and were broadly distributed (except capelin that was only observed in the northeast region) with and outside of the gyre-related currents. Note that herring larvae were as abundant west of the spawning regions as well as adjacent to them. By June, temperatures at 20 m had risen significantly (mean at 7.3°C) with the stratified layer depth approaching 50 m. The temperatures during June were more uniform over the sound with a range of 5.4 to 9.8°C; however, "hot spots" were still observed in the eastern sound and adjacent to the GOA. Density declined slightly from May, but this time apparently in response mainly to changes in salinity rather than temperature. Although the range of ocean flow lessened slightly from May (to 0.001 to 0.204 $m \cdot s^{-1}$), the mean flow was higher at 0.054 $m \cdot s^{-1}$. The flow into and out of the sound intensified from May with the formation of smaller topography-steered cyclonic gyres east and west of the inflow; overall, the exchange of surface water appeared to have increased over May.

Larval fish were still relatively abundant and widespread (not shown) with an increase in the relative abundance of herring over pollock. No capelin larvae were observed. The most notable feature in June was the increase in appearance of surface schooling forage fish (Fig. 4).

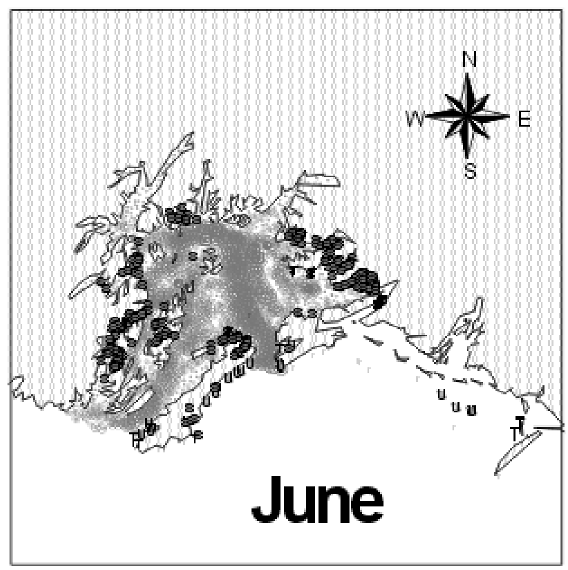

Fig. 4 Ecological features within Prince William Sound, Alaska during the month of June.

The most abundant species was juvenile herring inside the sound and adult pre-spawn capelin outside the sound. A small number of sandlance schools were also observed inside the sound. Black-legged kittiwakes were highly associated with surface schooling forage fish with notably large flocks associated with the capelin spawning aggregations. Gulls and sea lions (not shown) did not appear to be significantly associated with the juvenile herring, however there were aggregations of both observed near capelin spawning events. In July, temperatures at 20 m climbed to 10.1°C but the depth of the

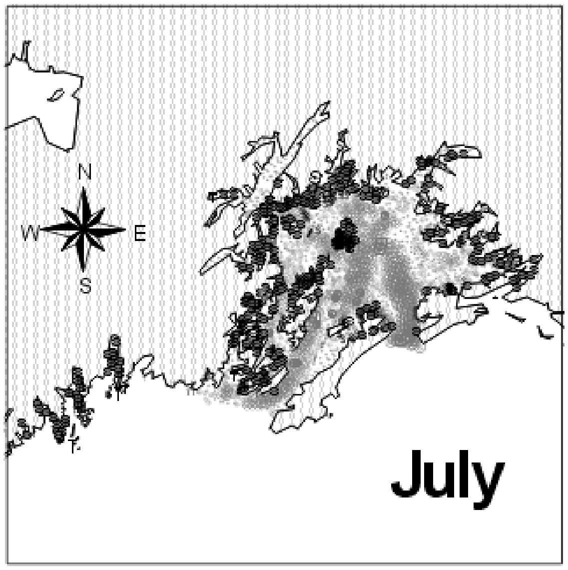

Fig. 5 Ecological features within Prince William Sound, Alaska during the month of July.

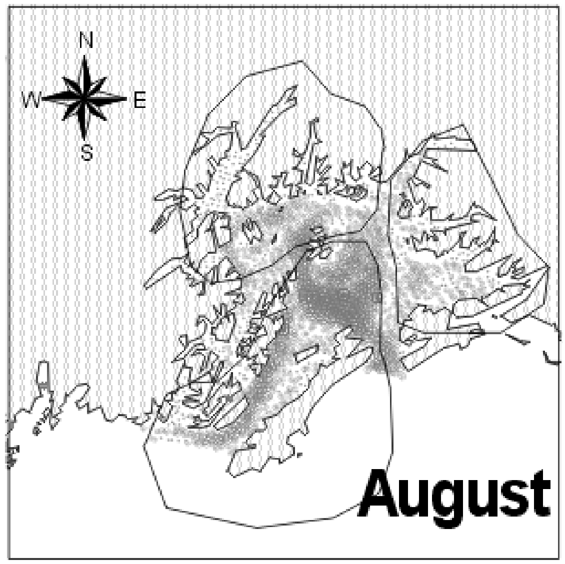

Fig. 6 Ecological features within Prince William Sound, Alaska during the month of August and delineation of proposed ecological "regions".

stratified layer was similar to June. The overall temperature range was 6.0 to 13.6°C with the warmest regions occurring again in the eastern and now northern sound. The coolest region remained in the central sound associated with strong currents. Densities were similar to June. The ocean flow was also similar to June ranging from 0.0002 to 0.315 $m \cdot s^{-1}$ with a mean flow of 0.054 $m \cdot s^{-1}$ (Fig. 5). Larval fish were overall less abundant than in June but still widespread with a decrease in the occurrence of both pollock and herring; the notable feature was the occurrence of large numbers of capelin broadly distributed within the sound (probably resulting from the spawning events observed in June; not shown). The numbers of surface schooling fish increased significantly over June largely due to an increase in both herring and sandlance (Fig. 5). This distribution of herring and sandlance extended well west of PWS along the Outer Kenai Peninsula. We believe this increase is due to recruiting events of age 0 fish for both species (based on unpublished data, E. Brown). As in June, kittiwakes were largely associated with the surface schooling fishes while aggregations of associated gulls and sea lions were not observed.

In August, both the stratified depth (over 50 m) and temperatures at 20 m (mean 10.4°C) peaked over this five-month period. Temperatures ranged from 4.3 to 12.7°C with the same pattern of higher temperatures around the "rim" of PWS but cooler temperatures associated with presumably ice-melt in the northern fjords. Density and salinity remained very similar to July. Although ocean flow peaked during this month (over the five month series) with a range of 0.0002 to 0.435 and a mean flow of 0.082 $m \cdot s^{-1}$ (Fig. 6). The flow into and out of the sound remained strong but the central gyre reversed direction to generally anti-cyclonic flow. Winds within PWS determined to a great degree the strength and directions of the gyres and surface currents. All the biological activity observed in the surface waters declined greatly during this month. Although capelin larvae were still present, they appeared to have migrated or advected out of PWS (Fig. 6).

The conclusion of this exercise is that there is variability in the seasonal spatial scale of bottom driven forcing events in PWS. In an analysis of spatially explicit ecological processes in PWS, there appear to be three major regions to be considered (Fig. 6).

The eastern portion of the sound is generally warmer, but influenced biologically by the central gyre and inflow and seasonally highly variable. The northern and northwestern part of the sound is generally quieter, less variable and less influenced by the inflow. The central region adjacent to the GOA is very dynamic, affected by the most intense flows and is very likely responding to events outside of PWS to a much greater degree than the other two regions. This last region is also probably associated with greater losses of larval fish (advection of larvae out of PWS). The Outer Kenai may be an "overflow" area for biological processes occurring within the sound.

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II. REVIEW OF THE PRESENT STATUS OF NATIONAL GLOBEC AND GLOBEC- LIKE PROGRAMS RELATED TO SMALL PELAGICS

On the second day of the REX Workshop, the participants considered recruitment prediction, spatial studies (nursery/spawning areas), size-at-age and somatic growth, species alteration, and assessment and sampling methods as discussion points to identify key questions.

Key questions

The participants considered the two following questions as key questions which were related to higher trophic levels and addressed in CCCC Implementation plan as the basic key questions.

1. How do life history patterns, distributions, vital rates, and population dynamics of small pelagic species respond directly and indirectly to climate variability? (PICES Scientific Report No. 4)?
2. Do small pelagic species respond to climate variability solely as a consequence of bottom up forcing? Are there significant intra-trophic level and top down effects on small pelagic species? (PICES Scientific Report No. 4)

and addressed the following as key questions specific to small pelagic species:

1. Do small pelagic species respond in same way between high and low latitude and longitude?
2. Can we distinguish between changes induced by climate change and those changes related to fishing other anthropogenic, or intrinsic biological variation?
3. How does small pelagic fish community structure vary with oceanographic conditions?
4. Do small pelagic species in the eastern and western Pacific exhibit similar patterns of year-class strength?
5. Does spawning time (duration) and spatial range change with stock abundance and size structure?
6. Does size at age change with stock size?

Key Hypotheses

At the 1997 REX workshop, the mid-water and demersal fish group considered the principal mechanisms underlying the fish species response to climate variability. Then they addressed key hypotheses to correspond to each mechanism. Following this approach, participants identified starvation, transport, concentration, prey suitability, prey type, competition, and predation mortality as mechanisms relative to survival of early life stages. Participants also considered that changes in distribution and growth rate resulting from climate changes in adult stages as important factors affecting survival of early life stages. From these discussions, the suggested hypotheses linking climate variability and the response of small pelagic species are listed as follows:

1. STARVATION

a. Survival of small pelagic fish larvae depends on matching hatch dates with the peak zooplankton production (i.e. the match miss-match theory). Factors that alter the timing of the spring bloom can influence “the match miss-match” between first feeding larvae and prey availability.

b. Survival of small pelagic fish larvae and juveniles depends on sustained secondary production through out the spring and summer month.

2. TRANSPORT

a. Survival of small pelagic fish larvae depends on advection to favorable nursery grounds. Atmospherically driven shifts in large-scale circulation patterns can impact recruitment success by changing larval distributions.

b. Survival of small pelagic fish larvae depends on advection to favorable nursery grounds. Density dependent or climatically induced changes in spawning grounds can impact recruitment success by changing transport condition in time and space.

3. CONCENTRATION - Survival of small pelagic fish larvae depends on mesoscale advection patterns that concentrate larvae and their prey. Mesoscale features such as eddies or frontal systems concentrate prey and enhance larval survival.

4. PREY SUITABILITY/COMPETITION- Survival of small pelagic fish larvae depends on the availability of the appropriate prey species at suitable size for consumption. Presence of other small pelagic species affects the survival through the competition for common food resources.

5. PREDATION MORTALITY -
   a. ADVECTION: Survival of small pelagic fish depends on advection processes that separate larvae and juveniles from their predators.
   b. SIZE DEPENDENT MORTALITY: Processes that enhance larval and juvenile growth rates will reduce predation mortality by reducing the time when larval or juvenile fish are vulnerable to predation.
   c. PREDATOR / PREY OVERLAP: Processes that separate predators from larvae and juveniles of small pelagic species influences the amount of predation mortality.

6. MATERNAL FACTORS - Survival of small pelagic fish larvae depends on maternal factors, such as fecundity, egg quality, mature age, and others, which are dependent on the physiological condition of adult and that is influenced by climate variability.

Workshop Recommendations

To facilitate the research cooperation for testing hypotheses, participants made following recommendations:

1. Conduct comparative analysis of larval and juvenile vital rates of small pelagic species from different regions of the North Pacific and its adjacent seas.
2. Collate and synthesize small pelagic species data for comparative studies. Initially, this could involve the exchange of scientists, data assembly, and development and application of analysis tools. Hopefully, some or much of this could be accomplished in 1999.
3. Choice of scale should be carefully chosen to detect mesoscale response.
4. Conduct comparative studies of stock structure of small pelagic species in the North Pacific. Specifically, we recommend analysis of genetics of small pelagic fish stocks to evaluate the potential for climate influence on marginal populations and stock separation.
5. Define suitable sampling protocols for use in assessing the distribution and ecology of small pelagic species.
6. Examine sampling characteristics of different types of gear, considering factors such as availability, selectivity, and catchability.
7. Choose sampling methods and technologies that are suitable for the temporal and spatial scales of the question.
8. Continue to encourage discussions of small pelagic species through REX Task Team. Conduct a CCCC symposium on small pelagic species for the year 2000.
9. Maintain an inventory of scientists active in small pelagic species research (perhaps activity for TCODE)
10. Consider hake, pollock, and non-commercial species (e.g. sandlance, osmerids) in the small pelagic species discussions.

APPENDIX A: REX WORKSHOP 1999: HERRING AND EUPHAUSIIDS

Background

Herring and euphausiids are key components of coastal ecosystems in the sub-arctic region in the North Pacific. Juvenile herring is a predator for euphausiids, but it is a competitor for copepods such as *Calanus* and *Neocalanus*. Biomass fluctuations of euphausiids usually correspond closely to fluctuations in primary production, so euphausiid biomass fluctuation may be strongly affected by climate variability. Changes in euphausiid biomass could affect the growth of juvenile herring, and eventually determine the degree of winter mortality. At the same time, predation mortality of juveniles by hake or pollock, etc. also is changed because these predators also feed on euphausiids. Therefore, to examine the ecosystem response, we must know the dynamics of the herring - euphausiid interactions through the comparative studies among areas in the sub-arctic region in the North Pacific.

Proposal

In the workshop, for the major herring populations in the Pacific Rim, we will compare the population dynamics, then identify the fluctuation patterns and changes in life history parameters with climate variability. We also will analyze the food web by area, and try to compare the ecosystem response to climate change developing a simple trophodynamic model.

Venue: Vladivostok, Russia
Time: two days just prior PICES VIII
Tentative co-conveners: W.T. Peterson (U.S.A.), V.I. Radchenko (Russia), and T. Wada (Japan)

Bass task team Report

THE BASS TASK TEAM IS CONCERNED WITH THE DEVELOPMENT OF THE BASIN-SCALE COMPONENT OF THE CCCC PROGRAM.

INTRODUCTION

No formal meeting of BASS was organized at the 1998 Annual Meeting, however a number of informal discussions were held. This report summarizes results of previous meetings, describes the activities of the Task Team that were conducted in 1998, and presents the 1999 activities proposed at the 1998 CCCC meeting.

The Basin Studies Task Team will facilitate the exchange of scientific data and encourage scientific research relating to the implementation of the PICES/GLOBEC Science/Implementation Plan (PICES 1996). In general, the oceanography and ecology of the eastern and western basins of the subarctic Pacific are poorly understood relative to the coastal areas. It is known that the central subarctic Pacific is productive as indicated by the large abundance of Pacific salmon, squid and other important fishes. Recent studies also suggest that the oceanography of the gyres is closely linked to the decadal scale changes in climate.

BASS held its first meeting during the Fourth Annual PICES Meeting in Qingdao, China, when an agreement on organization and general objectives was achieved. The task of BASS is to facilitate studies of the impacts of climate change and climate variability on the physical and biological processes in the gyres of the western and eastern subarctic Pacific Ocean. In general, it can be considered that these processes drive the shelf processes that impact on coastal marine resources.

The objective of the CCCC Program is to identify the impacts of climate change on the ecosystems of the subarctic Pacific. The scientific questions are as follows:

1. Physical forcing: What are the characteristics of climate variability and can interdecadal patterns be identified, how and when do they arise?
2. Lower trophic level response: How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?
3. Higher trophic level response: How do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?
4. Ecosystem interaction: How are subarctic Pacific ecosystems structured? Do higher trophic levels respond to climate variability solely as a consequence of bottom-up forcing? Are there significant intra-trophic level and top-down effects on lower trophic level production and on energy transfer efficiencies? The key research activities were identified as (1) retrospective analyses, (2) development of models, (3) process studies, (4) development of observations systems, and (5) data management.

At the second meeting of BASS, an action plan was developed that was achievable and would facilitate the implementation of the CCCC Program. BASS developed a work plan consisting of some general, longer–term goals and some specific action items. The plans are ambitious and lack specific commitment from the participating countries, however they provide background information for any group or country planning research in the subarctic Pacific.

Details of the plan can be found in PICES Scientific Report No. 7, and are summarized here for completeness:

Retrospective comparison of lower trophic level dynamics in the eastern and western subarctic gyres: a link between climate change and higher trophic levels.

Important questions include:

i. Is there sufficient data available from representative sites in each gyre for this comparison?
ii. Are there significant differences between the gyres in seasonable changes of these parameters?
iii. If so, what are the implications for factors controlling total and exportable production at each site?
iv. What are best sites for long-term observations and process studies?

Zooplankton standardization

A major barrier for both retrospective analyses and on-going process/monitoring studies is the lack of standardization of sampling equipment and methodology for zooplankton sampling. Differences to be resolved by:

i. Identification of important datasets of zooplankton abundance for the eastern and western gyre (with assistance of TCODE).
ii. Documentation of sampling methodologies used in these datasets.
iii. Development of conversion algorithms and guidelines for their application. This may involve new sample collections using different gear and methods.
iv. Develop recommendations for common sampling equipment and methodologies.

Time series measures of primary productivity and zooplankton stocks

Time-series measurements of primary productivity and zooplankton stocks in the open ocean sector of the subarctic Pacific are required to better understand the relationship between changes in plankton populations and changes in the physical-chemical environment. A longtime-series (1952-1981) of weathership data in the eastern subarctic Pacific was obtained at Ocean Station P (50°N-145°W). The Station P data are suitable for demonstrating whether variations in zooplankton stocks are related in some direct fashion to primary productivity. There are no comparable time series data from the western subarctic Pacific. Higher production rates and greater zooplankton standing stocks are thought to occur in the western subarctic Pacific. It is anticipated that the relationships in the western Pacific will be different because the physical conditions there differ markedly (deep mixed layer).

The BASS Task Team recommends that PICES promote the installation of robust instrumented surface moorings in the subarctic Pacific which are capable of providing well-calibrated data on phytoplankton standing stock, primary productivity, dissolved inorganic nutrient concentration and zooplankton biomass.

Inventory of higher trophic level species

It is difficult to consider the impact of physical changes in the two gyres because it is not possible to identify easily the higher trophic level residents. As part of the initial effort of standardizing data and building data bases, BASS will identify the key higher trophic level species, produce brief life histories and provide data from fisheries.

BASS will need to acquire the work or science plans of all agencies carrying out research in the eastern and western gyres. As part of the annual report of BASS, the proposed and completed research should be identified.

At its second meeting, BASS recommended that a series of theme papers on the dynamics of the ecosystems in the eastern and western gyres of the subarctic Pacific be produced and the results presented at a one-day symposium to be held at the PICES Annual Meeting in 1997. The symposium examined “Ecosystem Dynamics in the Eastern and Western Gyres of the subarctic Pacific”. The theme papers addressed ocean responses, climate forcing, nutrients and primary production, remote sensing, sediment traps, microplankton biomass and composition, netplankton biomass and composition, a model of phytoplankton production dynamics, salmon, common fishes, nekton, marine mammals and birds.

The symposium was held at the PICES Annual Meeting in 1997. All papers were reviewed and finalized during 1998. The symposium proceedings will be published (1999) in a special issue of Progress in Oceanography. A paper on phytoplankton seasonality in the eastern and western subarctic Pacific and western Bering Sea which was not presented at the symposium will be included in the proceedings.

References

PICES. 1996. PICES/GLOBEC Science Plan/Implementation Plan. *PICES Scientific Report No. 4,* 64pp

TASK TEAM RECOMMENDATIONS

Short-term

1. The Co-Chairmen of BASS, R.J. Beamish and M. Terazaki, have both asked to be replaced. BASS nominates Gordon A. McFarlane (Canada) and Andrei S. Krovnin (Russia) as the new Co-Chairmen.

2. In 1999, we propose to (1) identify new BASS members to assist in the development of a long-term work plan for BASS, and (2) hold a special workshop to develop a conceptual model of how subarctic gyres work and how they change with regime shifts (See Appendix A).

3. Assign BASS representative to coordinate provision of a list of annual cruises to PICES, through contacts in each member country and through other organizations such as NPAFC, GLOBEC, etc.

4. BASS received a proposal for an iron fertilization experiment from C.S. Wong.
   - BASS recognizes iron limitation as an important unanswered question in the North Pacific and at last year's meeting identified this as an area requiring further research
   - BASS recommends that CCCC-IP brings this proposed experiment into the CCCC Program and provides support to meet the goals of the experiment by identifying national expertise from PICES nations that could assist in carrying out the experiment.

APPENDIX A: BASS WORKSHOP 1999: DEVELOPMENT OF A CONCEPTUAL MODEL OF THE SUBARCTIC NORTH PACIFIC GYRES

Objective

Determine how the ecosystems of the subarctic North pacific gyres function and how they respond to regime shifts.

Outline

- Workshop format will be similar to the 1997 REX Workshop.
- We will use the information brought together in the BASS Symposium volume to identify research questions and opportunities. A conceptual model comparing the two gyres will be developed.
- The initial focus will be on three areas of research:
  - physical structure of the gyres in relation to climate change;
  - long-term changes in plankton abundance and species composition;
  - trophic relationship; fish, birds, mammals.

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