NOAA Climate and Living Marine Resources Workshop

May 14-15, 2008

Pacific Marine Environmental Laboratory
Seattle, WA

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Introduction, Context and Background

NOAA conducted a Climate and Living Marine Resources workshop May 14-15, 2008 at the NOAA Pacific Marine Environmental Laboratory in Seattle, WA. The 54 participants included living marine resource biologists and ecologists, oceanographers, climate scientists, resource managers and regulators, and senior NOAA climate and ecosystem leadership.

The overall purpose of the workshop was to explore and enhance internal NOAA cooperation and integration in the development, communication, and application of information related to the impact of climate on NOAA's living marine resource (LMR) management responsibilities. Specifically, the intent was to advance the development of a strategy for addressing the impact of climate on NOAA-managed LMRs, through focused cooperation in research, assessments and management applications within the agency and among our key partners.

This workshop was one of two related workshops conducted in 2008, with the second focused on climate and coastal impacts. The context for these workshops is laid out in the following sections.

I. The Challenge

NOAA currently faces two overarching challenges, the responses to which will shape the future of the agency for decades:

> a) The design, development, delivery and execution of effective climate services that provide applicable information relative to impacts and adaptation strategies; and
>
> b) The effective management of natural resources in the marine and coastal environment, and the development of technical stewardship programs and decision support tools that foster hazard resilient coastal communities in the face of socio-economic, environmental and climatic changes.

These efforts are not unrelated, and, in fact, could be enhanced through a purposeful strategy of integration and cooperation. The development of increased connectivity between the climate and coastal elements of NOAA offers significant benefits for multiple missions and programs within the agency, and, more importantly, for our external communities and constituents.

In addition, NOAA is increasingly called upon through existing and evolving legislation, interactions with stakeholders and government reports to integrate climate information in its natural resource management activities. Legislative drivers include the Magnuson Stevens Fishery Conservation and Management Reauthorization Act, the Endangered Species Act, the Marine Mammal Act, the Marine Sanctuaries Act, the Coastal Zone Management Act, and the Coral Reef Conservation Act. Stakeholders are organizing and articulating their desires to NOAA through means such as the Coastal States Organization's September 2007 Report on "The Role of Coastal Management Programs in Adaptation to Climate Change."

Finally, a 2007 Government Accountability Office (GAO) Report calls for Federal agencies to develop guidance for addressing the effects of climate change on Federal land and water resources. In response to this report, NOAA will consult with coastal and marine resource managers, both internally and within other federal agencies, to identify their needs for climate information and highlight the regional texture of climate and its related effects. By the end of 2008, NOAA expects to generate written materials to help foster the consideration of climate change in natural resource management.

II. Developing a NOAA Response to the Challenge

NOAA's two internal workshops were intended to advance the development of a strategy for ensuring the provision and application of climate information in natural resource management and the enhancement of coastal community resilience. These workshops were intended to complement and provide a larger framework for ongoing and evolving efforts within NOAA's climate and natural resource programs to address climate impacts and adaptation.

These workshops are contributing to the development of an overall agency strategy for generating and applying climate information related to natural resource and risk management in marine and coastal regions. They provide input and recommendations related to the development of guidelines for incorporating climate information in natural resource management, and for meeting these needs through climate services. Specifically, they address the needs and potential strategy for meeting these needs over the short and long term.

Case Studies

Four case studies were presented during the workshop to highlight current activities where climate and ecosystem information is being used to address management needs. These presentations defined the management goals and mandates for the studies, what climate and ecosystem information is required and how it is utilized, how living marine resource management is or may be improved, and who the user community is and what information they need.

In addition to the specific climate impacts on the living marine resources and the scientific knowledge gained on each topic and how it is being used, the case studies highlighted how climate and ecosystem scientists work together to address management priorities. The north Pacific fisheries case studies demonstrated the advantages of having climate and ecosystem scientists located geographically close to one another within institutions that frequently collaborate on projects of regional interest. These advantages include the facilitation of long-term working relationships, close coordination between climate and ecosystem scientists, the design of fully integrated climate and ecosystem studies, and frequent dialogue with regional living marine resource managers. The coral reef case study demonstrated the broad spectrum of developers and users of products to aid coral reef management in the face of climate change and the value of having many entities involved. Ocean acidification is a more recently recognized threat to living marine resources so this case study primarily focused on potential threats and topics that require more investigation. Abstracts of the four case study presentations are provided below.

Climate Considerations in the Management of Anadromous Fishes in the Pacific Northwest

Nathan Mantua – University of Washington

Pacific salmon have a complex life cycle, with portions spent in freshwater and ocean environments. Until relatively recently, management focused on factors affecting survival in the freshwater, even though the ocean phase composes most of a salmon's life and accounts for half the mortality and nearly all the growth of salmon. Salmon fisheries are managed at the level of individual stocks, and salmon hatcheries have contributed to increases in the number of salmon in the ocean. However, abundances of wild salmon along the west coast of the U.S. are now just a few percent of historic levels. For 2008 the Pacific Fishery Management Council adopted the most restrictive salmon fisheries catch limits ever for the West Coast, in response to the unprecedented collapse of Sacramento River fall Chinook and the exceptionally poor status of coho salmon from Oregon and California.

Short-term (3-6 month) salmon return forecasts produced for each river are based on assumptions about productivity trends and information about the number of spawning adults, jack returns, and juveniles produced in hatcheries. However forecast errors are frequently 50-100%. No climate information has been formally used, but many studies have looked to climate indicators for help in reducing forecast errors, as climate variations within the California Current system appear to influence the entire food web and are reflected by salmon survival. With relatively cool, less stratified waters, there is typically high salmon survival. Conversely, during warm periods with more stratified waters, there is typically low salmon survival in the ocean. Lessons learned for short-term forecasts include that the time and space scale of climate information provided must match the scale of management decisions in order to be useful.

Basin-scale research results are inappropriate for local scale management decisions like annual harvest planning. In addition, key aspects of ocean conditions for coho salmon are not likely predictable at seasonal-to-interannual timescales, highlighting the importance of monitoring.

On multi-year and longer time scales it is known that climate matters for Pacific salmon, but the lack of skillful forecasts limits the utility of this information. Skillful forecasts for the Pacific Decadal Oscillation, or other modes of Pacific decadal variability, are of great interest to salmon fisheries. Long-term salmon recovery and restoration planning also need to account for climate in decisions concerning where and how to invest efforts and in guiding freshwater management decisions. Finally, hatchery operations could benefit from climate information informing decisions on smolt release number and timing and optimal facility siting.

Climate Considerations in North Pacific Fisheries Management

Mike Sigler – NOAA/NMFS/Alaska Fisheries Science Center

Phyllis Stabeno – NOAA/OAR/Pacific Marine Environmental Laboratory

Alaskan marine ecosystems account for approximately half of the nation's seafood catch by weight. These fisheries have a value of $1.7B after initial processing and are used in a multitude of seafood products. NOAA is also charged with the protection of marine mammals, of which there are many that spend all or a portion of their lives in Alaskan waters. Tourism, much of which is based upon the natural resources that NOAA is responsible for, is very important to the economy and many Alaskans depend upon the ocean for subsistence harvests. These ecosystems are experiencing rapid climate change as evidenced by decreases in sea ice and increases in ocean temperatures. An ecosystem approach to management, which takes into account climate variability and change, is a primary means of addressing the management needs for Alaskan living marine resources.

A number of studies contribute to the understanding of Alaskan marine ecosystems. These studies include resource and oceanographic surveys that provide living marine resource abundance and biological and oceanographic condition information, biophysical moorings that elucidate conditions throughout the year, short-term projects focused on specific processes, and modeling studies that help tie together the various components and explain and predict ecosystem responses. All these components contribute to an understanding of how ecosystems function, enabling predictions of how some components will respond if there is, e.g., more or less sea ice, relatively warm or cold water, weak or strong winds. Examples include impact on winter-spawning flatfish recruitment through effects of advection in the eastern Bering Sea on transport to nursery areas and impact of ocean conditions on spatial distributions of living marine resources and niche partitioning between species. In 2008, the North Pacific Fishery Management Council reduced the Bering Sea pollock quota by about 30% from 2007 levels. Climate information supplied by NOAA indicating relatively warm ocean conditions contributed to this decision, in combination with recruitment and ecosystem data.

Coral Reef Management in an Era of Warming Oceans

David Kennedy – NOAA/NOS/Ocean and Coastal Resource Management

Coral reefs are among the most diverse ecosystems on the Earth and have a large impact on the world's economy through their contributions to seafood, tourism and coastal protection. However U.S. coral reefs are imperiled due to increasing thermal stress and changes in ocean chemistry. Increases in temperature are causing more frequent and widespread bleaching events in which corals release their symbiotic algae. While corals can recover from brief or mild stress, events of longer duration cause starvation and death. Reefs are deteriorating worldwide, with 2/3 of reefs already severely degraded. Much of this is due to thermal stress, bleaching and increased susceptibility to disease.

NOAA has produced a number of products to assist in warning coral reef managers of potential bleaching events via automated email alerts. These products include sea surface temperature (SST) data, SST anomalies, hotspots where SST is above the bleaching threshold, and a “degree heating week” product that accounts for accumulated thermal stress. NOAA, in association with outside partners, has also produced a Reef Manager’s Guide to Coral Bleaching which lists long term actions managers can take before bleaching occurs and short term actions to be taken during bleaching events. These products have helped pave the way for community-based early warning systems which derive from partnerships between NOAA, local scientists and managers, and the public.

Coral reefs are also susceptible to the changes in ocean chemistry caused by ocean acidification. The oceans absorb large portions of the anthropogenically produced CO_2 from the atmosphere. This is causing a decline in the pH of the ocean waters and a reduced availability of carbonate ions which are needed by corals to build their skeletons. A number of experiments have shown a decline in the rate of coral calcification with increasing levels of ocean acidity. Other activities supported by NOAA that could improve our understanding of how a changing climate affects reefs include carbonate chemistry monitoring and surveys, as well as preliminary satellite based models designed to track changes in surface ocean chemistry.

Ocean Acidification and its Potential Impacts on NOAA-Managed Living Marine Resources

Richard Feely – NOAA/OAR/Pacific Marine Environmental Laboratory

Over the past 200 years, the pH and CO_2 chemistry of the oceans have been changing because of the uptake of anthropogenic CO_2 by the oceans. When CO_2 reacts with seawater, the pH of the water decreases (hence the term ocean acidification) and the availability of carbonate ions is depleted. The pH of ocean surface waters has already fallen by about 0.11 units, from an average of about 8.21 to 8.10, since the beginning of the industrial revolution. Estimates of future atmospheric and oceanic CO_2 concentrations indicate that by the end of this century the surface ocean pH will likely decrease another 0.4 units, making it lower than it has been for more than 20 million years. The carbonate saturation depths have also shoaled towards the surface of the oceans due to the penetration of anthropogenic CO_2 into the oceans. High latitude regions may be some of the first to become undersaturated with respect to carbonate, while calcification rates in the tropics may decrease by 30% over the next century. A 2007 survey cruise found water undersaturated with respect to aragonite (a form of carbonate) in upwelled water along the continental shelf of western North America.

Changes in pH and carbonate chemistry may have serious impacts on marine ecosystems. Carbonate is critical to shell formation for marine organisms such as corals, shellfish, zooplankton, and some phytoplankton. Exposure to lower pH levels can cause decreased respiration rates, changes in blood chemistry, and changes in enzymatic activity. Results from laboratory, field, and modeling studies, as well as evidence from the geological record, indicate that marine ecosystems are susceptible to the increase in oceanic CO_2 and the corresponding decreases in pH. Studies examining the impacts of ocean acidification on marine organisms have been conducted on many scales, from aquaria to large scale mesocosm experiments. However, much of our present knowledge comes from abrupt CO_2/pH perturbation experiments with single species/strains, under short-term incubations, often with extreme pH changes. Therefore we know little about responses of genetically diverse populations, synergistic effects with other stress factors, physiological and micro-evolutionary adaptations, species replacements, and community to ecosystem responses. More research is needed to determine the temporal and spatial changes of the carbon system in the global oceans and their impacts on species and biological communities. This will enable a comprehensive characterization of the threat ocean acidification poses to marine ecosystems.

Breakout Sessions

Three breakout sessions, focused on topics and questions chosen to stimulate discussion around the important drivers for the workshop, generated much of the participant input during the workshop. For each breakout session, there were three breakout groups, all addressing the same topics and questions. Below are combined and condensed responses from the concurrent breakout groups for each of the breakout sessions and their respective questions. The responses in this section are relatively raw lists with specific answers to the questions. This information is provided here as it will be useful to those interested in specific issues. The overarching conclusions and recommendations resulting from the workshop, which were gleaned in large part from the breakout session discussions, are provided in the Summary section.

Breakout Session 1: The Implications of Climate Change for NOAA's LMR Portfolio

Question 1: What are the major climate change issues about which NOAA and its LMR management partners should be concerned?

Issues

- Physical/Chemical changes:
  - ocean properties (temperature, salinity, turbidity, nutrients, oxygen)
  - circulation, stratification, upwelling (changes to intensity and seasonal variability)
  - major climate cycles (e.g. ENSO, PDO, NAO, etc.)
  - storm tracks and intensity
  - frequency and magnitude of extreme events
  - wind patterns
  - cloudiness
- Loss of sea ice
  - loss of habitat
  - changes to stratification
  - changes in albedo
  - Arctic marine transportation, oil and gas development, fisheries development
- Sea level rise
  - changes in coastal habitat
  - saltwater intrusion
- Ocean acidification
- Altered freshwater systems (freshwater supply and quality)
  - precipitation timing, amount, and type (rain vs. snow)
  - freshwater temperatures
  - timing of freshwater delivery
  - allocation of freshwater
  - water quality (dissolved materials, sediment load)
- Other
  - climate change versus climate variability
  - unforeseen impacts

Responses

ocean productivity, distribution of organisms, migrations, transport, phenology, changes in community structure, species interactions and replacement, growth, reproduction, fitness, mortality, habitat impacts, unusual events

socioeconomic effects (fisheries, land use, water table, coastal erosion, tourism)

Question 2: Which LMR management processes need to be informed with climate change information? What are the temporal and spatial scales for these processes?

Processes:

Stock assessments for managed fish and protected species

Recovery plans for threatened and endangered species

Rebuilding plans for overexploited species

Regional Fishery Management Councils

Fishery Management Plans

Incidental Take authorizations for non-targeted species

Impacts on seafood safety and security

Ecosystem based management plans

Scales:

Information is routinely needed at annual or shorter time scales for management decisions (e.g., for total allowable catch decisions), whereas attribution between climate variability and climate change requires much longer time series.

Information is required for annual management decisions and long-term (10+ years) planning.

Different spatial and temporal scales are relevant depending upon the living marine resource being addressed.

Question 3: To what extent is climate information currently used in NOAA's LMR portfolio? What are the barriers (e.g., institutional, scientific, resource) to incorporating climate more fully in NOAA's LMR portfolio?

Use: Climate information is rarely applied in LMR management today. A few exceptions occur. These include:

Recovery planning for Pacific salmon

Total allowable catch for pollock

Ice seal listing determination

Coral management plans

Barriers:

Limited communication between climate and ecosystem communities

Disconnect between climate and living marine resource management communities - lack of understanding of the climate products needed or available

Inadequate incentives to facilitate collaboration between climate and ecosystem scientists

Insufficient understanding of how climate changes impact LMRs

Limited opportunities to support multidisciplinary activities as a single project between Line Offices

Lack of committed funding for long-term joint projects

Observing infrastructure – lack of synchronicity between physical, chemical, and biological observations

Gaps in environmental baselines

Time- and space-scale differences between management needs and climate predictions
Lack of an effective ecosystem framework within which to include climate information for LMR management
Some LMR managers see insufficient benefit in incorporating climate – the uncertainties are deemed too large such that there is not appreciable value added to LMR forecasts
Deficient data management and integration procedures and resources to effectively incorporate climate information

Question 4: Can priority be assigned to any of these issues and/or processes in the specific context of NOAA's LMR portfolio? If so, which are of greatest importance in terms of timeliness and impact?

Expand integrated climate and ecosystem observations
Develop regional and local scale climate predictions and validate with observations
Prioritize information needs based on impacts (i.e., based on immediacy of impact, degree of impact, and value of impacted resource)

Breakout Session 2: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

Question 1: What are the key decision support resources, products, tools and capabilities needed to address climate and LMR management?

Observations (physical, chemical, biological data) are needed at the time and space scales pertinent to the ecosystem.
Ocean condition forecasts are required. For these forecasts to be used, NOAA needs to develop and demonstrate their benefit to LMR stock assessments.
Longer term (10-30 yrs) ocean condition projections with probabilities need to be developed.
Uncertainty, confidence, or probability of occurrence should be provided with any predictions.
Climate and ecosystem response scenarios based upon hypotheses that can be tested (conceptual models to "what if" scenarios) must be developed.
Coupled climate-ecosystem models are necessary.
Regional environmental forecasts and reanalysis, downscaled from global climate models, are required to support long term projections and short term predictions.
3-10 yr projections are needed to be useful for fishermen's business perspective, i.e., the timescale for which the fishing industry makes major industry investment decisions.
Critical environmental thresholds have to be defined.
An environmental early warning system across relevant time scales is requisite.
Ecological indicators should be developed in concert with modelers and managers. Include these and other required data in an integrated system of observations.
Probabilistic predictions of sea ice extent and remote sensing products are needed.
Predictive models of economic and health impacts need to be developed.
Models are required that integrate regional observations to better understand climate ecosystem impacts at management levels.
Information ought to be presented in formats (e.g., risk maps, red light/green light, numbers, probabilities) tailored to the users.

Question 2: What are the associated climate and living marine resource science issues that NOAA should address, and the current status of associated observations, modeling, process studies, impacts and adaptation research and assessment (e.g., well covered, in development, non-existent)?

- Forecasting physical/chemical changes – The general trend is predictable (useful in the long-term), but interannual and decadal variability is difficult to predict.
- Data needs and availability issues include:
  - Quality of baseline information is species and area dependent – information quality ranges from very good to very poor.
  - Paleo data is very non-uniform in its spatial coverage. There are some high quality datasets, including down to decadal timescales.
  - Biological parameters are underrepresented in large scale observing systems.
  - Satellite data – ocean sensors need to be maintained. Due to an aging infrastructure there is a high risk of data gaps.
- Little is known about abrupt climate change and its impacts. This needs development.
- Key issues to be resolved with respect to ecosystem responses to climate drivers include:
  - Food web alterations
  - Thresholds
  - Resiliency of different ecosystems (e.g., influences of diversity, anthropogenic footprint, fishing)
  - Definition of healthy populations - how to define when a population is impacted by climate, attribution of ecosystem changes to specific climate drivers
  - Species specific adaptability
- Socioeconomic impacts must be addressed and require substantial development.

Question 3: What ecosystem information is needed by the climate science community to assess and predict climate feedbacks from human-induced alterations (e.g., ocean acidification, iron fertilization)?

- Large anomalies (shifts) in long term ecosystem time series may provide guidance to climate scientists to identify key events.
- Determination of biogenic feedbacks (e.g., organic carbon ballasting, increased dimethylsulfide (DMS) production from coccolithophores).
- How are biofeedbacks affected by rapid vs. gradual climate change?
- How will carbon fluxes be impacted by changes in ecosystems, primary productivity, reef building, albedo, and coastal inundation?
- Determination of what fraction of primary production is deposited in the sediments.

<u>Breakout Session 3: Future Directions and Next Steps</u>

Question 1: How should NOAA's climate and LMR communities work together to address major needs and priorities identified on the first day?

- Have a framework of the major management questions to be addressed – prioritization of focused problems.

Create a forum to facilitate exchange between LMR managers and scientists, and climate scientists to better define their needs and capabilities.

Consider alternative approaches to funding collaborative research including: establishing and sustaining regional climate and LMR programs (explore cross-region synergy); and supporting proposal driven collaborations (broadly announce opportunities so bring in all interested parties and ideas).

Conduct integrated activities where appropriate (e.g., enhance physical studies with more ecosystem variables and vice versa).

Leverage existing capabilities of programs and expertise of people so efficiency is maximized.

Question 2: Which institutions/programs need to be involved to implement these actions?

Regionally focused and steered programs should be linked through a national ecosystem and climate program which has long-term, dedicated support.

Social and economic science sectors must be included.

Regional stakeholders must be involved from the beginning through regional teams.

Offices and programs whose mission is to observe, monitor, or model climate should be consulted with and informed of regional LMR priorities.

Take advantage of existing capabilities – NOAA laboratories, Cooperative institutes, the NOAA Regional Integrated Sciences and Assessments (RISA) program, academia, Sea Grant, and other federal agencies

Question 3: What are some short- and long-term steps that can be taken?

Develop regionally specific lists from LMR managers of what they need.

Develop lists of climate and ecosystem capabilities.

Evaluate adequacy of current observational systems.

Submit regular reports to regional Fishery Management Councils (FMCs) and get feedback.

Establish rotational assignments between climate and LMR programs. Have shared post docs.

Support regular, regional workshops.

Encourage cooperation with other national and international programs (within and outside of NOAA).

Develop a long term strategic plan and funding requirements.

Support an emphasis on climate applications (e.g., observations, monitoring, projections, predictions) in support of ecosystem approaches to management.

Standardize assessment and monitoring methodologies to permit intercomparisons.

Develop guidelines on how to incorporate climate into LMR management.

Consolidate and reconcile climate information from various sources into a central source.

Develop cross-training for climate and LMR personnel so they are aware of each others capabilities, needs, and limitations.

Develop climate scenarios for regional LMR issues.

Develop targeted LMR climate information products (including probabilities of predictions).

Release products early so they can be evaluated.

Develop approaches for climate predictions and projections relevant to regional and local scales.

Develop a NOAA climate/LMR website with names, pictures, presentations, etc. to help make connections.
Provide seed money, from existing funds, to begin to answer some of the questions identified.
Identify a few regions that would serve as mini-laboratories that provide a method to assess the reliability of ecosystem indicators as proxies for complex mechanisms.

Summary

Conclusions

- **NOAA has unique capabilities and responsibilities with regard to climate and living marine resources.** NOAA is unique in its mandates and abilities to provide observations and predictions of climate and to manage LMRs. The case studies presented demonstrated capabilities focused on climate prediction and ecosystem impacts, with some work on socioeconomic adaptation.

- **It is essential for NOAA's climate projections and scenarios to span the full range of possibilities and associated impacts and provide measures of probability.** There is a large range of uncertainty in the physical climate drivers. Ecological responses further magnify the uncertainty. For LMR managers to make decisions on the best course of action for the resources they manage, they need to know the timescales, probabilities and bounds within which their decisions are being made.

- **A mix of standard and custom products will be required.** There are a wide variety of climate-LMR problems and issues. Some can be addressed with standardized products while others will require customized research and development of products.

- **Climate quality environmental baselines are needed.** There are legal and scientific reasons to establish environmental baselines with which to judge the implications of climate impacts on LMRs. Without adequate baselines, there are no standards for comparing current and future conditions.

- **The workshop initiated an important dialog.** NOAA's climate and LMR scientists and managers from around the country were brought together for the workshop. Many of the people had never met. There is significant benefit in raising awareness of others' expertise, activities, capabilities, products, and future goals. A basic, yet valuable, result of the workshop was the initiation of a dialog between climate and LMR scientists and managers to inform one another of their capabilities and needs.

Recommendations

- **NOAA must develop predictions and adaptation plans for climate impacts on LMRs.** The legal and public policy implications for climate impacts on LMRs regulated by NOAA place the agency at the forefront of impacts and adaptation. Due to its unique mandates for management of living marine resources, NOAA is responsible for the development of predictions and adaptation plans for climate impacts on LMRs.

- **Make "best available climate information" available through a National Climate Service.** Most NOAA regional climate impact studies to date are the products of individuals or groups and do not necessarily use consistently obtained climate information. This approach takes advantage of the innovation at the regional level, but increases the risk that NOAA does not have a clear, coordinated definition of "best available science". A National Climate Service should provide standardized observations and predictions of coastal and marine physical and chemical conditions to support LMR management.

- **Improve utilization of what is known and available.** There are tremendous capabilities distributed across NOAA, its partners, and other collaborators to provide meaningful climate services relevant to management requirements for LMRs. An inventory of relevant NOAA climate data, products and services useful to LMR scientists and managers should be conducted. NOAA must ensure that available data and information are identified and made easily available. While NOAA capabilities regarding climate impacts on LMRs are underfunded, much can be done with current resources, including targeted increases in the understanding of climate impacts on LMRs.

- **Establish regional climate and LMR programs.** NOAA should establish and maintain regional climate and LMR research and management programs guided by regional collaboration teams that include climate, ocean, LMR, social, and economic scientists, LMR managers and regulators, and regional stakeholders. Regional efforts must be coordinated at a national scale to ensure that approaches between regions are consistent to the extent possible and priorities are addressed with minimal redundancy.

- **Establish a program for short-term (up to 5 year) integrated climate and LMR projects.** Sustained funding for regional efforts should be balanced by proposal based funding to enable collaborations, enhance regional efforts, target broader scale questions, and maintain flexibility to address emerging issues.

- **Integrate climate and ecosystem observations.** Integrated climate and ecosystem observations are necessary to document ecosystem responses to climate changes. Presently many ecosystem observations are made without adequate climate observations and many climate observations are made without concurrent ecosystem observations. NOAA should ensure that climate and LMR measurements are coordinated when possible.

- **Develop and refine regional forecasts.** Regional environmental forecasts, downscaled from global climate models, should be developed in support of long term projections and short term predictions. Appropriate time horizons and spatial scales need to be defined depending upon the LMR and the question being addressed.

- **Establish an Endangered Species Act climate working group.** NOAA should establish guidelines for the incorporation of climate impacts into NOAA's mandated LMR management processes. As a first step, NOAA should convene a working group to develop standard operating procedures for incorporating climate information into Endangered Species Act actions.

- **Conduct regular climate – LMR workshops.** To facilitate communication between climate and LMR scientists and managers it would be beneficial to establish annual or alternate year climate – LMR workshops. These workshops would serve as a forum for the presentation of recent advances within the field of climate impacts on LMRs. They would also enhance the exchange of ideas between disciplines and regions, thereby furthering the development of management tools and products.

Appendix 1 – Workshop Agenda

NOAA Climate and Living Marine Resources Workshop
May 14-15, 2008
Pacific Marine Environmental Laboratory, Seattle, Washington

<u>May 14, 2008</u>

Plenary Session: Climate and Living Marine Resource Management (LMR) in NOAA

8:30 am	Welcome, Introductions, Context and Workshop Overview Moderator: Ned Cyr (Eddie Bernard, Steve Murawski, Chet Koblinsky)
9:10 am	An Overview of NOAA's Living Marine Resource Management Responsibilities (Steve Murawski)
9:30 am	Climate Change and Resource Management: The Legal Perspective (Ruth Ann Lowery)
9:50 am	NOAA's Climate Program and Service Directions (Chet Koblinsky)
10:20 am	Charge to Working Groups (Ned Cyr)
10:30 am	Break

Breakout Session 1: The Implications of Climate Change for NOAA's LMR Portfolio

10:40 am	Working Group Discussions

Discussion Questions:

1) What are the major climate change issues about which NOAA and its LMR management partners should be concerned?

2) Which LMR management processes need to be informed with climate change information? What are the temporal and spatial scales for these processes?

3) To what extent is climate information currently used in NOAA's LMR portfolio? What are the barriers (e.g., institutional, scientific, resource) to incorporating climate more fully in NOAA's LMR portfolio?

4) Can priority be assigned to any of these issues and/or processes in the specific context of NOAA's LMR portfolio? If so, which are of greatest importance in terms of timeliness and impact?

12:00 noon Lunch and Guest Presentation: Climate considerations in the management of anadromous fishes in the Pacific Northwest (Nathan Mantua, University of Washington)

Plenary Session: The Implications of Climate Change for NOAA's LMR Portfolio

1:15 pm Breakout Groups Report Out, Followed by Plenary Discussion

2:15 pm Bringing climate and ecosystem science together to address management needs (Steve Murawski)

2:45 pm Break

Breakout Session 2: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

3:00 pm Working Group Discussions

Discussion Questions:

1) What are the key decision support resources, products, tools and capabilities needed to address climate and LMR management?

2) What are the associated climate and living marine resource science issues that NOAA should address, and the current status of associated observations, modeling, process studies, impacts and adaptation research and assessment (well covered, in development, non-existent)?

3) What ecosystem information is needed by the climate science community to assess and predict climate feedbacks from human-induced alterations (e.g., ocean acidification, iron fertilization)?

Plenary Session: Key Decision Support Tool and Science Needs for Integrating Climate in LMR Management

4:40 pm Breakout Groups Report Out, Followed by Plenary Discussion

6:00 pm Adjourn

May 15, 2008

Plenary Session: Presentation and discussion of case studies for the successful integration of climate and ecosystem science for LMR management

8:30 am	Introduction to Day Two of the Workshop (Moderator: Mete Uz)
8:40 am	Remarks from the NMFS Perspective (Jim Balsiger)
8:50 am	Climate considerations in North Pacific Fisheries Management (Mike Sigler/Phyllis Stabeno)
9:20 am	Coral reef management in an era of warming oceans (David Kennedy)
9:50 am	Discussion
10:00 am	Break

Breakout Session 3: Future Directions and Next Steps

10:10 am	Working Group Discussions

Discussion Questions:

1) How should NOAA's climate and LMR communities work together to address major needs and priorities identified on the first day?

2) Which institutions/programs need to be involved to implement these actions?

3) What are some short- and long-term steps that can be taken?

Plenary Session: Future Directions and Next Steps

12:00 noon	Breakout groups report out, followed by discussion
1:00 pm	Lunch and Presentation: Ocean acidification and its potential impacts on NOAA-managed LMRs (Richard Feely)
2:15 pm	Discussion: Where do we go from here? Linking climate and LMR management in NOAA (Moderator: Steve Murawski)
4:00 pm	Adjourn

Appendix 2 – List of Participants

(* denotes Organizing Committee member)

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