**52nd Meeting of the NOAA Science Advisory Board**
**Washington, D.C.**
**16-17 April, 2015**

**Location:** **Washington Marriott Wardman Park**
**Washington I, Exhibition Level**
**2660 Woodley Rd. NW**
**Washington, D.C. 20008**
http://www.marriott.com/hotels/travel/wasdt-washington-marriott-wardman-park/

Presentations for this meeting have been posted on the Science Advisory Board (SAB) website: http://www.sab.noaa.gov/Meetings/2015/March/April_16-17_2015.html

**SAB members in attendance:**
Ms. P. Lynn Scarlett, Managing Director for Public Policy, The Nature Conservancy (Chair); ; Dr. Michael Donahue, Vice President, Water Resources and Environmental Services, URS Corporation; Dr. Robert Hicks, Professor of Economics, College of William and Mary; Dr. Jeremy Jackson, Senior Scientist Emeritus, Smithsonian Institution; Dr. Peter Kareiva, Chief Scientist and Director of Science, The Nature Conservancy; Dr. David M. Lodge, Professor, Environmental Change Initiative, University of Notre Dame; Dr. Jennifer A. Logan, Retired (Harvard University);; Ms. Jean May- Brett, Retired (STEM Partnership Coordinator, Louisiana Department of Education); Dr. Stephen Polasky, Professor, University of Minnesota; and Mr. Robert S. Winokur, Retired (NOAA, Navy).

**NOAA senior management and Line Office representatives in attendance:**
Dr. Kathryn Sullivan, Under Secretary of Commerce for Oceans and Atmosphere; Dr. Rick Spinrad, NOAA Chief Scientist; Dr. Holly Bamford, Acting Assistant Secretary for Conservation and Management; Ms. Mary Erickson, Director, National Centers for Coastal Ocean Science; Dr. Steven Fine, Deputy Assistant Administrator, NOAA Office of Oceanic and Atmospheric Research; Dr. Ming Ji, Chief Scientist, NOAA National Weather Service; Dr. Ned Cyr, NOAA National Marine Fisheries Service; Dr. Patricia Montanio, Assistant Administrator, Program, Planning and Integration; Dr. Stephen Volz, Assistant Administrator, National Environmental Satellite and Data Information Service; and RADM David Score, Director, Office of Marine and Aircraft Operations

**Staff for the Science Advisory Board in attendance:** Dr. Cynthia J. Decker, Executive Director; Dr. Bridget Seegers; and Mary Anne Whitcomb.

## Thursday, 16 April

### Opening Statement of the Chair and SAB Consent Calendar
Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

Lynn Scarlett welcomed everyone to the meeting. Ms. Scarlett asked for acceptance of the items on the consent calendar: November 2014 and February 2015 minutes and Working Group status reports; these items were accepted.

### NOAA Update
Kathryn Sullivan, Under Secretary of Commerce for Oceans and Atmosphere
Dr. Sullivan welcomed everyone to the meeting.

Summary

At this meeting NOAA will present a response to the SAB report on Coastal Habitat Restoration. We have a full leadership team as of March 17, when VADM Manson Brown was confirmed by voice vote of the Senate as our Assistant Secretary for Environmental Observation and Prediction. Manson Brown will play a major role driving the Administration's and NOAA's priorities for weather and water services, climate sciences as well as the agency's integrated mapping and Earth-observing capabilities. Other leadership Changes include Zach Goldstein as the Chief Information Officer; Craig McLean as the Assistant Administrator of the Office of Oceanic and Atmospheric Research and Cynthia Decker as the NOAA scientific integrity office.

The FY 16 President's budget is structured to target the four NOAA priorities: make communities more resilient; invest in observational infrastructure; evolve the weather services and achieve organizational excellence. There are numerous increases requested related to resilience; creating an investment strategy in related activities where the whole is greater than the sum of the parts. The largest increase is a $45M request in coastal resilience grants.

The budget request also supports priorities of Department of Commerce and national priorities including combating illegal fisheries internationally and providing tools to plan for the future as outlined in the President's Climate Action Plan and streamlining permitting to enable sustainable economic activity. NOAA has been active on the Hill; there have been 299 Hill briefings since January 1, 2015.

Research Portfolio

The Chief Scientist's office under Rick Spinrad's leadership is on a fast track to releasing a Strategic Research Guidance Memorandum which will sharply focus NOAA's R&D efforts on its four priorities. A second focus is on transitioning research to applications, operations and other uses, what we are now calling "R2X" which focuses on accelerating transition of research.

A third facet in focusing NOAA's research enterprise to be mission-optimized is to revisit our Cooperative Institute partnerships to meet 21$^{st}$ century needs; we are calling this "CI-21.". CI- 21 looks at how relevant the Cis are to NOAA; the discussion at last fall's SAB meeting was an integral input into CI-21 development. The fourth facet of NOAA's research enterprise to be discussed today is Publications Access to Research Results or PARR. In 2014 OSTP issued direction on increasing public accessibility of publications and digital data produced by federal researchers or by recipients of federal funds. NOAA has finalized its PARR plan and it will go into force in the first quarter of 2016.

Resilience-Science Advances

Atmospheric rivers are streams of high water vapor that can bring heavy rains to the West Coast in December-March. With drought in Southwest U.S, it has become more important to understand and predict precipitation associated with atmospheric rivers. NOAA completed a research mission in January-March 2015 to study these phenomena with a goal to improve forecasting and forecasting and outlook products for farmers, reservoir operators and others.

NOAA has developed a global dynamical model called HiFLOR able to simulate and predict category 4-5 hurricanes. This is the first time that a global general circulation model has successfully reproduced the observed year-by-year variations in category 4 and 5 hurricanes; these results highlight potential skill of HiFLOR for subseasonal and seasonal prediction of intense hurricanes.

CyAN is a new cyanobacteria assessment network that involves NOAA, the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGD) and will use ocean color to develop an early warning indicator for toxic and nuisance algal blooms in freshwater systems. This project will yield an improved understanding of the

environmental causes and health impacts of cyanobacteria and phytoplankton blooms in the United States.

Healthy Oceans

Despite strong management and sustainability of U.S. fisheries, the assault on our global oceans by the Illegal Unreported and Unregulated (IUU) activities undermines out stewardship investments and the profitability of legal, law abiding seafood industries worldwide. On March15, 2015, the IUU fishing task force released its action plan that identifies the aggressive steps that federal agencies will take both domestically and internationally to implement the recommendations the Task Force made in December 2014 to protect the U.S. reputation as a leader in sustainable fishing and that fish products are what they are advertised to be. In February 2015 NOAA submitted a Congressionally-mandated biennial report identifying nations whose fishing vessels were engaged in IUU fishing in 2013 or 2014.

The final rule for expansion and regulatory changes for the Gulf of Farallones and Cordell Bank National Marine Sanctuaries were published in the Federal Register on March 12. The expansion of the sanctuaries will provide comprehensive management and protection of the area's resources and habitats, while facilitating uses compatible with this resources.

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R2X Accomplishments

NOAA's Meteorological Assimilation Data Ingest System (MADIS), developed by ESRL/GSD, and was successfully transitioned to NWS operations in January 2015. MADIS is the front end that lets NOAA ingest data from international, federal, state, and local agencies; universities; volunteer networks and private sector partners to create a finer density and higher quality NOAA global observational database and delivery system.

NOAA's Air Resources Laboratory model development team provided the first major chemical modeling upgrade since 2007 to NOAA's National Air Quality Forecasting capability. NOAA's air quality forecasting informs state and local air quality forecasts and alerts, enabling people and communities to take actions that can reduce the severity of the episode. These model upgrades were implemented by NOAA's National Centers for Environmental Prediction into operations in January 2015.

In December 2014, the first real-time nowcast/forecast hydrodynamic model in the Great Lakes using the Finite Volume Coastal Ocean Model (FVCOM) was developed for Lake Eric and successfully transitioned to the National Ocean Service for implementation into operations.

Observations

In February there was a successful launch of the DSCOVR satellite, which will maintain the nation's real–time solar wind monitoring capabilities which are critical to the accuracy and lead time of NOAA's space weather alerts and forecasts. Without timely and accurate warnings, space weather events like geomagnetic storms caused by changes in solar wind have the potential to disrupt nearly every major public infrastructure system, including power grids, telecommunications, aviation and GPS.

NOAA, NASA, and the USGS submitted the work plan to the National Academy of Sciences for the next Decadal Survey for Earth Science and Applications. Work is just getting underway now and the survey will take 24 months to complete.

Organizational Excellence: Education

Citizen science: NOAA installed a rain gauge, part of the Community Collaborative Rain, Hail and Snow citizen science network, in the First Lady's garden at the White House. The White House decided to participate in this program, in partnership with the National Park Service and NOAA, to

support the Federal Community of Practice for Crowdsourcing and Citizen Science, which is part of its Open Government initiative.
NOAA is revising its Education Strategic Plan as specified in the America COMPETES Act. Based on NOAA's mission, scientific expertise, and the future needs of our society, the draft plan includes five education goals: science-informed society; conservation and stewardship; safety and preparedness; future workforce; and organizational excellence. The draft plan has been out for public comment; the final plan will be posted on the Education website.

Dr. Sullivan highlighted selected awards and recognition provided to NOAA scientists.

**NOAA Chief Scientist Update**
Richard Spinrad, NOAA Chief Scientist

Summary
Two goals of the presentations are to give an update on the role of NOAA's Chief Scientist and talk about specific areas of focus, which include strategic research guidance, research to application/operations/products (R2X) and NOAA's largest academic interaction; the Cooperative Institutes (CIs).

The role of the Chief Scientist includes working across line offices and with partners to increase and institutionalize the effectiveness of NOAA Research. Also, the Chief Scientist can look across the research portfolio for logic and goals. The Chief Scientist looks to add value and impact to the research portfolio by considering potential end-users. The Chief Scientist can look at NOAA research being done internally and externally and consider the strategic or tactical impact of the research portfolio.

Currently there is a large focus on internal strategic efforts, which include the development of a Strategic Research Guidance Memorandum (SRGM), R2X, a new role for the SAB, and reworking NOAA's relationships with the CIs through an effort called Cooperative Institutes for the 21st Century (CI21).

There is a need for NOAA to have a strategic approach to research and therefore the Office of the Chief Scientist is developing the SRGM. There is already an Office of Management and Budget and Office of Science and Technology Policy (OMB/OSTP) annual guidance memo on science and technology priorities, but it does not have granularity needed for agencies and the timing is too late. The SRGM will be a set of clearly expressed guiding principles for building NOAA's research portfolio considering NOAA's current research portfolio, mission needs, priorities, capabilities, roles, responsibilities and partners. The SRGM will be a critical piece of annually generated doctrine and its research priorities will be reflected in budget guidance. The SRGM is meant for anyone involved in NOAA and it will establish priorities with in NOAA.
The Framework of principles is:
- Mission alignment
- Research balance (applied vs. fundamental research, investment between ocean, weather, climate, fisheries)
- Workforce Excellence including career paths for research scientist.
- Scientific integrity
- Facilities and infrastructure.
- Partnerships. Balance between extramural an intramural.
- Transitioning R&D
- Accountability (tolerate some risks)

A piece of SRGM will focus on the acceleration of R2X. Historically projects have difficulty stepping from development to deployment and therefore demonstration (aka transition) is the new focus. There are successful R2X examples from weather operations. The tools are fantastic, but in each of the cases it took about a decade to move from development to operations. The question is can a focused effort accelerate the R2X timeline. NOAA has taken action to accelerate R2X, which includes hosting an R2X Summit in February to discuss challenges, lessons learned, and best practices. In April 2015 NOAA will have an R2X "Table Top" exercise to design and develop a process for identifying best candidates for accelerating transition and optimizing transition success.
Another current Chief Scientist priority is CI21, which came out of the July 2014 SAB meeting and it is fundamentally a chance to ask what/why/how is cooperative research best established, conducted, and assessed to meet NOAA's portfolio of mission needs. CI21 looks at variety of focus areas and how the CIs have dealt with them in the past and how the aspirational future might be better/different. Workforce development is critical for successful CIs. Mission alignment/cadence might require rethinking the length of CI agreements. The NOAA expectations of CIs do not always match the implementation partially because of the poor communication of expectations. CIs currently do not have much private sector involvement, but this might be a good option in the future. The next step with CI21 is a June 17 summit that will get together CI directors, partners, line office representatives, etc. to have a broad collaborative research discussion. Finding and recommendations will be output of the summit. This will evolve into the guiding conditions that will be built into the next round of CI agreements.

Dr. Spinrad requested the input from the SAB on scope-granularity of the research guidance, the best approach to have the most meaningful impact, and how to best identify and engagement stakeholders.

Discussion

Mr. Robert Winokur commended the SRGM and asked about the timeframe to be addressed by the SRGM and for some clarification on the relationship with the private sector and the leveraging of industry resources.
Dr. Spinrad responded that the 1-7 year context is the focus of SRGM and R2X. It is important to have short timelines for bringing priorities to the Hill. Dr. Spinrad wanted to be clear that private sector is not just industry.

Dr. Peter Karieva wondered if within NOAA leadership and scientists there is some sense of which CIs are functioning best.
Dr. Spinrad replied that they do not want to make all the CIs the same, but want to maximize what NOAA gets from the partnerships and also have a the ability to say what the institution and NOAA are getting out of CI.
Dr. Sullivan added there is a need to define NOAA's logic model for CIs and for shape of NOAA's research investment curve. If the agency does not do this, then other people do it for the agency. NOAA can make a strong case for the CIs and its research investments but has never come forward with that unified rationale. Instead each program fends for itself and this has pushed NOAA into shorter term research.

Mike Donohue appreciated the mention of the private sector involvement in the future of CIs and asked if there would be a role for the SAB at the June CI summit. Dr. Spinrad said definitely the SAB would be involved in the CI-21 Summit.

**NOAA Response to the SAB Coastal Habitat Restoration Report**
Buck Sutter, Director, NMFS Office of Habitat Conservation

Summary

Response to recommendations grouped by three themes: Restoration for Fisheries and Non-Fisheries Objectives (recommendations2-6); Availability of Monitoring and Evaluation Information (recommendations 1,7); and Leveraging our Capabilities to Maximize our Impact on Coastal Restoration (recommendations 8,9,10)

Habitat conservation is a cross-NOAA mission with a diversity of drivers that requires some diversity in programs. Over the last few years, NOAA has developed a Habitat Blueprint that provides a framework for integration. Guiding principles include prioritizing resources, making decisions in an ecosystem context, fostering and leveraging partnerships and improving delivery of habitat services.

Restoration for Fisheries and Non-Fisheries Objectives
NOAA agrees that our restoration mandates extend beyond fisheries mandates and that NOAA should focus on demonstrating the broad outcomes associated with restoration for fisheries and non-fisheries benefits. Efforts are underway as part of NOAA's Habitat Blueprint to identify habitat conservation projects that can achieve multiple objectives and leverage resources from across NOAA and its partners. The Russian River Habitat Focus Area was provided as an example of such a project which, in addition to rebuilding endangered Coho and threatened Chinook and steelhead stocks, accomplishes other objectives including improving frost, rainfall and river forecasts and increasing community resiliency to flooding damage.

Availability of Monitoring and Evaluation Information
NOAA agrees with the recommendation on the need get information out in a timely manner. NOAA has made a significant investment in the Restoration and Conservation Database that houses information on all habitat restoration projects overseen by the NOAA Restoration Center; the Restoration Atlas is the public-facing part of the database. While the SAB suggested that NOAA should make individual project monitoring information available, that is not a practical suggestion given the database structure. NOAA is moving forward on other ways to make information more accessible; as NOAA operationalizes the monitoring framework we will determine how to summarize monitoring information and determine how to make it accessible to the public.

Leveraging Capability to Maximize Impact on Coastal Restoration
NOAA agrees that we are in a strong position to leverage the funds and capabilities of others to achieve the multiple benefits that restoration can provide. We agree that ensuring that NOAA's influence on "indirect" projects should be valued and highlighted but we are still determining if there is anything more explicit that we need to do to highlight that influence in strategic or implementation plans.
The NOAA Habitat Conservation team is a way to bring together people in Washington and people on the ground doing the work together. This body looks at place-based collaborative conservation, habitat policy, habitat science, and strategic partnerships. Buck Sutter gave an example of work in Puget

Sound as a coordinated investment strategy that made a difference for farmers, and provides a better resource to improve numbers of Chinook salmon. The Habitat Blueprint focuses on both appropriated funds as well as funding from others to make a larger benefit.

Discussion

Denise Reed, ESMWG and report co-author, commented that what she sees in the response shows that there is work being done across on this issue. The NOAA habitat conservation team work is a good effort and identification of impacts on investment was what the ESMWG was thinking about rather than return on investment. Dr. Reed noted that the ESMWG found that the principles for restoration were well laid out; the group identified the idea of working with other agencies to make sure NOAA expertise is valued and utilized. The habitat conservation team can be either be seen as an external center of excellence that other agencies could use or it can be just an internal center of excellence. We also want to plan habitat conservation in an ecosystem context but we fail to report on ecosystem consequences-how do we demonstrate the ecosystem benefits of these restoration?

Holly Bamford thanked the ESMWG for the report; the review forced NOAA to look beyond fisheries in habitat restoration and out of that came the habitat restoration team. The team is still considered more internal but can be more external in the future. NOAA is looking at both leveraging NOAA resources and partners' resources. The Center of Excellence concept is adaptable and we hope it can include natural infrastructure including sea level rise and storm.

Buck Sutter said the team brings in expertise from outside of NOAA and this works well in the regions. Four years ago there was a question of whether habitat was worth the investment as it wasn't well connected. Telling the story of how a functional ecosystem is so important; and bringing in other partners is the way we are going to solve problems.

Steve Polasky asked when you expand things and become more holistic will it be harder to state your objective and return on investment. Buck Sutter said the objectives are specific and focused on that area on a place-based scale. As we mature the process into a place-based process we could use objectives from similar areas—for example, developed for a coral reef elsewhere. We are on a second year of a five year process.

Peter Kareiva said for some of the bigger scale NOAA projects in the Gulf, NOAA tracks job creation; reporting on jobs seems like a good idea. Buck Sutter responded that for the American Recovery and Reinvestment Act (ARRA) funding they received, NOAA tracked job creation; the challenge was that some of the jobs were short-term; however healthy fisheries create longer-term outcomes and jobs.

Kathy Sullivan said if you do the Russian River restorations correctly, there are jobs with doing that but the other side of the issue is that with the value of wineries what value of job loss did you avert? Buck Sutter said the Endangered Species Act is a powerful law and their partner is the Sonoma County water district; they will take a look at Dr. Sullivan's points.

Lynn Scarlett commented that she agrees with Dr. Sullivan that a consideration about objectives and outcomes is thinking about the avoided costs and damages as the result of these efforts
Michael Donahue asked if the data base structure can be altered to allow the monitoring information to be shared. Buck Sutter said the project-specific components are part of the data base structure they are trying to move to and the response used perhaps a poor choice of words.

**Strategy Session**

**Panel Discussion with Invited Speakers**
Moderator Stephen Polasky, Chair SAB Strategy Synthesis Subcommittee
Granger Morgan, Carnegie-Mellon University
Veerabhadran Ramanathan, Scripps Institution of Oceanography (via webinar)

Summary

Dr. Sullivan gave opening remarks for the strategy session stating that the the goal was provocative conversation and the eventual arrival at a constructive way forward.

Opening Statements
Veerabhadran Ramanathan stated that currently there is not an observing system that can capture all the potentially important variables keeping in mind that some important variables are not even known yet. There is a need to anticipate what may be important. A key thing to remember is weather is driven on the background of natural circulation and that background is changing. There is a need for integrated measurements and therefore a need to miniaturize them, because that helps make the instruments available to a larger community. Dr. Ramanathan stated that an important tool for the future is unmanned aerial vehicles (UAVs). It is important to capture the 3D structure of data and UAVs can do that. It is a limitation of satellites that much of the observations are flat and therefore the complexity is simplified. UAVs will be particularly good at hurricane measurements and will be valuable for a long list of important turbulent flux measurements such as moisture from the ocean and methane measurements from permafrost and fracking and the small local measurements must be matched to global measurements.
He pointed out that everyone wants to launch the next best instrument, but it is of utmost importance that traditional measurements continue to be made until the cross calibration of instruments is ensured.

Granger Morgan touched on three big topics: 1) resilience 2) communication of uncertainty 3) whether NOAA should invest in scenario development techniques. Dr. Morgan pointed out that built infrastructure, including power systems, are vulnerable to climate change, storm events, flooding ice storms, winds in addition to low frequency events like tsunamis, earthquakes, and volcanism. Good decisions need good data on the past and predictions for the future to help ensure resilience. Dr. Morgan acknowledged that there is a need to increase probability forecasting for variables such as wind velocity and flooding. Other big issues that need more much work include refining the planetary albedo measurements, understanding changes in ocean thermal structure, and ocean acidification. Many of these issues require the maintenance of times series with quality control. NOAA could develop instruments and the tools necessary for validating and calibrating the continuous time series and NOAA could take the lead in an interagency group. He acknowledged that scenario techniques can be useful if the point is simply to explore possibilities. However, it is important to keep in mind that scenarios give a false sense of the confidence of outcomes as more details are added. Therefore, it is incredibly important to use the results very carefully.

Discussion

Dr. Ramanathan added one major revolution is the miniaturization of instruments and the integrated observing systems. However, the observing systems have not fully exploited the new advantages of the AUVs, such as swarming instruments through a storm measuring all the important variables. The technology already exists and there is a need to launch a campaign.

It was pointed out that NOAA has historically developed some technologies that have eventually been adapted by the masses through funding by OAR. However, technology development is not currently part of a NOAA wide strategic approach to achieving its mission.

Past inter-agency successes were mentioned and it was stated that the current global issues demonstrate a need for strong long-term relationships between agencies not just occasional campaigns.

A series of comments were made on sampling design, the need for long term data sets and ways to adjust sampling design during events that combine optical, chemical, and biological monitoring. Adaptive sampling for environmental intelligence should be integrated with long term data to maximize the information in the data. There is a need to measure and understand the events as they occur and it is important to have an ability to respond to the unexpected.

Dr. Morgan returned to the needs of decision makers for probabilistic predictions for wind velocity, ice storms, and flooding. People use probabilistic precipitation forecast pretty well. NOAA could look to develop services and predictions with probabilistic vales and that would help end-users in a range of to make management and investment decisions.

Responses included that fundamentally NOAA makes forecasts based on probabilities and the seemingly deterministic forecasts reported may not be the best choice for all end-users as different users have different risk tolerances. Probabilistic forecasts can be good, but also complicated with time, space, and event details. The HAB forecasting effort for the great lakes tried probabilistic products and found there seems to be strength in communicating with thresholds and general warnings.

It was stated if NOAA wants to create an improved observing system there is a need to understand the human dimension. It was acknowledged that human health is an area where the integrated system would help greatly. It was asked how monitoring humans and other animals would change NOAA's approach to observing systems. It is important to include a wide variety of variables and NOAA should be careful not overly focus on climate change variables at the cost of all others.

Dr. Morgan asked if NOAA is ready to make important measurements of a low probability event. NOAA should be thinking of social vulnerability assessments to low probability event such as tsunamis, major solar events, volcanisms, sudden sea level rise, etc. Being a bit more prepared on the societal aspects could help a great deal, if a major low probability disaster did occur.

Dr. Sullivan said NOAA has not developed a clear and compelling agenda that can be followed annually and across programs bringing cohesiveness to NOAA. She suggested the goal should be to develop a question(s) that NOAA could build an observing system around. What blend of science, actions, values, etc. should NOAA focus on? Where should the reason or importance of the effort be focused? Potentially the question could be what are the challenges people facing and what measurements would help humans deal with these challenges.

The responses covered a range of topics including that ecosystem services create stories that are compelling to humans and humans are what NOAA is serving and therefore ultimately ecosystem services are what NOAA wants to measure. It was agreed that there is a need to have ecologists and economists, because simple monetary values of ecosystem services fall short in representing full value of ecosystem services. Solutions depend increasingly on system functionality as people worry about things like water quality, quantity along with costs and therefore ecosystem investments become more appealing. Many communities are reliant on the ocean for food security and the blue economy and people are concerned about threats to those resources. The importance of coastal ecosystems and the value in understanding the complexity in the coastal system and there should be funding for ecosystem scientists that are independent of the politics. NOAA could link its mission and actions to things that people care about.

There was a return to the logic model and the reason why NOAA should be doing certain thing? The coastal ocean should be studied not necessarily because ecologists think it is important, but because people care about it. NOAA might understand what people value, but it is not clearly understood how people respond to changes in things that they care about. Understanding community resiliency requires comprehending how a system will react. Currently there is limited understanding about how systems react. It was mentioned that scientists can do the research and understand impacts, but then the knowledge needs to work through the politics and the management issues.

It was observed that a unique thing that NOAA does is combine research talent with responding to issues and intervention. NOAA should maximize the use of this unique characteristic to work in the communities and deal with adaptation needs. NOAA has a set of investments and interventions, but there is difficulty in knowing the impact of interventions. What are the measurements that people wish they could measure to tell the good story about the impacts?

Dr. Morgan wanted to differentiate between risk communication and decision making. It is difficult to design a risk communication message. Empirical work on risk communication has been done and there is discussion about the best way to get out the message. In terms of decision making it starts by asking the correct questions. NOAA should work asking the right questions and talking to the experts. The FDA has made a lot of progress in this space by developing good approaches and FDA has a small group that studies decision making related to physical threats.

Dr. Morgan followed up on his comment on scenarios and the topic of alternatives to scenarios when people are trying to understand the possible outcomes of policy options. The big problem with scenarios is when they become elaborately developed with lots of details people tend to become overly confident in the scenario. General scenarios can work and might focus on 2-3 important variables. Then, it is possible to do bounding analysis or other analysis. He stated that companies use scenarios with bounding conditions and forward price curves, but company scenarios have a different set of objectives compared to NOAA scenarios. The scenario development can be useful based on the problem, but are not useful for exploring different futures. He does not disagree with doing analysis about future potential outcomes. But NOAA should not play out elaborate scenarios with too many specific details. Specific analysis can lead to details that add to people's confidence in a specific scenario while in reality the scenarios are less and less certain with additional details. A good question to ask is how robust are different adaptation strategies across scenario spaces. He then gave an example of specific analytic methods by the Rand Corporation for the Port of Long Beach dealing with potential sea level rise outcomes.

**Public Comment**

There was no public comment

**Friday, 17, April**

**Recap of Thursday Strategy Session**
Stephen Polasky, Char, SAB Strategy Synthesis Subcommittee
Lynn Scarlett, SAB Chair

Dr. Spinrad summarized the strategic dialogue thus far as covering a range of interesting subjects including challenges and opportunities for observing systems, sensor innovation, adaptive sampling, probabilistic forecasting, social vulnerability assessments for low probability/high impact events that bring in the human dimension and possible creative approaches to data assimilation.

**Invited Speaker and Discussion**
Simon Levin, Princeton University

Dr. Simon Levin began with the topics of ecosystem structure and function and ecosystem services. An ecosystems services approach asks the important question of what services an ecosystem provides. Once NOAA understands the importance of ecosystems then NOAA can work to protect them. NOAA should take action, because ecosystems are under pressure and sustainability is one of the greatest challenges humans face. Robustness of the systems depends on biological diversity.
Many processes are linear, but things like recruitment are highly non-linear and are dependent on ocean processes. Fisheries are shifting with climate and so are fishing communities. Therefore, there is a need for prediction with linkages to socio-economics. Marine ecosystems are systems, but traditionally management is often for one species and not as a complex system. There are processes happening at many scales and those dynamics need to be captured. Statistical mechanics of highly non-linear process could be developed to connect microscopic to macroscopic and this approach has begun with some general circulation models linked to biological models. A set of coupled models connect metagenomics and biological models with fluid dynamic models, but these currently are highly localized models. A key issue is to go from small to large and determine the essential details, because it is significantly more efficient to only process important variables. The goal is not to predict every detail, but predict emerging properties and look for early transition properties that give early warning. Early warning indicators could be used to prevent the collapse and/or shift of an ecosystem and therefore this area of research could have high payoff.

Dr. Levin moved to the social and economic component stating that the marine ecosystem is tightly link to coastal communities and therefore is linked to the economics and social system. Good management of the commons is critical as is the realization that individual decisions work their way up to the macro-system. Ralph Gomery wrote about systems and the need to deal with the known, unknown and the unknowable and that adaptive response can be quite effective. A successful example is the human immune system with early warning indicators, early responses, and an adaptive immune system that learns as it responds. It has the ability to respond to a variety of pathogens although it is unknown which pathogens it might deal with daily and through the years. Ecosystems have a similar need for adaptive response systems in a changing and not fully predictable world. There are features about a complex adaptive system that can make them more robust. Redundancy is one such characteristic. If one component of the system is lost the whole system should not collapse. A second characteristic of robust systems is heterogeneity/diversity, which gives systems a chance to adapt. Another characteristic is modularity or compartmentalizing, which limits the spread of a disaster. It is important to look at the interactions between groups.

Models can greatly improve prediction capabilities, but the models can't tell exactly what is going to happen. Therefore, it is important not to get locked into responding to yesterday's problems and instead be adaptive. Physicists, physical oceanographers, biologist, sociologist and economist all have models, which need to be linked. It is possible to create a model that takes into account every possible interaction, but there is a need to figure out which details can be ignored with sensitivity analysis and the recognition of the separation of time and space scales. True interdisciplinary partnerships across disciplines need to find intelligent and robust ways to simplify the model. Dr. Levin works with Andy Lowe, who said one reason we had the financial collapse was because the finance models are not as sophisticated as biological models. The Bayer Institute brought together ecologist and economists at a conference on the systematic risks of the banking system. They looked at the interconnectedness of banking and sub-prime loans worried them and they published *Ecology for Bankers* in Nature. The economists and ecologist learned to the benefit of both disciplines demonstrating that fostering cross discipline relationships is a good way to go. There is still a long way to go before the social and economic models will be ready to be joined to the natural science models, but advances are being made especially in economics. It would be great to have models for the role of social norms in societies in dealing with public goods and models of small fisheries and cooperative regimes that could guide scale up from local co-ops.

Dr. Levin continued that in multi-component modeled system there are a variety of potential places to see warning signals. Adding extra dimensions into the system increases the chance for more signals. Coupling the components in the model is the trick and it must be decided at what scale to link the models. He was unaware of any good models currently that include the human dimensions, but NSF is funding coupled natural and human system research. Fortunately ecosystem services do not require every detail to be known, but instead can focus on the emergent statistical properties of ecotypes and functional groups. The model characteristics will vary based on the goals ranging from a single species to ecosystem services.

Discussion

In discussion it was noted that NOAA could potentially develop better predictive models by doing some retrospective analysis on recent fish stock crashes, such as the cod in New England. It might give insight into future catastrophic environmental events. If NOAA has these advanced modeling capabilities it would be useful to see how they would have performed versus the mechanistic models used at the time. It would be useful with historical data sets to compare the model results with the current set of decision tools and determine if the modeling efforts would have led to different management decisions. It was added that NMFS is starting to use some multiple species models in the Bering Sea and are beginning to bring forward ecologically important data. There is a fully coupled bio-physical model linked to a Regional Ocean Modeling System (ROMS model). Also have single species climate models. Climate driven models could help with predictions.
It was stated that even with the development of information if there is no action, then the disaster can still happen. Therefore, it is important to understand how is it that people learn and take up science information without being scientists; and how do people use the knowledge, respond, and take up cooperative action. Elinor "Lin" Ostrom has done a lot of work on public decision making. It may not be NOAA's mission to engage itself through a complement of science-sociologists. However, it might be an appropriate place in the CIs for the conversations.

Dr. Levin studied population migrations of plankton, which led to the realization that they had to consider the individual movements that lead to collective migration and collective decision making. This led to an interest in how humans make decisions, the role of leaders and followers, and social norms. Why and how do attitudes shift? Most individuals are followers that use ideas from others.

What is the trade-off of having lots of leaders? What are the best ways to deal with people that do not have opinions? Social learning is incredibly important.

Dr. Sullivan stated that NOAA lives in a regulatory world and the fact it takes time to change is no excuse for not using the best tools and looking at the big picture. NOAA's role is not to lament the system, but instead be the steward and leader to drive and shape the agenda to create change with the best science and tools that are available. Then, Dr. Sullivan asked about the methods that could help NOAA deal with data poor stocks.

It was acknowledged that dealing with poor data stocks is tough and some investment in data mining techniques could be useful. Models can determine what data NOAA needs for good predictions. Also, there is a group called Science and Nature for People (SNAP) that has a working group trying different models and methods to get information about data poor stocks from the fishing community. Likewise, historical surveys can be rich data sources and NOAA should exploit these data sources. Analyzing the data can show a history of systems that is very compelling.
The discussion shifted to the large amount of coastal development including energy development. There is no dose response curve to development. Yet, there are social consequences and social impacts associated with large-scale planning. Therefore, when large scale spatial planning is done efforts should be made to locate the critical components of an ecosystem and system functionality. Then, try to incorporate the human component and cultural norms and prioritize that information.

Dr. Levin mentioned that ecosystem services competing can be cause complication and sometimes when one part is protected another may suffer. For example, the sea otter reintroduction shifted the fishery from shell fishery to fin fishery.

Dr. Sullivan noted that NOAA is trying to address coastal ocean observing with regional ocean observing systems. There are collaborators working in each region to develop regionally specific observing systems. NOAA drives interoperability, connectivity and common parameters. She agreed it was not as robust an observing system as open-ocean systems.

Dr. Levin closed with a thank you. He stated that advancements are made when you bring people together to work in a true multi-disciplinary area across diverse aspects of the system.

The Strategy Session wrapped up with comments from around the room.

Dr. Spinrad thought the process was successful. The key connections between the discussion and NOAA's mission strategy included a focus on critical transitions and the re-analysis challenge to look how ecosystems have collapsed and what were some of the critical transitions that could give early indication warnings. Also, the integration of models across disciplines that are scalable in time and space would be useful. Finally, he observed that there is a need to determine how to deal with data poor systems. The next steps for the SAB strategy efforts would be SAB to identify pieces of discussion that could serve for next steps of further development. NOAA will organize those pieces and give them back to the subcommittee. Then, NOAA and the subcommittee will identify the gaps that might be addressed at the August meeting perhaps by guests. Potential August speaker topics include risk communication, collective decision making, and innovative sampling strategies. By fall there should be a document with durability and longevity that is strategic and advisory in nature that have implications for strategic priorities.

Other topic highlights from around the room included: 1) citizen scientist opportunities to which NOAA should pay attention, because citizen based science can deliver really good, real time

information and it engages the public in a better way and NOAA success with science, service, and stewardship requires the next generation and education; 2) NOAA's needed to use the best technology and calibrate data with the long tested and measured techniques; 3) integrated ecosystem managements being something everyone agrees on, but what is the practical and incremental pathway for NOAA to achieve it; 4) the need to development the next steps to more explicitly incorporate economics and social science; 5) the huge gaps between coupled ecosystems and human systems and the acknowledgement that basic understanding is lacking in how people response to incentives, to knowledge, and different risk messaging; 6) the potential value of choosing a few model systems to study and see what NOAA can learn from them;7) the intersection between science and decision making including risk communication and how people take up science knowledge; 8) the need for interdisciplinary work to better understanding of tipping point and feedbacks.

Dr. Sullivan enjoyed both days of conversations and was provoked to think anew. This alone is not enough. The benefit to the conversations is to get some provocation to take a different look. The value to the organization is for the leadership to tell NOAA employees that they a part of an exciting future and not just turning the crank. The next steps would be a strategic landscape picture. The SAB could pick a portfolio of a NOAA activity and begin digging into the details.

**A Framework for an Ecosystem Approach to Fisheries Management under Projected Climate Change**

Anne Hallowed, NOAA Alaska Fisheries Science Center
Phyllis Stabeno, NOAA Pacific Marine Environmental Laboratory

Summary

Drs. Anne B. Hollowed and Phyllis Stabeno presented a talk titled: "*A framework for an ecosystem approach to fisheries management under projected climate change.*" This science talk related to some issues raised in a recent report on an Ecosystem Approach to Fisheries Management produced by the Science Advisory Board (SAB). In that document the SAB asked the questions: *To what extent is the impact of climate change / ocean acidification on ecosystems a game changer for fisheries and their management?* and *Fished ecosystems appear to be undergoing remarkable change. Can we predict how they will continue to change?* This presentation provided a regional case study on how NOAA can address these questions through implementation of the NMFS climate strategy.

The presentation highlighted the outcome of the recently completed 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). This report illustrates that marine ecosystems throughout the United States will be impacted by climate change, particularly high latitude ecosystems. As outlined in the NMFS Climate Strategy the next steps will be to identify representative fishing pathways to quantitatively project the implications of climate change within the constraints of national harvest guidelines and the Endangered Species Act. This step will require a partnership between OAR and NMFS that includes all elements of a multi-investigator interdisciplinary research team focused on:
a) Continued ocean monitoring to detect trends and anomalous events;
b) Retrospective studies to develop conceptual models of the mechanisms underlying biological responses of interacting species within the U.S. Large Marine Ecosystems;
b) Process studies to test proposed mechanisms;
c) Projection models to simulate proposed ecosystem change; and
d) Management strategy evaluations to test the implications of different strategies for sustaining marine fisheries under a changing climate.

A promising aspect of this enterprise is the emerging new capability to forecast short-term climate impacts. An example of this type of short-term forecast was presented, wherein climate conditions were projected for the northeast Pacific Ocean and Bering Sea in the fall of 2014. These projected conditions have proven to be quite accurate. Their accuracy has allowed NMFS to respond to the unique opportunity to learn from unusually warm ocean conditions in the Eastern Bering Sea, Gulf of Alaska and California Current. In particular, NMFS funded a special cruise in the Bering Sea to test existing hypothesis that production of large zooplankton will be reduced in warm ocean conditions.

Dr. Stabeno presented the results and current status of our understanding of the eastern Bering Sea shelf ecosystem. This understanding was derived from a long history of collaborative research between investigators from PMEL and AFSC, co-located in Seattle. This co-location permitted close collaboration promoting the development of multiple proposals for integrated research (e.g. Bering Sea Fisheries Oceanography Coordinated Investigation, the Southeast Bering Sea Carrying Capacity Program, GLOBEC and more recently the Bering Sea Study, a partnership between the North Pacific Research Board, the National Science Foundation and NOAA).

This long history of collaborative research between PMEL and AFSC supports a long-term ocean/fish monitoring system that included surveys, biophysical moorings, remote sensing, coupled bio-physical modeling and advanced data collection from ships of opportunity. Data derived from this long-term ocean/fish monitoring system provided an understanding of the processes underlying bio-physical linkages between ice and primary production, and subsequent responses of zooplankton and fish to climate driven environmental change.

Of particular interest to the SAB was the change in the nature of climate variability in the region. Past records show marked interannual variability in climate/ocean conditions. Beginning in 2000 the Bering Sea entered into a more multi-year pattern of either warm (2000-2005) or cold (2006-2013) conditions, with 2014 and 2015 shaping up to be warm years. This multi-year pattern has allowed researchers to refine their conceptual understanding of the bio-physical processes underlying recruitment of some commercial species. The new paradigm highlighted the importance of summer foraging conditions for juvenile fish to the subsequent overwintering success for walleye pollock. This example illustrates the critical need for on-going integrated monitoring of the Bering Sea system to continue to test and refine the functional form of species interactions under climate change.

Dr. Hollowed noted that the NFMS climate strategy calls for an operational program of climate projections to inform the relevant Fishery Management Councils of expected change and to identify climate-ready management alternatives given expected changes. She noted that projections of future representative fishing pathways must include not only climate driven change but other associated natural and anthropogenic drivers. She described the effort currently underway to utilize a multi-model projection effort to characterize the range of possible outcomes under a changing climate. This effort will utilize downscaled projections of future ocean conditions derived from a suite of global earth system models. Downscaled ocean conditions will be applied to five types of projection models ranging from minimally realistic single species stock projection models to fully integrated spatially

explicit ecosystem models will be applied. Less complex models will utilize ecosystem indicators derived from downscaled ocean conditions while fully complex models will embed fish bio-energetic responses with direct links to ROMS. As noted by the SAB this range of projection modeling types should reveal key strengths and weaknesses in NMFS projection modeling capability.

Dr. Hollowed noted that this Bering Sea multi-model projection effort represents one regional node of a much larger global effort to project the implications of climate change on marine fish stocks world-wide. An ICES/PICES/NOAA/IMR workshop in August 2015 will bring together scientists from around the world to coordinate this projection model effort with a target delivery date for projected impact assessments of 2019/2020. This type of multi-model approach was consistent with the approaches recommended by the SAB during the morning general discussion of ecosystem approaches to fishery management.

Dr. Stabeno and Dr. Hollowed ended their talk with a review of the core elements that made the Bering Sea case study so successful. Key elements include: a legacy of interdisciplinary research programs; the continued research partnership between PMEL and AFSC; the development and use of advanced technology for long-term ocean monitoring and remote sensing; and the continued integration of modeling teams with observationalists to ground-truth model output against observations. The speakers noted that operationalization of the OAR-NMFS projection modeling enterprise will necessitate a commitment to: maintaining a core suite of long-term observations and surveys; a new emphasis on evaluation of the predictive skill of models using the new short-term climate forecasting system; continued assimilation and integration of new observations into models; identification of thresholds for council action to allow the public and fishery dependent communities to prepare for the consequences of a changing climate.

Discussion

Dr. Jackson stated that we expected climate to play a role in these vulnerable areas. It would be good to do similar studies in other places including those that might be expected to less impacted by climate.

Dr. Hollowed agreed it would be good to have NOAA modeling teams in a variety of systems. The regional details are very important, especially if questions dealing with food security and food supply are going to be answered. It could also be possible to have simpler local models that could give good details, but that needs to be explored.

Dr. Polasky said that he works with complex models with a lot of moving parts. He wondered how much is being gained by the complexity of the model and what might be lost. And what approaches are used to go back to simpler models.

Dr. Hollowed responded that some of NMFS correlative models are very simple linking variance in recruitment to spawning biomass and environmental factors, but can explain nearly 60% of the variability. More complicated mechanistic models have been created, but they don't always do better

with respect to reconstructing observed recruitment patterns. With lots of computing power it is possible to do a Bayesian approach and let the model find the best solution.

Dr. Spinrad wondered if it is realistic to think in the near future that it will be possible to do earth system model ensembles with multiple initializations.

Dr. Hollowed responded that she thinks there will be both multiple models and the same model with multiple starts. The modeling group needs to decide the way forward. Perhaps it's going to be multiple approaches that are regionally based. The multiple initiation approach is a good idea. Also, it would be good with the simpler models to have an idea what that adds to the uncertainty.

Dr. Spinrad wondered if NOAA has the tools in place for such modeling efforts.

**Working Group Issues for Discussion**

Climate Working Group (CWG)
Holly Hartman, Chair CWG
Wayne Higgins Director CWG
Jennifer Faught Executive Secretary, CWG

Holly Hartman, CWG Chair, said the working group has had one virtual meeting and one in-person meeting a year and it is the consensus of the group that virtual meetings are not working and members want to go back to two in-person meetings a year. The Climate Program Office (CPO) is the sponsor of the working group and Wayne Higgins, CPO Director had nothing to add just to note that t it has been past practice to have one in person and one virtual meeting a year. This week the CWG had a virtual meeting and it was productive. It is not about topic or issues just the format.

Cynthia Decker said one virtual and one in person meeting a year agreed to in 2013 due to budget constraints. Virtual meetings are not optimal; the agreement was that the working groups should have at least one in person meeting a year but most working groups have moved back to two in-person meetings a year.
Lynn Scarlett asked if they need formal rules or if it can be worked out with the line office. Holly Hartman said she heard more formal rules were needed. Cynthia said the SAB had a concept of operations for working groups and the wording that the SAB working groups should have at least one in person meeting a year. It is up to the SAB whether they want to change that policy.
Lynn Scarlett suggested that CWG work with their sponsoring organization, the Climate Program Office; there is nothing official from SAB on this but just guidance so this SAB can't require to NOAA to do anything. Holly said this discussion on what other working groups are doing would help with the discussions with OAR.

Holly also provided a statement from the Climate Working Group on the Tropical Pacific Observing System (TPOS). The continued fragility of the TPOS is inconsistent with its importance to NOAA

information systems that inform early warning and community resilience to climate and weather events. At risk are skillful predictions of high impact climate events and continuity of observations about key climate indicators. TPOS failure would seriously compromise ENSO, drought, and atmospheric river forecasting. Further, the last several decades have seen increased ENSO diversity, with a succession of surprises in ENSO events. Our ability to understand and forecast these more diverse ENSO events requires a new approach and new tools.
The international Tropical Pacific Observing System-2020 Project (TPOS-2020) will catalyze and coordinate research and development of the Tropical Pacific observing system for the next decades. There is significant international interest in the Project and it is in NOAA's best interest to contribute the resources and leadership necessary to nurture these interests in order to evolve/improve the ocean observing system in this important part of the globe. It can hardly be over-emphasized that that TPOS forms the centerpiece of an indispensable integrated observing system for subseasonal-to-seasonal prediction. TPOS also makes connections to components across NOAA, including PMEL/CPO observations; GFDL models; and NWS operational systems, tools, products; and ties in with activities other agencies, including USGCRP activities.
Moored arrays like the Tropical Atmosphere Ocean (TAO) buoy array will continue to be essential even as technological advances offer new opportunities in a more diversified TPOS design; present NDBC operations probably are not sustainable for the long term. The TAO array, which was designed to send the tropical Pacific Ocean temperatures and winds to NOAA every minute via satellites, provides subsurface temperature information during the spring and summer of an El Niño year, information critical for initializing prediction models and for calibrating satellite data. The El Niño forecasts of 2012 and 2014 failed partially because of the lack of this subsurface information from a part of the TAO network which had failed due to a lack of maintenance.

Rick Spinrad thanked Holly Hartmann for this expression of value on the TAO array. If there is any advice on this topic from the CWG to the SAB, he suggested that it be on the science, less so on the management; as advice on science is the “what”; advice on management is the “how”. Rick said he is happy to have the dialogue with the working group on TOGA.

**Review of Actions**
Cynthia Decker, Executive Director, SAB

NOAA would synthesize ideas during strategy session and provide to subcommittee. Subcommittee will provide suggestions for speakers and provide revised outline for the August meeting and perhaps the fall meeting as well.