WESTERN
PACIFIC
REGIONAL
FISHERY
MANAGEMENT
COUNCIL

# **Ecosystem Science and Management Planning Workshop:**
Development of Ecosystem-based Approaches to Marine Resource Management in the Western Pacific Region

April 18-22, 2005

Council Office Conference Room
1164 Bishop St., Suite 1400
Honolulu, Hawaii 96813

July 18, 2006

These proceedings were compiled and edited by Jarad Makaiau, Paul Dalzell, Gerard DiNardo, Charly Alexander, Svein Fougner & Dirk Zeller.

# Table of Contents

## List of Tables

## List of Figures

## Preface

Much has been said and written in recent years about the need for application of ecosystem principles to the management of U.S. fisheries under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). While the topic of ecosystem principles has received increased attention recently in both the U.S. Commission on Ocean Policy and the Pew Ocean Commission, it has been the subject of discussions for several years previously. For example, the National Environmental Policy Act (NEPA) could be considered a legal embodiment of the need to consider how federal actions would affect the environmental resources (hence ecosystem-based principles) in which they were carried out.

The Western Pacific Regional Fishery Management Council, one of eight regional fishery management councils, is moving progressively to apply ecosystem principles in its fishery management plans. Recognizing that the Council has limited experience and tools for this work, and further recognizing broad, multi-Council interest in this arena, the Council has embarked on a series of workshops to exchange information and learn from outside experiences in resource management based on or integrating ecosystem principles into the planning and management process. The first such workshop was held April 18-22, 2005, at Council offices in Honolulu, Hawaii. The theme of this workshop was the science and data needs to support the application of ecosystem principles into planning and management. Experts from throughout the nation and the Pacific were invited to make presentations and engage in discussions about their work, experiences, and views on these topics. This report presents the results of the workshop.

## Introduction

Fishery management over the past decade has been moving away from developing single-species- and stock-policies, and towards considering fishery impacts on aquatic ecosystems more holistically. This shift was evident in the 1996 reauthorization of the US Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), which incorporated many elements of the Ecosystem Approach to Management (EAM). This included a requirement for Fishery Management Plans (FMPs) to incorporate considerations of essential fish habitat, which was defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." FMPs are required to "describe and identify essential fish habitat for the fishery, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat." The 1996 Magnuson-Stevens Act also contained a new National Standard (NS9) for by-catch, which was defined as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards." Conservation and management measures in FMPs were required to "minimize by-catch and to the extent by-catch cannot be avoided, minimize the mortality of such by-catch."

Moreover, the 1996 reauthorization of Magnuson-Stevens Act also included the establishment of an Ecosystem Principles Advisory Panel to expand the application of ecosystem principles in fishery conservation and management activities. Following the directives of Magnuson-Stevens Act, this Panel completed a report to Congress in 1999, entitled Ecosystem-Based Fishery Management. Further, the 2003 Pew Ocean Commission and the 2004 U.S. Commission on Ocean Policy both advised NOAA Fisheries to adopt ecosystem approaches to management. From the foregoing it was clear that the next reauthorization of the Magnuson-Stevens Act would likely include a requirement for the Regional Fishery Management Councils (RFMCs) to prepare Fishery Ecosystem Plans (FEPs). Recognizing this momentum towards FEPs, the Western Pacific Council convened a workshop in April 2005 to begin the preparations for moving from FMPs to FEPs.

The Workshop was held in Honolulu, April 18-22, 2005, at the Council offices. The three basic themes for the Workshop were Data, Models, and Indicators, recognizing that a later workshop would address social and economic policy and human organization issues.

## Workshop objectives and tasks

The objective of the Workshop was to identify science requirements to support Ecosystem-Based Approaches (EBA) for marine resource management in the Western Pacific Region. The tasks assigned to the Workshop were:

1. Review state-of-the-art ecosystem models applied to marine resource management and their application in governance systems;
2. Identify management requirements in the Western Pacific Region;
3. Identify the best suite of quantitative ecosystem indicators and associated tradeoffs to support management requirements in the Western Pacific Region;
4. Within the confines of existing mandates (e.g., Magnuson-Stevens Act, National Marine Sanctuaries Act), identify the most effective short-term application of EBA to marine resource management that can be implemented based on current data (and in this context, address whether the precautionary approach has a role);
5. Identify new data or models that would be required to advance EBA to marine resource management in the Western Pacific Region; and
6. Identify changes in policy or science administration that would be required to more effectively implement EBA to marine resource management.

The Workshop was divided into three parts (Figure 1): an initial plenary session during which presentations were given on Data, Models and (Ecosystem) Indicators; a breakout session, in which three working groups deliberated on these respective topics; and a final plenary session consisting of reports from the three working groups followed by a synthesis of the Workshop. The working groups were given the following directions to aid in their deliberations:

- Review issues/questions from the plenary session;
- Determine the key points made during the discussion of the questions;
- Determine if there are unresolved questions;
- Discuss ideas and make suggestions on priority questions and issues;
- Relate the discussions back to the primary tasks of the workshop; and
- Provide short term (1-2 years) and long term (> 2 years) recommendations.

A panel of invited experts was tasked to lead discussions in the plenary and working groups. The expert panel comprised the following individuals (in alphabetical order):

| | |
|---|---|
| Jerald Ault | University of Miami, RSMAS |
| Villy Christensen | University of British Columbia, Fisheries Center |
| David Fluharty | University of Washington, School of Marine Affairs |
| Mike Fogarty | NOAA, NMFS |
| Neil Gribble | Queensland Dept of Primary Industry, Northern Fisheries Center |
| Steve Murawski | NOAA, NMFS, Office of Science and Technology |
| Carl Walters | University of British Columbia, Fisheries Center |

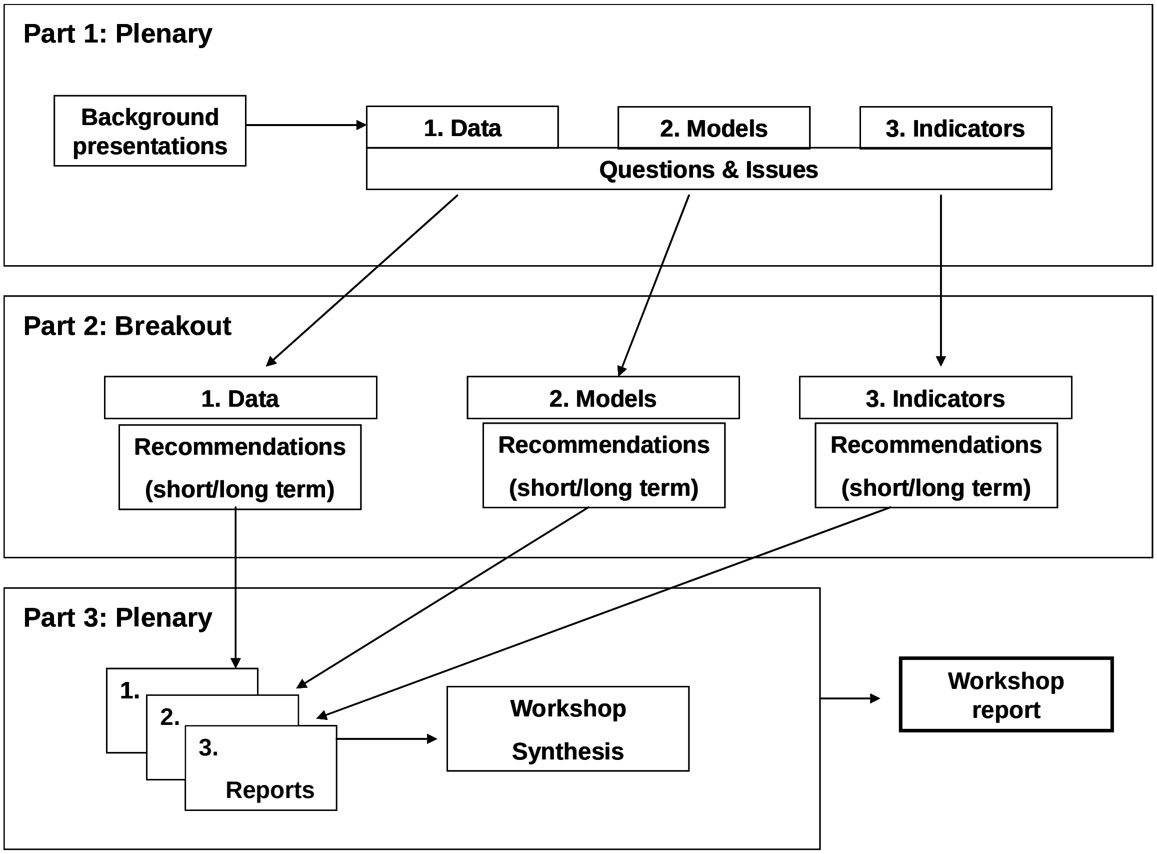



**Figure 1: Workshop structure and outline.**

At the closing session, panelist David Fluharty and workshop participant Michael Orbach presented a workshop synthesis and recommendations for the future. Council is hosting two further workshops, the first in early 2006 to focus on the social science needs for EAM, and a final integrative meeting to combine the outputs of the social science workshop and the present meeting to provide the Council with advice on policy and methods for EAM in fisheries. Thus, the present Workshop represents the first phase of a three-step process by the Council to implement an EAM in the Western Pacific Region.

The present report summarizes workshop presentations and discussions. In addition, it suggests a set of recommendations based on the breakout working group reports and general discussion items.

## Opening Remarks

**Presented by Kitty M. Simonds, Executive Director WPRFMC**

Aloha kakahiaka. Komo mai. Good morning and welcome. We have before us this week a daunting but exciting task. It was almost 20 years ago that National Marine Fisheries Service (NMFS) convened the first ecosystem workshop with the Regional Councils, producing the NMFS Program Development Plan for Ecosystems Monitoring and Fisheries Management. In 1999, NMFS published its document for the US Congress on ecosystem principles to fisheries management, which several of you present today were responsible for developing. We at the Western Pacific Regional Fishery Management Council began work that year on our Coral Reef Ecosystem Fishery Management Plan, *the first fishery management plan in the United States to take an ecosystem approach to fisheries management.*

All Councils have integrated, one way or another, ecosystem elements in their Fishery Management Plans. This Council is fully committed to the ecosystem approach, and we are now in the process of converting all of our existing species-based fisheries management plans to archipelagic fishery ecosystem plans.

Fishery managers, scientists and policy makers have been deliberating the ecosystem approach for years, including at the recent “Managing Our Nation’s Fisheries II” conference. Support for the concept has remained strong, but so many important factors - such as data and model requirements, ecosystem indicators, etc. - are yet to be determined.

It is our hope that the discussions that take place this week will leave us with some level of consensus on these critical issues. Undoubtedly, we may not all see eye to eye on all the details. But it is important that we reach some basic agreement so that we can move forward, and then through adaptive management, improve our management as our understanding grows.

As we debate these issues, let us be reminded of the Hawaiian proverb: I ka olelo ka make, i ka olelo ke ola. In the word is death, in the word is life. This proverb talks about how important what you say is. If you say the wrong thing, it could mean death for someone or something; if you say the right words, it could mean life for someone or something. So everyone should be careful of what they say. One should speak honestly and compassionately, and truly mean what one says and be responsible for what one says.

In closing I hope you have an enjoyable and productive workshop and that the outcomes of your discussions will greatly enhance and improve the management of fisheries in our islands. E kuahui like ka hana! (Let everybody pitch in and work together).

# Background presentations

## *General keynote presentations*

### Steve Murawski (NMFS): Principles of an ecosystem approach to fishery management…

**Principles of an Ecosystem Approach to Fishery Management (EAFM), with an update from the Workshop on 'Ecosystem-Based Decision Support Tools for Fisheries Management'**

The foundation of an Ecosystem Approach to Fisheries Management (EAFM) is the application of conservative and effective single-species approaches for the major stocks or fisheries in a designated region. Added to this base are considerations of the impacts of fisheries on non-target species, effects of fishing on habitats supporting production, predator-prey dynamics – particularly where both prey and predator are fished - and relationships between the biota and the physical environment. Given the complexity of marine ecosystems, relationships between species and their environment are likely complex and complicated. Management Strategy Evaluation (MSE) is a modeling approach that allows for testing the effects of alternative relationships among species in relation to harvesting scenarios. This presentation highlights the necessity for developing approaches, relationships, data and indicators in support of EAFM.

A problem managers have encountered in implementing an Ecosystem Approach to Management (EAM) is the lack of a 'road map' on how to integrate the various components of an ecosystem approach into a clear operational governance system. In an integrated EAM, the governance system examines a suite of information to develop management measures which achieve various strategic goals. This requires taking into account various perspectives and desired outcomes from a variety of stakeholders. It must also rely on a comprehensive ecosystem observing system to collect data at various spatial and temporal scales, and a management decision support system to synthesize the information and develop status indicators for individual ecosystem components, forecast of status and trends and evaluate the biological, social and economical effects of policy choices.

One of the most important challenges in Ecosystem Approaches to Fisheries Management (EAFM) is how to link high level principles such as maintaining healthy and productive ecosystem to informative performance indicators (Figure 2). Unfortunately, aside from basic fishery performance indicators related to fishery mortality rates and population sizes, there are no established criteria for determining what the proper reference levels are for ecosystems. Additionally, quantifying the relative improvement of societal benefit for a given management measure is a critical missing element for many of these other reference points.

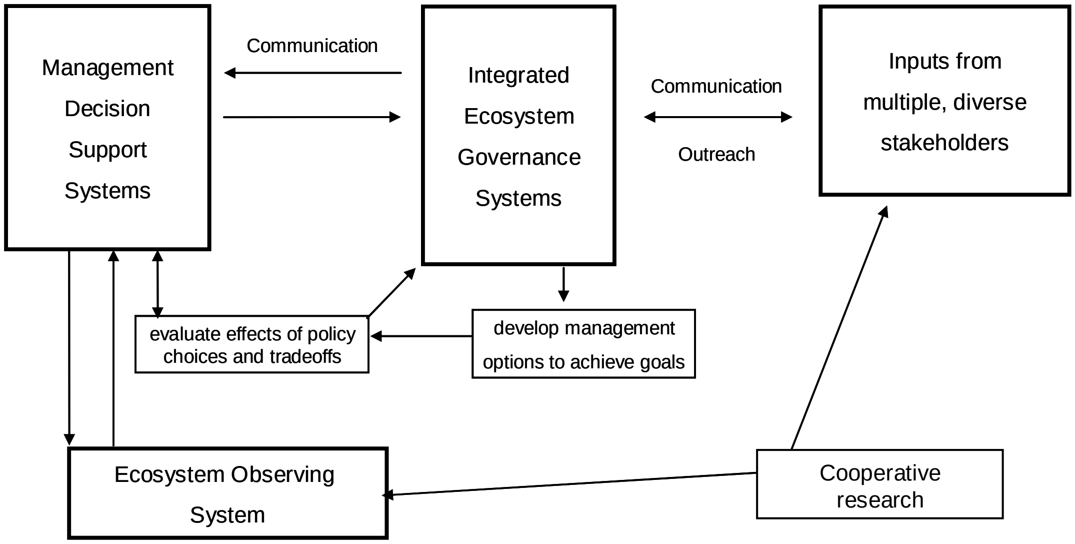



**Figure 2: Components of an integrated ecosystem approach to management.**

The literature on EAFM suggests that there are eight broad categories of operational objectives that should be considered in developing ecosystem fishery management plans:

1. **Conserving and managing the species**. Currently, fishery management policies require managers to conserve target species, and non-target species if they are protected, endangered and threatened species, as well as to minimize by-catch and adverse effects to habitat. There is increasing interest in how management can be strengthened to protect biodiversity;
2. **Minimizing by-catch**. The major societal focus for minimizing by-catch is to minimize waste;
3. **Managing tradeoffs**. Tradeoff approaches must look at benefits and costs of management options among fishing and non-fishing sectors to optimize fishery benefits, and prevent sequential depletion and effort transfer. Management processes should also be fair, equitable and transparent, consider cumulative impacts, and evaluate impacts of non-fishery sectors;
4. **Account for feedback effects**. This includes trophic interactions (i.e., predator/prey relationships), the effects of fishing on habitat productivity, irreversibility of fishing impacts and harvesting-induced regime changes;
5. **Establish appropriate ecosystem boundaries**. This is a challenging concept for fisheries management, as ecosystems can be defined on multiple scales depending on the problem one is dealing with;
6. **Maintain ecosystem productivity and balance ecosystem structure**. In principle, one should identify indicators and properties of an ecosystem which characterize a balanced state. However, ecosystems are dynamic and even if impacts were managed properly, it doesn't imply a balanced ecosystem;
7. **Account for climate variability**. Low-frequency (decadal) and high frequency (year to year) climate variability can have profound effects on ecosystem processes and

productivity. Management measures should err on the side of caution to account for this uncertainty; and

8. **Use adaptive approaches to management**. Currently, our ecosystem-level knowledge is often limited. Additionally, a high degree of uncertainty, particularly in the processes that inter-relate various aspects of this system, requires that manager proceed with caution and possibly experiment with different approaches and strategies to increase ecosystem knowledge.

## Decision tools supporting EAFM: Key Largo Workshop

In February 2005, NOAA held a workshop in Key Largo, Florida to look at the status of various areas of ecosystem approaches to management (see www.st.nmfs.gov/st7/ecosystem/workshop/2005). The workshop focused on four key areas: (1) the status of data and information; (2) inter-relating ecosystem components using functional relationships; (3) the status of use of indicators and reference points; and (4) the use of models and forecasts in managing using an ecosystem approach (Figure 3). The workshop also discussed the importance of decision support tools supporting ecosystem approaches to fisheries management.

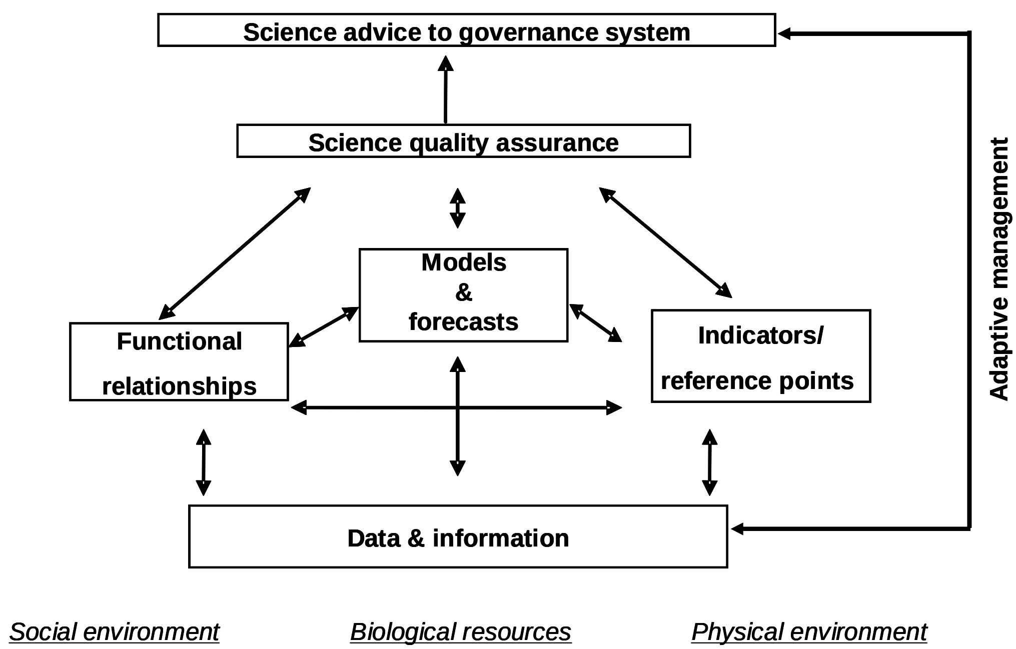



**Figure 3: Decision tools supporting Ecosystem Approaches to Fisheries Management.**

Decision support tools are important management methods as they link governance to data, indicators, models, and socio-economic analyses, and help diverse stakeholder groups to understand the likely consequences of alternative management actions and the tradeoffs across management objectives.

With respect to functional relationships, the participants at Key Largo observed that:

- Specification of functional relationships among ecosystem components is an essential precursor to the development of predictive ecosystem models in support of management;
- Determining the nature of functional relationships among ecosystem components will rely on evaluation of time series information, adaptive management experiments, and other approaches;
- Ecosystem considerations include the specification of the functional forms of bottom-up and top-down forcings in system dynamics;
- Incorporating the increased dimensionality accompanying ecosystem considerations results in changes in management reference points, and increases some aspects of uncertainty in predicted outcomes and the probability of complex dynamics including the possibility of alternative stable states;
- The degree of uncertainty emphasizes the need for risk assessment and the application of the precautionary principle under process uncertainty;
- While we cannot readily conduct controlled and replicated ecosystem-level studies, the prospects are good for learning about ecosystem control mechanisms from inter-system comparative studies as well as from intra-system time series studies;
- Evaluation of functional relationships for key components of an ecosystem may be facilitated using statistical approaches to guide formulation and parameterization of ecosystem-level models;
- Testing of ecosystem models is currently focused on fitting to time series data using log likelihood criteria while evaluating the relative impact of multiple drivers (climate, nutrient loading, habitat modification and fisheries);
- Related activities are in progress worldwide, including at several NOAA agencies and councils. Results indicate that most ecosystems are impacted by multiple drivers;
- Formal evaluation of how assumptions about functional relationships impact the predictive capabilities of ecosystem models for fisheries management is required;
- Evaluation requires information over long time periods as data-contrast is essential to test alternative hypotheses for functional response formulations;
- Such testing calls for back-calculation, and typically requires expanding time series of abundance and fishing pressure for multiple ecosystem components, including for non-commercial species – this calls for concerted data scavenging activities;
- Application of multiple modeling tools testing different functional relationships should be encouraged;
- Ecosystem modeling approaches should be designed to give reliable directional guidelines as part of a strategic management approach; this may best be performed as part of an adaptive management scheme; and
- Testing alternative hypotheses may call for adaptive management experimentation, notably where time series information shows little contrast. Examples include using closed areas, varying exploitation rate, production through stock enhancement, habitat modification using artificial reefs, etc.

With respect to indicators, the Key Largo workshop participants found that:

- Indicators are measures of an ecosystem characteristic or process that we are interested in. They may be stated by a stakeholder group, legislatively mandated or be of scientific interest;
- Values change directionally in association with the direction of change in that characteristic or process; and
- Indicators should be relatively convenient to measure and calculate using available data, and be easy to communicate to audiences, recognizing that different audiences (e.g., decision makers, interest groups, educational groups) may require different indicators.

With respect to the current use of indicators, the Key Largo participants noted:

- The use of indicators is growing in marine EAFM/EAM;
- Better understanding exists for biological aspects than for socioeconomic aspects;
- Lists of indicators covering multiple aspects of EAM have been assembled;
- Correlation-type relationships (without mechanistic) may be useful in determining state (i.e., status indicators);
- Indicators should not be treated as "performance targets" for management (management indicators) without direct mechanistic linkages;
- Most indicators are not yet usable as reference points;
- Empirical use of state indicators (e.g., biomass) as a function (or partial function) of pressure indicators (e.g., fishing rate) can help establish specified thresholds or Limit Reference Points; and
- Empirically based indicator thresholds need further development, but can be used now to establish intermediate decision criteria.

In selecting indicators, a working group of the International Commission for the Exploration of the Sea reviewed a variety of different indicators and established criteria that should be considered in terms of an ecosystem approach. They believed that indicators should be:

- Easy to understand;
- Responsive to manageable human activities;
- Responses linked in time to management action;
- Easily and accurately measured;
- Low responsiveness to other factors;
- Measurable over large areas; and
- Existing data available to provide historic dynamics.

In terms of selection metrics for indicators, considerations should be given to:

- How relevant it is to the situation;
- How much it will cost to monitor;

- How frequently the indicator requires re-evaluation;
- How strong the underlying signal is;
- How precise the indicator is;
- How accurate it is; and
- How sensitive it is to multiple drivers at the same time.

**The use of models to advise EAM**

The current state of ecosystem modeling appears advanced enough for use in EAM. Various multi-species and ecosystem models have been used to approximate the complex and dynamic interrelationships among biotic and abiotic processes occurring over a range of spatial and temporal time scales (Table 1). Simple models can be used to show the relative consequences of alternative management strategies. For the purposes of EBFM, there is a classification scheme that looks at the most informative types of operational models that have been used in various locations. It ranges from multi-species technical interactions or by-catch models to age-structured trophodynamic models. They require a variety of different data and they allow different amounts of spatial structure. Usually, there are data gaps that limit their application.

**Table 1: Categories of single-species (SS), multi-species (MS) and ecosystem models (ES).**

| Model type | Biological interactions | Predator-prey feedback | Environmental and/or lower trophic levels | Age structure | Spatial structure |
|---|---|---|---|---|---|
| MS fishery technical interaction models | | | | X | X |
| SS models with unidirectional drivers | X | | X | X | X |
| MS production models | X | X | | | |
| Age/size-structured MS models | X | X | | X | X |
| Aggregate trophodynamic ES models | X | X | X | | X |
| Age/size-structured trophodynamic ES or individual-based models | X | X | X | X | X |

World-wide, there are numerous experiences that demonstrate how models can perform in ecosystem approaches to fisheries. In Australia, management strategy evaluation (MSE) using ecosystem models provides a clear example of how such models can provide relevant information that is directly applicable to the ecosystem approach to fisheries. A variety of models have been nested, ranging from single species to ecosystem-based models within the evaluation. It starts with a basic rendition of the biophysical model, incorporates whatever exploitation issues there are in the system, and incorporates an observation- and a management-process. There is some level of uncertainty in this approach, but it does allow the system to quantitatively evaluate the strengths and weaknesses of various management proposals from a much broader context than just fisheries.

In general, ecosystem modeling needs are universal. There is a need for enhanced but targeted biotic, abiotic, and socioeconomic data to construct more useful and relevant ecosystem models. Also, characterizing uncertainty is vital for interpreting ecosystem model results and providing advice on the likely consequences of alternative management actions**.** There are also methods from other disciplines that could be useful for EAFM related modeling that we have not considered in traditional fisheries management. They include fuzzy logic, credibility theory, artificial intelligence, gaming theory, network analysis, decision theory, and a variety of methods used in economics.

In terms of ecosystem modeling, the interplay with policy is very important. There is a need to develop clear goals and constraints or people will want models to do everything. Management actions and research efforts need to be coordinated to better understand ecosystem dynamics. There is also a need to foster participatory decision-making, as more public concerns are raised about ecosystem protection.

Finally, there is a need to provide adequate support for ecosystem monitoring, research and modeling, with an emphasis on ecosystem goods and services, and appropriate metrics for accounting for non-consumptive ecosystem services that have an equal footing with the market-based goods that are being produced by these ecosystems.

## Carl Walters (Fisheries Centre, UBC, Canada): What goes wrong with ecosystem models…

### What goes wrong with ecosystem models as tools for policy design?

Policy design involves making choices, and choice by necessity involves making predictions about how impacts may vary with policy choice. Thus, there is no option to avoid predictive models of some sort. The question is which one(s) to use:

- Intuitive assessments of responses directions and magnitudes;
- Dogmatic predictions based on simplistic beliefs about ‘natural (less disturbed) must be better’;
- Simple models that emphasize ‘major’ interactions and dependencies; and/or
- Detailed models that pretend to capture ‘all’ the relevant factors.

The recent explosion in ecosystem modeling activity has produced many apparently credible models that fit historical data well and make reasonable policy predictions. However, habitat and environmental changes (including those caused by fishing) and intensive fishery removals are creating essentially novel situations. It would be extremely foolish for anyone to pretend to understand the ‘mechanics’ of ecological responses well enough to be able to predict ‘all’ important responses to these novel situations. The fact that we might be able to get 90% of model equations right does not mean that our model is 90% sure to give the right answers. A case in point is the fact that ‘details’ that are hard to model may have huge effects, for example, clouds and particulates (in climate models), ‘minor’ prey that are only eaten in small space-time windows (in ecosystem models), or compensatory behaviors in response to habitat change (in fish habitat models).

By generally considering our experience with ecosystem modeling, we can create a type of 'score card' (reminiscent of those you anticipated with dread while in high-school) for using such models to address ecosystem management questions (Table 2).

**Table 2: Score card for using models to address ecosystem management questions.**

| Issue | Grade | Comment |
|---|---|---|
| By-catch impacts | A- | We are not bad at predicting direct effects of fishing in general. |
| Top-down effects (predator culling or protection) | C | Trophic effects of fishing can be classified as 'top down' or 'bottom up' with respect to where management controls are exerted. |
| -on valued prey | B | Changes in M for prey species already subject to assessment. |
| -on 'rare' prey | F | Outbreaks of previously rare species. |
| Bottom-up effects (effects of prey harvesting on predator stocks) | C | Uncertainty here is about flexibility of predators to find alternative food sources when prey are fished. |
| Multiple stable states | B | Cultivation-depensation mechanism appears to be main mechanism that could cause 'flips'. |
| Habitat damage | D | Lack of understanding about real habitat dependencies, bottlenecks. |
| Production regime changes | C | Models look good when fitted to data, but have not stood test of time. |
| Selective fishing practices/policies | F | We have not yet looked closely at options in this area. |
| Regime shifts | C | Policy adjustments in response to ecosystem-scale productivity change. |

Unfortunately, so far, all of the predictive approaches seem to be more or less failing, some for obvious reasons, including:

- Lack of long term monitoring data on non-target species and life stages;
- Concentration of interaction effects (trophic, habitat) on early life stages (recruitment) that are difficult to monitor;
- Confounding of fishery, environmental, and trophic effects in historical data;
- Failure to anticipate 'new problems' (emergent novelty) due to unpredictable changes in system structure (e.g., exotic invasions, fisheries inventions, unexpected population changes); and/or
- Unpredictable pre-adaptations to habitat alterations.

Most ecosystem models today are age-structured. However, some older models (e.g., MSVPA, MSFOR) concentrated on estimating and predicting mortality rates for the older ages for which data are more readily available, while treating recruitment rates as ‘black boxes’ like we do in most single species models. Newer models (e.g., Ecosim) try to represent interaction effects at all life stages, particularly the higher mortality rates (and hence potential for change), habitat effects, and other factors affecting the recruitment component of the dynamics. However, at some stage this requires ‘real’ data for verification and testing of model behavior and predictions.

One hope has been that ecosystem models will somehow perform better than single species assessment procedures at prescribing single-species management actions, presumably by accounting more realistically for sources of population variation. That has happened in only a few very special situations; generally the single species prescriptions are very similar, since they are based on the same (unreliable) data. A more important hope has been to resolve uncertainties about importance of trophic interactions and fisheries interactions (e.g., by-catch, habitat damage) in causing conflicts among fisheries and between fisheries and other marine stakeholders; i.e., to answer ecosystem management questions that cannot even be asked with single species assessment models.

Attempts to test ecosystem models against historical data have revealed a set of potentially very serious weaknesses that will likely only be resolved through adaptive management experiments Thus, the modeling exercises should be used as aids in experimental design, rather than as trustworthy prescriptive tools. These weaknesses range from lack of information about major trophic components (e.g., mid-trophic level small fishes that have not been monitored in the past), via impacts of predation on recruitment processes that are technically difficult to measure, to ‘emergent’ impacts of species that were previously too rare to study. Furthermore, we can typically explain historical data equally well with a set of different models/hypotheses that make widely different policy predictions, especially in cases where historical effects of fishing and environmental change cannot be clearly separated.

Another serious impediment to development of useful ecosystem models has been the unwillingness by fisheries managers to clearly specify the set of actions or policy changes that would constitute an ‘ecosystem management’ program. Absent clear guidance about what policy options are to be compared, modelers have typically either tried to answer the wrong questions, or have chosen particular policy objectives regarding precautionary action and protection of non-consumptive values like biodiversity.

For example, assuming that the catch reconstruction undertaken by Zeller et al. (see later data section) is pointing in the right direction, then the Western Pacific region has an overwhelming and rapidly worsening regulatory problem with inshore fisheries. If anyone thinks more models, assessments or data collections are the answer, they should seriously ask themselves if that would not simply be procrastination. The options for dealing with this problem are:

- Ignore it (i.e., wait for bio-economic equilibrium at even more severely degraded state);
- Bandaid it (i.e., the approach taken in Florida: endless size and bag limit regulations to discourage fishers, lots of miniature MPAs that make people feel good but do not achieve anything ecologically); or
- Face it (i.e., immediately shut down all inshore fisheries, strictly enforce shut-down, reopen small areas/times of particular subsistence concern, initiate development of rights-based fishing systems).

In moving towards ecosystem-based management, what we really need is not 'better' models, but rather clarity and imagination about what to do differently, for example:

- Regulations that favor selective fishing, e.g., numerical quotas that create incentives to avoid taking smaller fish;
- Pulse rotation closures (of substantial spatial and temporal magnitude) that prevent erosion of biodiversity;
- TURFs with monitoring and enforcement responsibility; and
- Ecosystem-scale monitoring technologies.

Of special mention should be the observation that, particularly when fisher behavior is included, ecosystem models often predict highly 'counterintuitive' policy effects, even in terms of the direction of response. Such situations and experiences cry out for treating policies as experimental treatments, and emphasize the need to embed adaptive, experimental management firmly within the ecosystem-based management approach.

A word of caution to managers: If you want to get useful results from ecosystem models, be very careful to tell scientists exactly what policy options you want to examine with those models; otherwise scientists will give you the wrong answers to the wrong questions. Furthermore, ecosystem modeling for adaptive management would require a very different approach to assessment:

- Modelers would deliberately attempt to uncover alternative models that equally well explain historical data but imply very different policy choices:
  - Environment vs. fishing effects;
  - Environment vs. trophic effects;
- Policy options would include deliberate, diagnostic management experiments aimed partly at distinguishing among alternative models:
  - Spatial closures to test recovery predictions; and/or
  - Selective culling to test trophic interaction effects.

High uncertainty in ecosystem model predictions implies a clear need to treat all ecosystem management initiatives as adaptive management experiments. The problem is that you will probably fail to implement such experiments, because of:

- People who fervently believe that they already have the answers (i.e., know what policies to use);

- People who refuse to embrace uncertainty in policy design because they fear loss of credibility and authority;
- People who fear any risk of policy failure, and do not understand that ‘safe’ options are not safe; and
- The high cost of monitoring experimental responses, and/or high risks of investing in new technologies and institutional arrangements (e.g., data gathering by fisheries) to reduce monitoring costs.

## Session discussion

A question was raised about the kind of adaptive management experiments that would be the priority to explore our knowledge of models for management purposes. Prof. Walters replied that the key issue important in the Hawaiian area is ‘real MPAs’. He noted that he was not referring to small MPAs like Waikiki or relatively small gear closures, but rather ‘serious’ MPAs, big enough to have ecological integrity at an ecosystem and archipelagic scale. This would require experiments in institutional arrangements for management in both the outer islands (NWHI) and the main islands (MHI). Thus, this would essentially require experiments in governance, including stakeholder buy-in and participation, and governance associated enforcement and monitoring. Prof. Walters emphasized that this issue should be the priority.

Dr. Murawski added that ‘serious’ MPAs would also be helpful for scientific knowledge building in places where there is a sharp contrast, e.g., many of the MHI coastal areas. If it is an overfished area, and a properly monitored (before-after, replicated control-impact) and enforced ‘serious’ MPA is initiated, there will be a contrast developing over time in the population dynamics. Experience elsewhere has shown that such contrasts can occasionally be detected relatively quickly (i.e., within a few years), but generally may take many years or decades. Thus, it is always prudent to incorporate the long-term time horizon into the planning, governance, monitoring and enforcement aspects, and ensure stakeholder understanding of potential ecosystem time scales. Equally, if there is an area that is lightly or not exploited, one would probably want to do the alternative management experiment as well. Prof. Walters noted that such fishing/exploitation experiments could be enormously informative, if conducted at appropriates spatial and temporal scales, and comprehensively executed. A few of them have been done (e.g., on Australia’s Great Barrier Reef), and they provided a lot of insight.

Dr. Pooley indicated that there is a program at the NOAA Pacific Center called the Western Pacific Fishery Information Network (WPacFIN, www.pifsc.noaa.gov/wpacfin), which supported a ‘fishing out’ experiment in Guam a few years ago.

## *Western Pacific context*

### Paul Dalzell (WPRFMC): The Western Pacific Region and its Fishery Management Plans…

**The Western Pacific Region and its Fishery Management Plans: How far are they from ecosystem based fishery management?**

In 1976, the United States Congress passed the Magnuson Fishery Conservation and Management Act, which established eight quasi-federal Regional Fishery Management Councils to manage fisheries in the exclusive economic zone (EEZ) surrounding the United States. The Western Pacific Regional Fishery Management Council ('Western Pacific Council' or 'Council') is one such council, and is the policy-making organization for the management of fisheries in the exclusive economic zone (EEZ) adjacent to the Territory of American Samoa, Territory of Guam, State of Hawaii, the Commonwealth of the Northern Mariana Islands and the United States Pacific island possessions of Jarvis, Johnston, Wake, Howland and Baker Islands, Kingman Reef, and Palmyra and Midway Atolls (Figure 4). With a total EEZ area of 1.5 million $nm^2$, this is the largest area managed by any of the regional fishery management councils, and comprises about half of the total EEZ waters under United States jurisdiction. This tremendous area is spread across the Pacific dateline and the equator.

The original goals of the Magnuson Fishery Conservation and Management Act were to phase out foreign fishing in the U.S. EEZ and replace it with domestic fisheries. The Act has achieved its original goal; however, the expansion of domestic fisheries has in turn led to some of the problems that were faced through the 1980s and the 1990s with the depletion of some fishery resources and interactions with protected species.

Subsequently, the act was re-authorized in 1996 and is now known as the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). That re-authorization laid the groundwork for ecosystem-based fishery management by reinforcing requirements to end overfishing, rebuild overfished stocks, minimize by-catch and protect habitat. The Magnuson-Stevens Act also laid out 10 national standards to guide the future of fisheries management in the EEZ surrounding the United States. Every fishery management plan and plan amendment developed by Regional Fishery Management Councils have to address each of the 10 National Standards:

1. Prevent overfishing while achieving optimum yield;
2. Use best scientific information available;
3. Manage fish stocks as units;
4. Eliminate discrimination between residents of different states;
5. Consider efficiency;
6. Take into account variations and contingencies;
7. Minimize costs, avoid duplication;

8. Consider communities;
9. Minimize by-catch and mortality; and
10. Promote safety of human life at sea

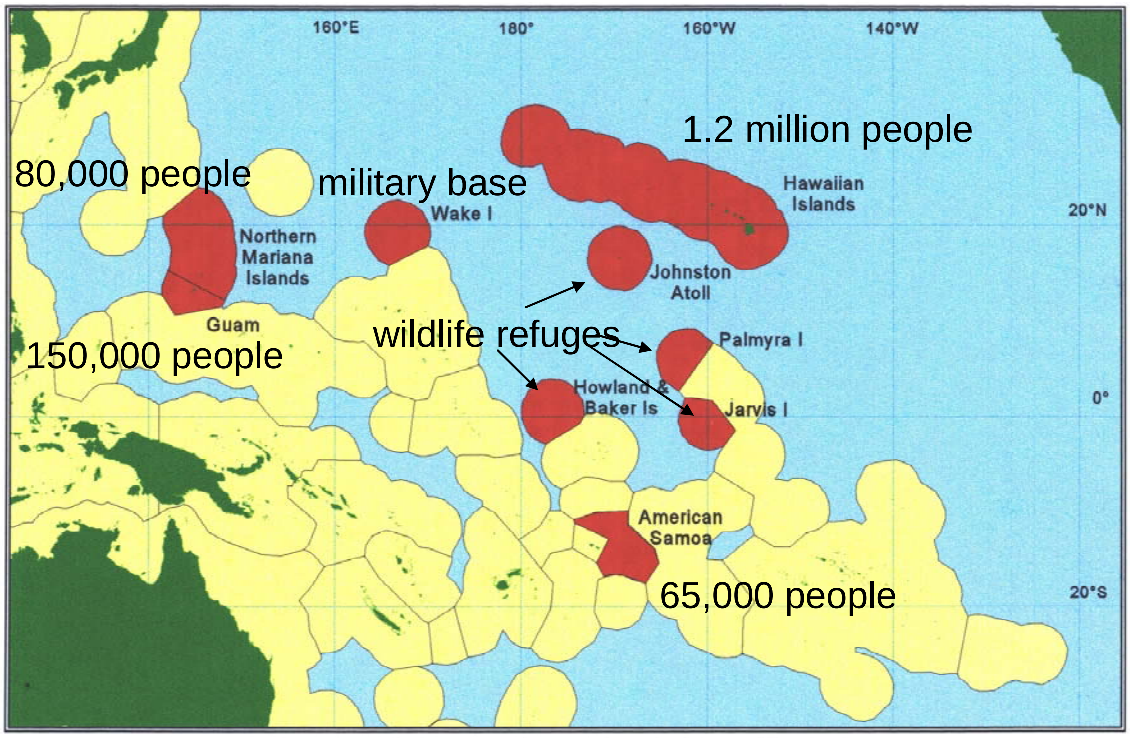



**Figure 4: U.S. EEZ in the Western Pacific Regional Fishery Management Council area of jurisdiction.**

The Magnuson-Stevens Act also laid out a process by which primary stakeholders, through the Regional Fishery Management Councils, play a substantial role in managing fisheries and resources in their respective areas. The Councils are made up of fishers and non-fishers knowledgeable about the fishery, as well as state and federal fisheries management personnel. Council members are appointed by the Secretary of Commerce for 3 year terms. The Western Pacific Council has 16 members; 3 of which are non-voting federal agency representatives. The current membership includes 13 voting members, 5 of which are local and federal fishery agency representatives.

The Western Pacific Council develops policies to manage fishery resources in the U.S. EEZ in the Western Pacific Region, prepares fishery management plans (FMPs) and plan amendments for fisheries and resources needing management, and provides a forum for discussion and decision making. The Council currently has five FMPs: ‘Bottomfish and Seamount Groundfish’, ‘Crustaceans’, ‘Precious Corals’, ‘Coral Reef Ecosystems’, and ‘Pelagics’. Given the nature of the Western Pacific region and its fisheries, all of the Council FMPs are multi-species plans dealing with species assemblages rather than individual species.

## Western Pacific Fishery Management Plans

Most of the domestic commercial fishing activities in federal waters surrounding the United States Pacific islands are variations of hook and line fishing. In Hawaii and American Samoa, longline fisheries dominate the fishing industries. Domestic commercial fishing activity in each region also includes hand-lining for large snappers and groupers on the outer reef slope, and trolling, hand-lining and longlining for pelagic fish. The now dormant trap fishery for spiny and slipper lobsters based in the remote Northwestern Hawaiian Islands (NWHI) was the only lobster fishery of any significance in the U.S. Pacific islands (lobster fishing continues in the Main Hawaiian Islands state waters). Mention should also be made of precious coral harvests, which have taken place in the past in federal waters in Hawaii, and are currently active in state waters. Harvesting of precious corals in Hawaii is conducted with SCUBA gear in shallow waters and is conducted by submersibles in deeper water.

Bottomfishing is conducted throughout the region, but is only of economic significance in Hawaii, where it represents a small fraction of total landed value of all catches. Most bottomfishing grounds in American Samoa, Guam, the Northern Mariana Islands and the Main Hawaiian Islands (MHI) are within the 0-3 nm zone and thus fall under state or territorial jurisdiction. However, the NWHI represents a substantial area of bottomfishing grounds within Council jurisdiction, and there are significant bottomfishing banks and seamounts in the MHI, such as Penguin Bank, that lie within or extend into federal waters. The four island groups also have a variety of small-scale inshore fisheries for reef fish, mostly within the 0-3 nm zone. The Council's newly developed Coral Reef Ecosystem Fishery Management Plan provides the Council with jurisdiction over any reef fishing conducted in federal waters.

### Bottomfish and Seamount Groundfish FMP

The Bottomfish and Seamount Groundfish FMP implemented in 1983 manages a multi-species complex of snappers (Lutjanidae), groupers (Serranidae), emperors (Lethrinidae) and jacks (Carangidae), and several species of seamount groundfish. The plan prohibits destructive fishing techniques, including explosives, poisons, trawl nets and bottom-set gillnets; establishes a moratorium on the commercial harvest of seamount groundfish stocks at Hancock Seamount; and implemented a permit system for fishing for bottomfish around the NWHI.

In 1988, the Council developed regulations that divided the NWHI into two fishing zones: the Mau and Hoomalu Zones (Figure 5). Access to the Mau Zone is limited to 10 permits, two of which are reserved for indigenous communities. Available permits are issued to fishers based on past participation in the MHI and/or NWHI bottomfish fisheries. Access to the more distant Hoomalu Zone is limited to seven permits, and entry is through accumulation of points through fishing in the MHI or Mau Zone. Fishers who have permits to fish in one zone may not fish in the other zone, and must meet minimum annual landing requirements to retain their permits.

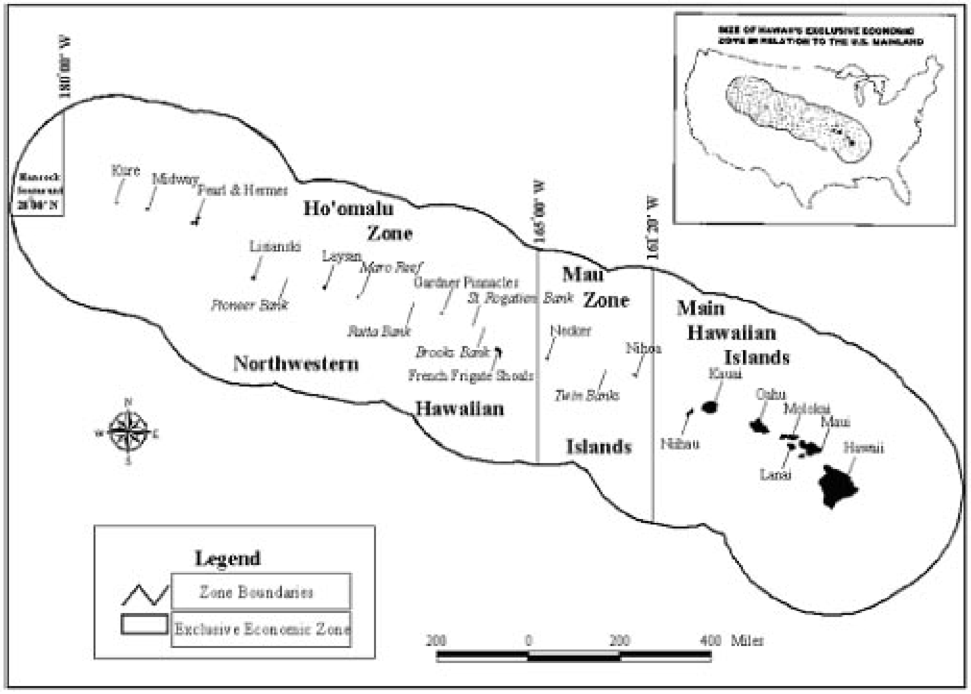



**Figure 5: The Mau, Ho'omalu, and Main Hawaiian Islands management zones.**

In addition to the deep-slope fisheries in the MHI and NWHI, a trawl and bottom longline fishery targeting Alfonsin (*Beryx* spp.) at the southeast Hancock Seamount in the NWHI and the Emperor Seamount Chain was initiated by Russian and Japanese fishing vessels in the late 1960s. After 10 years of high catches, overfishing caused the fishery to collapse. A moratorium on the harvest of Alfonsin on the Hancock Seamounts has been in effect since 1986 in an effort to rebuild the stock. The moratorium was initially in effect until 2004, but has been extended. Periodic reviews of the stock indicate that no recovery has occurred.

Crustaceans FMP

The NWHI lobster fishery developed in the late 1970s with several commercial vessels, relocated from the U.S. Pacific Northwest coast where crustacean overfishing was occurring. By the mid-1980s the NWHI lobster fishery was Hawaii's most lucrative fishery.

Under the Council's Crustacean Fishery Management Plan, implemented in 1983, 20 mile closed areas around Laysan Island and 0-10 fathoms depth closures throughout the remaining NWHI were established as a spawning refuge zone and to protect monk seals. Also, regulations required that traps deployed in the NWHI lobster fishery have juvenile escapement panels. Council also amended the Crustacean FMP to specify the maximum dimensions of the trap funnel entrance, to minimize the risk the traps posed to protected monk seals. In 1990, lobster catch rates dramatically declined, likely due to a climate-induced change in oceanic productivity throughout the NWHI, which also affected the abundance of reef fish, seabirds and Hawaiian monk seals. The decrease in lobster catch prompted the Council to establish a limited access program and fleet-wide seasonal harvest quotas that significantly altered fishing operations.

Vessels concentrated on trapping lobsters on the banks around Necker Island, Gardner Pinnacles and Maro Reef during the derby-style fishing season. From 1992 to 1997 Necker Island accounted for 48-64% of the total effort. In 1998, the quota was allocated among four fishing areas to prevent localized depletion of the lobster population at the most heavily fished banks, and to encourage fishers to broaden the geographical distribution of their effort.

The lobster harvest guidelines are an example of implementation of the precautionary approach to fisheries management, as they allowed only a 10% risk of overfishing to set the total exploitable population, and allocate 13% of that as the harvest guideline. Initially, a minimum size limit of 5 cm tail width for spiny lobsters and 5.6 cm for slipper lobsters was established, along with a ban on the retention of berried females. However, observations on the mortality of discarded lobsters, both on deck and through predation, led to a Council decision in 1996 to permit a ‘take all’ fishery in which all lobsters brought on deck were counted against the annual quota. The Hawaii lobster fishery landed 261,000 pounds with ex-vessel revenue of $1.2 million in 1999, which was the last year the fishery was active.

The majority of the vessels participating in this fishery voluntarily deployed satellite VMS for vessel location tracking and daily catch reporting. This allowed managers to monitor the progress of the fishery through ‘real time’ reporting of catches and gave immediate notice when annual quotas were reached.

While calculating the year 2000 estimates of exploitable population of lobsters in the NWHI, NMFS scientists expressed alarm at the increasing level of uncertainty in their computations. The scientists also noted a lack of appreciable rebuilding of lobster populations, despite significant reductions in fishing effort throughout the NWHI. Given these concerns, the Council in 2000 recommended that NMFS close the NWHI lobster fishery as a precautionary measure, until the stock status is understood.

Precious Coral FMP

The Western Pacific Council’s Precious Corals FMP was approved in 1980 and regulations for the fishery were promulgated in 1983. The plan established a permit requirement, harvest quotas for separate beds, a minimum size limit for pink coral, gear and area restrictions, and fishing seasons. In 1991 an amendment to the FMP defined a bed as overfished with respect to recruitment when the total spawning biomass (all species combined) has been reduced to 20 percent of its unfished condition.

The Hawaii precious coral fishery includes two distinct sectors. One sector extracts deep-water (400-1,500 m) pink, gold and bamboo corals. This fishery historically employed dredges and tangle nets to extract the precious coral, but the Council now requires selective methods, such as remotely operated vehicles and submersibles. Starting in 1973, Maui

Divers of Hawaii, adopted the use of a manned submersible to commercially extract pink, gold and bamboo coral at the Makapuu bed. These operations were discontinued in 1978 due to high operating costs. In 2000, American Deepwater Engineering collected precious corals at the Makapuu bed and in the Exploratory Area of the EEZ around the MHI. New precious coral beds continue to be discovered in the Hawaiian Islands archipelago, with new beds identified in both the MHI and NWHI during 2002 and 2003.

The second sector of the Hawaii precious coral fishery, which occurs predominantly in state waters, involves hand-collecting black coral using SCUBA divers at depths of 30-100 m. Since the inception of the black coral fishery in Hawaii in the late 1950's, fewer than 10 individual fishers have been active in the fishery at any one time. Harvest levels of black coral in Hawaii have fluctuated widely over the past four decades reflecting changes in demand. During the 1970's, the State of Hawaii drafted regulation requiring a minimum height of 48 inches, the estimated minimum size for maintaining maximum sustainable yield. In the 1990's, the state promulgated regulations to implement the size restriction. Between 1990 and 1997, the annual harvest of black coral in Hawaii ranged between 846-6,017 lb, with an annual average of 3,084 lb.

Much of the basic biology of deep-water precious corals (particularly gold coral), as well as their distribution, is poorly understood. Furthermore, there is controversy over the degree of adverse effects a NWHI precious coral fishery would have on populations of endangered Hawaiian monk seal. Although monk seals have been observed preying on eels found among precious coral colonies, the importance of eels in the monk seal diet is unknown.

## Coral Reef Ecosystem FMP

The Western Pacific Council's 2001 Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region was the first ecosystem-based plan for fisheries developed in the United States. It incorporates many of the principles and policies recommended by NMFS's Ecosystem Principles Advisory Panel. The goal of the FMP is to establish a management regime for the entire Western Pacific Region that will maintain sustainable coral reef fisheries, while preventing adverse impacts to stocks, habitat, protected species and the ecosystem. To achieve this goal, the FMP implements several management measures, including (a) designation of zoned Marine Protected Areas (MPAs); (b) permit and reporting requirements to fish in designated low-use MPAs (reporting of fisheries information in non-MPA areas will continue to be collected through locally administered monitoring systems), and if needed, a general permit program for all EEZ reef fisheries; and (c) a prohibition on non-selective/destructive fishing gears, and conditions on the types and uses of allowable gears.

The central feature of the Coral Reef Ecosystems FMP is adaptive management, which recognizes the uncertainty, changing conditions and resilience associated with coral reef ecosystems. Pacific island management systems for coral reef ecosystems have allowed Pacific islanders to survive for millennia by coexisting with coral reef resources and are best viewed as adaptive responses that have evolved over time, not as mere traditions.

Pelagics FMP

The Pelagics FMP, implemented in 1986, manages a number of species of tuna, billfish, pelagic sharks, wahoo, mahi, mackerel, gempylids, and pomfrets. The FMP banned the use of drift gillnets in the EEZ, established a limited entry permit and reporting program for longliners in Hawaii and American Samoa. The Council is now considering actions to limited entry for certain hand-line fisheries in Hawaii as a means to reduce overfishing of bigeye tuna. The FMP also prohibits longline fishing within 50 miles of the NWHI to prevent interactions with monk seals and other protected wildlife residing in the area. The FMP further closes large areas around the MHI and American Samoa to longlining to eliminate gear interactions between longliners and small-vessels engaged in hand-line and troll fishing for pelagics.

A significant component of the pelagics fisheries management regime is the conservation of sea turtles and seabirds. The Council's Protected Species Program includes several turtle conservation projects at nesting beaches and foraging grounds on the Pacific Rim and also testing and implementing turtle and seabird mitigation techniques and strategies.

## Western Pacific Ecosystem Based Fishery Management Initiatives

In working toward incorporating ecosystem-based management principles in Western Pacific fisheries management, the Council is considering managing fishery resources sub-regionally on an archipelagic basis. Under this approach, a Fishery Ecosystem Plan (FEP) would be developed for each geographic area under the Council's jurisdiction. For example, an FEP would be developed to manage fishery resources for the Mariana Islands Archipelago (Guam & CNMI), one for the Hawaiian Islands Archipelago, one for the Samoa Islands (American Samoa and possibly Western Samoa), and one for the Pacific Remote Islands. Within each FEP, benthic associated fishery resources (i.e., bottomfish, crustacean, coral reef ecosystems and certain precious coral management unit species) would be included and managed together. Although pelagic resources are a part of each island area's ecosystem, the Council is considering management of pelagic fisheries independently under a single Western Pacific Pelagic FEP. This is based on considerations of the larger international issues involved in this fishery.

To conclude, of immediate importance, from the Council's perspective, is gaining an understanding of the relationship between managing fisheries on an ecosystem interaction level rather than managing fisheries by traditional single species management approaches. Additionally, particular emphasis will need to be placed on the development of limit reference points, indicators, and performance standards for fishery regulations. Recognizing that ecosystems are neither static nor predictable, the basic tenets of ecosystem-based management must be founded on a precautionary basis within an adaptive management approach.

## Gerard DiNardo (NMFS, Honolulu): The Western Pacific Council's stock assessments…

**The Western Pacific Council's coral reef stock assessment and bottomfish stock assessment workshops**

In early 2004, the Western Pacific Council convened two workshops to address the needs for stock assessments of coral reef fish and deep slope bottomfish for the Western Pacific Region. The objective of the coral reef stock assessment workshop was to develop a plan to improve data collection and assessment methodology to a point where reliable resource assessments can be undertaken; while the objective of the bottomfish stock assessment workshop was to develop a plan to improve data collection and assessment. Expert panels were assembled for each workshop. For the coral reef stock assessment workshop, the panelists were Jerald Ault, Gavin Begg, Neil Gribble, Michel Kulbicki, Bruce Mapstone and Paul Medley. For the bottomfish stock assessment workshop, the panelists were Stephen Ralston, Sean Cox, Marc Labelle and Chris Mees. A series of short-, medium- and long-term recommendations were generated by each workshop, and are briefly summarized here collectively:

Short-term recommendations

- Define management objectives (short- and long-term) and management units (single species, species complex, etc.);
- Review, synthesis and analysis extant biological, ecological, and fishery data relative to management needs, and identify gaps;
- Based on gap analysis, design and implement fishery-dependent data collection programs and fishery-independent research/monitoring programs at appropriate spatio-temporal scales in the Pacific Islands region;
- To ensure compatibility, data should share sufficient common information in consistent formats to allow straightforward linking among data sets;
- Complete habitat inventory (e.g., multi-beam acoustic surveys) with measures of habitat suitability, and map habitat and associated biota;
- Review existing stock assessment models and re-assess under a variety of different scenarios; and
- Acquire funding and hire/contract necessary personnel to complete tasks.

Medium-term recommendations

- Combine data on common species collected in the bottomfish and coral reef fisheries for assessment purposes;
- Advance assessment tools through application of spatially structured models;
- Develop operational models for evaluating approaches to stock assessment and management; and
- Conduct pilot program to assess the feasibility of using hydroacoustics to survey bottomfish populations.

Long-term recommendations

- Assess meta-population structure of bottomfish stocks and recruitment connectivity between the MHI and NWHI;
- Investigate possibility that groupers aggregate to spawn in EEZ waters of the Western Pacific region; and
- Review existing stock assessment models.

## Session discussion

A question was raised on the state of knowledge about interconnectivity between the MHI and NWHI, and whether it is unidirectional. Dr. Dalzell suggested that the general belief is that there may be an east/west movement, that is, from the MHI to the NWHI. However, modeling undertaken of the dispersal of lobster larvae by Dr. Jeff Polovina's group at the Pacific Islands Fishery Science Center indicated that interconnectivity exists in both directions, and may be influenced by vertical migration and other larval behavior patterns. There are other signs of connectivity, e.g., taape (*Lutjanus kasmira*) was introduced into the MHI, but has dispersed to the NWHI, now being found as far north-west as Kure Island. With respect to larval dispersal, it appears that at least lobster larvae in the NWHI move both north-west and south-east along the chain. A practical implication of this issue relates to source- and sink-opportunities for stocks that are exploited in the MHI.

Dr. Polovina added that there are two factors that may influence connectivity between the NWHI and the MHI (see Dr. Polovina's presentation under Models below). First is the surface flow which moves predominantly north-west along the Hawaiian ridge as a response to the predominant tradewinds, in combination with Eckman transport. The deeper flow - the geostrophic flow - is part of the subtropical gyre, and predominantly flows south-east. Important also are eddies that generate around the islands and archipelago, and these typically propagate from east to west across the ridge, and can retain larvae for some time. Inter-annual variability influences this pattern.

It was suggested that concerns about connectivity between populations should not be restricted to connectivity within the Hawaiian Archipelago. For example, genetic analysis of Hawaiian bottomfish stocks suggested linkages with Johnston Atoll.

A question was raised about the next steps in furthering an ecosystem perspective within the context of the Council's multi-species FEPs. For example, by taking into account species interactions or regime shifts. Dr. Dalzell responded that the Pelagics FMP is likely the most advanced, given that NOAA's Pacific Science Center has been primarily pelagic focused in the past. This suggests that the transition from the Pelagics FMP to the Pelagics FEP would probably be the easiest transition. With the upcoming transition for the other FMPs, there will a requirement for more focused work on near-shore and benthic ecosystems.

It was suggested that one of the major problems encountered in assessment, both single-species assessments as well as ecosystem modeling, is determining the information and knowledge base. It appears that the actual assessment and modeling requires approximately five percent of the total time. The majority of the time is spend undertaking library and archival data-detective work, trying to determine and locate the data- and information-base. A fundamental question to be answered is who has the responsibility for doing this data-scavenging work needed for ecosystem-based fisheries management. Dr. Pooley noted that, if NOAA is going to do ecosystem-based modeling, assessments and management, then it would be the responsibility of NOAA's Pacific Islands Fisheries Science Centers and associated scientists to pull data and information together.

## *Data sources A: Fishery dependent data*

This session discussed available fishery dependent information for the development of ecosystem approaches to marine resource management in the Western Pacific region, and reviewed existing physical, biological, and economic data. The discussions focused on potential uses of these data for ecosystem-based management as well as gaps in the overall understanding of keys issues, including issues associated with historic population levels of commercial and recreational stocks.

### Kurt Kawamoto (NMFS, Honolulu): Fishery dependent data for ecosystem management

This presentation provided general information on the types of datasets available, and the agency responsible for their collection and maintenance (Table 3). NOAA National Marine Fisheries Service currently monitors four FMPs in Hawaii - the pelagic longline fishery, the NWHI lobster fishery (currently closed), precious corals, and bottomfish. The longest running data set with detailed size data (originally designed for economic data collection purposes) comes from the Honolulu Fish Auction, and has been conducted since at least 1948. In 2001, the State of Hawaii's Commercial Marine Dealer's Report replaced previous economic monitoring instruments. Data and information on the longline and bottomfish fisheries are provided by four sources; logbooks, the Honolulu fish auction, the dealer's reports, and the limited at-sea observers program (see presentation by Russell Ito below for more details on pelagic longline fisheries). Based on a data sharing agreement between the State of Hawaii and NOAA, analysts from NMFS also have access to all state data sets through the Western Pacific Fisheries Information Network (WPacFIN, www.pifsc.noaa.gov/wpacfin/) at NOAA's Pacific Islands Fisheries Science Center.

Examples of the details of the monitoring instruments and resultant datasets are given for both the federal NWHI Lobster FMP Fishery and the State of Hawaii Lobster Fishery in Figures (6 and 7). Fishery monitoring instruments for the Federal NWHI Bottomfish FMP Fishery are presented in Figure (8), while the monitoring approaches for detailed biological information is illustrated in Figure (9).

In summary, a variety of fishery dependent datasets exist. However, data quality differs depending on data type (e.g., catch versus effort), and varies over time.

**Table 3: Inventory of fishery dependent data for Hawaiian archipelago.**

| Responsible agency | Dataset name | Details |
|---|---|---|
| Federal | | |
| (FMP reporting requirements) | Pelagic longline | Daily longline logbook |
| | | Transhipment logbook |
| | NWHI lobster fishery | NWHI Crustacean daily logbook |
| | | Trip sales report |
| | Hawaii precious coral fishery | Daily logbook |
| | | Sales report |
| | NWHI bottomfishery | Trip daily logbook[a] |
| | | Trip sales report[a] |
| Federal | | |
| (other datasets) | PIRO longline observer (mandatory) | Economic data survey (trip) |
| | PIRO bottomfish observer (intermittent) | Economic data survey (trip) |
| | Honolulu fish auction data | NWHI bottomfish (size & sales) |
| | | Pelagic longline (size & sales) |
| | | Other (size & sales) |
| State of Hawaii | | |
| | Fishers catch report (commercial license) | |
| | Dealer's report | |
| | Longline trip report | |
| | Tuna handline trip report | |
| | Aku boat report | |
| | Baitfish report | |
| | Albacore trolling trip report | |
| | Crustacean trip report | |
| | Deep sea handline trip report | |
| | Net, trap, dive activity report | |
| | Aquarium fish cacth report | |
| | Pond operator's monthly report | |
| | NWHI bottomfish trip daily report[a] | |
| | NWHI trip sales report[a] | |

[a] State form, federal data requirement

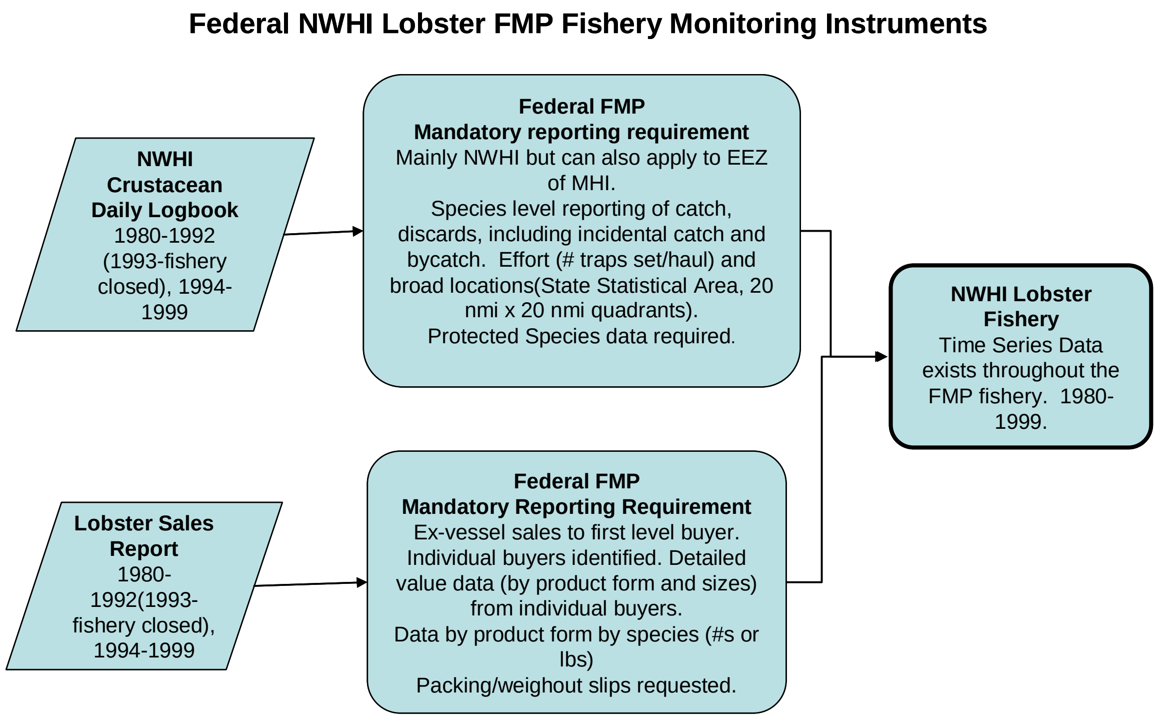



**Figure 6: Fishery monitoring instruments and resultant datasets for the Federal NWHI Lobster FMP Fishery.**

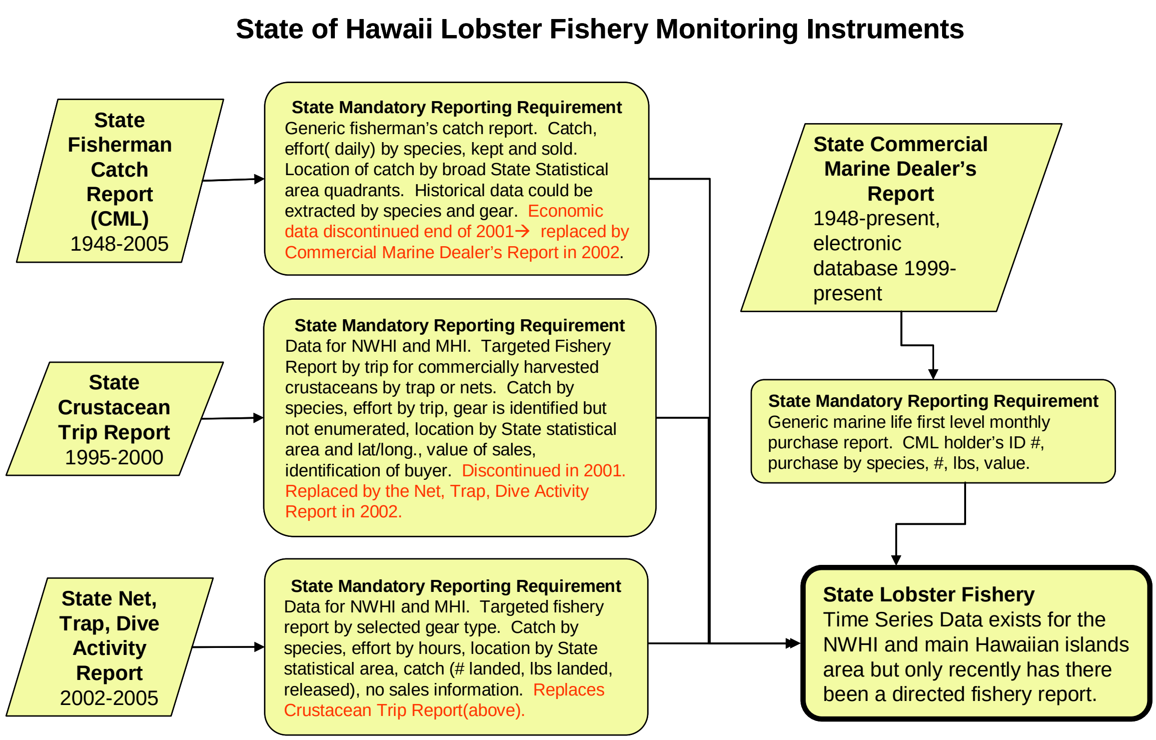



**Figure 7: Fishery monitoring instruments and resultant datasets for the State of Hawaii Lobster Fishery.**

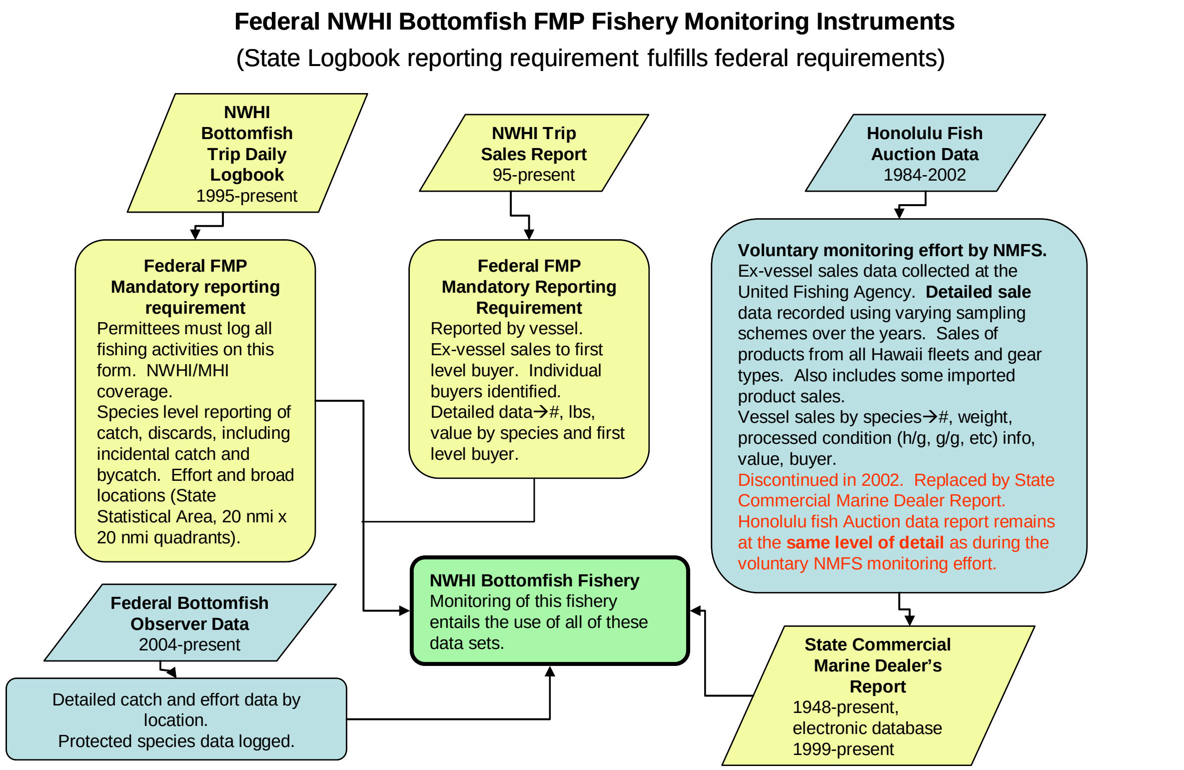



**Figure 8: Fishery monitoring instruments and resultant datasets for the Federal NWHI Bottomfish FMP Fishery.**

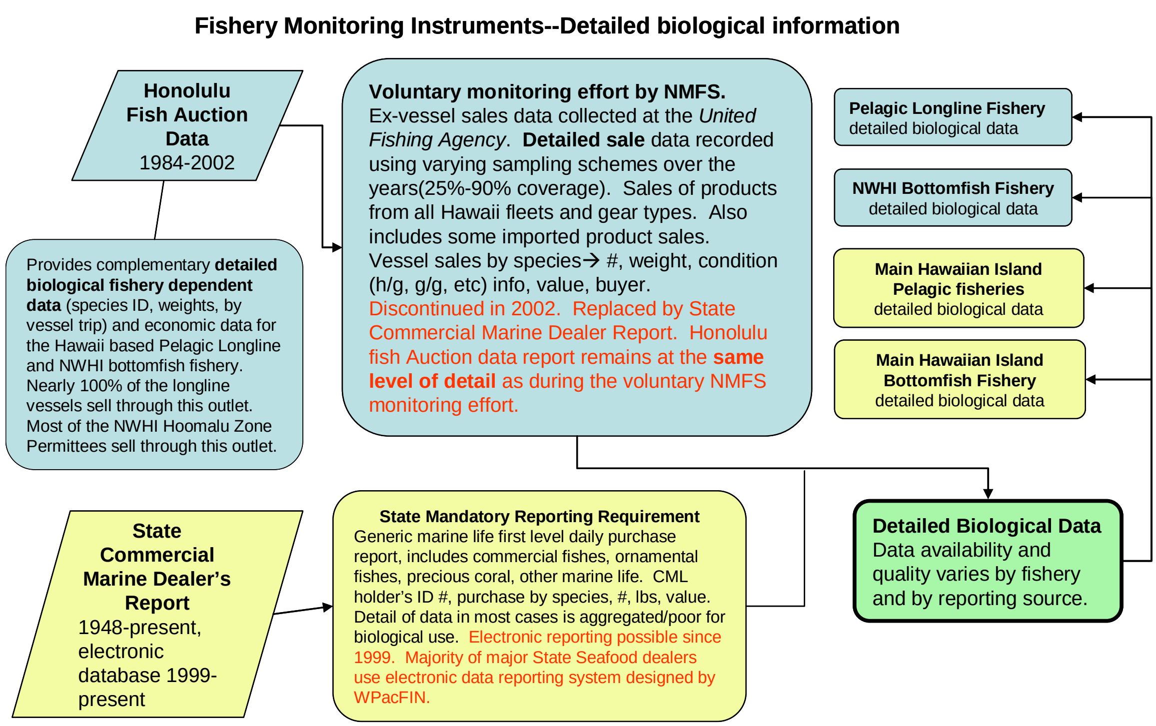



**Figure 9: Monitoring approaches and resultant data for detailed biological information for Hawaiian fisheries.**

## Russell Ito (NMFS, Honolulu): Fishery dependent data for the Hawaii-based longline fishery

The Hawaii-based pelagic longline fisheries is the economically most valuable fishery in Hawaii, and its fleet fishes in waters close to Hawaii, but often outside of EEZ waters (Figure 10). Fishery dependent data for the Hawaii-based pelagic longline fleet comes via both federal and state reporting requirements, whose details are listed and compared in Table (4).

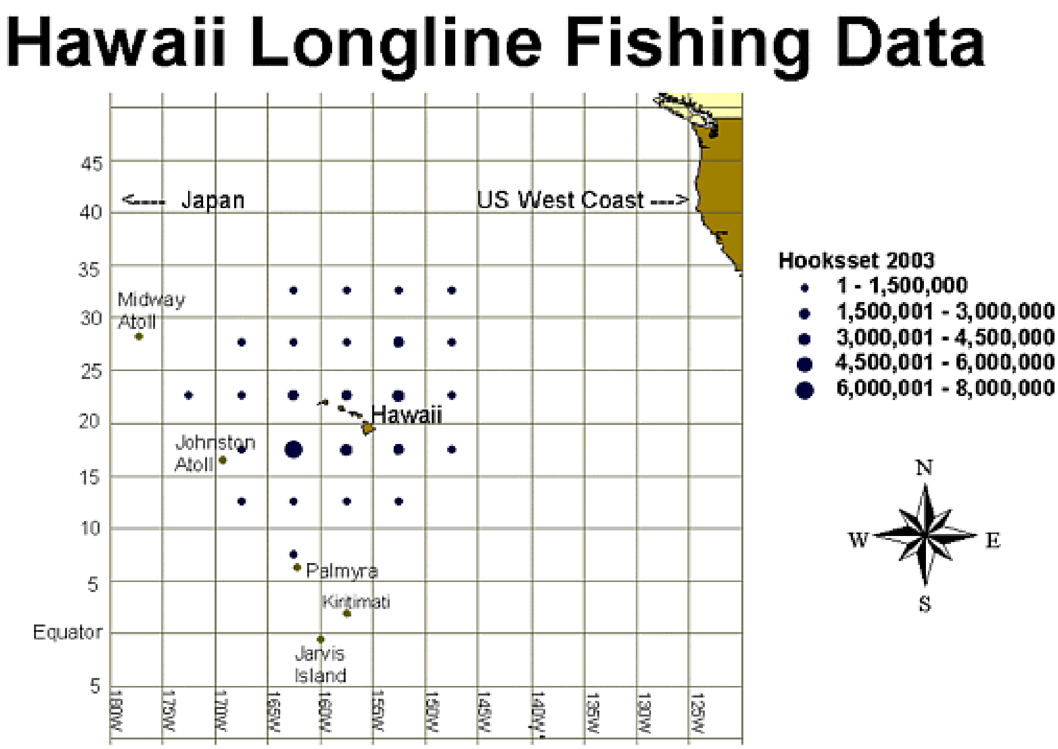



**Figure 10: Example of the spatial distribution of effort (2003 hooksets) of the Hawaii-based pelagic longline fishery (www.pifsc.noaa.gov/fmep/charts/index.html).**

**Table 4: Comparison of federal and state fishery dependent data collection mechanisms for the Hawaii-based longline fishery.**

| Item | Federal | | | State | | |
|---|---|---|---|---|---|---|
| | **Logbook** | **Fish auction** | **Observer** | **Catch report (C-3)** | **Trip report (C-5)** | **Fish dealer report** |
| **Key taxa** | Macro pelagic | Macro pelagic | Macro pelagic | Macro pelagic | Macro pelagic | Macro pelagic |
| **Geographic region** | Pacific | Pacific | Pacific | Pacific | Pacific | Pacific |
| **Sampling interval** | Daily | Random day | Daily | Monthly | Trip | Date of sale |
| **Duration** | 1990-present | 1987-2001[a] | 1990-1994 (voluntary), 1994-present (mandatory) | 1948-present | 1948-2001[b] | 1948-present |
| **<u>Parameters reported</u>** | | | | | | |
| **Date** | Date of operation | Date of landing | Date of operation | | | |
| **Location** | Lat. Long. | | Lat. Long. | State Stats. Areas | Lat. Long. | |
| **Effort** | Hooks set | | Hooks set | | | |
| **Biological data** | Catch # | # & weight | Length | Catch # & weight | Catch # & weight | Catch # & weight |
| | Species | Species | Species | Species | Species | Species |
| | Protected spp. interactions | | Protected spp. interactions | | | |
| | | Price and buyer of individual fish | | Value and buyer | Value and buyer | Value, buyer & fisher |

[a] Superceded by state dealer data. [b] Replaced by federal data.

## Michael Quach (NMFS, Honolulu): Fishery dependent data, WPacFIN

The Western Pacific Fishery Information Network (WPacFIN) was established by NOAA in 1981, with the mission to provide the best available fisheries data on a timely basis for use in managing fisheries resources in the U.S. Pacific EEZs. One of WPacFIN's key objectives is to assist U.S. Pacific islands fisheries agencies to establish and maintain monitoring programs by providing technical support and tools, including:

- Data collection system design and analysis;
- Computerized data processing system design and development;
- Data analysis and report generation;
- Training in all aspects of fisheries monitoring; and

- Secondary offsite data archived depository.

Four local member agencies are partners in this program:

1. American Samoa, Department of Marine and Wildlife Resources;
2. Commonwealth of the Northern Mariana Islands (CNMI), Division of Fish and Wildlife;
3. Guam, Division of Aquatic and Wildlife Resources & Bureau of Statistics and Plans; and
4. Hawaii, Division of Aquatic Resources.

General information and all data can be accessed freely through the Network's website (www.pifsc.noaa.gov/wpacfin). The overall approach attempts to utilize four monitoring programs and covers four types of fisheries (Figure 11).

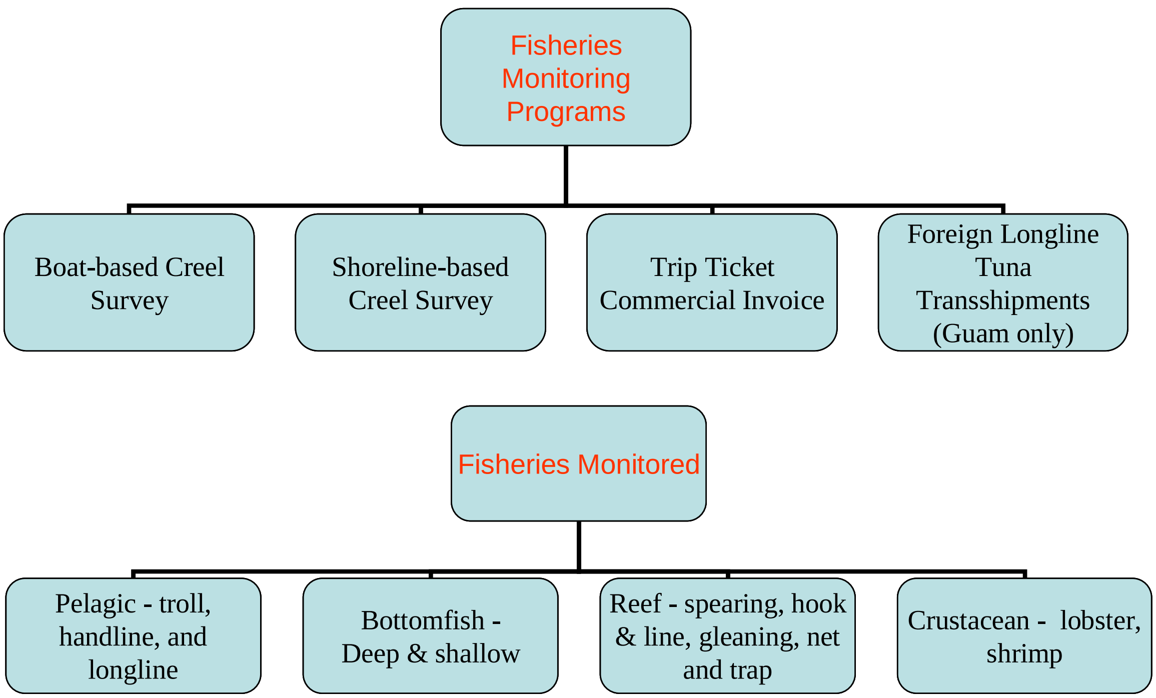



**Figure 11: General components of the U.S. Pacific islands long-term fisheries montiroing program developed and supported through WPacFIN.**

However, coverage, duration and frequency of programs differ between island entities, with little or not data available for earlier decades. As Hawaii was covered in previous presentations, this presentation focused on American Samoa, CNMI and Guam. Boast-based creel surveys are conducted at boat ports or ramps, and data collection consists of two main components - participation counts (trips) and fisher interviews. Survey days are randomly selected, and number of survey days range from 3-8 per month. Surveys are stratified by week-days, weekend-days and day- and night-time. Data expansion algorithms are applied consistently and are based on port, type of day, and fishing method. Summary details by island entities are presented in Table (5).

**Table 5: Boat-based creel survey data.**

| Island | Sampling interval | Data available | Parameters measured |
|---|---|---|---|
| American Samoa | 3-4 times/week, week-day and weekend, day and night | 1985-present | Length, weight, catch, species composition, gear, method, effort |
| CNMI | 6-8 times/month, week-day and weekend, daytime only, night-time as of March 2005 | 2000-present | Length, weight, catch, species composition, gear, method, effort |
| Guam | 2-4 times/week, Week-day and weekend, Day and night | 1985-present | Length, weight, catch, Species composition, Effort |

The shoreline-based surveys focus on accessible shorelines, and data collection consists of two components - participation counts and fishers interviews. Participation counts are based on a 'bus route' method, with predefined stopping points and time constraints. In Guam, aerial surveys are also used for participation counts to quantify fishing on less accessible shorelines. Survey days are randomly selected, and range from 2-4 times per week. Data expansions are based on island region, type of day and fishing method. Summary details by island entities are presented in Table (6).

**Table 6: Shoreline-based creel survey data.**

| Island | Sampling interval | Data available | Parameters measured |
|---|---|---|---|
| American Samoa | 3-4 times/week, week-day and weekend, day and night | 1991-1994, 2002-present | Length, weight, catch, species composition, effort |
| Commonwealth of the Northern Mariana Islands | 2-4 times/week, week-day and weekend, day and night | Begin 2005 | Length, weight, catch, species composition, effort |
| Guam | 2-4 times/week, Week-day and weekend, Day and night | 1985-present | Length, weight, catch, species composition, effort |

The program for Trip Ticket Commercial Invoices attempts to monitor fish sold locally. Data collection depends on invoices submitted by vendors (fish dealers, hotels, restaurants) who purchase fish directly from fishers. Each invoice usually compiles daily trip catches. Only American Samoa has mandatory requirements for vendors to submit invoice reports, the other islands have voluntary programs. Summary details by island entities are presented in Table (7).

**Table 7: Trip ticket commercial invoice program details.**

| Island | Sampling interval | Data available | Parameters measured |
|---|---|---|---|
| American Samoa | On-going daily sale trip tickets | 1990-present | Fisher, buyers, weight, price, value by species or species group |
| Commonwealth of the Northern Mariana Islands | On-going daily sale trip tickets | 1983-present | Fisher, buyers, weight, price, value by species or species group |
| Guam | On-going daily sale trip tickets | 1981-present | Fisher, buyers, weight, price, value by species or species group |

Guam also records information on tuna transshipments, consisting of a census of foreign longline trips that offload for transshipment out of Guam. The data collection depends on submission of transshipment agent's reports that are required by Guam's Customs Authority. Transshipment forms capture species, pieces and weight of fish transshipped, as well as fish that are rejected (which are generally sold on local markets).

## Summary

This series of presentations described the current and historic fishery dependent data sets from Hawaii and other areas of the Western Pacific, including log books, creel surveys, and observer data. Presenters described how these data are currently collected and maintained, how they are integrated with historic data sets, and how data managers are attempting to ensure regional consistency across data sets.

## Session discussion

Discussion focused on the temporal extent of some of the data, cross-validation of data (e.g., logbook, observer, and dealer reports), and data quality. Mr. Kawamoto and Mr. Ito were asked if they could discuss any efforts made to validate the data, to determine biases, completeness, accuracy etc., for both the state and the federal data. They responded that there is cross-referencing across the three datasets at the federal level, that is, the logbook data, the observer data, and the market data. The data sets constitute a triad, which is used to verify if fishers are accurately reporting their catch. With regards to data quality, it was suggested that observer data is typically the best quality data with respect to interactions with protected species, but there are also species identification problems for tuna. Dr. Pooley added that it is generally assumed, and has been validated, that the auction data are relatively accurate on species identification.

Prof. Walters asked how comfortable the Center is with reports of the mean body weight, as these catch characteristics can be a very powerful stock assessment indicator of mortality rates, and there is a controversy, at least for tuna and marlins, whether size at capture has declined substantially since the 1950s. Mr. Ito responded that this has to be looked at with caution. The areas fished has changed, so has the gear, and fishers will try to catch what is most valuable at any given time, so there are a lot of caveats when these data are analyzed. Nevertheless, the time series does not show any clear downward trend, but the data demonstrate considerable difference if a vessel sets deep and targets tunas versus setting shallow and targeting swordfish.

The issue of use of satellite Vessel Monitoring Systems (VMS) to monitor and record vessel location was mentioned as a excellent opportunity for spatial effort assessment. However, the Council's current policy is to use VMS only for enforcement, not research. With regards to creel surveys, there was a suggestion that more analysis needs to be done with this extensive data set. For example, mean body weight was suggested as a powerful stock assessment tool. However, the current weight data have many caveats.

An observation was made that while there may be a lack of data for some topics, there is also a surplus of data in other topics. Some of these data may be at risk of being lost and need to be recovered. It was suggested that establishing a fishery school at the University of Hawaii might be one way to create a pool of trained personnel needed to analyze the historical data. This would require dedicated long-term funding and commitments from state and federal institutions.

## *Data sources B: Resource and habitat data*

This section focused on recent and historic efforts to characterize the physical and biological marine resources associated with the islands and atolls of the Western Pacific region.

### Russel Brainard (NOAA, Honolulu): Multi-disciplinary monitoring, mapping and research data…

**Multi-disciplinary monitoring, mapping and research data for conservation and management of the coral reef ecosystems of the US-affiliated Pacific Islands**

This presentation gave an overview of efforts over the past five years to map and characterize shallow benthic habitats and associated fish and invertebrate communities on coral reef ecosystems of the U.S.-affiliated Pacific islands. Much of this work is funded by NOAA's Coral Reef Conservation Program, and the program partners with numerous federal (e.g., FWS, EPA, USCG), state (e.g., Hawaii - DLNR-DAR, Guam - DAWR) and academic and NGO agencies (e.g., UH, UCSC, JCU, CoML). The program applies a multi-disciplinary ecosystem approach, and includes mapping and monitoring activities:

- Benthic habitat mapping:
  - Shallow and deep water mapping;
  - Habitat utilization patterns;
- Long-term ecological monitoring:
  - Fish, coral other invertebrates, algae;
  - Water column biota (bioacoustics etc.);
- Long-term oceanographic monitoring:
  - Processes influencing ecosystems;
  - Hydrodynamic modeling;
- Ecological interactions:
  - Biophysical and trophic linkages; and
  - Ecosystem modeling.

The benthic habitat mapping integrates deep and shallow water mapping, using a variety of tools ranging from IKONOS satellite imagery to small-boat based multi-beam surveys, with ground-truthing ranging from use of ROVs to standard towed diver surveys. The approach taken is thematic, combining bathymetry, imagery, rugosity measures and habitat classifications. Mapping is integrated with ecological assessments via habitat utilization patterns, and provides boundary conditions for coupled hydrodynamic-biological models. Mapping data is available via a GIS-based web interface similar to NOAA's Ocean Atlas.

The ecological assessments are designed to:

1. Implement complementary assessment methodologies (belt-transects, stationary point counts, towed-diver/video surveys, rapid ecological assessments) for fish, corals, other invertebrates, and algae;
2. Systematically monitor reef resources to characterize their natural spatial variation and temporal change;
3. Conduct island inventories of key reef species as a major contribution to overall patterns of biodiversity;
4. Apply innovative ecological research techniques related to ecosystem-based management of reef-related resources;
5. Statistically interpret density and abundance estimates with reference to pertinent habitat, environmental and other ecosystem parameters and both natural and anthropogenic factors;
6. Improve our understanding of ecosystem linkages among fish and other reef organisms, across trophic levels; and
7. Provide the scientific basis for specific high-priority management questions related to estimating locally sustainable harvest levels of reef resources, the placement (and evaluation) of the effectiveness of MPAs or ecological reserves, the identification of ecosystem indicators, and contribution to adaptive management.

Ecological assessments and monitoring utilize a wide range of methods, from *in situ* observations (e.g., traditional fish belt transects, roving diver surveys, photo quadrates, video transects, towed diver surveys), bioacoustic surveys (e.g., ship-based echosounder surveys), passive acoustic moorings recording the ambient sound field to provide time series of diurnal, seasonal and annual trends in reef sound fields (to be correlated with ecological events/trends), bottomfish bait stations (for fishery independent bottomfish assessments) to CREIOS ocean observations (e.g., shipboard surveys, oceanographic moorings, satellite-tracked drifters).

In summary, prior to the present program, relatively little characterization data existed for the shallow water areas of the Western Pacific region, except at occasional, localized scales. The overall objective of the present investigations is to provide present-day baseline data to develop ecosystem modeling approaches for improved understanding and management of the region. A broad aim of this program is to link patterns and trends in time and space to small- and large-scale processes in an ecosystem-based manner.

## Frank Parrish (NOAA, Honolulu): Ecological and functional studies…

**Ecological and functional studies: Snapshots in time**

This presentation briefly reviewed the knowledge base across groups or complexes (e.g., corals, reef fish) with regards to functional aspect (e.g., movement). In general, efforts of this program are focused on small-scale, shallow areas around Pacific islands, and research relies on research cruises, field camps, remote sensing and collaborations with other projects and scientists. Historic information and data exist for some areas and habitat types, including:

- 1975-1982: NWHI Resource Assessment Survey (lobster, bottomfish, shrimp, kona crab);
- 1982-1984: Resource Assessments of the Marianas Archipelago (shrimp, bottomfish); and
- 1985-1988: Resource Assessment of the Southern Emperor-Northern Hawaiian Ridge Seamounts (demersal groundfish).

More recently, data exist from the 1986-2004 NWHI Lobster Surveys and the subtropical Frontal Zone Annual Oceanographic Series (1996-2000). Also, the NWHI Habitat Community Assessments undertaken from 1990-2004 examined reef, bank, slope and subphotic communities, while field camps assessed Monk seal foraging, sea bird reproductive success and undertook reef fish community and trophic studies.

An overall qualitative assessment of existing knowledge by data type of ecosystem processes and interactions across the Hawaiian archipelagic ecosystem is summarized in Table (8). The general understanding for ecosystem groups were ranked as good, moderate or poor across types of knowledge based on data available via the Pacific Islands Fisheries Science Center or the general scientific literature. In some cases, there is an abundance of historical data that can be mobilized to support analyses and management in this region.

**Table 8: Qualitative knowledge base by data type and species group matrix for Hawaiian archipelagic ecosystem, G: good; M; moderate; P: poor.**

| Group | Knowledge base[a] by data type | | | | | | |
|---|---|---|---|---|---|---|---|
| | Trophic | Movement | Life history | Abundance | Spatial | Temporal | Energy flow |
| Nutrient flux | - | P | P | P | M | P | P |
| Phytoplankton | G | G | M | G | G | G | M |
| Zooplankton | M | M | P | M | P | M | P |
| Pelagic micronekton | M | P | M | M | M | P | P |
| Benthic algae | M | M | M | M | M | M | P |
| Corals | M | P | G | M | M | P | P |
| Infauna | P | P | P | P | P | P | P |
| Ocotpods | M | P | M | M | M | M | P |
| Macro inverts | M | M | M | M | G | M | P |
| Lobster | P | M | M | M | M | G | P |
| Shallow reef fish | G | G | M | G | G | G | M |
| Reef slope fish | M | P | M | M | M | M | P |
| Comm. bottomfish | M | P | M | M | M | P | P |
| Subphotic fish | P | P | P | M | M | P | P |
| Jacks | G | M | M | M | P | P | P |
| Small coastal pelagics | G | P | G | P | P | P | P |
| Sea birds | G | M | G | G | M | M | P |
| Turtles | G | G | G | G | G | G | M |
| Reef sharks | G | M | G | P | M | M | M |
| Monk seals | M | G | G | G | G | G | M |
| Tiger sharks | M | P | G | P | P | P | M |
| Small cetaceans | P | P | P | P | P | P | P |
| Large cetaceans | P | P | P | P | P | P | P |

[a] Knowledge base scale: Good: Multiple regional studies, plus suitable body of related literature from other locations. Moderate: Limited regional studies or only literature from other locations as proxy. Poor: no regional studies.

## Bud Antonelis (NOAA, Honolulu): Northwestern Hawaiian Island Monk seal demographics

**Northwestern Hawaiian islands Monk seal and green sea turtle demographics**

This presentation described existing data on protected species in the NWHI, specifically Monk seals and green sea turtles. A number of studies have been conducted on Monk seals on an annual basis since 1984. Labor intensive field work focused on the NWHI, primarily at French Frigate Shoals, Kure, Laysan, Lisianski, Pearl and Hermes islands and Midway atoll. Investigations were undertaken at both the subpopulation as well as archipelagic scale, and utilized a variety of gears and technologies, including visual surveys, tagging, individual ID, and scat and spew analyses. Parameters that were targeted included:

- Abundance;
- Survival;
- Fecundity;
- Migration;
- Body condition;
- Causes of mortality; and
- Diet composition.

While Monk seals have a protracted breeding season, much of the reproductive activity is concentrated in spring/summer. Field work has been successful due to the excellent collaboration and cooperation of many partners, including the U.S. Fish and Wildlife Service and the State of Hawaii. While these investigations required substantial effort over a long time period, and have led to a better understanding of Monk seals, they have yielded relatively little data, and long term patterns have not yet been analyzed.

Green sea turtles are found throughout the Hawaiian archipelago. However, 90 percent of nesting typically occurs at French Frigate Shoals in the NWHI, where data have been collected since 1973. Green turtles also appear to use regular migration patterns throughout the NWHI. Sampling has been annual at French Frigate Shoals and other NWH islands, and periodic at selected foraging sites in the MHI. Additionally, turtle basking data, collected incidental to monk seal research, have been collected since 1982. Methods used for sea turtle research include nest surveys, tagging, individual ID, stranding investigations, foraging site surveys and fishery by-catch data collection. The main parameters investigated as part of the sea turtle program include:

- Index of population abundance;
- Migration;
- Somatic growth rates;
- Causes of mortality; and
- Diet composition.

## Session discussion

There were several questions regarding the availability of the recent characterization data. These data are to a large extent available via the web, although some of the biological data take time to process and post. All but the most sensitive data (e.g., location of endangered species) will eventually be posted for public access. There was also a question on whether any trophic interaction analysis had been done of key species. There is no current collecting of data for these types of analyses - scientists are relying instead on historic data, e.g., Jim Parrish's data.

It was suggested that there is a significant need to analyze existing data on key species, which may provide valuable insights. Examples cited included spiny lobsters (e.g., 1986-2004 data) and shark predation on monk seals. A point that was stressed was that these data need to be ‘rescued’ before they are lost due to decay of storage media (e.g., old computer disks and paper). Furthermore, substantial data may be hidden in research theses at the University of Hawaii, and such data urgently require a concerted data ‘mining’ exercise.

## *Data sources  C: Oceanographic data*

A single presentation described efforts to integrate existing recent and historic oceanographic observations from both *in-situ* measurements and remote sensing into a web-enabled format for inventory and analysis in the Pacific Ocean.

## Russell Moffitt (NMFS, Honolulu): Oceanography for ecosystem-based research…

**Oceanography for ecosystem-based research and management**

This presentation focused on the sources of physical oceanographic data for the Western Pacific and the available temporal and spatial resolution. The purpose for collecting these data is to better understand the horizontal and vertical structure of the ocean. Although extensive data exist on the broad, ocean-basin scale about major physical ocean phenomena and climate relationships (e.g., Figure 12), they are often insufficient in resolution for understanding smaller-scale, near-shore environments, for which high resolution, consistent monitoring is patchy (e.g., Figure 13). Therefore, while accessing existing data streams on physical processes is feasible, there is also an increasing need for finer-scale data that can assist with archipelagic ecosystem management. A key next step will be to determine what specific types of oceanographic data are needed, and the resolution required for improving our overall understanding of archipelagic environments.

The major parameters observed are:

- Temperature;
- Salinity;
- Dissolved oxygen and other gases;
- Concentrations of other chemicals (e.g., ‘nutrients’);
- Concentrations of organisms and organic material (e.g., chlorophyll pigment);
- Flow dynamics (currents, tides, waves);
- Sea-surface height anomalies;
- Air-sea flux, relation to global climate; and
- Patterns of horizontal and vertical structure.

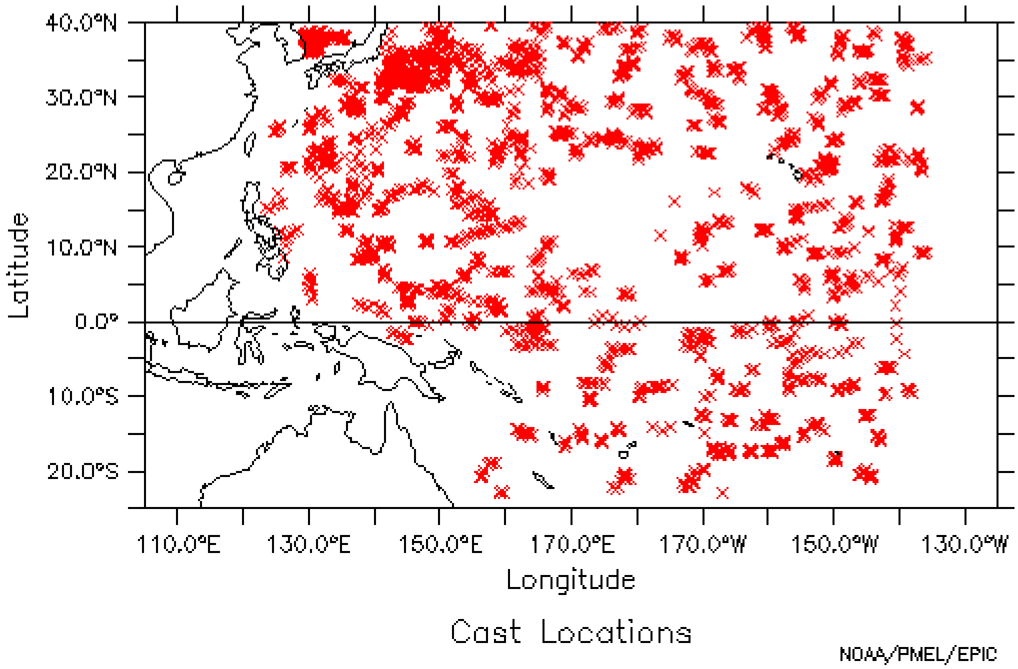



**Figure 12: Example of spatial distribution of large-scale oceanographic data sampling (e.g., salinity-temperature probes) throughout the Western Pacific ocean.**

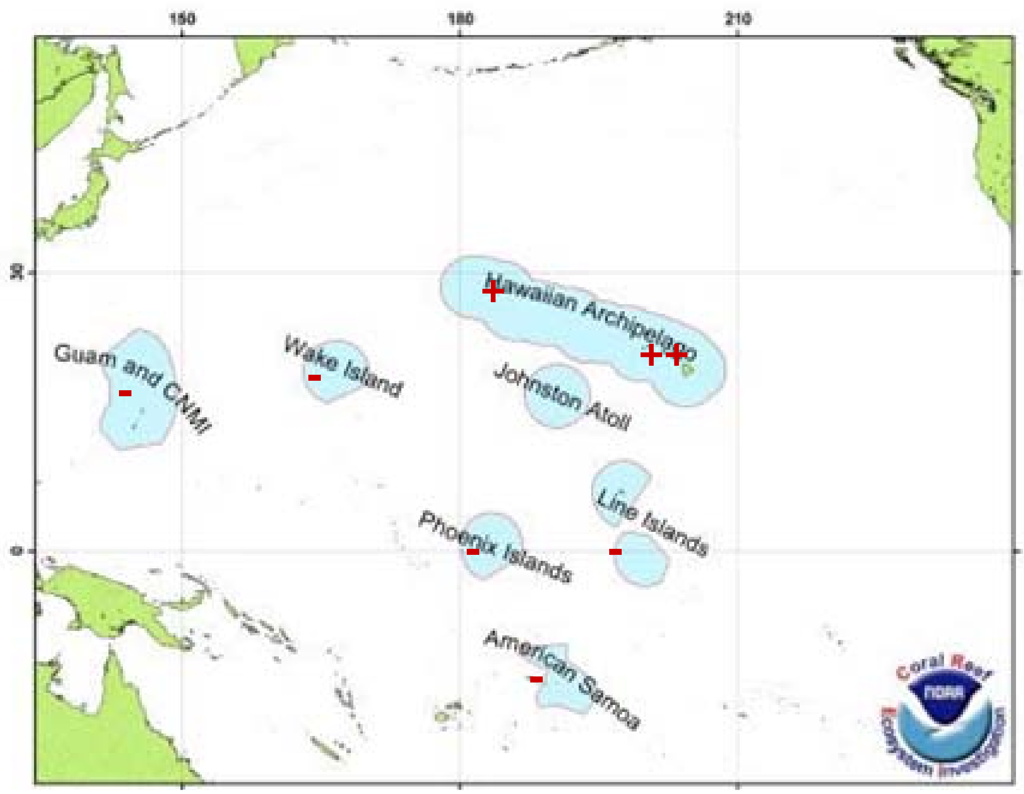



**Figure 13: Examples of sampling locations for higher resolution data collection associated with NOAA's Coral Reef Ecosystem Investigation initiative.**

Three ‘types’ of data are collected or generated:

- *In situ* observations;
  - Precision and high spatial (vertical) and sampling resolution;
  - Sparse and irregular across ocean basin and through time;
- Remotely sensed observations;
  - Synoptic coverage;
  - High temporal resolution;
  - Restricted to surface layer;
  - Limitations on parameters that can be measured; and
- Modeled parameters.

In summary, large-scale oceanographic data are available, illustrating the variability in space and time of the physical oceanographic environment, and provide good indices of basin-wide or regional climate variability. The question remains, what level of oceanographic information do we need to sue for incorporating into comprehensive regional ecosystem, models for resource management?

## Session discussion

The discussion focused on the use of modeling to assist in better understanding of coastal and shallow water processes by adapting existing oceanographic models. However, this likely requires fine-scale data that are currently not available for near-shore areas, as well as a better understanding of boundary conditions. This led to several suggestions regarding on-going activities.

For example, the Tropical Ocean Global Atmosphere (TOGA) array data in the central Pacific were suggested as an example of fine-scale data, although they are not available for a long enough time period for most modeling applications. Some nutrient-phytoplankton-zooplankton models go back many years, but only recent data are available for ground-truthing. An existing Navy model on ocean circulation may be useful, although coastal boundary conditions are poorly defined; a high resolution Hawaii circulation model is apparently being developed, as is a near-shore thermodynamic model of reef conditions; a NOAA model (OSCARS at NOAA's Pacific Marine Environmental Laboratory in Seattle) on surface layer velocity may be helpful with respect to connectivity; and some large-scale pelagic fish models are currently being refined to smaller scales. It was also suggested that the University of Hawaii may have a useful inventory of oceanographic models, and UH's Pelagic Fisheries Research Program has also been working on similar efforts to create ‘atlases’ of existing information. There was also some discussion about using models to fill in some of the apparent data gaps, but it was pointed out that such approaches must be carefully defined, as without the metadata the reliability of the derived data is uncertain.

## *Data sources D: Reconstructing catch time series*

### Dirk Zeller (Fisheries Centre, UBC, Canada): Reconstruction of coral reef fisheries catches…

**Reconstruction of coral reef fisheries catches for U.S. associated islands in the Western Pacific region, 1950 to 2002**

This presentation described an approach used to fill historic data gaps of fisheries catches, in order to describe a more appropriate baseline for coastal fisheries in the Western Pacific (see Zeller et al. 2005. Report to the Western Pacific Regional Fishery Management Council, Honolulu, 110 p.). Historic data deficiencies are a global problem. Using limited contemporary data, anecdotal historical data and information, and clearly defined assumptions combined with a conservative approach for approximating and quantifying other information, historic fisheries catch levels were suggested for key commercial and subsistence/recreational species.

Near-shore fisheries have played a key role in Pacific Island culture, supporting subsistence, cultural, and food security functions. However, data associated with near-shore fisheries are rare compared to the higher profile pelagic fisheries of major international commercial importance, such as tuna and billfish. This is partially due to the spatially scattered nature of landings sites for non-pelagic fisheries, making catch reporting or estimation more difficult, and results in incomplete official catch statistics. However, it is also often driven by the misperception that non-commercial and non-pelagic fisheries in many of the Pacific islands are deemed less 'important' than commercial operations (see Zeller, D., Booth, S. and Pauly, D. [2005] Underestimating small-scale fisheries: contributions to GDP. Fisheries Centre Working Paper # 2005-02, The University of British Columbia, Vancouver, Canada, [Available at: www.fisheries.ubc.ca/publications/working/2005/series5.pdf]).

Re-estimating historic catches in cases where time-series data are lacking, requires making distinct assumptions and interpolations between often widely spaced data 'anchor points'. These 'anchor points' are usually based on data sources such as localized case-studies, fisheries-unrelated investigations (e.g., human health- and consumption-studies) and generally unpublished gray literature. However, approaches such as the one used here are required, as it is counter-productive to continue the current approach for dealing with 'no time series data' by not reporting anything. This will usually be falsely interpreted as 'zero' catches in analyses and policy considerations. Increasing demand for accountability and holistic considerations with respect to sustainability and ecosystem-based approaches to management require a more complete accounting of catches, even if catches from earlier periods may be estimated with high uncertainty. Without it we cannot measure the full direct and indirect economic and cultural value of marine resources to society, or the costs of overfishing for local Pacific Island communities.

The purpose of this project was to assemble available information on catches for the non-pelagic fisheries of the U.S. associated islands of the Western Pacific region, specifically American Samoa, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), Hawaii, and the other isolated islands and atolls under U.S. jurisdiction, for the 1950-2002 period. The aim was to derive estimates of total removal of marine resources for this period, excluding large pelagic species (i.e., tunas and billfishes).

In summary, this study indicated the following:

- Re-estimated catches for all islands combined suggested a substantial decline of about 72% in total catches between 1950 and 2002. This contrasted with the pattern observed from the officially reported data alone, which suggested an increase in catches of about 19% (Figure 14); and
- The official reported data under-represented the re-estimated likely total catches for this time period by a factor of about 5 (Figure 14). This implies a substantial, if inadvertent, under-representation of the status of local, non-pelagic fisheries.

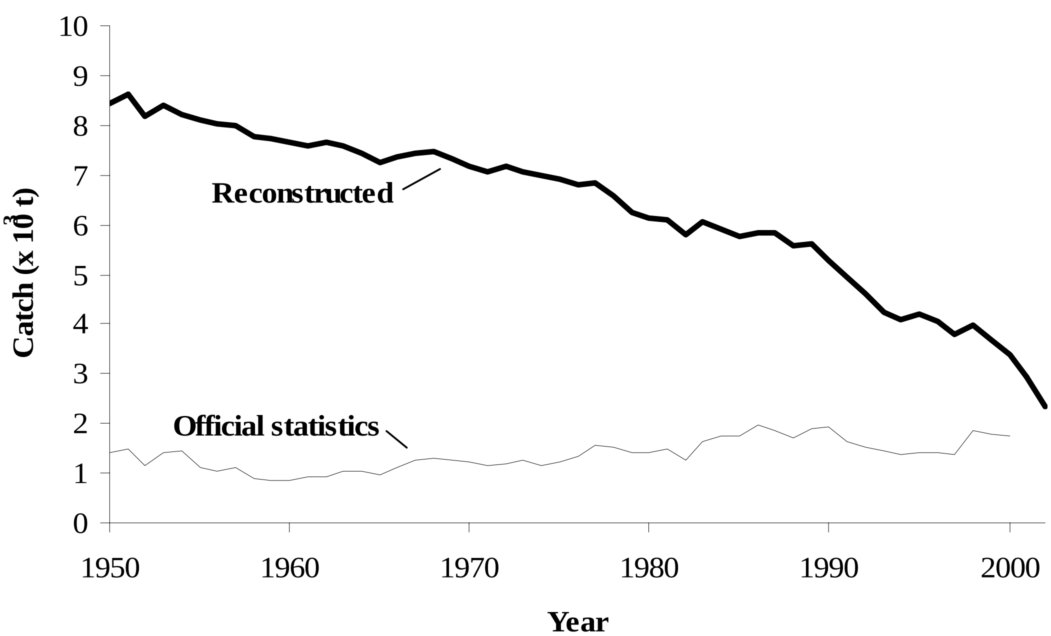



**Figure 14: Total reconstructed catches of non-pelagic fisheries for all U.S.-associated flag islands of the Western Pacific versus the officially reported statistics.**

As example, for American Samoa, the re-estimated catches suggested a 79% decline in catches for non-pelagic fisheries between 1950 and 2002 (Figure 15). Significant also was the 17-fold difference between the re-estimated catches and the official statistics (see Zeller et al. 2006. *Coral Reefs* 25:144-152).

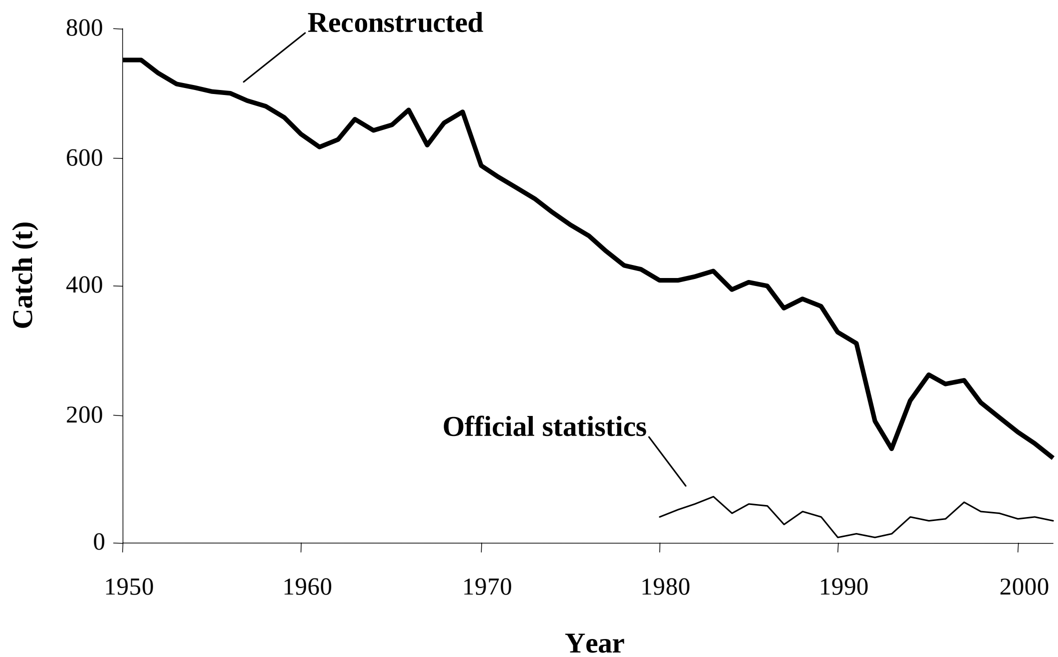



**Figure 15: Reconstructed non-pelagic fisheries catches for American Samoa.**

Similar patterns were observed for Guam (86% decline, 2.5 fold difference between re-estimated and official statistics) and the Commonwealth of the Northern Mariana Islands (54% decline, 2.2 fold difference). More limited data were also presented for the other islands (e.g., Midway and Johnston Atolls).

Historic catch re-estimations such as undertaken in the study presented here will be useful as baselines of historic patterns and trends within an ecosystem-based approach to management.

Accepting the distinctly different baselines of past catches as presented in this report sheds new light on issues and concerns for fisheries sustainability and conservation. It is suggested that management considerations regarding use and conservation of near-shore coral reefs, particularly around the main inhabited islands, are no longer about 'sustainability', but rather about rebuilding depleted ecosystems. Also, the forgone economic, social and food security benefits of not rebuilding will have to be considered when evaluating management strategies.

## Session discussion

This presentation stimulated a number of comments and questions that let to an extended discussion. Workshop participants acknowledged the need to creatively employ all sources of knowledge to estimate impacts where ‘hard’ data are insufficient. It was also suggested that the possibility may exist that reef fisheries were already at MSY by 1950 or shortly thereafter (at least around the populated main islands), thus leaving no production surplus for commercial fisheries or the often rapidly expanding human populations. It was also noted that there may be potentially significant differences in local productivity between Pacific islands (e.g., upwelling, nutrient circulation) that could be considered in future analyses, if data linking these differences to fish production can be established. It was also pointed out that research at Wake Island, and Midway and Johnston Atolls indicated that even small human populations can significantly reduce local stocks. Additional suggestions on the analysis presented included using biomass estimates to fill in data gaps and analyzing the structure of the harvest. However, it was countered that in most cases, biomass estimates for early time periods were even more difficult to obtain than catch information, although spatially segregated data sources (e.g., currently little or un-fished areas as ‘surrogates’ of biomass estimates for earlier time periods of exploited areas) may be useable to fill such gaps. It was suggested that such endeavors need to be undertaken cautiously with substantial local expertise and knowledge, as well as deep understanding and expertise of coral reef productivity. Confidence intervals or an approximation of the min/max range for values to better illustrate uncertainty were also suggested. Finally, the NWHI was suggested as good region to test this type of analysis as a baseline model for extraction estimates and as an example for looking at components of fauna with respect to how stocks are reduced in space and time. This discussion again supported the notion and need for experimental and adaptive management at the ecosystem scale.

Dr. Zeller was asked if any of the bait catches from the pole-and-line fleets that operated in the U.S. Flag Pacific Islands would reveal anything about productivity of lagoons. The feasibility of pole and line fishing was limited to where bait could be caught. There were extensive pole-and-line fisheries in the Marianas, right up to the time that the 200 nm mile zones were declared. This approach may be useful, although it was pointed out that baitfish were generally part of the so-called ‘small forage fish’ community, about which relatively little is known ecologically. This is also transpiring as a fundamental gap in ecological knowledge for ecosystem modeling purposes, due to the often central role of forage fish in trophic functions of ecosystems.

There was a question on how his methods were viewed by the mainstream anthropological community. Dr. Zeller responded that so far they had not been consulted in great depth, but his approach was being taken up by anthropologists to attempt a similar catch history re-estimation for Palau, and the present study (extended into economic valuations) found an interested and receptive audience at a recent fisheries economics conference. There was also a question about 19$^{th}$ century data sources for Hawaii. Dr. Zeller stated that he was familiar with Cobb’s report (Cobb, J.N. 1903. The Aquatic Resources of the Hawaiian Islands. Part II Section III. The commercial fisheries of the Hawaiian Islands. Bulletin of the United

States Fish Commission 23: 715-765) and used these data as an anchor point for his Hawaiian analysis.

It was suggested that it would be valuable to present the highest and lowest estimates to illustrate the uncertainties and assumptions using methods such as consumption rates to generate catch data. Dr. Zeller acknowledged the uncertainties in the estimates and agreed that this might be useful. There were comments on some of the high consumption rates for fishes in the Mariana Islands which had seemed implausibly high, yet were within range of published fish consumption rates in Micronesia. Dr. Zeller had thought that the quoted annual per capita consumption rate of 165 kg was too high, and had adjusted it downwards in his estimation, in line with a conservative approach.

Dr. Zeller was asked if he had been able to find any biological measures with which to calibrate the catch estimates. Dr. Zeller answered that this would be an interesting approach, but would require additional work beyond the scope of this initial study. In a follow up comment it was noted that the present study looked at catches and not biomass. There had been studies that compared biomasses between the Northwestern Hawaiian Islands, which are considered relatively pristine, with the Main Hawaiian Islands. Dr. Zeller noted that part of the problem in trying to find ways of looking at this with reconstructed data was allocating catches to individual taxa, given that information on taxonomic composition for early periods is usually very poor. As a consequence, in locations like American Samoa where data were incomplete over time, species composition was projected backwards proportionately, while realizing that there would have been shifts due to reef gleaning and different dietary preferences.

## *Models*

### Neil Gribble (QDPI, Cairns, Australia): Ecosystem-based management on the Great Barrier Reef…

**Ecosystem-based management of Australia's Great Barrier Reef Fisheries: Modeling and Policy Initiatives**

This presentation focused on an ecosystem model developed to provide some insights into management problems arising in one of the major fishery on the Great Barrier Reef (GBR), the prawn trawl fishery (Figure 16). The presentation consisted of four main components: a description of the Barrier Reef Marine Park and its fisheries; a summary of the ecosystem-based management policy and management initiatives; a summary of the data sources for the ecosystem model (based on the Ecopath with Ecosim suite of modeling tools); and the ecosystem model itself, used to look at temporal as well as spatial components and the need for satellite Vessel Monitoring Systems (VMS) for compliance and assessment.

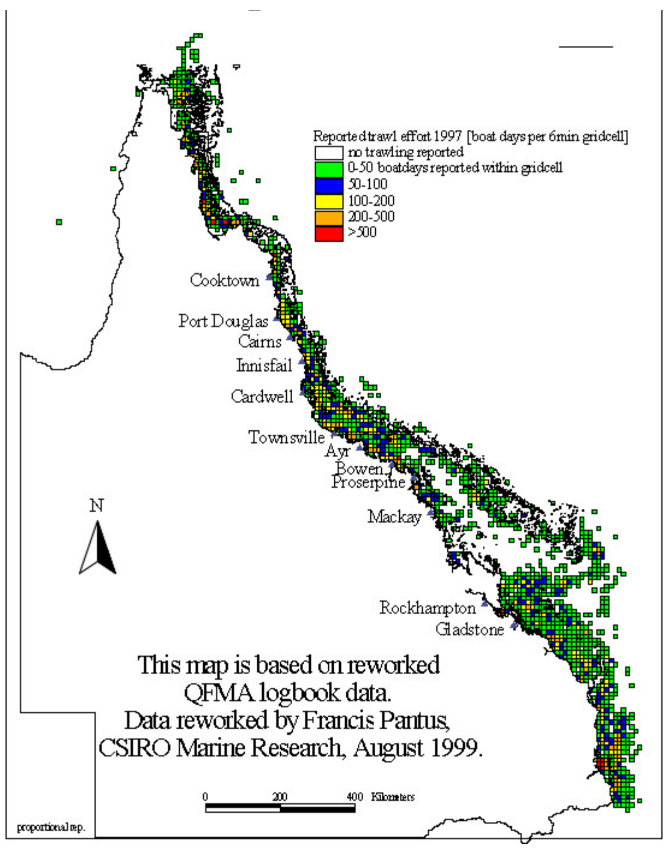



**Figure 16: Estimated spatial distribution of effort for the prawn trawl fishery on Australia's Great Barrier Reef in 1997.**

Several fisheries are active on the GBR:

- Commercial trawl fleet ~500 endorsements;
- Commercial hook and line fleet ~1,300 endorsements;
- Commercial gillnet fleet ~1,400 endorsements;
- Recreational fisheries, significant in some gear types (e.g., hook and line); and
- Indigenous, significant for some protected species (e.g., dugong).

Given that the GBR is a Marine Park and a World Heritage Area, management aims to strike a balance between fisheries and conservation. The ecosystem-based management policy in the GBR includes a suite of different legal instruments, both state and federal. Overall management of the GBR is based on shared state-federal jurisdiction. Specifically with regards to fisheries, the major federal legislation is the Ecological Protection & Biodiversity Conservation Act of 1999, which requires every federally managed fishery, and every fishery needing an export license to justify their ecological sustainability by 2005. Given that most of Australia's fisheries export, mainly to Asia, makes this a very powerful federal conservation tool. Fisheries need to demonstrate sustainability in target species, by-product (retained by-catch) and other by-catch species. For example, the trawl fishery in the World Heritage Area is limited by the quantity of syngnathids (seahorses) caught as by-catch. Thus, this fishery is to some extent managed for the sustainability of the most vulnerable species rather than the sustainability of the target species, which may be one of the characteristics for management using ecosystem-based approaches. Fisheries-related state instruments include the 1994 Queensland Fisheries Act, the legislated Fisheries Management Plans, the 80 designated Fish Habitat Areas (which prohibit development in the ecologically sensitive areas), and several dugong sanctuary areas. Thus, in summary, sustainable and ecosystem-based fisheries management in Australia's GBR relies fundamentally on two approaches: substantial spatial closures (~30% of all habitat types are closed to all extractive uses), and legislated requirements for fisheries to demonstrate ecological sustainability across all species captured.

The ecosystem model of the Northern Great Barrier Reef prawn trawl fishery (Figure 17) was developed by the author while at the University of British Columbia, with assistance from Prof. Carl Walters and Prof. Villy Christensen. The aim was to develop this model as a tool to assist with the evaluation of management plans for the World Heritage Area. Data source used for this project were numerous, and relied heavily on collaboration between several institutions, including Queensland Department of Primary Industries (QDPI), Commonwealth Scientific and Industrial Research Organization (CSIRO), Australian Institute of Marine Science (AIMS), and the Reef Cooperative Research Centre (Reef CRC) at James Cook University (JCU). The model structure was founded on the trophic guilds of Opitz (1996) for a Caribbean reef system, but were substantially 're-specified' for the GBR and expanded to 25 species/functional groups, including commercially important species and by-catch (Figure 18).

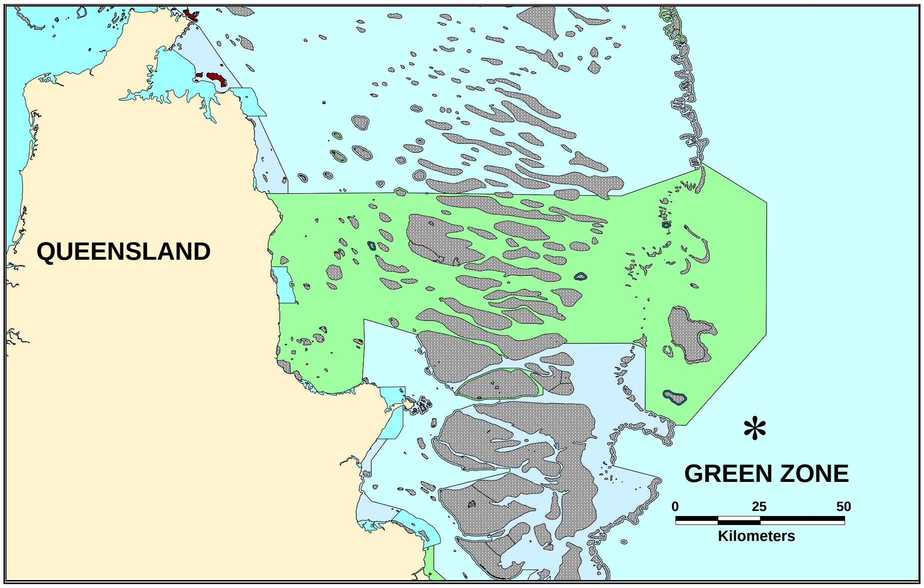



**Figure 17: Study area for the ecosystem model, showing area of prawn trawl closure on the northern GBR (green). Individual reefs are shown also.**

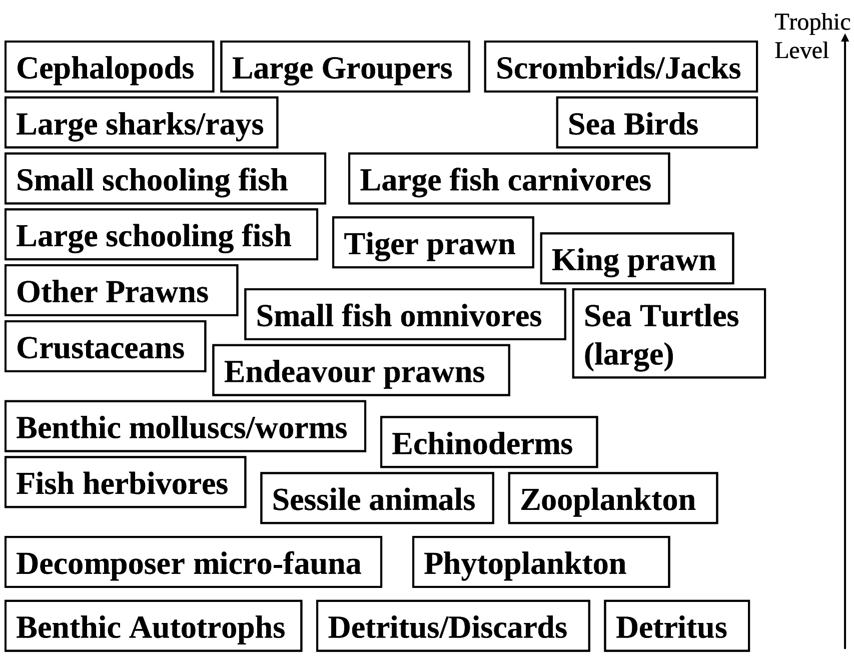



**Figure 18: Species and functional groups comprising the northern GBR prawn trawling model, including their relative trophic position.**

Given the complexity of this model (e.g., 5 parameters estimated for each of 1000 species grouped into 25 functional groups), model validation was carried out using temporal simulations, comparing the behavior of the simulations to that observed independently though logbook data and fishers experience (anecdotal information). As with all models, the aim was to capture the major biomass dynamics and trends of the much more complex real system. Subsequently, spatial simulations were conduced to examine the effectiveness of the spatial closure. Reliance on data obtained via compulsory Vessel Monitoring Systems (VMS) was crucial in being able to assess spatial management (closures) compliance, and to compare logbook-based information on spatial vessel effort with true vessel effort (Figure 19).

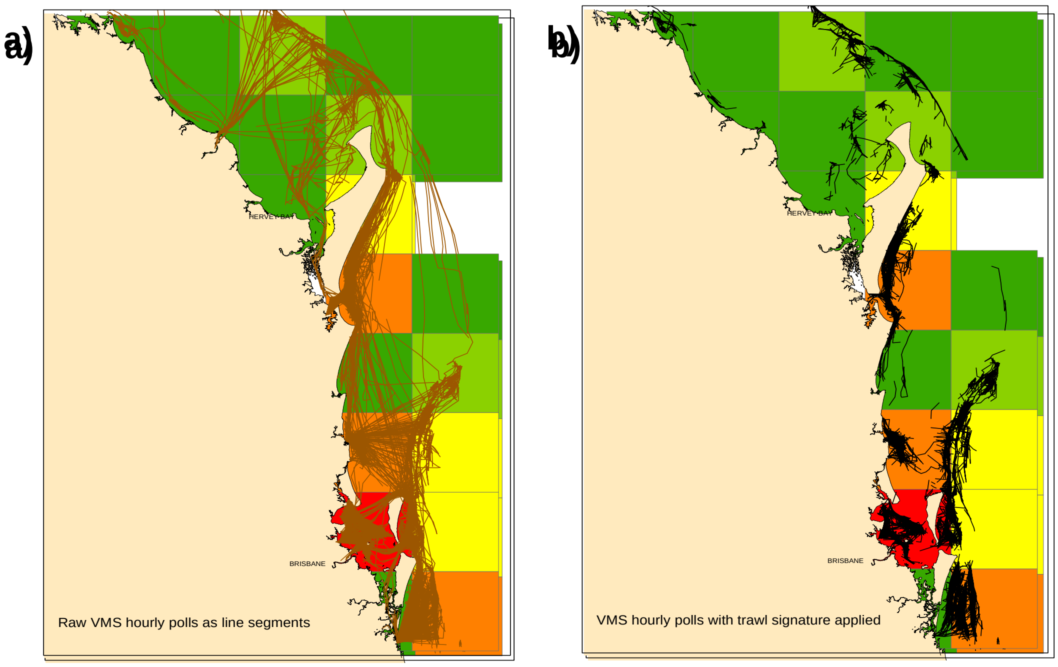



**Figure 19: Map showing examples of VMS signatures of prawn trawlers overlaid over compulsory daily logbook 30 minute effort grids, showing (a) raw VMS hourly polls as line segments, and (b) with trawl signature filter applied (i.e., speed dependent net deployment).**

In summary, the cross shelf closure simulations suggested:

- Fishing may concentrate on borders of MPA;
- Size of MPAs must allow for illegal fishing along the boundary (i.e., the 'edge effect');
- Vulnerable species (e.g., long-lived, slow growing, or rare) will benefit from MPAs;
- Opportunistic species may not benefit as much; and
- MPAs are only as good as the compliance, emphasizing the importance of both stakeholder buy-in as well as rigorous enforcement.

## Jerald Ault (University of Miami): Florida’s coral reef fisheries…

**Sustaining Florida’s multispecies coral reef fisheries**

The presentation focused on the author’s involvement in sustaining Florida's multi-species coral reefs and their fisheries. Florida has a population of 16 million people, and the reef system in South Florida generated 71,000 jobs and $6 billion U.S. in economic activity in 2001 alone. The Florida legislature designated Florida as the fishing capital of the world, and recreational fisheries last year generated $10 billion U.S. statewide in economic activity, which is 10 times the commercial value. However, the ecosystem goods and services are threatened by increased exploitation and environmental changes from rapidly growing human population, as well as global climate change.

Management of Florida’s coral reef systems is a complex endeavor, as evidenced by the diversity of zones and patterns of management rules (Figure 20). Overall, however, there is a growing awareness among all stakeholders that there is an increasing responsibility for ‘people’ to maintain critical ecosystem connections and functions. This is especially so given the dramatically increasing pressures of use and the likely impacts of climate change. As part of the authors research program on ecosystem-based management needs, fishery dependent data is augmented through fishery-independent surveys sampling strategies using, for example, stationary counts of reef fish via visual census. These assessments were undertaken between 1979 and 2005, included over 300 species and covered over 12,500 $km^2$ in surveyed areas. Such data permit one to link reef fish spatial abundance with benthic habitats, which in turn allows simple preliminary evaluations to be undertaken at ecosystem-scale, such as reef fish diversity by habitat type (Figure 21).

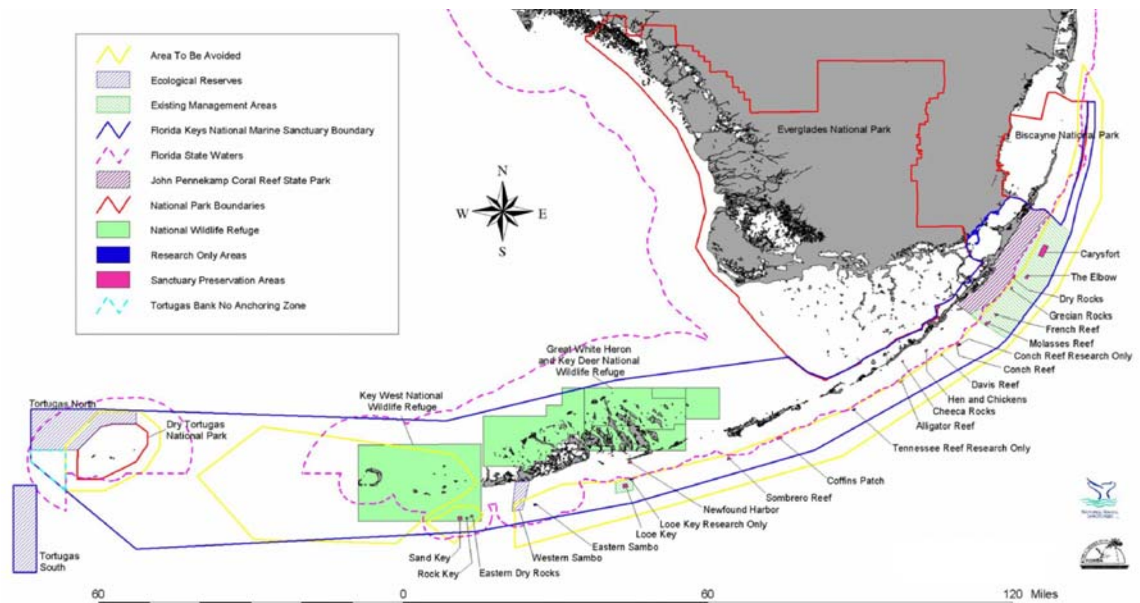



**Figure 20: Map of management zones for the southern Florida coral reef ecosystem.**

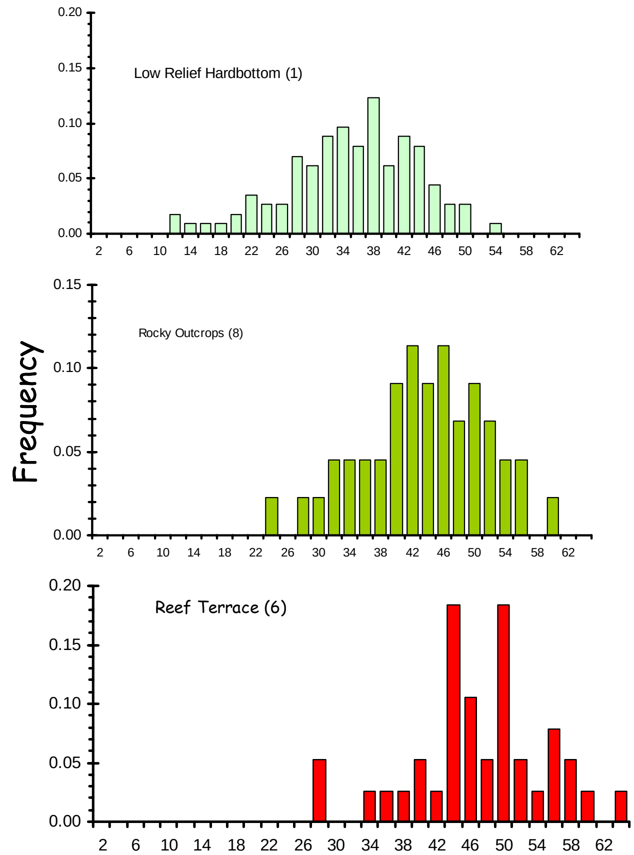



**Figure 21: Example of coral reef fish diversity patterns by habitat type, from the southern Florida reef ecosystem.**

In general, the combined fishery-dependent and fishery-independent data permits comprehensive and inclusive evaluations of the status and trend in fisheries components of the ecosystem, including examination of management benchmarks for the southern Florida multispecies reef fish community. For example, community control rules centered on biomass ($B/B_{MSY}$) and fishing mortality ratios ($F/F_{MSY}$) suggest that most species are being overfished (Figure 22). The general assessments and data collected at holistic ecosystem level over time and space also assists, for example, in the design of and decision on marine reserves for fishery management and wildlife conservation (e.g., Figure 23, see Ault et al. 2005. *Bull. Mar. Sci.* 76(2):595-622.).

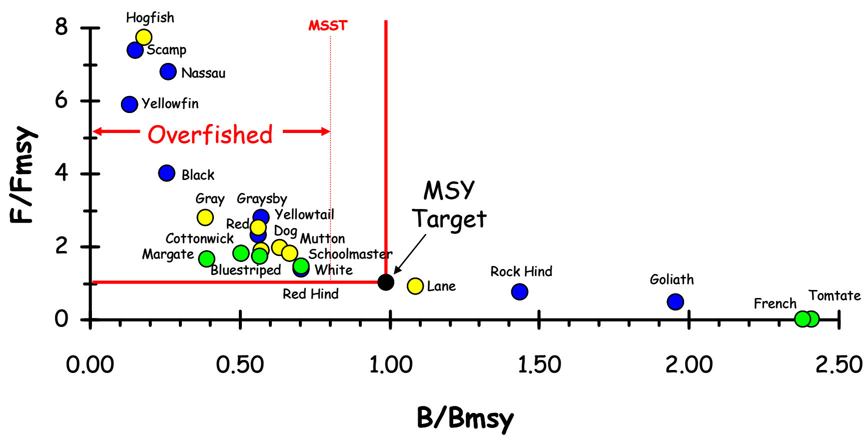



**Figure 22: Management benchmarks in the form of biomass and fishing mortality control rules for the southern Florida reef fish community, indicating overfishing for most species.**

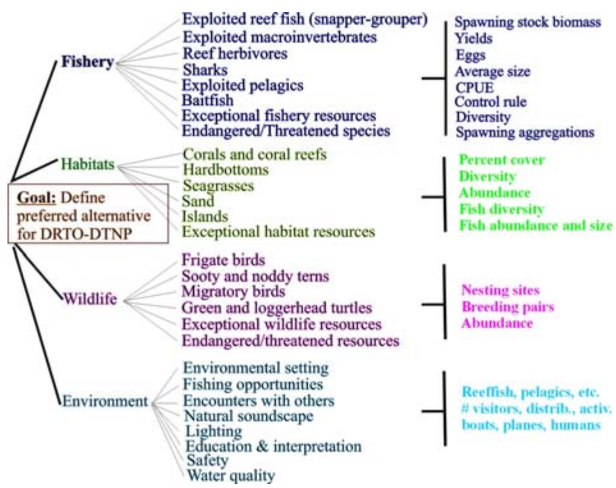



**Figure 23: Factors and measures being considered in the design of marine reserves as part of the ecosystem-based management approach to fisheries in the southern Florida reef ecosystem.**

Overall, the experience in Florida suggested that:

- Physics needs to be measured at scales that reflect biological process;
- Demographics need to be examined that cover community dynamics, e.g.,
  - Examine or determine rules that animals may follow in movements (habitat-foraging); and
  - Predator-prey interaction rates.

In summary, the challenge to achieving long-term sustainability requires new scientific approaches to monitoring and risk assessment, and management measures commensurate with the rising complexity of human-ecosystem interactions. Fisheries systems science framework is an important step towards meeting this challenge.

## Carl Walters (Fisheries Centre, UBC, Canada): Ecosystem modeling in Canadian fisheries…

**Applications of ecosystem modeling in Canadian Fisheries: Have they been of any use?**

Carl Walters began by saying that modelers aren't even close to be able to do autopilot type management with models. If someone is thinking a model is going to remove responsibility for judgment about uncertainties, and in particular, if managers or scientists are looking for a model to provide value-laden answers, then they are going to be disappointed by anything that modelers can do. Prof. Walters noted that Mike Orbach made a key point that scientists can't provide answers to value judgments. One of the difficult things happening with ecosystem modeling, as it happened before with single-species assessment, has been that managers try to pass the responsibility for value judgments to scientists. Managers ask the scientists to model the decision choice problem in tradeoff relationships, and scientists can't do that. A model can generate a collection of alternative predictions of what might happen under different circumstances; it might expose uncertainties that ought to cause a responsible manager to think carefully about how to do the management in an experimental, and be able to learn in the process. However, a model cannot tell you the appropriate level of risk to take, or dictate the appropriate precautionary approach to take. Nor should any scientist be asked to try to answer those questions as part of the analysis. When models simulations are run, e.g., a big MPA-designed model, like Jerry Ault's, it is done with a set of values included that are thought to represent those of managers. Scientists can present models that lay out a series of design alternatives under different objectives or weightings on different performance measures. However, modelers cannot say which ones are the right choices. Modelers can't be trusted to make prescriptions, nor should they. It would be wrong to think of a model as ever having that capability.

One strategy that is being tried out currently involves a three step process:

- Use 'big' models to expose strategic tradeoffs and risks, without pretense that their predictions are at all precise;
- Build much simpler 'back of the envelope' models or calculations to explain, justify, and check major findings from the 'big' models'; and
- Build very different, usually detailed and spatial, models to examine specific tactical options for regulation.

This kind of approach may allow exposure of the severity, or not, of tradeoffs, for example, in the case of the potential impact of restoration of Canada's Atlantic cod on shrimp fisheries, which have becomes more valuable than the cod ever was. Based on available data, this cod-shrimp tradeoff is apparently concave (Figure 24), thus 'balanced' policies trying to maximize both stocks and fisheries would fail, by producing low biomass and low catches for both species. This illustrates that sometimes modelers can try and expose the potential severity of tradeoffs amongst management objectives. What is being encountered in Canada is often hostility towards modeling, not because the models were right or wrong, or the science behind the models was problematic, but because they did expose how severe the management tradeoffs are. There was no nice compromise for management policy or a simple prescription of the 'right' course of action. The models suggested that such a simple answer did not exist.

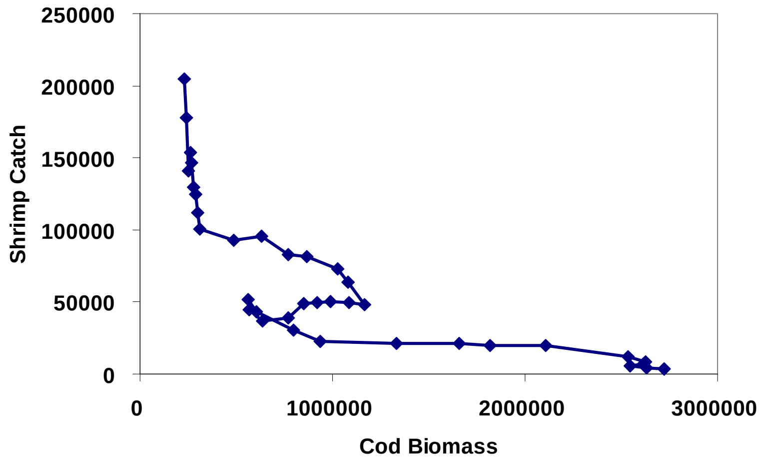



**Figure 24: The potential tradeoff between Atlantic cod biomass and shrimp catches on Canada's east coast, illustrating that 'balanced' policies that attempt to maximize both stocks' biomass and catches have a high likelihood of failing.**

Another issue for which models have been used is to help structure the 'who-done-it' debates that surround many major fisheries regulatory changes. This relates to the arguments of effects of fishing versus environmental changes versus marine mammals etc., and a prime example from the Hawaiians area is the lobster versus Monk seal issue. What has been found is that models have generally supported 'interactive effects' hypotheses, being the amplification of effects of 'natural' changes (i.e., productivity, predators) by fisheries exploitation. Such models have also exposed the extreme uncertainty about efficacy of culling programs (e.g., seals, cormorants) because of possible 'third party' responses (e.g., unexpected increases in hake rather than salmon along Canada's west coast).

The presentation concluded by stressing that time should be spent discussing the development of model based on empirical reference points for unexploited situations. A model cannot be trusted to determine what the potential for abundance and recovery is for a system. If an un-fished reference point area exists (e.g., parts of the NWHI or remote Pacific islands/banks in the case of CNMI or American Samoa), then the models may not need to back-calculate a history (with considerable uncertainty) that nobody looked at. This would be a valuable staring contribution to using any type of modeling in ecosystem-based management approaches.

## Villy Christensen (Fisheries Centre, UBC, Canada): Ecosystem modeling: Where are we?

**Using ecosystem modeling for fisheries management: Where are we?**

This presentation posed three questions: whether ecosystem modeling is an active research field; whether the models are potentially useful to fisheries management; and whether ecosystem models actually are being used for fisheries management. Specifically, the presentation concentrated on the third issue, and considered such issues as how much has been published based on ecosystem models and a brief review of modeling activity currently ongoing. Much is being learned about what happens in ecosystems, as ecosystem models tend to summarize what is known about ecosystems, such as what the resources are, how they interact, and how they are exploited. Some topics/aspects have been shown to be critical to modeling ecosystems, including concepts such as 'foraging arena' (Figure 25) and predator/prey relationships and associated predation mortalities, carrying capacity estimates (one way to estimate these is via stock reconstruction analysis), and total catch history. The importance of evaluating models by replicating historic trends (Figure 26) and making extrapolations to new situations was noted, as was the need to consider impacts from climate change, nutrient loading and habitat areas.

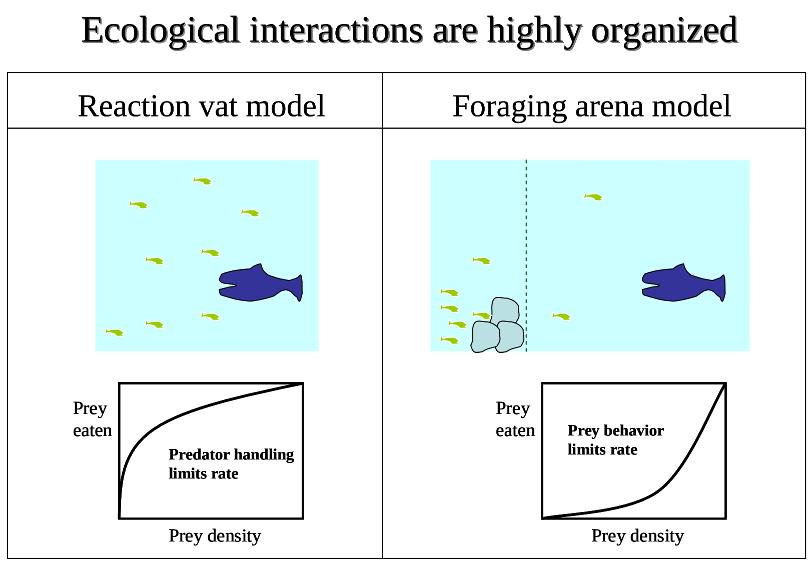



**Figure 25: Simplified visual representation of the 'foraging arena' concept underlying much of the recent improved simulations of trophic relationships in many ecosystem models, such as Ecosim.**

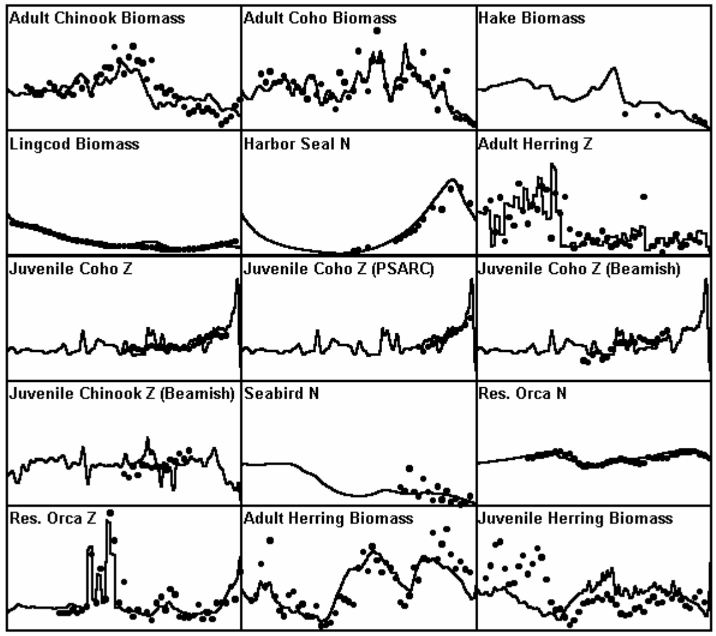



**Figure 26: Strait of Georgia (Canada) time series from assessments or surveys (dots) compared to Ecosim simulation runs (lines), illustrating the utility from evaluating models by fitting to observed time series data.**

In general, the experience from ecosystem modeling for fisheries purposes so far can be summarized as:

- Primary productivity anomalies may or may not be amplified through the food web;
- Possible to replicate development over time:
  - Often by incorporating environmental as well as fisheries impacts;
- Requires more data:
  - But mainly data we should be examining in any case - 'ecosystem history'; and
- Supplements single species assessments:
  - Does not replace them.

It was noted that, even though ecosystem models are being used to address some questions in fisheries management, they are rarely used in actual management decisions. We can begin to describe, with some credibility, the agents of mortality and trophic interdependence among ecosystem components, and begin to evaluate the relative impacts of fisheries and environmental factors (at least at the 'looking for correlation' stage). The relative rarity of use of ecosystem models for actual management can be linked to:

- Lack of experience with use of ecosystem models for predictive purposes;
- Ecosystem modeling is for strategic management (medium- to long-term time horizon), and supplements the tactical single species assessment;
- Fisheries management process is trapped in tactical management;

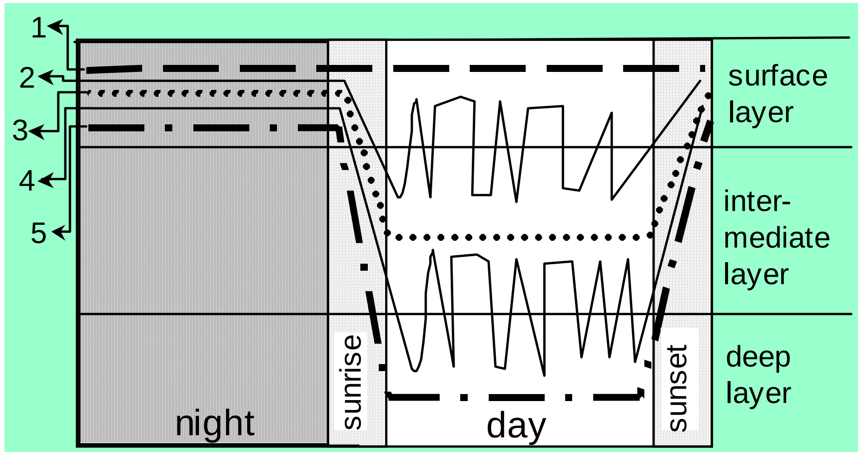
- Strategic decisions are non-existing; and
- Calls for institutional change.

In summary, the current situation suggests clearly that ecosystem manipulation is common in the real world, but is generally based on a less than optimal set of decision tools (which are often accidental). It is clearly time to implement strategic considerations as part of the management process, to move fisheries management out of the tactical management loop (focused on short-term time horizons) it currently is trapped in. However, this poses the question whether scientists, managers and stakeholders are ready to use models for strategic decision making. Ecosystem modeling will not replace single-species assessments; instead it relies heavily on these assessments. Overall, however, an adaptive environmental assessment and ecosystem management process is called for. Strategic experimentation driven by questions raised by modeling and assessments may be an approach we should consider seriously for determining future directions for management.

## Patrick Lehody (SPC, New Caledonia): A spatial ecosystem and population dynamic model

**A spatial ecosystem and population dynamic model**

This presentation illustrated a spatial ecosystem and population dynamics model developed for tuna species in the Pacific. During model development emphasis was placed on keeping a good fit between the level of information for the marine ecosystem (starting from the top predators), information and knowledge about the physics, primary food production, and commercial fish species. A simple definition was created of forage groups in the pelagic system, with three vertically stratified layers: those in the epi-, meso- or bathy-pelagic layer, with some species remaining all the time in their layer while others migrate vertically during nighttime (Figure 27). Six components were identified, which corresponds to what is observed in terms of vertical behavior of predators. To validate the model, historical data were used for recorded species, isotope analyses and indirect validation. This work supported the notion that for large-scale modeling of pelagic systems, e.g., focused on tuna resources, much of the required basin- or region-scale data layers exist.




1- epipelagic predators (e.g., skipjack, marlins and sailfish);
2- predators moving between the surface and intermediate layers during the day (e.g., yellowfin tuna);
3- predators mainly in the intermediate layer during the day (e.g., albacore tuna);
4- predators moving between deep and intermediate layer during the day (e.g., blue shark);
5- predators mainly in the deep layer during the day (e.g., bigeye tuna and swordfish).

**Figure 27: Five typical vertical movement behaviors simulated using a 3-layer and 2-prey-type pelagic system (adapted from Dagorn et al. 2000).**

Other current and upcoming projects were described, including:

- The Hawaiian-PFRP 'Mixed-resolution models for investigating individual to population spatial dynamics of large pelagics' project, in collaboration with Senina, Allain, Sibert, Murtuggude, Kirby, Ancheta and Polovina;
- The implementation of an optimization function, also in collaboration with Sibert, Senina and Ancheta from the Hawaiian-PFRP;
- Comparative analyses:
- Simulations in Atlantic and Indian Oceans (GLOBEC CLIOTOP WG4);
- Comparisons with other modeling approaches: IBMs, trophic models (e.g., Ecopath with Ecosim), statistical models (e.g., multifan-cl); and
- Developing a network of collaborations and users.

## Jeff Polovina (NMFS, Honolulu): Status of Hawaii ecosystem models

### Status of Hawaii ecosystem models

This presentation consisted of an overview of the status of some of Hawaii's ecosystem models, some of which were being discussed at this workshop. The models included trophic models (Ecopath with Ecosim) for the Northwestern Hawaiian Islands and the Central North Pacific, as well as spatial models, specifically a time-area-gear model, a passive movement model, and an active movement model. One of the reasons for re-evaluating the old Northwestern Hawaiian Islands Ecopath model (first published in 1984 in *Coral Reefs* 3:1-

11) was the work lately undertaken by Frank Parrish. The original Ecopath model was parameterized with help from Frank Parrish's father. Twenty years later, a multi-year survey of reef fish in the Northwestern Hawaiian Islands being conducted by Frank Parrish, Ed DeMartini, and a number of colleagues provided updated parameters, and suggested a revisit of the earlier model. The model is for French Frigate Shoals, and consists of approximately 20 functional groups, but whereas the original model contained only a single group for reef fish, the updated model is now separated into piscivores, benthic carnivores, planktivores and herbivores (Figure 28). Furthermore, the new model makes use of some IKONOS habitat characterizations (Figure 29).

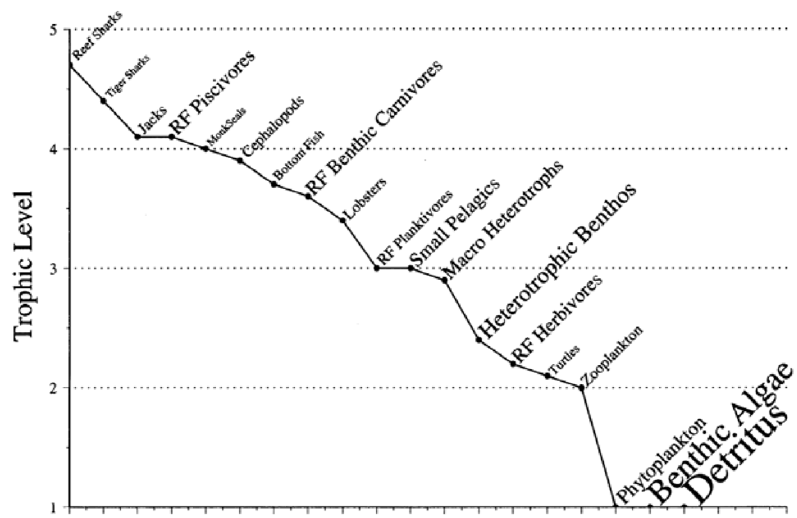



**Figure 28: Trophic levels and biomass scales (font size) for the updated Ecosim French Frigate Shoal model.**

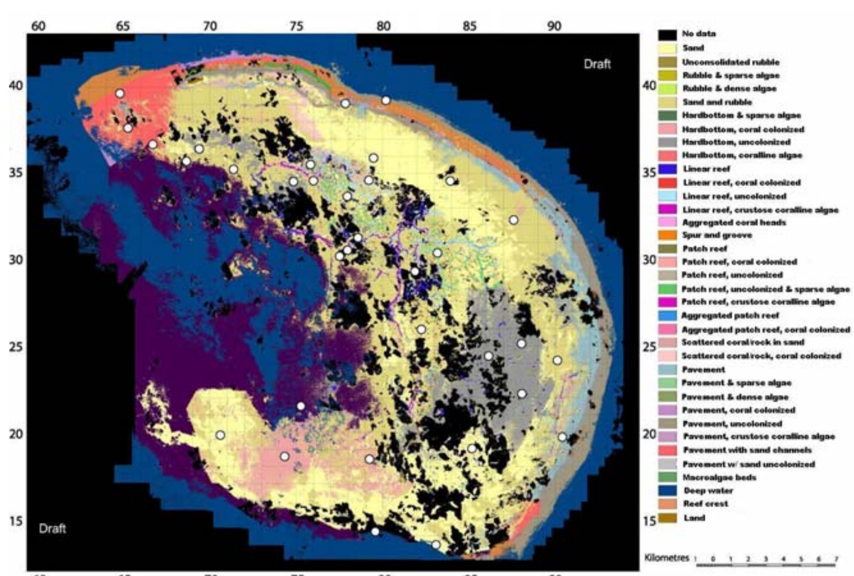



**Figure 29: Habitat information for French Frigate Shoals, as derived from IKONOS imagery.**

A model such as the present may find applications in:

- Determining the structure and dynamics of the ecosystem energy budget;
- Asking how biomass of a species of interest may respond to various forcing functions;
- Determining what may be the species groups that drive the ecosystem dynamics;
- Exploring what may be ecosystem indicator species; and
- Exploring the carrying capacities for one or more species.

One potential use of such a model (possibly with more detailed specification of key target and not-target by-catch species for which catch history data exist) may be as a reformulated early time period model for the MHI (i.e., under conditions of low exploitation). This would permit the opportunity to examine the potential response of the modeled ecosystem to existing historic data on fisheries catches and effort. Similar approaches to using data and models from the NWHI were also expressed previously, e.g., by Prof. Carl Walters.

Information was also presented on three different spatial models that are either being used or are in development. One deals with understanding the impact of the longline fishing fleet dynamics, and was applied to the pelagic ecosystem. The model was developed to examine how the spatial and temporal distribution of fishing (time/area closures) could be changed to reduce the incidental take of sea turtles, and how such management measures and their impacts could be evaluated. The historical spatial distribution of the longline fishing effort was based on logbooks (Figure 30). For data on protected species, the mode relies on observer data.

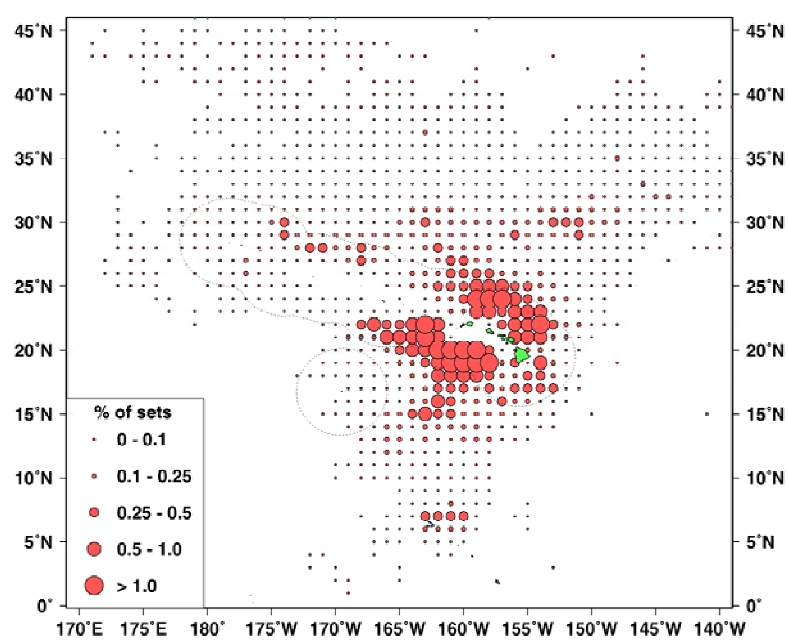



**Figure 30: Distribution of Hawaii based longline fishing effort (1994-1998).**

In this modeling scenario, 350,000 possible time/area closures were simulated (Figure 31). For example, a time/area closure that reduces the leatherback take by 70% may require that managers reduce fishing effort by approximately 40%. The model can be used to estimate the likely best time/area closure that may provide the required reduction in leatherback takes (based on conservation targets founded on sound population dynamics information), with approximated impact to the fishery.

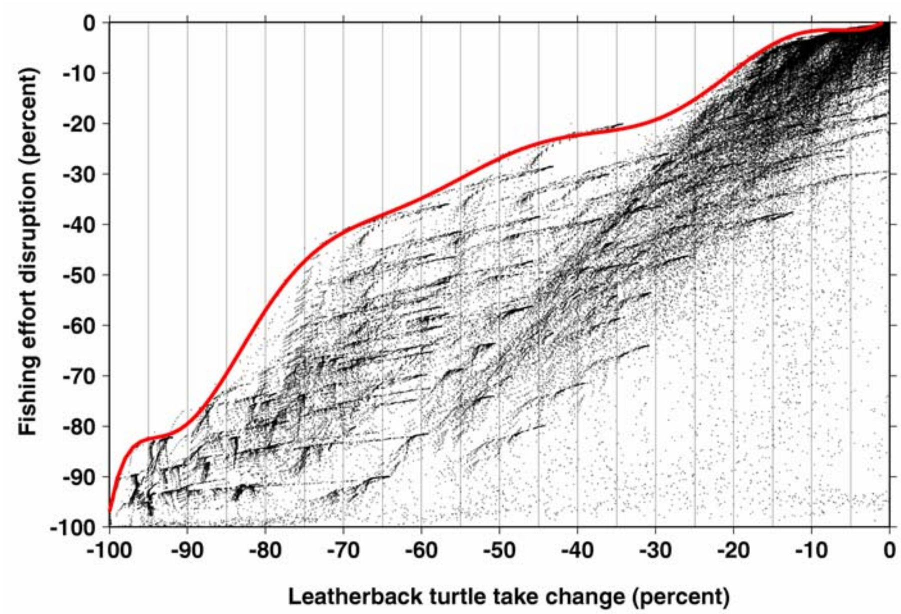



**Figure 31: 'Efficient frontier' identification in closure scenarios, based on 350,000 possible time/area closure simulations.**

The applications for this model may include:

- Describe the impacts of changes in spatial allocation of effort;
- What time, area and gear configurations achieve a desired level of incidental catch or by-catch while minimizing the impact on the fishery?; and
- Is an observed decline in landings of a species the result of shifts in fishing grounds or methods?

The second spatial model, which continues to be developed further, originated in work done with Dr. Pierre Kleiber and Mr. Don Kobayashi to simulate the transport of larvae in the Northwestern Hawaiian Islands. The model includes both surface and subsurface water currents based on data from satellite wind and altimetry. Simulated 'larvae' were released into the environment, some from Oahu, some from Necker and Maro Islands, and some from Midway Atoll. The simulation released 'larvae' every day, and removed them after six months (representing settlement of larvae out of the pelagic environment). Satellite based observations on temperature and chlorophyll encountered by the simulated 'larvae' act as habitat indices for survival and growth. The model can assist in developing potential hypotheses for different metapopulation dynamics and the potential for dispersal and retention in the archipelago. Results so far suggest that there is a certain amount of local retention, and advection between banks in both parts of the archipelago. Work on this larval disbursal model is ongoing, for example, by incorporating both wind-driven Eckman surface transport as well as the geostrophic transport to represent deeper flows, thus enabling simulation of the potential effects of diurnal vertical movements. Models such as the one descried here may be helpful in developing testable hypothesis for:

- The spatial and temporal dynamics of larvae of interest;
- Good and poor recruitment years;
- Source and sink locations; and
- Addressing the source/sink debate for NWHI and MHI.

One aspect that would require serious consideration and incorporation into this type of larval model is the documented, substantial swimming ability of late stage tropical fish larvae. Currently, model-larvae are treated as passive particles and are thus misrepresenting their disbursal as well as retention abilities.

The third spatial model deals with the distribution and movements of loggerhead turtles in the North Pacific, based on fishery by-catch and fishery independent tracking data (Figure 32). The observed pattern suggested a potential connectivity between East Asia, Hawaii and Baja California. The question was how the existing tracking data could be used to infer population dynamics for integration into a population model. Dr. Patrick Lehody used an elegant approach incorporating foraging, which lets the animals track their forage. The results suggested indeed a potential continuum of movements across the entire North Pacific Ocean. These data and models would benefit from further investigation.

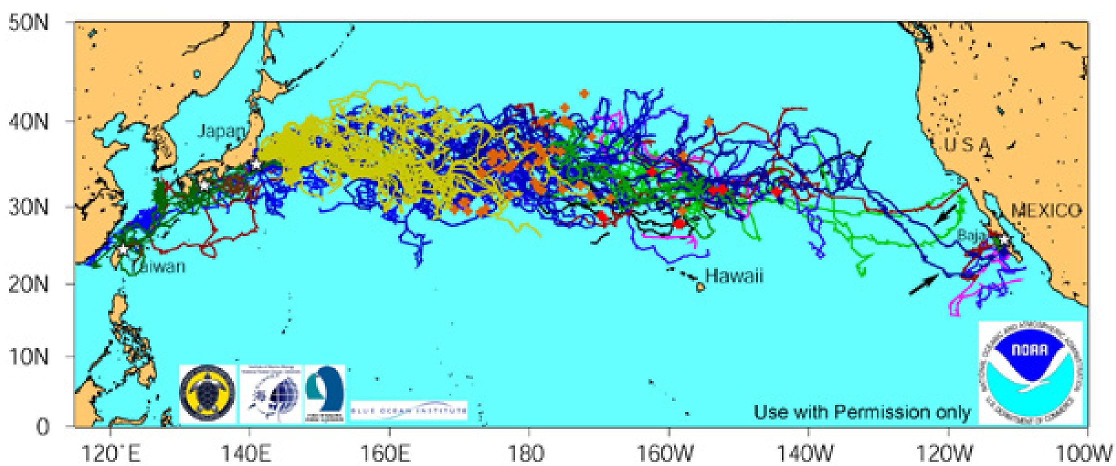



**Figure 32: Distribution and movement of loggerhead turtles in the North Pacific Ocean. Data consist of both loggerheads found in the 1990-1992 high-seas driftnet fishery, and track lines indicating movement of free roaming turtles fitted with satellite tracking transmitters between 1997-2005. Prepared by D.M. Parker in collaboration with J.J. Polovina, G.H. Balazs, I. Cheng, P.H. Duttoin, N. Kamezacki, W.J. Nichols and I. Uchida.**

In summing up, it was suggested that the issue of data, models and management is a circular relationship (Figure 33), in which management questions will determine the data that may need to be collected for a certain type of model to evaluate the questions posed. The resultant modeling outcomes will assist in visualizing the question posed, and may assist management in clarifying the issues. However, this process may also lead to the formulation of more questions and may serve as a feedback loop to managemtn as part of the learning process that will be involved in ecosystem-based management.

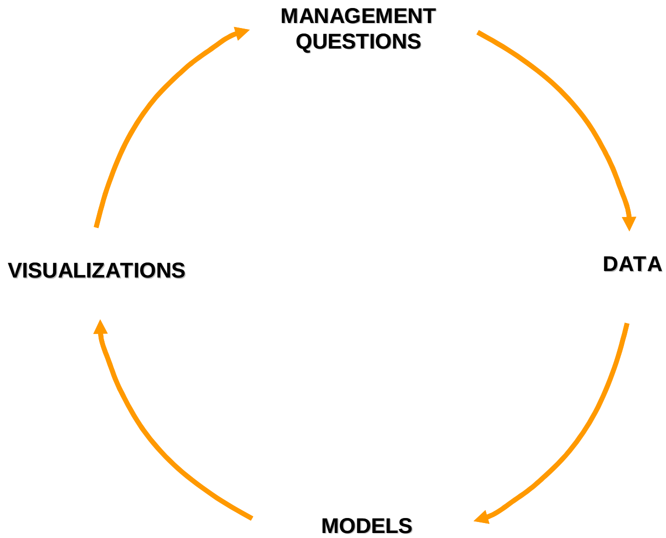



**Figure 33: Conceptualization of the relationship between management questions, data and models.**

## Session discussion

This session elicited the longest discussion. Prof. Villy Christensen asked if Neil Gribble's simulations of the effects of the prawn trawl fishery on Australia's Great Barrier Reef had been used for management. Dr. Neil Gribble indicated that it was used, among many other items, as part o the management process.

Dr. David Witherell commented on the model suggestion of increased fishing efforts outside the boundaries of the no-take zones. Dr. Neil Gribble acknowledged that this was a concern identified in the management plan, and effort limitation was included in the plan. Dr. Dirk Zeller asked if satellite VMS is planned for use in other fishery fleets besides trawl. Dr. Neil Gribble indicated that there are plans for the hook and line fishery, but this is complicated by the need to track individual dories, not only the mother boats. Dr. David Kirby cautioned on the potential for VMS tampering and suggested that other additional surveillance is required to protect against IUU fishing and validate the VMS information.

Prof. Carl Walters made a general comment that models are deliberately set up for users to play with them, which is crucial in understanding whether or not a model is working and how it is responding to changes. Prof. Walters added that modelers are not very good at modeling spatial effort dynamics to understand why fishers make the decisions they do.

Dr. Charles Alexander asked if the no-take zones in Neil Gribble's model were set up with consideration for edge effects of illegal fishing. Dr. Gribble answered that it was considered wherever possible, but zone choices were predominantly based on consideration of biodiversity conservation.

Dr. Michael Orbach asked if there has been any attempt to model the next stage, looking at the relative costs and benefits of the different options the model suggests. Dr. Gribble indicated that this was beyond what he did, but he expected that this would be within the sphere of management. He pointed out that the next steps for him will be to include three fisheries into the model, and then explore how the management plans for each fisheries interact in terms of ecosystem responses.

Dr. Gribble added that the modeling approach used (EwE) includes a module to look at cost and benefits, but that was outside the scope of his study, and needs to be undertaken by the management agencies themselves. Prof. Villy Christensen pointed out there are a number of indicators that can be extracted directly from the models, such as value of catch, profit in the fisheries etc.

Prof. Carl Walters commented on the presentation by Jerald Ault, and suggested that thanks to Jerald's work, a lot of effort is being put into trying to understand how animals are responding to environmental gradients. He also indicated that Prof. Steve Martell has done much of this type of work, and the results are a mixed bag. It appears that, at least in the pelagic fisheries that have been looked at so far, it doesn't make that much difference.

Dr. Jerald Ault pointed out that it is a conundrum between the modeling process and the data that support this process. A considerable amount of time has been spent in Florida thinking through the spatial aspects of the data. The coherence of the estimates suggests that the predictions are good, and there is some confidence in the predictions. A model is being developed now that expands this general concept to the entire U.S. Atlantic coast.

Dr. Mike Fogarty asked Jerald Ault to expand on how the community-level reference points were derived. Dr. Ault responded that that there is a rather large and articulated dataset, and a variety of assemblage constructs are being looked at with different kinds of metrics that represent abundance, frequency of occurrence, spatial structures etc., to try and get at what may be the best metrics. It has not been decided what the perfect metrics are, but a series have been used that help drive the current management paradigms, particularly in the fisheries area. The performance of the models is being scrutinized closely in South Florida, and the public and political interest in this problem is very large.

Prof. Carl Walters added that reviewers have been over the Florida reef modeling effort with a fine-toothed comb because it has the policy implication that managers should shut down the whole reef fishery; that if the model is even in the right ballpark, there shouldn't be any fishing down there. The reviews did not find anything that would invalidate the model results, and the only factor that could invalidate some of the conclusions would be if there is major movement of larger fish in the waters too deep to be picked up by the visual surveys. That was the only factor the reviewers could identify that could cause the data to be erroneous.

Dr. Ed DeMartini asked Carl Walters about the shape of the tradeoff relationships, and if he suspected there might be any fundamental difference in the lower trophic levels. Prof. Walters indicated that the idea that these tradeoffs ought to be linear or concave is essentially a thermodynamic argument, that if you appropriate more and more of the potential energy through-put of a species to support a fishery, then in terms of thermodynamics, it can't support as many species. That argument does not depend at all on what trophic level is being looked at. Where the argument gets dicey is when there are ontogenetic life history effects, where the effect of an organism of a lower trophic level is the opposite on two life stages of another creature.

Prof. John Sibert pointed out CCAMLR manages prey species by some rule that regulates the krill fishery and they set the quota based on what needs to eat it. Prof. Walters replied that in the earliest days of CCAMLR, there was the first big international convention with a charter to do ecosystem management. One of the first things that occurred was a very strong move by Australian scientists and others to say that the Antarctic is divided up physically in a series of regions or domains, and that this presented a perfect opportunity to manage adaptively and to do a whole series of large-scaled, careful experiments in fishery development. This could have helped examine the issue of what happens when krill, which forms the basis of the Antarctic food web, is exploited. However, instead, CCAMLR adopted a British approach, taken from the Whaling Commission led by a prominent British fisheries scientist, whose idea of what fishery science should be is to sit back and let the fishermen fish and hope to learn something from it. The failure of CCAMLR to proceed in anything like an intelligent way is probably the single largest failure of adaptive management in the world.

Prof. Sibert asked if CCAMLR had done any analysis of tradeoffs to see whether they're convex or concave. Prof. Walters suggested the models disagree pretty dramatically about what the shape of the tradeoffs is. Dr. Steve Murawski raised a question regarding the shape of the tradeoff relationship of shrimp population relative to the Atlantic cod. Prof. Walters responded that all that can be said is that in a series of locations around the Atlantic, as the cod collapsed in the late 1980s, the shrimp surveys all showed an explosive increase in abundance followed by the development of the shrimp fishery. However, one can't be sure what the tradeoff relationship looked like.

Dr. Chris Boggs asked whether adaptive management was allowed under the Sustainable Fisheries Act (SFA). Dr. David Fluharty commented that when an ESA issue dominates management, than adaptive management can't be used, but there are a lot of other examples where this approach can be applied. The SFA does not prohibit it, but when ESA or the protected species issue takes over, it restricts the range of options.

Prof. Carl Walters asked Dr. Patrick Lehody why he didn't examine the yellowfin tuna recruitment increase in the early 1980s to see if it could be explained. Dr. Lehody responded that he had not yet completed all the modeling simulations, and hence could not present the yellowfin tuna results.

Dr. Tim Adams pointed out that the work that Patrick Lohedy and colleagues are doing is actually influencing a lot of the advice the U.S. has given out to Pacific Island countries. Prof. Carl Walters indicated that Patrick Lehody’s work has substantial implications, as it demonstrates that much of the Pacific is driven by the same upwelling system spreading westward. This has huge global fishery policy implications, as it demonstrates that it is senseless to be dividing the Pacific up into a western and an eastern part.

Dr. Mike Fogarty asked Dr. Polovina, in relation to the larval dispersal simulation, if it was common to find gyre systems associated with banks, which would contribute to larval retention. Dr. Polovina answered in the affirmative.

Dr. Tom Hourigan asked how applicable the French Frigate Shoals reef fish model is for management questions in the Main Hawaiian Islands. Dr. Polovina indicated that, given the relatively good estimates of species composition and biomass, it would be possible to assemble a first step model. On the other hand, there have been discussion on preference for either an archipelago-wide model or a bank-specific model. However, it could be a fairly easy transition to make.

Prof. John Sibert reminded all participants that ecosystems are never static and probably never have reached equilibrium. Instead, ecosystems appear to be always responding to the last perturbation, and managers should not be given the impression that if humans would stop influencing ecosystems that everything would be constant from then on. It has to be always made clear that ecosystems have their own characteristic response times, and that includes response time to management actions. Prof. Carl Walters added as example that a three-year time lag is often the minimum before we can reliably detect a recruitment failure, and even that time frame is often optimistic.

Dr. Rusty Brainard suggested that one needs to keep in mind the likely impacts of fishery management decisions on other components of the ecosystem. Dr. David Fluharty suggested that paying attention to how things are scaled up and down and what the implications are might be a useful part of the discussion. Dr. Steve Murawski commented that one of the recurring themes in the models discussed here seems to relate to multiple drivers working in many of the systems, with effects of fishing overlaid onto these drivers. It may be worthwhile to start constructing models that imbed the dynamics of both of those factors at the same time. It may be possible to replicate those situations in models and see how much of a ‘knock-on’ effect there is between fishing and other anthropogenic changes that are going on.

Dr. Rusty Brainard commented that it appears fairly common that much of the variability is environmentally controlled, with fishing an additional disturbance factor. Maybe coupling hydrodynamic models and trophic interaction models might be a useful approach. Dr. Jerald

Ault commented that the problems faced in Florida required a nesting of models, with the hydrodynamic side being coupled with the biological component. However, high levels of detail are difficult to maintain and run computationally. Prof. Carl Walter's point that at some stage modelers need to average things to come up with the processes underlying the observed patterns, needs bearing in mind when increasing the complexity of models. Therefore, the actual management questions being addressed influence, to a large extent the level of detail needed in that model to replicate and understand the underlying process.

Prof. Carl Walters commented that the issue of large and complicated models comes up again and again; people feel they have to have giant models that do everything at the same time. About $200 million have been spent on that in the United States alone. However, there's not a single success story except maybe Jerald Ault's efforts in Florida. A model is nothing more than an intellectual device to help scientists and managers think about problems and possible solutions. Models are not there to crank out the final numbers. In fact, when models get big, it is not possible to tell if these models are cranking out the right kind of numbers. Big, complicated models do not have the capability to be used to ask 'what-if' questions, which is the most essential and most useful way to use models, resulting in a learning process for scientists and managers. The idea of building large models incorporating several layers of complexity should not be pursued, both because of the consistent track record of huge expense and poor results from very large models, and also because large models are not going to answer the right questions. Modelers are perfectly capable of building a large number of different focused models to each look at different questions at different scales. In Florida, high resolution hydrodynamic nutrient cycling models are run to look at nutrient loading patterns and dispersion off the coast. The results of these models are then used to drive considerably simpler ecosystem models to look at spatial organization and how the coastal productivity is moving through the food web. It is not reasonable to try doing all those calculations at once, because nobody would be able to 'play' with, and hence learn from these models. That is not going to change in the foreseeable future, until quantum computers come along with three to five orders of magnitude increases in computing speeds.

Dr. Jerald Ault suggested that this comes down to the questions being asked and how deeply the problem is to be looked into. There could be a marriage of both worlds, where a model is not made more complex than needed, but it can't be less complex than needed to address the questions that are being asked. Often, however, that middle ground is not exactly clear at first. The primary issues to first establish are the questions (policy issues) that need addressing, and then to determine the best model approach or structure for the questions that are being asked. Models are a great tool for exploring ideas because they give great freedom, but it is collective wisdom to decide how important the issues is and how much should be spent to analyze it in a modeling framework.

Prof. Carl Walters added that the Florida Everglades are a good example of why one shouldn't aim for big models. In 1991, the Everglades restoration ecosystem model that's driven the restoration strategy cost $30,000. Since then, $6 million have been spent on additional modeling, and not a single policy question answered. Disconnection between model development and policy application should be vigorously guarded against. In the case of Florida, the money would have been better spent on focused data collection schemes to fill gaps identified by simple modeling approaches using ‘game-playing’ scenarios.

Dr. David Fluharty proposed a dialogue to figure out what the problem is and what modeling can do to help. Prof. Carl Walters reiterated a warning that the early efforts in big ecosystem modeling for adaptive management found it to be completely unproductive to sit down and talk about management objectives. It was always more productive to concentrate on the range of management actions that could be taken and about which predictions were wanted. This could lead to identification of the suite of relevant performance indicators. This requires a modeling system that can respond to ‘what-if’ questions from people with different interests. This would then lead to the gradual exposure of the tradeoffs among those performance measures. Furthermore, the willingness of the various stakeholders to compromise can be exposed as well, and win-win opportunities may start to be become evident.

Dr. Mike Fogarty added that what is currently in place are some very clearly defined guidelines and objectives for fishery management that relate to optimum yield. Underlying that as a starting point, in the United States, at least, is Maximum Sustainable Yield. Thus, the question arises if equivalent types of ecosystem reference points can be developed that would help determine how to structure the modeling and how to go about asking the ‘what-if’ questions. There is a range of policy tools available, including changes in fishing mortality rates overall, the imposition of spatial management measures, different types of conservation engineering approaches to dealing with problems, etc. It is useful to think about objectives that are clearly related to the kinds of issues managers are currently dealing with. Looking at the set of policy tools available, the ‘what-if’ questions could be asked about how to use those tools to try to meet those objectives.

Dr. Michael Orbach made two points with respect to some of Prof. Carl Walter’s statements. Firstly, $200 million is trivial in terms of money spend by the public sector, in general, every year. Scientists and modelers have been relatively poor in what decision makers provide to support their efforts for resource management. That can change in the future. At the very least, a group such as the one assembled for this workshop ought not to view funding as a determining restriction on consideration of how to conceptualize the best way to be helpful. Maybe the current Administration is not going to follow the Ocean Policy Commission prescription to double ocean science funding. On the other hand, U.S. philanthropists these days are spending about as much as the annual NOAA budget on ocean issues. The present workshop should not view funding as a fundamental constraint. Secondly, the other constraint has to do with the comment about the modeling in the Everglades. What often happens in science is that topics or issues get popular, and are pursued vigorously for a while. Then something else becomes popular or deemed scientifically important, and is pursued for a while. It is possible that this is what happened in Florida. However, simply because this phenomenon happens or because someone may have gone down the wrong path with something, does not mean that that is the way it has to happen again. One of the reasons of having so many experienced and diverse people at the present workshop is the desire to avoid the mistakes of the past.

Prof. Carl Walters emphasized that the process of how a problem is approached and analyzed is critical. If there is a way to let nature tell us what it is capable of doing, like finding that reefs may provide reference point information without having to pretend an ecosystem model can generate them would be a real important investment option. To learn more about prey species and other species in the ecosystem that aren't fished and studied for single-species assessments, some funding is going to be needed in addition to funding for modeling. Getting more ecosystem money is going to be very welcomed on a lot of fronts that don't necessarily immediately involve modeling. Again, policy question driven targeting of theses issues is important. Here, input from experienced ecosystem modelers with regards to potential data- or knowledge-gaps to be filled from an ecosystem functional and modeling perspective is valuable, e.g., the repeated points made about forage fish.

Dr. Steve Murawski suggested that this may be a unique situation with island systems that are replicated 50-odd times, in terms of datasets. Within that total, there are situations with similar types of oceanography, and environmental and ecological parameters etc. There is probably a finite number of different situations, within which there is a range of exploitation histories. In a sense, types are replicated and exploitation histories within them are known. Perhaps it would be useful to construct a null-model that said, for example, that there are 50-odd replicates of the same system, and see if the basic null-model would predict the exploitation histories that you actually observed and what the outcomes would be. That would be type of first-level test of whether an ecosystem model could come close to replicating the actual historic scenarios, based purely on a fishing scenario, rather than one that is driven by the inherent variability in the system. Maybe this could be done in layers to try to understand the interaction effects of both the natural variability, as well as the exploitation scenarios. Hand-in-hand with the unique situation that occur with the different data collections for these island systems, if a set of models could be developed that would allow scientists to examine the data and model results, and explore the exploitation versus natural variability scenarios, that would be a big help.

Prof. John Sibert said that the phrase ecosystem-based management is incomplete, because management implies an object on which the action is taken. This raises the question of what is being managed. For example, in the past there had been an allusion to the problem of too many marine mammals and going out and culling them. If one is really concerned about coral reef ecosystems and small-island ecosystems that are overfished, then thought also has to be given to removing the people. It may not be possible to take away their right to fish, because that creates a whole different suite of problems, but it may be possible to remove them from the coral reef ecosystem. While he was semi-serious about the above scenario, if the objective of your action is not clear as part of the 'what is to be managed' question, all possibilities have to be considered. And if there is thought given to reducing people's ability to fish, it has to be considered what comes next. These fishers have to live on the islands, thus they would need some alternatives. This is not a trivial problem, and often at the core of ecosystem-based management.

Prof. Carl Walters added that a very good and experienced modeler he knows, Josh Korman from Canada, made an interesting point. Mr. Korman has been involved in projects ranging from the Everglades, Grand Canyon, British Columbia herring fisheries, to Florida Bank coastal ecosystem management model and salmon management. Some time ago Mr. Korman asked why so much effort was being spent on modeling. He suggested that if people would simply sit down and think through what the policy problem was in the first place, they would likely have done something completely different, because the problems often turn out not to be the same as initially assumed when science and modeling is called in. If it were recognized early that each problem is almost always a people problem in some way, 90 percent of the modeling he has done probably would not have occurred. Generally, it is not extensive or complicated modeling science that is needed; science questions can often be answered pretty quickly with relatively simple data and relatively simple models. One can also make very simple tradeoff calculations. The difficulty is when modeling and science become confused with policy and resource management values and decisions. Prof. Walters finished by concurring with John Sibert's observations about where the problem is in this area.

Prof. Carl Walters urged that the data should be looked at first. By examining the fisheries dynamic data, the survey and other datasets, one might be able to determine if patterns exist that could be explained by several different models or hypotheses. Dr. Pierre Kleiber expressed frustration in this business of ecosystem management, as it seems impossible to get a good picture of what management would mean in operational terms. Without this, there is somewhat of a vacuum.

Dr. Beth Flint suggested that people who manage fisheries have been issued a new mandate; they now must consider the ecosystem, and not only the effects on the target population, but the effects on all other components of the ecosystem. Perhaps the problem is that, in trying to incorporate that new mandate into the challenge of managing target species populations (e.g., through quotas or a level of biomass for harvest from a population), managers not only have to consider Maximum Sustained Yield or Optimum Sustained Yield, but also what effect this removal is going to have on, e.g., sea cucumbers, and four or more trophic relationships spread out from that target population. That may be why models are needed - because this is a more complicated problem than it used to be under conditions of single-species management.

Dr. Svein Fougner countered that it is a big step from saying managers have to consider these impacts to saying managers have to base decisions on higher value being attributed to the 'other' resources than to the target resources. This implies some kind of value scaling. Because of the Magnuson-Stevens Act and other applicable laws, managers have to consider impacts on target species, by-catch species, endangered species, marine mammals, seabirds, and fishing communities. But ultimately, managers have to make a decision as to what value to ascribe to the different elements that are affected directly and indirectly, and may give much lower value to those incidental impacts.

Dr. Tom Hourigan commented that there have now been workshops in all of the U.S. territories with fishers looking at coral reef fisheries management. For the most part, it is the fishing community itself which is not happy with the way coral reef resources are currently managed given the decrease in resources observed. The other aspect is that, as far as potential ecosystem impacts are concerned, experience from the Caribbean, where herbivores and other species have been overfished, has shown side effects such as disease, which have not clearly been attributed directly to human impacts but are deemed to be related. So it behooves managers to take precautionary measures to keep a system on the safe side of those types of ecosystem shifts that have been observed in the Caribbean.

Prof. Carl Walters suggested that when someone gets specific about what a preferred action might be (e.g., banning gillnets on coral reefs), it puts the modelers into a domain where modeling has not been done, and many of these issues often involve high resolution spatial questions and selectivity questions. It also involves very different kinds of data that would not ordinarily be used in either ecosystem modeling or stock assessment analyses. Models that are helpful to managers will not be developed until managers speak up. Modelers can often indicate that a model is not needed, or that the analysis can be done via simple calculations; or that some really messy approach is needed, or even that it will cost a whole bunch of money and time; but until the specific question is posed, little will happen.

## *Indicators*

### David Kirby (SPC, New Caledonia): What do scientists need to develop indicators…

**What do scientists need from fishery and conservation managers in order to develop models and indicators useful to policy development and management?**

This presentation arose from the frustration among scientists charged with developing ecosystem approaches to fisheries (EAF) on the lack of clear goals, and discusses and defines the roles and responsibilities for implementing EAF with respect to science, policy and the public (Table 9). EAF is intellectually based on Ethics, Ecology & Economics:

*Ethics*: Environmental and ecological ethics are branches of moral philosophy developed amidst a growing appreciation of the evolutionary origin of humans and our role in the global ecosystem. EAF, as a broadening of conventional fisheries management, is the pragmatic interpretation of ecological ethics as applied to fisheries

*Ecology*: The role of ecologists is to analyze data, to provide information and correct disinformation on the structure and functioning of ecosystems. It is important for the credibility of the scientific process to communicate both knowledge and uncertainties. Under EAF, the research scope needs to be broadened to cover all ecosystem components.

*Economics*: Economic valuation attempts to assign quantitative values to goods and services provided by environmental resources, whether or not market prices are available. Indirect Use values arise from supporting or protecting economic activities that have Direct Use values. Intrinsic values arise where individuals who do no currently make use of the goods and services of an ecosystem wish to see them preserved in their own right.

The practical foundation of EAF is in various binding and non-binding international agreements, such as the 1982 Law of the Sea Convention and the 1995 Code of Conduct for Responsible Fisheries, respectively. Further, the 2002 World Summit on Sustainable Development agreed to “encourage the application by 2010 of the ecosystem approach”.

The high-level policy goal of EAF is: “…to balance diverse societal objectives by *taking into account* the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions, and applying an *integrated approach* to fisheries within ecologically meaningful boundaries”. Implementation guidelines are presented in Garcia *et al.* (2003) [FAO Fish. Tech. Pap. 443] and FAO (2003) [FAO Technical Guidelines for Responsible Fisheries 4 Suppl. 2]. For scientists to develop models and indicators useful to policy development and management, managers need to:

1. Provide the management objectives – listen to the scientific advice, listen to stakeholder values, seek consensus but ultimately make clear decisions;

2. Remove institutional barriers to effective collaboration in research and management;
3. Rewrite existing legislation if not adequate; and
4. Obtain/provide funding for the expanded research base needed to support EAF, including the integration of empirical data and modeling, and the documentation and development of the value-systems that form the basis of prioritization.

**Table 9: Suggested roles and responsibilities of different stakeholders under EAF.**

| Issue | Scientist | Manager | User |
|---|---|---|---|
| **Principles and concepts of EAF** | | | |
| Ecological relationships should be maintained | | | |
| Limit impact of fisheries on ecosystem | | | |
| Apply precautionary approach in the face of uncertainty | *Research & Discuss* | *Discuss & Decide* | *Discuss & Implement* |
| Ensure both human and ecosystem well-being and equity | | | |
| Ensure management measures are compatible across entire distribution of resource (i.e., across jurisdictions and management plans) | | | |
| **Operational implementation** | | | |
| Identify specific issues | ✓ | ✓ | ✓ |
| Develop collective values | ✓ | ✓ | ✓ |
| Identify 'ecological relationships' | ✓ | | |
| Determine how ecosystems function | ✓ | | |
| Improve knowledge of impact of fishing on system components | ✓ | | |
| Define ecosystem boundaries | ✓ | | |
| Define management areas | | ✓ | |
| Ensure stakeholder participation | | ✓ | ✓ |
| Educate stakeholders about knowledge and uncertainties | ✓ | ✓ | |
| Develop appropriate bio-economic models | ✓ | ✓ | |
| Use them to explore management scenarios | | ✓ | ✓ |
| Investigate the effectiveness of, e.g., MPAs[a] | ✓ | ✓ | |
| Decide where to put MPAs | | ✓ | ✓ |

[a] MPA = Marine Protected Area

## Robert Wakeford (MRAG, UK): Development of marine biodiversity indicators…

**Development of marine indicators for assessment of the biodiversity loss of the marine environment**

This presentation focused on the results of a short-term project for the European Environment Agency to assess the state of biodiversity in European marine ecosystems by highlighting the main pressures and trends. The study focused on the use of sentinel species indicators and presented case studies.

The indicator approach has been selected to facilitate the process of transforming data into suitable information that can be used for reporting complex trends at different levels (e.g.. global, regional and national). Indicators can be used to help answer what is changing, and to what extent (state); why it is changing (pressure); why it is important, and what is being done (response). This Pressure-State-Response (PSR) framework can facilitate causal change analysis of complex phenomena in the marine environment, and simplify reporting and communication of results to a wide variety of stakeholders.

Development of the PSR framework requires the selection of suitable indicators. A number of different criteria exist to help choose indicators, but their final selection depends on the intended audience. Realistically, most indicators cannot be expected to meet all the criteria, but should be optimized for the purpose and audience using both scientific knowledge, experience and intuition.

Within Europe, several Marine Management Regions have been classified for assessing the ecological state of the environment. These include the International Council for the Exploration of the Seas (ICES) statistical areas, European Regional seas, ICES eco-regions and Large Marine Ecosystem (LMEs). Each classified region has a number of merits and complications for assessing the status of marine biodiversity, including data availability and changes to political and physical boundaries (e.g., oceanography and bathymetry).

A number of pressures on the marine environment have been identified from a range of commonly used indicators. Increases in fishing pressure, and measured fishing capacity (or engine power), has shown a general decline since 1990s. However, it is noted that fleet capacity reductions are likely to have been offset by increases in overall fleet efficiency and effort. Other pressures within Europe include increases in sea temperature and marine pollution.

In total, five different categories of species were presented that have the potential to serve as sentinel species within the same number of European waters: habitat creators, planktonic predators, top predators, water body indicators, and feed indicators. Case studies were presented for each indicator species in the Black Sea, Baltic Sea, North Sea, Mediterranean Sea and Celtic-Biscay shelf.

In conclusion, the results showed that the major anthropogenic pressures on the European marine environment are excessive fishing pressure and pollution (contamination and eutrophication). Sentinel species can be used to show trends that appear to coincide with these pressures within the marine ecosystem. However, additional information is required on the marine ecosystems to ensure that the observed trends in indicators can be fully interpreted, particularly if used in enforcing management policy.

## Mike Fogarty (NMFS, Woods Hole): Georges Bank ecosystem indicators…

**Indicators of change for the Georges Bank ecosystem**

Indicators can be helpful in understanding ecosystem change but are unlikely to evolve into tools for the establishment of reference points. The interpretation of indicators could be quite difficult and perhaps misleading, without a mechanistic understanding of how a system is operating, and of the accompanying modeling that will help in this understanding. Research on the Georges Bank ecosystem was used to illustrate these points.

The Georges Bank and the extension of the Northeast Continental Shelf off the Eastern United States is a highly productive area and have long been recognized as an important fishing area. On the Georges Bank, an anti-cyclonic gyre results from stratification and is driven by strong rotary tidal currents. This creates relatively high probabilities of retention of organisms on the Bank and promotes mixing water and nutrient regeneration resulting from the strong tidal forces and wind events. This has an important influence on the distribution of fish and shellfish on the Bank. Production in the central part of the Bank is primarily recycled production and may not be available to higher trophic levels. The outer parts of the bank, particularly around the 60 m isobath, is where new phytoplankton production occurs, driven by upwelling from deeper waters. However, zooplankton production is lower than expected on Georges Bank, based on the overall biomass spectrum for this system. This has now been shown to be dues to lower new production on the bank than was anticipated. Consequently, energy is quite tightly constrained for fish production, which in turn affects the dynamics of fish communities. On the decadal scale, there are also environmental changes driven by the North Atlantic Oscillation (NAO). When the NAO is negative, less Labrador Slope water penetrates to the Mid-Atlantic Bight and primary production in the system drops substantially.

Plankton surveys over time have shown that the dominant copepods, *Calanus finmarchicis*, and *Pseudocalanus* spp. have been relatively stable over the entire time period but some of the smaller bodied forms associated with warmer waters such as *Centropages*, *Oithona* and *Metridia*, have increased. There has also been a large increase in scallop biomass in this system due to a reduction in fishing mortality on sea scallops and the imposition of fishery closed areas. This may have important implications for the patterns of energy flow in the system, since scallops are concentrated in the area dominated by the new production on the bank.

Fish biomass trends on the Bank showed some dramatic changes over time, most notably there was a major increase in pelagic fishes, whilst gadoid fishes had declined. Over the period of observations (1963-2002) there had been a reallocation of the relative importance of planktivorous, benthivorous and piscivorous fish assemblages in the system. Planktivorous fish have increased substantially over time, which suggests lower levels of fishing mortality and possibly lower predation mortality on this component of the system. The large increase in productivity in the planktivores also suggested that there was a fundamental difference in the way energy was being redistributed and allocated on the bank, with much more energy currently going into the pelagic food web compared to the early 1960s and 1970s.

Interestingly, there were no overall trends in terms of the Shannon Index of diversity despite shifts in the relative species composition over time. Thus the results suggested that the Shannon Index may not be a particularly sensitive indicator of change. Further, there was also no major shift in species richness, although some evidence exists of an increase in richness in recent years due to the occurrence of more southern species on Georges Bank. There had been a slight decline in the mean trophic level of fishes on Georges Bank, due in part to the loss of some important piscivores such as cod but also by the increase in biomass of smaller pelagic fishes. The size spectra for benthivores showed a decline in the period of intensive exploitation in the 1970s and 1980s. But there had been an overall recovery by the 1990s, when more effective management was put in place. The piscivores show less of an overall change which reflected apparent replacements such as cod decline and spiny dogfish increase. Similarly there was little change for the planktivores, although in the late 1960s, early 1970s, the planktivore community became dominated by sand lance and other smaller bodied forms in the system.

In summary, the various fishery ecosystem indicators for the Georges Bank could be grouped in three broad matrices, representing the physical, human and biotic metrics (Figure 34).

Overall, the following conclusions emerge from this analysis:

- Increased biomass and production at lower trophic levels;
- Change in energy pathways to macrobenthic and pelagic food webs;
- Clear changes in fish community composition evident; and
- Changes in fish community dynamics appear to be reversible.

In summary, the Georges Bank is a system that historically has been strongly dominated by exploitation effects, while environmental influences have been subordinate, or at least less evident.

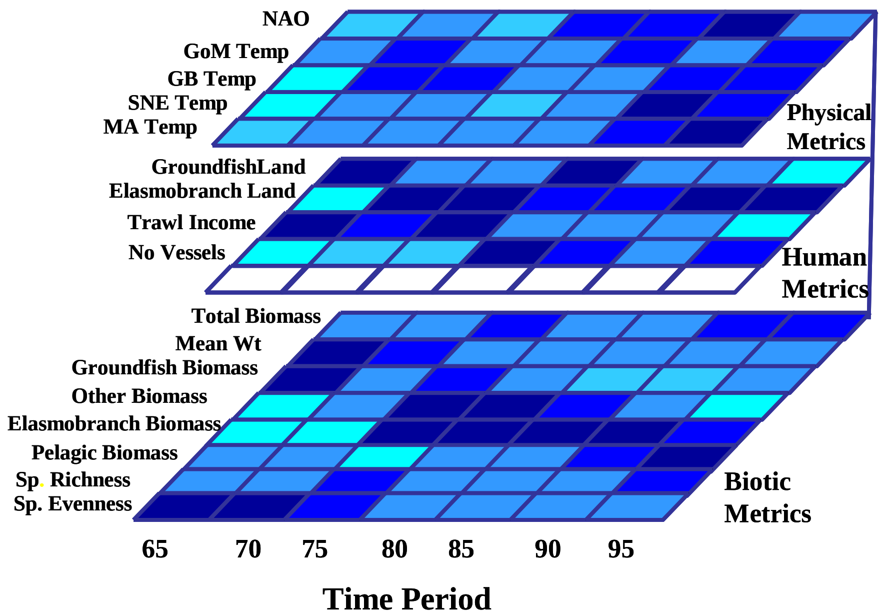



**Figure 34: Suggested triple-layer matrix of fishery ecosystem indicators as applicable to George's Bank, north-eastern USA.**

## David Witherell (NPFMC, Anchorage): Indicators for the north Pacific…

**Ecosystem approach and indicators for the north Pacific**

Dr. David Witherell provided an overview of the North Pacific Fishery Management Council's ecosystem approach to fisheries, which is built upon four goals:

1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability;
2. Maintain and restore habitats essential for fish and prey;
3. Maintain system sustainability and sustainable yields for human consumption and non-extractive uses; and
4. Maintain the concept that humans are part of the ecosystem.

The author presented a brief overview of existing ecosystem-based management measures:

- Strong science and research programs;
- Effective reporting and in-season management;
- Comprehensive observer program;
- Precautionary and conservative catch limits;
- Limits on by-catch and discards;
- Limited entry program;
- Habitat protection (e.g., year-round closures, Figure 35);
- Ecosystem considerations;
- Stakeholder involvement; and
- Interagency coordination.

With regards to special ecosystem considerations, specific measures have been taken to minimize potential impacts to marine mammals, seabirds, and other components of the Alaska ecosystem, with major measures being:

- Limits on total removals from the system (e.g., $2x10^6$ t annual limit);
- Prohibition on directed fishing for forage fish species;
- Requirement that longline vessels deploy seabird deterrent devices to minimize incidental by-catch;
- Numerous measures to protect Stellar sea lions from disturbance and potential competition with prey; and
- Marine reserves to conserve benthic biodiversity.

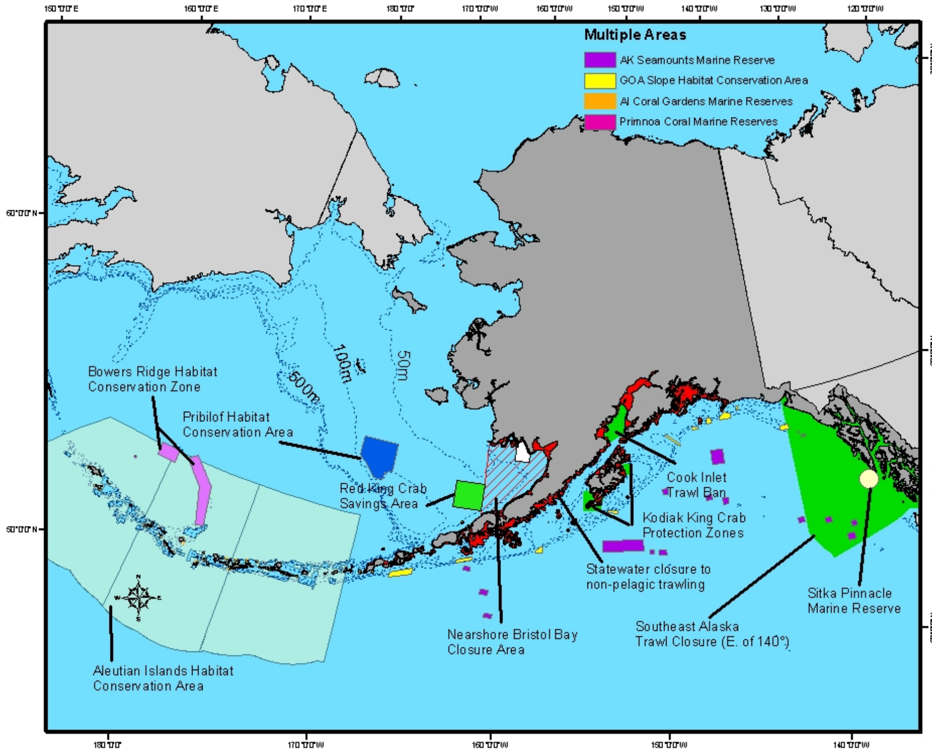



**Figure 35: Year-round closures in Alaskan waters.**

The North Pacific Council, through its Ecosystem Committee, is actively pursuing additional avenues to further implement an ecosystem approach. Given the unique environment of the Aleutian Islands ecosystem, the Council is planning to use this area as a test case for development of a separate FEP, and for development of EAM using a regional ecosystem council to discuss and exchange information on fishery and non-fishery activities. The Aleutian Islands FEP will be prepared later in 2006. Details of the FEP, including possible designation of an Aleutian Island Plan Team, are still being developed.

Additional considerations are being given to the various options available for implementing EAM governance options; including the NPFMC functioning as ecosystem council, FMC acting as administration support to an independent ecosystem council, or a separate agency setting up an ecosystem council (Figure 36)

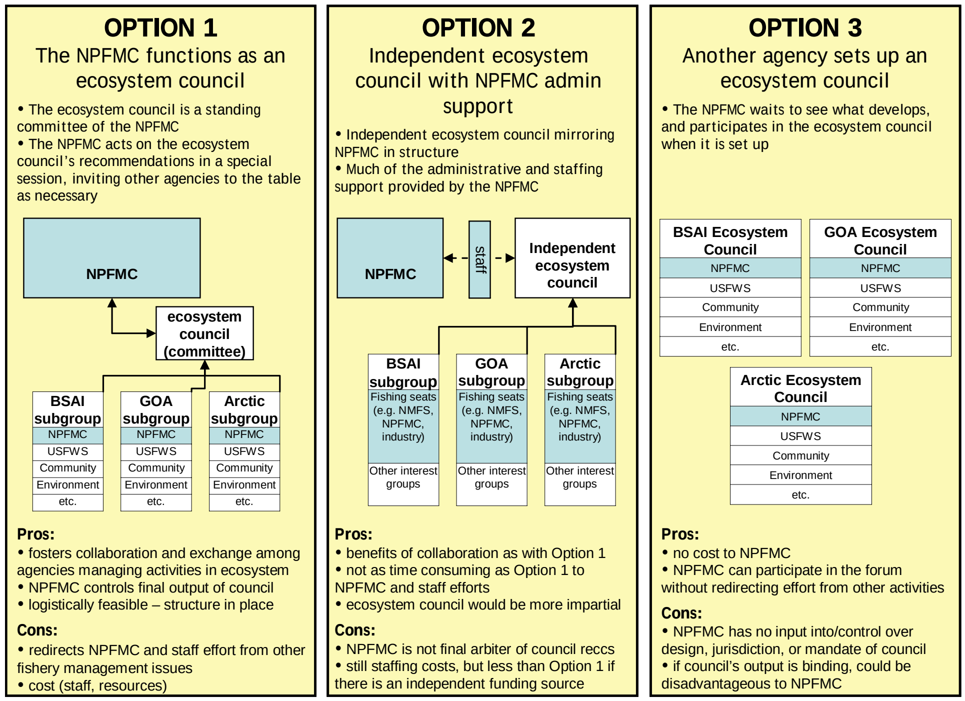



**Figure 36: Options being considered by the Northern Pacific Fishery Management Council for implementing an ecosystem council initiative.**

However, a more likely scenario may be an independent ecosystem council comprised of a selection of agencies with jurisdiction over the entire ecosystem area (Figure 37).

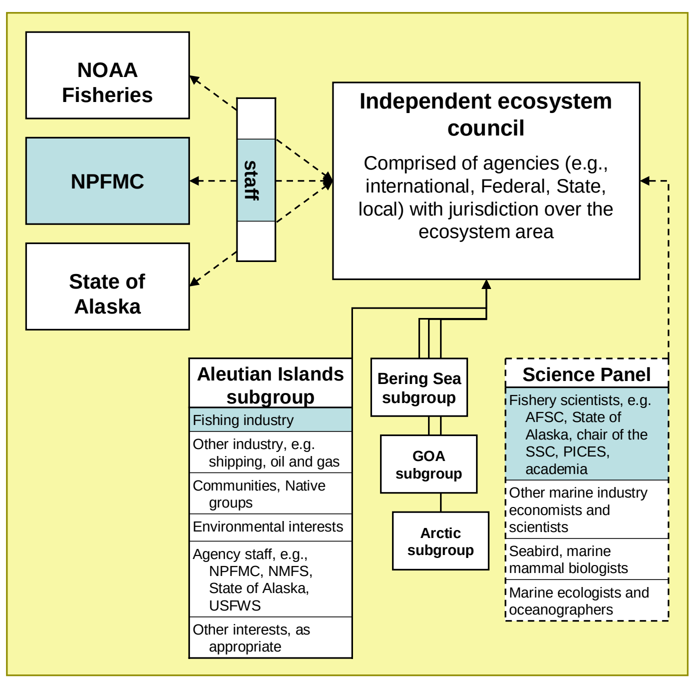



**Figure 37: Potential EAM management option for implementing an independent ecosystem council.**

Since 1995, the North Pacific Council has produced an Ecosystem Chapter as part of the annual groundfish SAFE report. The Ecosystem Chapter has been developed through voluntary contributions from scientists of several agencies, including NMFS, ADF&G, NPFMC, and USFWS, and was initiated to document marine mammal and seabird trends, but has evolved to contain a set of comprehensive ecosystem indicators (Figure 38).

| Indicator | Observation | Interpretation |
|---|---|---|
| Oceanography | | |
| PDO | PDO neg. w/ cool waters 98-02, PDO positive > Aug 02 | higher production with positive PDO |
| etc…. | | |
| etc…. | | |
| Habitat | | |
| Target Fish | | |
| Forage Fish | | |
| Misc. Species | | |
| Mammals | | |
| Seabirds | | |
| Aggregate Indicators | | |
| trophic level of catch | constant high level since 1960s | not fishing down food web |

**Figure 38: Two examples of the list of comprehensive ecosystem indicators developed in the Ecosystem Chapter of the annual NPFMC groundfish SAFE report.**

Environmental indicators include the PDO, SST, bottom temperature, ice cover, and others. Biological indicators are built around three primary ecosystem-based objectives:

1. Maintain predator-prey relationships;
2. Maintain diversity; and
3. Maintain energy flow and balance.

Indicators of predator-prey relationships include pelagic forage availability from survey data, concentration of fisheries on forage species, removals of top predators, and introduction of non-native species. Diversity (species, functional, genetic) is monitored through trawl surveys (e.g., richness, eveness, trophic levels, size). Indicators of energy flow include overall removals and species composition, trophic level of catch, fishing mortality rates, and discard amounts. Indicators are summarized in text tables as well as 'traffic light' figures. The next step in the process is to evaluate how these indicators can be better incorporated into ecosystem-based decision making.

From current experience, the practical effects of having an ecosystem chapter are:

- Awareness:
  - Non-target species (sharks, skates, grenadiers);
  - Seabirds and marine mammals;
  - Habitat impacts (sponges, corals etc.);
  - Fisheries not the only influence on system changes;
- Projections:

    - Ecosystem effects of different catch limits;
    - Industry investments;
- Information transfer:
    - All data available on web site for modelers;
    - Summary info useful for NEPA analysts.

The presentation concluded with some final thoughts on the need to:

- Develop regional objectives and goals for EAM and EAF;
- Develop ecosystem reference points for management change:
- Better package scientific data for sue by managers; and
- Begin preparing the FEPs to identify information gaps and other needs. However, EAF can be implemented regardless of the level of information available.

## Session discussion

Several participants emphasized the issue of resource managers frequently seeing themselves as being ‘downstream’ of legislation relevant to their activities, and are often not in a position to rewrite legislation. Indeed, it was suggested that managers may even be actively excluded from the policy and legislative process. Unfortunately, if managers are ‘downstream’ of the legislative process, then scientists are even further removed, yet still have to deal with the implications of the process. Thus, particularly in these circumstances, dialogue between the science and management level becomes absolutely crucial, in order to develop and foster functioning collaboration. Furthermore, the engagement by management in influencing and altering legislation (if required) in response to successful science-management interactions may need to be increased.

It was pointed out that in Table (9) of Dr. David Kirby’s presentation only scientists were associated with the categories “*Identify ecological relationships*”; “*Determine how ecosystems function*”; and “*Improve knowledge of impact to fishing*”, while managers and users were apparently excluded form this process. Concerns were raised how traditional ecological knowledge could be incorporated into this process. It was acknowledged that the presented outline was a generalized pattern, and where relevant, can and should be amended to accommodate specific requirements and needs, such as involving stakeholders with specific traditional knowledge.

Accounting for ecological and other traditional knowledge requires scientists to be more sensitive and open to. There clearly is, in many cases, a need for improved knowledge of fishers’ behavior, experiences, and beliefs. This calls especially on social scientists to collect and aggregate, and hopefully also quantify traditional knowledge, and compare and merge it with other data. An example was given on how traditional knowledge has contributed a missing link in understanding in science. In Lapland, reindeer scientists had been working on reindeer ecosystem management policies, but were not aware of the fact that the herders had started to artificially knock lichens out of trees for their reindeer to feed on, causing a non-sustainable depletion of food resources for their main herding species. This was occurring at a time of year and in locations not frequented by scientists, who weren't aware of this process going on. Yet, it caused a massive change in the structure of the ecosystem. This was only discovered after scientists engaged in dialogue with the reindeer herders. Similar examples obviously exist in fisheries.

It was also emphasized that Marine Protected Areas (MPAs) are generally considered part of the core ecosystem approach. However, it was suggested that the ecosystem approach needs to be broadened to investigate the effectiveness of a wide range of management tool holistically, while keeping in mind the large-scale spatio-temporal component of any consideration in the ecosystem context. What is required in an ecosystem based management approach is to identify the tradeoffs that come from existing single species considerations, and then examine and evaluate the whole suite of potential management measures relative to policy priorities and stakeholder needs and wishes.

There were comments and discussion on institutional barriers. Specifically, it was noted that several of the institutions participating in the present Ecosystem Science Workshop were in disagreement over jurisdictional responsibilities in the Northwestern Hawaiian Islands. Interestingly, it was also noted that the same agencies had collaborated well in scientific studies of the NWHI. It was agreed that there would likely always be some institutional tension and likely disagreement, particularly if one agency was concerned with extractive values while others have a conservation mandate. Also, measures that have been traditionally viewed as constraints within fisheries management will now often have to be considered as objectives within a broader management scheme. Consequently this tension may always exist, and intensive efforts are required on all sides to ensure such tension is turned into productive, collaborative and cooperative approaches.

There was discussion about incorporating experimentation into policy with respect to ecosystem management. For example, could the results from fishing be used in a conservation context to manage the ecosystem? The data streams that come from fishing and fishing records could also be useful from a conservation perspective, providing a sense of how the ecosystem responds to natural or anthropogenic perturbations. Clearly, the problem here is the experimentally un-replicated and un-controlled nature of the fishing 'experiment', i.e., the same problem that has plagued and complicated fisheries science for decades.

One of the guiding principles of EAF is to incorporate diverse stakeholder input. In the case of the Northwestern Hawaiian Islands, for example, there are a number of institutions that are representing diverse stakeholder views, such as conservation versus exploitation. Double representation of some stakeholder views and mandates from different institutions may also have been represented at the Workshop. This may be relatively unique to the Hawaiian situation. NOAA, as an institution, has a number of principles for ecosystem management. It is to be expected that NOAA will be applying all these principles in the same manner, irrespective of mandate or viewpoint of institutions and associated stakeholders. If this does not occur, then the conflicts that exist in the user groups could become amplified in the institutions. NOAA has many layers, including the National Ocean Service (NOS) and the National Marine Fisheries Service (NMFS), both of which have fundamentally different objectives. Furthermore, the National Parks Service focuses on generating a relatively pristine environment for maximum human enjoyment. In the case of the NWHI, several islands managed by the National Parks Service suffered from insufficient communication between each management unit, and this was exacerbated by poor communication between NOAA and the National Parks Service. This institutional problem requires concerted effort and serious consideration of system management as a centralized objective.

Another potential institutional problem relates to funding. Of major concern is the current state of under-funding of all aspects related to ecosystem-based approaches to management. To tackle the problem appropriately, both in science and management, will require substantial increases in funding across the board. If the position on funding needs will only be taken up by one of the relevant agency, it would be inefficient and ineffective. However, if all agencies and institutions associated with the ecosystem-based approach are aligning their position and mutual understanding for funding needs, then such a strong centralized voice focused on topic, not institutional preference, may be more effective and cost-efficient.

A point was raised with regards to the mechanisms for enhancing the dialogue among the different user and stakeholder groups. The present workshop was a good example of scientists and managers getting together. However, other mechanisms need to be explored to include all the different stakeholders, for example user groups, in a manner that is non-threatening and encourages open communication between all parties. Typically, when managers go to user groups, the discussions concern changes to regulation that are being imposed. This is a very difficult environment in which to have an open dialogue. Consequently, serious thought should be focused on how to structure multi-party dialogue beyond the science-management sphere that is cooperative and productive.

It was noted that the cases presented by Dr. Robert Wakeford were good examples of the difficulties science faces in relation to its general success to describe correlations, but rarely being able to assign causality. For example, it is not clear whether the collapse of tuna in the Black Sea that started the sequence of biomass changes that were shown in Dr. Wakeford’s presentation had anything to do with fishing or whether it was loss of cold deep water habitat. This was a classic example of effects confounding. Similarly, most ecosystem models suggest jellyfish blooms are a symptom and not a cause of change in the ecosystem, and are a consequence of the depletion of planktivores to eat their food. In both instances, there are diametrically opposed explanations for the observed changes? How would managers react to being presented with radically different explanations for the changes in ecosystem dynamics? These types of questions need to be raised, and policy development needs to consider precautionary responses to and management options for such scenarios.

This provoked further discussion on ecosystem change and how to determine the underlying causes. Could adaptive experiments be devised to investigate these processes? However, often this may require long time periods of experimentation (e.g., the Effects of Line Fishing experiment on Australia’s Great Barrier Reef) with the associated need for both long-term management resolve and appropriate resources and access for experimental and monitoring science.

The issue of ecosystem indicators had been raised at the Paris Symposium on Ecosystem Management in 2004. It was noted that even though there was a formulated way of selecting indicators, hardly any of the contributions to the meeting actually appeared to be using this method in selecting those indicators. However, there were principles for choosing suitable indicators. Dr. Wakeford was asked if he and his colleagues had formalized the way in which indicators were selected and if a formal procedure for indicator selection existed? Dr. Wakeford indicated that they did look at a range of potential indicators, but that the overriding driving force was availability of time series data for a potential indicator. Thus, historic data availability and estimates form a fundamental role in likely indicator selection.

This generated more comments about indicator selection, particularly species other than those taken in fisheries. It was unlikely, that there would ever be a fixed set of indicators that would provide answers for all scenarios in an ecosystem. It was noted that formal decision analysis has been done on the issue of whether to engage in large experimental changes in policy. What this analysis showed clearly was that experimental initiatives should not be performed gradually. If anything was to be changed it should be changed rapidly, unless it may lead to major social disruptions (e.g., rapid closures of fisheries in the Baltic Sea). Furthermore, in the case of Hawaii, there is high spatial replication and partial separation of habitat areas that create a whole suite of potential experimental units to facilitate experimental approaches without the potential for major social disruptions.

The issue was raised if indicator selection could lead to something that is comparable to biological reference points, but established on an ecosystem level. What would be required in this case is the development of ecosystem reference points from models, and a mechanistic understanding of what the relationships are between these ecosystem reference points and the drivers in a system that can be controlled. However, one of the fundamental problems is the lack of understanding of many of the mechanistic relationship between control and response. With respect to biodiversity indices, they can indicate the ecological properties of a system and the way it is operating. However, there will be a continuous need to monitor species composition. This led to a discussion about the possibility for a model to generate a type of ‘multi-variate’ reference point that would be useful and interpretable? In principle, it was thought this might be possible. However, clearly lacking from such an exercise is what would be the prescriptive action in response to ecosystem change. Reference points are just one part of the tools available to scientists and managers.

Initial discussion on Dr. David Witherell’s presentation focused on the differences and similarities between the North Pacific archipelagic plan and that of the Western Pacific. It was noted that both systems shared a number of islands and areas that seem to be fairly pristine. The North Pacific area has experienced some fishing, but some of the outer islands could be considered as a relatively undisturbed baseline. Another similarity is the level of oceanographic investigation of currents and water mass flow around the islands. However, it was noted that there was less intensive land use in the Alaskan islands than in Hawaii. Also some of the governance concerns, specifically jurisdictional issues, were generally less complex than in Hawaii. It was thought that the general approach the North Pacific Council is taking in terms of an overall cap on removals and some of the other constraints was a good example of a potential ecosystem-based approach to fisheries management.

Dr. Witherell noted that the North Pacific Council had conducted further analysis of the optimum yield limit, as there were some concerns that the relative catch allocation under that limit might depend on which species commands the highest price. Thus, the savings from a conservation aspect are not equally distributed among all the target species. This generated discussions about tradeoffs. It was noted that not all components in an ecosystem can be at optimum levels of exploitation, as there need to be constraints to protect target and non-target species. This is a major issue that scientists and managers have to consider, and it may be inevitable that some target stocks may have to be exploited at lower rates than might be considered optimum from the single-species perspective.

There was further discussion of the North Pacific overall cap on catches. It was noted that the biomass ratio versus the fishing mortality ratio for all the North Pacific stocks are offset conservatively from the trigger levels by a considerable amount, even for the weakest stock. This appears to be a useful level of precaution, as the stocks that are closest to the trigger points are the ones with the highest economic value.

The Alaska example was a good lesson on the importance of spatial fisheries data. There is a lot of emphasis on using GIS to understand the spatial dynamics of fishing effort in relationship to the resources. There was also discussion about the reference levels to trigger management action, particularly with regards to non-target species. The non-target species are generating considerable interest at the North Pacific Council level, as the level of harvesting should not drive any non-target stock into low or critical levels. North Pacific stock assessment scientists have been working on the non-target species, and are very interested in developing indicator or reference points, as well as control rules.

It was noted that the North Pacific ecosystem might shift towards dominance by pelagic species with substantial declines in productivity of currently dominant commercial species such as cod, pollock and flounders. The issue was raised whether the North Pacific Council is planning their response to such a change. Dr. Witherell responded that the response that the North Pacific Council might take to such a change was unknown. Instead, the managers are more concerned to have a management program in place that can adapt and respond quickly enough to any changes, even if specific responses are not pre-programmed. The problem will more likely be with fishers, who may be less able to respond quickly. Many Alaskan fishers appear to be in a position where they won’t be able to adapt quickly. However, the management program, in terms of allowable harvest, is ready and able to quickly adapt.

## Preparation for breakout groups

In preparation for the breakout groups, Dr. Steve Murawski reviewed the use of reference points. In fisheries management the concept and use of reference points is straightforward, they are model based fishing mortality rate and biomass reference points, and are directly related to market value of target stocks and catches. The problem in ecosystem-based management is that some of the objectives are market-value based ‘goods’, such as target fish biomass and fish catch. Other objectives relate to non-market values that come from the provision of ecosystem services. The problem with reference points in this context is the difficulty in valuation of ecosystem services, and incorporation of this into reference points.

Environmental status indicators are common in many different fields, e.g., eutrophication, water quality, status of protected species etc. However, setting the reference levels for these indicators is often a social decision, or heavily influenced by social issues. With regards to fisheries, many management decisions and responses under single-species management also include ‘societal values-based judgments’. Management in general, both for extractive use and conservation, relies on societal values, and thus requires management to make decisions based on these values. Making these decisions is outside the sphere of science; science can only inform the decision makers (management) by providing insights into the potential tradeoffs associated with each choice. Furthermore, quantifying the costs and benefits of monitoring and using an indicator is often a difficult choice. For example, the USDA Forest Service has struggled with this issue, as has the Environmental Protection Agency. Hence, the process of choosing indicators for marine ecosystem-based management could benefit from reviewing and learning from the approaches taken and decisions made by other agencies, both in the U.S. and outside.

One analogy that may be useful to lean on relates to the use of leading economic indicators to monitor the economy. For example, the Dow Jones Index is used routinely to monitor the performance of the economy. However, if the Federal Reserve Bank raises the interest rate, or any one of a number of other incidences occurs, it may require more than one indicator to understand how the economy may respond. Hence, what is required is an understanding of the relationship between the action occurring and the resulting effect on the economy, and a suite of indicators that may be sensitive to differing (or overlapping) drivers. In environmental settings, this may require not only a thorough evaluation of all available data and past trends and patterns, but may also require targeted experimental management approaches (adaptive management) for the foreseeable future to learn which potential indicators or sets of indicators may be useful, i.e., respond to the changes imposed through controlled experimentation. At the same time, sufficient understanding of the system needs to develop via targeted research to adjust to and detect unexpected changes, as may likely happen with global climate change, global dispersal of pollutants, increased shipping etc.

There was a comment that it might be helpful to be consistent with terminology, for example, at the present workshop ‘reference point’ had been used in three ways: as a benchmark, objective and indicator. It was suggested to agree on a single definition. Reference points could be thought of as a threshold for risk. For example, fisheries should not move to the wrong side of that point, because this may sets in motion undesirable changes in population and ecosystem function. Indicators are a good measure of the performance of the system that indicates the level of risk for that point relative to the reference point. Reference points are the risk threshold or management trigger point of the indicator, and is a benchmark against which to assess the performance of management achieving an operational objective.

The value of an indicator is that it suggests some action to be taken or to be avoided, depending on the ‘closeness’ of the indicator value to the reference point. There are two types of indicators. One is a status indicator, e.g., the status of protected resources, fishery resource or trophic dynamics of the system. The other type is the pressure indicator, e.g., how much fishing effort is in the system, how much climate change is occurring, or the direction and magnitude the Pacific Decadal Oscillation Index (PDOI).

It was stressed that none of the indicators are known without error and each has uncertainty associated with it. Scientists and managers need to think about the uncertainty of estimating those indicators. Caution was urged in investing large amounts of time and resources in the computation of control rules and reference points. Eventually there will be a change larger than anticipated in the control rule design. It may be more productive in big, complex systems such as the western Pacific to troubleshoot a whole range of scenarios, including extreme situations. The idea would be to lay out and quantify a range of scenarios with available models, and allow people to visualize these scenarios. Of major importance will be to include scenarios that reach well beyond what one may think the most likely outcomes are, as only these scenarios permit one to examine whether or not the strategic and tactical capability (in management, policy and science) to respond to such scenarios exists. One of the key lessons from experience in managing big systems is that whatever is visualized and anticipated, nature is likely to extend the range of responses that were anticipated. For example, Pacific salmon is a management system where a lot of the feedback policy design ideas were first developed. However, those original control rules have been abandoned as they did not include the extreme developments that occurred.

It was noted that there may be a slight dichotomy among the scientists working on indicators. One group prefers to quantify a variety of time-series, and then find criteria to set an objective level, e.g., an avoidance target or a management goal. The other group suggests using a traffic light model that is parsed into three levels (green, yellow and red). This still requires a quantitative approach, but it reduces the impression of false precision of an assumed fixed objective level. For example, being able to detect that a mean trophic level may be changing may be more important than knowing what is the absolute value of this trophic level.

It was noted that there had yet to be discussion about the objectives in EAF, as this could be a problem if they are not commensurate. Literature on multi objective decision making suggests that it is hard to achieve an optimum result once there are many objectives involved. This was something on which economists could possibly provide advice. The economist and political scientists Herbert Simons stated that sometimes things are too complex to think through entirely, because you may be dealing with different factors that are not commensurate. Consequently this may requires a different route, which in the coarsest sense would be based on ‘rules of thumb’. Responses are tracked and actions taken which are thought to correct a problem if one exists. However, this is a relatively qualitative mode, yet this is how EAF may end up being implemented. It might be argued, for example, that the two million ton overall harvest cap for the Bering Sea was, in the manner of speaking, a ‘rule of thumb’ for the overall cap that was simply developed from available information at the time.

A potential problem that was identified related to some indicators not being well understood by management and policy personnel. The challenge will be to make indicators for fishing, biomass, mortality, trophic level etc. interpretable and understandable by non-scientists, to allow people to decide what policy options they want. For example, a meeting sponsored by the Global Coral Reef Monitoring Network discussed a similar approach as a layered approach, where, in order to make intelligent decisions, scientists need data on a range of various indicators. However, the policy makers generally do not fully understand all these indicators. Thus, a scaled approach needed to be adopted for clarity and simplification. For policy makers and managers, the scientists would take all the various indicators and combine and scale these down to 3-5 indicators, with the additional use of the red, green, yellow scale.

It was pointed out that often scientists present managers with a range of different scenarios. This was often summarized in a decision table for each policy choice, and includes the potential likely outcomes of following that choice, and what the potential downside for each choice may be. Unfortunately, when these have been used in the past to inform management about risk, they have often been either misinterpreted, or have led to the irresponsible tendency to pick that policy that leads to the ‘*minimax*’ situation, i.e., the one that under worst conditions may lead to the least nasty outcome, rather than the policy choice that was optimum in any public policy sense. It is thought that part of the problem with decision tables was due to forcing managers to make those difficult decisions that they hoped someone else would do for them. However, to a large extent it was simply an inability to comprehend the table. This problem points clearly to the need for managers to (a) realize they are required to make the tough policy choice decision by virtue of their job; and (b) learn enough (or ask) about the scientific advice process to be able to properly understand the information presented to them in aid of their decision.

In the Western Pacific islands, near-shore fisheries were primarily conducted on coral reefs and in reef associated lagoons. These fisheries are so complex in terms of species composition, catch rates, effort distribution in space and time etc., that it almost makes the decisions relatively easy. Management controls such as catch quotas, total allowable catch, and effort limits may be meaningless since most the information required will be impossible to obtain, and it would be impossible to regulate effort or catch. Thus, there seems to be relatively little that could be done other than spatial management. For example, in Hawaii alone there are over 200 near-shore coral reef finfish species that are harvested, excluding aquarium fish, invertebrates and algae. However, the State of Hawaii still has to develop management initiatives, regardless of the complexity of the system.

Caution was expressed about the notion of '*ecosystem health*'. It was noted that an ecosystem is not an organism and it was potentially dangerous and misleading to suggest one could think of them as such. The concern about loss of individual parts and services is at the heart of many ecosystem management issues. Ecosystems cannot be measured in the same way an organism is measured. However, it was pointed out that the legal mandate for sanctuaries and refuges was to maintain 'healthy ecosystems for the benefit of the American people.' Furthermore, for public consumption, it may be difficult to find a substitute term that captures the imagination and broad understanding for ecosystem-based management better than '*health*'. A potential substitute may be '*ecosystem status*,' which has single-species history in the term '*stock status*,' or '*ecosystem integrity*.'

As examples of the issue of '*health*' or '*status*', Pearl Harbor was cited as a dead coral reef ecosystem, while the Northwestern Hawaiian Islands are considered relatively '*healthy*' coral reef ecosystems for several reasons: Firstly, is it has very low coral disease, and corals are a defining component of this ecosystem, along with coralline algae. The Northwestern Hawaiian Islands have the lowest prevalence of coral disease of any major reef ecosystem (however, this may also be the result of their location near the thermal bio-geographic limit for coral growth, and may change with climate change driven increases in sea surface temperatures). Secondly, they have a high degree of endemism, and to our knowledge, endemic species have not been displaced by introduced species. Thirdly, with respect to fish endemism, endemic species such as hapuupuu (*Epinephelus quernus*) appear to have maintained their status and abundance in the Northwestern Hawaiian Islands, although their status in the Main Hawaiian Islands is more uncertain given the likely overfishing or overfished nature of MHI bottomfish stocks. Thus, there appears a potential baseline that has so far not measurably changed. It was also noted that that relatively unperturbed ecosystems such as the Northwestern Hawaiian Islands may be characterized by having high abundance and large mean sizes of a variety of long lived species.

Some final comments in this session included a re-emphasis to avoid 'reinventing the wheel' when it comes to selecting indicators, and in the case of coral reefs in the Western Pacific to have a minimum set of relatively easily measured indicators that will be useful for management. Overarching, one has to remember that there are few if any environments in the world that are not affected by human actions, that the notion that protecting the pristine nature as a general rule is unlikely to be true. More correctly, the environment is being used by humanity to derive benefits, and ecosystem based management is about ensuring this use moves towards a holistic sustainable basis.

## Breakout working group reports

Breakout sessions on the three major topic areas - data source, models, and indicators - were conducted over two days by separate working groups staffed with workshop participants. A summary of the discussions and points made in each session was subsequently presented to the plenary. Following are the principal points reported by each breakout session.

### *Group 1: Data sources*

The group reported that they began with the basic question: "*What are data good for?*" during which they delineated three major categories - human dimensions, environmental aspects, and ecological issues. The group noted that data fill a dual and central role, both as indicators of ecosystem performance, as well as informing and 'feeding' the necessary models to evaluate tradeoffs associated with alternative management choices. Hence, model type, which in turn depends on priority management issues and key questions to be addressed, will dictate and influence the types of information and data needed. Hence, all data need discussions and recommendations from the present section will depend entirely on model requirements, and may vary between areas and over time.

Generally speaking, required data need to describe current ecosystem conditions as well as the history that led to these conditions. Efforts to do this should take advantage of all sources of data (quantitative and qualitative), and central electronic and freely available archives need to be established for easy access to all data. The incorporation of all data into relation databases that can freely cross-link is essential. Major emphasis should be placed on unrestricted use and global availability of data.[1] Researchers should work and liaise with long-time users of the ecosystem (e.g., fishers, ecotourism operators, native elders) to be sure that local information and knowledge is used to the extent practicable and reasonable.

Overall, an immediate step should include establishing a single point of responsibility and contact for data and information for the entire Western Pacific region (preferably a single person in charge of a small group of data-personnel), with the mandate to accumulate and assimilate information on location, extent and format of all existing data. Ideally, in the medium term, this should be taken a step further into a comprehensive, centralized depository of information and data, ideally with quantitative data encoded electronically into relational databases. It can not be overstated how important such a central contact facility will be as an archival 'pool' of knowledge on data (what exists, where is it, who controls it, advantages/shortcomings of data etc.), and how important sufficient long-term funding for such a knowledge depository is.

[1] Newly collected data could be restricted from public use and global access for an initial, limited time period (e.g., 1-2 years) to permit priority publication opportunity for the scientists undertaking the data collection (see Zeller, D., Froese, R. and Pauly, D.. 2005. On losing and recovering fisheries and marine science data. *Marine Policy* 29: 69-73).

The group identified several issues that need to be addressed with respect to data for ecosystem based management:

- Status of protected, endangered, and threatened species;
- Status of habitats;
- Biodiversity (including target and non-target species);
- Physical/natural variability;
- Feedback effects;
- Human pressure(s); and
- Definition of boundaries.

They then posed a number of specific questions developed in each of the three major categories: (1) human dimension; (2) environmental aspects; and (3) ecological issues.

## Human dimension

With respect to human dimensions, some issues relate to historic utilization patterns (requiring data mining) and the history of management measures. It was deemed important to try and integrate traditional ecological knowledge, both long- and short-term. Historic habitat utilization maps could be developed, both using available documents as well as input from long-term users. While for some areas (e.g., Hawaiian Islands) there may be extensive current and historic data, there are many areas in the Western Pacific with very limited historic information, requiring novel and bold approaches to derive approximate baselines of historic patterns of use. Obviously, there will likely also be a need to do periodic new surveys. All data search and collection efforts need to ensure that all marine recreational activities are incorporated, recognizing there may be little specific data available in many areas or time periods. This aspect lends itself to data mining, including across fields of specialization (e.g., natural sciences versus sociology). Overall, better use of sociological information in ecosystem science and management is required. This, however, requires urgently that this knowledgebase is generalized and transformed into data forms (i.e., quantified or semi-quantified) that can be directly used in evaluations and assessments for management purposes.[2]

It also was noted that the effects of current and historic management measures have to be documented, including considerations of short- and longer-term outcomes. It was noted that there is good information about what the management measures (if any) have been, but little information that documents the effects, and success or failure, of these measures in different locations and time periods. Fortunately, for most Council actions there are established

[2] It has been argued that, in order for sociological information to be useful in evaluations and assessments of resources in an ecosystem-based management setting, there is an urgent need for sociologists to begin quantifying their knowledge and information, and derive generalizations based on this knowledge (Pauly in press; Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. *Maritime Studies*).

processes for development and implementation of fishery and conservation management measures, but there is less relevant information by other agencies.

A point was raised that there is a need for better characterization of relatively pristine and little impacted places for which there are management issues that could be addresses in EAM. There are some historic data, but there is a clear need for management-based data mining to make the information available in the structure and format needed (electronic, relation database with cross-platform linkability) for use in EAM.

## Environmental aspects

In the context of environmental data, there were some issues that seemed relevant, including the need to evaluate temporal variability (based both in an historic as well as climate change context), high resolution mapping for environmental changes, and benthic habitat utilization by resources and humans.
With regards to mapping and habitat characterization, emphasis is to be placed on:

- Need for baseline historic maps;
- High resolution mapping technologies (e.g., high resolution multi-beam),;
- Representative, if limited ground-truthing (spatial coverage);
- Need for clear habitat-resource linkages (species habitat preferences);
- Improved mapping linkages between shallow and deeper waters; and
- Other new and developing technologies (semi-autonomous vehicles etc.).

It was recognized that connectivity of resources and areas needs to be better understood, including terrestrial watershed influences and connections to coastal areas. The issue of connectivity needs to incorporate archipelagic-wide passive and active movements of animals at various life stages (juvenile, adult as well as larval stages). This may require large-scale and long-term tagging studies (both for juvenile/adult and larval stages) combining traditional methods with advanced technologies (PIT, acoustic telemetry, satellite technology, pop-up tags, genetic tags etc.), as well as local confirmation studies of larval movement abilities, speeds and ranges as determined over the last decade by studies in Australia and elsewhere.

Among the types of habitat and environmental survey approaches suggested was the use of passive acoustics and bio-optical sensors (satellite imagery is not cost effective) for recording physical variability and climate change, and oceanographic methods for physical-biological linkages. Drifters can be used to track ocean circulation changes and deduce the potential for passive movements.

There were brief discussions of additional issues such as marine debris monitoring, and the need for data programs to ensure adequate documentation of events or activities in these areas. It was noted that there is some history of marine debris tracking, but it would be useful to have an ongoing at-sea debris data inventory.

## Ecological issues

Major data requirements relate to the need for good resolution (time and space) effort and catch data to better understand harvest and associated ecological effects of fishing on target and non-target stocks. Given the importance of non-commercial fishing (subsistence as well as recreational) in the Western Pacific region, reliable estimates of non-commercial catches and effort are urgently required.[3] A further priority is also reliable data on by-catch, best obtainable through properly designed and executed observer programs (which will also serve other data needs). There was also agreement on the urgent need for fishery-independent surveys to provide reliable estimates of abundance, biomass and size spectra in a habitat dependent stratified sampling scheme to maximize precision. While initiating these efforts represents immediate needs, the emphasis on these data requirements will require long-term efforts in resources and commitments.

With respect to fishery-independent surveys of insular area bottom fish stocks, it was suggested that, in addition to using standardized commercial-type gears, there could be a potential for bait camera stations for monitoring and comparing resource diversity. Clearly, this will require appropriate method standardization to allow reliable estimation of abundance, 'effort' and biomass, and will require use of 'four-camera 360 degree' stations to permit time limited stationary point-census approaches (which is not possible with single camera systems).[4]

It was also suggested that spatial distribution of fishing effort could be determined using Vessel Monitoring Systems (VMS) records. This can provide site-specific information on fishing effects. Furthermore, compulsory VMS, used not only for enforcement but available also for research and monitoring, combined with the earlier indicated observer program has been shown to provide the most reliable catch and effort data, and should be implemented for all fleets. Spatial stock structure may require carefully designed genetic studies, and the recently developed tagging approaches using genetic fingerprinting methods may be useful to directly measure exploitation rate of fisheries species.

The need for data to determine trophic relationships (i.e., diet compositions) was identified as a useful data contribution for trophic modeling. This may vary by area, exploitation rate and habitat type. Potential methods include fatty acids and isotope analyses, as well as direct diet studies via gut content analyses.

---

[3] Indications of the likely discrepancies between reported commercial data and potential total catches for all areas of Council responsibility were presented by a study that provided time-series estimates of the unreported catches (see Zeller, D., Booth, S. and Pauly, D. (2005) Reconstruction of coral reef- and bottom-fisheries catches for U.S. flag island areas in the Western Pacific, 1950 to 2002. Report to the Western Pacific Regional Fishery Management Council, Honolulu, 110 p.).

[4] Stationary point census counts are one method used for visual census on coral reef and reef-type habitats in which visual abundance estimates are feasible. A good introduction to this and related methods can be found in Samoilys (ed. 1997; Manual for assessing fish stocks on Pacific coral reefs, Department of Primary Industries, State of Queensland, Australia, ISSN 9812-0005, 78 p.).

There was some specific focus on the need for data on threatened and endangered species (e.g., seabirds, sea turtles, cetaceans), especially if they are affected by fishing activities. Data would include species distribution, genetic stocks, interactions with fisheries, role in food webs, abundance, migrations etc., and should cover all areas. A short- to medium-term need will be to map the overlap of the spatiotemporal distributions of these taxa with the spatiotemporal distribution of fishing by all relevant fleets and gears (e.g., seabirds versus tuna longliners).

There was also some concern about the need for data on the effects of introduced species on natural communities. This could include such factors as predation, competition and displacement effects of introduced species. There is need for a program to collect information on fouling organisms on vessels, and to measure the species composition and abundance in the benthic zone.

## Recommendations and priorities

Several data and information issues will require detailed discussion and inter-agency collaboration, e.g.:

- Data management;
- Data sharing agreements;
- Data archival, formats; and
- Public education and general access.

As a short-term need, the group recommended establishment of a *Data Needs Working Group* for research in EAF and/or EAM. As a priority, this working group needs to be guided by and focused on fulfilling data requirements for identified model choices, which in turn are driven by management issues and priorities. Data needs may include, but likely not limited to:

- Improved catch and effort data (including non-commercial);
- By-catch/by-product/fishery interactions and tradeoffs;
- Trophic interactions and diet;
- Habitat-species associations and habitat-fishery interactions;
- Spatial distribution and stock identification;
- Environmental variability;
- Life history/ontogeny;
- Spatially explicit processes;
- Consequences of and responses to climate change and regime shifts;
- Eutrophication/habitat alterations/inherent ecosystems productivity;
- Social/economic dimensions;
- Carrying capacity/lower trophic level and forage base interactions; and
- Spatial contrasts that reveal processes under differing use impacts.

## *Group 2: Ecosystem models*

The Ecosystems Models Breakout Group focused on a key question: "*Can we develop a flexible, quantitative framework to address management issues and the range of policy and regulatory options required to sustain resources under an ecosystems-based approach to management?*"

Placed in the context of the Western Pacific region, there was extensive discussion on the different management situations that exist throughout the region, ranging from localized NWHI bottomfish fishery management issues to broad regional pelagic fisheries management issues. There was discussion on the extent of transferability of data, indicators, and models across the region. For example, would it be possible to draw inferences about trophic relationships in the NWHI from what is known about the MHI, or how would this information hold up for the Northern Mariana Islands? It was noted that the trophic relationships of the different areas may be so different that such transfers or inferences are not reasonable and could lead to models that may give incorrect answers to 'what if' questions. Also, there was recognition of the need to set priorities (and the difficulty of doing so), recognizing the different values involved (e.g., Hawaii fisheries involve landings with higher monetary values, but they may not be more important than American Samoan fisheries in a social sense), the different types of data available in different areas, the different sets of resources in different areas, and the human dynamics at play. This raised the awareness of the likely need to employ risk-based procedures in doing modeling exercises and applying any modeling results.

There was consensus that the modeling endeavor has to include the following process elements:

- Identify resource and management issues;
- Identify potential management policies and options;
- Match the model to management policies and options;
- Identify data needs for the model(s) chosen;
- Inventory and obtain the data available; and
- Identify other biophysical processes of importance.

The group also noted that there are differences between models that may forecast changes in oceans and climate over time, and models that could be useful in a fishery management context to help determine appropriate responses to the results of the broader climatic or ocean models. The group emphasized the critical importance of clearly specifying the objective of any modeling exercise beforehand. For fishery managers, a model can be a tool to help get a sense of the likely impacts and implications of different management actions or measures. Hence, such models have to be focused on the specific fishery and associated resources (biological, ecological, social, institutional) that are involved in or affected by the management decisions to be made. The model would not be expected to solve a problem, but to inform management about impacts, and the potential implications and risks of alternative management measures. It was noted that the modeling exercise itself, if tightly structured, can be a tool that helps define more precisely the nature of the management problem or issue being addressed, the components of the environment that need to be encompassed by the model, the data needed for a useful model, and the tradeoffs involved in the management environment, including the potential risks and impacts of making a possibly inappropriate decision.

It was also recognized that it is difficult to build into models accurate information on likely responses to regulatory changes. This may raise the need to build in ‘adaptive management’ into the modeling routines, and it was suggested that one approach might be to develop ‘preliminary’ models whose predictions that can be field-tested and refined over time. However, it also was noted that the Western Pacific Fishery Management Council may find it difficult to be able to ‘test’ the predictions of ‘preliminary’ models, as the potential costs - to resources and/or to fishers - may be high. On the other hand, the potential risk and costs of not undertaking this ‘adaptive’ approach could be even higher in the long term. As is the case with all adaptive management situations, it requires the full understanding, buy-in and participation from the affected stakeholders.

With respect to likely models, there was agreement on some key data layers:

- Hydrodynamics;
- Biological community dynamics;
- Habitats and species-habitat associations; and
- Fishers’ behavior.

## Recommendations and priorities

The group agreed to the following priorities:

**Immediate**

- Identify management issues by area, and potential policy options available to Council; and
- Identify data needs and obtain available data suitable for models chosen.

**Short-term**

- Base model development.

**Long-term**

- Refine model capabilities, and adapt to changing issues and needs.

## *Group 3: Indicators*

The indicators group discussed the potential for various indicators that might be useful in the Western Pacific region. This included a suggestion to develop a classification scheme for indicators: indicators on the state of the ecosystem, indicators of particular pressures or ecosystem stressors, and indicators of ecosystem responses to pressures and stresses.

It was noted that while some indicators might be used to assess the state of an ecosystem or ecosystem component, they were also needed to address specific management needs. Some indicators would be needed to address specific legislative and statutory mandates such as protected species interactions and overfishing reference points for commercial and recreational fisheries.

It was important to recognize that most individual indicators would not be holistic ecosystem indicators *per se*, but would capture elements or selected properties of the ecosystem. These include primary production, which affects all levels of the ecosystem, or the assemblage properties of an ecosystem. The group also discussed the need to prioritize indicators, which likely will be subjective based on perceived management issues, but may over time identify effective indicators.

It was suggested that a model that might be useful to follow may be the North Pacific Council's approach to ecosystem based fishery management. This approach incorporates the concept of humans as part of the ecosystem. The goal of the North Pacific Council's approach is to:

- Maintain biodiversity consistent with evolutionary and ecological processes, including dynamic change and variability;
- Maintain and restore habitats essential for fish and prey; and
- Maintain sustainable yields for human consumption and non-extractive uses.

The North Pacific Council also has an Ecosystem Chapter which has evolved since 1995, when it initially focused on marine mammals. It later broadened to include other non-target species and ecosystem management policy, and now includes environmental and other indicators relative to ecosystem-based objectives. The goals of the Chapter are to monitor the efficacy of ecosystem-based management efforts and to track changes in ecosystems not easily included into single-species assessments. The objectives for ecosystem protection include maintaining predator-prey relationships, species diversity, functional diversity (e.g., trophic diversity, structural habitat variability), genetic diversity, and energy flow and balance.

As a cautionary note, one has to consider that the temperate and subarctic ecosystems of the North Pacific region may differ in various, but potentially unknown fashion from the higher diversity tropical ecosystems of the Western Pacific region.

For the present workshop, the indicators working groups' strategy was to develop a Pressure-State-Response framework. Part of this approach was to identify potential indicators for Pressure and State. It was noted that the final choice of indicators must be linked to specific management objectives, and the distinction between Pressure and State indicators can be blurred in some instances. It was considered likely that for some indicators no data would exist at present. The group also stressed the need to be aware if an indicator was developed from empirical data, or was modeled from observations on the ecosystem. A key consideration in developing indicators in the short- and long-term is availability of relevant data. A data availability study or review was considered paramount and critical (see Data Source report) if additional funding was to be sought for additional data collection.

The group discussed indicators for coral reef ecosystems and the coastal margins of much of the Western Pacific region. Indicators within the coral reef ecosystems could include coral and other habitat cover, abundance, size structure and distribution of fisheries target and by-catch non-target as well as introduced species. Other potentially useful measures might include morphological diversity of the reef area, such as rugosity. However, numerous studies have suggested that the link between rugosity and species diversity and/or abundance and/or biomass is often difficult to discern, and is heavily species- and size-dependent, and greatly influenced by the measure of rugosity employed. The fractal nature of habitat rugosity and the vast size spectrum of marine life on coral reefs makes the use of rugosity only useful for narrowly focused and targeted inquiries. Mapping was identified as a useful tool for documenting habitat distribution, employing tools such as side scan sonar, LIDAR and hyperspectral images from remote sensing. However, such information is only value-enhanced for holistic ecosystem-based management if abundance, use and association patterns of fish and invertebrate species with habitat types are established and quantified as part of the ground truthing of mapping approaches.

The group listed various indicators that could be used as measures of Pressure on or State of an ecosystem. Examples are given in Tables (10 and 11), with suggested criteria that might be used to rank the various indicators.

## Recommendations and priorities

The indicator working group made the following recommendations:

- Evaluate the list of candidate indicators;
- Solicit recommendations for the ranking of each proposed indicator by experts in each of the regions;
- Solicit entries for high ranking indicators for observation and interpretation by experts in each of the five regions;
- Amend in line with management issues/needs and subsequent assessment/modeling requirements; and
- Develop approaches for linking Pressure and State indictors, and the feedback effects of Response actions.

**Table 10: Potential indicators relating to pressures on ecosystems. Listed also are data sources or contacts if known, and suggested ranking criteria for use by expert panels in the region. NB: List is likely incomplete.**

| Metrics | Sources/ Contacts | Ranking Criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Available | Feasible | Cost | Sensitivity | Uncertainty | Mandate |
| **Physical metrics** | | | | | | | |
| Cyclones | | | | | | | |
| ENSO Index | | | | | | | |
| PDO | | | | | | | |
| SST anomalies | | | | | | | |
| Satellite altimetry | | | | | | | |
| Thermocline | | | | | | | |
| Satellite wind data | | | | | | | |
| High rainfall | | | | | | | |
| **Biological metrics** | | | | | | | |
| Primary production | | | | | | | |
| Chlorophyll densities | | | | | | | |
| Chlorophyll transition zone | | | | | | | |
| Harmful algal bloom | | | | | | | |
| Coral bleaching | | | | | | | |
| Invasive species | | | | | | | |
| Introduced species | | | | | | | |
| **Human metrics** | | | | | | | |
| Commercial fishing | | | | | | | |
| Licenses | | | | | | | |
| catch by gear | | | | | | | |
| effort by gear | | | | | | | |
| Recreational fishing | | | | | | | |
| # fishers per capita/area | | | | | | | |
| catch rate | | | | | | | |
| effort index | | | | | | | |
| Population density | | | | | | | |
| total population | | | | | | | |
| coastal population | | | | | | | |
| linear coastline | | | | | | | |
| per capita income | | | | | | | |
| Development | | | | | | | |
| building permits | | | | | | | |
| housing starts | | | | | | | |
| area of natural to man made | | | | | | | |
| runoff | | | | | | | |
| water quality | | | | | | | |
| Shipping traffic | | | | | | | |
| anchorages | | | | | | | |
| port of call | | | | | | | |
| manifests | | | | | | | |
| bilge/ballast | | | | | | | |
| water handling | | | | | | | |
| military | | | | | | | |

**Table 10: Potential indicators relating to pressures on ecosystems. Listed also are data sources or contacts if known, and suggested ranking criteria for use by expert panels in the region. NB: List is likely incomplete.**

| Metrics | Sources/ Contacts | Ranking Criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Available | Feasible | Cost | Sensitivity | Uncertainty | Mandate |
| small boat harbors | | | | | | | |
| track live aboard vessels | | | | | | | |
| boat based visitor entry | | | | | | | |
| Marine Debris | | | | | | | |
| accumulation rate | | | | | | | |
| Ship Groundings | | | | | | | |
| Eco tourism | | | | | | | |
| # of divers/dives | | | | | | | |
| Military Activities | | | | | | | |
| bombing freq. | | | | | | | |
| training exercises | | | | | | | |
| Port and airport security zones | | | | | | | |

**Table 11: Potential indicators relating to state of the ecosystems. Listed also are data sources or contacts if known, and suggested ranking criteria for use by expert panels in the region. NB: List is likely incomplete.**

| Metrics | Sources/ Contacts | Ranking criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Available | Feasible | Cost | Sensitivity | Uncertainty | Mandate |
| **Habitat** | | | | | | | |
| live coral cover | | | | | | | |
| incidence of disease | | | | | | | |
| size structure | | | | | | | |
| prop. alien/native | | | | | | | |
| crown of thorns | | | | | | | |
| diversity | | | | | | | |
| rugosity[a] | | | | | | | |
| habitat mapping | | | | | | | |
| bottom complexity | | | | | | | |
| **Apex predators /piscivores** | | | | | | | |
| diversity | | | | | | | |
| abundance | | | | | | | |
| biomass | | | | | | | |
| Mortality/productivity | | | | | | | |
| **Herbivores /omnivores** | | | | | | | |
| diversity | | | | | | | |
| abundance | | | | | | | |
| biomass | | | | | | | |
| mortality/productivity | | | | | | | |
| **Interactions with habitat** | | | | | | | |
| sea-urchins | | | | | | | |
| holothurians | | | | | | | |
| **Sea birds** | | | | | | | |
| population dynamics | | | | | | | |
| migration/movements | | | | | | | |
| **Sea turtles** | | | | | | | |
| population dynamics | | | | | | | |
| migrations/movements | | | | | | | |
| **Marine mammals** | | | | | | | |
| population dynamics | | | | | | | |
| migrations | | | | | | | |
| **Sentinel species** | | | | | | | |
| giant clams/oysters | | | | | | | |
| napoleon wrasse | | | | | | | |
| bumphead parrot fish | | | | | | | |
| marlin | | | | | | | |
| **Species Diversity** | | | | | | | |

**Table 11: Potential indicators relating to state of the ecosystems. Listed also are data sources or contacts if known, and suggested ranking criteria for use by expert panels in the region. NB: List is likely incomplete.**

| Metrics | Sources/ Contacts | Ranking criteria | | | | | |
|---|---|---|---|---|---|---|---|
| | | Available | Feasible | Cost | Sensitivity | Uncertainty | Mandate |
| **Genetic Diversity** | | | | | | | |
| **Ecosystem/Habitat Diversity** | | | | | | | |
| **Endemism** | | | | | | | |
| **Exotics** | | | | | | | |
| **Protected species** | | | | | | | |
| **Ciguatera** | | | | | | | |
| **Fibropapiloma** | | | | | | | |
| **Viral Epidemics** | | | | | | | |
| **Algal Blooms** | | | | | | | |
| **Invasive species** | | | | | | | |

[a] But see note in text regarding usefulness.

# Workshop synthesis

Drs. Mike Orbach and David Fluharty presented a synthesis of the workshop following the presentations by the break-out working groups and the final discussion of their conclusions and recommendations.

## Mike Orbach's summary synthesis

Dr. Orbach described his synthesis of the results of this meeting, and the suggested steps for the future. In this context, the term 'ecology' was deemed to include human actions and interactions, as well as human institutions, in addition to the usual biophysical descriptor of ecology. The present meeting had discussed primarily the biophysical ecology, science and fisheries, which were the given objectives of this meeting. However, the issue in ecosystem management is to address not only the biophysical components, but also the social, economic and institutional impacts and actions. Management and policy is, in its final assessment, all about social processes, choice and value-driven decisions. Examination of institutional 'ecology' requires investigation of different sectors: legislative, judicial, administrative etc. The linkages, interactions and issues in the social and human sphere can be described, and the way agencies behave with each other can be modeled. These human/social/political aspects will be the subject of the second workshop in this series.

The human constituents (often referred to as stakeholders), including fishing industries, communities, consumers, interest groups, and the general public interact with or care about fisheries, and it is these people whose behavior is subject to change. Ultimately, management is about influencing and causing behavioral change. The rules are made by policy and management organizations, and ultimately legally endorsed by state and federal legislatures. Thus, human actions and behavioral change is what is actually managed, not the fish, not the water, nor any of the other elements of the environment.

By and large the participants at the present workshop are scientists conducting scientific studies. However, science is non-normative, and it does not tell people how to behave. It only analyses and sometimes forecasts what might happen if humans choose different types of behavior. How to behave, and influence this behavior is governance and is based on human values, advocacy and decision-making.

To conduct ecosystem-based management, there is a need to conduct the analysis and the science. Thus, the issues presented and discussed here are crucial for the foundation of scientifically founded ecosystem-based management. However, the human component of ecosystem-based management needs facilitation, and somebody to conduct the 'advocacy' for behavioral change. Sometimes that is done by an NGO, sometimes by citizens. However, most often in human society it is a government agency. In fact, by definition, agencies essentially are advocates of the position they select and represent.

All fisheries policy and management decisions have social, economic and biological objectives, and subsequently have social, economic and biological effects. Scientists need to be able to estimate or approximate all three aspects in order to estimate and describe the tradeoffs of each management choice/action. All fishery policy and ecosystem management decisions involve not only choice, but result in tradeoffs. Hence, of fundamental importance in all likely modeling, for example, is ensuring that it helps estimate and describe the tradeoffs for people.

**Models**

Models are heuristic devices. They are ways to help organize information and assist in mode clearly think about the world. Clearly, models are only as good as the data they are based on, and they need to be designed with management objectives and issues in mind.

**Indicators**

Both indicators and data collection need to be guided by principles. These principles essentially are management issues and objectives, which should drive data collection, indicators choice and model development and use. The questions asked of data, indicators and models should be formed carefully, and with full endorsement and involvement of management and decision makers and management executors. In essence, management needs to be very clear about how to format the questions to scientists, no matter if it relates to models, data or section and use of indicators.

**Data**

Dr. Orbach suggested that there may be too much data collection going on at the moment, or at least much with very little focus or target on the questions at hand: ecosystem-based management. Often, such data collection may be based on other reasons, such as academic interest, personal scientific pursuits or historic interest in the specific topic. This is not meant to devalue this type of scientific endeavor, only to point out that not all scientific pursuits and data collections can or should serve ecosystem-based management functions or needs. Again, data needs for ecosystem-based management center on delineating important management issues and asking the right questions, which, combined with judicious use of modeling expertise will suggest the type of data required.

**Fishery ecosystem versus total ecosystems**

Fisheries are not independent of other things that happen in the world, in fact they are, and always have been embedded in ecosystems. Ecosystem management means water quality, it means habitat, it means diversity, it means runoff etc. The real challenge for management and science is how to set bounds for the system.

The ultimate ecosystem management question can be simply stated as: "*What would we do differently because of the relationship of one species, habitat or human behavior to another?*" Thus, the ecosystem question is about what does one do differently because of the linkages among numerous components, and how does one judge the ecosystem tradeoffs. It comes down to the fact that everything that is being done for ecosystem-based management, data collecting, indicator monitoring, modeling etc., has to revolve around describing and addressing the tradeoffs of management options, not just the impacts on single sectors.

## David Fluharty's summary synthesis

Dr. Fluharty pointed out initially that the presence of the accumulated body of scientific knowledge and experience present during this workshop, in the form of the participants professional background, is critical for making advances in the pursuit of ecosystem-based management. Management will often have to rely on this accumulated body of knowledge and experience for decision making, given that there will never be all the resources available to accomplish all the necessary management measures in the required time-frame . In essence, this should serve as a reminder that we actually already know something and are not starting at a zero baseline!

A key point that became apparent during this workshop was the repeated comments on and respect for the contributions that social scientists can and must make in ecosystem-based management. This was emphasized independently in all three break-out sessions, and it was refreshing that everybody perceives ecosystem-based management issues more broadly than just the bio-physical science components, i.e., that the information about the human systems also needs to be included. This is further enhanced by the fact that the second workshop will deal with socio-economic aspects of ecosystem-based management.

One way to develop a synthesis is to look at the criteria that others have put forward relative to ecosystem-based management and sustainable fisheries, for example as part of the National Research Council (1999) Sustainable Fisheries Report. In that document, several points were individually identified:

- Adopt conservative harvest levels;
- Adopt a precautionary approach with respect to uncertainty;
- Reduce excess capacity and assign 'rights' in fisheries;
- Establish MPAs as a buffer against uncertainty and management failure;
- Include by-catch and discards in catch accounting for all sectors;
- Institute scientific and stakeholder reviews in transparent decision processes;
- Conduct targeted research on structure and function in ecosystems; and
- Incorporate ecosystem-based goals in management decisions.

Interestingly, the 2004 report of the U.S. Commission on Ocean Policy made several major recommendations that relate directly to ecosystem-based management efforts:

- Double the amount of ocean funding;
- Create regional ocean ecosystem councils; and
- Refine the existing fishery management system… to strengthen the use of science and to move toward a more ecosystem-based management approach.

One may ask why specifically encourage and demand that fisheries embed themselves in the ecosystem-based management approach, given the large number of other anthropogenic challenges to marine ecosystems (e.g., development, pollution, climate change etc.)? Fisheries have several reasons and advantages for taking the lead in implementing ecosystem-based management:

- Overall, fisheries are the greatest cause of direct and indirect impacts on ecosystems;
- Fisheries have the advantage that a substantial body of scientific knowledge has been gained with regards to the impacts of fisheries;
- Generally, regular monitoring and assessment processes are established;
- Management systems are in place with usually broad authorities over fisheries and their impacts; and
- Open, transparent processes exist with significant opportunities for participation.

Thus, one can postulate that a ‘healthy’ ecosystem (being aware of the anthropomorphic danger in using this word) is good for ‘healthy’ fisheries. Hence, one could argue that implementing ecosystem-based fisheries management could lead to improved fisheries management of ‘healthy’, productive and sustainable fisheries.

What are some of the main prerequisites for ecosystem-based fisheries management?

- Effective control over fisheries by the management system;
- Ability to enforce regulations;
- Ability to monitor all harvest, including by-catch;
- Ability to control fishing capacity and effort; and
- Ability to establish incentives that match the goals.

Furthermore, to engage in ecosystem-based fisheries management, fisheries stakeholders should recognize the inherent and often considerable uncertainty associated with natural systems and the affiliated science; should insist that all management and exploitation be conservative and precautionary in nature; and should accept that the burden of proof rests with fisheries. In principle, stakeholders need to expect that fisheries will change under ecosystem-based fisheries management, specifically:

- Fisheries will be managed for stock abundance not scarcity or productivity, i.e., lower harvest rates from higher biomass;
- Less fishing capacity and employment;

- Higher incomes and use of technology;
- Practices with high habitat impacts replaced with alternative techniques or shut down;
- Greater use of spatially explicit management measures; and
- Restrictions on fisheries to accomplish other goals, e.g., biodiversity protection, ecotourism, recreational use.

In summary, the policy advice one can give to management as it moves towards ecosystem-based fisheries management consists of six general points:

1. Change the burden of proof;
2. Apply precautionary principle;
3. Purchase ‘insurance’, e.g., MPAs and spatial management options;
4. Learn from management experience in other areas and by applying ‘adaptive management’ approaches;
5. Use incentives to achieve goals; and
6. Promote fairness and equity within overall ecosystem-based management objectives.

# Conclusions and recommendations

## *Objective, tasks and approach*

The Western Pacific Regional Fishery Management Council is moving incrementally to apply ecosystem principles in its fishery management plans. Recognizing its limited experience and tools in ecosystem-based management approaches, the Council embarked on a series of three workshops to exchange information and learn from outside expertise. The present report summarizes the first workshop, held April 18-22, 2005, on the **topic** of the science and data needs to support ecosystem-based management approaches. The present conclusions and recommendations attempts to summarize the main points and issues presented in this report.

The **objective** of the Workshop was to identify science requirements to support Ecosystem-Based Approaches (EBA) for marine resource management in the Western Pacific Region. The **tasks** assigned to the Workshop were:

1. Review state-of-the-art ecosystem models applied to marine resource management and their application in governance systems;
2. Identify management requirements in the Western Pacific Region;
3. Identify the best suite of quantitative ecosystem indicators and associated tradeoffs to support management requirements in the Western Pacific Region;
4. Within the confines of existing mandates (e.g., Magnuson-Stevens Act, National Marine Sanctuaries Act), identify the most effective short-term application of EBA to marine resource management that can be implemented based on current data (and in this context, address whether the precautionary approach has a role);
5. Identify new data or models that would be required to advance EBA to marine resource management in the Western Pacific Region; and
6. Identify changes in policy or science administration that would be required to more effectively implement EBA to marine resource management.

The **approach** taken in the present workshop was to separate the general topic into three themes: **data**, **models** and **indicators**. The workshop utilized a combination approach of alternating plenary presentations/discussions lead by an invited expert panel with breakout working groups (by theme) reporting back to plenary for further discussion.

Principally, the foundation of ecosystem-based fishery management is the application of conservative and precautionary approaches for the major targeted stocks or fisheries in a designated region. However, added to this base are considerations of the impacts of fisheries on non-target species, effects of fishing on habitats supporting production and ecosystem functions, predator-prey dynamics, and relationships between the biota and the environment. It is this second added component that differentiates ecosystem-based management approaches from the more traditional, fisheries management approaches generally focused on maximizing yield or value from targeted stocks on a more or less single-species or targeted multi-species group basis (e.g., Hawaiian bottomfish). Given the complexity of marine ecosystems, relationships between species, as well as between species and their environment are likely complex and complicated, and often little understood or difficult to untangle. The resultant high levels of uncertainty place a premium on conservative and precautionary approaches to exploitation in an ecosystem-based management setting.

A problem managers have encountered in implementing an ecosystem-based approach to management is the lack of a 'road map' on how to integrate the various components of an ecosystem approach into a clear operational governance system. In an integrated approach, the governance system examines a suite of information to develop management measures which achieve various strategic goals. This requires taking into account numerous perspectives and desired outcomes from a variety of stakeholders, including those representing non-extractive interests and ecosystem services. An integrated approach must also rely on a comprehensive ecosystem observing system to collect data at various spatial and temporal scales, and a management decision support system to synthesize the information and develop status indicators for individual ecosystem components, forecast status and trends, and evaluate the biological, social and economical effects of policy choices.

The literature on ecosystem-based approaches suggests that there are eight broad categories of **operational objectives** that should be considered in developing fishery ecosystem plans (for details see Steve Murawski (NMFS): Principles of an ecosystem approach to fishery management…page 19):

1) Conserving and managing the species;
2) Minimizing by-catch;
3) Managing tradeoffs;
4) Account for feedback effects;
5) Establish appropriate ecosystem boundaries;
6) Maintain ecosystem productivity and balance ecosystem structure;
7) Account for climate variability; and
8) Use adaptive approaches to management.

## *Key points*

During the discussions and plenary sessions several key points were raised repeatedly, and are summarized here:

1) Management/policy issues need to be clearly and precisely stated prior to data collection or modeling/analyses being initiated;
2) Model or analysis choice must be driven firstly by management/policy issues, and secondly by available or obtainable data;
3) Adaptive management experiments, involving deliberate spatial comparisons of policy options (such as, e.g., MPAs) are of crucial importance for developing and implementing ecosystem-based management approaches;

4) Models cannot and should not determine the management decision, which, by its very nature, is choice driven and influenced by tradeoffs. Models are only intellectual devices to help scientists and managers think about problems and possible solutions;
5) Some data collection efforts, while labeled as ecosystem-based, may not be appropriately scaled (in terms of spatio-temporal sampling) or may not target useful variables or parameters for ecosystem-based fisheries management. Such research and monitoring efforts need to be better targeted and focused towards clearly identified management/policy issues, if the data collections are funded for and based on ecosystem-based management needs;
6) New or different data may need to be collected, depending on clearly identified management/policy issues, and the associated analysis/modeling needs. Such data activities should include data 'mining' and data recovery from old and/or unusual sources (e.g., research theses, unpublished grey literature, old print and electronic media etc.); and
7) Concerted efforts are required to reduce or overcome agency specific disagreements (e.g., jurisdictional boundaries) and miscommunication in an integrative approach to move towards system management as a centralized objective. It may be prudent to examine approaches taken and lessons learned elsewhere, e.g., the Australian experiences with managing the Great Barrier Reef Marine Park and World Heritage Area, with its joint state-federal jurisdiction and management agreement.

## *Recommendations*

Several **recommendations** can be extracted from the discussions and working group outcomes as presented in this report:

1) Clearly define and articulate management/policy issues and questions along lines of urgency and identified needs;
2) Assign a centralized resource entity with sufficient seniority and appropriate financial and human resources to establish and maintain a centralized data reference and contact point (the "who, what, where and how" of data);
3) Review and evaluate all currently available data and data collection schemes (biological, social, economic etc.), and initiate and maintain data 'mining' and recovery activities;
4) Undertake initial assessments and analyses of available data, based on key management/policy issues identified by management and stakeholders. This is primarily aimed at identifying strengths and weaknesses of current data and data collection programs, and pointing out obvious data gaps;
5) Identify and initiate adaptive management experiments at ecosystem scale;
6) Ensure that data collection and models/analyses for ecosystem-based management are coordinated with and driven by clearly identified management needs and issues;
7) Encourage keeping all models/analyses at the most 'simple' level possible, i.e., avoid temptation to build large, exceedingly complex models;

8) Ensure adequate support and resources for clearly identified ecosystem-scale monitoring, research and modeling/analytical investigations; and
9) Evaluate a suite of indicators (both existing fishery-based, as well as new and emerging ecosystem-based) in an evolving and adaptive process.

For summaries of the working group discussions on **data** see page 113; for **models** see page 119; and for **indicators** see page 121.

Overall, it was consistently emphasized that clear management objectives need to be outlined and policy issues identified before appropriate and suitable models/analyses and indicators can be proposed or developed, which in turn will be influenced by currently available data, and will determine future data needs. Thus, a key **recommendation** (see 1)) was that specific management issues are identified and clearly delineated, and potentially available management and policy tools and options clarified prior to analytical options and data needs being decided and implemented.

Simultaneously, a key **recommendation** (see 2)) was that a comprehensive data availability inventory needs to be undertaken, incorporating all quantitative and qualitative information available (ideally combining scientific as well as socio-economic data). This data inventory should be centralized, freely available and comprehensive. As examples of first steps in this direction one can consider WPacFIN's activities with respect to parts of fishery-dependent data, and the UH's Pelagic Fisheries Research Program's 'atlas' activities for documenting available information and oceanographic models. This endeavor should be a permanent feature for the entire Western Pacific region's ecosystem-based approach to science and management, and be lead by a dedicated and appropriately resourced data inventory entity of significant seniority (a centralized 'resource contact' responsible for the "who owns it, what exists, where is it, how can it be used" of data), and who facilitates utilization of the wide array of existing and likely future data. This inventory should include all data types, including qualitative information sources. In the initial phase, this data inventory entity should facilitate the establishment of a *Data Needs Working Group* for research in ecosystem-based approaches for fisheries management. Subsequently, potential useful models or analytical approaches can be outlined driven by management and policy issues and needs, but reflective of currently available data. Thereafter, additional future data needs can be identified. It should be noted that much of the data currently available were not initially collected under ecosystem-based management considerations or tied to any specific management issue of objective, and hence the utility of the information for such an application has not been determined for all data. These aspects should be considered as part of any data inventory initiative.

With regards to data needs, the utility of data 'mining' and data recovery from unusual sources and old media was also raised as an issue of concern. Substantial resources have been invested in the past to collect a wide range of data, both quantitative and qualitative in the scientific as well as socio-economic fields. Yet, much of these data were only utilized for a narrow (e.g., graduate research thesis), or at the time important aspect, and only exist in grey literature with limited print runs, or on old media. It has been shown that recovering such 'old' data can make significant contributions to science, and be of renewed interest as historic baselines for current and future ecosystem-based science and management[5]. Thus a **recommendation** (see 3)) was that data recovery and 'mining' activities should form an integral part of the data inventory activities. As an added incentive for such data activities are the opportunities to establish historic baselines of knowledge that are essential for ecosystem-based approaches, e.g., the reconstruction of likely historic fisheries catches in the Western Pacific region[6].

It was strongly suggested that existing data should be evaluated and assessed in detail first. By preliminary examining the presently existing fisheries dynamic, survey and other datasets in a collective and integrated manner, one might be able to determine if patterns exist that could be explained by several different models or hypotheses. This may provide a useful starting position for future data and model considerations. This endeavor should be undertaken in close collaboration with experienced management entities, and ideally with feedback from or coordination with experienced fishing entities to enable accounting for fishing and oceanographic history and knowledge. Furthermore, ecosystem-based management will place increasing demands on spatio-temporal data and information, both with respect to ecosystem components and functions, as well as resources use. Thus, VMS will increasingly become a central requirement for all extractive users in the context of ecosystem-based management approaches. Therefore, Council, NOAA and other responsible agencies should endeavor to use available VMS data for research efforts, and expand use of VMS for coverage of all fishing fleets. This may require concerted efforts in stakeholder engagement and buy-in, and possible adjustments in legal instruments. Such data provide unique and invaluable spatio-temporal information not obtainable otherwise (as it reflects fleet activities), especially if combined with vessel specific catch and effort information. These data will be essential for modelers to better understand spatial effort dynamics and why fishers make the decisions they do. Thus, a **recommendation** (see 4)) was that comprehensive, but preliminary meta-data-examinations and analyses of all available data (including VMS) should be undertaken as an initial step.

The use and utility of MPAs and spatial fishing/exploitation experiments was identified as a key **recommendation** (see 5)) lending itself to adaptive management within ecosystem-based fisheries management. The crucial importance of adaptive management experiments, involving deliberate large-scale and long-term spatial comparisons of policy options, was repeatedly emphasized as fundamental to ecosystem-based management. Of utility are only MPAs large enough to have ecological integrity at an ecosystem and archipelagic scale. Hawaii was cited as one case: this would also require experiments in institutional arrangements for management in both the NWHI and MHI, including governance, stakeholder buy-in and participation, and governance associated enforcement and

---

5 Zeller, D., Froese, R. and Pauly, D. (2005) On losing and recovering fisheries and marine science data. *Marine Policy* 29: 69-73.

6 Zeller, D., Booth, S. and Pauly, D. (2005) Reconstruction of coral reef- and bottom-fisheries catches for U.S. flag island areas in the Western Pacific, 1950 to 2002. Report to the Western Pacific Regional Fishery Management Council, Honolulu, 110 p. Zeller, D., Booth, S., Craig, P. and Pauly, D. (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. *Coral Reefs* 25: 144-152.

monitoring prior to and during establishment and management of MPAs. It was deemed prudent at all levels of management and science to incorporate the long-term time horizon (decadal and longer) into the planning, governance, monitoring and enforcement aspects, and ensure stakeholder understanding of the potentially long ecosystem time scales. Of key importance however, is that adaptive management experiments are undertaken at the appropriate spatial and temporal scales, and are comprehensively executed.

In terms of ecosystem modeling, the close interplay with policy and management options was identified as very important. A clear need was outlined to develop clear goals and constraints on the issues and questions to be addressed by models, to avoid arriving at a situation where models are called for to do everything. A model can generate a set of predictions of what might happen under different circumstances; it might expose uncertainties that should cause a responsible manager to think carefully about the management choices he/she has to make. Thus, management actions and research efforts need to be coordinated to better understand ecosystem dynamics. There is also a need to foster participatory decision-making, as more public concerns are raised about ecosystem protection. Thus, a **recommendation** (see 6) was to ensure that all data collection and modeling or analytical efforts under the topic of ecosystem-based management are closely coordinated with, and driven by management needs and policy issues. A further **recommendation** (see 7) was that models and analyses should be kept as simple as possible to permit clear and unambiguous addressing of ‘what if’ questions as part of the learning process, which is crucial in understanding whether a model is working and how it is responding to change.

There was also a **recommendation** (see 8) to ensure adequate support for ecosystem monitoring, research and modeling is available and being sourced. This needs to extend beyond the focus on extractive resources, to include an emphasis on ecosystem goods and services, and appropriate metrics for accounting for non-consumptive ecosystem services. These non-extractive goods and services will increasingly be deemed of equal importance (and ‘value’) with the market-based goods that are being produced by these ecosystems.

With regards to the last **recommendation** (see 9) on indicators, one of the larger challenges in ecosystem-based approaches to fisheries management is how to link high level principles such as maintaining healthy and productive ecosystem to informative performance indicators. Unfortunately, aside from basic fishery performance indicators (e.g., related to fishery mortality rates and population sizes), there are no established criteria for determining proper reference levels at the ecosystem level. Additionally, quantifying the relative improvement of societal benefit (including non-market and indirect values) for a given management measure is a critical missing element for many reference points.

It is important to recognize that most individual indicators would not be holistic ecosystem indicators *per se*, but would capture elements or selected properties of the ecosystem. It may be necessary to prioritize indicators, which likely will be subjective based on perceived management issues, but may over time identify effective indicators.

There seems to be no single suite of quantitative ecosystem indicators to support fishery management requirements in the Western Pacific Region. The number and variety of indicators available, and the amount of information on each, make it difficult to select any single suite of indicators that fit all species and fisheries.

On the other hand, it may be useful to develop an ecosystem indicator framework analogous to the Leading Economic Indicators that provide a guide to the condition of the U.S. economy. It may be possible to select (or 'evolve' or experimentally develop) a combination of indicators that, over time, would provide a tool to understand species/ecological relationships, and to support predictions of future status and conditions under given management decisions.

Proposed potentially useful indicators for ecosystem-based considerations (using the Pressure, State and Response approach) include information about status and trends of:

- Habitat ('quantity' and 'quality');
- Keystone/functional species dominants;
- Sentinel species;
- Protected species;
- Assemblage structure;
- Biodiversity;
- Pathogens;
- Harmful events (e.g., severe pollution events); and
- Fishery-based data (catches, species, size, catch per effort, mortality).

Thus, the final **recommendation** (see 9)) of the present workshop was to incorporate and evaluate a suite of indicators (possibly along the Pressure, State and Response groupings suggested in the workshop) in an evolving and adaptive process with input and review from experts in each region and region-wide. Initially, this suite will be based heavily on existing fishery-, habitat- and protected species-indicators, but the suite should be re-considered, amended and re-evaluated at every opportunity in line with management needs/issues and subsequent assessment/modeling requirements. Furthermore, the experiences of the North Pacific Regional Fishery Management Council should be more closely examined for potential applicability to the local situation.

## *Additional comments*

Several additional points were raised by the participants, and marked for attention by management agencies during this workshop, and are worthwhile noting:

The National Research Council (1999) Sustainable Fisheries Report put forward criteria for guidance in ecosystem-based fisheries management, with several points clearly identified that should form the guiding principles for the regions move towards ecosystem-based management:

- Adopt conservative harvest levels;
- Adopt a precautionary approach with respect to uncertainty;
- Reduce excess capacity and assign 'rights' in fisheries;
- Establish MPAs as a buffer against uncertainty and management failure;
- Include by-catch and discards in catch accounting for all sectors;
- Institute scientific and stakeholder reviews in transparent decision processes;
- Conduct targeted research on structure and function in ecosystems; and
- Incorporate ecosystem-based goals in management decisions.

Also, managers have to ensure the establishment and maintenance of the main prerequisites for ecosystem-based fisheries management:

- Effective control over all fisheries by the management system;
- Ability to enforce regulations;
- Ability to monitor all harvest, including by-catch;
- Ability to control fishing capacity and effort; and
- Ability to establish incentives that match the goals.

Furthermore, for scientists to develop models, undertake analyses and derive indicators useful to ecosystem-based management, managers need to:

- Provide clear management objectives - management should listen to available scientific advice, including careful consideration of uncertainties associated with the advice; consider the full range of ecosystem-stakeholder values and opinions; and attempt to seek consensus. Ultimately, however, management has to make clear decisions as to what the chosen objectives are;
- Remove institutional barriers to encourage effective collaboration in research and management;
- Develop better policies and legislation if currently inadequate; and
- Obtain/provide funding for the expanded research base likely needed to support ecosystem-based management.

As a further suggestion for management agencies responsible for the Western Pacific region, it has been suggested that there have been workshops with fishers in most if not all of the U.S. territories, looking at coral reef fisheries management. For the most part, it is the fishing community itself which is not happy with the way coral reef resources are currently managed, given the general decrease in resources observed over the last few years and decades. Furthermore, as far as potential complexity of ecosystem-scale impacts are concerned, experience from the Caribbean should be considered, where herbivores and other species have been overfished, resulting in a de-pauperate herbivorous community that subsequently has been affected by side effects such as disease. While the disease may not have been clearly attributable to direct human impacts, the effects of the disease were deemed closely related to indirect human impact due to the fishing related reduction in community structure. So it behooves managers to take precautionary measures to ensure both functional and structural integrity of ecosystems by maintaining biodiversity and habitats, as well as target and non-target stocks at conservatively high levels.

In order to engage in ecosystem-based fisheries management, fisheries stakeholders should recognize the inherent and often deep uncertainty associated with natural systems and the affiliated science; should insist that all management and exploitation be conservative and precautionary in nature; and should accept that the burden of proof rests with fisheries. This is a task that management agencies are well placed to actively engage in, facilitate and lead. In principle, stakeholders need to expect that fisheries will change under ecosystem-based fisheries management, specifically:

- Fisheries will be managed for stock abundance not scarcity or productivity, i.e., lower harvest rates from higher biomass;
- Less fishing capacity and employment;
- Higher incomes and use of technology;
- Practices with high habitat impacts replaced with alternative techniques or shut down;
- Greater use of spatially explicit management measures; and
- Restrictions on fisheries to accomplish other goals, e.g., biodiversity protection, ecotourism, recreational use.

In summary, as management in the Western Pacific region moves towards ecosystem-based fisheries management, six general points should be considered as main policy advice consistent with global scientific and management consensus:

1. Industry and management should endeavor to be pro-active in changing the burden of proof regarding impacts of fishing, by taking an active participatory role in research and monitoring, and resource conservation and sustainability;
2. Apply precautionary principle as default;
3. Purchase ‘insurance’, e.g., adequately sized MPAs and spatial management options;
4. Learn from management experience in other areas and by applying ‘adaptive management’ approaches;
5. Use incentives to achieve goals; and
6. Promote fairness and equity within overall ecosystem-based management objectives.

In closing, it is prudent to realize that a ‘healthy’ ecosystem (being aware of the anthropomorphic danger in using this word) is good for ‘healthy’ fisheries. Hence, one could argue that implementing ecosystem-based fisheries management could lead to improved fisheries management of ‘healthy’, productive and sustainable fisheries.

# Appendices

## *Appendix A: Workshop agenda*

### ECOSYSTEM PLANNING AND MANAGEMENT WORKSHOP

**DAY 1 - April 18, 2005** **8:30 a.m. - 5:00 p.m.**

**PLENARY**

8:30 Introduction to workshop and meeting objectives and purpose **Sam Pooley**

**Background presentations and discussions:**

9:00 Principles of Ecosystem Based Fishery Management (EBFM), including outputs of the workshop on ecosystem-based decision support tools for fisheries management **Steve Murawksi**

9:45 What goes wrong with ecosystem models as tools for policy design: and what can we do about it? **Carl Walters**

**10.30-10.50 Break**

10.50 Western Pacific Fishery Management Council's Fishery Management Plans (FMPs), how far are they from EBFM? **Paul Dalzell**

11:35 Recommendations from Council's Bottomfish and Coral Reef Fish Stock Assessment Workshops **Gerard DiNardo**

**12 noon – 1.00 pm Lunch**

1:00 pm Discussion/wrap-up of morning session and introduction to Topic 1 **Sam Pooley**

**Topic 1: DATA SOURCES - Available information for the development of ecosystem approaches to fisheries management in the Western Pacific Region**

1:15 pm Fishery Dependant Data: The Hawaii-based Longline Fishery **Russell Ito**

1:35 pm Fishery Dependent Data for ecosystem management in the western Pacific **Kurt Kawamoto**

1:55 pm Western Pacific Fishery Information Network Program **Mike Quach**

2:15 pm Multi-disciplinary monitoring, mapping and research data for conservation and management of the coral reef ecosystems of the US-affiliated Pacific Islands **Rusty Brainard**

2:35 pm Ecological and Functional Studies: Snapshots in time **Frank Parrish**

2:55 pm Northwestern Hawaiian Island Monk Demography **Bud Antonelis**

**3:15 – 3:35 pm Break**

3:35 pm Oceanography for Ecosystem-based Research & Management **Russell Moffitt**

4:05 pm Reconstructing catch time series for coastal fisheries in the western Pacific **Dirk Zeller**

4:35 pm Discussion and wrap up of Topic 1 **Sam Pooley**

**5:00 Reception**

**DAY 2 - April 19, 2005 8:30 a.m. - 5:30 p.m.**

**PLENARY**

8:30 Introduction to Topic 2 **Sam Pooley**

**Topic 2: ECOSYSTEM MODELS - Application and limitations of ecosystem approaches to fisheries and resource management**

8:45 Ecosystem-based management of Queensland fisheries: Modeling and policy initiatives **Neil Gribble**

9:30 Sustaining Florida's multispecies coral reef fisheries **Jerald Ault**

**Break 10:15-10:35**

10:35 Application of "ecosystem" modeling in Canadian fisheries **Carl Walters**

**11:20- 1.00 pm Lunch**

1:00 pm Using ecosystem modeling for fisheries management: Where are we? **Villy Christensen**

1:45 pm A spatial ecosystem and population dynamic model **Patrick Lehodey**

2.30 pm Status of selected ecosystem models being used in the central Pacific **Jeff Polovina**

**Break 3:15 - 3:35**

3:35 pm Discussion and wrap up of Topic 2 **Sam Pooley**

**5:30 pm Facilitator and Rapporteur Work Session**

**DAY 3- April 20, 2005 8:30 a.m. - 5:00 p.m.**

**PLENARY**

8:30 Introduction to Topic 3 **Sam Pooley**

**Topic 3: INDICATORS - Development and application as tools for ecosystem approaches to fisheries and resource management**

8:45 What do scientists need from fishery and conservation managers in order to develop models and indicators useful to policy development and management? **David Kirby**

9:30 Development of marine indicators for assessment of the halting of biodiversity loss in the marine environment **Robert Wakeford**

**10:15 – 10:35 Break**

10:35 Indicators of change in the Georges Bank Ecosystem **Mike Fogarty**

11:20 North Pacific Council approach to Ecosystem-Based Management **David Witherell**

**12:05 am – 1:30 pm Lunch**

1:30 pm Discussion and wrap-up of Topic 3 **Sam Pooley**

**3:30 – 4:00 Break**

**BREAKOUT SESSIONS**

**4:00 Formation of three break-out Working Groups to discuss data needs, models and ecosystem indicators for archipelagic and pelagic ecosystems management.**

5:00 pm Breakout Working Groups adjourn

**DAY 4 - April 21, 2005 8:30 a.m. - 5:00 p.m.**

**BREAKOUT SESSIONS**

8:30 Continuation of three break-out Working Groups to discuss data needs, models and ecosystem indicators for archipelagic and pelagic ecosystems management.

**12:00 noon -1:00 pm Lunch**

1:00 pm Continuation of three break-out Working Groups

3:00 pm Completion of Working Group discussions

3:30 pm Break-out group representatives and workshop staff review summary materials and discuss key recommendations and meeting report

**5:00 pm End of session**

**DAY 5 - April 22, 2005 8:30 a.m. - 1:00 p.m.**

**PLENARY**

8:30 Introduction to Day 5: goals and objectives **Sam Pooley**

8:45 Report from Working Group 1 and discussion **Steve Murawski**

9:30 Report from Working Group 2 and discussion **Jerald Ault**

**10:15-10:35 Break**

10:35 Report from Working Group 3 and discussion **Mike Fogarty**

11:20 Synthesis of workshop **David Fluharty/Michael Orbach/Sam Pooley**

12:00 Discussion and Workshop wrap-up

**1:00 pm Adjourn**

## *Appendix B: Workshop participants*

# Ecosystem Science and Management Planning Workshop Participants

## <u>Expert Panel</u>


**Jerald Ault**
Rosenstiel School of Marine and Atmospheric Science
University of Miami, 4600 Rickenbacker Causeway
Miami, FL 33149
ault@rsmas.miami.edu

**Villy Christensen**
Fisheries Centre
University of British Columbia, 2202 Main Mall
Vancouver, BC
Canada V6T 1Z4
v.christensen@fisheries.ubc.ca

**David Fluharty**
School of Marine Affairs
University of Washington, 3707 Brooklyn Ave., NE
Seattle, WA 98105
Email: fluharty@u.washington.edu

**Mike Fogarty**
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026
Michael.Fogarty@noaa.gov

**Neil Gribble**
QDPI, Northern Fisheries Centre
38-40 Tingira St. Portsmith, P.O. Box 5396
Cairns Qld 4870 Australia
Neil.gribble@dpi.qld.au

**Steve Murawski**
NMFS Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026
Steve.Murawski@noaa.gov

**Carl Walters**
Fisheries Center
University of British Columbia, 2202 Main Mall
Vancouver, BC
Canada V6T 1Z4
c.walters@fisheries.ubc.ca

## Steering Committee

**Sam Pooley (Chair)** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Sam.Pooley@noaa.gov

**Charles Alexander** NOAA National Marine Sanctuary Program
1305 East-West Highway, 11th Floor
Silver Spring, MD 20910
Charles.Alexander@noaa.gov

**Paul Dalzell** Western Pacific Fishery Management Council
1164 Bishop St., Suite 1400
Honolulu, HI 96813
paul.dalzell@noaa.gov

**Gerard DiNardo** NMFS Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
gerard.dinardo@noaa.gov

**Jarad Makaiau** Western Pacific Fishery Management Council
1164 Bishop St., Suite 1400
Honolulu, HI 96813
Jarad.Makaiau@noaa.gov

## Participants

**Tim Adams**
Secretariat of the Pacific Community
BPD5, Noumea Cedex, New Caledonia 98848
tima@spc.org.nc

**Judith Amesbury**
Micronesian Archeological Research Services
PO Box 22303
GMF, Guam 96921
judyamesbury@kuentos.guam.net

**Bud Antonelis**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Bud.Antonelis@noaa.gov

**Paul Bartram**
5329A Uhiuhi St.
Honolulu, HI 96821
pbartram@tripleb.com

**Keith Bigelow**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Keith.Bigelow@noaa.gov

**Chris Boggs**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Christofer.Boggs@noaa.gov

**Brian Bowen**
Hawaii Institute of Marine Biology
P.O. Box 1346
Kaneohe, Hawaii 96744
bbowen@hawaii.edu

**Rusty Brainard**
Pacific Islands Fisheries Science Center
Kewalo Research Facility
1125B Ala Moana Blvd.
Honolulu, HI 96814
rusty.brainard@noaa.gov

**Malia Chow**
NOAA National Marine Sanctuary Program
308 Kamehameha Ave, #203
Hilo, Hawai‘i 96720
Malia.Chow@noaa.gov

**Sean Corson** NOAA National Marine Sanctuary Program
6600 Kalaniana'ole Hwy #300
Honolulu, HI 96825
Sean.Corson@noaa.gov

**Gerry Davis** NMFS Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814-4700
Gerry.Davis@noaa.gov

**Ed Demartini** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Edward.demartini@noaa.gov

**Tamra Faris** NMFS Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814-4700
Tamra.Faris@noaa.gov

**Svein Fougner** 32506 Seahill Drive
Rancho Palos Verdes, CA 90275
sveinfougner@cox.net

**Beth Flint** US Fish & Wildlife Service
300 Ala Moana Blvd., Rm. 5-231
Honolulu, Hawaii 96850
Beth_Flint@fws.gov

**Alan Friedlander** The Oceanic Institute
41-202 Kalanianaole Hwy.
Waimanalo, Hawaii 96795
afriedlander@oceanicinstitute.org

**Mike Fujimoto** Hawaii Division of Aquatic Resources
1151 Punchbowl Street, #330
Honolulu, Hawaii 96814

**Marcia Hamilton** Western Pacific Fishery Management Council
1164 Bishop St., Suite 1400
Honolulu, HI 96813

**Dennis Heinnmann** The Ocean Conservancy
Pacific Regional Office
116 New Montgomery Street
San Francisco, CA 94105

**Thomas Hourigan** NMFS Office of Habitat Conservation
1315 East-West Highway
Silver Spring, MD 20910
tom.hourigan@noaa.gov

**Evan Howell** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Evan.Howell@noaa.gov

**Russell Ito** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Russell.Ito@noaa.gov

**Patrick Lehody** Secretariat of the Pacific Community
BPD5, Noumea Cedex, New Caledonia 98848
PatrickL@spc.int

**Kurt Kawamoto** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Kurt.Kawamoto@noaa.gov

**David Kirby** Secretariat of the Pacific Community
BPD5, Noumea Cedex, New Caledonia 98848
DavidK@spc.int

**Pierre Kleiber** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Pierre.Kleiber@noaa.gov

**Don Kobayashi** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Donald.Kobayashi@noaa.gov

**Randy Kosaki**
NOAA National Marine Sanctuary Program
308 Kamehameha Ave, #203
Hilo, Hawai‘i 96720
Randall.Kosaki@noaa.gov

**George Krasnick**
TEC Inc.
1001 Bishop Street, Suite 1400
Honolulu, HI 96813
GJKrasnick@tecinc.com

**James Maragos**
US Fish & Wildlife Service
300 Ala Moana Blvd., Rm. 5-231 or
P.O. Box 50167
Honolulu, Hawaii 96850
Jim_Maragos@fws.gov

**Steve Martell**
Fisheries Centre
University of British Columbia, 2202 Main Mall
Vancouver, V6T 1Z4, Canada
s.martell@fisheries.ubc.ca

**Jesse Mechling**
NOAA Ecosystem Goal Team
1315 East West Highway, Rm 15532
Silver Spring, MD 20910
Jesse.Mechling@noaa.gov

**Earl Miyamoto**
Hawaii Division of Aquatic Resources
1151 Punchbowl Street, #330
Honolulu, Hawaii 96814

**Russell Moffitt**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Russell.Moffitt@noaa.gov

**Lance Morgan**
Marine Conservation Biology Institute
15805 NE 47th Court
Redmond WA 98052
lance@mcbi.org

**Francis Oishi**
Hawaii Division of Aquatic Resources
1151 Punchbowl Street, #330
Honolulu, Hawaii 96814
Francis.G.Oishi@hawaii.gov

**Michael Orbach**
Director's Office
Duke University Marine Lab
135 Duke Marine Lab Road
Beaufort, NC 28516
mko@duke.edu

**Don Palawski**
US Fish & Wildlife Service
HI & Pacific Isle NWR Complex
P.O. Box 50167
Honolulu , Hawaii 96850
Don_Palawski@r1.fws.gov

**Frank Parrish**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
frank.parrish@noaa.gov

**Jeffrey Polovina**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Jeffrey.Polovina@noaa.gov

**Michael Quach**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Michael.Quach@noaa.gov

**Bill Robinson**
NMFS Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814-4700
Bill.Robinson@noaa.gov

**Robert Schroeder**
Pacific Islands Fisheries Science Center
Kewalo Research Facility
1125B Ala Moana Blvd.
Honolulu, HI 96814
Robert.Schroeder@noaa.gov

**Mike Seki**
Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Michael.Seki@noaa.gov

**Inna Senina** Pelagic Fisheries Research Program
University of HI Manoa
1000 Pope Road, MSB 33
Honolulu , Hawaii 96822
senina@hawaii.edu

**John Sibert** Pelagic Fisheries Research Program
University of HI Manoa
1000 Pope Road, MSB 33
Honolulu , Hawaii 96822
sibert@hawaii.edu

**Kitty Simonds** Western Pacific Fishery Management Council
1164 Bishop St., Suite 1400
Honolulu, HI 96813
Kitty.Simonds@noaa.gov

**Robert Skillman** Pacific Island Fisheries Science Center
2570 Dole St.
Honolulu, HI 96813
Robert.Skillman@noaa.gov

**Rob Toonen** HI Institute of Marine Biology
P.O. Box 1346
Kane'ohe, Hawai'i 96744
toonen@hawaii.edu

**Robert Wakeford** Marine Resources Assessment Group
18 Queen Street
London
W1j 5PN, UK
r.wakeford@mrag.co.uk

**Michael Weiss** National Marine Sanctuary Program
1305 East West Highway
SSMC-4
Silver Spring, MD 20910
Michael.Weiss@noaa.gov

**Aulani Wilhelm** NOAA National Marine Sanctuary Program
6600 Kalaniana'ole Hwy #300
Honolulu, HI 96825
Aulani.Wilhelm@noaa.gov

**David Witherell** North Pacific Fishery Management Council
605 West 4th, Suite 306
Anchorage, AK 99501-2252
David.Witherell@noaa.gov

**Dirk Zeller** Fisheries Centre
University of British Columbia, 2202 Main Mall
Vancouver, V6T 1Z4, Canada
d.zeller@fisheries.ubc.ca