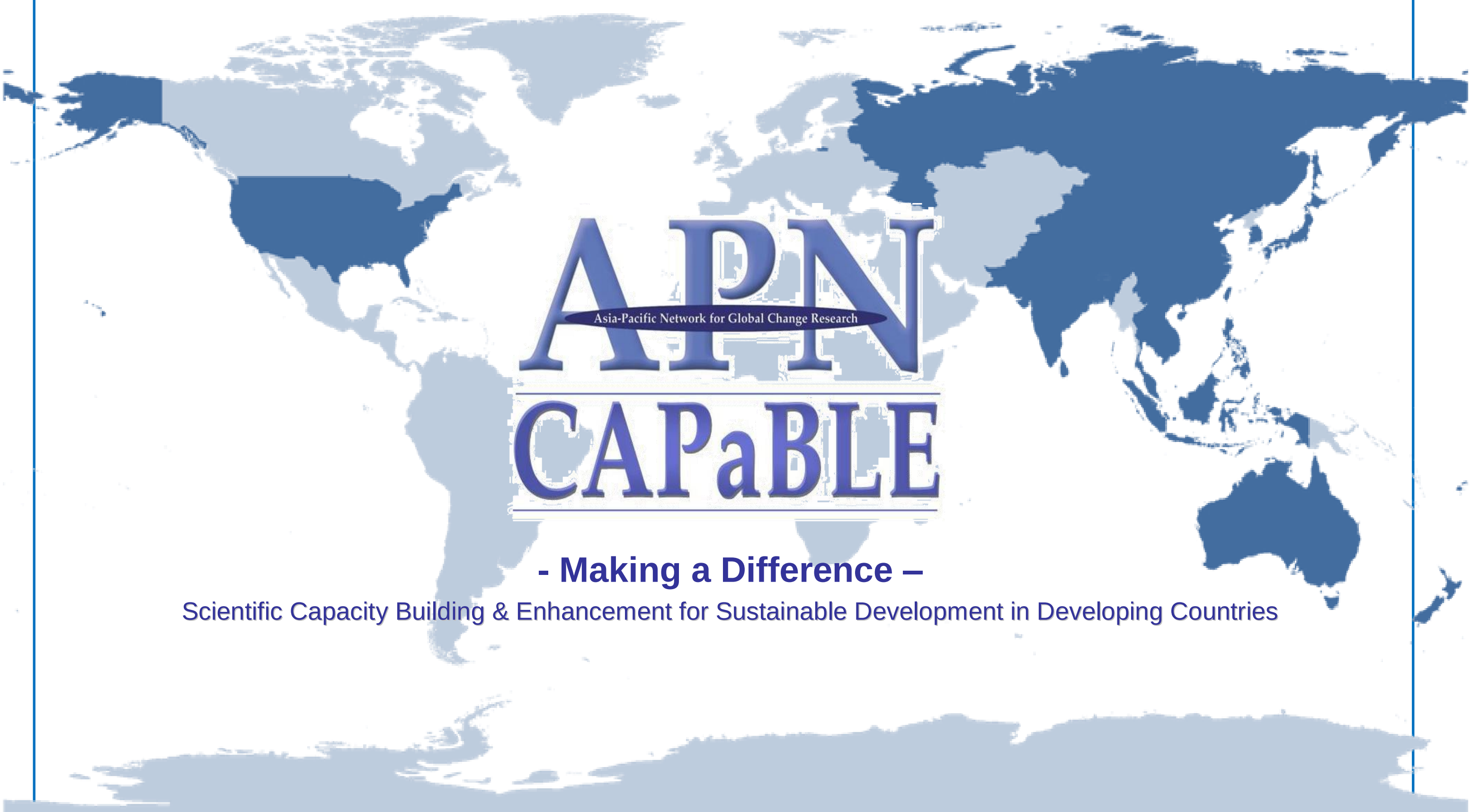
FINAL REPORT for APN PROJECT

Project Reference Number: CBA2011-10NSY-Ngari

International Workshop on Climate and Oceanic Fisheries, and Development of Climate Tools for Fisheries



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Australian Government

SPC Secretariat of the Pacific Community

Cook Islands Meteorological Service

THE UNIVERSITY OF AUCKLAND NEW ZEALAND Te Whare Wānanga o Tāmaki Makaurau

International Workshop on Climate and Oceanic Fisheries, and Development of Climate Tools for Development

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Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

The International workshop on climate and oceanic fisheries in Rarotonga, Cook Islands, 3-5 October 2011 considered strategies for reducing climate risks due to climate variability and extremes for oceanic fishers, to make food production more sustainable. A special issue of the journal Climatic Change is being prepared on improving climate services distributed to all appropriate agencies and organizations involved in designing and implementing strategies and related services to fishers. Recommendations for the provision of improved climate services to the fisheries communities to most National Meteorological and Hydrological Services, and Fisheries Agencies were made and methodologies and practices utilizing weather and climate risk management tools for fishers, and introduction in one Pacific Island country were developed. Sustainable oceanic fisheries in many of the ocean basins involving developing countries can be fostered through use of climate products and services, as well as those climate risk technologies selected for trial. All the different agencies sponsoring this workshop are engaged in the transfer of production and traditional technologies, to developing countries as discussed under WSSD Plan of Implementation, Part 107.

Objectives

The main objectives of the project were:

1. To review the effects of climate and climate variability on seasonal to decadal time scales on oceanic fisheries;
2. To evaluate of the impact of 21st century climate change on oceanic fisheries;
3. To identify fisheries risk assessment or management evaluation tools that incorporate climate in order to improve the sustainable management of oceanic fisheries;
4. To evaluate the implications of climate change for use of oceanic fish for food security, livelihoods and economic growth;
5. To recommend the adaptation and management measures needed to maintain oceanic fisheries for climate change, and
6. Develop climate services for fisheries in the Pacific.

Amount received and number years supported

The Grant awarded to this project was: US$ 40,000 for Year 1: 2011/12

Activity undertaken

An International workshop on climate and oceanic fisheries was held in Rarotonga, Cook Islands from 3-5 October 2011. The Cook Islands Meteorological Service provided significant logistical support to involve junior scientists from developing small island countries, as well as engagement between climate services and fisheries organizations in the Pacific. There was significant involvement from the University of Auckland, the World Meteorological Organization, CSIRO, and the Pacific Community (SPC). The Australian Government through BoM and AusAID supported participants from Meteorological Services from Pacific Island Countries (PICs).

The format of the international workshop was as follows:

• Opening Session: Following welcome addresses from different sponsors of the workshop, and a keynote address;

• Five technical sessions covering different objectives of the workshop. In each session there will be presentations by invited speakers, both from developing and developed countries, each of which will be followed by comments from discussants from developing countries;

• A final session on the workshop conclusions and recommendations.

Keynote papers were given on:

a) Effects of climate variability, from seasonal to decadal time scales on fisheries;
b) Evidence of the impacts of climate change on ocean fisheries;
c) Impacts of 21st century climate change on fisheries;
d) Risk management tools that can be used to improve sustainable fisheries management;
e) Use of climate change risk management in adapting strategic plans to reduce the potential impacts of climate change on fisheries and food security;
f) Climatic tools for fisheries management.

After the workshop this APN project developed and assessed climate tools for the Cook Islands with follow on activities including:
• bringing together experts, media and fishers and their communities to improve communication of important climate information to end users;
• communicating knowledge on climate events which will impact on fisheries production; and
• developing ways of interfacing these climate tools via various media communication technologies.
It is proposed that this will be accomplished through a workshop and field work in fisher communities and Government offices. Over the course of this end user workshop, experts/trainers led users in creating the appropriate climate tools, converting these to media products (video/radio/print) which communicates issues of importance to local fishers for preparing for climate variations, such as La Niña events, and extreme climatic events that impact on fish production for management of oceanic fisheries.

Results

The workshop focused on the tropical Pacific Ocean because although many of the Pacific Island countries and territories (PICTs) depend heavily on oceanic fisheries and need to rely on the assistance of interdisciplinary teams to plan the sustainable use of their fisheries resources. Historical records and near real-time ocean observing and analysis systems indicate that the oceans of the world are changing. These changes are 'over and above' the interannual and decadal variability caused by climate oscillations such as the El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Indian Ocean Dipole (IOD), North Atlantic Oscillation (NAO) and Southern Annular Mode (SAM). For example, the temperature of the tropical Pacific Ocean at a depth of 80 m has increased by 0.6 – 1.0^{o}C since 1950. This warming has increased the stratification of the water column and reduced the supply of nutrients to the mixed layer of the ocean. Interannual to decadal variability causes major fluctuations in the distribution and abundance of oceanic fish species. Variation in the distribution of skipjack tuna and catch of Peruvian anchovy due to ENSO are prime examples. Changes to the oceans due to global warming are now beginning to alter the food webs that support oceanic fisheries, and cause more permanent shifts in the distributions of fish species.

The observed trends in changes to the oceans are projected to continue. Although there is uncertainty about the exact nature of these expected changes due to the limitations of the existing global climate models, continued global warming is likely to (1) increase the stratification of the oceans, causing further reductions in the availability of nutrients to the photic zone, (2) affect the strength of major ocean currents; and (3) reduce dissolved oxygen levels. Increases in atmospheric carbon dioxide are also expected to make the oceans more acidic. In turn, these changes to the tropical Pacific Ocean are expected to reduce net primary productivity and the biomass of zooplankton, leading to changes in the nature of food webs that support oceanic fisheries.

The distributions of skipjack, yellowfin and bigeye tuna in the Western and Central Pacific Ocean are projected to shift progressively to the east. These shifts in distribution are expected to occur in large part due to the expansion of the Warm Pool, and relocation of the prime feeding areas for tuna at the convergence between the Warm Pool and the waters of the Pacific equatorial divergence, to the east. Continuous observations of the physical, chemical and biological variability of the oceans are needed to parameterize and validate the models needed to assess the effects of climate change on oceanic fisheries. These observations must distinguish natural variability from global climate change.

At least 50 years of data on the physical properties of the ocean are required to identify climate change trends. Open access to data, and rescue of historical data (including data recorded by fishing fleets), are essential for building better models. The Pacific-wide network of fisheries observer programmes is an important potential addition to the physical oceanography monitoring system, and should be replicated in other fisheries management areas. However, fisheries observer programmes should not be limited to collecting physical data. Investments are needed to expand observations of the response of micronekton to variation in the physical and chemical features of the ocean. Such observations can then be used to calibrate acoustic data on abundance and distribution of micronekton to greatly expand coverage using ships of opportunity.

Projections for the responses of the oceans and the fish stocks they support to climate change indicate that well-designed adaptations will be required to reduce the threats and capitalize on the opportunities. Due to the effects of the other major and more immediate drivers affecting fisheries sectors, win-win adaptations are needed that address strong existing drivers (e.g. the effects of population growth and the use of fish for food security) in the near term, and climate change in the long term. The effects of fishing and interannual to decadal variability in surface climate and the oceans are likely to swamp any effects of climate change on the distribution and abundance of the fish species supporting oceanic fisheries over the next few decades. The effects of climate change are expected to dominate. The projected effects of climate change on oceanic fisheries should be evaluated now. Managers can then incorporate this information with the effects of the many other drivers influencing fish stocks, especially in cases where the exploitation rate of fish stocks is high and any negative effects of climate change may increase the risk of recruitment failure.

The importance of focusing on addressing the risks posed to fisheries by other drivers in the near- to mid-term is illustrated well where the main aim is to provide fish for food security. In such situations, the effects of population growth will have a much more powerful effect on exploitation rates and the availability of fish than climate change. Although the effects of climate change are expected to take time to emerge, managers must start to integrate the projected implications of climate change on fish distribution and abundance with sustainable harvest practices now. This will help avoid the coincidence of excessive fishing pressure and adverse climatic conditions for target species. Action is needed now because the management measures needed to confer increased resilience to stocks can take many years to be fully effective, depending on the life span of the species. It is encouraging to see that several countries are actively moving towards eliminating overfishing, rebuilding overfished stocks and evaluating the vulnerability of their fisheries to climate change.

This second workshop brought together experts, media and fishers and their communities to improve communication of important climate information to end users. The communication knowledge on climate events that impacted on fisheries production such as ENSO and the PDO was fully discussed. The participants developed ways of interfacing these climate tools via various media communication technologies. This was accomplished through a workshop and field work in fishers communities and Government offices in the Cook Islands. The appropriate climate tool were developed, converted in to media products (video/radio/print) to communicate issues of importance to local fishers for preparing for climate variations, such as El Niño events, and extreme climatic events that impact on fish production for management of oceanic fisheries.

Relevance to the APN Goals, Science Agenda and to Policy Processes

The provision of better climate services can help fishers make better decisions by avoiding or reducing the impact of climatic events on fisheries production and therefore lead to positive outcomes for their livelihoods. These services however, need to be properly communicated and disseminated and need the support of policy makers in every country. The attention of the policy makers to the conclusions and recommendations of the workshop will be drawn in two ways: through the proceedings of the workshop which will include all the papers presented at the workshop and the discussions and through communication of recommendations and conclusions to all Member countries of WMO. Participants from APN countries will be encouraged to promote the linkages between science and policy discussed during the workshop. The workshop will also promote linkages between various national, regional and international institutions participating in the workshop. Such linkages are crucial for improving climate services. Also, the assessment of climate risk management tools will be made for Pacific Island nations.

Potential for further work

Sustainable oceanic fisheries in many of the ocean basins involving developing countries can be fostered through use of climate products and services, as well as those climate risk technologies selected for trial. All the different agencies sponsoring this workshop can be engaged in the transfer of production and traditional technologies, in particular to developing countries as discussed under WSSD Plan of Implementation, Part 107.

Publications (please write the complete citation)

Special edition of Climatic Change with 18 papers being edited from the International Workshop.

References

Badjeck, M.-C., Mendo, J., Wolff, M., Lange, H 2009: Climate variability and the Peruvian scallop fishery: the role of formal institutions in resilience building. Climatic Change **94,** 211-232.

Bell J., Batty M., Ganachaud A., Gehrke P., Hobday A., Hoegh-Guldberg O., Johnson J., Le Borgne R., Lehodey P., Lough J., Pickering T., Pratchett M., Sheaves M., Waycott M. 2009: Preliminary assessment of the effects of climate change on fisheries and aquaculture in the Pacific. In: R. Gillett (ed) Fisheries in the Economies of Pacific Island Countries & Territories. Pacific Studies Series, Asian Development Bank, pp. 451-469.

Cheung, W.W.L., Lam, V.W.Ll., Sarmiento, J.L., Kearney, K., Keller, D., Pauly, D. 2010: Large-scale redistributipon of fisheries catch in the global ocean under climate change, Global Change Biology **16,** 24-35. Cochrane, K., De Young, Cassandra., Soto, D. and Bahri, T 2009: Climate change implications for fisheries &aquaculture, FAO Fisheries & Aquaculture Technical Paper No 530, FAO Rome, 212 pp.

Global Partnership & Fisheries Climate & Aquaculture 2009: A strategic framework for fisheries, aquaculture & climate change. ftp://ftp.fao.org/FI/brochure/climate_change/pacfa/pacfa.pdf

Murawski, S 2010: Climate change effects on fish and fisheries: Some impressions & priorities. International Symposium on Climate Change Effects on Fish & Fisheries, 25-29 April 2010, Sendai, Japan.

Perry, R.I., Cury, P., Brander, K., Jennings, S., Mollmann, C & Planque, B 2010: Sensitivity of marine systems to climate and fishing : Concepts, issues & management responses **79**, 3-4, 327-332.

Acknowledgments

Acknowledgment are due to the University of Auckland which provided significant scientific support, WMO, CSIRO who provided the necessary links into the fisheries research community, and the SPC. Many of the co-sponsors - NOAA, the North Pacific Marine Science Organization (PICES), FAO Fisheries, OECD, Global Program on Fisheries (PROFISH) of the World Bank, the International Council for Exploration of the Sea (ICES) and the Climate Impacts on Oceanic Top Predators (CLIOTOP) program provided a very effective global spread to involve participants from developing countries. The Australian Government through BoM and AusAID supported participants from PICs.

TECHNICAL REPORT

Preface

A major conclusion from the ICES/PICES/FAO Symposium on *Climate Change Effects on Fish and Fisheries: Forecasting Impacts, Assessing Ecosystem Responses and Evaluating Management Strategies* in Sendai, Japan, in 2010 was that new commitments to truly interdisciplinary studies – from climate-to-fish-to-fisheries – need to be forged. This project contributed to this process. The workshops in Rarotonga in October and December 2011 focused on the tropical Pacific Ocean, because many of the Pacific Island countries and territories (PICTs) depend heavily on oceanic fisheries and need to rely on the assistance of interdisciplinary teams to plan the sustainable use of their fisheries resources.

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1.0 Introduction

Fisheries play a crucial role for food supply, food security and income generation. According to the Food and Agricultural Organization (FAO), fish is a major source of protein diets, and comprises about 20 percent of animal protein in the diets of over 2.8 billion people – and can reach 50 percent in the world's poorest regions and up to 90 percent in small island developing states and coastal areas. The FAO concluded in 2008 that fisheries are threatened by climate change with higher water temperatures, melting glaciers, changes in ocean salinity and changes in cyclone patterns. These all are shifting the patterns and abundance of fish stocks. Developing countries that depend on fish for food and exports will have a real challenge in adjusting to changes. Marine ecosystems are not in a steady state, but are affected by the environment, which varies on many spatial and temporal scales. Fish populations respond to these variations in different ways. Interannual or El Niño scale changes in the ocean environment may result in changes in the distribution patterns of migratory fishes and can affect reproduction, recruitment and growth in other species. Decadal and longer scale variations may have other impacts, potentially including cyclic changes in the production level of marine ecosystems in ways that may favour one species or group over another. Long-term records of the abundance for most species are limited to historical commercial and recreational landings. This makes climate related trends in fish abundance difficult to detect. Most studies of ocean climate and fish abundance have been on interannual time scales, investigating potential relationships with climatic cycles such as El Niño and La Niña and the Pacific Decadal Oscillation. There is speculation at what prolonged warming over the next century could bring, and our best guesses would be based on the types of variability in oceanic fisheries abundance observed at the interannual and decadal scales. The Intergovernmental Panel on Climate Change (IPCC) in its 4th Assessment Report has concluded that climate change and variability is likely to modify the productivity and distribution of oceanic fisheries, with unpredictable consequences. Colder water species productivity may be reduced in subtropical waters and the distribution of spawning areas and fisheries may be affected; their ability to extend their range further southward towards the poles is likely to be limited by the lack of availability of suitable habitat. Warmer water species productivity may be enhanced in subtropical waters and distribution of more tropical species may expand southward. Increasing climate variability will make fisheries predictability and management more challenging, together with the paucity of knowledge of climate change effects on regional fisheries. Fish and fisheries are fundamental to life in many areas, especially in the Pacific. Given the means and opportunity, fishers like hunters before them ultimately deplete the resources that they target. These existing pressures will demand the development and implementation of appropriate methods to address issues of vulnerability to climate. Increased understanding of climate and its impacts on oceanic fisheries then, is critical in the future management of the fisheries resource for subsistence, market-based economies and cultures. It is this with this background that the Cook Islands Meteorological Service with the World Meteorological Organization (WMO) together with the CSIRO (Australia), University of Auckland (New Zealand) and Secretariat of the Pacific Community (SPC) organized, along with several other regional and international co-sponsors, an International workshop on climate and oceanic fisheries in Rarotonga, Cook Islands from 3-5 October 2011. Following the workshop climate tools for fisheries management were developed for pne Pacific Island nation.

The meeting was opened by the Honorable Tom Marsters, Deputy Prime Minister of the Cook Islands. Mr Arona Ngari, the Permanent Representative of Cook Islands with the World Meteorological Organization (WMO), welcomed the participants, and thanked the co-sponsors and the local organizers for their support for the Workshop. Further welcome and introductions were provided by Dr Jim Salinger of the University of Auckland, Leader of the Fisheries Task Team of WMO Commission for Agricultural Meteorology (CAgM); Dr Peter Dexter, Co-President, Joint Commission for Marine Meteorology (JCOMM) and IOC of WMO, Dr Karen Evans, Australian Commonwealth

Scientific and Industrial Research Organisation (CSIRO), ; Dr Johann Bell, Secretariat of the Pacific Community (SPC); and Robert Stefanski, Chief of the Agricultural Meteorology Programme of WMO.

The Workshop was developed to address of issue of increasing climate variability that will make fisheries management, and the forecasts of fisheries production, more challenging. A better understanding of climate and its impacts on oceanic fisheries is critical to the management of these valuable resources for subsistence and market-based economies, and cultures. Developing countries and SIDS that depend heavily on fish for food and exports will also need assistance in adapting to the effects of climate change on their oceanic fisheries.

The terms of reference of the World Meteorological Organization's (WMO) Commission for Agricultural Meteorology (CAgM) and the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) include the study and review of advances in the science technology, and development of proposed methods and practices utilizing weather and climate data and products as a resource for fisheries. The objectives of the Workshop included:

- To review the current understanding and status of marine and oceanic climate and climate variability, in particular in the South Pacific;
- To review the effects of climate and climate variability on seasonal to decadal time scales on oceanic fisheries, including through an evaluation of available historical data on marine climate and oceanic fish abundance;
- To evaluate of the impact of 21st century climate change on oceanic fisheries;
- To identify fisheries risk assessment or management evaluation tools that incorporate climate variability in order to improve the sustainable management of oceanic fisheries;
- To evaluate the implications of climate change for plans to optimise the use of oceanic fish for food security, livelihoods and economic growth; and evaluate the potential use of fish abundance data for climate change research;
- To recommend the adaptation and management measures needed to maintain oceanic fisheries in the face of climate change.

Forty-seven participants from twenty-two countries participated in the workshop. The Co-sponsors of the event included the Asia-Pacific Network (APN), the Government of the Cook Islands, NOAA, the University of Auckland, the Australian Government (through CSIRO, the Bureau of Meteorology and AusAID) and the Secretariat of the Pacific Community.

2.0 Methodology

The Cook Islands Meteorological Service provided significant logistical support to involve junior scientists from developing small island countries, as well as engagement between climate services and fisheries organizations in the Pacific. The University of Auckland provided significant scientific support for this project. Dr Salinger was a co-convenor of the workshop together with Dr R Stefanski of WMO. Dr Salinger, being on the editorial board of Climatic Change, is arranging for publication of the workshop papers in a special volume. Dr Alistair Hobday of CSIRO provided the necessary links into the fisheries research community, especially as relates to engaging experts in spatial management and migration of large pelagic species, environmental influences on marine species, and the impacts of climate change on marine resources. Dr Johann Bell of SPC, who plans future directions for engagement in the fisheries sector, engages in the planning of the use of fish for food security in the Pacific. Many of the co-sponsors - NOAA, the North Pacific Marine Science Organization (PICES), FAO Fisheries, OECD, Global Program on Fisheries (PROFISH) of the World

Bank, the International Council for Exploration of the Sea (ICES) and the Climate Impacts on Oceanic Top Predators (CLIOTOP) program will provide a very effective global spread to involve participants

from developing countries. The format of the workshop is as follows:

• Opening Session: Following welcome addresses from different sponsors of the workshop, and a keynote address.
• Five technical sessions covering different objectives of the workshop. In each session there will be presentations by invited speakers, both from developing and developed countries, each of which will be followed by comments from discussants from developing countries.
• A final session on the workshop conclusions and recommendations.

The Workshop was organized in the following sessions:

1: Effects of climate variability, from seasonal to decadal time scales
2: Historical ocean climate and fisheries data
3: Impacts of climate change on oceanic fisheries
4: Impacts of 21st century climate on fisheries
5: Management tools to improve sustainable fisheries
6: Adapting to the impacts of climate change on fisheries
7: Climate tools to assess vulnerability and for fisheries adaptation
8: Recommendations and conclusions

Twenty-three papers were presented in the above seven sessions which generated considerable discussion on a number of the workshop issues.

Follow on activities included:

- bringing together experts, media and fishers and their communities to improve communication of important climate information to end users;
- communicating knowledge on climate events which will impact on fisheries production; and
- developing ways of interfacing these climate tools via various media communication technologies.

This was accomplished through a workshop and field work with fishers management and officers in the Ministry of Marine Resources of the Cook Islands 7 – 9 December 2011. Over the course of the workshop, experts/trainers led experts and users in creating the appropriate climate tools, converting these to media products (video/radio/print) which communicates issues of importance to local fishers for preparing for climate variations, such as El Niño events, and extreme climatic events that impact on fish production for management of oceanic fisheries.

3.0 Results and Discussion

Keith Brander. Climate change, oceanic fisheries and conservation: There are historical pressures on global fisheries (from overfishing) and due to this; there is a need for management. It was highlighted that current atmospheric and climate variability is accelerating and compounding issues in fisheries management. Other notes:

- Variation/change in characteristics in oceans (sea temperature, salinity, acidity) affect productivity/distribution of marine life thus climate change should be considered in fishery management and fishing practice;

- EU “common fisheries policy”, in the field of marine environmental policy: currently climate change is not directly mentioned in fishery policy framework. In the future?
- Actions against climate change should be decided upon the speed/range of climate change in the applied regions.

Session One:

Jim Salinger: Seasonal Decadal Climate Variability and case studies indicating it’s effects in Pacific, Indian, Southern and North Atlantic oceans. Generally, the indicators of climate variation/change (e.g. teleconnection indices, mainly driven from SST and SLP) have been used as indicators of oceanic fish catch/productivity, showing the impact of climate variation to fisheries. Key notes:

- Pacific: ENSO conditions were compared with normal conditions and La Niña. Difference in surface temperatures impact on fisheries on a 3-5 year timescale;
- Pacific Decadal Oscillation (PDO) – Pacific wide phenomena on decadal timescales. Positive phase similar to ENSO produce stronger winds in north, weakening of winds in the eastern Pacific, warming in central Pacific, and cooling near New Zealand. The negative phase is more like a La Niña phase. Both phases impact on Pacific fisheries;
- Fisheries scientists alerted climate scientists to both ENSO/La Niña phenomenon, and the PDO;
- Historical climate variability evident from sediment records prior to human impact in Pacific;
- Indian Ocean – Dipole. Anomalies in SST more than 2 degrees. Does not appear to be as cyclical as ENSO. Causes inter-annual variability in Indian Ocean fisheries;
- North Atlantic Oscillation -positive and negative phases in wintertime (Dec.Jan. Feb. Mar). In more recent decades the NAO has been getting stronger related to warmer winters in Europe. The NAO impact on North Atlantic fisheries;
- Southern Ocean ‘Southern Annular Mode’ (SAM) – variability and strength of westerly winds in Sothern Oceans (pulsating). Not as regular as ENSO. Recently it has been trending upwards. Impacts on SST warming and cooling. SAM may cause variability in fisheries in Southern Oceans, but not much research on this has occurred yet;
- All phenomena have impacts on fisheries.;
- Observed changes in ocean climate: last 5 years (2006-2010) compared with 1951 -1980 – warming in Atlantic, Indian and Pacific oceans (although La Niña in equatorial Pacific causes some cooling). Generally ocean temps rising 0-700m layer;
- Surface pH has generally decreased by 0.1 units in past 200 years;
- Observed changes in fisheries have occurred in past 25 years;
- Need to identify climate and non-climatic impacts for improved fisheries management. Roundtable Discussion of Keynote and Dr Salinger:
- General message 1: there is an obvious gaps in southern ocean (observations, modelling and research)
- Greater dependency on fishery in southern hemisphere (particularly small islands) leads to better understanding on climate impact to fisheries required.

Session Two:

1. **Scott Woodruff. Evaluation of Marine Climate Data:**

- In situ marine data (via JCOMM Marine climatogical data):
  - Rescue
  - Management
  - Evaluation

- Presented marine climate data near Rarotonga;
- Provided overview international comprehensive ocean- atmosphere data set (domain specific archive) by Woodruff et al 2011: IOCOADS Release 2.5 *Int J Climatology 31: 951-967*
  - Use IMMA format (ascii), currently existing limit in / concerns on WMO BUFR format, to comprehensively record climatological data
- Historical data dominated by national ship data collections (esp from Europe and Japan);
- Recent marine platform mixture of BOS, drifting and moored buoys plus VOS metadata;
- Some data from fishing vessels (Japan, Norway and South African – all whaling vessels). Currently only marine/met data are archived, no biological data in record therefore encouragement of enhanced observations from fishing vessels is required, which are of great value in historical data archive;
- Data rescue – some have been digitised – much still in paper form requiring rescue. 3 key steps: Imaging, digitisation, and transfer to IMMA format. Time consuming to adhere to international standards. GCOS sets standard to maintain best practices for marine data collection and transfer;
- International data management issues – need reliable, open data access, especially of historical data (which do not necessarily have clean disciplinary 'fit').

2. Ed Harrison. Oceanic Variability and change around the Cook Islands:

- Historical data challenges at Pacific regional level – limits statements for temperature and sea level. Smaller scale (both spatial and temporal), more variability observed;
- If recent decadal variability continues, the next few decades will be affected more by trend than by long-term trend;
- Emphasis to keep the GOOS strong and on-going in order to identify trends from as many parameters as technically possible. Need the support of governments to implement and maintain GOOS;
- Provided some results specifically for the Cook Islands (Rarotonga), based on two tide gauges and satellite info. Lots of variability;
- Explanation that only recent decade of monitoring by Argo has provided comprehensive ocean climate data worldwide and for Pacific;
- Western Pacific sea level is rising more substantially than elsewhere around world, based on spatial variability of a 20 year trend of records;
- In Pacific, temp trends harder to identify than sea level trends due to extreme spatial and temporal sampling issues;
- Dr John Church indicates a minimum of 50 years sea level data to identify a trend. How many years of ocean climate data required for SST trend? Not enough years of SST recorded yet to have reliable estimates? But the models at least make it possible to have scenarios which can be considered.

3. Alistair Hobday (Karen Evans). Evaluation of oceanic fisheries data:

- Discussed the way to detect climate impacts from oceanic fisheries data;
- Relevance of climate change to fisheries and how do scientists and policy makers interpret variability in climate compared to climate change? Shifts in climate identified in fisheries with flow-on effects to economies – micro to macro scales. Decision-makers need to account for this;
- Case study – links between coral reef production and food security – monitoring sustainable levels in the Pacific. Climate change will also shift this balance and therefore potential to impact heavily on the system;

- Impacts from climate variability and change: Range of Primary (eg. Distribution, abundance, physiology) & Secondary impacts (eg. Prey species, habitats, ecosystems), and impacts on fisheries and people (eg. storms, sea level rise, reef bleaching etc);
- Note challenges in
  - biological data management, particularly in setting standards;
  - need to share data;
  - data collection – long term, and perhaps targeted monitoring is required;
- Different types of fisheries data (eg public observations, tagging, fishery catch, modelled etc) are not equally useful for climate signals and there are often gaps in data. Useful data includes, for example, electronic tag data (which can indicate shifts in foraging/spawning distributions, growth rates and changes in abundance), and modelled data (to identify TRENDS). More challenging to collect accurate fisheries data in developing regions because of the cost of equipment to assist data collection;
- Identifying climate signals against non-climate signals: Trends in data may also be due to other impacts (eg habitat destruction not related to climate variability). It is important to understand limitations and biases in data;
- Management needs – derived from application of observations into management tools. Robust tools required to accommodate different stakeholder objectives (eg Fishery managers – maximising catch, fishers – maximise profits, governments/policy makers – maximise sustainable development and societal benefit;
- CSIRO Program CLIOTOP – Climate Impacts on Oceanic Top Predators.

4. M Santos. Seasonality of commercially important pelagic fishes in the Philippines – overfishing or climate change?:

- Climate change policy in the Philippines is via the Climate Change Commission;
- Consistently predicted to be one of the top 10 countries affected by climate change. Philippines has 70% population in coastal areas;
- 6th fish producing country in world, 9th aquaculture production in world and 3rd largest seaweed producer in world;
- Ph largest marine biodiversity in world (with many biogeographic areas). Also largest pressure on conservation. Limited historical data on fisheries;
- Fisheries impacted by ENSO events;
- National Stock Assessment Program (NSAP) – creating standardised specific time series on marine capture fisheries info. Following FAO standards;
- Oceanic tuna (especially skipjack) is a major economic species in Ph. Also Sardines, Roundscads, Mackeral and Anchovies (from different geographic areas). Inter-annual variability between species – impacts from climate as well as other seasonal and geographic parameters.;
- Clearly management of fisheries is complicated, and localised management is recommended.

Session Three:

1. Jeff Polovina. Projected Climate change impacts on North Pacific marine ecosystems

- IPCC Reports and Models – challenges faced by climate community that describes coupled ocean-atmosphere systems. The models do not explore much about how trophic levels will respond to climate change;
- NOAA GFDL Earth System Model: coupled model + biogeochemical module
  - includes trophic levels (with zoo and phytoplankton);

- NOAA GFDL Earth System Model: coupled model + biogeochemical module
  - includes trophic levels (with zoo and phytoplankton);

- 3 approaches in climate models to make inferences about higher trophic level impacts:
  - Define dynamic biomes and then examine spatial and temporal changes (model derived biome boundaries overlain on SeaWIFS climatology) – results indicate biomes (eg large phytoplankton, zooplankton) over the 21st Century, and biome boundaries in the Northern Pacific; Biomes are an important indicator of transfer of energy up the food web;
  - Use climate model output to drive size based ecosystem models at specific locations;
  - Using climate model to drive Ecopath and Ecoism model for Hawaii based long-line fishery. The model is run and tuned to historical stock assessment. Indicates trophic interaction over a timescale.
- Carrying capacity of ecosystem appears to be declining so managers can use the information to make informed management decisions and approaches (eg. Managers can choose to maintain biomass above 50% knowing the predicted outcome from model output);
- Only one climate model has been used in this study but other evidence indicates that the models are robust;
- Summary that over 21st Century, a change in wind conditions and increased ocean warming will increase oceanic vertical stratification and redistribute nutrients. Suggestion that the South Pacific should be modelled separately given that climate variability there is different to the Northern Pacific;
- Attention to the regional variation in the projection: Adaptation to CC needs regional approach.

2. **Patrick Lehodey. Modelling the impact of climate change on Pacific tuna stocks and fisheries.**

- Skipjack, Yellowfin, Bluefin, Albacore and Bigeye are the major tuna species in the Pacific;
- Ecosystem models using ocean physics (3-D), biogeochemical (3-D and primary production), prey and predators population dynamics models – integrated approach. SEAPODYM (Spatial Ecosystem and Populations Dynamics Model);
- Predict observed variability and then project climate change impact for each species. Validation methods are also used to test robustness of model (including exporting it to the Indian Ocean). Also tried modelling during El Niño and La Niña conditions;
- The climate model produced a bias in the mid latitude (for skipjack?) – corrections were applied to this bias;
- New results are more realistic over the historical period though there are still several parameters that cannot be correctly estimated.;
- Recent publication indicated temperature below 21 and above 33 degrees are the lethal limits for survival of yellowfin;
- Understanding impact of climate change on tuna pops is linked to capacity to explain, the model predicts effect of natural variability for history prior for which we have data. With realistic forcing, the model seems relatively robust. More fishing data is required for optimal models (the data exists but difficult to access);
- New simulations with temperature corrected confirm extension of skipjack to subtropical land in eastern Pacific Ocean, but with lower biomass and decreasing trend after 2070s;
- Models for albacore seem robust;
- SST above 33-34 degrees will likely be a threshold for spawning of tropical tunas;
- Fishing impact will remain key driver of tuna stocks.

3. **Dr Lan. Climatic and marine environmental variations associated with fishing** conditions of tuna species in Indian Ocean:

- The Indian Ocean Dipole's (IOD) influence on tuna stocks has not previously been shown, although it was anticipated. The teleconnections between ENSO/La Niña and Indian Ocean

Dipole and influence on tuna fisheries were noted. Case study on Taiwan longline fishery in Arabian Sea determined a link between IOD (and related SST) and tuna fisheries there, as well as predicted impacts from climate change in future using various scenarios of 1-4 degree differences from the normal SST (eg. increase and decline in different areas of the Indian Ocean). Fish stocks respond to positive and negative IOD events.

4. **Malcolm Francis. New Zealand tuna and pelagic sharks and ocean warming**

- NZ traverses a large range of latitudes and SST (from 8 degrees Celsius in south, to low 20s in north). It has massive influence on range of tuna and pelagic sharks and therefore geographic distribution of fisheries area. Climate change and ocean warming is predicted to influence the range of these fish;
- Observed data in tuna long-line fishery since 1987 –short time of records;
- Skipjack tuna catch observed to occur between 19-21 degrees (optimal catch temperature range). When temperature declines (for seasonal reasons), tuna migrate north to warmer tropical waters;
- Albacore troll catch is strongly correlated to ENSO mean annual index;
- There is difficulty predicting long-term climate change impacts from ocean warming to fisheries around New Zealand for various reasons including:
  - ENSO short term variability can skew signals for predicted climate change impacts. In the future, it appears that the ENSO cycle will have a more pronounced influence on the fisheries that predicted ocean warming from climate change;
  - Ocean currents are constrained by bathymetry, which ultimately influences movement of warm and cooler waters – which in turn influences wind regime, and therefore ocean cooling may occur in the southern areas.

5. **Vivekanandan. Effect of fishing and climate change** on fishing down marine food web along southeast coast India (this person was absent, so another presentation was given by a Cook Island NGO on the concern for chemicals in the marine food web.
   There is great concern for implications of chemicals and heavy metals (eg. Mercury) and pollutants (POPs) in the food chain, from fish to humans. Little data from the Pacific. A USP study indicated toxic levels in swordfish and tuna, but too little evidence for firm statements. Concerns are at local and regional level (Pacific Islander consumption) and global (Pacific Island fish are exported worldwide). London Protocol provides some form of international regulation. Currently few Pacific Islands signed to the London Protocol.

Session Four:

1. **Anne Hollowed. 21st Climate Change impacts on marine fisheries**

- Understanding ecosystems processes in the Bering Sea provides an indicator of what modelling is possible to identify cc impacts on marine fisheries. This can be extended somewhat to Pacific fisheries. Strengths and weaknesses to all the models. Big negative is the lengthy time to run the models, which can take up to several months;
- Loss of Arctic sea ice due to climate change is predicted up to a month earlier than normal, and a month later forming – two months longer of no-ice – this has huge impacts on production of fisheries;
- Projecting climate impacts using coupled models is useful for ecosystem processes, but scientists also need to consider the global demand for fish in the future. This requires extra social and economic parameters (coupled marine social-ecological systems on a global scale).

There is no single perfect model for climate change impacts on fisheries. Co-ordinate monitoring and assessment is required to support global models. Multiple models and using various scenarios for different regions are useful. Uncertainty needs to be communicated as well.

2. **Valerie Allain. Pacific wide observation system to monitor biological changes of the pelagic ecosystem**.

- Pacific tuna fisheries are the largest in world and predicted to be impacted by climate change. Therefore a Pacific wide observation system is imperative to monitor biological changes of the pelagic system, and contribute to understanding it's sustainability. Tropic and ecosystem interactions also need to be considered (including meso-zooplankton and micro-nekton);
- The diet composition of yellowfin tuna in the Eastern Pacific was identified in the research, and indicated the diverse range of species needed for health and sustainability of tuna.;
- Large scale monitoring of mid and trophic levels of ecosystem are non-existent. Recommendation that a large scale monitoring of the ocean biological parameters is required (in addition to PI-GOOS – which monitors the physical oceanography) to provide a greater opportunity to establish resource at the Pacific Ocean scale;
- Current monitoring opportunities include:
  - Fisheries 'observer' programs are currently operated by PIC governments, which assist the identification of catch, catch composition and biological data;
  - Tagging Top predators (eg. Sharks) which indicate distribution and their link to biodiversity.

3. **Alex Sen Gupta. Oceanography of tropical Pacific Part 1.**

- People are increasingly using models on smaller scales than they were designed for. Selection of models (resolutions, performance) should depend on the purpose and area of applications;
- Multi model mean does have advantages in that it allows for better simulation of current climate than any individual model. However, biases in ocean models propagate to other climate models (especially ENSO scenarios);
- Limitations and uncertainties in the reliability of models need to be considered;
- Comment from CSIRO that fisheries models use the median (and not the mean).

4. **Alex Ganachaud. Oceanography of tropical Pacific Part 2.**

- A summary was presented of the current state of the Pacific Ocean, the observed changes (over past 50 years) and predicted changes (by the IPCC) of ocean state in next 50 years. See the powerpoint presentation for key conclusions.

5. **Kevin Hennessey. Climate Change projections in the western tropical Pacific**.

- PCCSP (Pacific CC Science Program) – the talk provided summary and update on the PCCSP (funded by AusAid and implemented by CSIRO and Geoscience Australia);
- The PCCSP was driven by the IPCC Report (Ch 16) which demonstrated projections for limited domain on climate and climate change science of SIDS – especially in Pacific;
- Climate projections from PCCSP will be published in Nov 2011.

Roundtable of Session 4: Uncertainty tends to increase as conducting the modelling/projection to application (e.g. fish productivities). Improved monitoring and observations will improve predictions of climate change impacts in the Pacific in future, including better understanding and addressing uncertainty issues. Communication of uncertainty in science models to the general public is important yet potentially dangerous, as politicians and policy makers might use the uncertainty to respond with a 'do nothing' result. Science communication needs to be handled sensitively, especially as the climate prediction models become more complicated.

Noting the importance of fisheries in Southern Hemisphere, it was recommended that enhanced activities in S.H. should be conducted for understanding the impact of climate variation/change to fisheries, perhaps those active groups in N.H. (e.g. PICES). Some ongoing efforts by the SPC in this area is noted. It may be considered by a new joint CAgM-JCOMM task team.
A 'Climate Futures' web-based software training workshop for the Pacific Islands is being conducted in Cook Islands by CSIRO and the PCCSP.

Session Five:

1. **David Brown. Benefits of Global Partnerships for Climate Change, Fisheries and Aquaculture. (PaCFA)**

- Over 500 million people depend directly and indirectly on fisheries and aquaculture for their livelihoods – important sector for world food;
- Preparing and response to cc impacts are priority – particularly FAO is aiming to build ecological (especially in ocean and aquatic systems), economic and social resilience;
- PaCFA: global and voluntary partnership comprising >20 int'l organizations and programmes, aiming to raise the profile of fisheries/aquaculture in the global CC discussion;
- There is a recognition that smaller island developing states and marginal communities depend on fishing for food and fisheries for economic stability, and therefore resilience needs to be built in these communities.

2. **Eva Plagnayi-Lloyd. Risk Management tools for sustainable fisheries management**.

- The different definitions of 'risk' and 'adaptation' were discussed – knowing the definitions assist with creating the most appropriate risk management tools for sustainable fisheries management. Fisheries management at the national scale usually aims to avoid various risks. Climate change is a new 'risk' in fisheries management – management tools need to be developed to avoid the impacts of climate change. Risk management needs to account for multi-dimensional uncertainties from modelling;
- Introduce Management Strategy Evaluation (MSE): a risk management tool used in fisheries;
- A case study on beche-de-mer fisheries was provided;
- Suggestion to utilize spatial MSE approaches as risk management tools for sustainable fisheries, along with continuous monitoring, which is very important.

3. **Amanda Amjadali (via teleconference). Pacific Ocean Climate Products facilitated by Climate and Ocean support Program for the Pacific.**

- POCPs are requested by PICs. A summary and demonstration of these was provided;
- BlueLINK and its implications for forecasting ocean climate in the Pacific was also described;
- Pacific Ocean Climate Web Portal is available for use by PICs.

4. **Dr Zhang. An IFRAME approach for assessing, forecasting and managing Korean fisheries under a changing climate.**

- Trawl catches for yellowfin tuna in South China Sea – more than 95% of catch are starfish.
- Declining biomass of Southern Bluefin tuna is evident in waters off Korea.
- Korea aiming to develop tools for ecological sustainable development of fisheries in order to maintain sustainability of target species.

Ms Pamela Marau (Cook Islands Ministry of Marine Resources) – Comment: Presentations over the past two days show a need for more stock assessment to feed into models of CC impacts. SPC recently developed software that assists stock outputs by fisheries and sub-regions. Possible collaboration is required between those doing climate and fisheries modelling. The Western Central Pacific Commission – has indicated projected changes in fish stock and distribution. Awareness of these outputs is increasing. Encouragement of more work is required towards high resolution forecasting models to help PICS prepare and adapt to predicted changes in the future. Policy development in the Pacific takes a lengthy time, especially due to political and financial issues. Some PIC fisheries have already adopted ecosystem based management (including CI) under a doc that is updated every two years. Some tools already provided are highly technical which can be difficult with lack of technical skills in many PICs. Capacity building is encouraged. PICs appreciate uncertainties explained as it helps to understand the varying knowledge and statements made on sustainable fisheries in the Pacific. PICs want to keep up to date on the climate change information. Request from fisheries whether it were possible to reduce the number of models used to refine projection outputs? Comment from Alex Sen Gupta that no model is yet perfect, so don't want to narrow down the use of models until more certainty is known.

Roundtable of Session 5: There is the suggestion to start showing policy makers the negative eg – NOT doing surveys leads to less knowledge and even greater uncertainty in fisheries management. A discussion was raised to question how governments of the world could stop the exploiters of the fisheries from depleting the fish stocks in international waters – a separate and pressing issue from CC that requires urgent attention. Effective management and compliance measures are already in place to trace the origin of vessels in international and PIC EEZs but the capacity to control can be challenging over a wide area. Studies on the economics (e.g. cost benefit analyses) of fisheries is also underway in the PICs – the economic information contributes to capacity building to change attitudes of illegal fishing by islanders in PIC EEZs and international waters. It is important to communicate the benefits of having a healthy ecosystem. Recently, the human dimension in fisheries management is becoming more prevalent (e.g. the personal cost of overfishing is communicated in order to alter attitudes and prevent overfishing).

This second workshop brought together experts, media and fishers and their communities to improve communication of important climate information to end users. The communication knowledge on climate events that impacted on fisheries production such as ENSO and the PDO was fully discussed. The participants developed ways of interfacing these climate tools via various media communication technologies.

This was accomplished through a workshop and field work in fishers communities and Government offices in the Cook Islands. The appropriate climate tool were developed, converted in to media products (video/radio/print) to communicate issues of importance to local fishers for preparing for climate variations, such as El Niño events, and extreme climatic events that impact on fish production for management of oceanic fisheries.

4.0 Conclusions

The main aims of the workshop are:

1: To review the effects of climate and climate variability on seasonal to decadal time scales on oceanic fisheries;
2: To evaluate of the impact of 21st century climate change on oceanic fisheries;
3. To identify of fisheries risk assessment or management evaluation tools that incorporate climate variability in order to improve the sustainable management of oceanic fisheries;
4:To evaluate the implications of climate change for plans to optimise the use of oceanic fish for food security, livelihoods and economic growth;

5: To recommend the adaptation and management measures needed to maintain oceanic fisheries in the face of climate change.

The effects of fishing and inter-annual to decadal variability in surface climate and the oceans are likely to swamp any effects of climate change on the distribution and abundance of the fish species supporting oceanic fisheries over the next few decades. Eventually, however, as climate forces oceanic change further, the effects of climate change are expected to dominate. Nevertheless, the projected effects of climate change on oceanic fisheries should be investigated and evaluated now and this information made available to fisheries managers and government policy makers. Managers can then incorporate this information with the effects of the many other drivers influencing fish stocks, particularly in cases where the exploitation rate of fish stocks is high and any negative effects of climate change may increase the risk of recruitment failure. Action is needed now because the management measures needed to confer increased resilience to stocks can take many years to be fully effective, depending on the life span of the species. It is encouraging to see that several countries are actively moving towards eliminating overfishing, rebuilding overfished stocks and evaluating the vulnerability of their fisheries to climate change.

Climate variability and change from seasonal to decadal time scales

On climate variability and change from seasonal to decadal time scales ENSO causes seasonal to interannual variability of Pacific fisheries. The IPO causes decadal variability of Pacific fisheries and the IOD causes interannual variability in Indian Ocean fisheries. The NAO also effects seasonal variability in some North Atlantic fisheries and SAM also may cause fisheries variability in the Southern Oceans. Warming is causing shifts in distributions of fish. So well informed adaptive co-management is needed to resolve both climate and non-climate threats to fisheries. Small island countries with high dependency on fisheries need improved understanding of climate and fisheries.

Historical Ocean Climate and Fisheries Data

Historical ocean data trends are mixed in what they measure, so data rescue of early records is essential. Both sea level and ocean surface temperatures have been rising in the Pacific in recent decades but it is difficult to quantify the latter. Interannual to decadal variability swamps any long term trend over the next few decades. Adaptation planning needs to cover many timescales and multiple levels of climate change. Diversity and variability abounds around the Philippines – Indonesia region. It is important to ensure the capture of fisheries data that already exists. In the Philippines changes are complex which requires localised management.

Impacts of climate change on fisheries

Over this century a change in wind field and increased ocean warming will increase oceanic vertical stratification and redistribute nutrients. For much of oceanic North Pacific productivity and carrying capacity declines, with greatest declines near the boundary of the expanding subtropical gyre. Impacts from climate and fishing may vary with trophic level and fishing effort reduction may be needed to maintain ecosystem structure under multiple climate and anthropogenic stresses. Understanding the impact of climate change on tuna populations in the Pacific is linked to our capacity to explain, model and predict the effect of natural variability for the historical period for which we have data. There have been important developments of new observing technologies and progress in near real-time ocean analysis systems. There is biological evidence of changes in ecosystem function, shifts in habitat range, ecological novel species assemblages and multiple anthropogenic stresses. The impact of fishing will remain a key driver of tuna stocks, and conservation measures can take 10 to >20 years according to life span of the species to be fully effective. SST above 33-34°C will be likely a threshold for spawning of tropical tunas, unless genetic plasticity allows for some adaptation. Several modelled mechanisms need to be fully evaluated (e.g., spawning migration) investigated in details (food competition) or added (bioenergetics). The IOD index (DMI) was also found to be negatively correlated with yellowfin tuna (YFT) CPUE in the western Indian Ocean. Areas with high CPUE were decreased in the western Indian Ocean during the positive IOD events and increased in the negative IOD events. The optimal areas for high YFT CPUE as identified by SST and NPP decrease in the western Indian Ocean during the positive IOD events and increase during the negative IOD events. In the New Zealand, area distributions and centres of abundance of pelagic fishes are expected to move southward. Medium-term variation in SST caused by ENSO will have a greater effect on pelagic fishes than global warming, which will eventually become noticeable during La Nina phases of ENSO in the New Zealand area.

Impacts of 21st century climate on marine fisheries

Coupling higher trophic level responses to climate change into existing GCMs or ESMs may not be practical given the complex functional response of fish and fisheries . A global perspective is needed to project long-term trends in fisheries. Uncertainty must be communicated, and statistical and dynamical downscaling provides means to translate the impact of broad-scale climate changes to regional scales, but no perfect method exists. The Pacific-wide network of fisheries observer programs provides an important addition to the physical oceanography monitoring system and to the fisheries catch and effort data collection. Analyses of the dynamic oceanographic *biomes* (Hobday et al. 2011) is an immediate priority to evaluate the most efficient design for future sampling regime. For oceanography multi-model means results in a better simulation of current climate than any individual model and cancels non-systematic errors and internal climate variability. However systematic errors are not averaged out and climate signals are smeared out. It may be needed first to select best models or exclude the worst compared with 20th century observations. Downscaling and regional models are required for higher resolution to capture many processes important to biological systems, and understanding local sensitivities and possibilities. Bias adjusting of models removes systematic errors in the mean state but assumes the mean state and climate signal are independent of each other. The tropical Pacific Ocean is warming, with enhanced signal in the upper 100-200m with more stratification limiting the nutrient supply and reducing mixed layer. Some ocean currents are projected to change with equatorial divergence region projected to shrink. Dissolved oxygen decreases and the ocean becomes more acidic and sea level could rise by another 80-140 cm. Uncertainty tends to increase as modelling goes from climate to fisheries. Climate change projections for the western tropical Pacific indicate that it will become warmer, generally wetter, with heavier rainfall, with greater potential evapotranspiration and fewer, but more intense tropical cyclones occur.

Management tools to improve sustainable fisheries

Over 500 million people depend directly and indirectly on fisheries and aquaculture for their livelihoods. FAO is aiming to build ecological (especially in ocean and aquatic systems), economic and social resilience. PaCFA is a global and voluntary partnership comprising over 20 international organizations and programmes, aiming to raise the profile of fisheries/aquaculture in the global CC discussion. There is a recognition that smaller island developing states and marginal communities depend on fishing for food and fisheries for economic stability, and therefore resilience needs to be built in these communities. Existing risk management tools such as Management Strategy Evaluation (MSE) can be extended to evaluate how well different harvest strategies perform (especially in the face of uncertainty) in meeting multiple objectives, including managing trough climate variability and change. A multi-species bêche-de-mer fishery example was used to highlight that spatial approaches based on monitoring and adaptive feedback performs the best overall. It is important to account for uncertainties at all levels of climate models, observations, and in biology and human dimension models. Spatial MSE approaches can be used as risk management tools for sustainable fisheries, along with continuous monitoring. Marine applications for seasonal forecasting of SSTs, winds and salinity are being developed for coral bleaching and long-line fishing for Pacific Island countries. The Bureau of Meteorology, CSIRO, and RAN, through CAWCR, have developed Bluelink as an operational ocean forecasting system. Bluelink operational products and re-analysis are now being archived with a view to developing model-derived ocean climatologies. BOM is developing an interactive web portal to deliver metocean data, data products, analyses and derived products for PICs. The Pacific Web Portal Climate is being developed. Catches for yellowfin tuna in South China Sea are on the decline because more than 95% of catch are affected by starfish with a declining biomass of Southern Bluefin tuna evident in waters off Korea. IFRAME preliminary results indicate that this approach has potential as a tool for assessing and forecasting risk indices of objectives, species and fisheries. Korea is aiming to develop tools for ecological sustainable development of fisheries in order to maintain sustainability of target species.

Adapting to the impacts of climate change on fisheries

Oceanic Fisheries program at SPC provides services in 15 areas within the Pacific Islands region. Projected impacts from CC are expected to influence fisheries across the region and therefore government revenues are likely to increase. For smaller nations in the central and eastern Pacific. An adaptation policy already in place in the eight Pacific Islands nations that are the Parties to the Nauru Agreement is to restrict 'days' of fishing in different EEZs. These 'days' can be traded between vessels licensed to fish in the EEZs of these countries, providing a practical way for the fleets to follow fish as the tuna move in response to El Niño and La Niña events). The current subsistence catch of tuna in the Pacific is trivial compared with the commercial catch and a greater proportion of the commercial tuna catch will need to be allocated to food security in the future. Inshore anchored fish aggregating devices (FADs) are a win-win adaptation to increase access to tuna for food security in the tropical Pacific. FADs can deliver better access to tuna now and are expected to be favoured if climate change increases the productivity of tuna across the region until 2035, and then in the eastern Pacific until 2100.

Climate tools to assess vulnerability and for fisheries adaptation

The WMO Global Framework for Climate Services requires identification of relevant user needs from the fisheries sectors. JCOMM requires identification of fisheries users for services. The WMO focus is to support Member countries and associated services to public and subsidence activities. SAMOA has the smallest EEZ in the Pacific Ocean which limits fishing opportunities for its fishermen. Anomalies observed in sea surface temperature (SST) and sea surface height (SSH) in the Samoan EEZ in 2003, are associated to a dramatic decline in the catch rate of albacore tuna. These unforeseen changes in albacore distribution resulted in economic overfishing and overcapacity by the longline fleet. The adverse economic effect of this period is still felt in the fishery today. For PNG monitoring is very important. Tuna is a major resource for KIRIBATI. Local fisheries councils manage fisheries in SOUTH KOREA and IFRAME being developed. In USA Fisheries Conservation and Management Act has overfishing criteria with an increased movement to ecosystem based management. SPC notes fisheries oceanographers are working to assist fisheries management. PHILIPPINES are developing a policy to adapt to climate change. The most important fisheries in the world for anchovy and mackerel occur off PERU where ENSO is crucial. JAPAN is working towards sustainable fisheries management which link to climate. Catches off Japan have decreased. A strong ecosystem management based approach is in place in AUSTRALIA. Climate change impacts are of great concern along the Great Barrier Reef. Global production of capture fisheries has stabilized which reflects that fisheries are not sustainable. FAO notes a global trend towards sustainable management. Management of fisheries is the more pressing issue ahead of climate change. For the COOK ISLANDS rural communities are reliant on reef ecosystems for protein so increased SSTs, acidification and more intense tropical cyclones are of much concern.

5.0 Future Directions

Major Recommendations

1. **Fisheries need to be properly managed given the increasing influence of climate change on fish resource distributions**. More immediate threats need to be addressed (overfishing, population growth, urbanization) before climate change, which is a longer term issue. The most practical way to make fish stocks resilient to climate change is to improve the management of fish habitats (particularly through integrated coastal zone management), and limit the extent of fishing to ensure that there is always adequate spawning biomass to replenish stocks (accepting of course that environmental conditions will not always be conducive to good recruitment). Such measures will maximize the potential autonomous adaptation of fish habitats and fish species to climate change.

2. **There is a need to maintain, expand, coordinate and improve monitoring of meteorological, oceanographic and fisheries data**. Commercial fishing fleets should be strongly encouraged to contribute to global databases on variation in key features of the ocean. This is essential for better understanding oceanic systems and the impacts of change throughout these systems and to better improve models. Such programs will allow for the collection of time series substantive enough to improve understanding of natural variability associated with short-term and longer term ocean/climate phenomena (e.g. seasonal/inter-annual/ENSO/PDO) and allow the better building of natural variability into current climate models. In association, the negative impacts of not supporting ongoing data collection schemes need to be communicated.

3. **Uncertainty must be taken into consideration and communicated at least at the scientific level; communication of uncertainty to the public must be done with caution**. A multi-model approach is preferred to account for uncertainty. Multi-disciplinary studies (surface climate, oceanography and fisheries) are needed to discern the relative importance of the effects of fishing and climate on the variation we see in the abundance of fish stocks.

4. **There is a need to share information and capacity** among the national, regional, and international institutions and organizations involved in fisheries and climate change.

5. **The possible effects of climate change on oceanic fisheries should be communicated to governments and in particular, uncertainty or the range of possible effects in projections needs to be articulated.** This is required for better understanding variability in the outputs and projects of models and ensuring that adaptation measures are appropriate at the scales at which they are being developed. In the case of developing countries, governments should be assisted to interpret model projections and make comprehensive assessments of the vulnerability of the oceanic fisheries on which they depend. These vulnerability assessments should be based on improved models of the responses of the oceans, food webs and fish populations to global warming and increased carbon dioxide emissions.

6. **Agencies involved in collecting meteorological, oceanographic, biological and fisheries data should work more closely together to improve our understanding of the likely effects of climate change on oceanic fisheries.** In particular, these agencies should endeavor to provide

more comprehensive information to parameterize coupled global climate models and biogeochemical models. Commercial fishing fleets should be strongly encouraged to contribute the information they routinely collect on the physical features of the ocean to global databases. Partnerships between higher capacity institutions (capable of modeling requirements) and SIDS are key for better regional understanding of impacts and for facilitating adaptive management policies essential for food and economic security

Recommendations from Sessions

Opening session
Coping with effects of climate variability and change should be an integral part of fisheries management so there is an urgent need to address the challenges of overfishing and climate change with climate change mitigation actions are very urgent.

Climate variability and change from seasonal to decadal time scales
Much more work is required to improve relationships between climate and fisheries communities, above all in the Southern Oceans because of gaps in observations, modelling and research.

Historical Ocean Climate and Fisheries Data
Reliable open access to data, especially historical, is essential with oceanographic and surface meteorological research requires easy to access data from PIC EEZs. At least 50 years of physical data are required to identify trends, and models need to be used from scenarios. For this WMO and JCOMM should enhance interdisciplinary observations and data management. Satellite projects and new "surface temperature" (land) initiatives should be used as an important new avenue for closer linkages between communities.

Impacts of climate change on fisheries
Efforts should be supported to act now to rebuild heavily exploited stocks (e.g. Bigeye tuna) and adaptation to climate change requires a regional approach facilitated by global collaboration. Adaptation planning needs to cover multiple temporal scales and needs to account for multiple levels of climate change and more data collection is needed on biological parameters (tagging, larvae, etc.).

Model parameterization from ocean observations or ocean re-analyses needs to be adjusted to the climate model environment. Ocean predictions from climate models are not fully comparable for historical period to results achieved from ocean reanalysis. More work with biogeochemical models and experimentation is needed to provide reliable projections of dissolved $O_2$and primary production.

Impacts of 21st century climate on marine fisheries
Coupling lower trophic level responses into GCMs and ESMs would be a useful development. Continuous and global time series are needed for climate change monitoring, and distinguishing between natural variability and global climate change trend is the challenge even in the oceanographic data. There is a need for preliminary analyses to design a suitable sampling plan for detailed ecological *analyses of observer data* available to provide feedback on critical data needed for ecosystem modelling and monitoring.

Enhancement of activities on monitoring and modelling of fisheries in the Southern Hemisphere are required with ongoing efforts by SPC and the new WMO Task Team. Developing future policy frameworks is needed and will require integration of stakeholders and policy makers. Networks of fisheries observer programs should developed in other fisheries management areas. (The Pacific-wide network of fisheries observer programs provide an important addition to the physical oceanography monitoring system and to the fisheries catch and effort data collection.)

There is a need for higher model resolutions to capture many processes important to biological systems and human dimension and economics must be added to the ecosystem approach in fisheries management as one way of estimating the impact of climate change. Investments to continue/expand observations of the response of micronekton to variation in the physical and chemical features of the ocean are needed to improve the biogeochemical models used to project changes in major fish stocks under climate change (e.g. skipjack tuna in the tropical Pacific). Such observations should be used to calibrate acoustic data on abundance and distribution of micronekton to greatly expand coverage using ships of opportunity.

Management tools to improve sustainable fisheries

Environmental variables in the stock assessment are required to provide data into climate change impacts models. High resolution forecasting model development is needed to assist Pacific Island countries to prepare and adapt fisheries to climate change as policy development takes a long time. Communication of the benefits of healthy marine ecosystems is important and user feedback is needed on data and products and on the application and of utility these data products derived from BOM web portal. Studies on the ecological effects of biogeochemical changes, such as acidification and reduction in oxygen content, are required together with studies of climate change impacts on habitat quality and socio-economic attributes are also necessary.

Adapting to the impacts of climate change on fisheries

Positive adaptations are needed that address strong existing drivers (e.g. the effects of population growth of the use of fish for food security) in the near term, and climate change in the long term.

Climate tools to assess vulnerability and for fisheries adaptation

Knowledge and experiences need to be shared for more developed countries to assist less countries with resources ecosystems is important.

References

Badjeck, M.-C., Mendo, J., Wolff, M., Lange, H 2009: Climate variability and the Peruvian scallop fishery: the role of formal institutions in resilience building. Climatic Change **94,** 211-232.

Bell J., Batty M., Ganachaud A., Gehrke P., Hobday A., Hoegh-Guldberg O., Johnson J., Le Borgne R., Lehodey P., Lough J., Pickering T., Pratchett M., Sheaves M., Waycott M. 2009: Preliminary assessment of the effects of climate change on fisheries and aquaculture in the Pacific. In: R. Gillett (ed) Fisheries in the Economies of Pacific Island Countries & Territories. Pacific Studies Series, Asian Development Bank, pp. 451-469.

Cheung, W.W.L., Lam, V.W.Ll., Sarmiento, J.L., Kearney, K., Keller, D., Pauly, D. 2010: Large-scale redistributipon of fisheries catch in the global ocean under climate change, Global Change Biology **16,** 24-35. Cochrane, K., De Young, Cassandra., Soto, D. and Bahri, T 2009: Climate change implications for fisheries &aquaculture, FAO Fisheries & Aquaculture Technical Paper No 530, FAO Rome, 212 pp.

Global Partnership & Fisheries Climate & Aquaculture 2009: A strategic framework for fisheries, aquaculture & climate change. ftp://ftp.fao.org/FI/brochure/climate_change/pacfa/pacfa.pdf Murawski, S 2010: Climate change effects on fish and fisheries: Some impressions & priorities. International Symposium on Climate Change Effects on Fish & Fisheries, 25-29 April 2010, Sendai, Japan.

Perry, R.I., Cury, P., Brander, K., Jennings, S., Mollmann, C & Planque, B 2010: Sensitivity of marine systems to climate and fishing : Concepts, issues & management responses **79**, 3-4, 327-332.

Appendix

Programme

MONDAY 3 OCTOBER

08:00 - 09:30 hrs Registration at Edgewater Hotel, Rarotonga

09:30 hrs Prayers and Welcome
Government representative
Cook Islands Government
Arona Ngari
Permanent Representative of Cook Islands with WMO
09:45 hrs Address
Dr Jim Salinger
University of Auckland
Task Team Leader, Commission for Agricultural Meteorology (CAgM) of WMO
09:50 hrs Address
Dr Peter Dexter
Co-President, Joint Commission for Marine Meteorology (JCOMM) and IOC of WMO
09:55 hrs Address
Dr Alistair Hobday
Co-Chair, Climate Impacts of Top Ocean Predators (CLIOTOP)
10:00 hrs Address
Dr Johann Bell
Secretariat of the Pacific Community (SPC)
10:05 hrs Address
Robert Stefanski
Director, Agricultural Meteorology Programme
World Meteorological Organization (WMO), Switzerland

10:10 hrs Group Photograph and Tea/Coffee Break

10:40 hrs Workshop Keynote Opening Address
Dr Keith Brander
ICES/GLOBEC, Danish Institute of Aquatic Resources, Technical University of Denmark
Climate change, oceanic fisheries and conservation
11:25 hrs Vote of Thanks
Dr R Stefanski
Director, Agricultural Meteorology Programme. WMO, Geneva, Switzerland

Session I : Effects of climate variability, from seasonal to decadal time scales

11:30 hrs Effects of climate variability, from seasonal to decadal time scales on fisheries
Dr Jim Salinger
University of Auckland, Auckland, New Zealand
12:15 hrs Short contributions from 3 discussants (5 minutes)
12:30 hrs Round table discussion with presenters

13:00 hrs Lunch

Session II: Historical ocean climate and fisheries data

14:00 hrs Evaluation of marine climate data
Dr Scott Woodruff
National Oceanic and Atmospheric Administration (NOAA/ESRL), USA
14:30 hrs Oceanic variability and change in the Pacific
Dr Ed Harrison
NOAA/PMEL, Seattle, USA
15:00 hrs Evaluation of oceanic fisheries data
Dr Alistair Hobday
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Hobart, Australia
15:30 hrs Seasonality of commercially important pelagic fishes in the Philippines: overfishing or climate change?
Dr Mudjekeewis Santos
National Fisheries Research and Development Institute,
Quezon City, Philippines

16:00 hrs Tea/Coffee Break

16.30 hrs Rescuing and securing climate data in Oceania
Rod Hutchinson,
Bureau of Meteorology, Melbourne, Australia

Session III: Impacts of climate change on oceanic fisheries

17:00 hrs Climate change impacts on marine ecosystems
Dr Jeffrey Polovina,
Pacific Fisheries Science Center, NOAA, Honolulu, USA
17:30 hrs Modelling the impact of climate change on Pacific tuna stocks and fisheries
Dr Patrick Lehodey,
CLS, Toulouse, France

19:00 hrs Workshop Reception

TUESDAY, 4 OCTOBER 2011

08:30 hrs Climatic and marine environmental variations associated with fishing conditions of tuna species in the Indian Ocean
Kuo-Wei Lan,
Taiwan Nation University, Keelung, Taiwan
08:50 hrs New Zealand tuna and pelagic sharks and ocean warming
Dr Malcolm Francis,
National Institute of Water and Atmospheric Research, Wellington, New Zealand
09:00 hrs Effect of fishing and climate change on fishing down marine food web along southeast coast of India
Dr E Vivekanandan,
Madras Research Centre of Central Marine Fisheries Research Institute, Chennai, India
9.30 hrs Roundtable with presenters

Session IV: Impacts of 21st century climate on fisheries

09:50 hrs 21st century climate change impacts on marine fisheries
Dr Anne Hollowed,
National Marine Fisheries Service, Seattle, USA

10:20 hrs Tea/Coffee Break

10.50 Pacific wide observation system to monitor biological changes of the pelagic ecosystem
Dr Valerie Allain
South Pacific Commission, Noumea
11:20 Oceanography of the tropical Pacific, part 1: Climate models and their limitations
Dr Alex Sen Gupta,
University of New South Wales, Australia
11:45 Oceanography of the tropical Pacific, part 2: Historical changes and future projections
Dr Alex Ganachaud,
IRD, Noumea, New Caledonia
12.10 Climate change projections in the western tropical Pacific
Dr Kevin Hennessey,
CSIRO Division of Marine and Atmospheric Research, Aspendale, Australia
12.30 Roundtable with presenters

12:50 hrs Lunch

Session V: Management tools to improve sustainable fisheries

13:45 hrs Benefits of the Global Partnership for Climate Change, Fisheries and Aquaculture (PaCFA)
Dr David Brown
Food and Agriculture Organization (FAO)
14:15 hrs Risk management tools for sustainable fisheries management
Dr Eva Plaganyi-Lloyd
CSIRO, Queensland, Australia
14:45 hrs Pacific Ocean Climate Products facilitated by the Climate and Ocean support program for the Pacific
Amanda Amjadali
Bureau of Meteorology, Melbourne, Australia
15:15 hrs Tea/Coffee Break

15:45 hrs Discussants
Ms Pamela Mauru,
Ministry of Marine Resources, Cook Islands
then roundtable with presenters

Session VI: Adapting to the impacts of climate change on fisheries

16:10 hrs Implications of climate change on fisheries in the tropical Pacific: addressing economic development and food security
Dr Johann Bell
SPC, Noumea, New Caledonia
16:45 hrs Discussants (3) and roundtable
17:30 Adjournment

19:00 hrs Workshop

Dinner Address

WEDNESDAY, 5 OCTOBER 2011

Session VII: Climate tools to assess vulnerability and for fisheries adaptation

09:00 hrs The global framework for climate services: Climate tools for ocean fisheries management
Dr Robert Stefanski WMO, Geneva, Switzerland
09:30 hrs An IFRAME approach for assessing, forecasting and managing Korean fisheries under a changing climate
Professor Chang Ik Zhang,
Division of Marine Production System Management, Pukyong National University, Busan Korea
10:00 hrs Discussion with presenters

10:35 hrs Tea/Coffee Break

10:35 hrs Perspectives from Fisheries managers from around the World

12:00 hrs General Discussion

12:30 hrs Lunch

Session VIII: Recommendations and conclusions

13:30 hrs Policy options for adaptation and management for oceanic fisheries with climate change

14:30 hrs Panel Discussion on GFCS
Dr Stefanski (WMO); Dr Brown (FAO);
Dr Brander (GLOBEC); Dr Woodruff (NOAA); Dr Plaganyi-Lloyd (CSIRO);

16:00 hrs Tea/Coffee Break

16:30 hrs Addressing Climate and Oceanic Fisheries: Workshop Summary and Recommendations
Dr Jim Salinger, Dr Peter Dexter and Dr Robert Stefanski
University of Auckland, New Zealand; Bureau of Meteorology, Australia; and WMO, Geneva.

17:00 hrs Discussion

17:20 hrs Vote of Thanks on behalf of Co-Convenors
Robert Stefanski
World Meteorological Organization, Switzerland
17:30 hrs Vote of Thanks from Host Country
Arona Ngari
Cook Islands Meteorological Service, Cook Islands
17:40 hrs Workshop closure
Secretary of Fisheries
Government of the Cook Islands

Workshop on Development of climate tools for fisheries management
Rarotonga, Cook Islands 7-9 December 2011

Wednesday 7 December

Time	Activity	Description
8.30am	Prayer & welcome	Village pastor
9am 9.30	Introduction Climate of the tropical South Pacific	Workshop goals and format (Dr Jim Salinger, Janita Pahalad and Phoebe Fletcher) Climate of the South Pacific – sub tropical high, trade winds, intertropical convergence zone and South Pacific Convergence Zone (Dr Jim Salinger) Climate communication on the islands, Arona Ngari, Cook Islands Meteorological Service
10am	*Morning Tea*	
10.20am	Climate of the Southern Cook Islands	Identifying the climate of the Southern Cook Islands (Arona Ngari/Dr Jim Salinger)
10.50am	Groups discussions	
11.05am	Climate variability	Summary and overview of El Niño/Southern Oscillation and its impacts on the islands (Dr. Jim Salinger, University of Auckland/Arona Ngari, Cook Islands Meteorological Service) Summary and overview of Interdecadal Oscillation (Dr Jim Salinger) Variability of SPCZ and Tropical cyclones (Janita Pahalad)
1pm	*Lunch*	
2pm	Climate products for fishers	Ocean climate web portal products – SSTs, currents, winds, salinity, ENSO projections (Amanda Amjadali)
3pm	*Afternoon tea*	
3.05pm	What media do	The media, their role in communicating expert information to users, basic techniques used. Phoebe Fletcher, University of Auckland.
4pm	Workshop task: Small group work to discuss	Communicating expert information about climate products which could help fishers in specific fisheries planning and practices. Review of group outcomes.
4.45pm	Groups report back	Groups explain strategy to workshop

Thursday 8 December

Time	Activity	Description
9am	Group briefing	Using media to communicate expert information: uses of video and internet; skeleton storyboards and direction suggestions: Phoebe Fletcher, University of Auckland
9.20am	Groups leave for media recording	
11am	*Morning tea*	
11.20	Recording	
1pm	*Lunch*	
2pm	Recording	
3pm	Workshop	Systematic collection and analysis of climate information and impacts/adaptive strategies for fisheries and impacts of El Niño and La Niña events, and Interdecadal Pacific Oscillation

		Arona Ngari, Cook Islands Meteorological Service
3.30pm	*Afternoon tea*	
4.45pm	Groups report back	Group discussion of impacts of climate variability on fisheries
5 pm	Close	

Friday 9 December

Time	**Activity**	**Description**
9am	Production preparation	Production teams interview local fishers on impacts of climate on fishers and fisheries management
11am	Morning tea	
11.20am	Production preparation	Production teams prepare draft versions of media products
1pm	Lunch	
2pm	Production preparation	Visit to Fisheries Management Centre
3.00pm	Conclusion	Panel discussion: debrief, lessons learned, way forward.

Funding sources outside the APN

Activity	Organisation	In-Kind (US$)	Cash (US$)
World Meteorological Organization		30,000	
Australian Government		50,000	
French Government		20,000	
Administration Support	University of Auckland		20,000
CSIRO		10,000	
SPC		20,000	
Personnel support	Cook Islands Government		20,000
Ministry of Fisheries, Cook Islands		5,000	
Total	**75,000**		**100,000**

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Glossary of Terms

APN	Asia Pacific Network for Global Change Research
AusAID	Australian Government Overseas Aid Programme
BoM	Bureau of Meteorology
CAgM	Commission for Agricultural Meteorology
CAWCR	Centre for Australian Weather and Climate Research
CLIOTOP	Climate Impacts On top Ocean Predators
CSIRO	Commonwealth Scientific and Industrial Research Organization
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
ENSO	El Niño/Southern Oscillation
FADs	Fishing Aggregate Devices
FAO	Food and Agriculture Organization
GCOS	Global Climate Observing System
GOOS	Global Ocean Observing System
ICES	International Council for Exploration of the Sea
IFRAME	Integrated Fisheries Risk Analysis Method for Ecosystems
IOC	International Oceanographic Commission
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
IPO	Interdecadal Pacific Oscillation
JCOMM	Joint Commissions for Oceanography and Marine Meteorology
NAO	North Atlantic Oscillation
NOAA	National Oceanographic and Atmospheric Admonistration
NPP	Net Primary Productivity
PaCFA	Global Partnership on Climate, Fisheries and Aquaculture
PDO	Pacific Decadal Oscillation
PIC	Pacific Island Country
PICES	North Pacific Marine Science Organization
PROFISH	Global Programme on Fisheries
SAM	Southern Annular Mode
SPC	Secretariat of the Pacific Community
SSH	Sea surface height
SST	Sean surface temperature
WAMIS	World Agricultural Meteorology Information Service
WMO	World Meteorological Organization
WSSD	World Summit on Sustainable Development