

South Pacific Regional Fisheries Management Organisation (SPRFMO)

DRAFT Research Programme

1. Introduction

The development of a research programme within a Regional Fisheries Management Organization (RFMO) is essential to facilitate collaboration and coordination within and between different organizations and contracting parties.

These programmes should prioritise research in line with clearly defined objectives and should have a short, medium and long term scope.

The convention of the South Pacific Regional Fisheries Management Organization (SPRFMO) calls for cooperation in scientific research. The main fisheries identified in the SPRFMO convention area are the Chilean jack mackerel (*Trachurus murphyi*) fishery and associated species, the orange roughy (*Hoplostethus atlanticus*) fishery and associated species and the squid (*Dosidicus gigas*, *Sthenoteuthis oualaniensis*, *Ommastrephes bartrami*) fisheries.

The SPRFMO research programme should incorporate, as much as possible, the different components of the exploited resources and their associated ecosystems, and encompass both the Precautionary Approach and the Ecosystems Approach to Fisheries Management. Five main components are proposed:

- Environment and variability patterns at different temporal and spatial scales
- Chilean jack mackerel
- Deepwater species
- Squid
- Ecosystems Approach to Fisheries Management

The SPRFMO has already made important progress in summarising all available information, which is accessible at the web site of the organization¹ and constitutes a base line of information for the region.

¹ <http://www.southpacificrfmo.org/swg-meetings/>

2. Environmental variability at different temporal and spatial scales

The South Pacific is impacted by environmental variability from seasonal to secular scales, including El Niño - La Niña oscillations and the Pacific Decadal Oscillation (PDO) among other variables.

Seasonal changes are significant at high latitudes, diminishing at low latitudes near the equator. In contrast, equatorial waters are strongly influenced by El Niño events. The PDO is characterized by warm or cold waters and impacts the North, equatorial region and the South Pacific, with 20-30 year phases of warm or cool water alternating in the eastern Pacific. On the other hand the Arctic influence into the Southern Pacific is important and has different impact in the jack mackerel stock.

Tasks to be developed

- Determination of different environmental scenarios in the South Pacific.
- Identify patterns of seasonal, inter-annual (e.g. El Niño - La Niña), decadal or secular variation in environmental conditions that are likely to affect jack mackerel in the South Pacific.
- Investigate the effects of those environmental conditions on the distribution and population dynamics of jack mackerel on short-, medium- and long-term timescales.

The Permanent Commission for the South Pacific (CPPS)² has conducted regional oceanographic surveys since 1999 for the monitoring and forecasting of El Niño.

3. Chilean jack mackerel

Chilean jack mackerel (*T. murphyi*) is widely distributed in the South Pacific, from the south of Ecuador to southern Chile and extending from south-central Chile across the Pacific Ocean and reaching New Zealand and Tasmanian waters.

Information regarding the biology, geographical distribution and historical development of the fisheries is available at the SPRFMO web site³.

The Chilean jack mackerel research programme is structured by: 1) Biology and Ecology, 2) Stock Structure, 3) Stock Assessment and 4) Conservation, Rebuilding Plan and Management Procedures. These components are interdependent and should be linked as progress is made.

² www.cpps-int.org

³ <http://www.southpacificrfmo.org/jack-mackerel-sub-group/>

3.1. Biology and Ecology

Research on biology and ecology of Chilean jack mackerel has included a wide range of topics such as geographical, seasonal and depth distribution, habitat, migration patterns, life history, spawning and growth biology, natural mortality, trophic interactions and the influence of environmental conditions on these parameters.

Tasks to be developed

Monitoring and evaluation of biological and environmental parameters is fundamental to understand how environment influences the distribution and biology of jack mackerel and also the whole ecosystem.

Tasks linking biology and environmental parameters:

- An important topic that deserves specific research is the effect of the Oxygen Minimum Zone (OMZ) on jack mackerel. There are indications that jack mackerel do not occur in waters with less than 1 ml O₂/l and that dense schools require at least 3 ml O₂/l (Bertrand et al, 2006-MEPS). Jack mackerel are also not observed in sea layers of less than 40 m high.
- The link between El Niño periods and recruitment. The occurrence of El Niño appears to have a positive influence on recruitment.

Tasks on biological parameters:

- There is an apparent differential growth between jack mackerel in the north and in the south, with faster growth rates in the north. An age calibration workshop was organized in 2011 based on otoliths from the south. Further work is therefore necessary and the recommendations from the ageing workshop held in 2011 should be followed up. This includes age validation, calibration of age reading criteria (images and web based tools could be used) and the development of a reference collection of otoliths or images from the whole distribution area of jack mackerel (see document SWG-11-05 on the proposed working plan for age estimation). Peru performed an age validation study for the north and it would be important to include a collection of these otoliths in the age calibration study.
- Analyse the migration patterns linked to feeding and spawning. Chilean jack mackerel seems to aggregate for migration and feeding while it seems to scatter for spawning. Also, spawning areas appear to vary spatially and temporally.

3.2. Stock Structure

The stock structure of the Chilean jack mackerel is a key subject for the management of this resource in the South Pacific. It is fundamental that the establishment of management areas is based on biological criteria.

Important research has been developed by different participants in the past and in recent years regarding the population structure analysis of jack mackerel. This information is available and summarised at the SPRFMO web site.

However, the different analyses and studies performed on population structure have yet to provide a clear picture and results are not entirely consistent.

Tasks to be developed

Two different research areas on population structure analysis are proposed to be developed:

- Development of the international joint research programme:
The Science Working Group of the SPRFMO developed a proposal in 2008 for an international joint research programme to analyse the population structure of Chilean jack mackerel. This proposal includes a widescale biological sampling scheme and the application of a wide number of techniques as: genetics analysis, morphometrics (otoliths and body), parasites, life history and microchemistry of otoliths. This programme is very comprehensive and applies the state of the art methods used in other areas for population structure studies, but specifically excludes tagging.
Currently, progress on this programme is based on collaborative research between parties. The international joint research programme is available at the SPRFMO web site⁴.
- Simulation based analysis on stock structure and management
This task should be linked to the stock assessment component and management strategy evaluation related to conservation and rebuilding plans. This task does not foresee additional biological sampling or processing techniques and should be complementary to the research programme on population structure.
Through this task, all available data and information should be combined to identify the most likely stock structure hypothesis for Chilean jack mackerel. Different management strategies should be evaluated through simulations, in order to analyse the outcomes of considering uncertainty in population structure.

3.3. Stock Assessment

The main aim stock assessments is to provide managers with information on the exploitation status and what measures could be adopted to support sustainable exploitation in line with management objectives. For this purpose it is necessary to routinely collect:

- Fisheries related information, including detailed spatial and temporal catch and effort statistics, and biological information (fish length, age and maturity stage).
- Fisheries independent information as: 1) acoustic surveys to estimate abundance and the spatial distribution of the species and 2) egg surveys to provide alternative relative estimates of the spawning biomass.

Fisheries dependent information should be submitted by all parties fishing actively for small pelagic species according to the data submission standard⁵. Fisheries independent information has been provided in the form of reports and presentations by the coastal states.

⁴ See Annex D of the Workshop Report: <http://www.southpacificrfmo.org/2008-chilean-jack-mackerel-workshop-santiago/>

⁵ <http://www.southpacificrfmo.org/standard-submission-templates/>

Stock assessment models are commonly used to describe the past dynamics of an exploited stock and its expected future development according to different management measures. Biological reference points are commonly used to classify the stock status and assess the future developments and these are currently under investigation by the SWG (see Tasks below).

During 2010, an Assessment Simulation Task Team within the SPRFMO developed the Joint Jack Mackerel stock assessment model (JJM)⁶. The JJM is a statistical catch-at-age model and further developments of this model should include a spatial and seasonal structuring and the incorporation of environmental variables that might influence the population dynamics.

Tasks to be developed

The following tasks should be maintained or developed.

Data related tasks:

- Collection and reporting of fisheries information as specified in the data collection standards.
- Acoustic and egg surveys should be routinely undertaken and reported.

Stock assessment model related tasks:

- Further development of the JJM model to incorporate seasonal and spatial structuring in order to evaluate area specific management measures as seasonal and/or spatial closures (e.g. for areas with concentrations of juveniles or adults);
- Further development of the JJM model to incorporate the effect of environmental factors on the population dynamics, spawning success and recruitment of Chilean jack mackerel (see section on Biology and Ecology – effect on El Niño periods and the Oxygen Minimum Zone);
- Analyses of the effects of other possible management measures such as minimum landing size and minimum mesh sizes;
- Estimation of biomass and fishing mortality reference points;

3.4. Conservation, Rebuilding Plan and Management Procedures

The development of conservation and rebuilding plans and the adoption of management procedures require communication and close collaboration between fisheries management and science. Management Strategy Evaluation (MSE) is an important tool to incorporate uncertainties in stock assessment and provide managers with information on likely future stock dynamics according to different management procedures. This tool can help managers to find the right balance between biological risk and stability or profitability of harvesting over time.

⁶ see SWG-09-JM Documents at <http://www.southpacificrfmo.org/ninth-swg-meeting/>

Tasks to be developed

- For the development of conservation and rebuilding plans and adoption of a management procedure using MSE, it is necessary to have clear management objectives and biological reference points. This component of the Chilean jack mackerel research programme is therefore dependent on managers to decide on management objectives and on progress regarding the research components linked to stock assessment and development of biological reference points.
- It is emphasized that development and evaluation of Management Procedures and Harvest Control Rules are iterative processes that will require sequential, repeated and close consultation between scientists, fisheries managers and Commissioners throughout the process.
- Consider uncertainties related with stock dynamics, biology (e.g. density dependent maturity), ecology and stock structure.

4. The Deepwater Research Programme

The level of deepwater fishing activity in the SPRFMO Area is currently low. However, fishing effort levels have potential to increase; and relatively low levels of demersal fishing effort can have rapid and long-lasting impacts on Vulnerable Marine Ecosystems (VMEs)⁷ and the sustainability of deep-sea fisheries resources. To address these concerns, Prepcon2 (Cali, 2011) agreed that the SWG work plan should include (1) predictive habitat modelling to evaluate the probability of the presence of VMEs, (2) development of methods to assess the sustainability of deepwater species and the provision of advice on their stock status and potential management approaches and (3) evaluate the composition and rates of bycatch of non-target, associated and dependant species, including risk and impact assessments.

Tasks to be developed

The following tasks focus on deepwater target species and vulnerable marine ecosystems. Research associated with assessing the impact of fishing on deepwater non-target, associated or dependent species is included under Section 5, which describes a general approach for assessing bycatch across all SPRFMO fisheries.

4.1. Biology of Target Species

In addition to catch and effort data inputs (described under 3.2.3), quantitative stock assessments require an understanding of species biology. Such information will also provide a guide to species productivity (the stock's ability to support fishing and to respond to rebuilding initiatives). Important biological information requirements include:

- Age and growth, including growth curves and age-length keys, estimates of size at maturity and maximum age (longevity). Differences in growth rates of males and females and spatial origin of samples should be explored. Standardised otolith

⁷ www.cbd.int/doc/meetings/mar/ebsa-ettp-01/other/ebsa-ettp-01-background-info-en.pdf

interpretation and validation protocols will be required to guide otolith age determination.

- Estimation of reproductive capacity by size or age, including spatial and temporal variation.
- Estimates of natural mortality (M), using a range of estimation techniques.
- Allometric (length-weight) relationships.
- Characterisation of migration and movement, spatial and temporal patterns at appropriate scales (e.g. intra-season, inter-annual). This could use a range of techniques possibly including natural and artificial tags, commercial fishing location and density information.

Work on stock structure and on connectivity and mixing rates between deepwater fishing sites (e.g. seamounts), will contribute to the understanding of the sustainability of fishing. Options to explore stock differentiation include:

- Genetic studies using high-resolution genetic markers.
- Studies of otolith microchemistry.
- Fine spatial scale analysis (e.g. by seamount) of CPUE trends and changes in age or length composition.
- Morphometric studies.
- Parasites of the target and fish bycatch species, including individual presence/absence and community structure analyses.
- Tagging experiments.

4.2. Assessment of Target Species

Data required for traditional quantitative stock assessments (catch, fishing effort, CPUE, acoustic surveys, swept-area surveys, age and length composition) for deepwater fisheries are sparse, and it is unlikely that traditional stock assessments will be possible for most deepwater species. However, several approaches are available for evaluating the likely sustainable levels of catch (or fishing effort) for the main target species, such as orange roughy and alfonso. The selection of approaches will depend on the availability of necessary data. The assessment approaches presented below range from those with low data requirements (spatial management or effort limitation) through to those with high data requirements (quantitative stock assessments).

Catch and fishing effort data at a suitable resolution are essential for all assessment approaches, including the spatial management of target species and protection of VMEs. For the purposes of scientific mapping of demersal fishing effort data, SWG10 recommended using a data resolution of 0.1° (6 minutes) or finer. Appropriate fishing effort data will be required for CPUE analyses and quantitative assessments of deepwater species, including, for example, tow-by-tow data for trawl fisheries and set-by-set data for line fisheries. Catch history for long-lived, low productivity species can also be used to define useful statistics, including estimation of unfished biomass levels, when applied at appropriate spatial scales.

Science in support of spatial management approaches

One approach to estimating the sustainable levels of fishing mortality of deepwater species is to develop spatial habitat prediction models for the species of interest, similar to those

developed by Davies & Guinotte (2011) for scleractinian corals. For deep-water target species, habitat prediction models would provide estimates of habitat available in the SPRFMO Area for each species (e.g. orange roughy), with evaluation of the probability of occurrence of these species in different habitats. Fishing mortality levels might then be managed by limiting access to some proportion of the predicted orange roughy habitat, e.g. by closing a certain percentage of suitable flat areas or seamounts, or closing a percentage of the species total habitat in the SPRFMO Area. This approach would require additional work to 'ground-truth' the predicted habitat extent with real fish distribution and density information. It would also be necessary to explore a range of possible spatial management options in terms of the overall percentage closed and how the total area could be divided into effective subareas.

Estimation of sustainable yield by feature or area

The predicted habitat approaches described above can be extended to the estimation of sustainable yield levels per feature (e.g. seamount) or area. This would extend the meta-analysis estimation of carrying capacity for orange roughy by Clark et al. (2001, 2010). These analyses related estimates of biomass to physical characteristics of fished seamounts, e.g. latitude, geological association, depth at summit and estimated slope, to provide estimates of unfished biomass on seamounts across the entire Area. Results of such analyses could then be used to provide advice on sustainable yield levels for particular features or areas.

Acoustic surveys

Minimum biomass estimates might be derived from acoustic surveys, although in isolation they may provide estimates of absolute abundance. Technological developments are likely to enable the development of new operational approaches to estimating the stock size and status of deepwater species. For example, multibeam acoustics and acoustic optical systems (AOS) are now enabling resolution of mixed species targets according to their backscatter. This can enable, for example, differentiation of orange roughy (oil-based buoyancy) from gas-based buoyancy species and elasmobranches, based on the multi-frequency backscatter profile. This research technology is currently at an early stage of development for use by commercial vessels.

Quantitative stock assessment

Traditional quantitative stock assessments require time-series of catch and fishing effort data, the size or age composition of catches, information on growth and maturity and an index of abundance. The CPUE from deep-water trawling may not be a reliable index of abundance for species like orange roughy and alfonsino. Therefore, alternative indices of abundance need to be developed. For example, a time-series of abundance estimates might be compiled through regular acoustic surveys. Quantitative assessments would benefit from an understanding of stock boundaries and mixing rates between areas.

4.3. Identification and Mapping of Vulnerable Marine Ecosystems

It is not economically feasible to survey deep-water habitats across the entire SPRFMO Area. Therefore, alternative approaches should be used to identify and map probable VMEs:

- The primary approach is likely to rely on the development of predictive habitat models for VMEs in the SPRFMO Area, such as that developed by Davies & Guinotte (2011) for global scleractinian coral habitat. These models should be of an

adequately high resolution, tailored to the SPRFMO Area, and should include all species considered to be VME indicator species in the SPRFMO Area (e.g. stony corals, gorgonians, soft corals and sponges).

- Several participants have introduced interim move-on rules to try to limit damage to potential VME areas. All benthic bycatch data collected as part of monitoring these move-on requirements should be regularly compiled and analysed to map the location of potential VMEs (i.e. areas that triggered a move-on rule). These benthic bycatch data should also be used to inform existing predictive habitat models for VMEs in the SPRFMO Area and to enable the development of these and new models.

5. The Squid Research Programme

There are three species of squid that have been identified as of interest within the SPRFMO Area:

- Jumbo flying squid (*Dosidicus gigas*).
- Purple-back flying squid (*Sthenoteuthis oualaniensis*)
- Neon flying squid (*Ommastrephes bartrami*)

The key areas of research required for squid are to do with improving understanding in the biology of the different species, including growth, mortality, migrations, stock structure and population dynamics. That these are very short lived species requires a somewhat different approach to both science and fisheries management.

Tasks to be developed

The key areas of science include both monitoring and research, including:

- Record and report catch (tonnes) and effort separately for each species and gear type.
 - i. For jiggers record number of jig line hours separately for single and double machines.
 - ii. For trawlers, number of tows, hours fished per tow and catch per tow.
- Collect detailed biological data from the fishery on a short timescale (e.g. weekly) for:
 - i. length-frequency (dorsal mantle length – DML to the nearest cm below);
 - ii. weight (g) to calculate length-weight;
 - iii. sex (M, F, immature);
 - iv. maturity.
- Consider the need to collect appropriate material to investigate questions of stock structure: natural tags (e.g. parasites), standard fisheries tagging studies, genetic samples.
- Consider the existing knowledge of and need to further investigate migrations using established tag technologies.
- Consider the need for stock assessment surveys, both swept area bottom trawl and acoustic surveys.

- Collect and analyse diet data for squid to identify the types and species of key prey types and spatial and temporal variability in diet, including cannibalism.
- Collect and analyse diet data for all predators of squid, focussing on fish, seabirds and marine mammals, to identify key predators and the seasonal and spatial patterns in predation.
- Assess the applicability of various stock assessment approaches and existing mathematical models with respect to estimating squid stock size, especially to define data needs. This principally includes survey methodologies and mathematical models.
- Define key habitats, including spawning and nursery grounds.

In order to address the different research areas described, collaboration with researchers working on the same and similar species outside of the SPRFMO Area would be important.

6. Ecosystems Approach to Fisheries Management

The Ecosystem Approach to Fisheries Management (Garcia *et al.*, 2003) should consider the interaction between the fishing activity and the marine ecosystem and that fisheries are surrounded by and part of an environment and should not be managed in isolation. Impacts on species associated with certain fisheries should be considered but also on other species occurring in the ecosystem such as seabirds, marine reptiles and marine mammals that might be accidentally caught or experience direct or indirect competition for resources.

In particular, for the Chilean jack mackerel fishery, it is important to consider that general trophic interactions and relations between predator-prey species in the ecosystem may be affected by the large extractions due to fishing .

6.1. Assessment of the Impact of Fishing on Non-target, Associated or Dependent Species

An initial approach to assessing the impact of fishing on non-target ('bycatch'), associated or dependent species is to compare the distribution of species of concern with fishery distributions, such as the assessments by Baird *et al.* (2012) for seabirds. This information can be used in ecological risk assessments (ERAs) to evaluate the risk of significant impacts on bycatch species in particular fisheries or areas. Such risk assessments can be improved with the addition of fishery-specific information. In the absence of information on the fishery of interest (e.g. jack mackerel trawling in the SPRFMO Area), Baird *et al.* (2012), for example, substituted information from a Chilean trawl fishery for hake can be informative. Additional details on fishing seasons, time of day, characteristics of the fishing gear, type and use of existing mitigation measures and type and scale of observed interactions would improve the assessment of each fishery.

Adequate and representative observer data are essential for estimating interaction rates and the total mortality of bycatch species, and in identifying fisheries or areas where bycatch interactions may need to be managed. Observer data must be collected in accordance with the SPRFMO Observer Data Standards. Appropriate targeting and prioritisation of observer effort is required to obtain information on those species most at risk.

Observer data must be regularly summarised and reviewed in order to detect changes in bycatch risk ratings for each fishery. This will also ensure that observers are collecting the correct data and that coverage rates are adequate to detect interactions with bycatch species (including fish, marine mammals, seabirds, marine reptiles, sensitive benthic species and other vulnerable species). This should include information on the nature of interactions with bycatch species, life status and amounts released or discarded. This information can be used as a basis to recommend appropriate bycatch mitigation measures and performance standards. Observer data will also be useful for monitoring the effectiveness of, and improving, measures to manage bycatch.

Tasks to be developed

- Review observer data collection protocols and coverage levels for each SPRFMO fishery. This will help to align various national observer programs and identify gaps in the observer coverage of particular areas, fisheries, bycatch species or groups, or types of interactions that may need to be addressed.
- Estimate interaction rates and total mortality for bycatch species across each fishery. This will require data to be collected and submitted in accordance with SPRFMO's data standards. It will provide initial guidance on trends in bycatch in fisheries and activities or areas where bycatch may need to be investigated.
- Undertake ecological risk assessments (ERAs) to evaluate the risk of significant impacts on bycatch species. Where possible, this work should be delivered at a spatial scales appropriate to the species concerned, as a bycatch species might be subject to low level interactions in a number of fisheries, but when combined these separate impacts might become significant .
- ERAs are a cost-effective way of identifying priority or 'high-risk' species in particular fisheries or areas that might require increased monitoring or management intervention. The final task would then be to select or develop and test appropriate mitigation measures and performance standards for managing fishery interactions with high-risk species. This may require more additional research or analysis such as in the types of interactions with bycatch species.

Using available observer and other appropriate data:

- Conduct initial evaluations of the composition and rates of by-catch of non-target, associated and dependant species, both retained and discarded, including impact assessments of the jack mackerel fisheries.
- Quantify accidental catches of non-target fish, seabirds, marine reptiles, marine mammals and other species potentially occurring in the fisheries targeting jack mackerel and conduct initial evaluations regarding potential impacts.

It should be noted that, to enable the above evaluations to be done, participants will need to ensure that data collected by observers includes data on retained and discarded by-catch, as required by the Data Standards for observer data.

7. Prioritization and recommended development of the programme

Financing and collaboration between contracting parties of the SPRFMO is essential to develop and deliver this research programme.

There is currently no centralised financing of research through the RFMO, which could be important to enhance and link the current research developing independently by contracting parties.

Observer Programs

The Observer Data Standards provide a useful starting point for collecting data and samples of target species and addressing the SPRFMO's obligations in assessing the impact of fishing on non-target, associated or dependent species. However, the SPRFMO Secretariat will need appropriate funding and staffing if it is to effectively coordinate the various observer programmes across the SPRFMO Area. This will include work in developing data collection protocols (e.g. observer forms and lists of tasks), training (e.g. species identification and sampling procedures), managing data and reviewing coverage and data quality.

8. References

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