REPORT OF THE SOUTH PACIFIC REGIONAL FISHERIES MANAGEMENT ORGANIZATION CHILEAN JACK MACKEREL WORKSHOP

30 June – 4 July 2008,
Santiago, Chile

Introduction

The need for a Jack Mackerel Stock Structure and Assessment Workshop was identified at the third meeting of the Science Working Group (SWG) of the proposed South Pacific Regional Fisheries Management Organization (SPRFMO), held in Reñaca, Chile, in April 2007. The SWG identified the need for urgent work to develop working stock structure hypotheses upon which to base future stock assessments of Chilean jack mackerel (*Trachurus murphyi*) in the SPRFMO area, and proposed that a dedicated workshop be conducted to discuss and develop agreed working hypotheses, and to consider assessment requirements and inputs under such stock structure hypotheses.

The SWG also agreed that a proposal should be developed for a multi-lateral and multi-disciplinary research programme to further investigate stock structure for Chilean jack mackerel in the South Pacific and a *Jack Mackerel Stock Structure Task Team* was established to develop a draft research proposal under joint convenorship of Dr Serra (Chile) and Dr Glubokov (Russian Federation). The Chilean Jack Mackerel Workshop was also to review and finalise this draft proposal.

The Chilean Jack Mackerel Workshop was organized and convened jointly by SPRFMO and the Government of Chile, with Technical Assistance from the Food and Agriculture Organization of the United Nations (FAO), and was held in Santiago, Chile, from 30 June – 4 July 2008. Financial support for the workshop was also provided by the EU and FAO.

Session 1: Opening Session

Opening Ceremony

The Chilean Jack Mackerel Workshop was held from 30 June to 4 July 2008, in Santiago, Chile. The meeting was attended by 58 participants from Australia, Chile, China, Cuba, Ecuador, European Union, Japan, New Zealand, Pacific Islands Forum Fisheries Agency, Peru, Russian Federation, South Korea, USA, Venezuela and FAO.

The opening Ceremony was chaired by Jose Graziano Da Silva, Assistant Director-General, FAO Regional Representative for Latin America and the Caribbean, Jorge Chocair Santibañez, Undersecretary of Fisheries of Chile, Jorge Csirke-Barcelli, Director, FAO Fisheries and Aquaculture Division, and Susie Iball, Data Manager for the Interim Secretariat, South Pacific Regional Fisheries Management Organization (SPRFMO).

In the opening ceremony, Dr. Csirke-Barcelli welcomed participants on behalf of FAO, stressing the relevance of jack mackerel as the main fishery resource of the south Pacific area. He also pointed out the importance of the workshop as a catalytic step for the creation of the new regional fisheries management organization for the south Pacific. Dr. Csirke-Barcelli stated that FAO was pleased to assist member countries and regional fishery organizations to manage fishery resources and carry out the exploitation of those resources in a sustainable manner. He wished participants success in reviewing the available scientific information on the behaviour and stock structure of jack mackerel stocks in the south Pacific.

Dr. Graziano Da Silva congratulated the Chilean Government for the organization of the workshop on the Chilean Jack Mackerel. He mentioned that Chile is a centre for the work of FAO in Latin America. He also stressed the need for agreements on the protection of natural resources, especially in a period when the world price of food continues to increase. Dr. Graziano Da Silva informed the participants that FAO was assisting member countries in fisheries management and development, with great concern for the declining abundance suffered by several fishery resources, specially those resources of great economic and social relevance. He also stated that FAO was assisting countries of the Caribbean, Central and South America with national and regional fisheries and aquaculture projects aimed at developing capacity in key areas such as scientific research, fishery legislation, institutional building, rural aquaculture development, and aquatic environment protection. He expressed his hope that the meeting was successful.

Dr. Chocair Santibañez welcomed the participants on behalf of the Government of Chile and thanked FAO for its technical assistance and sponsorship in the organization of the Chilean Jack Mackerel Workshop. He also thanked the European Union for its contribution to the realization of the event. Dr. Chocair Santibañez stated that this scientific meeting will be a relevant input for the assessment of jack mackerel stocks in the south Pacific Region. He pointed out that the workshop was expected to produce a technical high level debate and provide relevant background data and information to meet the challenge associated with the exploitation of jack mackerel, one of the most important fishery resources requiring management, due to its straddling nature. He also stressed that jack mackerel would be one of the most important fishery resources to be regulated by the new fisheries regional organization that is being negotiated for the south Pacific area. He wished success to the participants in their deliberations and recommended them to spare some time to appreciate the beauty of Santiago.

The full list of participants to the Workshop is attached in Annex A.

Confirmation of Chairperson

Dr Jorge Csirke-Barcelli, Director: Fisheries & Aquaculture Management Division of the FAO, was confirmed as Chair of the Workshop. Dr Csirke-Barcelli welcomed all participants and encouraged everyone to work successfully towards achieving the objectives of the workshop.

Independent Experts

The Workshop was facilitated by the invited external experts: Dr. James Ianelli – NOAA (stock assessment) and Dr. Pablo Abaunza – of the Horse Mackerel Stock Identification Research project (HOMSIR) (stock structure). Dr Tore Stromme – from the IMR, Norway (acoustic surveys) was unable to attend and provided his apologies.

Nomination of Rapporteurs

Alexander Morison, Chair of the SPRFMO Jack Mackerel Sub-Group, and Andrew Penney, Chair of the SPRFMO Science Working Group, were nominated as main rapporteurs for the workshop, to be assisted by the independent experts and other participants as necessary.

Workshop Objectives

The objectives of the Workshop were:

- To review all available information for Chilean jack mackerel, and to develop a working hypothesis / hypotheses regarding jack mackerel stock structure in the region.
- To review available data and information available for use in jack mackerel stock assessments, and to agree on data inputs, biological parameters and assumptions to use in joint stock assessments of the jack mackerel stocks discriminated under the working hypotheses developed at the workshop.
- To review and finalise the project proposal prepared by the Jack Mackerel Stock Structure Task Team.

Session 2: Jack Mackerel Stock Structure

The following presentations were made to the session on Jack Mackerel Stock Structure. Abstracts of the presented papers are provided in Annex B.

Keynote Presentation

Horse Mackerel Stock Identification Research (EU Project – HOMSIR): A multidisciplinary approach using genetic markers and biological tags in horse mackerel (*Trachurus trachurus*) stock structure analysis. Pablo Abaunza, Project Coordinator, Instituto Español de Oceanografía (IEO), Spain.

Session 2 Papers

#2: **Distribution of early developmental stages of jack mackerel in the Southeastern Pacific Ocean**. Sergio Núñez, Sebastián Vásquez, Patricia Ruiz and Aquiles Sepúlveda.

#3: **Genetic variation on mtDNA Cytb sequence of three populations of Chilean jack mackerel, *Trachurus murphyi* from the Southern Pacific.** Min Zhang, Yong-jiu Xu, and Cheng-hui Wand.

#4: **Changes in the latitudinal and longitudinal distribution of the jack mackerel aggregations in the Peruvian sea between 1996-2007.** Ericka Espinoza, Miguel Ñiquen and Roberto Flores. Instituto del Mar del Perú (IMARPE)

#5: **Distribution of jack mackerel (*Trachurus murphyi*) related to oceanographical features between north Peru to north Chile.** Ñiquen, M.A. and C.L. Peña.

#6: **Inter-annual and seasonal variability of oceanological conditions in the Southern Pacific Ocean in connection with the pelagic ecosystem structure**. P.Chernyshkov, E.Timokhin, and A. Glubokov .

#7: **Jack mackerel (*Trachurus murphyi*) distribution peculiarities in the high seas of the south Pacific in relation to the population structure.** Soldat V.T., Kolomeiko F.V., Glubokov A.I., Nesterov A.A., Chernyshkov P.P., and Timokhin E.N.

#24: **Research and management of Chilean jack mackerel (*Trachurus murphyi*) exploited in the South East Pacific Ocean.** M.A. Barbieri.

#19: **An overview of the New Zealand jack mackerel fishery: catch composition, catch trends, seasonality and length-frequency composition.** Andrew Penney and Paul Taylor.

Session 2 Information Paper

The following additional information paper was submitted:

#1. **Seasonal distribution and abundance of jack mackerel (*Trachurus murphyi*) eggs and larvae off northern Chile 1981-2007** Mauricio Braun and Vivian Valenzuela.

Discussion of Jack Mackerel Stock Structure

The papers presented in this session provided overviews and updated information on the following main aspects relevant to developing working hypotheses on jack mackerel stock structure in the south Pacific Ocean (see abstracts in Annex B):

- Overview of international experiences with gathering, analyzing and interpreting a wide range of information to develop scientifically objective and robust definitions of jack mackerel stock structure upon which to base effective management measures.
- Information and analyses on Chilean jack mackerel biology, distribution, spawning and migration patterns relevant to understanding the possible distribution of jack mackerel stocks in the SPRFMO area.
- Results of surveys and analyses of commercial catch and effort distribution of Chilean jack mackerel fisheries showing distribution patterns of biomass or catches over time and geographic area.
- Results of previous genetic, morphometric or other natural marker studies providing information on possible relationships between jack mackerel caught in different areas of the south Pacific Ocean.
- Data and information on oceanography in relation to distribution of jack mackerel biomass or catches, and analyses of large-scale oceanographic features, anomalies and decadal changes which might influence jack mackerel abundance or distribution, or which might indicate likely distributions and boundaries of possible jack mackerel stocks.

Important issues and observations identified during discussion of these papers were:

There is clear evidence that jack mackerel abundance and distribution patterns, and therefore probably stock structure, are strongly influenced by oceanographic and environmental factors. These factors affect jack mackerel abundance and distribution patterns over different spatial and time scales, from within-year influences on migration and spawning patterns, to large-scale decadal shifts in distribution and abundance.

During suitable oceanographic conditions, stocks of Chilean jack mackerel are clearly capable of undergoing rapid and substantial expansions, such as the substantial increase in abundance, and apparent increase in distributional range of jack mackerel across the south Pacific, between the mid-1980s and mid-1990s.

Key issues to try and understand in relation to such expansions include whether these result from simultaneous increases in different stocks in response to large-scale and/or long-term climatic changes and oceanographic events, or whether these primarily result from substantial expansion of one major stock (such as the southeast Pacific Ocean stock), with subsequent separation of the increased biomass into separate stocks in different ocean regions (such as a southwest Pacific Ocean stock previously proposed by some authors).

Under the latter scenario, the question then arises as to whether such stocks become self-sustaining, or whether they slowly decline, unless sustained by further influx of jack mackerel from the east. In either case the question also arises as to presence and level of any mixing with the original parent stocks to the east.

It is important to use a wide variety of data and techniques to evaluate linkage / separation between jack mackerel in different regions, in order to develop scientifically objective and robust definitions of stock structure. Different techniques or data can provide different results, and integration of a number of methods is required. The approach taken by the HOMSIR project provides a good example of an effective multi-disciplinary research programme.

The strong influence of environmental factors on every aspect of jack mackerel distribution indicates that environmental or oceanographic factors are likely to play a strong role in determining the boundaries between stocks. Potential stock structure hypotheses based on other data should be tested against oceanographic information wherever possible, to ascertain whether oceanographic evidence supports or refutes the proposed stock boundaries.

It is equally important to understand how short-term oceanographic factors may be creating temporary distribution patterns, particularly in egg and larval distribution that may not indicate separate stocks, but simply indicate separate areas suitable for spawning or larval survival. There is certainly a need to ascertain whether proposed stocks show clear spawning areas. In this regard, it is notable that surveys have found spawning along much of the Chilean and Peruvian coasts, and continuous spawning from inshore waters out to west of 90° W off southern Chile and in the high seas in 1970s and 1980s. It is also worth noting that continuous spawning areas do not necessarily indicate a single stock. It is possible for there to be a cline over a continuous distribution range.

Caution must be exercised in drawing inferences regarding stock structure only from commercial effort or catch distribution data. There are many operational and economic reasons why commercial fleets might target or avoid specific areas at different times, and absence of fishing in an area may not indicate an absence of fish, or a separation between stocks. Patterns in the distribution of commercial catch and effort data reflect the combination of the behaviour of the fleet and of the target fish stocks. Fishery-independent and properly designed surveys provide better information on fish, egg or larval distribution patterns, and greater reliance should be placed on such surveys, than on commercial catch and effort data. In the absence of survey data commercial data can be used.

The Workshop identified that the following important questions to be addressed in developing working stock structure hypotheses upon which to base initial stock assessments:

- The extent of relationship or separation between jack mackerel caught off southern Peru and off northern Chile.
- The extent of relationship or separation between jack mackerel caught ‘inshore’ (or within EEZs) and ‘offshore’ (or on the high seas) off southern Chile.
- The source of jack mackerel fished in the New Zealand area, and whether these derive from some separate south west Pacific Ocean stock.
- The position of boundaries between straddling and high seas stocks[1] in the south Pacific Ocean.

Noting the current absence of fisheries and general lack of recent information on jack mackerel in the high seas in the central and southwest Pacific Ocean, the Workshop noted that objective evaluation of stock structure in that region required further data which might be generated by the proposed multi-disciplinary *Jack Mackerel Stock Structure Research Programme*. Southwest Pacific Ocean stock structure was considered to be of lower priority than establishing working stock structure hypotheses for the central and southeast region upon which to base stock assessments over the next few years.

To focus further discussion on the south-eastern region, the Workshop identified the following key questions:

- What is the evidence for separate ‘Peruvian’ and ‘Chilean’ jack mackerel stocks, and where would the most likely division be between such stocks?
- What is the evidence for a single shared jack mackerel stock between Peru and Chile, and is this a scientifically plausible alternate hypotheses to separate Peruvian and Chilean stocks?
- What is the evidence for a single Chilean southeast Pacific Ocean stock extending from inshore waters out onto the high seas, and what is the most likely westward extent of such a southeast Pacific Ocean stock?
- Is the existence of separate straddling and purely high seas jack mackerel stocks off southern Chile a plausible alternate hypothesis to a single southeast Pacific Ocean stock, what is the evidence for

[1] The definitions of straddling and high seas stocks follow those used in FAO Technical Paper No. 495.

a separation between such stocks, and where would the most likely division be between such stocks?

It was agreed to clearly document the evidence available that either supports or contradicts each of the different working stock structure hypotheses.

The Chair drew the attention of participants to the current wording regarding jack mackerel stock structure hypotheses contained in the SPRFMO Chilean Jack Mackerel Species Profile, which states in the overview that:

"There have been a number of competing stock structure hypotheses, and up to four separate stocks have been suggested: a Chilean stock which is a straddling stock with respect to the high seas; a Peruvian stock which is also a straddling stock with the high seas; a central Pacific Ocean stock which exists solely in the high seas; and, a southwest Pacific Ocean stock which straddles the high seas and both the New Zealand and Australian EEZs. However, further collaborative research is required to confirm and/or clarify this hypothesised stock structure as a basis for effective management regimes."

The Chilean Jack Mackerel Species Profile goes on to summarises the main evidence and references for these alternate hypotheses in more detail in the section on Population Structure. The Chair proposed that this wording be considered as the staring point for further discussion of alternate hypotheses on stock structure. He emphasised that discussions should focus on summarising scientific evidence for any proposed alternate hypotheses, particularly new information or analyses that had been presented to the Workshop.

Participants continued discussions on the questions posed in Session 2 regarding the existence of separate or shared stocks in the Peruvian and Chilean fishing areas, and the evidence supporting a hypothesis of the existence of separate Peruvian and Chilean stocks, or the alternate hypotheses that jack mackerel caught by Peru and Chile constitute a single shared stock. The evidence for alternate hypotheses regarding jack mackerel stocks off the coasts of Peru and Chile is summarised in Table 1.

<u>Comments on stock identification studies for Table 1 (To be considered also in Table 2)</u>:

- It is pertinent to remember here that in any stock identification research some techniques show differences but others not. When differences are detected with any technique, the reasons underlying the differences should be explained. Thus, only heterogeneity and not homogeneity can be demonstrated (Waldman, 1999; Abaunza *et al.*, 2008). So, when it said that there is evidence supporting homogeneity, it actually means that it does not contradict that statement.
- The stability over time (in a scale that the researcher should evaluate) of the differences found between population groups is one of the fundamental criteria when identifying stocks. This is true for any stock identification technique but it could be even more pertinent in life history traits analysis. Numerous studies have demonstrated temporal variation in life history parameters in response to changing environmental conditions and/or exploitation patterns. Therefore, it does highlight the need to examine these parameters among stocks over consistent time frames (Begg, 2005). On the other hand, the absence of these analysis and the inherent difficulties in finding conclusive evidences in life history traits studies, entails a need to formulate a range of possible interpretations. This is the reason why in Table 1, some of the references are included as both support for and against the definition of two separate stocks in Chilean and Peruvian waters.
- Many of the works included in Table 1 are not dealing explicitly with the comparison between jack mackerel found in Chilean and Peruvian waters but with the analysis of population characteristics in one of the areas, which eventually could allow us to recognize a possible stock unit in that area.

Table 1. Summary of evidence for separate jack mackerel stocks in Peruvian and Chilean waters, or for a single stock shared across these two regions.

Separation between Peruvian and Chilean Jack Mackerel: Evidence.		
Technique	**Supporting**	**Against**
Parasites	Oliva (1999): A central-northern Perú population separated from a Chilean stock. (Problem: lack of samples from southern Perú).	
Genetics	Koval (1996): Analysis with allozymes. (Problem: Grey literature, low number of loci included in the analysis. Peer-reviewed paper is required).	
Life history traits (distribution, reproduction, growth…)	Evseenko (1987); Serra (1991); Nesterov *et al.* (2007): • Two main spawning grounds (Peru and above all off central Chile), distribution, abundance, size composition. • Santander and Flores (1983); Gorbunova *et al.* (1985), Dioses (pers. comm.): • Presence of spawning activity in Peruvian waters every year. Braun and Valenzuela (Paper #1): • Low eggs and larval density in the northern Chilean waters, increasing towards southern Iquique (20º S). Nuñez *et al.* (Paper #2); Ruiz *et al.* (Paper #13); Government of Chile (WD. #24): • Main spawning ground in Chilean waters between 35º-40º S. Castillo (Paper #9); Córdoba *et al.* (Paper #11); Gutiérrez *et al.* (Paper #16) : • Fisheries based on permanent and large concentration and biomass off Chile and Perú. Espinoza *et al.* (Paper #4); Ñiquen and Peña (Paper #5); Ojeda *et al.*, Paper #8); Bernal *et al.* (Paper #12): • Distribution patterns are different in Perúvian and Chilean waters: in Perú larger fish towards the North and in Chile towards the South. • Complete size/age structure in both Perú and Chilean waters. Castillo (WD. #9); Gutiérrez *et al.* (Paper #16): • Acoustic biomass concentrated northern to 17º S and southern to 20º S. Gutiérrez *et al.* (Paper #16), and Dioses (pers. comm) : • Oceanographic characteristics: differences	Braun and Valenzuela (Paper #1): • Important spatial and interannual changes in egg distribution in northern Chile. Some years with a significant abundance. Castillo (WD. #9): • Continuous jack mackerel distribution through the Northern coast of Chile before an el Niño event (1983). Arcos *et al.* (2001): • Influence of El Niño events in distribution patterns. Northern Chile as an important nursery area. Espinoza *et al.* (Paper #4); Ñiquen and Peña (Paper #5); Ojeda *et al.*, #8); Bernal *et al.* (Paper #12): • Similarity in catch at length compositions from North of Chile and South of Perú. • Similarity in cohort dynamics (recruitments) observed in the catch at length compositions since 1998 from southern Perú to southern Chile. • Presence of juveniles in northern Chile and southern Perú * * (note that this could be evidence for two independent recruitment areas, or for one recruitment area)

	in water masses salinity between Perú and Central-South of Chile. • Characteristics of diet composition; Existence of feeding grounds in Perúvian coastal areas.	

The evidence summarised in Table 1 was used to propose the following alternative working hypotheses regarding Perúvian and Chilean stocks:

Hypothesis 1: **Jack mackerel caught off the coasts of Perú and Chile each constitute separate stocks which straddle the high seas.**

This is the current hypothesis expressed in the Jack Mackerel Species Profile and used in past stock assessments. There is a fairly substantial amount of historic and current evidence supporting this hypothesis (see Table 1).

However, there are some indications of shifts in distribution, and perhaps of possible mixing, in the southern Perú / northern Chile area related to oceanographic changes, and additional work is required to determine the most likely boundary between separate Perúvian and Chilean stocks.

For the purposes of jack mackerel assessments to be conducted in the immediate future, separation at the Perúvian / Chilean border would be a reasonable and convenient assumption to use under this stock hypothesis, until further information becomes available to improve the definition of stock boundaries.

Hypothesis 2: **Jack mackerel caught off the coasts of Perú and Chile constitute a single shared stock which straddles the high seas.**

Some new information on similarities in biological and population structure trends observed off southern Perú and off Chile were presented at this workshop in support of this alternate hypothesis (see Table 1).

Additional work is required to further investigate a wider range of data which might support or reject this hypothesis, as proposed under the multi-disciplinary *Stock Structure Research Programme*.

With regard to hypotheses regarding Perúvian / Chilean jack mackerel stock structure, the Workshop noted a number of other alternatives or possibilities which should specifically be investigated under the proposed Jack Mackerel Stock Structure Research Programme:

- Some degree of inter-dependence or relationship between separate Perúvian and Chilean stocks resulting from regular distribution shifts and mixing in the southern Perú / northern Chile area.

Participants then discussed the questions posed in Session 2 regarding the existence of a single stock, or of multiple stocks, in the area extending westwards from Chile out to about 120°W, and the evidence supporting a hypothesis of a single Chilean stock extending across this region, or a possible alternate hypothesis of separate straddling and purely high seas stocks across this region. The evidence for possible alternate hypotheses regarding jack mackerel stocks extending westwards off Chile is summarised in Table 2.

Table 2. Summary of evidence for a single jack mackerel stock off Chile, extending from the coast out to 120°W, or for separate straddling and high seas stocks across this range.

Single Chilean Southeast Pacific Ocean stock		
Technique	**Supporting**	**Against**
Genetics	Poulin *et al.* (2004); Cárdenas *et al.* (2005): • Mitochondrial DNA analysis. Samples from Chile and New Zealand. No differences were found. • Problem: The works were directed to distinguish *Trachurus* species and not populational differences. FIP-IT/96-15, (1996): • RFLP on nuclear DNA. No differences. Samples from Northern and Southern Chile, New Zealand and Tasmania. • Problem: grey literature. Peer-reviewed paper is required. Zhang *et al.* (Paper # 3). • Mitochondrial DNA analysis. No differences were found between samples collected at 71ºW and 94ºW. • Problem: small sampling size, peer reviewed paper is required).	
Life history traits (distribution, reproduction, growth…)	Inpesca (2008) (Paper #24): • The spatial distribution of central-south purse seine fleet shows the continuous distribution and the seasonal patterns of jack mackerel off central Chile, from the coast to areas beyond the Chilean EEZ. Zhang *et al.* (Paper #15); Corten (Paper #18): • Presence of continuous jack mackerel catches by Chinese and EU vessels (from 78º W to 110º W) and the seasonal movements (EU fleet). Evseenko (1987); Cubillos *et al.* (2008). Nuñez *et al.* (Paper #2): • The spawning of jack mackerel in the main reproductive region of this population starts inside the Chilean EEZ and could be extended beyond the 92º W up to 110ºW. Penney and Taylor (Paper #19): • Coincident trends in catches between Chilean and New Zealand areas. Cordoba *et al.* (Paper #11): • Biomass distribution by acoustics	Soldat *et al.* (Paper #7): • Three population groups in the central Pacific Ocean: 105ºW-125ºW; 125ºW-155ºW; 155ºW-175ºW. Based on the discontinuities observed in the jack mackerel distribution. The analysis was made by plotting the catch rates by quarter from Russian research vessels operating westward to 100º W from 1982 to 1991. In the three proposed jack mackerel groups there is spawning activity and a complete range of ages can be obtained (from juveniles to adults). The argument is supported by the existence of permanent eddies in the area (Chernyshkov *et al.*, Paper #6). • Problem with Paper #7: Data were available from eighties and early nineties but there is no current information.

The evidence summarised in Table 2 was used to propose the following alternative working hypotheses:

Hypothesis 3: **Jack mackerel caught off the Chilean area constitute a single straddling stock extending from the coast out to about 120°W.**

This is one of the current hypotheses expressed in the Jack Mackerel Species Profile, and is the hypotheses currently used in Chilean stock assessments. There is a fairly substantial amount of evidence supporting this hypothesis (see Table 2).

However, there is little information upon which to base a reliable definition of the westward boundary of such a stock, and additional work is required to determine the most likely westward boundary of a straddling Chilean stock.

For the purposes of jack mackerel assessments to be conducted in the immediate future, the westward boundary of this stock could be assumed to be about 120°W, to cover all areas currently fished in the southeast Pacific Ocean, until further information becomes available to improve the definition of this boundary.

Hypothesis 4: **Jack mackerel caught off the Chilean area constitute separate straddling and high seas stocks.**

Little information is available upon which to base a reliable definition of the boundary between such stocks. Additional work is required to determine to most likely position of such a boundary.

Future research conducted under the proposed Jack Mackerel Stock Structure Research Programme needs to include specific work to focus on:

- Obtaining the data and information required to ascertain whether separate oceanic stocks exist on the high seas across the so-called 'jack mackerel belt', and where the boundaries between any such stocks would lie.
- Conducting surveys out as far as possible to provide more reliable information on boundaries between possible straddling and high seas jack mackerel stocks.

Session 3: Jack Mackerel Stock Assessment Data & Surveys

The following presentations were made to the session on Jack Mackerel Stock Assessment Data & Surveys. Abstracts of the presented papers are provided in Annex B.

Session 3 Papers

#9. **Jack Mackerel (*Trachurus murphyi*) spatial distribution and seasonal acoustic biomass estimated in north of Chile. 1981 - 1990**. Jorge Castillo P.

#11. **Jack Mackerel (*Trachurus murphyi*, Nichols, 1920) acoustic survey in the central coast of Chile** José Córdova, Roberto Bahamonde and Victor Catasti.

#16. **Distribution changes and interactions of Jack Mackerel off Perú as observed using acoustics (1983-2008)**. Mariano Gutiérrez , Arnaud Bertrand, Michael Ballón, Pepe Espinoza, Ana Alegre and Francois Gerlotto.

#13. **Reproductive Parameters and Spawning Biomass of Jack Mackerel (*Trachurus murphyi*), in 1999-2006, determined by The Daily Egg Production Method**. Patricia Ruiz, Aquiles Sepúlveda, Luis Cubillos, Ciro Oyarzun, and Javier Chong.

#15. **Report of data collection on Jack mackerel in South-East Pacific**. Min Zhang, Xiaorong Zou, and Yingqi Zhou.

#12. **Catch size compositions for jack mackerel (*Trachurus murphyi*) off Chile (1975-2006)** Claudio Bernal, Antonio Aranis, Carlos Martínez, and Cristian Canales.

#18. **The fishery for jack mackerel in the Eastern Central Pacific by EU trawlers in 2007.** Ad Corten.

#10. **Catch per Unit Effort of Chilean jack mackerel (*Trachurus murphyi*) of the purse seine fishery off south-central Chile (32º10' – 40º10' S) 1981-2005.** Cristian Canales, L. Caballero and A. Aranís.

#17. **Program Bio-oceanographic Research of resources Jack mackerel and Pacific mackerel in Perú**. Miguel Ñiquen Carranza.

Session 3 Information Papers

The following additional information papers were submitted:

#14. **Short review of natural mortality and size at first maturity on jack mackerel (*Trachurus murphyi*) in the southeastern Pacific.** Luis Cubillos, Claudio Gatica, and Rodolfo Serra.

#8. **Methodology employed for age determination in Chilean Jack Mackerel (*Trachurus murphyi*).** V. Ojeda, V. Bocic and L. Muñoz.

The papers presented in this session provided overviews and updated information on the following main aspects relevant to jack mackerel stock structure and stock assessment in the south Pacific Ocean (see abstracts in Annex B):

- Results of acoustic biomass, egg and larval surveys showing distributions of jack mackerel life history stages over time and geographic area, and how these have changed, particularly in relation to localised or large-scale oceanographic features and anomalies.
- Descriptions of past and present jack mackerel fisheries within EEZs and on the high seas, and analyses of distributions of fishing effort and catch, and how these vary seasonally or have changed historically over time and area.
- Results of jack mackerel biological studies related to size composition, growth, maturity, reproduction, feeding and trophic interactions with other species (predators or prey).
- Summaries of jack mackerel monitoring, data collection and research conducted to date, overviews of planned future research, and how planned future research could contribute to the proposed multi-disciplinary *Jack Mackerel Stock Structure Research Programme*.

Important issues and observations identified during discussion of these papers were:

- There are substantial inter-annual changes in the distribution and abundance of jack mackerel that occur for reasons that are not always well understood. Such changes are evident in shifts in the distribution of the main concentrations of jack mackerel from northern to southern Perú (which was associated with, but commenced prior to, an el Niño event) and off southern and central Chile from waters within to waters beyond the Chilean EEZ.
- Interpretations of patterns of distribution of jack mackerel could be assisted by examination of patterns in water quality parameters, particularly temperature, salinity and dissolved oxygen. There are well established preferred temperature and salinity ranges for jack mackerel that vary among

different life history stages. There is also evidence that the depth range inhabited by jack mackerel may be restricted by the vertical distribution of regions of low dissolved oxygen.

- There are suggestions that the distribution patterns of jack mackerel may also be influenced by the distribution of ecologically related species, including major prey items, and potential predators, particularly the jumbo flying squid. The distribution of jack mackerel in some areas is positively associated with the distribution of preferred prey such as euphausids and negatively associated with the distribution of jumbo flying squid.
- Any stock boundaries identified may not be static and marked by an absence of jack mackerel but may be transition zones whose extent shows some variability over time. The lack of fixed oceanic boundaries and the dynamic nature of the distribution of jack mackerel imply that stock boundaries are likely to be similarly variable.
- There is much evidence of regular onshore and offshore migrations by jack mackerel but there is much less direct evidence of north-south migrations. Annual offshore and onshore movements are associated with the reproductive cycle of jack mackerel and are reflected in similar movements of fishing fleets. Movements along the shore are also thought to occur but are mainly inferred from spatial and temporal patterns in size distributions.
- There are significant issues in using standardised CPUE from commercial jack mackerel fisheries as an index of abundance.
- Wherever possible, efforts should be made to cooperate with commercial fishing vessels to use acoustic data collected during fishing operations.

Session 4: Stock Assessment Approaches

The following presentations were made to the session on jack mackerel Stock Assessment Approaches. Abstracts of the presented papers are provided in Annex B.

Keynote Presentation

Assessment approaches when spatial distribution adds uncertainty to stock structure. James Ianelli, NOAA, USA.

Session 4 Papers

#20. **Chilean jack mackerel stock assessment model.** Cristian Canales and Rodolfo Serra.

#21. **Maximum sustainable yield (MYS) and optimum effort of fishing of jack and pacific mackerel (*Trachurus murphyi, Scomber japonicus*) in Perú (1997-2006).** Christian Garcia.

#22. **Preliminary estimation of current state of Chilean Jack Mackerel (*Trachurus murphyi*) stock in the high seas of the South East Pacific**. Dmitry Vasilyev, Alexander Glubokov and Doonam Kim.

An additional presentation was given illustrating the use of acoustic surveys and echogram analyses to estimate biomass of various biological components in the water column:

Acoustic study of spatio-temporal distribution of zooplankton biomass off Perú. Presented by Mariano Gutiérrez (Original author Michael Ballon).

The papers presented in this session provided overviews and updated information on the following main aspects relevant to jack mackerel stock structure and stock assessment in the south Pacific Ocean (see abstracts in Annex B):

- International multilateral experiences with conducting surveys and assessments of the spatially complex Alaska pollock stocks in the Bering Sea and Aleutian Islands, specifically in relation to assessment approaches to deal with uncertainty or alternative hypotheses regarding stock structure.
- Alternate stock assessment methodology and approaches used in recent assessment approaches for jack mackerel off Perú and Chile, and on the high seas in the southeast Pacific Ocean, and approaches taken to dealing with spatial complexity in stock distribution patterns and with uncertainty in the data.

Discussions of Sessions 3 and 4 — Jack Mackerel Surveys and Stock Assessments

The objective of the workshop addressed in these sessions states:

> *To review available data and information on jack mackerel stock assessments and to agree on data inputs, biological parameters and assumptions to be used in joint assessments of the jack mackerel stock or stocks in light of the working hypotheses developed at the Workshop.*

Important issues and observations identified during discussion of the papers on jack mackerel assessments and surveys were:

- A substantial amount of information important for jack mackerel assessment and stock structure analysis has been gathered during separate studies in different regions of the south Pacific Ocean. However, there has been little cooperative or coordinated work across entire regions. There is an urgent need to coordinate any such future work to ensure that information is gathered in a consistent and coordinated way across the full extent of known jack mackerel fisheries so that these data can be used together to evaluate alternative stock structure hypotheses or assessment approaches.
- From the papers that were presented on acoustic survey methods, there is a need to present measures of uncertainty. In particular, the extent of sampling with auxiliary vessels or the survey ship itself is unclear. This is important not only for species composition determination, but for length frequency of jack mackerel. This is critical for converting acoustic backscatter to biomass based on target strengths obtained from length frequency distributions.
- Caution must be applied when interpreting apparently similar trends (such as in length-frequency composition, cohort progression, catch and CPUE) in different areas. There are many reasons for possible synchrony between such trends in different areas, and they do not necessarily indicate that fish exhibiting similar trends come from the same stock. There are many potential reasons for synchrony, including similar growth, mortality and depletion rates in separate relic stocks which derived from an initial rapid expansion, or large-scale oceanographic changes which result in similar responses (such as strong year classes) in adjacent but separate stocks.
- Alternative indices should be investigated and a common protocol followed. For example, acoustic backscatter from vessels of opportunity (commercial vessels) should be pursued for potential data collection characteristics (e.g., ICES paper 287). It was noted that the use of purse seine CPUE may present difficulties of interpretation due to changes in capacity, properly accounting for search time as an effort measure, and the general phenomena known as hyper-stability that is common with fisheries on pelagic shoaling species.
- Large-scale oceanic gyres and meso-scale eddies occur on different time scales, and with different persistence, across the southern Pacific Ocean. These features all appear to influence jack mackerel distribution and movement patterns, and data on such features should be integrated into efforts to develop reliable stock structure hypotheses wherever possible.
- It is notable that many of the successful multi-stock assessment and management approaches adopted internationally rely on high levels of scientific observer coverage to gather data required for such assessments.

Data Inputs

The following table provides an inventory of data that may be available for conducting stock assessments. Regionally, the columns are intended to reflect sources of data rather than implied stock structure assumptions. Note, source country of data is noted in column headings or as superscripts.

Region	Perú	N-C Chile	C-S Chile	W of EEZ Chilean	W of EEZ	W of 120 Russ. Fed.	NZ (EEZ only)
Fishery							
Catch	1950-2007, monthly, 1995-2007, daily	1975-2007	1975-2007	1981-2007	1979-91[R] 2000-07[C] 2003-07[K]	1980-83, 1989-91	1985 – 2007
Effort	1980 - 2007, by fleet, trip	1975-2007	1981-2007	1992-2007	1979-91[R] 2003-07[K]	1980-83, 1989-91	1985 – 2007
Standardization	Vessel, area, month	-	Yes	Yes/No	1979-91[R]	1980-83, 1989-91	Vessel, area, month
Fishery Age	-	1975-2007	1975-2007	1992-2007	1979-91[R] 2006[C]	1980-83, 1989-91	1990 - 2007, otolith sections
Fishery length frequency	1990 - 2007	1975-2007	1975-2007	1981-2007	1979-91[R]	1980-83, 1989-91	1986 - 2007
Surveys							
Acoustic	1983 - 2007	1981-1995, 2006-2007	1997-2007	2003-2007	1986-88, 2002-03[R] 2003[K]	1980-83, 1989-91	No
Spawning		No	1999-2006	1999-2006			No
Eggs and larvae		1982-2007	1999-2006	1999-2006	2003[K]		
CPUE	1996 - 2007, Std by haul, trip-length	No	No	No	1986-88, 2002-03[R] 2000-07[C] 2003[K]	1980-83, 1989-91	1991 - 2007, standardised MWT
Survey age		No	1997-2007	2003-2007	1986-88, 2002-03[R]	1980-83, 1989-91	No
Survey size	1983-2007	No	1997-2007	2003-2007	1986-88, 2002-03[R]	1980-83, 1989-91	No
Biological data							
Growth	Oto: 1980, 2005; Scales: 1983	Yes	Yes	Yes	1979-91, 2002-03[R] 2000-07[C] 2003[K]	1980-83, 1989-91	Yes, from otoliths
Maturity (age/size)	Yes, surveys and fisheries	Yes	Age and size	Yes	Yes[R] 20006[C]	1980-83, 1989-91	Yes, obs. and landings
Natural mortality	Yes		Yes				Possibly
Environmental indices							
	SST, Salinity, 1960-2007	SST, salinity, 1964-2007	SST, salinity, 1964-2007		Temperature and salinity profiles 1979-1991, 2002-03[R]. SST, salinity 2003[K]	Temperature and salinity profiles 1980-1983, 1989-1991[R]	Possibly SST

[C] =China, [R] =Russian Federation, [K] = Republic of Korea

Models

The stock assessment approach should be able to use all available data and require a minimum number of assumptions. The procedure should be robust to data and provide a rigorous means of evaluating uncertainty and sensitivity to assumptions. The outputs should include stock trends—historical and projected near term along with diagnostics and measures of uncertainty. Recruitment patterns should be evaluated and where possible, examine relationships with environmental data. Retrospective analyses should also be included as diagnostics.

Spatially disaggregated models may assist in providing regional trends and exploitation patterns. Alternatively, spatial considerations should be properly accounted for when compiling data for a model where areas are combined. Prior to any model application, precise descriptions of data treatment are required. For example, how age-length keys are applied to length frequencies by strata should be detailed. Also, for acoustic surveys, it is important to note the extent to which schools identified by their acoustic backscatter have been sampled for species composition and length (and age) compositions.

The choice of an assessment method should have transparency as a primary goal. Standardization of software and algorithmic approaches is less important than comprehension. To the extent possible, data should remain in their natural form as observations with minimal manipulations needed for model fitting. This will facilitate standard forms of data presentation among different countries and regions. Models that require relatively demanding datasets (e.g., full matrices of catches at age in each year) may be more difficult and stall progress on assessment modelling. The modelling approach should be pragmatic and consider present developments and past analytical efforts that have been made. In this sense, Chilean scientists have already developed a fairly flexible set of models that could easily be developed further for application while retaining transparency. However, world practice shows that the application of a single *a priori* chosen group of models for stock assessment can be misleading. A broader range of stock assessment models based on different approaches and statistical principles is generally required for comprehensive analysis and data exploration.

As more data are introduced and models become more complex, transparency will eventually suffer, particularly as stakeholders become increasingly concerned about how assessment results interact with future recommendations for changes in TAC. To alleviate future issues, particularly as new hypotheses on stock structure are developed further, the workshop recommends that application of management strategy evaluations be considered. The developing modelling efforts can form the basis for an operating model needed to evaluate simpler management strategies.

A future management strategy may include a specific estimation model based on anticipated future data from an operating model. For example, it may be that the TISVPA method (Paper #22) may prove to be a robust approach towards evaluating stock status relative to objectives. Various models, ranging from a simple survey-based index or CPUE approach (e.g., surplus production model), to a more complex age structured approach such as the models presented in WDs #20 and #22, may prove useful for providing recommendations.

The following table provides a matrix of the value of different data demands (relevance) by source locations relative to possible stock assessment model configurations. This is intended to guide how much information is required for selected models.

Relevance legend: H=high, M=Medium, L=Low, “-”=Not applicable.

Nº	Stock Assessment	Perú	N-C Chile	C-S Chile	W of EEZ	W of 120	NZ
1	Combined area model	M	M	H	H	M	L
2	Spatially disaggregated model	H	H	H	H	M	L
3	Perú	H	-	-	-	-	-
4	Perú/N-C Chile	H	H	-	-	-	-
5	N-C Chile	-	H	-	-	-	-
6	S-C Chilean	-	-	H	H	-	-
7	Chilean	-	H	H	H	-	-
8	High seas stock(s)	-	-	M	H	H	H
9	NZ Stock	-	-	L	M	M	H

Relative to the hypotheses presented in Session 2, stock assessment could commence based on the combined area model (model 1). This would correspond to Hypothesis 2. Models number 3 and 7 corresponds to the data requirements for Hypothesis 1. Model 7 corresponds to Hypothesis 3 whereas

Hypothesis 4 could be addressed (at the time that data become available) potentially using all model configurations, depending on the outcome of further stock structure information.

Discussion Summary of Survey and Stock Assessment Session

The workshop noted that a plan should be developed that specifies clear steps towards developing a stock assessment modelling approach that can be agreed upon. This should include formal steps for data compilation and dissemination for application to stock assessment modelling. Development of a plan by the Jack Mackerel Subgroup for collaborative research in the development of models including the ability to create a system for evaluating alternative management strategies was noted as being important. Such planning and model development will provide the opportunity to easily incorporate new information (e.g., on stock structure hypotheses) as it becomes available.

The recommended model approach should be flexible enough to evaluate different hypotheses and data types (e.g., length frequency information) while remaining clear and understandable. The Jack Mackerel Subgroup is requested to pursue the organization of the appropriate protocols for vetting data, agreeing on applications, and overseeing stock assessment model developments.

Overview of Data Submissions to the SPRFMO Interim Secretariat

A summary of the status of data submission to the interim SPRFMO Secretariat at the time of the Workshop was presented by Susie Iball, Data Manager of the interim Secretariat, and is attached as Annex C. Participants noted that most submissions to date consisted of data aggregated by 5°x5° square and year, and that data aggregated at this level are inadequate for analyses related to developing stock structure hypotheses, and certainly not adequate for conducting stock assessments.

The workshop noted that the data standards adopted by SPRFMO require participants to collect data in the detail and at the level of resolution specified in the Annexes 1–4 of the Data Standards, for trawl fishing, purse-seine fishing, bottom longline fishing and vessel data. However, participants were only required to submit data to the Secretariat "*in sufficient detail to facilitate effective stock assessment*", and that no definition had yet been provided by the SWG or Jack Mackerel Sub-Group of what resolution of data would be required for stock assessment.

Participants emphasised the critical importance of having access to detailed, fine-scale catch, effort and biological data, both for the purpose of conducting analyses necessary to investigate alternate hypotheses regarding jack mackerel stock structure, and for conducting stock assessments.

The participants in the Chilean Jack Mackerel Workshop therefore recommended that:

> ***Recommendation 1*: Data for stock assessments of jack mackerel are required at the finest level of detail and resolution stipulated in the Annexes to the SPRFMO Data Standards for the various fishing methods[2]. Participants to the negotiations should be required to submit data on their jack mackerel fisheries at this level of detail and resolution, as required by the Interim Measures and subject to the SPRFMO confidentiality agreement.**

The Workshop further noted that the interim Secretariat was required to keep all fine-scale submitted data confidential, and was only permitted to summarise and provide "*public domain*" data, aggregated by 5°x 5° square and year. Non-public domain data can only be provided "*In response to a written request from the collective Parties to the Negotiation, for the purposes documented by those Parties*", or "*In the absence of a written request from the collective Parties to the Negotiation - only with the authorization of the Participant(s) that originally provided that data.*" Data aggregated at the level of 5°x5° square, and particularly only by year, were of little use for scientific purposes beyond identifying broad trends.

[2] The latest versions of these Data Standards are available on the SPRFMO website: www.southpacificrfmo.org

The participants in the Chilean Jack Mackerel Workshop therefore recommended that:

> ***Recommendation 2*: Consideration should be given by Data & Information Working Group and the participants in the negotiations to establish a SPRFMO to amend the definition of public domain data in the SPRFMO Data Standards to provide for release of data aggregated at the level of 1°x1° square, month and gear.**

As soon as fine-scale data are made available, the Secretariat was requested to prepare summaries of actual data, and not just meta-data, summarising catch, effort and CPUE by 1°x 1° square, month and gear, as well as catch-at-age and catch-at-length data, for use at future SWG meetings.

Session 5. Jack Mackerel Stock Structure Research Programme

The following presentation was made on the draft Jack Mackerel Stock Structure Research Programme. The finalised Jack Mackerel Stock Structure Research Programme is attached in Annex D.

Session 5 Paper

#23. **Population structure of Chilean jack mackerel, *Trachurus murphyi*, in the South Pacific Ocean: Full proposal for an international joint research programme.** Rodolfo Serra and Alexander Glubokov.

Discussion of the Jack Mackerel Stock Structure Research Programme

The Workshop noted that a number of important foci of research to be conducted under this research programme had already been identified during previous discussions:

- The most important questions relate to determination of the most likely position of boundaries between jack mackerel stocks, short-term and long-term shifts in positions of these boundaries and mixing rates between stocks, particularly in the Perúvian / Chilean border area, and between straddling and high-seas stocks.
- There is an immediate need to move towards greater joint planning and coordination of existing research activities which occur in areas of different proposed jack mackerel stocks, and for the extension of these research activities to cover areas of possible boundaries and mixing between stocks.
- It appears to be particularly important for jack mackerel stock structure studies to integrate information on key environmental data, particularly sea surface temperature, current directions and rates and large-scale stable oceanic features, into studies of distribution of life history stages.
- Data must be gathered using standardised procedures, protocols analysis methods and database structures, and it will be essential to move towards a shared database under the Jack Mackerel Stock Structure Research Program.
- Some of the most serious challenges to the proposed research activities relate to obtaining adequate information to understand stock structures, beyond the range of current fisheries, and the costs of such research.

During discussion, participants identified a number of other important characteristics of successful stock research projects, such as the HOMSIR Project:

- A Jack Mackerel Research Programme Steering Committee, including representatives from major participants in the jack mackerel fisheries, will need to be established to coordinate the research programme, and to plan details of implementation.

- Experience with the HOMSIR project has shown that it would be useful to have specific coordinators for the analyses of the various stock discrimination data types to be collected, such as morphometry, genetics, otolith micro-chemistry, parasites, tagging etc. Each coordinator would be responsible for finalising protocols for each method, and coordinating the sample collection and distribution, and the analysis for that data type. An overall programme coordinator would also be advisable.
- Experience with the HOMSIR project has shown that it will be particularly important to obtain replicate samples and data after the first survey/s, with comparative sampling in at least two separate years, and perhaps a follow-up programme 10 to 15 years later, to detect changes which are likely to occur in stock distribution patterns. A quick initial analysis of the initial sampling phase is also useful to detect problems with sampling design, and to revise sampling design or sampling protocols for the replicate comparative sampling.
- Substantial effort must be focussed in the initial stages on establishing standardised sampling protocols, and planning the logistics of sample gathering, storage and transport to analysis laboratories, particularly maintaining a secure frozen chain during sample transport. This should be the initial focus of the coordinators. It would be useful to conduct a specific *Jack Mackerel Sampling Protocols and Methods Workshop* to prepare these protocols.
- In addition to standardised sampling protocols between vessels, countries and laboratories, it is important to have protocols for sampling within vessels. All samples should not come from a single tow, but need to be representatively spread across the agreed sampling strata in time and space, especially for the analysis of life history traits.
- HOMSIR experience has also shown that it is important to minimise the number of laboratories conducting each specific type of analysis, to minimise or prevent differences resulting for subtle differences between laboratories. Ideally, only one or two laboratories should conduct each type of analysis. Of these, one of the most important would be the initial fish sampling laboratory, which will be responsible for taking measurements and photographs for morphometry, collecting otoliths, extracting parasites and taking genetic samples. This should ideally all be done at one laboratory to simplify and minimise transport of frozen samples. Samples can then be correctly prepared and catalogued, and each type of sample (photographs, otoliths, parasites, etc) forwarded to the laboratory responsible for analysis of that sample type.
- The proposed research programme should not be considered to imply the exclusion of other jack mackerel research options that might be conducted by individual countries. For example, tagging studies might also be useful to directly evaluate movement patterns, and may provide direct evidence of mixing across proposed stock boundaries, or provide information on movement between areas of the high-seas for which there are no distinct chemical markers detectable in otoliths.
- In order to modify the illustrative budget and make it more realistic, participants are asked to consider which research activities or analyses they will be able to contribute to, to nominate research participants and to commit to involvement on various aspects of the programme at the earliest opportunity.
- The major obstacle to initiating a number of aspects of the proposed research relates to obtaining funding, particularly for shared activities, such as joint research cruises and workshops. It is expected that countries will finance the participation of their own scientists in sampling, analysis and workshop activities. It is also expected that much of the financial support is likely to be provided in kind, by various participants actually conducting sampling or analysis. However, there will still be substantial costs associated with conducting standardised analysis of samples at one or two identified specialist laboratories, or conducting joint research cruises. These will require actual financial contributions by many countries to fund a particular centralised activity. In the absence of an established SPRFMO, it is unclear what mechanisms are currently available to receive, control and distribute funding for shared multi-lateral activities.

The draft Jack Mackerel Stock Structure Research Programme proposal was modified to reflect key aspects of these discussions, and is attached in Annex D.

The workshop recommended that the SPRFMO Jack Mackerel Sub-Group will need to address the following aspects of further planning and implementation of this programme at the coming meeting in Canberra in October 2008:

- Establishment of the Jack Mackerel Research Programme Steering Committee.
- Encouragement of indications of who will be committing themselves to participating in various aspects of the programme.
- Revision of the budget to reflect information on participation, and identification of who might be able to contribute to funding of research, either in kind (by actually conducting sampling or analyses), or by providing funding for joint research cruises, or laboratory analysis of samples.
- Consider the feasibility and planning of a possible Protocols and Methods Workshop, and identify potential laboratories that might be able to conduct the various sample analyses.
- Prepare a calendar of proposed activities to be undertaken under the Research Program.

Recommendations on these aspects will need to be submitted through the SPRFMO Science Working Group for the consideration and approval of the participants to the SPRFMO negotiations, particular to obtain government commitment and support for required funding and active participation in the proposed research.

Adoption of Report

Prior to the closure of the workshop the Chilean delegation read a declaration regarding their views on the fourth hypothesis on population structure.

The report was adopted after incorporation of all agreed amendments.

Closure of the Workshop

In his capacity as Chair of the SPRFMO Jack Mackerel Sub-Group, Mr Alexander Morison noted the substantial effort that gone into organizing and running the Workshop, and thanked Chile, as host country, and the FAO as facilitator, for all arrangements. The work presented at the workshop constituted an important advance in jack mackerel research, which would help clarify future thinking regarding jack mackerel stock structure and assessment. Progress made at the workshop boded well for future work, and Mr Morison noted that the measure of future success would be how well participants progressed with continued sharing of information.

The Chair, Dr Jorge Csirke-Barcelli, thanked the rapporteurs, external experts and all participants for their valuable contributions to the workshop, and noted that the results gave confidence in future work in the region. The Chair also thanked the interpreter for her hard work in interpreting alone for the entire workshop.

On behalf of all participants, Mr Morison thanked the Chair for his skilful chairmanship and diplomatic guidance through the week. The Chair closed the meeting at 15h00.

Annex A

SPRFMO Chilean Jack Mackerel Workshop: List of Participants

EXTERNAL CHAIR AND EXPERTS

Name	:	Jorge Csirke
Organization	:	FAO
Role	:	Chair of the Workshop
Address	:	Viale delle Terme di Caracalla 00100, Of. F 505 Rome Italy
Telephone	:	39-0657056506
E-mail	:	jorge.csirke@fao.org

Name	:	Pablo Abaunza
Organization	:	Instituto Español de Oceanografía
Role	:	External Expert
Address	:	Apartado 240, 39080 Santander, España
Telephone	:	34-942291060
E-mail	:	pablo.abaunza@st.ieo.es

Name	:	James Ianelli
Organization	:	Alaska Fisheries Science Center
Role	:	External Expert
Address	:	Bldg 4, 7600 Sand Pt Way NE Seattle WA 98115
Telephone	:	206 5266510
E-mail	:	Jim.Ianelli@noaa.gov

INTERNATIONAL ORGANIZATIONS

CPPS

Name	:	Gonzalo Pereira
Organization	:	Permanent Comission for the South Pacific
Role	:	General Secretary
Address	:	Guayaquil, Ecuador
Telephone	:	593-4 222 1202, 222 1203
E-mail	:	gpereira@cpps-int.org

FAO

Name	:	Jorge González de la Rocha
Organization	:	FAO RLC
Role	:	Oficial Principal de Pesca y Acuicultura
Address	:	Av. Dag Hammarskjold 3241, Vitacura Santiago, Chile
Telephone	:	56-2 3372239
E-mail	:	jorge.delarocha@fao.org

Name	:	Jose Graziano da Silva
Organization	:	FAO
Role	:	Assistant Director and Regional Representative
Address	:	Avenida Dag Hammarskjold 3241, Casilla 10095, Santiago

PACIFIC ISLAND FORUM FISHERIES AGENCY

Name	:	Maruia Kamatie
Organization	:	Pacific Islands Forum Fisheries Agency
Role	:	Observer
Address	:	Honiara, Solomon Islans
Telephone	:	677- 21124 ext. 278
E-mail	:	maruia.kamatie@ffa.int

INTERIM SECRETARIAT

Name	:	Susie Iball
Organization	:	South Pacific Regional Fisheries Management Organization
Role	:	Data Manager, Interim Secretariat
Address	:	SPRFMO Interim Secretariat, L4, ASB Bank House, PO Box 3797, Wellington 6140 101-103 The Terrace, Wellington, New Zealand
Telephone	:	64 4 499 9894
E-mail	:	susie.iball@southpacificrfmo.org

SPRFMO PARTICIPANTS

AUSTRALIA

Name	:	Alexander Morison
Organization	:	Bureau of Rural Sciences, D.A.F.F.
Role	:	Chair, Jack Mackerel Sub Group, Delegate
Address	:	G PO Box 858, Canberra Act 2601
Telephone	:	61-2 62725534
E-mail	:	sandy.morison@brs.gov.au

CHILE

Name	:	Mario Acevedo
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168, Valparaiso
Telephone	:	56-32 2502700
E-mail		macevedo@subpesca.cl

Name		Antonio Aranis
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32-2151500
E-mail	:	aaranis@ifop.cl

Name	:	Maria Alicia Baltierra
Organization	:	SONAPESCA
Role	:	Delegate
Address	:	Barros Errazuriz 1954 of. 206
Telephone	:	56-2-2692533
E-mail	:	mab@vtr.net

Name	:	Maria Angela Barbieri
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168 Valparaiso

Telephone	:	56-32 2502700
E-mail	:	mabarbieri@subpesca.cl

Name	:	Esperia Bonilla
Organization	:	Subsecretaría de Pesca
Role	:	Organization Committee
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	ebonilla@subpesca.cl

Name	:	Claudio Bernal
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32-2151500
E-mail	:	cbernal@ifop.cl

Name	:	Leonardo Caballero
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32 2151500
E-mail	:	lcaballero@ifop.cl

Name	:	Cristian Canales
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32 2151500
E-mail	:	ccanales@ifop.cl

Name	:	José Raúl Cañon
Organization	:	ASIPNOR
Role	:	Delegate
Address	:	El Golf 150 Piso 15, Santiago, Chile
Telephone	:	56-2-4764000
E-mail	:	jcanon@corpesca.cl

Name	:	Valeria Carvajal
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168, Valparaiso
Telephone	:	56-32 2502700
E-mail	:	vco@subpesca.cl

Name	:	Jorge Castillo
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32 2151500
E-mail	:	jcastillo@ifop.cl

Name	:	Jorge Chocair
Organization	:	Subsecretaría de Pesca de Chile
Role	:	Subsecretario de Pesca

Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	jchocair@subpesca.cl

Name	:	Vilma Correa
Organization	:	Servicio Nacional de Pesca de Chile
Role	:	Delegate
Address	:	Victoria 2832, Valparaiso
Telephone	:	56-32-2819311
E-mail	:	vcorrea@sernapesca.cl

Name	:	Susana Delgado
Organization	:	Subsecretaría de Pesca
Role	:	Organization Committee
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	sdelgado@subpesca.cl

Name	:	David Flores
Organization	:	Subsecretaría de Pesca de Chile
Role	:	Undersecretary of Fisheries' advisor
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	dflores@subpesca.cl

Name	:	Silvia Hernandez
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	shernandez@subpesc.cl

Name	:	Cristian Laborda
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	claborda@subpesca.cl

Name	:	Carlos Martinez
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32 2151500
E-mail	:	cmartine@ifop.cl

Name	:	Luis Felipe Moncada
Organization	:	ASIPES
Role	:	Delegate
Address	:	O'higgins 940 Of. 804, Concepcion
Telephone	:	56-41-2248561
E-mail	:	asipes@asipes.cl

Name	:	Sergio Nuñez
Organization	:	Instituto de Investigación Pesquera

Role	:	Delegate
Address	:	Av. Cristobal Colón 2780 - Talcahuano
Telephone	:	56-41-2920410
E-mail	:	snunez@inpesca.cl

Name	:	Rodrigo Polanco
Organization	:	Subsecretaría de Pesca
Role	:	Delegate
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	rpolanco@subpesca.cl

Name	:	Jacqueline Salas
Organization	:	Subsecretaría de Pesca
Role	:	Organization Committee
Address	:	Bellavista 168 Valparaiso
Telephone	:	56-32 2502700
E-mail	:	jsquiroga@subpesca.cl

Name	:	Aquiles Selpulveda
Organization	:	Instituto de Investigación Pesquera
Role	:	Delegate
Address	:	Av. Cristobal Colon 2780 Talcahuano, Chile
Telephone	:	56-41-2920410
E-mail	:	asepulveda@inpesca.cl

Name	:	Rodolfo Serra
Organization	:	IFOP
Role	:	Delegate
Address	:	Blanco 839, Valparaiso
Telephone	:	56-32 2151500
E-mail	:	rserra@ifop.cl

CHINA

Name	:	Yingqi Zhou
Organization	:	Shanghai Ocean University
Role	:	Delegate
Address	:	334 Jungong Road, Shanghai, China
Telephone	:	86-21-65710392
E-mail	:	yqzhou@shou.edu.cn

CUBA

Name	:	María Victoria Fernandez
Organization	:	Ministerio Industria Pesquera
Role	:	Delegate
Address	:	5ta Ave. #256, Balovento, Playa Ciudad Habana, Cuba
Telephone	:	53-7 2725849
E-mail	:	victoriafc205@gmail.com

Name	:	Alina González
Organization	:	Ministerio Industria Pesquera
Role	:	Delegate
Address	:	5ta Ave. #256, Balovento, Playa

		Ciudad Habana, Cuba
Telephone	:	53-7 2725849
E-mail	:	alin170960@yahoo.es

ECUADOR

Name	:	Roberto Retamales
Organization	:	Ministerio de Agricultura, Ganadería, Acuicultura y Pesca de Ecuador
Role	:	Delegate
Address	:	Av. 4 Calle 12-13
Telephone	:	593-5-2627911 / 593-097891236
E-mail	:	roretamales@gmail.com

EUROPEAN UNION

Name	:	Ad Corten
Organization	:	European Union
Role	:	Delegate
Address	:	De Waterdief 52, 1911 Ft Uitgeest, Netherlands
Telephone	:	31-251313280
E-mail	:	adcorten@yahoo.co.uk

Name	:	Joachim Gröger
Organization	:	European Union
Role	:	Delegate
Address	:	Palmaille 9, 22767 Hamburg Germany
Telephone	:	0049 40 38905-266
E-mail	:	joachim.groeger@t-online.de

JAPAN

Name	:	Hiroki Miyamoto
Organization	:	Nippon Suisan Kaisha LTD
Role	:	Observer
Address	:	6-2 Otemachi 2-Chome Chiyoda – Ku Tokyo, Japan
Telephone	:	81-3-3244-7192
E-mail	:	miyamoto@nissui.co.jp Miyamotohiroki88@gmail.com

NEW ZEALAND

Name	:	Andrew Penney
Organization	:	Ministry of Fisheries
Role	:	Chair of the SPRFMO Science Working Group
Address	:	12th Floor ASB House, 10-103 The Terrace, PO Box 1020, Wellington, New Zealand
Telephone	:	64 4 819 4788
E-mail	:	andrew.penney@fish.govt.nz

PERÚ

Name	:	Ulises Munaylla
Organization	:	Instituto del Mar del Perú
Role	:	Delegate
Address	:	Esq. Gamarra y Gral. Valle s/n Chucuito, Callao
Telephone	:	511-4202000
E-mail	:	umunaylla@imarpe.gob.pe
Name	:	Miguel Ñiquen
Organization	:	Instituto del Mar del Perú
Role	:	Delegate
Address	:	Esq. Gamarra y Gral. Valle s/n Chuchito Callao, Perú
Telephone	:	511-4202000
E-mail	:	mniquen@imarpe.cl
Name	:	Teobaldo Dioses
Organization	:	Instituto del Mar del Perú
Role	:	Delegate
Address	:	Esq. Gamarra y Gral. Valle s/n Chucuito, Callao
Telephone	:	511-4202000
E-mail	:	tdioses@imarpe.gob.pe
Name	:	Richard Inurritegui
Organization	:	Sociedad Nacional de Pesquería
Role	:	Delegate
Address	:	Av. Javier Prado Oeste 2442 San Isidro, Lima 27 Perú
Telephone	:	511-2612970
E-mail	:	rinurritegui@terra.com.pe
Name	:	Mariano Gutierrez
Organization	:	Tecnológica de Alimentos S.A.
Role	:	Delegate
Address	:	Km. 14.1 Carretera a Ventanilla, Callao Perú
Telephone	:	511-6111400
E-mail	:	mgutierrez@tasa.com.pe
Name	:	Arturo Aranda
Organization	:	Corporación Pesquera Inca S.A.
Role	:	Delegate
Address	:	Calle Francisco Graña 155, Urbanización Sta. Catalina Lima 13 Perú
Telephone	:	511-2134000
E-mail	:	AAranda@copeinca.com.pe
Name	:	Federico Iriarte
Organization	:	Pesquera Diamante S.A.
Role	:	Delegate
Address	:	Calle Amador Merino Reyna 307, San Isidro Lima, Perú
Telephone	:	511-998145401 / 511-7100344
E-mail	:	firiarte@diamante.com.pe
Name	:	Angel López de Paz

Organization	:	Corporación Hayduk
Role	:	Delegate
Address	:	Av. Carnaval Moreyra 340, 3° piso, San Isidro, Lima Perú
Telephone	:	511-2113249 / 511-994173858
E-mail	:	alopez@hayduk.com.pe
Name	:	Emilio Méndez
Organization	:	Austral Group
Role	:	Delegate
Address	:	Av Argentina 3028, Callao, Perú
Telephone	:	511-4659580
E-mail	:	emendez@austral.com.pe

RUSSIAN FEDERATION

Name	:	Pavel Chernyshkov
Organization	:	AtlantNIRO
Role	:	Head of Oceanic Bioresources Department
Address	:	5 Dm. Donskoy str., Kaliningrad, Russia, 236000
Telephone	:	7(4012) 225-425
E-mail	:	ptchern@atlant.baltnet.ru
Name	:	Alexander Glubokov
Organization	:	VNIRO
Role	:	Head of delegation
Address	:	V. Kzasnoselskaya, 17 Moscow, Russia
Telephone	:	007-499-264-91-43
E-mail	:	glubokov@vniro.ru
Name	:	Dmitry Vasiliev
Organization	:	VNIRO
Role	:	Delegate
Address	:	107140 V. Kzasnoselskaya, 17 Moscow, Russia
Telephone	:	007-499-264-89-74
E-mail	:	dvasilyev@vniro.ru

REPUBLIC OF KOREA

Name	:	Doonam KIM
Organization	:	National Fisheries Research & Development Institute
Role	:	Delegate
Address	:	Shirang-ri ,Kijang-up, Kijang-gun Busan 619-902, Republic of Korea
Telephone	:	82-51-720-2324
E-mail	:	dnkim@nfrdi.re.kr
Name	:	Chul Woong OH
Organization	:	Deptartment Marine Biology Pukyung National University
Role	:	Delegate
Address	:	Dae-yon dong, Nam-gu Busan, Republic of Korea
Telephone	:	82-51-629-5925
E-mail	:	ohcw@pknu.ac.kr

VENEZUELA

Name	:	Pastor Vicent
Organization	:	Instituto Socialista de Pesca y Acuicultura
Role	:	Delegate
Address	:	Av. El Bosque, entre Sta Lucía y Sta. Inés Torre Credicard, Piso 9 Caracas, Venezuela
Telephone	:	0058 2129 528356
E-mail	:	pastorvicent@gmail.com

Name	:	David López
Organization	:	Instituto Socialista de Pesca y Acuicultura
Role	:	Delegate
Address	:	Av. El Bosque, entre Sta Lucía y Sta. Inés Torre Credicard, Piso 9, Caracas, Venezuela
Telephone	:	0058 2129 528356
E-mail	:	dlopez@inapesca.gob.ve
		Chile
Telephone	:	56-2 337-2324
E-mail	:	

Name	:	Andrés Mena
Organization	:	FAO RLC
Role	:	Consultant on Fisheries
Address	:	Av. Dag Hammarskjold 3241, Vitacura Santiago, Chile
Telephone	:	56-2-9232163
E-mail	:	andres.menamillar@fao.org

Annex B

SPRFMO Chilean Jack Mackerel Workshop - Compilation of Abstracts

Keynote Addresses:

Horse Mackerel Stock Identification Research (EU Project – HOMSIR): A multidisciplinary approach using genetic markers and biological tags in horse mackerel (*Trachurus trachurus*) stock structure analysis. Pablo Abaunza, Project Coordinator, Instituto Español de Oceanografía (IEO), Spain**.**

[No Abstract]

Assessment approaches when spatial distribution adds uncertainty to stock structure. James Ianelli, Alaska Fisheries Science Center, NMFS/NOAA, USA.

The situation for Chilean jack mackerel is unique as the population(s) span a very broad area and the fishery has expanded and evolved in a way that emphasizes the importance of understanding the stock structure and spatial interactions. In this presentation, the case for walleye pollock (*Theragra chalcogramma*) stock assessments in the Bering Sea are presented and contrasted with the situation for Chilean jack mackerel. These two species do share a number of commonalities, including similar demographic characteristics (e.g. longevity, age at first maturity) and apparent stock plasticity (i.e., the ability to expand into “new” areas). For pollock, there are stock structure issues that occur within the US EEZ (among and within management areas), between Russia and the US, and internationally in the region known as the “Donut Hole.” Pragmatic approaches towards these complex issues are presented and assumptions about stock structure are covered in sensitivity analyses and are reflected in the formally risk-averse control rules governing the upper limit of allowable catch levels. Management in the US deals with spatial aspects of fish distributions and the fisheries by having area-specific quota limits when species are relatively stationary. Other spatial and temporal catch restrictions were noted to apply for a variety of reasons, including ecosystem considerations such as the forage needs of Steller sea lions.

Workshop Papers:

1. Seasonal distribution and abundance of jack mackerel (*Trachurus murphyi*) eggs and larvae off northern Chile 1981-2007. Mauricio Braun and Vivian Valenzuela.

We herein summarize the results of 85 seasonal surveys for eggs and larvae carried out by the IFOP between 1981 and 2007 within the EEZ, from the northern limit with Perú to the port of Antofagasta (24° S). These results indicate that egg and larva density peak in winter-spring, with a greater concentration towards the southern zone of the study area. Annually, a clear tendency for egg density to decrease stands out. The signal for larva density is more erratic due to their capacity to avoid the sampling net.

2. Distribution of early developmental stages of jack mackerel in the Southeastern Pacific Ocean. Sergio Núñez, Sebastián Vásquez, Patricia Ruiz and Aquiles Sepúlveda.

Chilean jack mackerel (*Trachurus murphyi*) is a highly migratory pelagic species that inhabits the Southern Pacific Ocean, constituting the most important fishery for Chile. This species exhibits an onshore migration during the summer related to coastal food availability, and an offshore migration towards reproductive oceanic areas (beyond Chilean EEZ) in early spring. During the spawning peaks (November) of 1999-2007, eggs and larvae of jack mackerel were collected from systematic surveys carried out in oceanic waters (75º-92º W) off central Chile, using 5-10 fishing vessels. The eggs abundance shows a decreasing trend for 1999-2007 spawning period, with a strong variability of positive stations (72.7% for 1999 and 26.5% for 2007), and mean densities values ranged from 581.7 ind 10m-2 (1999) to 39.8 ind 10 m-2 (2007) constituting the lowest values of the analyzed series. For larvae, similar results were obtained, with positive stations ranged from 77.0% (2000) to 30.1% (2007), and mean densities values fluctuating between 265.9 ind 10m-2 (2000) and 65.1 ind 10m-2 (2007). Our results reveal lower abundance of eggs for 2005-2007, and more variable trend on larval densities for 2003-2007 period. Spatial distribution of eggs and larvae were modeled by geostatistical techniques, showing that the bulk of jack mackerel spawning occurs in oceanic waters off central Chile, centered between 33-38ºS and from 82º extending to 92°W and beyond. The higher densities of jack mackerel early developmental stages were associated to 16-18ºC isotherm position, moderate winds (4-8 m s-1) and turbulence index (<100 m3 s-3), and low currents (< 15 cm s-1), suggesting that the spawning process located offshore central Chile could be associate with the southern boundary of the Subtropical Convergence Zone.

3. Genetic variation on mt-DNA Cyt-b sequence of three populations of Chilean jack mackerel, *Trachurus murphyi* from the Southern Pacific. Min Zhang, Yong-jiu Xu and Cheng-hui Wang.

Mitochondrial cytb gene sequences of Chilean Jack mackerel (*Trachurus murphyi*) with 730bp were examined, the samples were collected from the Southeast Pacific beyond Chile's EEZ in 2006 (OEZ2006) and 2007 (OEZ2007), and collected inside of Chile's EEZ in 2006 (IEZ2006). The observation shown that 11 haplotypes were found in 39 analyzed samples and only one haplotype was shared among three populations, which has 23 polymorphic sites in analyzed 730 bp sequence. 3 and 22 polymorphic sites were detected in OEZ2006 and OEZ2007 respectively, and no sequence variation was found in IEZ2006. The haplotype diversity ratios were 0.3309, 0.6405 and 0.0000, and nucleotide diversity ratios were 0.0005, 0.0043 and 0.0000 in OEZ2006, OEZ2007 and IEZ2006 respectively. The results from AMOVA analysis indicated that no significant genetic divergence among three populations. NJ tree also showed that all individuals from three populations clustered into one clade. It might be concluded that the three fish stocks of Chilean Jack mackerel inside and outside of EEZ in the Southern Pacific could be one population.

4. Changes in the latitudinal and longitudinal distribution of the aggregations of jack mackerel (*Trachurus murphyi*) in the Perúvian sea during 1996 – 2007. Ericka Espinoza, Miguel Ñiquen and Roberto Flores

In this study, we described the spatial changes of jack mackerel (*Trachurus murphyi*) distribution in the Perúvian sea during 1996-2007 using the information of the fishing set positions of the Perúvian purse seine fleet collected by on board observes and to relate the jack mackerel and their relationship to the dominance of some types of water masses. Jack mackerel presented two marked scenarios in its distribution: Scenario 1 (1996-2001), in a latitudinal gradient all catches were made between 03°S and 14°S (North - Central Region) and longitudinally the fleet operated in the 10-250 nautical miles range. Also, it is important to highlight that the "last time" we observed adults in the north zone was in 1997. In scenario 2 (2002-2007), jack mackerel "disappeared" of the north zone observing all fishing locations between 10° and 18°S (Central - South Region), except in 2006, while its longitudinal distribution was near the coast (between 10-170 nm). With regard to the relationship resource-environment, in scenario 1, jack mackerel was found in the four different types of water masses. In the scenario 2, it was distributed mainly in the mixing zone of the masses of Cold Coastal Water and Superficial Subtropical Water. The change in the distribution of jack mackerel to the south was partially determined by environmental conditions and the convergence of other factors such as food. In this sense, the change of its food composition since 2002 to munida, which would indicate that the availability of the prey was an important factor, although further observations are needed.

5. Distribution of jack mackerel (*Trachurus murphyi*) related to oceanographical features between north Perú to north Chile. Ñiquen, M.A. and C.L. Peña.

One of the most productive fishing areas of the world is found in Perú and Chile. The productivity of their fishing grounds is due to the system of currents along their coastline, associated with upwelling processes that support great biomass of large pelagic resources, mainly jack mackerel (*Trachurus murphyi*).

In the hypotheses related to the structure of jack mackerel population, it was consider the following points:

Between 1983 and 2005 it is possible to distinguish two opposite states, in 1983 there was a wider distribution and very high biomass whereas in 2005 there was narrow distribution and lower biomass, in north Perú jack mackerel disappeared (Fig. 1).

In the central-south Perú jack mackerel availability increases when cold conditions prevail on this zone.

In September 2001, Oceanographical Regional Survey found an important oceanic front, originated by sub-Antarctic upwelling waters at 14-15°S (San Juan), characterized by high concentration of nutrients. This activity showed good correlation with high biomass and catches of jack mackerel. Also there was a homogeneous surface lawyer of temperature between Pisco (14ºS) and Iquique (21ºC).

Latitudinal distribution of jack and pacific mackerel length structure in south Perú – north Chile showed similar structures and both fishery catches at least one modal group similar (Fig.3). Also, abundance of juvenile's jack mackerel is higher in north Chile.

In conclusion, these spatial and temporal movements of jack mackerel correspond to interdecadal and interannual changes of environmental conditions, and they are important for resource management.

6. Inter-annual and seasonal variability of oceanological conditions in the Southern Pacific Ocean in connection with the pelagic ecosystem structure. P.Chernyshkov, E.Timokhin and A. Glubokov.

The water structure and dynamics in the Southern Pacific Ocean was studied as the basic factor determinative the pelagic ecosystem structure in the area, including South Pacific jack mackerel (*Trachurus murphyi*) populations. The following results were obtained:

on the average long-term schemes of geostrophic circulation in the upper 200-m layer, relatively isolated anticyclonic circulations were detected in the eastern, central and western parts of the Southern Pacific Ocean, where zones of high biological productivity were observed and South Pacific jack mackerel occurred at all life cycle stages (eggs, larvae, juveniles and adults);

cluster analysis of the principle components fields (atmospheric pressure, sea-surface temperature and sea-level anomalies based on altimetric data) allows to identify 5 classes of areas in the Southern Pacific Ocean, which differ in the seasonal and inter-annual variability patterns;

spectral, inter-spectral and regression analysis of oceanological parameters series allows to assume series coherence at individual frequencies, as well as availability of frequencies typical to specific areas.

Since the Southern Pacific Ocean has the more extended open boundary with Antarctica as compared to the Atlantic and Indian Oceans, the larger volumes of intermediate Antarctic water rich in nutrients penetrate into the temperate latitudes. Under the impact of anticyclonic circulations, appeared owing to hydrodynamic instability in the frontal zones of the ocean, these water masses are ascending to the surface, where relatively isolated zones of high biological productivity able to support individual South Pacific jack mackerel stock units are formed.

7. Jack Mackerel (*Trachurus murphyi*) distribution peculiarities in the high seas of the South Pacific in relation to the population structure. Soldat V.T., Kolomeiko F.V., Glubokov A.I., Nesterov A.A., Chernyshkov P.P. and Timokhin E.N.

The materials on jack mackerel occurrence, distribution and biology collected in 139 research, fish-detecting and commercial fishing Russian expeditions to the South Pacific in 1978-1991 are presented. Mean annual (1982-1991) maps of jack mackerel *Trachurus murphyi* aggregations distribution by quarter in one-degree square grid are given. Distribution of spawning and immature jack mackerel in the catches taken in the South Pacific area is shown. The analysis of the zonal, in longitude, jack mackerel occurrence at different stages of reproduction cycle in the high seas of the ocean between 30° and 50°S is made. It has been determined that in the high seas of the Pacific Ocean southward of 30°S, outside the 200-mile zones of the coastal states, there exist appropriate conditions for jack mackerel reproduction and existence at all stages of life cycle. It provides the recruitment for the fishing part of jack mackerel stock in the oceanic waters of the South Pacific.

8. Methodology employed for age determination in Chilean jack mackerel (*Trachurus murphyi*). V. Ojeda, V. Bocic and L. Muñoz.

FOP has been carrying out growth-at-aging studies in different Chilean fisheries since late 1960. Currently, the age readings are being certified under NCh ISO 17025. Particularly in the jack mackerel fishery, age composition in the catches has been a relevant element for the indirect understanding of changes in the stock. There is an availability of reliable age readings since early 1970, which have been used for developing size-age keys and catch-at-age matrix per zone, constituting the input data in the stock assessment process. In this document a summary of the main methodological details used for determining the jack mackerel age, and the results obtained in the last 10 years are provided.

9. Jack mackerel (*Trachurus murphyi*) spatial distribution and seasonal acoustic biomass estimated in the north of Chile. 1981 - 1990. Jorge Castillo, P.

The Jack Mackerel spatial distribution and seasonal acoustic biomass estimates are provided; it was carried out between the coast and the 200 nm in northern Chile, in the 1981-1990 period. The biomass seasonal changes and its geographic distribution with respect to the 1982-1983 presence of the El Niño event were analyzed. The most important results indicate that the jack mackerel modified its presence and geographic distribution in the studied zone during the spring of 1981, previous to the 1982-1983 El Niño event, suggesting a movement to the south.

The maximum jack mackerel biomasses were estimated in the 1981-through-1983 winter periods, reaching a 5.8-million-tons top in 1981. Since 1982, an important reduction in the jack mackerel biomass is registered, reaching a 34-thousand-tons minimum in 1995. This change matches the presence of the El Niño event in 1982-1983.

10. Catch per Unit Effort of Chilean jack mackerel (*Trachurus murphyi*) of the purse seine fishery off south-central Chile (32º10' – 40º10' S) 1981-2005. Cristian Canales, Leonardo Caballero and Antonio Aranís.

The CPUE standardization results of the purse-seine fleet operating in south-central Chile (32º10' – 40º10' S), reported by Caballero and Aranis (2005), were analyzed. Both CPUE and catch success were modeled through a Generalized Linear Model, in which the year, hold capacity, and month factors were the most representative in the explanation of variable. Catch success corresponds to the ratio between fishing trips with catches and the total trips fishing for jack mackerel, while in the CPUE the fishing trips with catches registers were considered as an effort measure. When considering catch success as an availability measure, the CPUE ratio steadily increases in the last 8 years; this doesn't happen when considering catch success as an indirect efficiency or catchability measure. With the latter, the CPUE keeps a similar trend in the catch mean age, and decreases during the whole 90's. It is considered that catch success could reflect technological changes in the fleet, its efficiency and catchability; thus, it can be used as a correction factor of the CPUE signal of fishing trips with catches.

11. Jack mackerel (*Trachurus murphyi*, Nichols, 1920) acoustic survey in the central coast of Chile. Jose Cordova, Roberto Bahamonde and Victor Catasti.

Acoustic surveys have been carried out by IFOP since 1991 in the central zone off Chile. These surveys were carried out in autumn, in order to determine the distribution and biomass of jack mackerel. Between 1997 and 2002, the analysis area was delimited dynamically, considering the jack mackerel distribution in the survey time. In this period, the surveys were done inside the EEZ.

Since 2003, the jack mackerel distribution was more distant to the coast and with a trend to the south, extending the analysis area to 400 nautical miles (nm) from the coast. This situation determined two steps in the survey protocol; first, an area exploration with industrial vessels in perpendicular transects each 25-30 nm. Second, it considered an acoustic survey in order to estimate the biomass in the identified area. The acoustic information (Sa and TS) was registered each 0.5 nm. The results show variations in the space used by this resource, with important changes in the biomass and its distribution.

12. Catch size compositions for jack mackerel (*Trachurus murphyi*) off Chile (1975-2006). Claudio Bernal, Antonio Aranis, Carlos Martínez and Cristian Canales.

The sampling effort made from 1975 to 2006 for generating Chilean jack mackerel (*Trachurus murphyi*) size structures is presented herein, along with the size compositions per studied zone. Off northern Chile, only juvenile size structures were recorded. The average sizes showed a downward trend until 1999, when it reached about 22 cm FL and stabilized through 2006. The size structures recorded off southern Chile, however, revealed important cohort development in 1980, 1986-1987, and 1997-1998, explaining both the development of the fishery and the changes in jack mackerel abundance.

The information gathered has allowed us, on the one hand, to follow the jack mackerel stock dynamic spatially-seasonally through stock evaluations and, on the other hand, to strengthen hypotheses regarding the structure of Chile's jack mackerel stock.

13. Reproductive parameters and spawning biomass of jack mackerel (*Trachurus murphyi*), in 1999-2006, determined by the daily egg production method. Patricia Ruiz1, Aquiles Sepúlveda1, Luis Cubillos, Ciro Oyarzún and Javier Chong.

The daily egg production method, DEMP (Lasker, 1985), it was applied to estimate the spawning biomass in jack mackerel (*Trachurus murphyi*) in the maximum reproductive period. In addition, reproductive parameters are described for the population, which has a widespread oceanic spawning habitat off central Chile, extending more than one thousand nautical miles offshore. The analyses were made on the basis of seven surveys carried out in oceanic waters (32∘S–39∘S, 75∘W–92∘W), from 1999 to 2006. In each survey, a grid of plankton stations was sampled through vertical hauls with WP2 plankton nets by using several purse-seine fishing ships sampling simultaneously along the E–W transects. In the same surveys, adult jack mackerel were randomly sampled from fishing sets. For to characterizer the reproductive condition of the population, the follows parameters were estimated: mean weight of mature females (W), spawning fraction (S), batch fecundity (F) and the sex ratio (R). For the estimation of the spawning biomass, the spawning area and the daily egg production rate (P0) were estimated, according to Stauffer and Picquelle (1980). The reproductive parameters in jack mackerel showed a high variability between years, especially the spawning fraction (range of 7 - 19 % of the population). The mean weight of mature females (W) and the batch fecundity (F) have shown to an important increase in the last years, which is coincident with the present situation of the resource (major lengths and weights in the most recent years). In the application of DEMP, it is suggested that the daily egg production (P0) and the spawning fraction (S) are the parameters with greater uncertainty and their fluctuations, influence of direct way in the estimation of the spawning biomass. Further research is suggested for improvements future DEPM application for jack mackerel.

14. Short review of natural mortality and size at first maturity on jack mackerel (*Trachurus murphyi*) in the southeastern Pacific. Luis Cubillos, Claudio Gatica and Rodolfo Serra.

This manuscript presents a short review of natural mortality parameters and size at first maturity to jack mackerel (*Trachurus murphyi*). In summary, this specie is characterized by a slow growth with early maturity. In this context the jack mackerel has the better growth performance that others carangids. The natural mortality parameters better associated with the size structure presents in the fishery were in the range between 0.3-0.33 year -1. The size at first maturity fluctuates between 21.6 to 30 cm FL (fork length), this high variability is mainly related with the school structure and capture zone. However, most of these values are concentrated between 23 and 27 cm FL.

15. Report of data collection on jack mackerel in South-East Pacific. Min Zhang, Xiaorong Zou and Yingqi Zhou.

The information in this paper is summarized from the Surveys on Chilean Jack Mackerel in the southeast Pacific Ocean, which were carried out by Chinese fishing fleet during 2000-2007 cooperating with the Chinese fishery scientific observers program. The biological data and environment data were measured on board by the observers and catch data were collected from log books of fishing vessels or directly from the catch.

16. Distribution changes and interactions of jack mackerel off Perú as observed using acoustics (1983-2006). Mariano Gutiérrez , Arnaud Bertrand , Michael Ballón, Pepe Espinoza , Ana Alegre and Francois Gerlotto.

Jack Mackerel (JM: *Trachurus murphyi*) is being acoustically assessed since 1983 by the Instituto del Mar del Perú (IMARPE). That monitoring supported the management of the fishery of JM off Perú which was initiated by foreign fleets. By the mid 1990's an offshore Perúvian purse seine fleet was developed though its activities were early affected by changes in distribution and a reduction of JM abundance after the strong El Niño event of 1997-98. Since this event, cold coastal waters extend far from the coast, the oxycline is shallow, anchovy dominate the system, and the population of squat lobster (*Pleuroncodes monodon*) and jumbo squid (*Dosidicus gigas*) exploded. On the opposite the abundance and availability of JM, sardine and mackerel reduced dramatically. Using a GAM approach we show the changes of abundance and related (abiotic) parameters of JM along the period in which IMARPE conducted acoustics surveys, and describe the negative correlations among the abundance of mentioned species. Using acoustic data from commercial fishing we also show interactions between JM and its preys, mainly euphausiids. These results support the hypothesis according to which the main drivers of JM distribution along the South American coast are the prey distribution and the location of the Oxygen Minimum Zone (both effect can be related). Finally we emphasize on the use of acoustic techniques to collect simultaneous in situ data from fishing vessels about a variety of species, preys and predators, to support the necessary ecosystem approach adapted to the fishery of JM.

17. Program Bio-oceanographic research of resources jack mackerel and Pacific mackerel in Perú. Miguel Ñiquen Carranza.

Jack mackerel (*Trachurus murphyi*) and Pacific mackerel (*Scomber japonicus*) have wider geographical distribution on Perúvian coast, doing latitudinal and longitudinal migrations, related to environmental conditions. Historical data about availability of jack mackerel on Perúvian coast until 1998 show wider distribution and great abundance, with biomass estimates about 8,5 millions tons in 1983, and annual yields lower than 400 thousands tons, excepting 1997. Update data after 1998 show restricted distribution to central-south of Perú, with biomass estimates lower than 2,0 millions tons, and annual yields lower than 300 thousands tons, excepting 2001.

A key point on development of jack mackerel and pacific mackerel fishery was the effect of legal rule D.S. 001-2002 (06-09-2002), that establish exclusive use of these species for direct human consumption, which has restricted catches and allow development of Industrial fleet with system Refrigerated Sea Water, with special features for human consumption. Also, on April 12, 2007 were establish the Fishery Management of Jack and Pacific mackerel Regulation, approved by D. S. N° 011-2007-PRODUCE, which promotes rational exploitation of these resources. The monitoring pelagic fisheries and research surveys, mainly for anchovy, let us to know fishing effort and biological data of jack mackerel and pacific mackerel, nevertheless, we need to get better jack mackerel data from 100 miles offshore in front of Perú, in order to obtain more elements for management.

In this sense, IMARPE will do special researches Jack and Pacific mackerel, with focus on biology, habitat and fisheries, based on Program “Bioceanographical research of Jack mackerel and Pacific mackerel resources”, approved by R.M. 489-2008-PRODUCE del on May 20, 2008, with financial support by Vice-Minister of Perúvian Fishery, with the proposal to get integral knowledge of the biological and fisheries features of these resources.The main activities of the Program are recovery historical data of jack mackerel fisheries and the execute of two surveys by year, both with amplitude upper than 100 miles, one of them will be between May 31 to July 14, looking for distribution and concentration, and the second one in spring, looking for to know the development of main biological process as spawning, recruitment and feeding. Something special on these surveys will be the sampling collections for isotopic analyses which let us try to identify unit stocks of jack mackerel. These activities will be supervised by experts of several issues; that include participation of IMARPE, Vice-Minister of Perúvian Fishery, private sector and international consulting.

18. The fishery for jack mackerel in the Eastern Central Pacific by Dutch trawlers in 2007. Ad Corten.

After two years of test fishing by a single trawler, the Dutch fleet in 2007 increased to 5 units. Because an observer programme was not yet in place, the crew of the vessels was asked to take length measurements of the fish. This working document describes the distribution of the fishery from month to month, and it presents monthly length distributions of the catch. During the fishing season, the fleet gradually moved north-west, to reach the vicinity of Eastern Island (115° W) towards the end of the season. Compared to the previous two years, the fish were distributed further to the west. This must have been related to unusual hydrographic conditions in 2007.

19. An overview of the New Zealand jack mackerel fishery: Catch composition, catch trends, seasonality and length-frequency composition. Andrew Penney and Paul Taylor.

The New Zealand jack mackerel fishery targets three species, *Trachurus declivis*, *T. novaezelandiae* and *T. murphyi.* First catches were documented in 1946, but the targeted fishery, assumed to be *T. declivis*, started in the mid-1960s, with annual catches increasing to 20,000 t by the time jack mackerels were included in the New Zealand Quota Management System in 1986-87. In 1986 it was also first recognised that *T. murphyi* contributed to the increasing New Zealand jack mackerel catch. Commercial catches of jack mackerels are not reported separately by species, so observer and shed sampling programmes were implemented to estimate species proportions. The contribution by *T. murphyi* has differed substantially between areas, and over time. By 1986-87, all of the catch in the eastern-most JMA 3 area on the Chatham Rise consisted of *T. murphyi.* This species first appeared in catches in the other areas around 1987-88, increasing to 40% by 1994-95, and decreasing again to <10% by 2001-02. Estimated catches of *T. murphyi* increased from zero in 1986-87 to over 25,000 t in 1995-96, lagging slightly behind the similarly rapid rise in total South Pacific catches. New Zealand catches then declined to 2,400 t by 2002-03, increasing slightly to 4,645 t by 2005-06, again lagging a year or two behind the decline in total South Pacific catches. CPUE analysis shows that catch rates also underwent a steep decline after 1996. Length-frequency composition has remained relatively constant from 40-60 cm, while age composition has increased steadily, consistent with an ageing New Zealand population. Geographic distribution of catches over time shows initial appearance around the Chatham Islands in 1984-85, westward expansion from 1986-87 to 1994-95 as catches increased, followed by an eastward contraction to 2006-07, as catches declined. Most of this information supports the hypothesis that *T. murphyi* in the New Zealand region are a small, and perhaps periodically separated, component of a larger South Pacific stock which undergoes periodic expansions or migrations.

20. Chilean jack mackerel stock assessment model. Cristian Canales and Rodolfo Serra.

Herein, we present the methodological details of the evaluation model for the Chilean jack mackerel stock off Chile, within and outside of the EEZ. The model uses a statistical age at catch approach in which the information is considered to be subject to an observation error and is analyzed through verisimilitude estimators. The data input into the model correspond to a series of landings from 1975, age catch compositions made by Chile and the former USSR, age compositions from acoustic cruises, acoustic biomass series off central-southern Chile, and an estimated spawning biomass index from cruises for eggs and larvae. We model two hypotheses of processes related to the exodus from fishing zones and decreased abundance.

21. Maximum sustainable yield (MSY) and optimum effort of fishing of jack mackerel (*Trachurus murphy*) and pacific mackerel (*Scomber japonicus*) in Perú (1997-2006). Christian Garcia.

Surplus production model of Pella Tomlinson (1969) with catch data, effort and catch per unit effort of jack mackerel (*Trachurus murphyi*) and pacific mackerel (*Scomber japonicus*) was applied for this fishery in Perú from 1997 to 2006, the goal was calculate of maximum sustainable yield (MSY) and optimum effort (OE). In both, results of model showed several alternatives, in maximum sustainable yield as optimum effort, due to parameter “m”. So, if this value is equal to 1 (m=1) then it results as Fox model, and if it is equal to 2 (m=2) it is Schaefer model. Based on determination coefficient r2 obtained by the quotient between U observed and the calculate by others models, it was determined that the best model is when parameter m range around 1. For that reason Fox model will be most adequate, because adjust better to data, showing r2= 0.69 with MSY = 562166 tons and OE = 30 hours per trip in average.

The unit effort that was taken for development of the model is an effective unit effort, based in the hours per trip in average of the total annual trips. For management it was calculated, from MSY obtained, the number of boats and holding capacity necessary. For these results we use some indicators as number of annual trips average, efficiency (catch between holding capacity displacement) and number of trips by vessel by year.

22. Preliminary estimation of current state of Chilean Jack Mackerel (*Trachurus murhyi*) stock in the high seas of the South East Pacific. Dmitry Vasilyev, Alexander Glubokov and Doonam Kim.

The state of the stock was estimated using the following data:

- Catch-at-age (2003-2006), calculated from the total catch data, Vanuatu size structure of catches, the age-length key and average weight-at-age data from Russian surveys (2002-2003);
- Age structure of the stock for the beginning of 2003 from Russian surveys;
- The value of instantaneous natural mortality coefficient was assumed equal to 0.23 for all age groups.

Clearly understanding that the amount of available information about the modern state of jack mackerel stock in the high seas of the South East Pacific is close to lower limit for any stock assessment, we nevertheless made an attempt to make use of a separable cohort model of the ISVPA-group, implemented, among many other models, for stock assessment in frames of International Council for the Exploration of the Sea (ICES). The model is based on some principles of robust statistics what helps to extract weak signals from noisy data. The version of the model used for the assessment attributes residuals in cohort part of the model to errors in catch-at-age data, assuming that selection pattern is stable. This version is often more robust for noisy catch-at-age data. Additional robustness of cohort part of the model with respect to outliers in catch-at-age was attained 1) by minimization of the median of the distribution of squared residuals in logarithmic catch-at-age as a measure of closeness of the model fit to catch-at-age data, and 2) by condition of unbiased model description of logarithmic catch-at-age data. An additional signal about the size of the stock is taken from minimization of residuals between age proportions in the stock in 2003 taken from Russian surveys and from the cohort part of the model. Here the absolute median deviation (AMD) of logarithmic residuals in age proportions is used as a measure of closeness of fit. The AMD is the median of distribution of deviations of absolute logarithmic residual from their median value. The overall objective function of the model is composed as a weighted sum of catch-at-age-based and survey-based components (the weights reflect the efficient number of data points for each source of information).

According the results of the assessment (estimates of stock biomass (2+) in comparison to catches, recruitment at age 2, average fishing mortality (weighted by age groups abundance), and selection pattern by years) the stock biomass is relatively stable with the average about 7 million tonnes.

23. Population structure of Chilean jack mackerel, *Trachurus murphyi*, in the South Pacific Ocean: Full proposal for an international joint research programme. Rodolfo Serra and Alexander Glubokov.

[No Abstract. Full proposal, as updated at the Workshop, attached as Annex D.]

24. Research and management of Chilean jack mackerel (*Trachurus murphyi*) exploited in the South East Pacific Ocean. M.A. Barbieri.

[No Abstract]

Additional Cited References:

Abaunza, P., Murta, A.G., Campbell, N., Cimmaruta, R., Comesaña, A.S., Dahle, G., García Santamaría, M.T., Gordo, L.S., Iversen, S.A., MacKenzie, K., Magoulas, A., Mattiucci, S., Molloy, J., Nascetti, G., Pinto, A.L., Quinta, R., Ramos, P., Sanjuan, A., Santos, A.T. Stransky, C. and Zimmermann, C. 2008. Stock identity of horse mackerel (*Trachurus trachurus*) in the Northeast Atlantic and Mediterranean Sea: integrating the results from different stock identification approaches. Fisheries Research, 89: 196-209.

Arcos, D.F., L. Cubillos and S. Núñez. 2001. The jack mackerel fishery and El Niño 1997-1998 effects off Chile. *Progress and Oceanography*, 49:597-617.

Begg, G.A. 2005. Life history parameters. In: Cadrin, S.X., Friedland, K.D., Waldman, J.R. (Eds.). *Stock Identification Methods. Applications in Fishery Science*. Elsevier, Academic Press, Amsterdam, 119-150.

Cardenas, L., C.E. Hernandez, E.Poulin, A.Magoulas, I. Kornweld and F.P. Ojeda. 2005. Origin, diversification, and historical biogeography of the genus *Trachurus* (Perciforms: Carangidae). *Molecular Phylogenetics and Evolution.* 35: 496-507.

Cubillos, L.A., J. Páramo, P. Ruíz, S. Núñez and A. Sepúlveda. 2008. The spatial structure in the oceanic spawning of jack mackerel (*Trachurus murphyi*) off central Chile (1998-2001). *Fisheries Research*, 90: 261-270.

Evseenko, S.A. 1987. Reproduction of the Perúvian jack mackerel *Trachurus symmetricus murphyi* in the South Pacific. *Journal of Ichthyology*, 27: 151–160.

Gorbunova N.N., Evseenko S.A and S.V. Garetovskiy. 1985. The distribution of ichthyoplankton in the frontal zone in Perúvian waters. *Voprosy ictiologii*, 25(5): 770-782. (in Russian)

Koval, L.I. 1996. Polymorphic locus frequency in Perúvian horse mackerel and females intra-population heterogeneity in growth rate. *ICES Council Meeting Papers*., ICES, Copenhagen, CM 1996/H:35, 9 pp.

Nesterov. A.A., V.N. Chur and F.V. Kolomeyko. 2007 . Russian fishery and researches in the Southern Pacific Ocean in 1978-1991 and 2002-2003. Presented In: The jack mackerel fishery in the South Pacific Meeting. March 22, 2007, Talcahuano, Chile. Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), Kaliningrad, Russia.

Oliva, M. 1999. Metazoan parasites of the jack mackerel *Trachurus murphyi* Nichols, 1920 (Teleostei: Carangidae) in a latitudinal gradient from South America (Chile and Perú). *Parasites* 6(3): 223-230.

Poulin, E., L. Cardenas, A. Silva, J. Juarez and P. Ojeda. 2004. The brief history of the Chilean jack mackerel: population genetic inference from mitochondrial DNA control regions. (Unpublished manuscript).

Santander, H. and R. Flores. 1983. Spawning and larval distribution of four pelagic species and their relations to marine environmental variations off Perú. In: *Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, San Jose (Costa Rica), 18 Apr 1983*. Sharp, G.D. and J. Csirke (Eds), *Proceedings: FAO Fisheries Report, FAO, Rome, Italy*, 291(2-3): 835 - 870 (in Spanish).

Serra, R. 1991. Some important life history aspects of the Chilean jack mackerel, *Trachurus symmetricus murphyi. Invest. Pesq*., 36: 67 - 83.

Waldman, J.R. 1999. The importance of comparative studies in stock analysis. Fisheries Research 43, 237-246.

Annex C

Chilean Jack Mackerel, Jack Mackerel and Unspecified Mackerel and Vessel Data Received by the Interim Secretariat to Date (as at 4 July 2008)

Susie Iball: Data Manager, SPRMO Interim Secretariat

Table 1: General Overview of Chilean/ Jack/ Unspecified Mackerel Data Received to Date

Data Type		Received by SPRFMO to Date (4 July 08)
		Yes/No
Catch	Annual Aggregated Catch Data	For some Participants, years and areas
Catch	5 Degree by 5 Degree Square Data	For some Participants, years and areas
Catch	Tow by Tow Data	**None received** (NZ data in preparation)
Vessel Details	Details of Vessel Capacity, etc	For some Participants, years and areas
Vessel Effort	No. vessels fishing, no. vessel days fished, no. operative hours fished	For some Participants, years and areas
VMS	Vessel monitoring positional data	For some Participants, years and areas
Observer	As specified in data standards.....e.g. observer details, catch and effort, length-frequency, biological sampling, incidental bycatch, VME and tagging data	**None received** - except for length frequency data from Vanuatu for 2003 -2006 (jack mackerel)

Table 2: Mackerel Fisheries Catch Data Received by the Interim Secretariat to Date
(Note that only those Participants who have sent in some catch data are included in this table)

		Annual Aggregated Catch Data				5x5 public domain data		
PARTICIPANT		Years	Areas	Species		Years	Areas	Species
Australia		2007	SPRFMO	Chilean jack mackerel (0t)				
		2007	Within Australian EEZ	All jack mackerel species (*T. declivis, T. novae - zelandiae*)				
Belize		2007	SPRFMO	Horse and chub mackerel		2007	5x5 squares	Horse and chub mackerel
		2001-2006	SPRFMO	Horse mackerel		2001-2006	5x5 squares	Horse mackerel
China		2000-2007	FAO 87	Jack mackerel		2000-2007	FAO 87	Jack mackerel
Chile (may include catch within EEZ)		2007	FAO 87	Chilean jack mackerel & horse mackerel		*	*	*
		1985 - 2006		Jack mackerel		*	*	*
Cook Islands		2007	Unspecified	Jack/horse mackerel (*Trachurus* spp)		2007	Lat/ long	Jack/horse and chub mackerels
Cuba		1980 - 1991	Unspecified	Jack mackerel		*	*	*
European Community		1972 - 2007	Unspecified	Chilean jack mackerel and chub mackerel		2007	5x5 squares	Jack mackerel & Pacific mackerel
Faroe Islands		2007	FAO 87	Jack mackerel		*	*	*
Japan		1975 - 2004	FAO 87	Chilean jack mackerel and chub mackerel		*	*	*
Korea		2007	Unspecified	Horse mackerel and mackerel		*	*	*
New Zealand		2002 -2007 (preliminary estimates)	High Seas catches	Jack mackerels (0t), blue/English mackerel and mackerel spp		2002 -2007 (preliminary estimates)	High Seas catches only	Jack mackerels (0t caught in high seas) and blue/English mackerel
		1984/85 - 2005/06	NZ EEZ	Chilean jack mackerel				
Russian Federation [USSR]		1969 - 2007	FAO 81	Pacific mackerel and greenback horse mackerel		*	*	*
		1972 - 2007	FAO 87	Chilean jack mackerel and chub mackerel		*	*	*
Vanuatu		2003-2007	Unspecified	Chilean jack mackerel and chub mackerel (*Scomber japonicus*)		*	*	*

* No data received to date

Table 3: Summary of Jack/Horse/ Unspecified Mackerel Annual Aggregated Catch Data (t) NB: Does not include data submissions specifically identified as chub/ Pacific mackerel.

	AUSTRALIA	BELIZE	BELIZE	CHILE	CHILE	**CHILE**
SPECIES	Jack mackerel (*T. declivis*, T. novae -zelandiae) (t)	Horse mackerel (t)	"Mackerel" – unspecified (t)	Jack mackerel: species not specified (t)	Chilean jack mackerel (t)	Horse mackerel (t)
METHOD	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
AREA	Australian EEZ	Unspecified	Unspecified	Area 87	Area 87	Area 87
YEAR	Catch was only taken within Australian EEZ; no Chilean jack mackerel	Not clear if includes some chub mackerel		*Includes catch from within waters of national jurisdiction	*Includes catch from within waters of national jurisdiction	*Includes catch from within waters of national jurisdiction
2007	680	#	#		1293515 (prelim)	297110 (prelim)
2006		481		1,366,770		
2005		867		1,430,434		
2004		0		1,451,599		
2003		0		1,421,296		
2002		0		1,518,994		
2001		0		1,649,933		
2000				1,234,299		
1999				1,219,689		
1998				1,612,912		
1997				2,917,064		
1996				3,883,326		
1995				4,404,193		
1994				4,041,447		
1993				3,236,244		
1992				3,212,060		
1991				3,020,512		
1990				2,471,875		
1989				2,390,117		
1988				2,138,255		
1987				1,770,037		
1986				1,184,317		
1985				1,456,989		
1984						
1983						
1982						
1981						
1980						
1979						
1978						
1977						
1976						
1975						
1974						
1973						
1972						
1971						
1970						
1969						

Data not shown as less than 3 vessels were fishing

Table 3 Continued

	CHINA	COOK Is.	CUBA	ECUADOR	EC	EC	FAROE IS	JAPAN
SPECIES	Jack mackerel (t)	Jack mackerel (Trachurus spp) (t)	Jack mackerel (t)	Chilean jack mackerel (t)	Chilean jack mackerel (t)	Jack mackerel: species not specified(t)	Jack mackerel (t)	Chilean jack mackerel (t)
METHOD	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
AREA	FAO Area 87	FAO Area 87	Unspecified	Ecuadorian EEZ	Unspecified	Unspecified	FAO87	FAO Area 87
YEAR				Catch was only taken within Ecuadorian EEZ	*Unspecified "mackerel" was also reported for some years	*Unspecified "mackerel" was also reported for some years	May contain some small quantities of unspecified mackerel	
2007	140,582	7		927	123,511		38,700	
2006	160,000				62			
2005	143,000				6			
2004	131,020							
2003	94,690							
2002	76,261			604				
2001	20,090			133,969				
2000	#			7,122				
1999				19,072				7
1998				25,900				
1997				30,302				
1996				56,782				
1995				174,393				
1994				36,575				
1993				2,673				
1992				15,022		7,842		
1991			5,769	45,313		109,292		
1990			31,047	4,144		81,909		157
1989			14,784			11,584		#
1988			12,335			76,036		#
1987			34,226			864		#
1986			43,387			828		#
1985			42,287			847		5,229
1984			24,428			80,848		#
1983			45,981			40,357		#
1982			61,016			7,600		
1981			50,930			2,029		#
1980			54,295			7,540		
1979						45,495		#
1978						29,455		1,667
1977						1,078		2,273
1976						719		#
1975						680		
1974						55		
1973						35		
1972								
1971								
1970								
1969								

Data not shown as less than 3 vessels were fishing

Table 3 Continued

	KOREA	NZ	NZ	RUSSIA	RUSSIA	VANUATU
SPECIES	Horse mackerel (t)	Jack mackerel (Trachurus spp) (t)	Chilean jack mackerel (t)	Greenback horse mackerel (t)	Chilean Jack Mackerel (t)	Chilean Jack Mackerel (t): Trachurus murphyi
METHOD	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Midwater trawl
AREA	Unspecified	Proposed SPRFMO Area	NZ EEZ	FAO Area 81	FAO Area 87	Unspecified
YEAR	*Unspecified "mackerel" was also reported for some years		** Based on NZ fishing year; taken from paper #19 - A. Penney			
2007	10,940	0		0	0	
2006		0	4,645	0	0	129,535
2005		0	3,759	0	7,040	77,356
2004		0	3,083	0	62,300	94,685
2003		0	2,401	0	7,540	53,959
2002		0	4,470	0	0	
2001			5,345	0	0	
2000			8,226	0	0	
1999			16,203	223	0	
1998			20,376	52	0	
1997			19,569	886	0	
1996			25,331	2,280	0	
1995			21,013	1,602	0	
1994			20,604	1,804	0	
1993			19,938	4,260	0	
1992			9,301	2,892	32,000	
1991			7,519	127,000	591,800	
1990			3,154	67,518	1,122,297	
1989			3,167	56,543	1,096,292	
1988			1,488	#	938,288	
1987			0	107,329	818,628	
1986			2,228	146,200	78,500	
1985			?	133,300	837,700	
1984			?	22,300	1,056,600	
1983				10,651	866,500	
1982				4,953	735,898	
1981				0	771,630	
1980				13	544,970	
1979				0	532,209	
1978				254	49,220	
1977				710	0	
1976				0	0	
1975				0	0	
1974				0	0	
1973				0	0	
1972				0	5,500	
1971				0		
1970				0		
1969				0		

Data not shown as less than 3 vessels were fishing

Table 4: Summary of 2007 Jack/Horse Mackerel Data Received in 5x5 Degree Squares (kg)

Participant	EUROPEAN COMMUNITY			CHINA			BELIZE	
Area				FAO Area 87				
5x5 Degree Square	No. Vessels Operating	Chilean jack mackerel (kg)		No. Vessels Operating	Jack Mackerel (kg)		No. Vessels Operating	Horse Mackerel (kg)
10-15S, 80-85W	1	x						
10-15S, 80-90W	1	x						
15-20S, 85-90W	1	x						
20-25S, 85-90W	1	x						
20-25S, 80-85W	2	x						
25-30S, 100-105W	1	x						
25-30S, 95-100W							1	x
25-30S, 85-90W	3	270,912					1	x
25-30S, 80-85W	2	x						
25-30S, 75-80W	1	x						
30-35S,110-115W				11	935,000		1	x
30-35S,105-110W	4	3,319,719		11	149,000		1	x
30-35S, 100-105W	6	14,209,116		11	5,659,000		1	x
30-35S, 95-100W	5	2,220,158		11	1,700,000		1	x
30-35S, 90-95W	7	9,317,419		11	14,340,000		1	x
30-35S, 85-90W	6	6,057,936		11	17,623,000		1	x
25-30S, 80-85W	1	x						
35-40S, 105-110W							1	x
35-40S, 100-105W	5	1,836,827					1	x
35-40S, 95-100W	4	2,586,204		11	4,320,000		1	x
35-40S, 90-95W	7	11,849,848		11	3,149,000		1	x
35-40S, 85-90W	5	9,047,976		11	4,236,000		1	x
35-40S, 80-85W	4	20,804,053		11	25,943,000		1	x
35-40S, 75-80W	3	2,133,672		11	3,393,000		1	x
40-45S, 85-90W	3	8,833,332		11	8,162,000			
40-45S, 80-85W	3	25,953,782		11	46,697,000		1	x
40-45S, 75-80W	2	x		11	3,044,000			x
45-50S, 80-85W				11	263,000		1	x
45-50S, 85-90W				11	969,000			
TOTALS		123,510,850			140,582,000			x

X Data not presented as is for less than 3 vessels

Table 5: Vessel Details Data Received to Date

PARTICIPANT		Vessel Type	Vessel information received?	No. Vessels	Data Provided to Required Standard? (Annex 4)	Years Data Provided For	Fisheries/species	Comments
Australia		Pelagic fishing vessels	*	*	*	*		
		Other vessels	Yes	Between 6-14 trawlers and 5-6 non-trawling vessels per annum	No	1987-2006		Numbers of vessels only provided
Belize		Pelagic fishing vessels	Yes	10	Generally	2007, 2008	Mackerel fisheries	1 midwater trawler actively fishing in 2007; 9 midwater trawlers authorised to fish but not actively fishing during 2007. GT
		Other vessels	Yes	1	Yes	2007, 2008	Orange roughy and alfonsino fisheries	Vessel details provided for 1 deep water trawler which is in the process of being de-registered from Belize. GT
Chile		Pelagic fishing vessels	Yes	138	No	2007	Pelagic	Vessel names and total GT only were provided
		Other vessels	*	*	*	*		
China		Pelagic fishing vessels	Yes	11	No	2006, 2007		
		Other vessels	Yes	82	No	2006	Jumbo flying squid	Many vessel detail variables missing. GT
Cook Islands		Pelagic fishing vessels	Yes	4	No	2007, 2008	Jack and horse mackerel fisheries	Names and GRT info only provided
		Other vessels	*	*	*	*		
Cuba		Pelagic fishing vessels	Yes	Varies between 4 - 18 per annum	No	1980 - 1991	Jack mackerel	Names only provided
		Other vessels	*	*	*	*		
European Community		Pelagic fishing vessels	Yes	8	Generally	*		All details provided except for moulded depth, beam and hold capacity. GT
		Other vessels	No	*	*	*		

* Indicates no data provided to date

Table 5 Continued

PARTICIPANT		Vessel Type	Vessel information received?	No. Vessels	Data Provided to Required Standard? (Annex 4)	Years Data Provided For	Fisheries/species	Comments
Japan		Pelagic fishing vessels	Yes	1	Yes	2007, 2008		Data includes 1 midwater trawler authorised to fish, but not actively fishing during 2007. GRT
		Other vessels	Yes	4	Yes	2007, 2008		Data includes 4 squid vessels; unsure which unit of vessel "length" has been provided. GRT
Korea		Pelagic fishing vessels	Yes	3	Yes	2007		Unclear whether tonnage is GT or GRT
		Other vessels	*	*	*	*		
New Zealand		Pelagic fishing vessels	*	*	*	*		No non-squid vessels were actively fishing in the pelagic fishery during 2007
		Other vessels	Yes	43	Yes	May 07 - Apr 08	All high seas	GT
Russian Federation [USSR]		Pelagic fishing vessels	Yes	3 (2007), 5 (2008)	Yes	2007, 2008		Data includes 3 midwater trawlers which were authorised to fish, but not actively fishing during 2007. GRT
		Other vessels	*	*	*	*		
Vanuatu		Pelagic fishing vessels	Yes	4	Yes	2007		GRT
		Other vessels	*	*	*	*		
Chinese Taipei Fishing Entity		Pelagic fishing vessels	*	*	*	*		
		Other vessels	Yes	13	No	2007	Squid	Total GT for 13 squid vessels = 10159 GT
		Other Vessels	Yes	Between 13 - 29 vessels per year	No	1992 - 2006	Squid	Data not provided on the number of squid vessels per year, only on the range in number of vessels for the period 1992 - 2006

* Indicates no data provided to date

Annex D

Population Structure of the Chilean Jack Mackerel, *Trachurus murphyi*, in the South Pacific Ocean: Full Proposal for Discussion of International Joint Research

Draft proposal for the Jack Mackerel Sub-group of the Science Working Group (SWG), South Pacific Regional Fisheries Management Organization.

CONTENTS

Population structure of the Chilean jack mackerel, *Trachurus murphyi*, in the South Pacific Ocean: full proposal for discussion for an international joint research.

1. Background

The Science Working Group (SWG) of the RFMO agreed during the meeting held in Hobart, Tasmania, in the 2nd International Meeting, that the uncertainty in the stock structure of *Trachurus murphyi* was a key question to be addressed for future fisheries management.

An understanding of the number and distribution of any discrete stocks within the jack mackerel population is needed if yields are to be effectively estimated and the risk of localized depletion is to be minimized. This project aims to address this key information gap and determine the nature of any discrete stocks and appropriate management areas.

It was also indicated that the proposal should contain a wide-ranging study with samples from throughout the range of the species and that a multiple technique approach was needed to resolve the stock structure question with an acceptable degree of certainty.

The Science Working Group decided during the 3rd International Meeting held in Reñaca (Chile) to develop a proposal to investigate the stock structure of the jack mackerel and Rodolfo Serra from Chile and Alexander Glubokov from Russia were nominated as the Task Team for this purpose. In Chile the following scientists collaborated in developing the proposal: Ricardo Galleguillos, Marcelo Oliva, Aquiles Sepulveda, Fransisco Cerna, Ciro Oyarzun, Juan Carlos Quiroz; Juan Carlos Saavedra, Jaime Letelier, Samuel Hormazabal and Sergio Nuñez.

2. Distribution and present understanding of its stock structure

The Chilean jack mackerel is distributed throughout the southeastern Pacific, ranging from the Galapagos Islands and south of Ecuador to southern Chile. Its current distribution also extends from south-central Chile across the Pacific Ocean, to New Zealand and Tasmanian waters (Evseenko, 1987; Serra, 1991; Elizarov *et al.*, 1993; Taylor, 2002).

A large increase in abundance over the 20 years to 1991 has been reported (Serra, 1991; Elizarov *et al.*, 1993) which is believed to explain its wide present distribution. Serra (op. cit.) also described a seasonal migration between coastal and oceanic waters for the Chilean subpopulation, and related this to "reproductive and trophic processes". In Chilean fisheries, large jack mackerel tend to be more common toward the south. A similar tendency for there to be larger fish in southern waters is also seen in the New Zealand fishery (Taylor, in prep.).

The existence of up to three separate stocks of Chilean jack mackerel are suggested by the existing data collected throughout the range of this species. In South America there is evidence for at least separate Perúvian and Chilean stocks based on the results of genetic studies (Koval 1996), of generalized studies using distribution, abundance, size composition, and reproductive distributions (Evseenko 1987, Serra 1991, Storozhuk *et al.* 1987), and of studies of parasites (Oliva, 1999). There is also evidence for at least one stock in the high seas of South Pacific Ocean based on reproductive distributions (Evseenko 1987), and morphological and parasite information (Duran & Oliva 1983, Romero & Kuroki 1985, Kalchugin 1992, Avdeyev 1992; all in: Taylor, 2002; Kotenev *et al.*, 2006). The independence of the High Sea stocks from the South East Pacific Ocean straddling stock is an open question.

Evidence shows that following a strong increase in its abundance from the early 1970s, *T. murphyi* expanded its distribution along the southwestern coast of South America (Ecuador, Perú and Chile) and toward the west and crossed the Pacific Ocean along the West Wind Drift, reaching New Zealand waters in the early to mid 1980s (Bailey, 1989; Serra 1991; Elizarov *et al.* 1993; Taylor 2002).

Although a large population of *T. murphyi* has existed in New Zealand waters following its initial invasion sometime during the early to mid 1980s, there is little evidence to support the stock being self-sustaining. According to Taylor (2002), New Zealand waters appear to be conducive to the establishment of a self-sustaining stock, although analyses are compromised by inclusion of data for *T. declivis and T. novaezelandiae.* The widespread distribution of prey species in New Zealand waters and the highly adaptable feeding strategy of *T. murphyi* largely preclude the possibility of food being limiting and the reproductive condition of specimens sampled in New Zealand indicates a wide geographic range of fish in maturing and spawning condition. However, few juvenile specimens have been taken during the approximately 20 years that *T. murphyi* has been present in New Zealand waters and recent monitoring shows that this species is now less abundant at the surface than during the mid 1990s (Taylor in prep).

The diverse work done does not show a clear picture in regard with the stock structure and the results from different authors are not entirely consistent. However an important conclusion is that although the results show that the population of Chilean jack mackerel is not homogeneous, the boundaries of some identified stocks units are not clear. In conclusion present knowledge of the jack mackerel stock structure deserves further investigation to fully identify the number and extent of discrete stocks of jack mackerel over its entire range.

3. Objectives of the study

The overall objective is:

To determine the stock structure of *Trachurus murphyi* to inform future fisheries management.

The specific objectives are:

To describe the stock structure of Trachurus murphyi.
To define the discrete stock boundaries
To determine mixing rates among relevant stocks

4. Methods

The overall objective would be achieved by integrating the results of different techniques in a multi-methodological approach. This approach was applied in the HOMSIR project (Horse Mackerel Stock Identification Research; www-homsir.com). Waldman (1999) and Begg and Waldman (1999) discuss this approach, which represents "the state of the art" for stock identification. Due to the different requirements of each technique and variability in the scale at which stocks can be identified, the application of multiple techniques for stock identification may confirm a particular stock structure first detected by a single procedure used in isolation. Overlaying all available information from a range of techniques will enable a generalized and definitive pattern of stock structure to be developed in accordance with the needs of fishery management (Begg and Waldman, 1999).

It is proposed to use the following techniques to differentiate the stocks: genetic tags, morphometry (body and otolith), parasites, life history patterns including physiological adaptations, and microchemistry of otoliths.

Tagging jack mackerel to learn about its migration patterns and population structure was also evaluated but due the very high cost to tag fish all over its distribution (price of tags; vessel time) and that the time frame to get results due to the longevity of the jack mackerel exceed the other techniques and therefore was not included in this proposal.

There is a need to develop an agreed protocol for sampling and analytical procedures. To integrate the results obtained by different techniques it is preferable that the same specimens are used whenever possible. This will reduce the influence of individual differences and facilitate the identification of immigrants from other stocks. Also, if fish samples taken from different locations and are to be processed in different laboratories then standardization and intercalibration procedures will need to be undertaken. Finally, the statistical analyses to be applied need to be agreed.

5. General Sampling Scheme (spatial and temporal scales)

Two scales of variability exist: geographic and temporal. Therefore the samples have to be collected from throughout the range of the species (see the approximate sampling sites Figure 1) and on more than one occasion over at least one year. To learn about the intra and inter stock variability of the marker associated with each technique, periodic samples need to be collected, for example one sample per quarter and sampling location. However a general recommendation is that at least one set of samples should be taken during the spawning season to increase the chance of detecting discrete stocks and to minimize the influence of any mixing at other times of the year.

To learn about the seasonal variability of the markers and the influence of seasonal migrations, samples should also be taken out of the spawning season on the feeding grounds. Interannual variation is also important and therefore a two year sampling program is recommended to learn about the stability of the markers derived from the different techniques. Chile is developing an investigation with a similar approach and these results could be used as a guide to allow refinements to the sampling strategy. Finally, the number of samples taken during the year will be function of the available funds. Because interannual variation could be more important than seasonal variation for stock identification a final decision about a replicate sampling during the spawning season should be taken in accordance with available funds. One option is to consider the results of the Chilean project and others that might be available as a first step and present proposal as the second step. Participants in the research project should take final decision.

For the design of potential sampling locations present knowledge of the jack mackerel distribution and stock structure was considered. In **figure 1** an example of potential sampling locations throughout the distribution of jack mackerel are shown. There are 19 sites identified which includes five sampling locations between 110 and 170º W. Sampling from all sites in all seasons would be difficult due to the large distances and the high cost involved particularly in sampling between 110 and 170º W. But it would be important to get at least one sample from these locations during the spawning period. The relative larger number of sampling locations in southern Perú and northern Chile and between 90º and 130º W is explained by presumed stock boundaries.

The sampling program should be designed to collect adults, giving preference to a size range from 30 to 45 cm FL, to minimize the potential effects of fish size on the measured parameters. However, some samples of juveniles are also needed, particularly to identify any age-related migration patterns studies with otolith microchemistry, and some sampling locations should be selected for this purpose.

5.1 Sample size

The minimum size of each sample is 100 fish. This sample size is required for genetic analyses. For this technique and to support the results with α of 0.05 and β of 0.1 a sample size between 50 and 132 specimens per locality is needed (Richardson *et al.* 1986).

To assure 100 fish in good condition a sample of 120 adult fish of size between 30 and 45 cm FL is recommended. Jack mackerel of larger sizes exist but to minimize the size effect in the results this range is proposed.

Another complementary sample of 60 juveniles (equal and less than 20 cm FL) for microchemical analysis of otoliths is required from Central Perú, Northern Chile, South-Central Chile, mid South Pacific and New Zealand. The purpose of these samples is to allow reconstruction of life history migratory patterns.

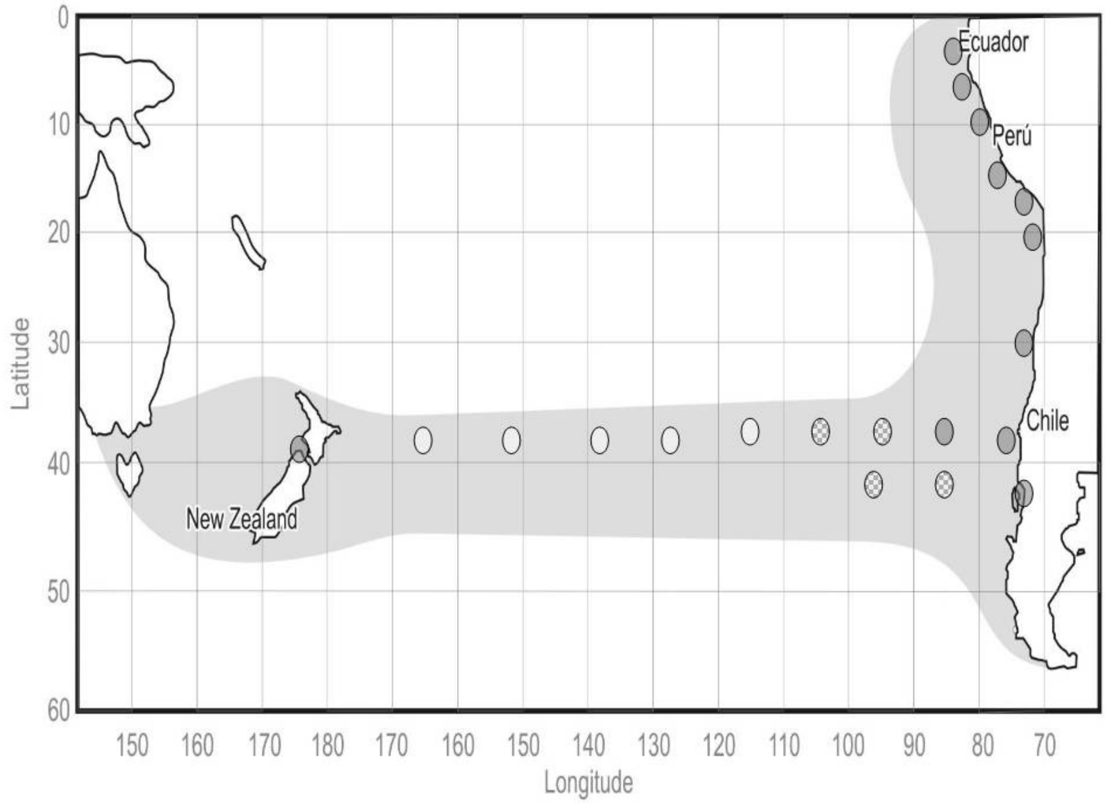

Figure 1. Distribution of jack mackerel (*Trachurus murphyi*) in the South Pacific Ocean and potential sampling locations. Darker circles indicate samples to be taken from coastal fisheries; circles with dots indicate samples from the international fleet; and empty circles indicate samples to be collected with a research vessel.

The information for each fish sampled that should be recorded is:

Geographical reference (name, Latitude and Longitude)
Number of fish (sequential)
Date
Fork length of fish (cm)
Total weight (gr)
Sex
Maturity

5.2 Sample Processing

To reduce the influence of individual variability on results the different pieces of information should come from the same fish, i.e. the body morphometry, otolith morphometry, tissue for genetics, parasites, and trace elements from otoliths should be obtained from the same fish.

Otoliths are fragile and need to be stored in suitable containers to avoid breakage.

6. Techniques

The techniques to be used are: body and otolith morphometry, genetics tags (mtDNA, msDNA), parasites, microchemistry of otoliths, and life history patterns which are discussed further down. Most of these techniques have been applied already to the jack mackerel to investigate the population structure but independently from each other. Exceptions are otolith morphometry, microchemistry and organ indices (hepatic, gonadosomático).

6.1 Morphometry

This technique will focus on the application of geometric morphometrics to describe variation in the shape of the body of jack mackerel and their otoliths, as a tool for the identification of intraspecific variation from different areas of the South Pacific.

6.1.1 Body morphometry

A few studies have been done to investigate the stock structure of the jack mackerel based on genetic and phenotypic characteristics. George-Nascimento and Arancibia (1992) described differences in parasites and morphometric features from individuals of three different fishing zones along the Chilean coast. Arancibia *et al.* (1995) conclude the existence of differences in the body morphometry of jack mackerel, comparing individuals collected from local fisheries from the north (Iquique) and the central zone of Chile.

Hernández *et al.* (1998) found significant differences in body shape and meristic counts of jack mackerel sampled in 5 localities along the Chilean coast during 1995 and 1996. However, simultaneous studies based on genetic tracers did not show evidences about the existence of different subpopulations between localities along the Chilean coast (Alay *et al.*, 1996).

Differences in morphological characteristics between putative stocks indicate that the stocks have spent some periods of their lives in different environments (Begg *et al.*, 1999; Cadrin, 2000) and therefore have the potential to develop different life history characteristics. But there is also a possibility that a high grade of interchange or heterogeneity exists that could be affected by environmental changes or life history trends. This could affect management strategies if assumed stock units prove not to be discrete. An example of this is the interannual differences in morphological characteristics of jack mackerel that are observed along the Chilean coast. Individuals from one locality in central-south Chile show significant differences with a locality in the north of Chile during years close to the El Niño event 1997-98, but no significant differences were found between morphometric characteristics of individuals from the localities in the north of Chile sampled 3 to 4 years before the occurrence of this event (Hernández *et al.*, 2007).

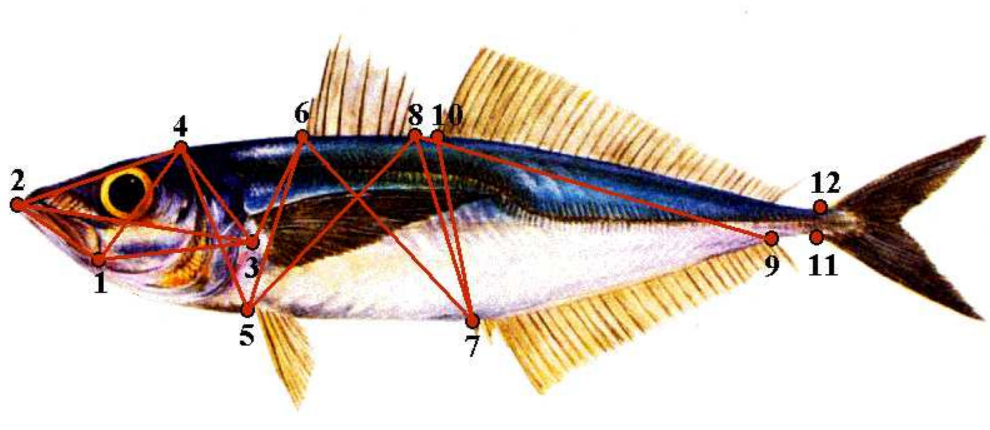

Figure 2. Morphometric measurements for *T. murphyi*.

6.1.1.1 Data

Morphometric measurements will be based on the methods proposed by Winans (1987) (**Figure 2**). But, it is suggested that the reduced set of measurements be used as selected by Arancibia *et al.* (1996) and Hernández *et al.* (1998), based on the work by George –Nascimento and Arancibia, (1992). These measurements correspond with the lines between following points: (1-2), (1-3), (1-4), (2-3), (2-4), (3-4), (3-6), (4-5), (5-6), (5-8), (6-7), (7-8), (7-10), (8-9). This lines needs to be measured with the precision of 1 mm.

This data should be obtained from a sample of 100 fish from each location.

6.1.1.2 Statistical analysis

In order to get morphometric measurements that are independent from the size of the fish transformation of the data is necessary. Both logarithmic transformation (Schaefer, 1991) and multivariate types (Winans, 1984; Cortes *et al.*, 1996) have been suggested but Hernandez *et al* (MS) indicates that the logarithmic transformation give better results.

Exploratory multivariate analysis will be used to find the measurements that explain the largest differences between locations, like multiple discriminatory analyses (Winans, 1987). Analysis of covariance will also be used to assess location and fish size effects

Multivariate analysis techniques like Principal Components Analysis (PCA) should be used to reduce and describe body shape measurements of different regions based on the first three PCA functions. Analysis of Covariance (ANCOVA) can be utilized to evaluate sources of variation due to effects like locality, year and season of the year, using as covariable the fork length (FL). Finally, discriminant analysis should be used to differentiate morphometric characters between regions.

6.1.2 Otolith morphology

Variations in otolith morphology have been defined as population-specific (Messieh 1972, Postuma 1974, McKern *et al.* 1974, Neilson *et al.* 1985, Smith 1992) and successful stock discriminations by means of otolith shape analyses have been reported for a range of temperate marine fishes (e.g., Bird *et al.*, 1986; Castonguay *et al.*, 1991; Casselman *et al.*, 1981; Smith, 1992; Campana and Casselman, 1993; Friedland and Reddin, 1994; Rätz, 1994; Colura and King, 1995; Begg *et al.*, 2001; Smith *et al.*, 2002). An application for the horse mackerel from the Northeast Atlantic and Mediterranean also exists (Turan, 2006; Stransky, in press).

The left otoliths should be used for morphological analysis and for age determination and the right otolith saved for microchemical analysis. To standardize morphological measurements the left otolith should be examined with the external face upwards and the rostrum to the right.

The techniques applied for stock differentiation can be divided in three categories. The first is the traditional one-dimensional linear measurements of size-related attributes, such as otolith length and width (e.g., Begg and Brown, 2000; Bergenious *et al.*, 2006; Bolles and Begg, 2000) and distances between specific features on the otolith (e.g., Turan, 2000). Internal otolith measurements, such as nucleus length (e.g., Messeih, 1972; Neilson *et al.*, 1985) and width of hyaline bands or increments (e.g., Begg *et al.*, 2001) also fall within this category. The second category include two-dimensional size measurements, such as area, perimeter (e.g., Campana and Casselman, 1993; Begg and Brown, 2000; Bolles and Begg, 2000) and different shape indices, including circularity and rectangularity (e.g., Friedland and Reddin, 1994; Begg and Brown, 2000; Bolles and Begg 2000, Tuset *et al.*, 2003). A third, more recent morphological technique examines the two-dimensional outline of otolith shape using Fourier analysis (e.g., Bird *et al.*, 1986; Smith, 1992; Campana and Casselman, 1993; Begg and Brown, 2000; Smith *et al.*, 2002; Stransky *et al.*, in press).

6.1.2.1 Morphological analysis

A microscope image (10x magnification) should be used to project onto a computer screen by using a video camera. From each otolith the area, length, perimeter, width and two shape indices (circularity and rectangularity) should be recorded by using an image analysis system (i.e. OPTIMAS, IMAGE PRO) (Bolles and Begg, 2000; Pothin *et al.*, 2006). Circularity should be measured as the squared of the otolith perimeter divided by its area. The perimeter of the otolith can be traced against the counter clockwise direction and digitized into more than one hundred x-y equidistant coordinates by using the distal edge of the otolith rostrum as a common starting point for the coordinates. Rectangularity should be calculated as the area of the otolith divided by the area of its minimum enclosing rectangle.

Fourier analysis produces a series of cosine and sine curves from the coordinates of a traced outline which, when added together, describe the outline of the traced form. The cosine and sine curves can be defined mathematically in a series of Fourier descriptors and used as variables to compare otolith shapes among individuals or potential stocks (Christopher and Waters, 1974; Younker and Ehrlich, 1977). The resultant set of complex numbers or descriptors should be subsequently normalized for differences in otolith position. The harmonics, called Fourier descriptors, can be used in combination with the other morphological variables and shape indices to compare otoliths between cohorts and among regions and subareas within regions. The main features of the otolith shape, however, are generally captured by the first 10-20 harmonics (e.g., Campana and Casselman, 1993; Friedland and Reddin, 1994). The minimum number of Fourier descriptors required to explain at least 90% of the recorded shape of the otoliths should be calculated similarly to the range-finding procedure of Smith *et al.* (2002). More than one hundred descriptors will be collected from two randomly selected otoliths from each subarea and cohort and then will be normalized for position, size and rotation as described above. These descriptors, therefore, will be used in the statistical analyses to compare the spatial and temporal patterns in otolith shape of *T. murphyi*.

6.1.2.2 Statistical analysis

i) one-dimensional linear measurements

A relationship between otolith shape and otolith growth rate (assumed to be correlated to fish length) may confound spatial or temporal differences in otolith shape (Campana and Casselman, 1993). To minimize effects of this potential correlation there are two recommendations: 1) include only fish in a very restricted range of fork length (FL) and same age (e.g. 5 years old), and 2) standardizing morphological variables by fish FL where a significant relationship existed between the variable and FL before further analyses. The effect of FL on each morphological variable will be examined by analysis of covariance (ANCOVA; Winer *et al.*, 1991). The primary interests in these analyses are 1) to test whether morphological variables differed with FL for any group of samples; and 2) if so, to test whether the slopes of regressions of morphological variable on FL are homogeneous among groups. If a significant regression is detected and homogeneous among groups, the effect of FL is removed from each measurement.

ii) multi-dimensional size measurements

Multivariate analysis of variance (MANOVA; Tabachnick and Fidell, 1983) is used to investigate the effects of sex (females, males) on otolith shape and to test for spatial and temporal differences in otolith shape.

A principal component (PC; Tabachnick and Fidell, 1983) analysis is done first on the combined data set of both the shape variables and Fourier harmonics to reduce the number of variables to be incorporated in the MANOVA. Wilk's lambda criterion is used to test for group differences. A posteriori univariate analysis of variance (ANOVA) is used to explore patterns for each of the PCs separately when significant effects are indicated in the MANOVA. The communalities and variable loadings of the PCs are subsequently examined.

Two forward stepwise canonical discriminant analyses (CDA) are computed by using the shape variables and Fourier harmonics to examine the otolith shape of *T. murphyi* in multivariate space and to investigate whether otolith shape could be used to classify samples to spatial scale and cohort of origin. The factor used as a separating variable in the CDA depended on the significant effects determined in the MANOVA (i.e., cohort, region, or subarea, or any interactions between these factors). The CDA is used in this way as a confirmatory technique.

iii) two-dimensional Fourier analysis
The Fourier transformation can be performed using Elliptical Fournier Analysis (EFA, Rohlf and Archie, 1984). Differences in Fourier descriptors can be tested by covariance analysis and allocated cross-validation into groups by discriminant analysis, specifically linear discriminant function analysis (Klecka, 1980). Otherwise, the average residuals from linear regressions of each Fourier descriptor on fish fork length can be compared in a set of multivariate technique (hierarchical cluster, detrended correspondence analysis and multidimensional scaling) to derive a detailed stock-specific comparison.

In this way, from reproduced outlines of the averages Fourier descriptors average otolith shapes stocks-specific are obtained. For all tests, the assumption of normality and homogeneity of variance for each morphological should be examined and some available transformations can be selected.

6.2 Genetic Markers

Many different genetic markers are available for research of genetic differentiation in populations of living marine resources. Each method has some advantages and disadvantages in relation for any particular question. Protein electrophoresis was introduced in the mid-1960s and remains a simple and powerful molecular tool in many ecological and evolutionary applications. These protein markers are particularly effective at addressing questions related to genetic identity, parentage and relationships among conspecific populations and application to the study of intermediate taxonomic levels (Avise, 2004; Koljonen and Wilmot, 2005). Genetic markers isolated from the DNA molecule are available for studies in population genetics. The mitocondrial DNA (mtDNA) is a small, double stranded circular DNA molecule. The molecule is around 16 000 base pairs long, and in animals contains 13 genes coding for proteins, and one noncoding control region, called D-loop in vertebrates. Mitocondrial DNA is an effective molecule to use for analysis of intraspecific genetic variation and genealogy. Nuclear DNA markers, as a single copy, and repetitive sequence markers, are very useful for population genetics studies. Nuclear DNA genes that encodes for protein products are single copy. The noncoding areas in the DNA molecule associated with genes are loci with highly repetitive DNA sequences termed microsatellites and minisatellites. Microsatellites loci are sequences between 1 and 6 base pairs in tandem repeat motif. A minisatellite locus typically shows 10 to 40 base pairs in length. This locus has high levels of genetic variability in terms of allelic diversity and heterozygosity. Microsatellite analysis is one of the favored genetics approach for the analysis of stock structure in fishes considering the amount of polymorphism in this loci, (Magoulas, 2005).

Population genetic studies on the jack mackerel

The first study on jack mackerel (*Trachurus murphyi*) was done in 1986. In this study 25 loci were analyzed, corresponding to 19 enzymes. The polymorphic systems analyzed to differentiate stocks correspond to four polymorphic enzymes. Samples from different locations inside the EEZ were analyzed,(Galleguillos and Torres, 1988).

Another study was done in 1994 and its main goal was the jack mackerel stock structure between 20º12'S-70º13'W and 45º20'S-73º37'W. A total of 23 loci were analyzed consequently, with the analysis of 15 enzymatic systems. Six polymorphic systems made the comparative study between stocks possible. No differences were found among the samples taken from northern to southern Chile (FIP-IT/ 94-19).

Nuclear DNA techniques were employed for the first time in 1996. In this study with the Restriction Fragment Length Polymorphism (RFLP) technique, the ITS-2 zone of a ribosomal gene was analyzed with a total of 600 pb. 11 restriction enzymes were trialed, of which 7 were used. The samples taken from Mocha Island (38º21'S-73º52'W), Juan Fernandez Island (33º30'S-79º39'W) and Iquique (20º12'S-70º13'W) off Chile, and in New Zealand and Tasmania did not show genetic differences using ITS-2. In addition, the control region and the ATCO gene from mtDNA were standardized for future investigations (Sepúlveda *et al.*, 1996).

In another study no differences was found in the DNA of jack mackerel from different localities off the Chilean coast and individuals collected in New Zealand and Australia (Sepúlveda *et al.*, 1998).

The fourth and last study was done in 2002 in which samples taken in Talcahuano, San Antonio and Iquique in Chile. The molecular techniques employed correspond to mtDNA and microsatellites DNA (msDNA). The results show a lack of genetic structure in *T. murphyi,* when different haplotypes found in the control region and 4 loci of the microsatellites are compared (Ojeda and Poulin, 2002). Similar results were obtained in 2004 which include samples taken also off New Zealand (Poulin *et al.*, 2004)

6.2.1 Population genetic methods

Different molecular approaches can be applied to study the population structure of *Trachurus murphyi*: microsatellite DNA, and molecular markers sequencing from mitocondrial DNA.

<u>MicrosatellitesDNA.</u>

Microsatellites loci are found in all prokaryote and eukaryote genomes. Due to their inherent very high levels of genetic variation they have become a very useful tool in stock identification studies. Microsatellites are considered to be neutral markers with no functional significance. Typically at least 4 to 10 microsatellite loci are screened in populations studies, however analysis of a large number of loci provide more information about the evolutionary history of populations.

One of the problems in applying microsatellites is the need to develop PCR primers for *Trachurus murphyi.* This is the first step for microsatellite analysis. It is possible to get PCR primers information from closely related species (heterologus primer) like *T. trachurus.* Four markers are available for *T. trachurus* (Kasapidis and Magoula, 2008). But more importantly, present research done in Chile has permitted the identification of specific markers for *T. murphyi.* At present 17 polymorphic microsatellites loci specific for *T. murpyhi* are available. This was obtained from a genomic library of specimens sampled off central Chile to investigate its stock structure. The repeat motifs isolated microsatellites from *T. murphyi* are: (CA)3, (ATG)4, (CATC)6 and (TAGA)4. It has been described that tetranucleotides could be more useful to differentiate the stock structure of the jack mackerel and which are now available. At present these markers have been standardized and are ready to be used over the entire jack mackerel distribution.

<u>Mitocondrial DNA.</u>

The D-loop region in the mtDNA has been selected in studies of population structure in several species. The amplified region can be studied by sequencing and is possible to screen a large number of individuals. In *Trachurus murphyi* the primers useful for the amplified D-loop region (TTCCACCTCTAACTCCCAAAGCTAGTAG)
(CCTGAAGTAGGAACCAGATG) have been described (Lee *et al.* 1995).

6.2.2 Statistical analysis

From the corrected microsatellite data for null alleles, the genotypic and allelic frequencies will be estimated for each loci. The observed heterozygosity can be directly compared to expected as a measure of deviation from Hardy-Weinberg equilibrium.

To establish the differentiation level between the different localities in the study, a molecular ANOVA (analysis of molecular variation AMOVA) of the allelic frequencies within and between the populations will be done based on Excoffier *et al.* (1982).

To differentiate the populations the "Fixation index" from Wright (1978) (FIT, FST, FIS, Hartl, 1980) will be calculated, which are based in a model of infinite alleles based on the variance (=θ) (Weir &

Cockerham, 1984); the levels of significance will be tested according to Workman & Niswander, (1970), using FSTAT (Goudet, 1995).

The genetic distance (Nei, 1978) will be estimated with a matrix of genetic distance versus geographic distance to assess the isolation by distance of the populations through the Mantel test (Mantel, 1967) using GENETIX v4.05 (Belkhir *et al.*, 2004).

The genotypic and allelic frequencies will be compared with a test for homogeneity between the sampled locations through a contingency table. The homogeneity will be verified with G-test (Whitmore, 2000). The significance level will be calculated for contingency table with a Monte Carlo method (1000 iteration) as was proposed by Roff & Bentzen (1989).

The distribution of the genotypic frequencies in the sampled locations will be analyzed with an exact test of population differentiation, under the null hypothesis "that the genotypic frequencies are identical between the populations". For this test a contingency table is considered with a Markov Chain Monte Carlo (MCMC) procedure. The value for P is estimated to determine the significance of each comparison for all the loci, with the Fisher exact test (Raymond & Rousset, 1995).

A demographic analysis will be done using the program BOTTLENECK (Piry *et al.*, 1999). It will be used to test the recent bottle neck events or effective decline of the population size by historical changes in the distribution of the allelic frequencies. For each loci 1000 permutations will be done to assess the two mutations models for microsatellites: IAM, infinite alleles model (Kimura & Crow, 1964); and SMM, scaled mutations model (Kimura & Ohta, 1978).

6.3 Parasites

Since the pioneer paper by Herrington *et al.* (1939), parasites have been successfully used as biological tags in population studies not only in marine and freshwater fish in order to evaluate stock discreteness, migratory movement and habitat (Moser, 1991; MacKenzie and Abaunza, 1998; Oliva 2001; Oliva and Ballon 2002; Oliva et al 2004), but also in molluscs, crustaceans and mammals (Balbuena *et al.*, 1995; González and Kroeck, 2000; Pascual and Hochberg 1996; Thompson and Margolis 1987, Oliva and Sanchez 2005).

As pointed out by MacKenzie and Abaunza (2005) the basic principle underlying the use of parasites (both metazoan and protistan) as biological tags is that fish can become infected with a particular parasitic species only when they come within the endemic area of that parasite. The host parasite association implies two kinds of parasites: those specific to the host that in turn represent an evolutionary system; and generalist parasites, close associated with an ecological process. In the first case we have an association in an evolutionary scale that can give important clues about population structure; in the second case we can get information on migratory movements. Other approaches imply that if infected fishes are found outside the endemic area of the parasite, we can infer that these fish had been within that area at some time in their past history (MacKenzie and Abaunza, 2005). In this case it is mandatory to know the exact distribution of that parasite species, a problem not easy to solve. The use of parasites as biological tags require meeting criteria that are well described and explained by Mckenzie and Abaunza (2005).

Parasites have been used successfully to identify the population structure in some marine fishes from Chile like hake *Merluccius gayi* (George -Nascimento 1996, Oliva and Ballon 2002), *Merluccius australis* (Gonzalez and Carvajal, 1994), red rockfish *Sebastes capensis* (Oliva and Gonzalez, 2004), anchovy *Engraulis ringens* (Valdivia et al, 2007), hoki *Macruronus magellanicus* (Oliva, 2001) and jack mackerel *Trachurus murphyi* (George-Nascimento 2000; Aldana et al 1995; Oliva 1999), among others. The problem of local variability in the parasite fauna of anchoveta was clarified by Chavez *et al.* (2007).

With regard to the jack mackerel, parasitological information is a little confusing because the analytical procedures used by different authors do not follow a common pattern. The most comprehensive studies are those by Oliva (1999) and George-Nascimento (2000). Both studies analyzed metazoan parasites in the jack mackerel along the Chilean and Perúvian coast (Oliva, 1999) and from Iquique to Valdivia (George-Nascimento 2000). The data of Oliva (1999) strong suggest two stocks (Central - Northern Perú and a unique stock along the Chilean coast) based on univariate analyses. George-Nascimento suggests two ecological stocks in Chilean waters: a northern and a southern stocks, based on a multivariate analysis, unfortunately, George-Nascimento (2000) pooled the northern and southern localities and did not analyze a potential latitudinal gradient. Unpublished re-analyses of Oliva's data (1999), based on multivariate analyses using not only parasites as explanatory variable but also fish length, shows that the difference is a function of fish length but not parasites.

6.3.1 Statistical analysis

A sample size of about 60 specimens needs to be taken from each locality. This sample size should ensure the presence in the sample of any metazoan parasites that are present in at least 5% of the population (McDaniel 1975). The sampling strategy should be focused on adults fish. Samples are recommended to be taken on a seasonal basis. The sampling strategy must be replicated at least once, thus two samples should be taken from each locality and each season separated by one year.

The percentage of infected fishes with a particular parasite species in the sample (the prevalence of infection) and the mean number of parasite individuals of a given species in each infected host (the intensity of infection) will be estimated according to Bush *et al.* (1997). Differences in these measures between sexes will not be considered.

Univariate techniques

Significance in potential differences in parasite population descriptor between localities should be explored, with a significance of $\alpha = 0.05$ for all statistics as follows:

- Prevalence of infection: should be assessed using a 2 * n contingency table with the G likelihood test or chi square test. The size of the table (n) is function of the number of sampling points.

- Mean intensity of infection: should be assessed with one-way ANOVA; the number of categories is function of the number of sampling points. Because parasites are typically over dispersed, the data need be transformed to log (n+1) in order to reduce variance by re-scaling the data.

Multivariate techniques

The univariate techniques permit the assessment of the differences for each parasite species but not for the parasite community structure. To evaluate if the community structure is a good predictor of the site of capture, two multivariate techniques can be used:

Exploratory analysis. A principal component analysis will allow us to explore potential association between different sampling points and their parasites. (Oliva and Ballon 2002).

Multivariate discriminant analysis will used to evaluate the discriminant (locality) capacity of the parasite community. (Oliva *et al.* 2005)

6.4 Otolith Microchemistry

Otoliths appear to be a good natural marker for fish populations. Unlike bones they are metabolically inert; once deposited otolith material is unlikely to be reabsorbed or altered (Campana and Gagné, 1995). Otoliths are predominantly composed of calcium and trace elements that are derived from the waters inhabited by the fish. Because water bodies often differ in the concentrations of trace elements, stock may often be distinguished by the chemical signature retained in otoliths (Begg and Waldman, 1999). A further advantage of the use of otoliths is that by analyzing selected portion of it, the trace elements signals can be associated with particular growth stages that can potentially be used to reconstruct migration patterns (Elsdon and Gillanders, 2003). This last method requires some studies to learn how environmental and biological factors (temperature, salinity, exposure time, ontogeny) affect the otolith chemistry for a proper interpretation of the fish migratory history, influences that seems to be species specific. Campana and Gagné (1995) found that otoliths elemental fingerprinting has the potential to become an effective and accurate means of stock identification for cod; Ashford, Arkhipkin and Jones (2006) validated this technique for examining population structure in Patagonian toothfish, demonstrating that otoliths nucleus chemistry can discriminate between stocks in a fully marine environment.

Stock mixing can also been investigated with this technique but first it must be shown that elemental fingerprints differ among stocks. Campana *et al.* (2000) demonstrated its effectiveness on cod.

Otoliths chemistry has been identified as a useful technique especially in cases where the genetics techniques has shown homogeneity while other techniques like life history patterns and parasites have suggested the existence of different stocks, for example in the Patagonian toothfish (Ashford, Arkhipkin and Jones, 2006).

The use of trace elements signature as natural tags makes three central assumptions (Campana *et al.* (2000):

There are characteristic and reproducible markers for each group
All possible groups contributing to the group mixture have been characterized
Markers remain stable over the interval between characterization and mixing

To avoid contamination the sagittal otolith pair has to be removed from the fish using plastic forceps, rinsed with distilled water to remove the tissue and blood, and stored in vials or paper bags. All otoliths need to be carefully treated in the laboratory before the trace element concentration analysis, to eliminate the risk of contamination. Detailed description of treatment procedures can be found in Campana and Gagné (1995), Campana *et al.* (2000) and Ashford *et al.* (2006).

A sample of 60 fish from each of 15 sampling areas and 60 juvenile fish from each of three sampling areas will be taken. Because fish from different spawning grounds may subsequently mix, large sample sizes enhance the ability to detect the underlying groups from their nucleus chemistry, and estimate the proportion occurring in each sampling area that derive from each spawning ground. This is especially important where proportions are small: because of spatial effects, fish in some areas - even though occurring in low numbers - can make disproportionately large contributions to subsequent generations.

6.4.1 Laboratory Procedures

We will use a Thermo Finnegan Element 2 double-focusing sector-field ICP-MS to examine otoliths for minor and trace element chemistry. Samples will be introduced in automated sequence (Chen *et al.* 2000) using a New Wave Merchantek UP-213 laser ablation system and a PFA microflow nebulizer. Ablated otolith material from the sample cell will be mixed in the spray chamber with HNO_3 aerosol introduced by the nebulizer, and the mixture carried to the ICP torch.

Laboratory calibration standards will consist of dissolved otolith reference material obtained from the National Research Council of Canada, similarly introduced to the spray chamber by the nebulizer as an aerosol before being carried to the ICP torch. Blanks of HNO_3 aerosol will also be used. To control for operational variability in the laser-ICPMS, our standard operating procedure is to use a randomized blocks design with each petrographic slide as the blocking factor, considered randomly drawn, and each sampling area considered a fixed treatment. Readings of count-rates (counts•s^{-1}) for blanks and references will be obtained before and after random presentation of the otolith sections in each block.

Otoliths will be analysed for ^{48}Ca, ^{25}Mg, ^{55}Mn, ^{88}Sr, and ^{138}Ba, and reported as ratios to ^{48}Ca. To calculate elemental Ca (Me•Ca^{-1}) ratios, background counts will be subtracted from otolith counts by interpolating between readings taken before and after each block of otoliths, and the corrected otolith counts will be converted to Me•Ca^{-1} concentrations using the references. To sample the nucleus, we will use a grid raster type with a laser beam of diameter 20 µm traveling at 6 µm•s^{-1}, set at 60% power and frequency at 10 Hz. This will give a predicted crater depth of approximately 100 µm (Jones and Chen 2003, equation 3).

6.4.2 Statistical Methods

A spatially discrete population structure implies fish in each area were spawned separately from those in other areas, and therefore were exposed to different early life environments. To test for these differences, we will apply analysis of variance (ANOVA), using separate univariate analyses to examine the behaviour of each element ratio. Multivariate outliers will be identified by plotting robust squared Mahalanobis distances of the residuals (D^2_i) against the corresponding quantiles (Q-Q plot) of the chi-square distribution, and the assumption of multivariate normality will be checked analytically using tests (α = 0.05) based on Mardia's multivariate skewness and kurtosis measures (Khattree and Naik 1999). If variance-covariance matrices are not equal, we will use univariate ANOVA for each Me•Ca^{-1} ratio instead, testing for univariate normality using the Kolmogorov-Smirnov test (α = 0.05) and equality of variances using the F_{max} test, with Student-Newman-Keuls (SNK) Multiple Range tests for pairwise comparisons between sampling areas, adjusted for an experiment-wise α.

Spatial heterogeneity can also result when fish, though spawned separately, then disperse and mix in different proportions between sampling areas. Therefore, to examine whether spatial heterogeneity is due to discrete populations or mixing of more than one, we will employ cluster analysis to detect fish crossing between sampling areas, using Ward's minimum variance hierarchical approach. To determine the quality of clustering, we will use root mean square standard deviation (RMSSTD), semi-partial R-square (SPRSQ), R-square (RSQ), and between-cluster sum-of-squares (BSS) to measure the loss of homogeneity through successive merging of clusters (Khattree and Naik 2000).

6.5 Life History Patterns

A fish stock may exhibit differences in one or more life history parameters compared to other stocks of the same species. According with Begg *et al.* (1999), vital population parameters, such as growth, survival, age-at-maturation, fecundity, and biological aspects such as distribution, abundance and spawning grounds are the consequences of life history modes to which fish stocks have evolved. Differences in these parameters and patterns have long been used to identify separate management stocks assuming that phenotypic variation is due to genotypic and environmental controls. In addition, differences in life history parameters are considered as an evidence of discrete stock units for management purposes (Ihssen *et al.*, 1981). Also other life history traits like size structure, maturity and fecundity express the interaction between the genetic background and environmental influences, and provide evidence for stock structure (Begg, 2005).

Serra (1991), based on the distribution of the abundance, seasonality (abundance, catch), spawning time, spawning ground and size structure, proposed the existence of two self-sustaining sub-population of jack mackerel within the Southeast Pacific Ocean, one located off Perú and the second off Chile extending into the high sea. Its results were supported by Oliva (1999) examining the parasites species composition.

With the goal of identifying the stock structure of jack mackerel, in this proposal a set of life history traits could be considered to study the spatial and temporal variability in the selected parameters and to discuss their contribution to the definition of the population structure. Biological information of jack mackerel related with the distribution of abundance, size-structure, fecundity and other reproductive indicators like eggs and larvae, reproductive season, condition factor, could be analyzed along its entire geographical distribution. The patterns in the distribution of the abundance and the size structure can provide further evidence in terms of recruitment and mortality processes; the otolith mass growth rate should provide further evidence of growth rate patterns variability, while batch fecundity, relative fecundity, and other indicators such as gonadosomatic and hepatosomatic indexes and condition factor, can provide evidence for population discreteness within an holistic approach for the identification of the stock structure.

6.5.1 Patterns in the distribution of abundance and size structure

The abundance and spawning distributions could also be considered. At present, a series of surveys and fishery-dependent information is available and it would be necessary to put this information in the context of spatial patterns that could help to verify the results found by Serra (1991) for the Southeast Pacific.

Time series of length-frequency data or catch-at-length data are also important to examine the size structure between areas and seasons. This kind of data allows the estimation of average length and the size range, and the identification of areas with concentrations of juveniles or adults.

In order to identify spatial patterns of distribution in abundance, spawning grounds, etc., the compilation of the information available in different countries needs to be done. This information is available in Ecuador, Perú, Chile, Russia, Ukraine, China, New Zealand, Vanuatu, Holland and Faroe Islands.

6.5.2 Reproductive indexes and others

A compilation of biological data, such as fork length, total weight, eviscerated weight, ovary weight, liver weight, parameters of the length-weight relationship, macroscopic and histological maturity stages allows for estimation of organ ratios like gonadosmatic index, condition factor, and muscle mass (e.g. Kjesbu *et al.* 1998, Ganias *et al.* 2007). These indexes will be explored depending on the availability of the specific data in each location.

6.5.3 Statistical analysis and methodological approach

Time series of reproductive indexes, gonadosomatic index, maturity stages, condition factor will be analyzed by using Generalized Additive Models (GAM), particularly the techniques available in the package 'mgcv' (Wood, 2000, Wood and Augustin, 2002; Wood, 2003) for the software and language R (Ihaka and Gentleman, 1996). Similarly, length frequency data will be analyzed by using Generalized Linear Models by using the package 'MASS' (Venables and Ripley, 2002). These techniques will take into account location as the main source of variation and other co-variable affecting the variable response. Similarly, ANOVA and MANOVA techniques will be applied for simple comparison of a single response variable.

6.6 Oceanographic Features

An important aspect to be considered is the oceanographic description of the jack mackerel habitat, in particular in association with the stock structure to be found, since physical processes might structure sub-populations acting as barriers that prevent population exchange or due to other factors like favouring areas for reproductive or feeding purposes. This might help in the interpretation of the stock structure of the jack mackerel.

The large distribution of the jack mackerel has been well described, particularly by the research done by Russia, Chile, Perú and New Zealand (see jack mackerel species profile). In this large distribution of the jack mackerel abundance is not homogeneous as can be inferred from the catches in the different fishing grounds and present knowledge from surveys. For example, the largest concentration of the resources seems to be in front of south-center Chile, and a second main concentration off central and northern Perú. What explains the concentration of the jack mackerel in the two areas? Oceanographic processes at the meso and macro scale might help to understand this. To have previous knowledge about the stock structure of the jack mackerel would facilitate in characterizing the environment of each stock which unfortunately is not the case. But working hypothesis would help.

6.6.1 Data

The data used for this purpose would come from research and fishing surveys, satellite and oceanographic buoys. From research and fishing surveys data on temperature, salinity, oxygen, chlorophyll and zooplankton can be obtained. From satellite sea surface temperature, wind, chlorophyll and sea level can be obtained. Available climatic maps might also be used.

An inventory of the available data and data sources is a first step and to have it in a data base a second and crucial step.

6.6.2 Method
Different statistical method should be used like

a) Spatial analysis with geostatistical tools and empirical orthogonal functions.
b) Time domain analysis like autocorrelations, cross correlation, vectorial correlation and empirical orthogonal functions.
c) Frequency domain analysis like spectral analysis, phase and coherence spectra.
d) Time-frequency domain analysis like wavelet and cross wavelet (Torrence and Compo, 1998; Torrence and Webster, 1999).

7. Integrated Analysis

For an integrated analysis of the results from all the techniques a similar approach as with the HOMSIR project could be followed. For the analysis of the results obtained it is necessary to take into account the nature and the temporal scale of each technique. Some of them have an evolutionary meaning, like the genetics, in which the time and the geographic scales are very important. The case of expanded distribution colonizing new areas could be an example. However when differences are found with any technique, those are true and the difference found has to be explained. Thus is important to note that only heterogeneity and not homogeneity can be demonstrated (Waldman, 1999).

The start is to examine the results, discussing and relating the different findings, taken into consideration the time scale (microevolution and macroevolution), the geographical factor and the oceanographic information.

Other options can be discussed during the development of the project.

8. Budget

Due to the inconveniency that the Task Team takes decision about the participation of the different parties in the research some considerations for a proper understanding of the budget are:

All the countries that fish for jack mackerel (coastal and distant flag vessels) and that are part of the RFMO negotiation process was assumed that would participate. These countries are Ecuador, Perú, Chile, New Zealand, Vanuatu, Russia, Holland, Faroe Islands and the Popular Republic of China.

It is also considered that all countries will participate in the five techniques identified, which are genetics, morphometry, parasites, microchemistry of otoliths and life history patterns. This means five scientists per country plus one for oceanographic aspects. In total six, have to be nominated to integrate the different working sub-groups. This do not exclude that a full team works in the project in each country.

The baseline for the calculations is a sample size of 100 fish per sampling site and a sampling exercise in the whole region. The sampling exercise involve the 15 sampling locations (Ecuador, Perú, Chile and N. Zealand), plus 3 samples extra of juveniles for microchemistry and 5 samples taken with a research vessel.

The cost of scientist and technicians was assumed that it would be financed by each country. Exceptions are additional man power for oceanography.

Two scenarios were developed, one with one sampling (main spawning season) and another with three sampling events (autumn, winter and main spawning season).

The cost to survey the zone between 100º and 170º W is identified separately due to its high cost and uncertainty.
After knowing the participating countries and number of scientists per country the budget can be adjusted easily.

An overall budget is described below for the two scenarios and a detailed description by method and item is given in Annex.

8.1 Scenario: One sampling exercise

	US$
Sampling	30070
Genetic technique	127500
Morphometry: body	18000
Morphometry: otolith	141298
Parasites technique	118500
Life history pattern	
Microchemistry of otolith	130604
Oceanography	14000
Workshops (travel)	1000000
Unforseen expenses (10%)	157997
SUBTOTAL	**1737969**

Research vessel samples

	US$
Sampling	44800
Genetic technique	42500
Morphometry: body	4000
Morphometry: otolith	4000
Parasites technique	5000
Life history pattern	
Microchemistry of otolith	12000
SUBTOTAL	**112300**

TOTAL	**1,850,269**

8.2 Scenario: Three sampling exercise

	US$
Sampling	90210
Genetic technique	382500
Morphometry: body	36000
Morphometry: otolith	159298
Parasites technique	235500
Life history pattern	
Microchemistry of otolith	333686
Oceanography	14000
Workshops (travel)	1192700
Unforseen expenses (10%)	244389
TOTAL	2,688,283

For total cost in this scenario the cost of the research vessel samples is added.

TOTAL US$	2,800,583

For each scenarios the cost of the research vessel operation should be added

8.3 Cost of research vessel to survey area from 120º W to 170ºW
(1 survey)

Research Vessel	US$
Research vessel cost 1	4,740,000
Research vessel cost 2	3,160,000

* Russian vessel: cost 1 or 2 depend on Russian funding for a CCAMLR survey

It is crucial for a final budget to know the number of participating countries and the techniques in which they will directly participate. Participants should be required to provide information on the intended participation in the program.

Participants should also provide information on their possible in kind and financial contributions to the research program.

ITEMISED BUDGET ESTIMATES

Budget description by item

Sampling

Exercise for sampling the fisheries 1 time

	US$
Input	2500
Technician	720
Sample transport in Perú	1500
Sample transport in Chile	1000
Sample transport from abroad	6500
Flight ticket (national)	3600
Per diem (US $100 day)	3600
Unforeseen expenses	2000
SUBTOTAL	21420

Exercise for sampling fishing vessels outside EEZ.
Assume no sample transport.

	US$
Input	1000
Technician	1250
Flight ticket	4600
Per diem (US $100 day)	1800
SUBTOTAL	8650

TOTAL 30070

Exercise for sampling in research vessel

	US$
Input	2000
Technician	400
Sample transport (5 samples)	34000
Flight ticket (international)	4600
Per diem (US $200 day)	1800
Unforeseen expenses	2000
TOTAL	44800

Cost of sampling in the fisheries plus research vessel

TOTAL sampling	74870

Exercise for sampling the fisheries 3 times

	US$
Input	7500
Technician	2160
Sample transport in Perú	4500
Sample transport in Chile	3000
Sample transport from abroad	19500
Fligth ticket (national)	10800
Per diem (US $100 day)	10800
Unforseen expenses	6000
SUBTOTAL	64260

Exercise for sampling fishing vessels outside EEZ.
Assume no samples transport.

	US$
Input	3000
Technician	3750
Fligth ticket	13800
Per diem	5400
SUBTOTAL	25950

TOTAL sampling 3 times	90210

TOTAL sampling plus research vessel	135010

GENETIC METHOD

1 sampling exercise: Coastal and International Fleet samples

Genetic method	
Laboratory inputs, DNA extraction, analysis	90000

Reading	37500
Subtotal	127500

Samples from 100º to 170º W

Genetic method	
Laboratory inputs, DNA extraction, analysis	30000
Reading	12500
Subtotal	42500

TOTAL	170000

Exercise for sampling the fisheries 3 times

Genetic method	
Laboratory inputs, DNA extraction, analysis	270000
Reading	112500
Subtotal	382500

TOTAL	425000

MORPHOMETRIC METHOD

Body morphometry

Exercise for sampling the fisheries 1 time

Morphometry: body	
	US$
Inputs	4500
Photographic camera	9000
Other	4500
SUBTOTAL	18000

Samples from 100º to 170º W

Morphometry: body	
Inputs, Photographic camera	2000
Other	2000
SUBTOTAL	4000

TOTAL	22000

Exercise for sampling the fisheries 3 times

	US$
Inputs	13500
Photographic camera	9000
Other	13500

SUBTOTAL	36000

Plus samples from 100º to 170º

TOTAL	40000

Otolith morphometry

Exercise for sampling the fisheries 1 time

	US$
Inputs	4500
Microscope	20000
Image Analyser*	102298
Analitical trade (0.1 mg)	10000
Other	4500
TOTAL	141298

*Considered for four countries

Samples from 100º to 170º W

	US$
Inputs	2000
Other	2000
SUBTOTAL	4000

TOTAL	145298

Exercise for sampling the fisheries 3 times

	US$
Inputs	13500
Microscope	20000
Image Analyser	102298
Analitical trade (0.1 mg)	10000
Other	13500
TOTAL	159298

Plus samples from 100º to 170º W

TOTAL	163298

PARASITES METHOD

Exercise for sampling the fisheries 1 time

	US$
Lab inputs	54000
Microscope	60000
Other	4500
SUBTOTAL	118500

Samples from 100º to 170º W

	US$
Lab inputs	4500
Other	500
SUBTOTAL	5000

TOTAL	123500

Exercise for sampling the fisheries 3 times

	US$
Lab inputs	162000
Microscope	60000
Other	13500
SUBTOTAL	235500

Plus samples from 100º to 170º W

TOTAL	240500

MICROCHEMISTRY OF OTOLITHS

Exercise for sampling the fisheries 1 time

	US$
Personnel	36571
Supplies, general expenses	6000
Otolith processing	43200
Travel	6204
Subtotal	91975
Indirect cost (42%)	38629
SUBTOTAL	130604

Samples from 100º to 170º W

	US$
Otolith processing	12000

TOTAL	142604

Exercise for sampling the fisheries 3 times

	US$
Personnel	101586
Supplies, general expenses	12000
Otolith processing	115200
Travel	6204
Subtotal	234990
Indirect cost (42%)	98696
TOTAL	333686

Plus samples from 100º to 170º W

TOTAL	345686

OCEANOGRAPHY

Calculated for four countries

	US$
Personnel (additional)	8000
1 PC	6000
TOTAL	14000

WORKSHOPS

It was considered as a minimum necessary to held five WS. These are one to initiate the project (planning, decisions on method and procedure), for progress review, one for analysis of results and write report on different methods, one to integrate the results from the different method and write report, a last to review final report.

Two additional meetings were considered necessary, one for life history patterns and the other for oceanography.

For the 3 times sampling scenario an additional WS was included (i.e. 6 WS)

Exercise for sampling the fisheries 1 time

	US$
Flight tickets	634500
Per diem	324000
Meeting expenses	5000
SUBTOTAL	963500

Additional Workshops (LHP, Oceanography)

	US$
Flight tickets	32900
Per diem	2800
Meeting expenses	800
SUBTOTAL	36500

TOTAL	1000000

Exercise for sampling the fisheries 3 times
(plus 1 more WS)

	US$
Flight tickets	761400
Per diem	388800
Meeting expenses	6000
SUBTOTAL	1156200

Plus additional Workshops (LHP, Oceanography)

TOTAL	1192700

9. References

Adams, P. B. 1980. Life history patterns in marine fishes and their consequences for fisheries management. *Fish. Bull.*, 78: 1-12.

Akkiran, N. 1985. A systematic study on Carangidae (Pisces) employing the otolith characters in the Eastern Mediterranean. *Bilj. Notes Inst. Oceanogr. Ribar.*, 63: 1-9.

Alay, F., F. González, J. Gavilán, J. Cabello y R. Chávez. 19974. Sección III. Genética. En: Unidades de Stock en el recurso jurel de la I a IX Regiones. *Informe Final Proyecto FIP 019-94.* 118 p.

Aldana, M. Oyarzun J. and M. George_Nascimento. 1995. Isopodos parasitos comoindicadores poblacionales del jurel *Trachurus symmetricus murphyi* (Nichols, 1920) (Pisces:Carangidae) frente a las costas de Chile. *Biología Pesquera* (Chile) 24:23-32

Arancibia, H, A. Hernández, L. Vilugrón, L. Cubillos, S. Núñez, R. Alarcón, L. Miranda y G. Vásquez. 1995. Sección I. Morfometría y Merística. En: Unidades de Stock en el recurso jurel de la I a IX Regiones. *Informe Final Proyecto FIP 019-94.* 118 p.

Araya, M., Cubillos, L.A., Guzmán, M., Peñailillo, J., Sepúlveda, A. 2001. Evidence of a relationship between age and otolith weight in the Chilean jack mackerel, *Trachurus symmetricus murphyi* (Nichols). *Fisheries Research*, 51: 17-26.

Ashford, J.R., A. I. Arkhipkin and C. M. Jones. 2006. Can the chemistry of otolith nuclei determine population structure of Patagonian toothfish *Dissostichus eleginoides*? *J. Fish Biol.*, 69: 708-721.

Avise, J.C. 2004. Molecular Markers, Natural History, and Evolution. Sinauer Associates Inc. 684pp.

Bailey, K. (1989). Description and surface distribution of juvenile Perúvian jack mackerel, *Trachurus murphyi*, Nichols from the subtropical convergence zone of the central South Pacific. *Fishery Bulletin*, 87: 273–278.

Balbuena, J.A., Aznar, F.J., Fernández M., Raga, J.A. 1995. Parasites as indicators of social structure and stock identity of marine mammals. In: Blinx, A.S., Walloe, L., Ultang, O (eds.) Whales, Seals, Fish and Man. *Developments in Marine Biology*, 4: 133-140.

Begg, G. A. 1998. A review of stock identification of haddock, Melanogrammus aeglefinus, in the northwest Atlantic ocean. *Mar. Fish. Rev.*, 60: 1-15.

Begg, G. A. and J. R. Waldman. 1999. An holistic approach to fish stock identification. *Fish. Res.*, : 35-44.

Begg, G. A., and R. W. Brown. 2000. Stock identification of haddock Melanogrammus aeglefinus on Georges Bank based on otolith shape analysis. *Trans. Am. Fish. Soc.*, 129: 935-945.

Begg, G. A., K. D. Friedland, and J. B. Pearce. 1999. Stock identification and its role in stock assessment and fisheries management: an overview. *Fish. Res.*, 43: 1-8.

Begg, G. A., W. J. Overholtz, and N. J. Munroe. 2001. The use of internal otolith morphometrics for identification of haddock (*Melanogrammus aeglefinus*) stocks on Georges Bank. *Fish. Bull.*, 99: 1-4.

Begg, G.A., Hare, J.A., Sheehan, D.D. 1999. The rol of life history parameters as indicators of stock structure. *Fisheries Research*, 43: 141-163

Begg, G.A. 2005. Life history parameters. In: Stock identification methods, applications in Fishery Science, Cadrin, S.X., Friedland, K.D., Waldman, J.R. (Ed.), Academic Press, San Diego, p. 119-159.

Bergenius, M. A. J., G. A. Begg, and B. D. Mapstone. 2006. The use of otolith morphology to indicate the stock structure of common coral trout (*Plectropomus leopardus*) on the Great Barrier Reef, Australia. *Fishery Bulletin*, 104: 498-511.

Bird, J. L., D. T. Eppler, and J. D. M. Checkley. 1986. Comparisons of herring otoliths using Fourier series shape analysis. *Can. J. Fish. Aquat. Sci.*, 43: 1228-1234.

Bolles, K. L., and G. A. Begg. 2000. Distinction between silver hake (Merluccius bilinearis) stocks in the U.S. waters of the northwest Atlantic based on whole otolith morphometrics. *Fish. Bull*., 98: 451-462.

Booke, H. E. 1999. The stock concept revisited: perspective on its history in fisheries. *Fish. Res*., 43: 9-11.

Bush AO, Lafferty KD, Lotz JM, Shostak AW (1997) Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *J. Parasitol*, 83**:** 575-583

Cadrin, S. X. 2000. Advances in morphometric identification of fishery stocks. Rev. Fish Biol. Fish. 10:91-112.

Campana, S. E., and J. M. Casselman. 1993. Stock discrimination using otolith shape analysis. Can. J. Fish. Aquat. Sci. 50:1062-1083.

Campana, S. E. and J. A. Gagné. 1995. Cod stock discrimination using ICPMS elemental assay of otoliths. In: D. H. Secor, J. M. Dean and S. E. Campana (eds.). 1995. Recent Developments in Fish Otolith Research. The Belle W. Baruch Library in Marine Science. Number 19. University of South Carolina Press. Pages 671-691.

Campana, S. E., G. A. Chouinard, J. M. Hanson, A. Frechet, J. Brattery. 2000. Otolith elemental fingerprints as biological tracers of fish stocks. *Fish. Res*., 46: 343-357.

Casselman, J.M., Collins, J.J., Crossman, E.J., Ihssen, P.E. and Spangler, G.R. 1981. Lake whitefish (Coregonus clupeaformis) stocks of the Ontario waters of Lake Huron. *Can. J.Fish. Aquat. Sci*., 38: 1772-1789.

Castonguay, M., P. Simard, and P. Gagnon. 1991. Usefulness of Fourier analysis of otolith shape for Atlantic mackerel (*Scomber scombrus*) stock discrimination. *Can. J. Fish. Aquat. Sci*., 48: 269-302.

Chavez R, Valdivia, I, y M E. Oliva 2007 Local variability in metazoan parasites of thepelagic fish species, *Engraulis ringens*: implications for fish stock assesment using parasites as bioloogical tags. *Journal of Helminthology* (in press).

Christopher, R. A., and J. A. Waters. 1974. Fourier series as a quantitative descriptor of miospore shape. *J. Palaeontol*., 48: 697-709.

Colura, R.L. and King, T.L. 1995. Using scale and otolith morphologies to separate spotted seatrout (Cynoscion nebulosus) collected from two areas within Galveston Bay. In: Secor, D.H., Dean, J.M. and Campana, S.E. (eds.): Recent developments in fish otolith research. University of South Carolina Press, Columbia, p. 617-628.

Elizarov, A.A.; Grechina, A.S.; Kotenev, B.N.; Kuzetsov, A.N. (1993). Perúvian jack mackerel, *Trachurus symmetricus murphyi*, in the open waters of the South Pacific. *Journal of Ichthyology,* 33: 86–104.

Elsdon, T.S. and B. M. Gillanders. 2003. Reconstructing migratory patterns of fish based on environmental influences on otolith chemistry. *Rev. Fish Biol. Fish*., 13: 219-235.

Evseenko, S.A. (1987). Reproduction of the Perúvian jack mackerel *Trachurus symmetricus murphyi* in the South Pacific. *Journal of Ichthyology 27*: 151–160.

FAO (Food and Agriculture Organization of the United Nations). 1995. Code of conduct for responsible fisheries. FAO, Rome, 41 p.

Friedland, K. D., and D. C. Reddin. 1994. Use of otolith morphology in stock discriminations of Atlantic salmon (Salmon salar). *Can. J. Fish. Aquat. Sci*., 51:91-98.

Galleguillos, R. Torres 1988.Identificación de unidades poblacionales pelágicas. Informe Final. Subsecretaria de Pesca. IFOP. PUC Talcahuano.

Ganias, K., Somarakis, S., Koutsikopoulos, C., Machias, A. 2007. Factors affecting the spawning period of sardine in two highly oligotrophic Seas. *Marine Biology* (in press). DOI 10.1007/s00227-006-0601-0

Garcia, S. M., and R. Grainger. 1997. Fisheries management and sustainability: a new perspective of an old problem? In Developing and sustaining world fisheries resources: the state of science and management: second world fisheries congress proceedings (D. A. Hancock, D. C. Smith, A. Grant, and J. P. Beumer, eds.), p. 631-654. CSIRO Publishing, Collingwood, Australia.

George-Nascimento M. y H. Arancibia. 1992. Stocks ecológicos del jurel (*Trachurus symmetricus murphyi* Nichols) en tres zonas de pesca frente a Chile, detectados mediante comparación de su fauna parasitaria y morfometría. *Revista Chilena Historia Natural*, 65: 453-470.

George -Nascimento, M. 1996. Populations and assemblages of metazoan parasites in thehake *Merluccius gayi* (Guichenot) (Gadiformes: Merluccidae) from the southeastern Pacific Ocean: Stock implications. *Journal of Fish Biology*, 48: 557-568

George-Nascimento, M. 2000. Geographical variations in the jack mackerel *Trachurus symmetricus murphyi* populations in the southeastern Pacific Ocean as evidenced from the associated parasite communities. *J. Parasitol.*, 86: 929-932.

Gonzalez, L. and J. Carvajal. 1994. Estudio parasitológico de Merluccius australis (Hutton, 1872) del mar interior de Aysen. Invest. Pesq. (Chile) 38: 75-85.

Gonzalez, R.A.and Kroeck, M.A. 2000. Enteric helminths of the short-fin squid *Illex argentinus* in San Matias Gulf (Argentina) as stock discriminants. *Acta Parasitologica*, 45: 89-93.

Hernández A., A. Sepúlveda y L. Miranda. 1998. Morfometría y merística del jurel (*Trachurus symmetricus murphyi*) a lo largo de Chile. En: D. Arcos (Ed) *Biología y ecología del jurel en aguas Chilenas*: 47-66.

Hernández A., A. Sepúlveda, L. Cubillos y L. Miranda. 2007. Diferenciación morfométrica del jurel a lo largo de Chile en el mediano plazo (1991-1999) (manuscrito).

Herrington W.C, Bearse, H.M. and Firth E.E. 1939. Observations on the life history,occurrence and distribution of the redfish parasite *Sphyrion lumpi. United States Bureau of Fisheries, Special Report*, 5:1-18

HOMSIR Project. www.homsir.com.

ICES (International Council for the Exploration of the Sea). 1997. Report of the study group on the precautionary approach to fisheries management. *ICES Council Meeting* (CM) 1997/assess 7, 41 p.

Informes Técnicos FIP 1996. Migración del Jurel desde y hacia la ZEE de Chile Central FIP-IT / 96-15. Instituto de Investigaciones Pesqueras.

Informes Técnicos FIP. 1994. Unidades de stock en el recurso Jurel de la I a la XI Regiones FIP-IT / 94-19.Instituto de Investigaciones Pesqueras.

Ihssen, P.E., Booke, H.E., Casselman, J.M., McGlade, J.M., Payne, N.R., Utter, F.M., 1981. Stock identification: materials and methods. *Can. J. Fish. Aquat. Sci*., 38: 1838-1855.

Ihaka, R., Gentleman, R., 1996. R: A language for data analysis and graphics. *Journal of Computational and Graphical Statistics*, 5: 299-314.

Jennings, S., J. D. Reynolds, and S. C. Mills. 1998. Life history correlates of responses to fisheries exploitation. *Proc. R. Soc. Lond*., B 265:333-339.

Kasapidis, P. and A. Magoulas. 2008. Development and application of microsatellites markers to address the population structure of the horse mackerel *Trachurus trachurus. Fish. Res*., 89: 132-135.

Kjesbu, O.S., Witthames, P.R., Solemdal, P., Walker, M.G. 1998. Temporal variations in the fecundity of Arcto-Norwegian cod (*Gadus morhua*) in response to natural changes and temperature. *Journal of Sea Research*, 40: 303-321.

Klecka, W.R. 1980. Discriminant Analysis. Sage Publications, Beverly Hills, CA. 290pp.

Koljonen,M.L R. Wilmot.2005 Genetics Análisis: Allozymes In: Stock identification methods. Applications in Fishery Science. Ed. S.X.Cadrin, K.D.Friedland,and J.R.Waldman. Academic Press. USA. 719 pp.

Kotenev, B. N., K. G. Kukhorenko and A. I. Glubokov. 2006. Main results of the Russian multidisciplinary ecosystem research, and exploratory fish-finding of concentyrations of hydrobionts and their fisheries development in the South Pacific. Scientific and Technical Documents for the First International Meeting concerning the establishment of the South Pacific Regional Fisheries Management Organization. Ministry for Agriculture of the Russian Federation. Federal Agency for Fisheries.

Koval, L.I. (1996). Polymorphic locus frequency in Perúvian horse mackerel and females intrapopulation heterogeneity in growth rate. *ICES Council Meeting Papers., ICES, Copenhagen (Denmark) CM 1996/H:35*, 9 pp.

Lee WJ, Conroy J, Howell WH, Kocher TD, 1995. Structure and evolution of teleost mitochondrial control region. *J Mol Evol*, 41**:** 54–66.

MacLean, J. A., and D. O. Evans. 1981. The stock concept, discreteness of fish stock, and fisheries management. *Can. J. Fish. Aquat. Sci*., 38:1889-1898.

MacKenzie K. and P. Abaunza (2005) Parasites as biological tags in (Cadrin, Friedland &Waldman eds) Stock identification methods: Applications in fisheries science. 211-226.

Magoulas, M .2005. Mitocondrial DNA. In Stock identification methods. Application in Science. Ed. S.X.Cadrin, K.D.Friedland,and J.R.Waldman.Elsevier Academic Press. USA. 719 pp.

Messeih, S. N. 1972. Use of otolith in identifying herring stocks in the southern Gulf of St. Lawrence and adjacent waters. *J. Fish. Res. Board Canada*, 29: 1113-1118.

McDaniel, D. 1975. Procedures for the detection and identification of certain fish pathogens. *Fish Health Section, American Fisheries Society*, 118 pp.

Moser, M. 1991. Parasites as biological tags. *Parasitol. Today*, 7: 182-185.

Neilson, J. D., G. H. Geen, and B. Chan. 1985. Variability in dimensions of salmonid otolith nuclei: implications for stock identification and microstructure interpretation. *Fish. Bull*., 83: 81-89.

Ojeda, P. and E. Poulin. 2002. Identificación de Unidades de stock del jurel (*Trachurus murpyi* Nichols) en el Pacífico Sudoriental mediante Análisis de marcadores Moleculares. Informe Final PUC.

Oliva M. 1999 Metazoan Parasites of the jack mackerel *Trachurus murphyi* Nichols, 1920 (Teleostei, Carangidae) in a latitudinal gradient from South America (Chile and Perú). *Parasites*, 6(3): 223-230.

Oliva M.E. 2001 Metazoan parasites of *Macruronus magellanicus* from southern Chile as Biological tags. Journal *Fish Biology*, 58: 1617-1622.

Oliva M and Ballón I. 2002 Parasites of the Chilean hake *Merluccius gayi* as a tool for stocks discrimination . *Fisheries Research*, 56: 313-320.

Oliva M. and Gonzalez M.T. 2004 Metazoan parasites of *Sebastes capensis* from two localities in northern Chile as tools for stock identification. *Journal of Fish Biology,* 64(1): 170 - 175.

Oliva M., Gonzalez M.T & E. Acuña.2004 Metazoan Parasite Fauna as Biological Tag for the Habitat of the Flounder *Hippoglossina macrops* from Northern Chile, in a Depth Gradient. *Journal of Parasitology*, 90:1374-1377

Oliva M.E & M. Sánchez 2005 Metazoan parasites and commensals of the northern Chilean scallop *Argopecten purpuratus* (Lamarck, 1819) as tools for stock identification. *Fisheries Research*, 71: 71-77

Pascual, S. And Hochberg, F.G. 1996. Marine parasites as biological tags of cephalopods hosts. *Parasitol. Today*, 12:324-327.

Postuma, K.H. 1974. The nucleus of the herring as a racial character. J.Cons.Int.Explor.Mer, 35(2):121-129.

Poulin, E., L. Cardenas, A. Silva, J. Juarez and P. Ojeda. 2004. The brief history of the Chilean jack mackerel: population genetic inference from mitochondrial DNA control regions. (Unpublished Manuscript).

Pino, C.A., Cubillos, L., Araya, M., Sepúlveda, A. 2004. Otolith weight as an estimator of age in the Patagonian grenadier *Macruronus megellanicus*, in central-south Chile. *Fisheries Research*, 66, 145-156.

Rätz, H.-J. 1994. Assessment of the migration of Atlantic cod (Gadus morhua L.) between the stocks off West and East Greenland in 1984-86 by means of otolith typing. *J.Northw.Atl.Fish.Sci*., 16:7-18.

Rohlf, F.J. and J. W. Archie. 1984. A comparison of Fournier methods for the description of wing shape in mosquitoes (Diptera: Culicidae). *Syst. Zool*., 33: 302-317.

Schaefer, K. 1991. Geographic variation in morphometrics characters and gill-raker counts of yellowfin tuna *Thunnus albacares* from the Pacific Ocean. *Fishery Bulletin*, U.S. 89:289-297.

Serra, R. (1991). Some important life history aspects of the Chilean jack mackerel, *Trachurus symmetricus murphyi*. *Invest. Pesq.* (Chile) 36: 67 - 83.

Sepúlveda, A., L. Cubillos, A. Grechina, H. Peña, L. Vilugrón, A. Hernández, L. Miranda, P. Sobarzo, R. Serra, M. Braun, G. Böhm, V. Valenzuela, R. Galleguillos, R. Montoya, R. Quiñones. 1998. Migración del jurel desde y hacia la ZEE de Chile central. Fondo de Investigación Pesquera, *Informe Final FIP*, 96-15: 273 p.

Smith, K. M. 1992. Regional differences in otolith morphology of the deep slope red snapper Etelis carbunculus. *Can. J. Fish. Aquat. Sci*., 49:795-804.

Smith, P. J., S. G. Robertson, P. L. Horn, B. Bull, O. F. Anderson, B. R. Stanton, and C. S. Oke. 2002. Multiple techniques for determining stock relationships between orange roughy, Holostethus atlanticus, fisheries in the eastern Tasman Sea. *Fish. Res*., 58:119-140.

Spanakis, E., N. Tsimenides y E. Zoures. 1989. Genetic difference between populations of sardine *Sardina pilchardus*, and anchovy *Engraulis encrasicolus*, in the Aegean and Ionian seas. *Journal of Fish Biology*, 35: 365-378.

Stephenson, R. L. 1999. Stock complexity in fisheries management: a perspective of emerging issues related to population sub-units. *Fish. Res*., 43:247-249.

Storozhuk, A.Y., K.A. Truveller, A.L. Baturin, I.B. Guleva y G.N. Nefedov. 1987. Estructura poblacional del jurel Perúano. En: D. Arcos y A. Grechina (eds.). 1994. Biología y Pesca Comercial del Jurel en el Pacífico Sur. Pp: 131-140.

Stransky, Ch., A. Munta, J. Schliekeisen and Ch. Zimmermann. In press. Otolith shape analysis as a tool for stock separation of horse mackerel (Trachurus trachurus) in the Northeast Atlantic and Mediterranean. Fisheries Research.

Tabachnick, B. G., and L. S. Fidell. 1983. Using multivariate statistics, 509 p. Harper and Row, Publishers, New York, NY.

Taylor, P.R. (2002). Stock structure and population biology of the Perúvian jack mackerel, *Trachurus symmetricus murphyi. New Zealand Fisheries Assessment Report 2002/21.* 78 p.

Taylor P.R. (in prep.) Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. symmetricus murphyi*, and *T. novaezelandiae*) in JMA 1, JMA 3, and JMA 7 during 2003–04. *Draft New Zealand Fisheries Assessment Report*.

Thompson, A.B. and Margolis, L. 1987. Determination of population discreteness in two species of shrimp, *Pandalus jordani* and *Pandalopsis dispar*, from coastal British Columbia using parasite tags and other population characteristics. *Can. J. Fish. Aquat. Sci*., 44: 982-989.

Turan, C. 2000. Otolith shape and meristic analysis of herring (*Clupea harengus*) in the North-East Atlantic. *Arch. Fish. Mar. Res*., 48:213-225.

Turan, C. 2006. The use of otolith shape and chemistry to determine stock structure of Mediterranean horse mackerel Trachurus mediterraneus (Steindachner). *Journal of Fish Biology* 69: 165–180.

Tuset, V. M., I. J. Lozano, J. A. Gonzalez, J. F. Pertusa, and M. M. Garcia-Diaz. 2003. Shape indices to identify regional differences in otolith morphology of comber, Serranus cabrilla. *J. Appl. Ichthyol*., 19:88-93.

Valdivia, I, Chavez R and M E. Oliva 2007 Metazoan Parasites of *Engraulis ringens* as tools for stock discrimination along the chilean coast. *Journal Fish Biology* (in press).

Venables, W.N.and B.D. Ripley. 2002. Modern Applied Statistics with S, 4th ed. Springer-Verlag, New York.

Winer, B. J., D. R, Brown, and K. M. Michels. 1991. Statistical procedures in experimental design, 3rd ed., 1057 p. McGraw-Hill, New York, NY.

Waldman, J. R. 1999. The importance of comparative studies in stock analysis. *Fish. Res*., 237-246.

Winans, G. 1987. Using morphometric and meristic characters for identifying stocks of fish. National Marine Fisheries Service Northwest and Alaska Fisheries Center. *NOAA Technical Memorandum NMI S-SEFC* 199: 25-62.

Wood, S.N., 2000. Modelling and smoothing parameter estimation with multiple quadratic Penalties. *J. R. Statist. Soc*., B 62, 413-428.

Wood, S.N., 2003. Thin-plate regression splines. *J. R. Statist. Soc*., B 65, 95-114.

Wood, S.N., Augustin, N.H., 2002. GAMs with integrated model selection using penalized regression splines and applications to environmental modelling. *Ecological Modelling*, 157, 157-177

Younker, J. L., and R. Ehrlich. 1977. Fourier biometrics: harmonic amplitudes as multivariate shape descriptors. *Syst. Zool.* 26:336-342.