International Consultations on the Establishment of the
South Pacific Regional Fisheries Management Organisation

CHILEAN JACK MACKEREL MANAGEMENT SYSTEM

SYNTHESIS AND RECOMMENDATION

I. INTRODUCTION

Jack mackerel has been present in the Chilean catch statistics since the 1950´s mainly by artisanal fishermen first and by industrial vessels later. At present, it is one of the most important industrial fisheries in the country, accounting for almost of the 85% of the total jack mackerel catches in the **FAO 87** statistical area.

The importance of the jack mackerel fishery in the economic and social term for Chile, the resource has been the subject of an extensive and priority research program since 1990. This ambitious research program was stablished by the Chilean Government under the Fishing Act statement and through a public research funding system managed by the Fisheries Research Council. At present, more than 70 specific projects on different subject involving jack mackerel are been carried out by different Universities and private research teams throughout the country. The main feature of this research program, managed by the Fisheries Research Council, is that is based on a peer review system. Scientific results have given rise a significant number of peer reviewed publications in domestic and foreign journals with an editorial board.

Scientific data obtained through the research program has been basically used to support all the fisheries management and administrative decisions made by the Chilean Fisheries Authorities, according to the Fishing Act.

The Jack Mackerel fishery has gone through different stages in its development, from its beginnings in the 1970s to its full exploitation in the 1990s, overexploitation in the early 2000s, until an stable population level in 2007.

Since 1998, a series of drastic administrative decisions have been introduced into the fishery, such a reduction of the fishing effort by more than 50%, a conservative Total Allowable Catch, with the lowest risk percentage possible, the introduction of individual transferable quota per fishing ship owner (ITQ); and, consequently, an increase in the annual research budget, in order to increase hydroacoustic surveys and egg production method studies, both as a direct measure of jack mackerel biomass.

The above has involved a substantial social and economic effort by the government, fishing industry, in order to bring this fishery back to a reasonable fishing level, so as to achieve the sustainability of this important activity.

In summary, this mean that for the last 30 years Chile has managed this fishery according to conservative and sustainability principles. Therefore, the fishing fleets had have to adapt technologically to those changes moving from the initial coastal fishery activity, and to recently expanded to an oceanic fishery. Fish processing is carried out exclusively in fish plant located close to the land, a fact that has a large social well-being. The Fishing Act declared the jack macherel fishery to be in a state of fully exploitation, consequently it determined the fishing effort for periods. El Niño 96-97 event, one of the strongest in a decade, had not only affected small pelagic fisheries but large pelagics and highly straddling fishery too, as is the case with the jack mackerel.

Consequentely, the Fishery Authority decreed an adequate biomass quota and the Industry had to adjust the fishing effort accordingly. Simultaneously, an individual transferable quota was stablished for this fishery. Scientific research on jack mackerel populations has been used to support all the administrative decisions adopted by the Undersecretariat of Fishery.

. In this context, as with any fishery under exploitation, determining the level of surplus biomass to be harvested each year is of utmost significance. Therefore, all fishing states need to devote time and to invest financial resources with the sole purpose of keeping the fishery at a sustainable level.

Stock assessment method, on the other hand, are the key issue in any population analysis that undoubtedly involve the use of statistical modeling estimations, in order to make predictions on the reaction of a certain fish population to alternative management choices. This, in turn, is the main issue that any fishery management system has to face: turning numbers into quantitative and useful figures and, most importantly, turning these figures into useful choices.

Therefore, the basic concern here goes beyond predictions and methodologies. The scientific community knows very well that large efforts have been made in this sense as well as the risk, and often embarrassing business, of predicting settings where there are no management choices to be made except, perhaps, as an aid to scientific thinking and the formulation of hypotheses.

On the other hand, it is widely accepted that the fundamental purpose of fisheries management is to ensure sustainable production over time from a well-defined fish stock. Practically all management actions apply to a certain area of the fishing activities limited to a particular habitat, and this is not just a matter of yes-or-no decisions; it is also a matter of degrees in the quantitative choices on about the results of fishing, catch limits, and ultimately the balance between financial resources, regulation and production.

The SWG´s report of the Chilean Jack Mackerel Workshop of the South Pacific Regional Fisheries Management Organization held in Santiago, Chile from June 30 to July 4, 2008 has developed different working hypotheses on the stock structure of jack

mackerel in the South Pacific Ocean, acknowledging that future jack mackerel stock assessments have to discriminate and choose from among those hypotheses using in the analysis or employ a combination of hypothesis.

The aim of this document is to describe the Chilean Scientific Committee point of view on the Jack mackerel stock assessment and the Chilean decision making process according to the regulations established in the Chilean Fishing Act.

II. CHILEAN JACK MACKEREL BIOMASS ASSESSMENT PERFORMANCE

Stock assessments that Chile considered for its fishing administration and management included a series of data collected from the fishery from 1975 to 2007. Fishing information inside and outside the EEZ by national and international vessels was also included. In this context, catch information from the former USSR fleet between 1979 and 1992, and recently by the People's Republic of China, Vanuatu, Holland and the Faroe Islands were also taken into account in order to estimate the exploitable biomass for the entire area (Table 1).

The relevant information considered in this analysis includes the age composition of the catches by zone or fleet, landings, and a series of direct or indirect indicators such as the biomass evaluated through hydroacoustic surveys and the spawning biomass using the Daily Egg Production Method (DEPM).

The catch statistics of jack mackerel for the different fishing areas and fleets (national and international), if available, have also been considered in the stock assessment. Information on Chilean catches is based on statistics from official data provided by National Fisheries Service for the full time series. However, information collected by IFOP (Instituto de Fomento Pesquero) for 1975-2001, INPESCA (Fisheries Research Institute) for 1989-2007; and data from the former URRS fleet based on catch statistics as a result of their fleet operation in the Southeast Pacific Ocean for the period

1978-1992 have also been partially used. Data from the People's Republic of China fleet was also included using information provided at bilateral meetings with Chile, as well as data from other countries during meetings of the SWG from the SPRFMO (Canales & Serra, 2008).

Table 1. International landings (tons) used in stock assessment

Year	China	Holland	Vanuatu	Faroe I.	Total
2001					
2002	76,261				76,261
2003	96,000		53,959		149,959
2004	130,000		94,685		224,685
2005	130,000	5,381	53,711		189,092
2006	130,000	67,532	91,879		289,411
2007	130,000	67,532	91,879	29,221	318,632

A noticeable fact in the above table are the stable catch level reported by China, Holland and Vanuatu in recent years.

Jack mackerel stock assessment for the period 1975 -2007 covers the following specific information:

- Catch-at-age matrix by zone. The catch-at-age matrix included data generated through a permanent sampling of fish size and otoliths at the landing ports. The size composition of the Soviet fleet catch (obtained by INPESCA from VNIRO) is also included. Due to the lack of catch-at-age matrix from the former Soviet Union fleet, the size composition was subsequently converted into age using an age-length key from the major Chilean fishery spot located off the center-south fishing area. This is supported by the similarity of the size composition of catches

made by both fleets, due to the inshore and offshore seasonal ontogenetic migration of jack mackerel.

- Mean weight at age matrix, which is estimated considering the mean length at age and the length-weight relationship.

- Biomass from acoustic surveys (1997-2007) and its corresponding age compositions.

- CPUE index in the Centre-South Zone 1996-2003. The assessment does not include the CPUE as it 2004 because this index was strongly affected by regulations imposed to the fishery.

- Spawning biomass for the years 1999-2001 and 2003-2006 estimated from eggs surveys and the daily egg production method (DEPM).

- Sexual maturity function which defines as immature specimens of aged 3 and younger, while mature individuals are those aged 6 and older. Specimens aged 4, 5 and 6 are considered to have reached a sexual maturity of 4%, 50% and 96% respectively.

- The natural mortality rate is assumed to be constant between the ages and years with a value of M=0.23 per year.

Each year, prior to submitting its recommendation to the authorities, the Chilean Jack Mackerel Scientific Committe, analyzes and discusse the above information and topics, which are usually taken into account in the annual analysis on the status of the jack mackerel populations. The information analyzes the following topics:

1.- Stock structure
2.- Stock Unit
3.- Fishery Dependent Index
    Main indicators
    Catch evolution
    Spatial pattern of the jack mackerel fishery
    Size structure of catches in the north and south fishery unit
    Modal size structure
        Analysis of small sizes in the catches
    Annual historical catches and size composition
    Analysis of Abundance Index
4.- Fishery Independent Index
    Hydroacoustic Biomass
    Egg Production Method
5.- Assessment Model
    Analysis of the related assessment output
    Model fit
    Abundance, recruitment and biomass
    Fish Mortality and Exploitation Index rates
    Spawning Biomass

The above information and their results as also been presented and analyzed in the Scientific Working Group (SWG) of the SPRFMO and in the Pelagic Subgroup.

According to Canales & Serra 2008, the current status of the Jack mackerel fishery shows a apparently declining trend in its spawning biomass and recruitment together with an increasing trend in recent years in its explotation index, mainly due to the increasing catch and operations of distant water fisihing vessels off the Chilean EEZ .

Table 2. Summary of the jack mackerel stock evaluation per hypothesis.

Hypothesis	SSB (ton)	SSB/SSBo	-log Like	p	AIC
S1=Distribution change	4,807,400	0.2697	4,360	61	8842
S2= Contraction of biomass distribution	4,083,400	0.2418	4,372	63	8871

SSB: Spawning biomass, SSBo: Virginal Spawning biomass, -log Like: - log likelihood, p: parameters number, AIC: Akaike information criterion

They have reviewed two different scenarios (Table 2) change in the distribution and contraction on biomass distribution on the south pacific. Both comes out within a range of 4.8 - 4.1 M.Ton. Simply stated, this means that the current fishery scenario presents a high risk for the stock and to achieve the sustainability of the fishery in the future.

III.- ANALYSIS OF THE JACK MACKEREL POPULATION

In order to define “stock unit” it is necessary to consider, first the concept of homogeneity and isolation of the fish population. The main feature of a stock unit is the self-sustainability of the population, with a limited migration between other stock units.

Considering that Chilean Jack Mackerel has a broad area of distribution in the South Pacific Ocean and within which it develops ontogenetic migration, the null hypothesis should consider a stock unit large enough so that population growth and mortality exceed migration (Hilborn and Walters, 1992).

The stock unit concept by itself include the self-sustainability of a homogenous fish population where individuals have the same growth opportunities and at the same

chances mortality or probability of dying either by natural causes or through removal by fishing.

However, any large fish population living in an extended area will certainly show different in terms of the fish batch population with different growth rates, age, migration patterns, different reaction to fishing intensity and also different reproductive indexes. Therefore, before accepting or rejecting the existance of one or several stock units in a single species population, it is essential to emply a population structure conceptual model (Arcos, 2001) that allows us to account for the different population indexes observed in the fish population within the extended area.

Serra (1991) in this context, based on distribution, abundance, landing site, catches, size composition and reproductive index proposes the existence of two jack mackerel subpopulations in the Southeast Pacific Ocean: one off northern Peru and another off the coast of Chile, both with an oceanic fraction according to the operational records of the international fleet off the Economic Exclusive Zone of Chile and Peru.

This concept was also analyzed by Arcos et al. (2001), to propose that the jack mackerel populations in the South Pacific are characterized by a spawning area, a coastal feeding habitat, and a recruitment area.

Results have also been published with findings on the differences between individual catches in north and centre-south Chilean waters. This research study published by George-Nascimento and Arancibia (1992) and Hernández et al. (1998) is based on the ecological or dynamic stock population concept, instead of the self-sustainability of the fish population, using the parasitic fauna and morphometry of the individuals.

The authors finally concluded that Jack mackerel caught in the northern part of Chilean waters have a different life history compared to the southern individuals, mainly

due to the large ontogenetic migration that occurs in the Southeastern Pacific Ocean. Similar results were also informed by Arancibia et al., (1995) and Hernández & Sepulveda (1999).

The self-sustainability of the population and the life history cycle drawn from the Chilean and Russian information in the South Pacific Ocean were the main reasons that the Chilean Jack mackerel Scientific Committee has accepted to work in the biomass assessment with a single stock unit for the Jack Mackerel populations off Chilean EEZ and the high seas and, consequently, the prediction model; after that, management decisions according with the fishing act have been made under this stock scenario: the single stock population.

However, the large spatial distribution of the jack mackerel in the South Pacific Ocean, the large spatial habitat where it´s distribute, would increase the uncertainty of the scientific information. To overcome this issue would mean that it is completely necessary to require an increase in the scientific observations in the South Pacific Ocean.

IV. JACK MACKEREL SPATIAL PATTERN DISTRIBUTION

The present population information analyzed (Arcos & Grechina, 1994) and the large spatial area covered by the Jack Mackerel means that this species use different habitats in its distribution as an energy strategy: warm waters for spawning, enriched waters for feeding and a relatively stable environment for recruitment. Warm waters can be found related to the anticyclonic gyre in the Southeast Pacific Ocean; enrichment waters with high food concentration can also be found related to upwelling ecosystem areas on the coast off Peru and Chile; an stable environment can be found in areas of low kinetic energy associated to the Chile-Peru current system (Grechina et.al. , 2008).

Grechina (1998) analyzed the spatial distribution of each catching tow in 1980-1990 by the former Soviet Union high seas fleet in the Southeast Pacific Ocean. The observations showed that juveniles concentrated more often off the coast of Peru and northern Chile in the eastern part of the Pacific Ocean, extended to 120ºW. According to this information, juveniles under 20 cm are usually found in an area towards the east and north of 30ºS.

This information also allow to conclude that in the east portion of the Pacific and south of 30ºS, largest size of jack mackerel are usually found. One remarkable fact to notice here is that Jack mackerel reaches its first sexual maturity at a size close to 25cm. Therefore, individuals over the 25cm which are usually found south of 30ºS are able to carry out ontogenetic migration from the coast to the high seas for spawning.

Serra (1991) and Arcos et al. (2001) showed that ontogenetic migration is driven by the following processes: first, feeding activity in the coastal area clearly under upwelling productive influence and, second, by the reproductive spawning process in the high seas within warm waters and third, an active migration process between those areas.

The upwelling region off the central coast of Chile (33º-40ºS) is commonly recognized as the main feeding ground in late summer, autumn and early winter (Quiñones et al., 1997; Miranda et al., 1998). Thus, the newly recruited juvenile fraction reaches this area at the beginning of the cycle, feeds in the coastal waters and migrates to high and warm waters. Spawning apparently takes place along the Southeast Pacific Ocean boundary system, either in coastal warm waters influenced by the upwelling front or in warm oceanic waters related to the border of the Southeast Pacific anticyclonic gyre (Evseenko, 1987; Grechina, 1998; Grechina et al., 1998). However, south of 30ºS the spawning area can be found up to 100ºW. Nevertheless, Grechina (1998), and Elizarov et al. (1993) informed of an egg and larvae high-concentration focus as far as

160°W using information from 10 icthyoplankton cruises undertaken by the former Soviet Union between 1980 and 1989.

According to the above authors, this egg and larvae distribution is closely related to intermediate waters located between the subantarctic and subtropical fronts (Grechina, 1998, Grechina et al., 1998).

Recent information has confirmed that the main spawning area of Jack mackerel within the Southeast Pacific Ocean has not changed significantly, having extended towards the west of 80°W and north of 38°S (Sepúlveda et al., 2000).

The reproductive index has shown that jack mackerel spawns in spring, usually from September to November, depending on the ocean waters and, some years spawning extends to early autumn (Grechina et al., 1998; Oyarzún et al., 1998; Aracena et al., 1998).

Using all the information available, Arcos et al. (2001) have drawn the following habitat and migration circuit:

a) An oceanic breeding area in the boundary of the Southeast Pacific Ocean with an identified spawning spot between 35°-40°S, extending as far as 120°W;
b) A coastal feeding area off the central and north coast of Chile and south and north of the Peruvian coast, always related to a major upwelling focus and high productivity waters.
c) Finally, a recruitment area related to warm waters located around the anticyclonic gyre of the Southeast Pacific Ocean.

Considering that the migration pattern of Jack mackerel usually involves a significant fraction of the whole population and this migration would occurs under regular periodicity as the result of a split and spare habitat in the South Pacific (Wooton, 1992),

movements from one habitat to another should determine seasonal behavior observed on the fishing ground, as shown by fleet catches in the South Pacific.

In this migration behavior, another spatial distribution pattern could be easily detected, according to different times and spatial seasonal scales; and this should also be related to an ecological energy advantage in a balance between costs and benefits of each habitat. It is also believed that this balance could change in different life cycle stages, which is enough reason to associate each habitat to the amount of energy that the individual uses during its life cycle.

The main characteristic of the conceptual framework described above is its explanatory capability, when the biological processes that explain the self-sustainability of the population are integrated.

In fact, the main spawning area of Jack mackerel is the oceanic waters located around the southeast anticyclonic gyre in the South Pacific (90°-82°W, 34°S-38°S, Sepulveda et al., 1999; FIP 2000-10). The spawning season is restricted to spring (Southern Hemisphere), when the intensification of the high pressure cell occurred inducing upwelling in the coast; therefore, the eggs and larvae are dynamically kept through an active water transport induced by the oceanic branch of the Chile-Peru current systems.

The result of those processes is that juveniles are transported towards the northern warm waters. On the other hand, as the individuals grow, they have to migrate towards areas with high abundance of adequate high food concentration, i.e.- the upwelling ground off the Peruvian coast or the northern Chilean coast. This energy accumulation strategy became plausible, considering the energy spent in swimming and sexual maturity.

This conceptual framework also account very well for the changes in the availability of Jack mackerel in the fishing ground, supported by changes in size structures as observed during warm and cold periods in the South Pacific. During El Niño event warm waters are advected southwards through Kelvin waves. Depending on the strength of the El Niño event, there would be a large or small juvenile proportion in the catches made by the southern fishing fleet off the south of Chile. As they approach the size of first sexual maturity, Jack mackerel apparently tend to remain in southern waters until migration takes place and the oceanographic condition segregates the new annual class (Arcos et al., 2001).

The large individual concentration found in winter in the central south waters could be explained by the energy accumulation strategy used by this species before migrating offshore for spawning, and it also explains the lack of significant individual concentration along the coastal waters during spring.

V. CHILEAN FISHERIES UNDERSECRETARIAT: DECISION MAKING PROCESS

The management of Chilean fisheries are carried out under the provision of the Fishing Act enacted in 1991. Specifically in the jack mackerel fishery, administrative regulations have been applied since 1980. These regulations have posed a challenge for the structure of scientific research.

Since jack mackerel is a highly straddling population which undergoes ontogenetic migrations, spatially distributed in Southeast Pacific Ocean, the Chilean fishing fleet operates within the EEZ or, in some periods, in oceanic waters beyond the EEZ. According to Chilean Fishing Act, all regulations subscribed and approved in order to manage the fishery are applied wherever the fleet operates, either in the EEZ or in oceanic waters beyond the EEZ.

Therefore, scientific studies have been conducted using the information available in both areas to ensure the sustainability of the resource, despite the economic and social cost involves.

The procedure adopted by the Fisheries Authority to administrate and manage this fishery have been dealt with through the following procedure:

1.- Determination of a fishing mortality criteria according to biological reference points, risk levels to reach such criteria, and at different levels of exploitation in line with international fish populations standards recommendations.

2.- Determination of a Total Allowable Catch based on the best information available pursuant to the criteria described above. This management measure is adopted by the Chilean Fishery Authority with the prior aproval of the Chilean Fishery Council.

3.- Once the TAC has been stablished as outlined above, maximun catch limit per ship owner are applied.

After this procedure, the annual TAC is passed, and the official decret is published.

Alternatively, the Fisheries Authority has also implemented the following technical actions on the fishery:

1.- effective control on fishing effort, which in turn means suspended access to the fishery that together with the full exploitation regime of the fishery have been an effective way to control the levels of the population at a productive surplus state. In practice, this control means a moratorium on new fishing licenses;
2.- individual ship owner allocation quotas; (Maximun Limits of catches)
3.- effective access control to the fishery;
4.- efficient biological monitoring mechanism.

The Fisheries Authority had to face different issues, in order to manage jack mackerel in the high seas adjacent to the Chilean EEZ. This resource undergoes high migration in the South Pacific, it has been characterized as an straddling species; therefore, its regulation and conservation would require measures that should be adopted in an effective way for the entire area of its distribution, which simply means that any regulation that is only applied or restricted to part of the total area of its distribution would certainly not ensure conservation of the whole population.

For that reason, the Undersecretariat of Fisheries has extended the management measures established for the Chilean EEZ to the adjacent oceanic area; therefore, all Chilean fishing boats, regardless of the fishing operation area, are bound to comply.

RECOMMENDATION

The Chilean Fishery Authority has used several mechanisms described above in order to administrate and control the fishery, to make it a sustainable fishery, based on the precautionary approach defined on the Code of Conduct for Responsible Fishery (FAO, 1995).

The rules of the precautionary principle seek to:

(a) determine the exploitation status for the stock;

(b) establish biological reference points;

(c) classify the assumable mortality for the fishing activity and spawning biomass limits;

(d) describe security and uncertainty frameworks with respect to limit reference points, consequently, precautionary reference points; and

(e) assess the risks associated to the different levels of mortality.

Acknowledging the wide spatial distribution of the fishery, the scientific uncertainty and the presence in the South Pacific of a recruitment area that, according to the prevailing environmental conditions, might increase the presence of juveniles in the fishing ground as shown by the increase in the proportion of juveniles in the fish landing, the Chilean Fisheries Authority has implemented national restrictions or bans on the fishing activity, in order to avoid an increase in the fish mortality, otherwise that could otherwise lead to a collapse of the fishery.

Therefore, Chile has implemented strict fishing controls at least over the last 10 years, introducing regulations that have finally allowed the jack mackerel population to showed signs of recovery or according with the most recent stock assessment at least showed an slightly biomass increment.

This scenario would mean that for the year after the operational fishery activity on the Jack mackerel should be completely limited, at least to the actual level of fishing mortality.

However, the voluntary interim measures adopted by the SPRFMO, which are voluntary, seemed not to be completely effective in limited the total level of gross tonnage and consequentely the fish catch on oceanic water. That meant that is necessary to review the interim measures previously adopted in May meeting, 2007, III^{er} Conference held at Reñaca Chile.

Furthermore, it is also expected that the Scientific Working Committee of the South Pacific Regional Fisheries Management Organization shall recommends to declaring Jack Mackerel fishery in a statu quo condition, which in turn mean to freeze the effort and fishing mortality at the present level of the fishing activity; and second, it should also recommend, according to the precautionary approach, a global fishing mortality suitable to the current state of the population that would ensure the sustainability of the overall stock.

VI. CONCLUSION

- Jack mackerel is distributed along the coast of Peru and Chile it straddles into oceanic waters, and is a self-sustainable population.

- Due to the large spatial distribution, the population of *Trachurus* uses different habitats during its life history, where areas for growth and feeding, spawning and recruitment have been recognized.

- Considering the large spatial distribution, it is also possible to find subgroups with different ecological characteristics. However, there is no doubt that all these subgroups have a common origin.

- Mixing and interdependence between juveniles and adults are affected by interannual environmental conditions, which explain changes in the availability of Jack mackerel in the usual fishing ground.

- Fishing has been under regulation since the 1980´s, and different administrative regulations have been implemented in order to ensure the long term sustainability of the fishery.

- The Jack mackerel population is a straddling stock and, at least for the Chilean EEZ, it is under a full exploited regime. In this context, it is urgent to establish international regulations for the extraction activities that are compatible with the measures adopted for the Chilean EEZ. The result of such action, if it implemented, should be to ensure the effectiveness of the management and conservation regime adopted by Chile in the last 10 years, thereby ensuring the sustainability of the stock in the South Pacific Ocean.

- From the Chilean point of view it extremely urgent that the Scientific Working Group of the SPRFMO recommends to declare the Jack mackerel fishery in a ***statu quo*** condition, that in turn implies freezing the effort at the present level of the fishing activity. Secondly, it should also recommend, according to the precautionary approach, a global catch quota suitable to the actual status of the population that would ensure the sustainability of the overall stock.

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