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**South Pacific Regional Fisheries Management Organisation**

Assessment Simulation Task Team 6-9 April 2010

ASTT-03

## **Observations and Proposals Regarding SPRFMO Jack Mackerel Stock Assessments**

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### **Observations on Results of the 2009 Chilean Assessment**

- ***The Role of Recruitment***

Recruitment has clearly been the key factor contributing to biomass increases and (coupled with F) biomass declines in the Chilean jack mackerel fishery over the period 1975 – 2008 (Serra and Canales 2009, SPRFMO SWG 2009). Appropriate and robust modelling of recruitment will be required in assessments, and estimates of future recruitment will be particularly important to conducting projections.

- ***Historical Regime Shifts***

There are indications of (probably environmentally driven – see section below on environmental indices) ‘regime shifts’ in the jack mackerel stock, related to recruitment levels over particular periods. This raises the question of how to deal with these regime shifts in stock assessment modelling approaches. Will it be necessary, feasible or appropriate to try and explicitly model these regime shifts? Perhaps as periods of different average recruitment? Or stochastic recruitment with some degree of autocorrelation in recruitments?

Key historical phases in the fishery are apparent in the overlay of Chilean assessment results in Figure 1. Apparent regime shifts are indicated by different periods of average productivity (surplus production) and recruitment. Following the remarkably high recruitment in 1985-86, and resulting high biomass over the following five years, the jack mackerel population modelled in the Chilean assessment has shown periods of sequentially declining average biomass and recruitment. As a result, as catches (landings) have increased to exceed surplus production, or decreased below surplus production following introduction of TACs, the stock has undergone sequential periods of increase or re-building (where surplus production exceeded annual landings) or over-fishing (where landings exceeded surplus production) (Figure 1).

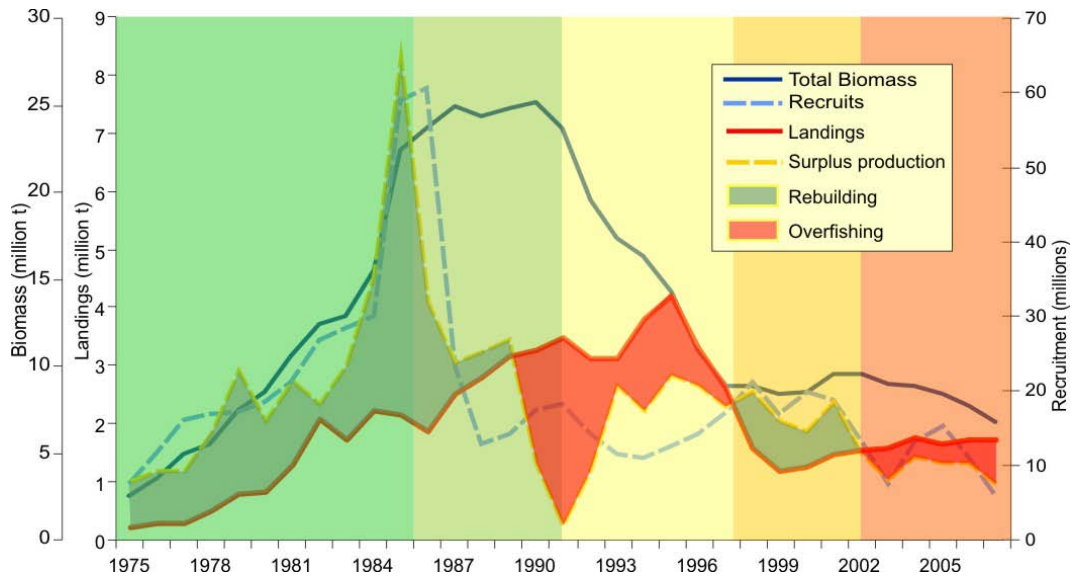


Figure 1. Overlay of trends in jack mackerel biomass, recruitment, landings (C) and surplus production (P) from the updated Chilean assessment, with indication of key historical phases in the fishery and periods of stock re-building ( $P > C$ ) and over-fishing ( $C > P$ ).

Under this assessment, different average values of biomass, recruitment, landings and surplus production over these periods of re-building or over-fishing can be considered to characterise four main phases in the fishery (Figure 2). From 1977 - 1987 there was a period of high recruitment, averaging 29 million fish per year, with remarkably high 1983 and 1984 year classes recruiting in 1985 and 1986. This was a period of low average catches (1.5 million t) and, as a result, surplus production was high and biomass levels averaged 14 million t, actually increasing rapidly over the period. Following this increase in biomass, 1988 - 1996 was a period of high biomass (averaging 20 million t), but also of rapid increase in fishing effort and very high average catches (3.4 million t). This was also a period of fairly low annual recruitment (14 million fish) and so surplus production was well below catches and overfishing occurred throughout the period.

As a result of the high level of overfishing over 1988 - 1996, biomass declined rapidly and the period 1997 - 2001 was a period of low biomass (8.8 million t). Notwithstanding this biomass decline, recruitment appears to have improved to average 19 million fish while surplus production remained constant at 2.2 million t. Management action resulted in catches being brought down to average 1.6 million t, well below surplus production, and so this was a period of stock re-building. The recent period 2002 - 2007 saw an increase in landings to average 1.7 million t over a period when recruitment is estimated to have declined to its lowest historical average level of 11 million fish per year. Surplus production is estimated to have declined to average only 1.3 million t, well below average landings, resulting in this being a further period of overfishing and biomass decline.

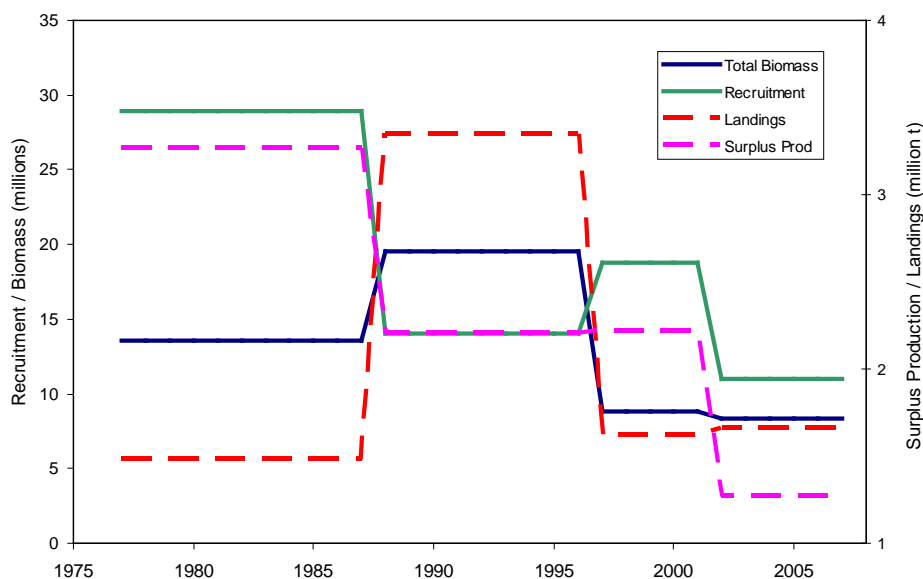


Figure 2. Averaged values of jack mackerel biomass, recruitment, landings and surplus production over four periods in the fishery: 1977 - 1987, 1988 - 1996, 1997 - 2001 and 2002 - 2007.

### • Stock-Recruit Relationships

Recent low recruitments at a time of historically low biomass suggests that, at least at lower biomass levels, there is some real descending limb of a stock recruit relationship. On the other hand, dramatic increases in recruitment in the mid-1980s, and apparently increased recruitment at a time of low biomass in the late 1980s, indicates high variability and a weak S-R relationship. This raises the question of what form of stock-recruitment relationship, or what levels of average recruitment, should be used in assessments. More importantly, the

combination of regime shifts and possibility of low recruitment being related to low biomass raises questions about what recruitment relationship or levels (and uncertainty) to use in projections, if and how to model regime shifts in assessments and projections, which levels (average or stochastic) of recruitment to use and whether to consider auto-correlation in predicted future recruitment.

### **Assessment Specifications and Inputs**

Stock-recruit relationships will require exploring in model scenarios. Questions arise that will need to be dealt with in the stock-recruit relationship put into the model, and/or in the shape and CVs of priors on recruitment and the S-R relationship:

- What is the appropriate form of this relationship?
- What CVs around this?
- Alternately, how might one model regime shifts in recruitments at different biomass levels?

Prompted by strong evidence of the dependence of biomass trends on recruitment, questions have arisen about fishing mortality rates on immature fish, and the impact of various fishery components which catch different age-classes. This, in turn, raises questions about appropriate modelling of total mortality rates on small fish, and therefore of modelling  $M$ . It seems that  $M$  is currently fixed and assumed equivalent for all age classes. This may be inappropriate and, if  $M$  is higher on smaller fish, will likely result in over-estimation of  $F$  on smaller fish. This, in turn, could bias model estimates of trends in  $F$  on particular age classes or cohorts, and would affect projections exploring the effect of different catch rates of different fisheries or age classes. Questions that arise are:

- What is the most appropriate way to model  $M$ ?
- Should this be fixed or estimated?
- Either way, what would be the values / priors on  $M$ , and what form would the Age- $M$  relationship take?

### **Assessment Scenarios and Sensitivity Runs**

Potential model scenarios and inputs suggested by the above question include:

- Alternate parameterizations of  $M$ , estimation vs. specification of  $M$ , and different  $M$  for different ages.
- Alternate stock-recruit relationships (steepness estimates) and CVs around these.
- Options for modelling regime shifts in recruitment, including the possibility of incorporating an environmental index in the S-R relationship or recruitment indices (see section below on environmental indices).

### **Outputs, Indicators and Reference Points**

To be able to respond to questions about effects of fishing on smaller fish, outputs should include modelled trends in  $F$  by age class, and by cohort, in addition to the reporting of aggregate  $F$  over 2+ or 4+ (or other) groups of ages. Suggested outputs could include:

- All of the outputs shown in the updated Chilean assessment, including inter-annual trends in recruited biomass, spawning biomass, recruitment, surplus production and landings.

- Inter-annual trends in  $F$ , including trends in  $F$  on recruited biomass (2+), spawning biomass (4+?), but also trends in  $F$  on each age class, and on each cohort, through the history of the fishery.

With regard to possibly useful indicators, outputs should include:

- Trends in Spawning Biomass Ratio (SBR),  $B/B_{msy}$  (e.g. spawning biomass) and  $F/F_{msy}$  (e.g. for recruited fish, or spawning fish). (Note that, if regime shifts are being modelled, or fishing patterns (selectivities) have changed, this may require determination of different MSY levels at different stages of the fishery.)

## Projections

The one component which has previously not been included in presentation of results from the Chilean assessment has been projections. In terms of the revised SPRFMO pelagic interim measures, the interim SWG Scientific Committee has been specifically required to conduct an assessment and “*projections of stock status associated with the impact of a range of possible management measures, including minimum size lengths for Trachurus species and minimum fishery specific net mesh sizes*” (revised pelagic interim measure 22, report of the 8<sup>th</sup> SPRFMO meeting). Projections to be conducted should include:

- Projections of stock biomass (recruited or spawning) and  $F$  (on specific age classes and aggregated ages) under different future catch levels. These should also be expressed in relation to some of the proposed reference levels, e.g. SBR,  $B_{msy}$  or reference catch levels.
- Projections of stock biomass (recruited or spawning) and  $F$  (on specific age classes and aggregated ages) under alternative different future catch levels by the various component fisheries (i.e. increased or decreased proportion of catch taken by specific fisheries with different selectivities).
- Projections of stock biomass (recruited or spawning) and  $F$  (on specific age classes or aggregated ages) after implementation of minimum size limits or mesh size restrictions on particular fisheries. Note that evaluation of effects of minimum size limits and mesh sizes will have to either have information on effectiveness of such measures (i.e. resulting real changes in selectivity and reduction in catches of small fish), or will have to make assumptions regarding effectiveness. Ultimately, what needs to be correctly modelled is the real changes in selectivity that result from implementation of such measures.

A difficult but critical matter to address in conducting projections will be the question of what recruitment and recruitment uncertainty to use in projections. This will likely require a range of recruitment scenarios to be explored, including various fixed recruitment levels, stochastic recruitment under some S-R relationship, and possibly regime shifts in recruitment. While there have clearly been strong environmental effects on jack mackerel recruitment (see next section), there will be problems incorporating an environmental index to predict future regime shifts as we have no future data on such indices, and would have to assume certain (precautionary) environmental trends.

## Environmental Indices

The occurrence of increased recruitment over 1997 - 2001 at a time of low biomass confirms that, as expected for highly fecund, migratory pelagic species, the stock-recruit relationship is not particularly strong and that environmental factors probably have a strong effect on jack mackerel egg and larval survival, and therefore on resulting recruitment strength.

A comprehensive exploration of alternative environmental indices still needs to be conducted, and the most appropriate index for the Chilean jack mackerel stock will need to be identified or developed. However, Figure 3 shows an initial exploration of the relationship between estimated jack mackerel recruitments trends and the filtered Interdecadal Oscillation Index (IPO). (In this analysis the filtered IPO has been shifted back by two years to account for the two-year difference between spawning and recruitment.)

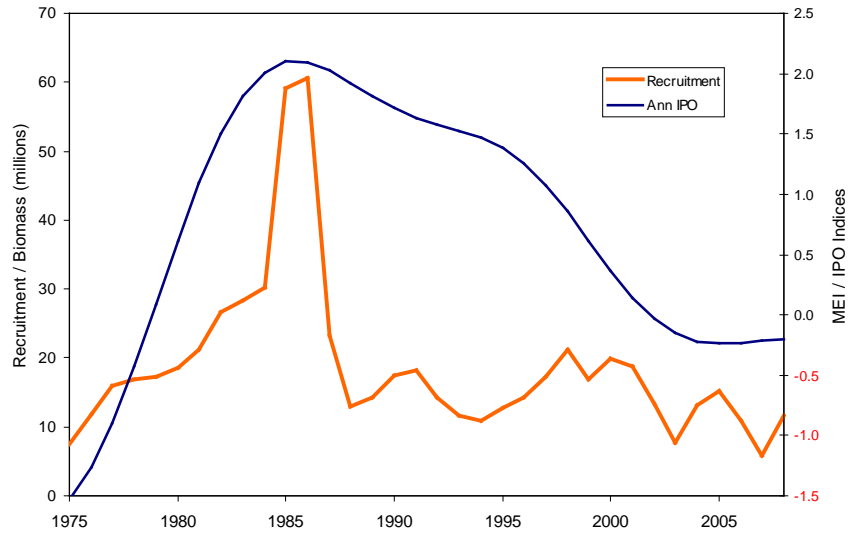


Figure 3. Overlay of trends in jack mackerel recruitment (estimated by the updated Chilean assessment) and the filtered Interdecadal Pacific Oscillation (IPO) index from two years previously.

There is a visually striking correspondence between the peak and trough in the IPO with the highest and lowest estimated recruitment levels in the Chilean jack mackerel assessment. The overall correlation between these two variables, using the IPO from two years prior to each recruitment estimate, is 0.52, although the linear scatterplot  $r^2$  is only 0.28 (Figure 4). The relationship shows a central plateau region of moderate recruitments across a wide range of moderate IPO values, but with potential for remarkably high recruitment at very high IPO, and low recruitment at low IPO (Figure 4).

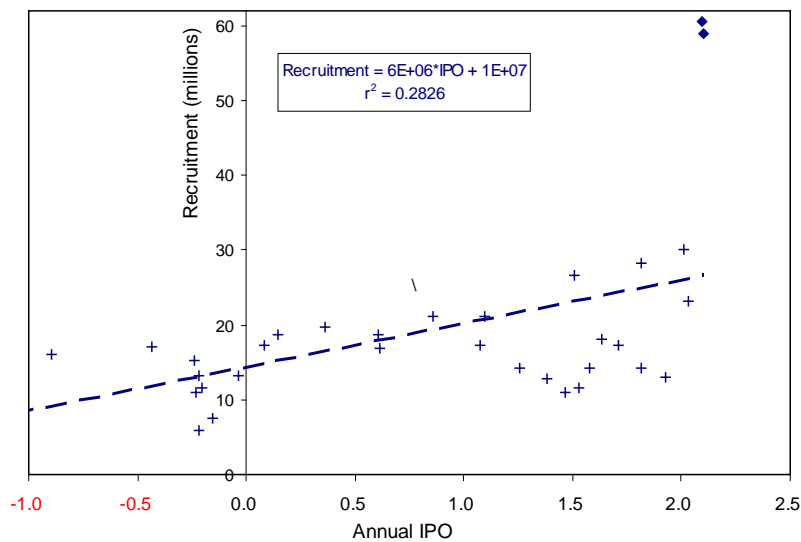


Figure 4. Scatterplot and fits to the relationship between the filtered Interdecadal Pacific Oscillation (IPO) index and jack mackerel recruitment (estimated by the updated Chilean assessment). (♦ shows very high 1985 and 1986 recruitments)

These correlations suggest that an environmental index, such as the IPO or some other index specifically developed to be particularly representative to conditions in the SE Pacific, might usefully be used to improve model fits to recruitment and to adjust the S-R relationship for historical environmental changes, and perhaps to define boundaries between regime shifts. However, without future values of the environmental index, assumptions will have to be made before environmental indices can be incorporated into projections.

For the immediate future, it may be useful to explore the value of the IPO in improving fits to recruitment, but to conduct projections only under two environmental / recruitment scenarios: moderate IPO and average recruitment around 15 - 20 million fish, and lower IPO and recruitment (as currently seems to be the case) of 8 - 10 million fish.

## Stock Structure

Consideration still needs to be given to the stock structure hypotheses to explore in assessments, and how to specify assessments under different hypotheses. In this regard, much of the available information on jack mackerel stock structure suggests the likelihood of some sort of jack mackerel meta-population (see Gerlotto *et al.* 2009). Under conditions of high productivity and recruitment, jack mackerel appear to expand and coalesce to form a large meta-population within which sub-populations would be difficult to distinguish. Under conditions of low recruitment and productivity, this meta-population then appears to break up into a number of sub-populations which contract into centres of suitable productivity to support feeding, and water temperature to support spawning. It is not at all clear how one might model this within assessments, other than as a single management unit.

## References

- Gerlotto, F., A. Bertrand M. Gutierrez (2009). Analysis of the changes in spatial distribution and population structure of the jack mackerel *Trachurus murphyi* in southern Pacific during the period 1980-2009. Presentation to the ICES/FAST Working Group, Ancona, Italy, May 2009.
- Serra, R. and C. Canales (2009) Updated Status of the Chilean Jack Mackerel Stock. Document SP-08-SWG-JM-08 tabled at the 8<sup>th</sup> Meeting of the SPRFMO Scientific Working Group, 22pp.
- SPRFMO Scientific Working Group (2009) List of Jack Mackerel Indicators Selected by the Jack Mackerel Sub-Group as the Basis for Providing Stock Status Advice in 2009. Annex 3 to the Report of the Jack Mackerel Sub-Group. *In*: SPRFMO Eighth International Meeting, Report of the Science Working Group, Auckland, New Zealand, 2 – 6 November 2009.