South Pacific Regional Fisheries Management Organisation

1st Meeting of the Scientific Committee

La Jolla, United States of America, 21-27 October 2013

SC-01-23

Revisions to Jack Mackerel Species Profile

Information describing Chilean jack mackerel (*Trachurus murphyi*) fisheries relating to the South Pacific Regional Fishery Management Organisation

WORKING DRAFT Based upon **SP-07-SWG-JM-02**

~~30 APRIL, 2009~~
18 OCTOBER, 2013

1. Overview

This carangid mackerel is widespread throughout the South Pacific, from the shelf adjacent to Ecuador, Peru, and Chile; throughout the oceanic waters along the Subtropical Convergence Zone; in the New Zealand EEZ south of about 34 ºS; and, in south-eastern waters of the Australian EEZ.

From mitochondrial DNA sequencing *Trachurus murphyi* has been identified as a distinct species (Poulin et al. 2004). Some earlier biological summaries have assumed synonymy with *T. symmetricus* and incorporated information from Californian studies of that species, which may therefore be misleading.

T. murphyi has become a particularly important commercial species atracting international attention since the 1970s. There have been a number of competing stock structure hypotheses, and up to four and more 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 respect to the high seas; a central Pacific stock which exists solely in the high seas; and, a southwest Pacific stock which exist solely in the high seas and, New Zeland-Australian stock which straddles the high seas and both the New Zealand and Australian EEZs. Four alternative working stock structure hypotheses for *T. murphyi* were developed at the Jack Mackerel Stock Structure and Assessment Workshop in Santiago in 2008 (SPRFMO 2008) concerning the relationship between stocks of *T. murphyi* found in the area extending westwards from Chile out to about 120°W, and the relationship between Peruvian and Chilean stocks of *T. murphyi*. The four working hypothesis identified in SPRFMO (2008) are: 1) Jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks which straddle the high seas; 2) Jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock which straddles the high seas; 3) Jack mackerel caught off the Chilean area constitute a single straddling stock extending from the coast out to about 120°W; and, 4) Jack mackerel caught off the Chilean area constitute separate straddling and high seas stocks. Although it has been recognized that further collaborative research is required to confirm and/or clarify these hypotheses and provide a basis for effective management regimes, recent research shows differences in the reproductive patterns, growth rates and other characteristics of Jack mackerel in Peru and in central-southern Chile which are consistent with that of separate stocks (Hypothesis 1 above).

Jack mackerel are predominantly caught by purse seine and midwater trawl.

Since the start of the fishery by Chile in 1950 the majority (~75%) of the global catch has been taken by Chilean vessels predominantly within its EEZ. During the period 1978-1991 the fleet of the former USSR took an accumulated catch of ~13 million tonnes in the high seas area. Prior to 2002 most of the Chilean catch of *T. murphyi* was taken within its EEZ, but between 2003 and 2011 the percentage of Chilean catches taken outside the EEZ has fluctuated between a minimum of 9% in 2006 and a maximum of 58% in 2008, with only 2% in 2012. The maximim recorded Chilean catch was 4,400,193 tonnes in 1995, all taken within its EEZ. The maximum Chilean catch from the high seas within the South Pacific region was 519,738 t in 2008. In recent years Chile, Peru and other flag states including Belize, China, Cook Islands, Faroe Islands, EC, Republic of Korea, Russia, Ukraine and Vanuatu have taken catches on the high seas in the South Pacific region.

In Peru there are landing records of Jack mackerel since 1907 (Coker 1907, 2010) with continuous statistics since 1939. Annual catches were low, although increasing from 10 to a few hundred tonnes per year prior to 1963 (Tilic 1963). Since then catches had a steep increase, to 129,211 t in 1974, to 504,992 t in 1977 and a maximum recorded catch of 723,733 t in 2001, all taken within the Peruvian EEZ. Since 2002 the Peruvian annual landings of Jack mackerel have been lower and have fluctuated within a maximum of 277,568 t in 2006 and a minimum of 58,075 t in 2010. Most of these Peruvian catches have been made within its EEZ except for 2010 when up to 70% was caugth in the high seas. In 2012 Peru caught 174,069 t of *T. murphyi*, 97% of which were taken within its EEZ.

At the western extent of the species range the catches are much smaller. New Zealand catches of *T. murphyi* reach a maximum of 26,386 t in 1996 but have declined to less than 4,000 t in recent years.

The biology of *T. murphyi* is reasonably well known and biological productivity is believed to be medium, with first spawning length at 20 – 25cm, moderate fecundity, fairly rapid growth and a maximum age of at least 35 years (New Zealand estimation), Annual replacement yields are moderately high.

Jack mackerel *T. murphyi* is at present the most important straddling fish species being exploited in the South Pacific both within areas under national jurisdiction, were national regulations apply, as well as in the high seas were since the adoption of the Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean in April 2010, fisheries is being regulated under the aegis of the SPRFMO.

For the Chilean straddling stock (under stock structure hypothesis 3), Chilean stock assessment in 2008 indicated that the spawning biomass ratio had declined to just above 30% of unfished levels and was still falling. Given the moderate productivity of this species, and according to the Chilean assessment, caution with respect to any increases in fishing mortality is needed.

Peruvian assessments of the status of the Peruvian Jack mackerel stock (under stock structure hypothesis 1) have indicated high biomass levels in the 1980s and early 1990s, with maximums of 8.5 million tonnes in 1993 and annual catches around 400 000 tonnes, which would correspond to situation of under-exploitation. However, the estimated total biomass fall to less than 2 million tonnes in 1998/99 with an annual catch lower than 300 000 tonnes. It is worth noting that the Peruvian stock assessment surveys don’t cover the entire area of distribution of Jack mackerel and, therefore, these surveys don’t estimate the total biomass of the stock, and should be taken as the minimum estimated biomass of Jack mackerel within the Peruvian neritic zone and/or as an index of its availability within the neritic zone.

Acoustic biomass estimates of Jack mackerel in Peru have been extremely variable, ranging from maximums of 8.5 million tons in 1983 and 1993 to minimum of 1,200 tons in 2010 in more or les the same general area. From these acoustic estimates it is clear that in Peru there has been a period of great abundance and availability of *T. murphyi* between 1983 and 1996, followed by a period of low abundance and availability from 1996 to date (Segura y Aliaga 2013).

According to the Russian assessment of the high seas biomass of Jack mackerel (under stock structure hypothesis 4) in the south Pacific in the area of available international catch data was relatively stable with the average of about 7 million tonnes (comment: taken from 6 SWG JM report, Canberra, 2008).

For the other stocks given the absence of current information, it is not appropriate to provide detailed comment. However, given the moderate productivity of this species in other areas and the lack of information about current stock biomass levels, due caution is appropriate.

Further research is required to improve the understanding of the stock structure of *T. murphyi* to aid the development of appropriate management units, to obtain biomass estimates for stocks actively fished as inputs to stock assessment modelling, to undertake stock assessment for the fished stocks to provide robust fisheries management advice, and to evaluate bycatch levels, bycatch composition and levels of incidental catch of associated and dependent species in the active high seas fisheries to address issues associated with an ecosystem approach to fisheries management. At present, the SPRFMO Scientific Committee is carrying out parallel assessments of the Jack mackerel stock(s) in the Eastern South Pacific under the two main working hypothesis already identified, that is: that Jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks (far-north and southern-central Chile stocks, hypothesis 1) which straddle the high seas; and, that Jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock (hypothesis 2) which straddles the high seas. So far, all analyses using the JJM indicate a steep decline in the abundance of Jack mackerel in the whole area since the mid-late 1990s, with much lower potential yields and a recommended total catch limit of 438,000 t for the whole range of the species in the SE Pacific in 2013.

This profile is a living document. It is a draft report and requires additional information to complete.

2. Taxonomy

Shaboneyev (1980) summarises *Trachurus* to 12 species; the Integrated Taxonomic Information System (ITIS) at http://www.itis.usda.gov/index.html to 15 species. Three species exist in the South Pacific—*T. murphyi*, *T. declivis*, and *T. novaezelandiae*. The latter two species occur in the Western Pacific almost exclusively in coastal waters within EEZs.

2.1 Phylum

Chordata

2.2 Class

Osteichthyes/Actinopterygii

2.3 Order

Perciformes

2.4 Family

Carangidae

2.5 Genus and species

Trachurus murphyi (Nichols, 1920)

2.6 Scientific synonyms

Historically *Trachurus symmetricus murphyi*

2.7 Common names

Chilean Jack mackerel (FAO, Chile, Russia), Murphy's mackerel (New Zealand), Pacific Jack mackerel (Russia), Peruvian Jack mackerel (Australia, Russia), Jack mackerel, horse mackerel, jurel (Chile, Peru, Ecuador).

2.8 Molecular (DNA or biochemical) bar coding

See Poulin et al. 2004.

3. Species characteristics

3.1 Global distribution and depth range

The Chilean jack mackerel is distributed throughout the south eastern Pacific, both inside EEZs and on the high sea, ranging from the Galapagos Islands and south of Ecuador in the north to southern Chile; ranging from the South America in the east to Australia and New Zeland in the west (Evseenko 1987, Jones 1990, Serra 1991a, and Elizarov et al. 1993; Kotenev et al., 2006) (see Fig. 1).

Serra (1991a) summarised depths for aggregations of *T. murphyi* and Guzman et al. (1983) used hydroacoustic equipment to record the species down to 250 m off the coast of northern Chile; in central and southern Chilean waters, Bahamonde (1978) described it as occurring down to 300 m; and, Japanese trawlers have recorded it to depths of 300 m beyond the Chilean EEZ (Anon 1984, Anon 1985).

Cordova et al. (1998) described a diurnal migratory behaviour, with fish being found deeper during the day (50-180 m) than at night (10-40 m).

Regarding the presence of Jack mackerel along the Peruvian coast, fishery records from 1907 (Coker, 1907 1910) confirmed by more recent statistics (Ñiquen et all 2013) show that Jack mackerel always has had a wide distribution along the Peruvian coast, with regular recorded landings from Paita (05ºS) to Mollendo (17ºS). Furthermore, various archeological studies have also shown that Jack mackerel was already known to, and was captured along the whole Peruvian coast by ancient Peruvians since the Holocene, 6,000 to 10,000 years ago (Csirke, 2013). There are however indications that the overall abundance and availability of Jack mackerel along the Peruvian coast has had large mid- to long-term fluctuations (Csirke *et al* 2013; Espino 2013; Flores *et al* 2013; Dioses 2013).

In fact, after a period of apparent low abundance in the 1950s and 1960s, following the El Niño 1972 and particularly between 1976 and 1979 the distribution areas of Jack mackerel expanded, suggesting a displacement of their concentrations towards the southern part of the Peruvian coast (south of the 10°S), with further expansions during El Niño 1982-83 (Zuta et al., 1983). Icochea et al. (1988) describe a very coastal distribution of the main Jack mackerel concentrations being targeted by a pelagic trawl fleet in Peruvian waters during 1983 (an El Niño year), followed by a wider distribution reaching as far as 150 miles offshore during the cooler conditions of 1984. Data from the same fleet shows that the vertical distribution of Jack mackerel has had significant vertical movements from the surface to depths of 350 m (Dioses and Ñiquen, 1988).

Using more updated information Dioses (2013a) describes three patterns in the vertical distribution and depth of Jack mackerel schools and catches associated with varying environmental conditions: schools are distributed between 100 and 200 m deep and catches are high and don't vary much between day and night during strong events of El Niño; schools are distributed between 0 and 75 m deep and fishing is shallower and farther offshore when strong upwelling occurs; and, during warmer conditions due to the strengthening of the southern extension of the Cromwell current schools have a wider vertical distribution, between 0 and 300 m deep, and main catches are closer to the coast, deeper during daylight and shallower at night.

As noted by Ñiquen et al (2013) the monthly catches of *T. murphyi* by the Peruvian industrial and artisanal fleets before 2002 were higher in the northern part of Peru (Mancora-Chimbote, 04-09º S) while after 2002 the catches were higher in the southern-central zone (Huacho-Ilo, 11-18º S), except for 2006 and 2012 when the fleet also operated in the north. They also note that fishing activities for Jack mackerel in Peru takes place from very close to the coast to as far as 200 nm offshore, with a more coastal distribution during warm periods.

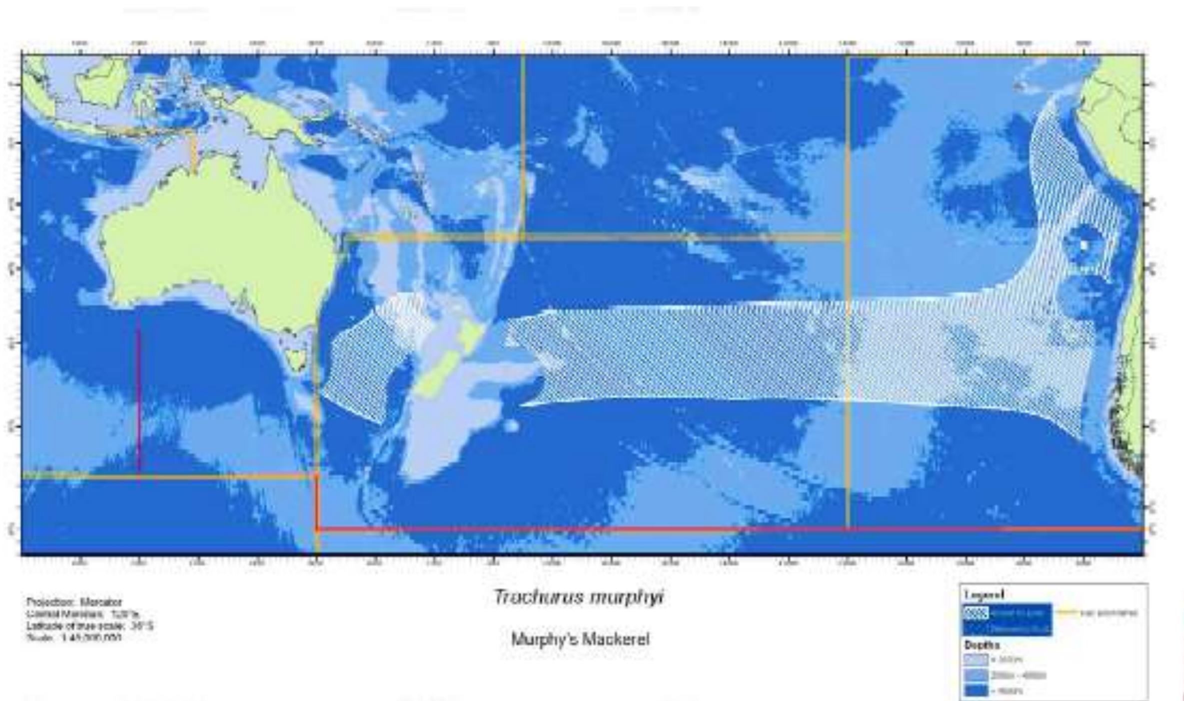

Figure 1. Distribution of Jack mackerel in the high seas in the South Pacific

3.2 Distribution within South Pacific area

Elizarov et al. (1993) coined the phrase "Jack mackerel belt" to describe the distribution of *T. murphyi* across the South Pacific (Fig. 1). The Jack mackerel belt is described as having a north-south breadth of "10 to 15 degrees" across "the southern sub region of the southeast Pacific Ocean (SEPO) and southwest Pacific Ocean (SWPO)", which varies with season as "spawning groups concentrate mainly in the north of 40ºS in spring and summer and south of 40ºS in autumn and winter to feed".

Following the strong increase in its abundance from the early 1970s, *T. murphyi* expanded its distribution 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 1991a, Elizarov et al. 1993, and Taylor 2002).

In Peru, the preferred habitat for *T. murphyi* is defined by the highly productive oceanic front formed by the Cold Coastal Waters (CCF) and the Subtropical

Surface Water (SSW), which influences the abundance and horizontal and vertical distribution of Jack mackerel schools and other pelagic species such as mackerel *Scomber japonicus* in the water column with temperatures ranging between 14 °C and 20 °C (Dioses et al 1989, Dioses 2013).

In Perú, during El Niño, Jack mackerel and other pelagic species are concentrated under a strong and deep thermocline. Jack mackerel catches occur at depths greater than 100 m, at temperatures of 15-20 ° C and salinity between 35.0 to 35.1 ups and oxygen concentrations greater than 1 ml / L. Under these conditions the catches tend to be high and do not vary significantly during the day due to reduced distribution range of schools. In this case, the resource is more accessible and vulnerable to trawl fleet (Dioses 2013).

After El Niño, the isotherms greater than 15° C are much shallower as they approach the coast, with salinity higher than 34.95 ups, and oxygen of 1-3 ml / L. The cartches are more superficial and oceanic, fluctuating with oceanic front extension. In this case the line of 1.0 ml / L of oxygen is located about 50 m deep, which explains the presence of surface schools of Jack mackerel and their absence at greater depths. The resource is more accessible to the purse seine fleet (Dioses 2013).

When ESCC intensifies the equatorial front (South Extension Cromwell Current), Jack mackerel (T. murphy) is captured at depths greater than 100 m during the day and near the surface at night. Catches reach higher values in the day because at night is more dispersed in the surface due to the scattering of their food. In this case it is more vulnerable to the trawl fleet during the day and to the purse seine fleet during the night (Dioses 2013).

Noticeable changes in the distribution, availability and abundance of *T. murphyi* have been reported in Peru, particularly over the period 1983-2013. These changes correspond to inter-decadal and inter-annual changes in environmental conditions, including those due to the strong El Nino event in 1997-98 (Ñiquen and Peña 2008, Espino 2013, Gutiérrez et al. 2008, Flores 2013, Dioses 2013a). These changes have produced shifts in the distribution of catches from between 4 and 9º S (1997-2001) to between 10 and 18º S (2002-2013) and have been attributed to a combination of changes in the environmental conditions and changed food availability (Espinoza et al. 2008, Gutiérrez et al. 2008, Ñiquen et al 2013, Alegre et al 2013).

Acoustic surveys off the central coast of Chile since 1991 have found that since 2003 there have been important changes in the distribution of main biomass of *T. murphyi* which has become more distant from the coast. (Cordova et al. 2008)

Off New Zealand, catches of *T. murphyi* initially appeared around the Chatham Islands in 1984-85, showed a westward expansion from 1986-87 to 1994-95 as catches increased, and then contracted eastward to 2006-07 as catches declined (Penney and Taylor 2008).

Jack mackerel are also found within the Australian and Equadorian EEZs.

3.2.1 Inter-annual and/or seasonal variations in distribution

A large increase in abundance over the 20 years to 1991 has been reported (Serra 1991a and 1991b, Elizarov et al. 1993), which is considered to be the cause of its large present distribution. Serra (1991a) also described a seasonal migration between coastal and oceanic waters for the Chilean subpopulation, and related this to “reproductive and trophic processes”, stating that “this migration forms a pattern which determines the seasonal availability of the resource in the coastal and oceanic fisheries and establishes an important factor for stock assessment.” In Chilean fisheries waters, large jack mackerel tend to be distributed toward the south. A similar tendency for larger fish in southern waters is also seen in New Zealand fisheries waters (Taylor in prep.).

Russian researchers detected several geographically isolated groupings of jack mackerel within the species belt; these groupings were attached to zones having stable hydrological conditions. Each one makes circular seasonal migrations (Chur et al., 1984; Kashirin, Melnik, 1984; Vasilieva et al., 1984; Rudometkina et al., 1988; Elizarov et al., 1992; Kotenev, 1992; Kotenev et al., 2006; Soldat et al., 2008).

In oceanic waters, beyond 120ºW, Elizarov et al. (1993) described a migratory pattern whereby jack mackerel move from productive, cold southern waters, northward into subtropical waters where they spawn, and then return. Young of the year of the Chilean stock moved eastwards, arriving on the shelf and beginning to recruit into the fishery at age 2.

3.2.2 Other potential areas where the species may be found

None likely based on the species biology and the oceanography of the area.

3.3 General habitat and behaviour

T. murphyi is a schooling pelagic species adapted to both neritic and oceanic environments.

Areas of abundance of *T. murphyi* are considered to be associated with areas of high productivity from upwelling of cooler, nutrient-rich waters (Ñiquen and Peña 2008, Chernyshkov et al. 2008). However, after El Niño 1997-98 the cold coastal waters extended far from the coast and had been associated with a reduction in *T. murphyi* abundance (Gutiérrez et al. 2008).

An analysis of long-term average geostrophic circulation patterns in the upper 200 m layer of water identified relatively isolated areas of anticyclonic circulation in the eastern, central and western parts of the southern Pacific Ocean. All life history stages of *T. murphyi* were reported from within these zones which were considered to be areas of high biological productivity (Chernyshkov et al. 2008).

The variability in the marine environmental conditions off Peru responds to a complex combination of environmental patterns that change at different time scales. These patterns can range from seasonal to secular and can be identified, and eventually can be monitored through the temporal changes in various environmental variables and indexes such as sea surface temperature (SST), the Pacific Decadal Oscillation (PDO) index, the multivariate El Niño Southern Oscillation (ENSO) index and the Southern Oscillation Index (SOI), amongst others (Espino 2013).

The analysis of these and other indicators allow the identification of seasonal (summer-winter), inter-annual (El Niño-La Niña), inter-decadal warm and cold multiyear periods (El Viejo–La Vieja) (Chavez, et al, 2003), and secular (Espino 2003, 2013) scale patters. From all these variable scale patterns, the most relevant in trying to explain the changes in availability of Jack mackerel during the past 30 years are the inter-annual processes that correspond to the dynamic of El Niño Southern Oscillation (ENSO) and the multiyear longer term ones, better known as inter-decadal (Espino 2013).

Some of these inter-annual (El Niño-La Niña) and inter-decadal warm and cold multiyear periods (El Viejo–La Vieja) can also be observed from the variability of the depth of the isotherm of 15°C, the spatial distribution of salinity and the depth of the minimum oxygen line. There is a clear deepening of the 15^{0}C isotherm during the decades of the 1980s and 1990s, which is an indicator of favorable sub-surface conditions for the presence and expansion of fish stocks such as hake and Jack mackerel, associated with equatorial currents such the Southern Extension of the Sub-superficial Cromwell Countercurrent (SESCC) and the Peruvian Subsurface Current (PSSC) (Flores et al. 2013)

Also, for the same time period, the spatial distribution of salinity and of the depth of the oxygen minimum shows that toward the end of the 1970s and during the1980s and 1990s the prevailing conditions were those determined by the intrusion of Superficial Subtropical Waters (SSW), with the type of water masses that are preferred by the Jack mackerel off Peru. The water masses of the Surface Subtropical Waters (SSW) provide the preferred environmental conditions reported for the Jack mackerel off Peru, with temperatures ranging between 15°C and 20°C, salinities between 35.1 ups and 35.6 ups and oxygen content between 1.0 and 6.0 mL/L (Moron 2013; Flores et al 2013).

3.4 Biological characteristics

Morphology: body elongate and slightly compressed. Enlarged, scute-like scales on primary lateral line. Termination of dorsal accessory lateral line below 2nd to 5th soft ray of dorsal fin. Pectoral fin tip extending to be above the two detached spines anterior to the anal fin. Eye moderate size with well-developed adipose eyelid. Posterior margin of upper jaw below anterior margin of eye. Jaws vomer, palatine, and tongue bearing minute teeth (Kawahara et al. 1988).

Colour when fresh: dark blue dorsal body, silver-white ventrally; upper posterior margin of opercula bear a black spot; pale pelvic fins; caudal, pectoral, and dorsal fins dusky; anal fin pale in the front, dusky in the rear.

Several authors have described *T. murphyi* to be an indeterminate batch spawner, based on histological studies and on the oocyte-size-frequency-distribution (OSFD) of reproductively active females, and their “presence over a long temporal extension of seven to nine months per year” (Dioses et al. 1989, George 1995, Oyarzún et al. 1998, Perea et al 2013). This conclusion is supported by evidence from Evseenko (1987) and

Bailey (1989) who state that *T. murphyi* spawns wherever environmental conditions are suitable. The suitable environmental conditions seems to be water warmer than 15 ºC, with highest densities having been found in waters of 16 – 19 ºC, and low current (less than 15 cm.s^{-1}) (Evseenko 1987, Nuñez et al. 2004).

Trachurus murphyi spawns in austral spring and summer, with the main spawning season from October to December (Serra 1983 and 1991a, Elizarov et al. 1993, Oyarzún et al. 1998, and Perea et al 2013) and it spawns throughout its whole distribution range. Santander and Flores (1983) and Dioses et al (1989) described Jack mackerel spawning in Peru as mainly occurring between 14º00'S and 18º30'S. However, more recent analyses by Ayon and Correa (2013) show that between 1966 and 2010 Jack mackerel larvae were present (and therefore spawning occurred) every year along the whole Peruvian coast, with clear year to year north-south shifts in the centres of higher larvae abundance associated with shifts in environmental conditions. The annual mean larvae densities for the positive stations in the period 1966-2010 estimated by Ayon and Correa (2013) ranged from 3 to 1131 larvae/m^2, with a median of 21 larvae/m^2, noting that while the frequency and abundance of larvae has been variable there has been no particular trend for the 56 years of observations. However, they describe important changes with time in the spatial larvae distribution. From 1960 to 1979 Jack mackerel larvae were present particularly in the southern part of Peru, while during the period 1980-1989 there was a wide distribution along the whole Peruvian coast, with higher densities north of Punta Falsa (06ºS). Later on, during the period 1990-1999 the main larvae distribution areas were to the north of 16ºS, with an expansion toward the south between 2000 and 2010. The centers of gravity of the larvae spatial distribution per year also showed some important differences in the distribution by latitude and distance from the coast, with three clear periods: the first one between 1966 and 1978 with main larvae concentrations between 14°S and 18ºS closer to the coast; the second between 1979 and 1994 more to the north, between 4°S and 14ºS, and more offshore; and, the third one between 1995 and 2010, with the centers of gravity located in an intermediate position between the other two (Ayon y Correa 2013).

In Peru, the spawning areas are limited by the CCW (salinities lower than 35,0 ups) and SSW (salinities higher than de 35,1 ups), with temperatures above 18ºC and oxygen content around 5,0 mL/L. In these water columns the spawning schools of Jack mackerel tend to be located at depths between 10 and 80 m, with an ideal salinity of 34,9 to 35,1 ups and an oxygen content from 3.0 to 5.0 mL/L (Dioses 2013a).

On the other hand, the main spawning ground of the Chilean subpopulation is off central Chile in coastal waters and extending beyond 200 miles of the EEZ to about 93º W (Serra 1991b, Nuñez et al. 2004, and Arcos et al. 2005). An additional area of spawning has been recorded in the area between 105°E and 125°E (Kotenev et al 2006).

The results of 85 seasonal surveys of eggs and larvae between 1981 and 2007 off northern Chile (north of 24º S) found that egg and larva density peaked in winter-spring, with a greater concentration towards the southern part of this area (Braun and Valenzuela 2008).

Annual surveys of the distribution of early developmental stages of *T. murphyi* between 1999 and 2007, in waters off central Chile, found that most spawning was centred between 33 and 38º S and from 82 to 92º W (Núñez et al. 2008). Higher densities of eggs and larvae were associated with water temperatures of 16-18º, moderate winds (4-8 m s-

1), a low turbulence index (< 100 m3 s-3), and slower current speeds (< 15 cm s-1) (Núñez et al. 2008). This supports the view that spawning occurs along the subtropical convergence, between the southern and northern limits (42 ºS and 36 ºS). The western centre of the spawning occurs within 130 ºW to 155 ºW and 35 ºS to 40 ºS (Evseenko 1987, Elizarov et al. 1993).

According to Oyarzún and Gacitua (2002) and Oliva et al. (1995), 10–15% of females spawn each day during the period of most intensive spawning, meaning that the average female spawns every 7–10 days at this time.

In Chile the mean length at first spawning has been described at 22 cm (Marcelo Oliva , Instituto de Investigaciones Oceanológicas, Universidad de Antofagasta, Chile, pers. comm.) and 23 cm FL (Basten & Contreras 1978), and more recently is considered to be 25 cm FL, but the size at first maturity has been reported to vary between 21.6 and 30 cm FL among different areas (Cubillos et al. 2008).

The length at first maturity of *T. murphyi* in Peru was first estimated as 25,0 cm fork length (FL) by Abramov and Kotylar (1980) and 23 cm total length (21 cm FL) by Dioses et al. (1989). More recently, Perea et al (2013) analyzed information from 1967 to 2012 and estimated a total length at first maturity of 26.5 cm, with no significant changes over observed period. They also confirmed that in Peru *T. murphyi* has a single relatively extended spawning period with a maximum in November each year, showing that for the more than four decades of observations *T. murphyi* has spawned regularly every year in Peruvian waters. They also noted that the reproductive activity of *T. murphyi* has a greater variability off Peru and the spawning period has peaks of lesser magnitude but extend longer than observed in the spawning occurring off Chile. Perea et al (2013) also report that the highest frequency of months with high gonadosomatic index (GSI) are observed during the period 1986-1998, while in the previous years (1967-1985) there were fewer months with relatively high GSI, and this frequency has been even lower from 1999 to-date.

Several papers have been published describing *T. murphyi* growth functions. Cubillos et al. (1998) summarised 22 studies. *T. murphyi* can be described as having a moderate growth rate. In Chile ages are estimated using transversely sectioned otoliths. The maximum recorded age is 19 years, which contrasts strongly with the maximum age of 35 years estimated in New Zealand and the maximum age reading of 11 years reported in Peru. Some of the difference in these estimates can be explained by New Zealand specimens being larger, and therefore older, than those taken in Chile, as would be expected for an animal near the extreme of its range. However, some of the difference may be the result of differing ageing methodologies used in the two countries—counts of whole otoliths are used in Chile, whereas counts from embedded, sectioned otoliths are used in New Zealand.

The method used to estimate ages for *T. murphyi* in Chile have been validated using the bomb radiocarbon method (Ojeda et al. 2008).

In Peru, the age and growth of Jack mackerel has been determined by the direct reading and measuring of annual growth rings in whole otoliths (Dioses 2013b) and have been confirmed by independent observations through the reading of micro-increments or daily rings in otoliths (Goycochea 2013) and length frequency analysis of commercial and research survey catches (Diaz 2013). The growth parameters estimated by Dioses (2013b) are L_∞=80.77 cm, W_∞=3744.10 gr., K=0.155/year, and t_0=-0.356. The same author tested the validity of the methodology being used by checking the growing similarity between rings (whose growth decreases with the formation of a new ring) and the monthly variation of otolith marginal increment, while Goycochea (2013) and Diaz (2013) obtained very similar results using independent methods and diferent sources of data.

Kochkin (1994) sampled specimens from both the South West Pacific Ocean (SWPO) and the South East Pacific Ocean (SEPO) between 1983 and 1990 and investigated growth using otoliths and length frequencies. His estimated von Bertalanffy relationship was $L_t = 74.2405[1 - e^{\mathbf{-0.1109(t + 0.8113)}}]$, and he determined L_{max} to be $0.943L_\infty$.

Gili et al. (1996) investigated growth using otholiths sampled from the central Chile fishery. Their estimates of growth parameters were: K=0.094; L_∞=70.8 cm FL; and t_0=-0.896.

Natural mortality has been estimated to be in the range of 0.30 to 0.22 y^{-1} based on size composition data (Cubillos et al. 2008). The Chilean assessment model uses a value of 0.23 y^{-1} for all age groups (Canales and Serra, 2008 unpublished report)

Natural mortality for *T. murphyi* in Peru has been estimated as M= 0.31 per year, based on the growth parameters of the von Bertalanffy growth function and other traits of the Jack mackerel life cycle in Peru.

3.5 Population structure

There have been a number of competing stock structure hypotheses, and up to four and more 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 stock which exists solely in the high seas and, New Zeland – Australian stock which straddles the high seas and both the New Zealand and Australian EEZs.

Alternative working stock structure hypotheses for *T. murphyi* were developed at the Jack Mackerel Stock Structure and Assessment Workshop in Santiago in 2008 (SPRFMO 2008). The development of these hypotheses was based on information presented at the workshop or previously published. The report of this workshop contains a summary of the evidence supporting or opposing these hypotheses and the main hypotheses concerning the relationship between Peruvian and Chilean stocks of *T. murphyi* could be summarized from SPRFMO (2008) as follows:

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.

Additional work is required to determine the most likely boundary between separate Perúvian and Chilean stocks. For the purposes of *T. murphyi* assessments to be conducted in the immediate future, some separation between Peru and Chile 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. A separation that takes into account the Subtropical Convergence Zone has also been suggested.

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

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. These included 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, much in line with the proposal of a possible metapopulation suggested by Gerlotto et al (2010, 2012).

Hypotheses concerning the relationship between stocks of *T. murphyi* found in the area extending westwards from Chile out to about 120°W:

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 the hypotheses currently used in Chilean stock assessments. There is a fairly substantial amount of evidence supporting this hypothesis.

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 *T. murphyi* 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 the most likely position of such a boundary.

Further collaborative research is required to confirm and/or clarify these hypotheses and provide a basis for effective management regimes. Nevertheless, recent research undertaken on the Peruvian stock of Jack mackerel (IMARPE-PRODUCE 2012a, 2012b; Csirke et al 2013) has shown that there are substantive differences in the reproductive patterns, growth rates and other important biological and environmental population characteristics which are consistent with that of separate stocks, where by Jack mackerel caught off the coasts of Perú and Chile each would constitute separate stocks which straddle the high seas (Hypothesis 1 above). These biological and envirionmental characteristics include (IMARPE-PRODUCE 2012b): a) the habitat, with high productivity related to the high environmental variability; b) a "more r" adaptive response to this habitat (in respect to other stocks of the region); c) faster individual growth; d) a south-north life-history migration pattern with all phases of the life cycle being present off Peru; e) higher plasticity of the reproductive behavior as adaptation to a different and more variable climatic regime; f) comparatively smaller size (and age) at first maturity, even in the absence of any significant effect of fishing; g) long term stability of size (and age) at first maturity; and, h) a permanent main spawning center off Peru.

Accordingly, the Jack Mackerel Sub-group (JMSG) of the Science Working Group (SWG) of the SPRFMO at its 11th Session (SWG-11) carried out parallel assessments of the Jack mackerel stock(s) in the Eastern South Pacific under the two main working hypothesis already identified, that is: that Jack mackerel caught off the coasts of Peru and Chile each constitute separate stocks (far-north and southern-central Chile stocks - hypothesis 1) which straddle the high seas; and, that Jack mackerel caught off the coasts of Peru and Chile constitute a single shared stock (hypothesis 2) which straddles the high seas. In following up on the SWG-11 reccomendations, the SPRFMO Commisssion at its 1st Commission Meeting requested the newly established Scientific Committee to continue the work on evaluating alternative hypotheses on Jack mackerel stock population structure and consequences of alternative management approaches. Within this context, and pending more conclusive findings on the stock population structure of Jack mackerel, the Commission requested the Scientific Committee (SC) to continue and expand the stock assessment work under both the stock hypotheses considered in the 11th SWG Meeting, and this is one of the main tasks for its 1st Session (SC-01) in La Jolla, 21-27 October 2013.

3.6 Biological productivity

The biology of *T. murphyi* is reasonably well known. Biological productivity is believed to be medium, with first spawning at 20 – 25cm, moderate fecundity, fairly rapid growth and a maximum age of ~20-30 years. Annual replacement yields are moderately high.

3.7 Role of species in the ecosystem

This species is a generalist feeder capable of utilising a wide range of prey species (Konchina 1979)~~,~~ and may be acting as a energy flow channeler from primary producers to top predators. However, its wide range of prey species shows that it is not restricted to this role. As the "bloom" event in the early to mid 1990s indicated (4.4 M t were taken in the Chilean fishery in 1995) (Table 1), which coincided with a peak in aerial sightings records in New Zealand waters (P.R. Taylor, NIWA, New Zealand, unpublished data), population size of *T. murphyi* can be extremely high. Little is known about its predators, though Bailey (1987) tentatively identified juvenile jack mackerel from the stomachs of albacore tuna (*Thunnus alalunga*) taken in the central South Pacific (36ºS to 42ºS and 148ºW to 165ºW) as *T. murphyi*. It has also been found in the stomach contents of swordfish off the Chilean coast (M. Donoso, IFOP, Chile, pers. comm.). Generally it can be expected that its predators will be similar to those of other carangid mackerels and will include tunas, billfish, and sharks. As a consequence of the large size of the Jack mackerel and its important role as both predator and prey, this species is likely an important node in Pacific Ocean predator-prey networks. Depletion of the jack mackerel would likely cause unpredictable, substantial and enduring changes in the abundances of its predators and prey, which may not be easily reversible by reduction of fishing mortality.

4. Fisheries characterisation

4.1 Distribution of fishing activity

Three fisheries can be identified off the Chilean coast. The first is in northern Chile, from the boundary with Peru to 24º S. A second fishery operates from 24º S to 32º S. The main fishery is located off central Chile, from 32º S to about 43º S within and outside the EEZ. In the two first fisheries the target species are small pelagic fish with jack mackerel as secondary target species. From 1978 to 1992 an international fishery operated on the high seas of the proposed SPRFMO area. The main fleet was from the former USSR, but vessels from Cuba and the German Democratic Republic also fished. Since 2002 vessels from other flags have fished in this area.

The Peruvian purse seiner fleet targeting on Jack mackerel mainly operates in the coastal area along the Peruvian coast, mostly within the first 100 nm from the coastline moving farther offshore only when no or very little fish is found in reasonable commercial concentrations inshore. The historical information on latitudinal distribution of Jack mackerel catches along the Peruvian coast shows a wider distribution until 1998, with high indexes of abundance especially from the 1970s throughout 1998, with catches fluctuating between 50 and 500 thousand tons per year. Since 1998, the main fishing grounds were mainly found in the central-south Peruvian region and the annual catches fluctuated at a lower level than the previous period, with the exception of 2001 when the catch was 775 thousand tons. In the period 1970–2012 there was a strong seasonality in the Jack mackerel catches, with best catches in summer and spring. During recent years the best catches were mostly taken in summer (Ñiquen et al. 2013).

4.2 Fishing technology

T. murphyi is caught mainly by purse seine and midwater trawl net. In Chile, it is targeted extensively by domestic purse-seine vessels. In the northern Chilean fishery a Marco type of purse seiner is used, while in the fishery off central Chile purse seiners with their fishing gear at the deck level are used, similar to the Scandinavian design. The international fleet was historically composed mainly of large Russian midwater trawlers.

In 2008, the size of the purse seine fishing fleet in northern Chile was about 71 vessels, with an average size of 370 cubic metre of hold capacity, while the size of the fishing fleet in the central Chilean fishery was 50 vessels with an average hold capacity of 1105 cubic metre and an average length of 55 metres.

The Peruvian pelagic fishery has traditionally been focused on catching anchoveta (*Engraulis ringens*) for the production of fishmeal and fish oil. A directed fishery for other pelagic fish, such as Jack mackerel (*T. murphyi*) and chub mackerel (*Scomber japonicus*) devoted to direct human consumption started to operate in 2002 (D.S. 001-2002-PRODUCE). The Peruvian purse-seiner fleet authorized to fish for Jack mackerel uses a mesh size of 38 mm and historically most of the catches of Jack mackerel in Peruvian waters have been taken by purse-seiners, although in 1984- 1991 up to 40 factory stern-trawlers from the ex-Soviet Union and Cuba were licensed under bilateral agreements to operate in Peruvian waters. In 2011 the Peruvian industrial purse-seine fleet licensed to fish for *T. murphyi* in Peruvian waters comprised 62 industrial steel vessels with a total hold capacity of 30,177 m^3 and 42 industrial wooden vessels with a total hold capacity of 3,082 m^3 (Ñiquen et al 2013).

4.3 Catch history

The majority of the total global catch comes from FAO area 87, the Southeast Pacific (Table 1).

Since the start of the fishery in 1950 the majority (~75%) of the global catch has been taken by Chilean vessels predominantly within its EEZ. From 1950 to 1994 over 54 million tonnes of jack mackerel were taken by Chile. The Chilean fishery for *T. murphyi* peaked at around 4.5 M t. in 1995. Between 1994 and 2001, almost 100% of the Chilean catch of *T. murphyi* was taken within the EEZ, but from 2002 onward an important fraction has been taken outside the EEZ. During the period 1978-1991 the fleet of the former USSR took a catch of ~13 million tonnes in the high seas area. According FAO data the total catch of *T. murphyi* for 2007 was around 1.99 million tonnes including 690,851 tonnes taken in high seas (428,234 tonnes taken by distant water fishing nations). This total has varied between 1.758 and 2.04 million tonnes since 2002.

In recent years Chile and other flags including Belize, China, Cook Islands, Faroe Islands, EC, Republic of Korea, Russia, Ukraine and Vanuatu have taken catches on the high seas in the South Pacific region. The proportion taken by distant water fishing nations has increased from 4.4% in 2002 to 21.6% in 2007 and the proportion taken by Chile in high seas varied from 3.3% (2002) to 25.6% (2003). The proportion taken by Chile in high seas in 2007 was 13.2%. Other coastal states (Peru and Ecuador) didn't catch beyond national EEZes.

The Peruvian fishery has reports on Jack mackerel catches since the beginning of the last century (Coke 1907, 1910) and historical catch records show that there were regular catches of Jack mackerel off Peru since 1939 (Tilic 1963), while archeological records provide multiple evidences that ancient Peruvians were already catching and consuming Jack mackerel in the Holocene, 6,000 to 10,000 years ago (Csirke 2013). Official landings in more modern times did not exceed the 60 tonnes/year prior to 1950. In the late 1950s catches increased to a few hundred tonnes/year and the 1960s catcheds increased from the few hundreds to the thousands tonnes a year increasing to 129,000 t in 1974. Since then, annual catches have been fluctuating between almost 40,000 t and 400,000 t, except for the 504,992 t in 1977 and the maximum recorded 774,603 t in 2001. The annual landings of jack mackerel in the period 2002 – 2011 show a decreasing trend since 2007, with a minimum in 2010. However, the increase of Jack mackerel catches during 2011 has partially reversed the decreasing trend observed in recent years. In 2012 the total catch in Peruvian waters was 168,779 t (Ñiquen 2013).

In New Zealand, *T. murphyi* forms part of the jack mackerel catch, which also includes *T. declivis* and *T. novaezelandiae.* The estimated catch of *T. murphyi* reached a maximum catch of 25,331 t in 1995-96 before declining to 2,401 t in 2002-03 then rising to 4,645 t in 2005-06. The majority of New Zealand's jack mackerel is caught within the EEZ.

Jack mackerel are very rarely caught in Australian fisheries.

4.4 Stock status

Chilean stock

A Chilean assessment of the status of jack mackerel, using a statistical catch-at-age model based on a Bayesian estimate approach, covered the area from the northern Chilean border to 45° S within the EEZ, and out 105°W between 35° S and 45°S. In this initial assessment (Serra *et al*, 2006 unpublished report), the spawning biomass in this area was estimated to be 5,500,000t, with a confidence interval 2,000,000t – 8,900,000t in 2005. This represented a spawning biomass ratio of just under 40% of unfished levels and the stock was assessed as being fully exploited. An update of the Chilean assessment of the status of jack mackerel in March 2008 (Canales and Serra, 2008 unpublished report) indicated that the spawning biomass ratio had declined to just above 30% of unfished levels and was still falling. This assessment incorporated catches by distant water fishing nations out to 120º W since 2001 including catches of 315,000 tonnes by such nations in 2007.

Peruvian stock

The acoustic estimations of jack mackerel biomasses were limited to the first 80 to 100 nm of the Peruvian jurisdictional waters and have been extremely variable, ranging from 8.5 million tons in 1983 to only 1,200 tons in 2010. There has been a period of high abundance and great availability of Jack mackerel in the coastal area between 1983 and 1996, which has been followed by a period of low abundance and lower availability within this coastal area from 1998 to date (Segura y Aliaga 2013).

A biomass dynamic model (Hilborn and Walters, 1992) of the Schaefer type was implemented for Jack mackerel in Peru since 2007, using time series of catch, standardized CPUE (catch/trip) and an index of the acoustic biomass between 2002 and 2011. With the biomass dynamic model applied to the period 2002 – 2011 the biomass of Jack mackerel off Peru was estimated to be around 850 thousand tonnes (±90 thousand tonnes) with an estimated MSY around 187 500 tons. According to this model, the estimated fishing mortality (F) applied to the stock has averaged 0,2 (±0,09) per year and the consequent exploitation rate (E) has fluctuated around 0,35 (±0,14) per year.

Peru has also developed an ad-hoc model called “Length Integrated Stock Assessment Model” for assessing the Jack mackerel biomass. This model numerically integrates the length distribution of all cohorts, where individuals in classes of 1cm evolve uniformly but independently from each other. The total biomass estimated by this ad-hoc model seem to capture fairly well the magnitudes and patterns of change reported for this important stock since 1970 until 2012, with biomasses ranging from 0.48 to 1.25 Million tonnes.

Other stocks

According to the Russian assessment (TISVPA) of the high seas biomass of Jack mackerel (under stock structure hypothesis 4) in the south Pacific in the area of available international catch data is relatively stable (Vasiliev et al., 2008).

The SWG-11 that met in Lima in October 2012 estimated a total biomass of Jack mackerel for the whole SE Pacific in the range of (2.5 to 3.5?) million tonnes **(check values)** with a recommended total catch of 438,000 t.

4.5 Threats

Not listed by the IUCN.

Table 1: Reported catches (t) of Chilean jack mackerel by country for FAO area 87 from 1950 to 2006. (to be updated using SPRFMO data to include EEZ and high seas catches)

Country	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**
Chile	1 000	700	1 300	1 900	2 000	1 200	1 400	4 700	5 600	11 200
Peru	0	100	100	100	100	100	700	400	200	400
South Pacific Region Total	1 000	800	1 400	2 100	5 100	5 800	11 600	6 500	5 800	11 600
Outside South Pacific Total										
Grand Total	1 000	800	1 400	2 000	2 100	1 300	2 100	5 100	5 800	11 600
Country	**1960**	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**
Chile	6 200	5 400	9 000	8 700	10 300	12 700	17 600	26 400	23 800	16 600
Peru	300	200	700	200	1 700	2 600	4 300	3 100	2 800	4 200
South Pacific Region Total	6 500	5 600	9 700	8 900	12 000	15 300	21 900	29 500	26 600	20 800
Outside South Pacific Total										
Grand Total	6 500	5 600	9 700	8 900	12 000	15 300	21 900	29 500	26 600	20 800
Country	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**
Bulgaria	-	-	-	-	-	-	-	-	-	4 726
Chile	104 000	149 900	86 000	121 600	193 512	261 205	342 269	340 806	586 681	597 511
Cuba	-	-	-	100	-	800	900	-	1 000	19 000
Japan	-	-	-	-	-	-	35	2 273	1 667	120
Korea, Republic of	-	-	-	-	-	-	-	-	819	-
Peru	4 700	9 200	18 800	42 800	129 211	37 899	54 154	504 992	386 793	151 591
Poland	-	-	-	-	-	-	-	-	-	1 180
Un. Soc. Sov. Rep.	-	-	5 500	-	-	-	-	-	49 220	532 209
South Pacific Region Total	108 700	159 100	110 300	164 500	322 723	299 904	397 358	848 071	1 026 180	1 306 337
Outside South Pacific Total										
Grand Total		159 100	110 300	164 500	322 723	299 904	397 358	848 071	1 026 180	1 306 337

Table 1 (cont.):

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Bulgaria	15 065	12 629	13 561	24 324	14 694	2 290	-	-	-	-
Chile	562 262	1 060 909	1 494 683	865 272	1 426 301	1 456 989	1 184 317	1 770 037	2 138 255	2 390 117
Cuba	83 971	74 227	83 881	54 875	34 008	32 258	46 833	35 980	44 209	24 486
Ecuador	-	-	-	24 937	10 000	-	-	-	-	2 312
Estonia	-	-	-	-	-	-	-	-	82 590	77 351
Georgia	-	-	-	-	-	-	-	-	23 134	26 358
Germany	1 031	-	-	-	-	-	-	-	-	-
Japan	-	29	-	1 694	3 871	5 229	6 835	8 815	6 871	701
Korea, Rep. of	-	-	-	-	62	641	-	2 018	-	-
Latvia	-	-	-	-	-	-	-	-	128 966	128 692
Lithuania	-	-	-	-	-	-	-	-	75 122	102 980
Peru	123 380	37 875	50 013	76 825	184 333	87 466	49 863	46 304	118 076	140 720
Poland	528	-	7 136	39 943	80 129	-	-	-	-	-
Russian Fed.	-	-	-	-	-	-	-	-	498 214	662 626
Ukraine	-	-	-	-	-	-	-	-	130 262	98 285
Un. Sov. Soc. Rep.	494 402	554 646	555 367	591 005	570 612	563 968	673 049	818 628	-	-
South Pacific Region Total	1 280 639	1 740 315	2 204 641	1 678 875	2 324 010	2 148 841	1 960 897	2 681 782	3 245 699	3 654 628
Outside South Pacific Total										
Grand Total	1 280 639	1 740 315	2 204 641	1 678 875	2 324 010	2 148 841	1 960 897	2 681 782	3 245 699	3 654 628

Table 1 (cont.):

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Bulgaria	1 649	-	-	-	-	-	-	-	-	-
Chile	2 471 875	3 020 512	3 212 060	3 236 244	4 041 447	4 404 193	3 883 326	2 917 064	1 612 912	1 219 689
Cuba	41 197	30 828	3 196	-	-	-	-	-	-	-
Ecuador	138	23 123	22 818	9 946	23 723	174 393	56 781	30 302	25 900	19 072
Estonia	78 627	60 318	376	-	-	-	-	-	-	-
Georgia	36 130	12 181	-	-	-	-	-	-	-	-

Japan	157	-	-	-	-	-	-	-	-	7
Latvia	113 221	83 719	2 298	-	-	-	-	-	-	-
Lithuania	80 874	109 292	7 842	-	-	-	-	-	-	-
Peru	191 139	136 337	96 660	130 681	196 771	376 600	438 736	649 751	386 946	184 679
Russian Fed.	688 551	419 650	31 357	-	-	-	-	-	-	-
Ukraine	124 894	57 788	-	-	-	-	-	-	-	-
South Pacific Region Total	3 828 452	3 953 748	3 376 607	3 376 871	4 261 941	4 955 186	4 378 843	3 597 117	2 025 758	1 423 447
Grand Total	3 828 452	3 953 748	3 376 607	3 376 871	4 261 941	4 955 186	4 378 843	3 597 117	2 025 758	1 423 447

Country	**2000**	**2001**	**2002**	**2003**	**2004**
Chile	1 234 299	1 649 933	1 518 994	1 421 296	1 451 599
China	-	-	76 261	94 690	131 020
Ecuador	7 144	134 011	604	-	-
Ghana	2 472	1 157	-	-	-
Korea, Rep. of	-	-	-	2 196	9 227
Peru	296 579	723 733	154 219	217 734	186 931
Russian Fed.	-	-	-	132	-
South Pacific Region Total	1 540 494	2 508 834	1 750 078	1 736 048	1 778 777
Grand Total	1 540 494	2 508 834	1 750 078	1 736 048	1 778 777

Source: FAO Database 2006

4.6 Fishery value

In determining fishery value, three key types of jack mackerel products are considered: products for human consumption; fishmeal production from reduction fishing; and, fishmeal production from the processing waste stream.

In Chile, the industry, that uses jack mackerel as raw material, generated revenues of US$164.9 million from export for human consumption and US$264.4 million from fish meal during 2005. Overall prices average US$655.9 per tonne for fishmeal and US$733.6 per tonne for the human consumption products.

The majority of New Zealand's small high seas catch is landed as fishmeal. The average FOB[1] return for fishmeal not suitable for human consumption for the last 12 months was NZ$1.25/kg. Total revenue from New Zealand jack mackerel exports in 2005 was NZ$30 694 218 (5.8% of total exports), however, this mainly comprised of catch from within the EEZ (New Zealand Seafood Exports Report 5A, 2005).

5. Current Fishery Status and Trends

5.1 Stock size

Historic estimates of biomass for various parts of the South Pacific

Using virtual population analysis estimates for mixed stocks, it was determined that in the 5–7 years before 1993, the biomass of *T. murphyi* remained stable, varying from 12–22 M t in total: 1.3–2.4 M t in the northern SEPO (north of 30ºS of the South East Pacific Ocean), 10–14 M t in the southern SEPO (south of 30ºS) and eastern part of the SWPO, and 6–8 M t in the central and western SWPO (Elizarov et al.,1993). An acoustic / trawl survey in the SWPO (105 – 165ºW) in 1987 was used to estimate total biomass in this region as 8 M t (Nazarov & Nesterov 1990). Depending on the proportion of acoustic signal assumed to be plankton (about 50 M t), biomass of *T. murphyi* was estimated to be about 5–7 M t (Vinogradov et al. 1991). An acoustic / trawl survey in the SEPO (beyond Chilean EEZ to 105ºW, area 362 ths.sq.miles) in 2002-2003 was used to estimate total biomass in this region as 7,635 M t (Nesterov et al., 2004).

Chilean stock

The biomass of the Chilean stock of *T. murphyi* has been estimated with statistical catch-at-age models (Serra et al. 2005), hydroacoustic methods (Cordova et al., 2004) and the daily egg production method (Arcos et al., 2005).

Serra (1983 and 1991b) and Serra et al. (2005) described the increase in abundance of the Chilean jack mackerel subpopulation since the early seventies. Associated with this increase, the population expanded its distribution, crossing the South Pacific Ocean along the West Wind Drift (Serra, 1991a; Elizarov et at. 1993). The Chilean stock attained a

[1] Unit value is calculated by dividing the FOB value in NZ$ by the weight in kg. (FOB= Free on Board. The value of export goods, including raw material, processing, packaging, storage and transportation up to the point where the goods are about to leave the country as exports. FOB does not include storage, export transport or insurance cost to get the goods to the export market.)

total biomass of about 21 M tonnes by the end of the 1980s. It has declined since to about 6 M tonnes in 2008 due to reduced recruitment and fishing.

Peruvian stock

The biomass of *T. murphyi* off the Peruvian coast was estimated by a surplus production model to be 8.5 million tonnes in 1983 with an annual yield generally of less than 400,000 tonnes, but the biomass was estimated to have fallen to less than 2.0 million tonnes in 1998 with annual yield of less than 300,000 tonnes (Garcia 2008).

The biomass of Peruvian jack mackerel have been also estimated by an ad-hoc model called Length Integrated Stock Size Estimation for 1972 to 2012, ranging from 0.48 to 15.69 million tonnes.

A biomass dynamic model (Hilborn and Walters, 1992) of the Schaefer type provide management advice using the Peruvian time series of catch, standardized CPUE (catch/trip) and an index of the acoustic biomass between 2002 and 2011. The results obtained with this method confirms that the fishing mortality is around 0.2 per year and the exploitation rate is around 0.35 per year

Other stocks

An TISVPA model of *T. murphyi* stocks on the high seas in the south-east Pacific in the area of available international catch estimated the biomass to be about 7 million tonnes (Vasilyev et al., 2008).

A Korean hydroacoustic research survey in August-December 2003 estimated biomass from three strata with a total 5,742 nm sq. area (the three strata were on the high seas in the vicinity of 29°S – 35°S, 83°E – 95°E) to be 1,461,335 tonnes (SD ± 569,920) (Kim, DooNam, pers. comm.).

5.2 Estimates of relevant biological reference points

5.2.1 Fishing mortality

Chilean stock

For the Chilean stock in 2008, using fishing mortality related to a target reference point of SB / SB0 = 40%, , F / F_{SB40} was 1.29.

Other stocks

There is no current information for the other stocks

5.2.2 Biomass

Chilean stock

For the Chilean stock in 2008 the Spawning Potential Ratio (Mace et al., 1996) was 0.24.

Other stocks

There is no current information for the other stocks

5.2.3 Other relevant biological reference points

Southwest Pacific stock

Recent aerial sightings data in New Zealand waters shows that this species is now less abundant at the surface than during the mid-1990's (Taylor, 2002).

Other stocks

A surplus production model for the fishery in Peru was used to estimate the maximum sustainable yield (MSY) using data for the period 1997 to 2006 (Garcia 2008). This estimated MSY to be 562 000 tonnes.

There are no other reference points for the other stocks.

6. Impacts of Fishing

6.1 Catch of associated and dependent species

No estimates available.

6.2 Unobserved mortality of associated and dependent species

This is unlikely given the methods used (mid-water trawl and purse seine) and the small mesh sizes of that gear allowing limited escapement.

6.3 Bycatch of commercial species

Chilean fisheries

The main bycatch of the jack mackerel fishery is chub mackerel (*Scomber japonicus*) which can form substantive quantities at times (see the species profile at http://www.southpacificrfmo.org/working-groups/public/current-work/). Other species taken are hoki (*Macruronus magellanicus*), snoek (*Thyrsites atun*) and in recent years giant squid (*Dosidicus gigas*).

Peruvian fisheries

No current information available.

Central Pacific fisheries

No current information available.

Southwest Pacific fisheries

For high seas fisheries in the Southwest Pacific, the small jack mackerel catches are typically a bycatch of trawl fishing for other species (e.g. alfonsino). In the absence of current targeting of the species in the area, the bycatch information is presented in the relevant species profiles.

6.4 Habitat damage

No direct habitat damage known in the mid-water trawl and purse seine fisheries and such damage is unlikely due to the gear types used.

6.5 Trophic relationships

There may be some concerns related to any excessive fishing-induced reductions in Jack mackerel abundance, and the effects this may have on stability of Pacific Ocean predator-prey networks.

For the Peruvian stock the diet of Jack mackerel has been characterized by the predominant intake of Euphausiidae. The time series analysis of *T. murphyi* diet between 1977 to 2011 distinguished two scenarios, from 1977 to 2000 the Jack mackerel diet was strongly dominated by Euphausiidae, and since 2000 *T. murphyi* consumed a greater diversity of prey, mainly Euphausiidae, but also squat lobster *Pleuroncodes monodon* and Zoea. However, in Jack mackerels larger than 51 cm increases the intake of mesopleagic fish (W = 15.8%), other Teleosteii (W = 16.9%) and Mollusca (W = 10.8%). Also, between 17 and 18° S there was a slight increase in mesopelagics (% W = 10.7 to 12.8) which had also a slight increase in the diet beyond 130 miles from the coast (% W = 12.9 to 13.4) (Alegre et al 2013). It is noted that the first scenario corresponds to warm conditions and the second to cold conditions, both coincident with observed multidecadal periods described by Chávez et al. (2003, 2008).

The stomach fullness index of Jack mackerel in Peru decreased with the distance form the coast, and *P. monodon* was been found in stomachs of Jack mackerels caught as far as 80 nm from the coast, which does not coincide with the distribution of this prey mainly associated with cold coastal waters (CCW) (Alegre et al 2013). This finding could be explained by the migratory nature of Jack mackerel, moving easily from an epipelagic oceanic to a neritic environment. Jack mackerel is also considered as facultative predator (Kochina, 1980, 1983) with seasonal migrations inside the coast in spring and summer and towards the ocean in autumn and winter (Muck and Sánchez, 1987; Zuzunaga, 1986). The 15 °C isotherm depth which corresponds to the depth of zone of minimum oxygen (ZMO) facilitates the access of Jack mackerel to the coast for feeding, expanding in this way the habitat of this species (Bertrand, 2004).

7. Management

7.1 Existing management measures

Chilean fisheries

In Chile the fishery is managed under a scheme of annual total allowable catch that, in the case of the industrial fleet is allocated under a scheme of "maximum catch limits per shipowner" according to the shipowner's historical catch records, and a correction factor established in fisheries law for the hold capacity of the fishing vessels. Management includes spatial and sectoral controls (artisanal, industrial). Large reductions in catch occurred from the end of the 1990s due to regulations introduced to halt declining trends. A minimum size restriction is also applied in Chilean fisheries to protect the small fish and to avoid growth overfishing. Similar regulatory controls are applied to the Chilean fishery outside the EEZ as the catch is considered to be taken from the same (straddling) stock.

For the 2007 year, the total quota approved by Chilean authorities is 1,600,000 tonnes.

Peruvian fisheries

Peru has adopted a legal and institutional framework for the establishment of fisheries conservation and management measures under principles of the Code of Conduct for Responsible Fisheries (FAO, 1995). In 2002 the Peruvian fishery for *T. murphyi* was restricted to providing fish exclusively for human consumption, which restricted catches and allowed the development of an industrial fleet fitted with refrigerated seawater systems. Further measures were introduced in 2007 to promote the rational exploitation of this resource (Zuzunaga 2013). At present, and according to the principles of the General Fisheries Law (Decreto Ley Nº 25977), the fisheries activities in Peru are to be managed promoting their sustainable development and ensuring a responsible use of the living aquatic resources in harmony with the preservation of the environment and conservation of the biodiversity (Zuzunaga 2013).

Central South Pacific stock

There is no information available.

Southwest Pacific fisheries

In New Zealand fisheries waters, *T. murphyi* is managed as part of the tri-species jack mackerel fishery, with total allowable catches set for the combined species catch in a number of geographical regions (quota management areas) within the EEZ. A high seas permitting regime applies to all New Zealand vessels fishing the high seas, but there are no jack mackerel specific management measures in place beyond the EEZ at this time.

In Australian waters, *T. murphyi* is a minor part of a multi-species purse seine and mid-water trawl fishery based mainly on other species (*T. declivis* yellowtail scad *T. novaezelandiae*, blue mackerel *Scomber australicus* and redbait *Emmelichthys nitidus*). This fishery is managed by a combination of input and output controls including annual total allowable catches and individual transferable quotas. A high seas permitting regime applies to all Australian vessels fishing the high seas, but there are no jack mackerel specific management measures in place beyond the EEZ at this time.

7.2 Fishery management implications

Chilean stock

The Chilean (straddling) stock of *T. murphyi* has been declared to be fully exploitated under Chilean Fishing Law. The fishery management objective is to avoid further decline in the stock. For this purpose, annual catch quotas are applied to the industrial and artisanal fisheries. Introduction of this regulation and other measures caused a decrease in the fleet size due to rationalization of investment in the pelagic fishery. The fleet size in the northern fishery decreased by 30%, and by about 80% off central Chile. Current stock assessment suggests that this stock is at full exploitation and, given the moderate productivity of this species, caution with respect to any increases in fishing mortality is needed.

Southwest Pacific stock

Given the absence of current information, it is not appropriate to provide detailed comment for this stock. However, given the moderate productivity of this species and the lack of information about current stock biomass levels, due caution is appropriate.

Peruvian stock

The overall guidance of the Peruvian fisheries legislation is contained in the National Act for the Sustainable Use of Natural Resources (Ley Orgánica para el Aprovechamiento Sostenible de los Recursos Naturales) and the Peruvian General Fisheries Act (Ley General de Pesca). The main objectives are to promote the sustainable development of the Peruvian fisheries as a source of food, income and employment while ensuring that the aquatic living resources are exploited in a responsible manner, optimizing socio-economic returns in full harmony with environmental and biodiversity conservation concerns (Zuzunaga 2013).

The current regulations establish a minimum mesh size for fishing for jack mackerel of 38 mm (1 inch) for the purse seine nets and 76 mm (3 inches) in the codend for the middle water trawl nets. It is also prohibited to catch process and market jack mackerels smaller than 31 cm total length (Zuzunaga 2013).

Special regulations (Ministerial Resolutions) establish and modify closed seasons, fishing seasons and the corresponding catch quota limits. The current regulation (Decreto Supremo Nº 011-2007-PRODUCE), establishes a restricted access regime limited only to vessels with operative onboard cooling systems devoted to properly store and preserve their catch which could only be used for direct human consumption. In the case of the purse seine fleet, the entrance of new vessels to the fishery is only authorized if it replaces the same hold capacity of an already existing vessel with a valid fishing license for jack mackerel that will be decommissioned transferring its fishing license to the new vessel. Trawl fishing vessels can only operate at bottom depths greater than 200 meters (Zuzunaga 2013).

Central South Pacific stock

Given the absence of current information it is not appropriate to provide detailed comment for this stock. However, given the moderate productivity of this species and the lack of information about current biomass levels due caution is appropriate.

7.3 Ecosystem Considerations

All stocks

Habitat is unlikely to be of concern in this fishery due to the fishing methods used.

Large extractions of any important species such as jack mackerel may lead to changes in predator-prey relationships, which in turn could lead to shifts in food-web structure. These shifts in community structure are not necessarily reversed by the reduction of fishing pressure. Neira et al. (2004), using eco-trophic modelling, found that fishing could have a negative eco-trophic impact on important fisheries resources such as the horse mackerel. Ecosystem modelling of pelagic species in upwelling systems has highlighted the alteration of matter fluxes in trophic webs caused by jack mackerel fishery removals. The estimated potential annual consumption of zooplankton by jack mackerel removed by fishing is equivalent to about 2.7 - 5 million tonnes C y^{-1} (Cury et al. 2000). The implications for the management of this fishery are unknown.

Bycatch data for jack mackerel fisheries in the proposed South Pacific RFMO area are very limited. Without quantitative information it is not possible to provide other than generic precautionary advice. Detailed data collection in the various fisheries should be undertaken to enable detailed assessment of bycatches.

Catch of associated and dependent species in the jack mackerel fisheries has not been documented on the high seas. Given the experience in other purse seine fisheries in the Pacific (which catch sharks, billfish and cetaceans in the central eastern Pacific) and other mid-water trawl fisheries which discard fish waste at sea (which result in mortality of seabirds in the south western Pacific), some incidental catch will occur in the Southeastern Pacific. Without information it is not possible to provide other than generic precautionary advice. Detailed data collection in the various fisheries should be undertaken to provide an opportunity to enable assessment of associated and dependent species by-catches.

8. <u>Research</u>

8.1 Current and ongoing research

There has been a substantial amount of historical research on this species, particularly by Russia. However, substantially less research has been conducted over the past decade, except within the EEZs of a few coastal states.

Chile

The Chilean jack mackerel fishery is monitored by observers and sampling programmes for the main fleets and at all landing locations. Biological sampling of landings for species composition, size, weight, sex and maturity is undertaken. Otoliths for age studies are also collected. Fishery independent monitoring surveys are also undertaken, including acoustic surveys off north and south-central Chile and annual egg production surveys to estimate the spawning stock using a daily egg production method.

Peru

The research on Jack mackerel includes the following programs:

- **Pelagic Resources Monitoring Program:** The main goal is the collection of daily information on species composition and size of catches that is later integrated in a large database which is the source for population's dynamics models construction.
- **Fishing Logbooks Program:** Is an onboard program of observers which supports the pelagic fish stock assessment and management in Peru. The program has evolved since its beginning and is now being updated to the framework of the Ecosystem Management. Currently, the monitoring issues are: effective effort, discards, biologic data collection, sightseeing of birds, mammals and turtles, collecting of water samples, taking pictures of acoustic records, among others.
- **Hydroacoustic direct assessments and application:** To determine spatial distribution, relative or absolute abundance index to recommend management measures.
- **Satellite Monitoring of fishing fleet:** This system is used to monitoring fishing vessels fleet activities in "real time".

The use of this kind of data allows the access to diary information on the main fishing areas where the industrial fishing fleet operates. Once this information is complemented with biological data obtained on board, it allows us to evaluate the magnitude of the fishery in a daily basis.

Korea

Experimental mid-water trawling and hydroacoustic surveys were conducted in the Southeastern Pacific Ocean by the Korean research vessel, TAMGU No.1 and two commercial mid-water trawl vessels during August-December 2003.

New Zealand

The within-EEZ jack mackerel fishery is monitored by observers and sampling programmes for the main fleets, and at all main landing locations. Biological sampling of the landings for species composition, size, weight, sex and maturity is undertaken and otoliths are collected for age studies.

Russia

An hydroacoustic / trawl survey in the SEPO (beyond Chilean EEZ to 105ºW, area 362 ths.sq.miles) was conducted in 2002-2003. An hydroacoustic / trawl survey in the SEPO is carrying out in August-November 2009

8.2 Research needs

Research is required to:

- Improve the understanding of the stock structure of *T. murphyi* to aid the development of appropriate management units.

  This should be done using multiple techniques such as genetics, otolith microchemistry, morphometrics, parasites and ecology to discriminate between separate stocks and test the current stock structure hypothesis. A collaborative approach in undertaking and funding this project will be required for a comprehensive and enduring outcome.

- Obtain biomass estimates for all stocks that are actively fished as inputs to stock assessment modelling.

  This will need careful planning to ensure that biomass estimates are obtained using standard methods that can be utilised for stock assessment purposes and that populations areas are identified correctly.

- Undertake a stock assessment for the actively fished stocks to support the provision of robust fisheries management advice.

  A preliminary task is the compilation of relevant data for undertaking stock assessment. A review of the available data will determine the types of assessment that might be able to be used. Any assessment should be done using a modern method capable of integrating all relevant available data and that can provide the types of management advice sought by the SPRFMO negotiation participants.

- Evaluate the bycatch levels and bycatch composition in the active high seas fisheries to allow assessment of interactions between fisheries and consideration of the issues associated with an ecosystem approach to fisheries management.

  This will require collection of detailed bycatch data across fisheries at the species level.

- Evaluate levels of incidental catch of associated and dependent species to allow determination as to whether the catches are adverse and where appropriate the development of mitigation measures.

  This will require the collection of verifiable data from the fishery across a representative sample of area, seasons and fishing methods

9. Additional remarks

None at this time

10. References

Abramov, A.A., Kotlyar, A.N. (1980). Some biological features of the Peruvian jack mackerel, *Trachurus symmetricus murphyi*. Journal of Ichthyology 80: 25–31.

Alegre, A., P. Espinoza & M. Espino (2013). Trophic ecology of Jack mackerel *Trachurus murphyi* (Nichols 1920) in Peru, 1977–2011. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 075-082. (Volume published in Spanish with titles, abstracts and captions in English).

Anon (1984). Report of survey for the development of new distant water trawling grounds in 1983. Kaihatsu News No 40.

Anon (1985). Report of survey for the development of new distant water trawling grounds in 1984. Kaihatsu News No 45.

Anon (1997). Review of the state of world fishery resources: marine fisheries. 15 Southeast Pacific, FAO statistical area 87. FAO Fisheries Circular No. 920 FIRM/C920.

Arcos, D., C. Gatica, P. Ruiz, A. Sepulveda, M.A. Barbieri, R. Alarcon, S. Nuñez, J. Chong, J. Cordova, A. Rebolledo, C. Gonzales, F. Contreras, M. Aguayo, F. Vejar, P. Torres and C. Toro. (2005). Condición biologica de jurel en Alta Mar, año 2004. Informe Final Proyecto FIP 2004-33. Fondo de Investigación Pesquera.

Avdeyev, V.V. (1992). On the possible use of parasitic isopods as bioindicators of the migratory routes of horse mackerels in the Pacific Ocean. Journal of Ichthyology 32: 14–21.

Ayón, P. & J. Correa. (2013). Spatial and temporal variability of Jack mackerel *Trachurus murphy* (Nichols 1920) larvae in Peru between 1966-2010. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 083-086. (Volume published in Spanish with titles, abstracts and captions in English).

Bahamonde, R. (1978). Distribución y abundancia relitiva de los principales recursos demersales entre Corral (40ºS) y el Cabo de Hornos (57ºS). Instituto de Fomento Pesquero IFOP/JAMARC. Informe Interno.

Bailey, K. (1987). Townsend Cromwell surveys South Pacific albacore resource. Catch, 14(7); 20–22.

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

Barbieri, M. A. (2008). Research and management of Chilean jack mackerel (*Trachurus murphyi*) exploited in the South East Pacific Ocean. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Basten, J.; Contreras, P. (1978). Observaciones preliminares sobre la pesquería del jurel *Trachurus murphyi* (Nichols) en la zona norte de Chile. Períoda julio 1975–julio 1978. Universidad del Norte Departamento Pesquerías Informe Técnico. 62 p.

Bernal, C., A Aranis, C Martínez and C Canales. (2008). Catch size compositions for jack mackerel (*Trachurus murphyi*) off Chile (1975-2006). Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Bertrand, A. M. Barbieri, J. Córdova, C. Hernández, F. Gómez & F. Leiva (2004). Diel vertical behaviour, predatoreprey relationships, and occupation of space by jack mackerel (*Trachurus murphyi*) off Chile. ICES Journal of Marine Science, 61: 1105e1112.

Bogorov, V.G. (1967). Biomass of zooplankton and productive regions of the Pacific Ocean. Plankton Tikhogo Okeana (Pacific Ocean Plankton), 221–229. Nauka, Moskow.

Braun, M. and V. Valenzuela (2008). Seasonal distribution and abundance of jack mackerel (*Trachurus murphyi*) eggs and larvae off northern Chile 1981-2007. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Canales, C. and R Serra. (2008). Chilean jack mackerel stock assessment model. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Canales, C. L Caballero and A Aranís. (2008). Catch per Unit Effort of Chilean jack mackerel (*Trachurus murphyi*) of the purse seine fishery off south-central Chile (32º10' – 40º10' S) 1981-2005. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Castillo, J. P. (2008). Jack mackerel (*Trachurus murphyi*) spatial distribution and seasonal acoustic biomass estimated in the north of Chile. 1981 - 1990. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Chavez, F. P., J. Ryan, S.E. Lluch-Cota & M. Ñiquen. (2003). From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. Review: Climate. SCIENCE Vol 299: 217-221.

Chavez, F. P., A. Bertrand, R. Guevara-Carrasco, P. Soler & J. Csirke. (2008). The Northern Humboldt Current System: Brief history, present status and a view towards the future. Progress in Oceanography, 79, 2-4, p. 95-105.

Chernyshkov, P., E.Timokhin and A. Glubokov. (2008). Inter-annual and seasonal variability of oceanological conditions in the Southern Pacific Ocean in connection with the pelagic ecosystem structure. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Chur, V. N., A. A. Nesterov, K. V. Kashirin (1984). Distribution of jack mackerel *Trachurus murphyi* Nichols in the southern part of the Pacific Ocean. Fishery studies in the open areas of the World Ocean. Collection of scientific papers. M.: VNIRO: 56-70. (In Russian).

Coker R.E. (1907). Condición en que se encuentra la pesca marina desde Paita hasta bahía de la Independencia. Boletín del Ministerio de Fomento, Año VI, Nº 2, 30 de noviembre de 1907, 89-117.

Coker R.E. (1910). Condiciones de la pesquería de Mollendo. Boletín del Ministerio de Fomento, Año VIII, Nº 8, 31 de octubre de 1910, 64-114.

Cordova et al. (1998). Evaluación hidroacústica del recurso jurel en la ZEE de Chile. IFOP/FIP 98-11. Informe Final. 200 págs. +figs.

Cordova, J. R Bahamonde and V Catasti. (2008). Jack mackerel (*Trachurus murphyi*, Nichols, 1920) acoustic survey in the central coast of Chile. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Cordova, J., M. Espejo, S. Nuñez, y J. Ortiz. (2005). Evaluación hidroacústica del recurso jurel entre la V y X Regiones. Invierno año 2004. Informe Final. Proyecto FIP2004-06.

Corten, A. (2008). The fishery for jack mackerel in the Eastern Central Pacific by Dutch trawlers in 2007. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Csirke J. (2013). The Jack mackerel *Trachurus murphy* in Perú. In: Csirke J., R. Guevara-Carrasco & M. Espino (eds.). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. Special issue 20(1): 005 – 008 (Volume published in Spanish with titles, abstracts and captions in English).

Csirke J., R. Guevara-Carrasco & M. Espino (eds.). (2013). Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 124p. (Volume published in Spanish with titles, abstracts and captions in English).

Cubillos, L., C Gatica and R Serra. (2008). Short review of natural mortality and size at first maturity on jack mackerel (*Trachurus murphyi*) in the southeastern Pacific. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Cubillos, L., R. Alarcón, L. Vilugran, A. Sepúlveda, M. George-Nascimento, M. Araya, M. Medina, J. Zambrano, M. Guzman, L. Martinez, J. Peñailillo, R. Gili, Z. Young, V. Alegria, V. Bocic, L. Muñoz y L. Cid. (1998). Validación de los métodos aplicados en la determinación de edad y crecimiento y determinación de la mortalidad del jurel en la zona centro.sur. Informe Final Proyecto FIP 95-10, 170 p.

Cury, P.; Bakun, A.; Crawford, R.J.M.; Jarre, A.; Quiñones, R.A.; Shannon, L.J.; Verheye, H.M. (2000). Small pelagics in upwelling systems: patterns of interaction and structural changes in "wasp-waist" ecosystems. ICES Journal of Marine Science 57(3): 603–618.

Díaz, E. (2013). Estimation of growth parameters of Jack mackerel *Trachurus murphyi* (Nichols 1920) caught in Peru, from length frequency analysis. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 061-066. (Volume published in Spanish with titles, abstracts and captions in English).

Dioses, T. (2013a). Abundance and distribution patterns of Jack mackerel *Trachurus murphyi* (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 067-074. (Volume published in Spanish with titles, abstracts and captions in English).

Dioses, T. (2013b). Age and growth of Jack mackerel *Trachurus murphyi* (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (*Trachurus murphyi*) in Peru. Rev. peru. biol. special issue 20 (1): 045-052. (Volume published in Spanish with titles, abstracts and captions in English).

Dioses, T. & M. Ñiquen (1988). Aspectos generales sobre la biología y pesquería del recurso jurel (*Trachurus murphyi*) en Perú. En: Pesca Perú, 1988. Forum: Características en el diseño de una embarcación ideal para la captura de especies pelágicas. 14-15 enero 1988, 40p.

Dioses, T., Alarcon, V.H.; Nakama, M.H.; Echevarria, A. (1989). Desarrollo ovocitario, fecundidad parcial y distribucion vertical de los cardumenes en desove del jurel *Trachurus murphyi* (N). (Oocyte development, partial fecundity and vertical distribution of the spawning schools of jack mackerel, *Trachurus murphyi* N.). Revista de la Comision Permanente del Pacifico Sur. 287–294.

Duran, B.L.E.; Oliva, M.M. (1983). List of Peruvian marine fish parasite copepods. Estudios Oceanologicos. Facultad de Recursos del Mar, Universidad de Antofagasta 3: 69–73.

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

Espino, M. (2003). Estrategia de Gestión Oriental para el Pacífico Oriental con especial mención a la pesquería peruana. Tesis para optar el grado de Magíster en Geografía con mención en Ordenamiento y Gestión Ambiental. Unidad de Post Grado, Facultad de Ingeniería Geológica, Minera, Metalúrgica y Geográfica, Universidad Nacional Mayor de San Marcos. 102 p.

Espino, M. (2013). The Jack mackerel Trachurus murphyi (Nichols 1920) and the environmental macro-scale variables. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 009-020. (Volume published in Spanish with titles, abstracts and captions in English).

Espinoza, E M Ñiquen and R Flores. (2008). Changes in the latitudinal and longitudinal distribution of the aggregations of jack mackerel (*Trachurus murphyi*) in the Perúvian sea during 1996 – 2007. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

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

FAO (2005). Review of the state of world marine fishery resources. FAO Fisheries Technical Paper, No. 457. Rome. 233pp.

Flores, R., M. Espino, G. Luque & J. Quispe. (2013). Environmental variability patterns in the Peruvian waters. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 021-028. (Volume published in Spanish with titles, abstracts and captions in English).

Garcia, C. (2008). Maximum sustainable yield (MSY) and optimum effort of fishing of jack mackerel (*Trachurus murphy*) and pacific mackerel (*Scomber japonicus*) in Perú (1997-2006). Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

George, M.R. (1995). Aspects of the reproductive cycle of southern Pacific jack mackerel, *Trachurus murphyi* Nichols, 1920, off northern coast of Chile. Ices C.M 1995/H30: 12.

Gerlotto F., M. Gutierrez & A. Bertrand. (2010). The distribution of Jack mackerel *Trachurus murphyi* in the South Pacific Ocean: a metapopulation hypothesis. FAST-ICES-WG annual meeting. SWNFS, NOAA, San Diego, April 2010.

Gerlotto, F., M. Gutiérrez & A. Bertrand. (2012). Insight on population structure of the Chilean Jack mackerel (*Trachurus murphyi*). Aquatic Living Resources, 25(4): 341-355

Gili, R., V. Alegría, V. Bocic, L. Cid y H. Miranda. (1996). Estudio biológico pesquero del recurso jurel en la zona centro sur, V a X Regiones. Determinación de la estructura de edad y parámetros de crecimiento del jurel. FIP 018 - 93.

Goicochea, C., J. Mostacero, P. Moquillaza, T. Dioses, Y. Topiño & R. Guevara-Carrasco. (2013). Validation of the formation rate of growth rings in otoliths of Jack mackerel Trachurus murphyi (Nichols 1920). In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 053-060. (Volume published in Spanish with titles, abstracts and captions in English).

Gutiérrez , M., A Bertrand , M Ballón, P Espinoza , A Alegre and F Gerlotto. (2008). Distribution changes and interactions of jack mackerel off Perú as observed using acoustics (1983-2006). Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Guzman, O.; Castillo, J.; Lillo, S.; Pineda, P.; Rodriguez; Giakoni, I. (1983). Estudio de recursos pelágicos. Programa monitoreo de los recursos pelágicos. I. Prospección zona Arica–Coquimbo. (18º30’–30º00’S). CORFO. Gerencia de Desarrollo. IFOP (AP 83–32). 48 p.

Hilborn, R. & C. Walters. (1992). Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty. Chapman & Hall, New York, 570 pp.

Icochea L., A. Chipollini & M. Ñiquen. (1988). Análisis de pesquería de arrastre pelágica en la costa peruana durante 1983-1987 y su relación con el medio ambiente. Rev. Com. Perm. Pacif. Sur. 455-465. Memorias del Simposio Internacional de los Recursos Vivos y las Pesquerías en el Pacífico Sudeste. Viña del Mar.

Kalchugin, P.V. (1992). The population structure of the Peruvian jack mackerel. Soviet Journal of Marine Biology 17: 95–100.

Kawahara, S.; Uozumi, Y.; Yamada, H. (1988). First record of a carangid fish *Trachurus murphyi* from New Zealand. Japanese Journal of Ichthyology 35: 2 212–214.

Kochkin, P.N. (1994). Age determination and estimate of growth rate for the Peruvian jack mackerel, *Trachurus symmetricus murphyi*. Journal of Ichthyology 34: 39–50.

Konchina, G.V. (1983). The feeding niche of the hake *Merluccius gayi* (Merlucciidae), and the jack mackerel, *Trachurus symmetricus* (Carangidae) in the trophic system of the Peruvian coastal upwelling. J. Ichthyol., 23(2): 87-98.

Konchina, G.V. (1980). The Peruvian jack mackerel, *Trachurus symmetricus murphyi*, a facultative predator in the coastal upwelling ecosystem. J. Ichthyol., 20(5): 46-59.

Konchina, Y.V. (1979). The feeding of the Peruvian jack mackerel, *Trachurus symmetricus murphyi*. Journal of Ichthyology 19: 52–61.

Kotenev, B.N., Kukhorenko, K.G., Glubokov, A.I. (2006). Main results of the Russian multidisciplinary ecosystem research, and exploratory fish-finding of concentrations of hydrobionts and their fisheries development in the south Pacific. Moscow: VNIRO. 37 p.

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

Mace, P., L. Botsford, J. Collie, W. Gabriel, P. Goodyear, JJ. Powers, V. Restrepo, A. Rosenberg, M. Sissenwine, G. Thompson, J. Witzig. 1996. Scientific review of definitions of overfishing in U.S. Fishery Management Plans. Supplemental Report. NOAA Technical Memorandum NMFS-F/SPO-21. 20 pp.

Messie, M.; Chavez, F. (2011). Global Modes of Sea Surface Temperature Variability in Relation to Regional Climate Indices. Journal of Climate, 24: 4314-4331.

Morón O. (2013). Climatología de la salinidad superficial frente a la costa peruana (1960 -2008). Inf Inst Mar Perú-Callao. 38 (1):7-39.

Muck, P; Sánchez G. (1987). The importance of mackerel and horse mackerel predation for the Peruvian anchoveta stock (a population and feeding model). In: D. Pauly and I. Tsukayama (Eds.). The Peruvian Anchoveta and Its Upwelling Ecosystem: Three Decades of Change. ICLARM Studies and Reviews 15, 351 p.

Nazarov N.A.; Nesterov, A.A. (1990). Jack mackerel, *Trachurus murphyi*, in the southwestern part of the Pacific Ocean. Transactions of the All-Union Symposium of Reserves of Biological Nutritive Resources in the Open Ocean and Seas of the USSR (Kaliningrad, 10–22 March 1990). Moscow, 131–133.

Neira, S.; Arancibia, H.; Cubillos, L. (2004) Comparative analysis of trophic structure off central Chile in 1992 and 1998. Ecological Modelling. 172: 233-148.

New Zealand Seafood Exports (2005) Report 5A. New Zealand Seafood Industry Council.

Nunez, S., J. Letelier, D. Donoso, A. Sepulveda y D. Arcos. (2004). Relating spatial distribution of the Chilean jack mackerel eggs and environmental factors in the oceanic waters off Chile. Proceedings (Tomo II) of the Pan Ocean Remote Sensing Conference, 2004. Remote Sensing of Oceans, Coasts and Atmosphere: Developments and Applications. Gayana, Vol. 68 Nº 2: 444-449.

Núñez, S, S Vásquez, P Ruiz and A Sepúlveda. (2008). Distribution of early developmental stages of jack mackerel in the Southeastern Pacific Ocean. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Ñiquen, M,. and Carranza. (2008). Program Bio-oceanographic research of resources jack mackerel and Pacific mackerel in Perú. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Ñiquen, M.A. and C.L. Peña. (2008). Distribution of jack mackerel (*Trachurus murphyi*) related to oceanographical features between north Perú to north Chile. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Ñiquen, M., M. Bouchon, D. Ulloa, A. Medina. (2013). The Jack mackerel Trachurus murphyi (Nichols 1920) fishery in Peru: an analysis of catches and the fishing fleet. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 097-106. (Volume published in Spanish with titles, abstracts and captions in English).

Ojeda, V. Bocic and L. Muñoz. (2008). Methodology employed for age determination in Chilean jack mackerel (*Trachurus murphyi*). Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008. Doc. CHJMWS pap #8: 11p

Oliva, J; G. Claramunt; G. Herrera; C. Padilla y P. Pizarro (1995). Reproducción In: Alegría, V. (Ed.), Estudio Biológico Pesquero sobre el recurso jurel en la zona norte (Regiones I y II). IFOP.

Oliva, M.E. (1999). Metazoan parasites of the jack mackerel *Trachurus murphyi* (teleostei, Carangidae) in a latitudinal gradient from South America (Chile and Peru). Parasite 6: 223-230.

Oyarzún, C. y S. Gacitúa. (2002). Aspectos reproductivos, fecundidad parcial y frecuencia de desove del jurel, año 2001. In: Cubillos, L. (Ed.) Condición biológica del jurel en alta mar, año 2001. Preinforme Final Corregido, FIP 2001-12. 168 p. + Anexo.

Oyarzún, C., J. Chong y M. Malagueño. (1998). Fenología reproductiva en el jurel, *Trachurus symmetricus* /Ayres, 1855)(Perciformes, Carangidae) en el área de Talcahuano-Chile: 1982-984. En: D. Arcos (ed). Biología y Ecología del Jurel en Aguas Chilenas: 67.75.

Penney, A. and P Taylor. (2008). An overview of the New Zealand jack mackerel fishery: Catch composition, catch trends, seasonality and length-frequency composition. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Peña, N.; Mariátegui, L. (1987). Variación estacional de la actividad reproductiva del jurel *Trachurus murphyi*. En: H. Salzwedel y A. Landa (eds.). En Recursos y Dinámica del Ecosistema de Afloramiento Peruano. Bol. Inst. Mar Perú. Callao. Vol. Extraord. 285 – 289.

Perea, A., J. Mori, B. Buitron y J. Sánchez. (2013). Reproductive aspects of Jack mackerel Trachurus murphy (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 029-034. (Volume published in Spanish with titles, abstracts and captions in English).

Poulin, E., L. Cárdenas, C. E. Hernández, I. Kornfield y F. P. Ojeda. (2004). The brief history of the Chilean jack mackerel: population genetic inference from the mitochondrial DNA control region. J. Fish Biol. 65: 1160-1164.

Romero, R. C.; Kuroki, H. B., (1985). *Lernanthropus antofaganstensis* sp. nov. (Copepoda: Lernanthropidae) parasitic on *Anisotremus scapularis* in Chilean waters, and new records of *Lernanthropus trachure* (Brian 1903). Journal of Natural History 19: 407–414.

Ruiz, P., A. Sepúlveda, L. Cubillos, C. Oyarzún & J. Chong. (2008). Reproductive parameters and spawning biomass of jack mackerel (*Trachurus murphyi*), in 1999-2006, determined by the daily egg production method. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Sánchez, J., A. Perea, B. Buitrón y L. Romero. (2013). Scale of gonad maturity stages of Jack mackerel Trachurus murphyi (Nichols1920). In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 035-044. (Volume published in Spanish with titles, abstracts and captions in English).

Santander, H.; De Castillo O.S. (1971). Desarrollo y distribución de huevos y larvas de jurel *Trachurus symmetricus murphyi* (Nichols) en la costa peruana. Inf. Inst. del Mar del Peru, Callao N° 36.

Santander, H.; Flores, R. (1983). Los desoves y distribución larval de ciertas especies pelágicas y sus relaciones con las variaciones del ambiente marino frente al Perú. En Sharp, G.D. y J.Csirke (eds) Actas de la Consulta de Expertos para examinar los cambios en la abundancia y composición por especies de recursos de peces neríticos. San José, Costa Rica, 18-29 abril 1983. Una reunion preparatoria para la Conferencia Mundial de la FAO sobre ordenación y desarrollo pesqueros. FAO Fish.Rep./FAO,Inf,Pesca, (291) vol.2: 553p.

Segura, M. y A. Aliaga. 2013. Acoustic biomass and distribution of Jack mackerel Trachurus murphyi (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 087-096. (Volume published in Spanish with titles, abstracts and captions in English).

Serra, J.R. (1983). Changes in the abundance of pelagic resources along the Chilean coast. In: G.D. Sharp and J. Csirke (Eds.) Proceedings of the Expert Consultation to examine changes in abundance and species composition of neritic fish resources. San José, Costa Rica, 18 - 29 April 1983. FAO Fish. Rep. 291 (2): 255 - 284.

Serra, R and A Glubokov. (2008). Population structure of Chilean jack mackerel, *Trachurus murphyi*, in the South Pacific Ocean: Full proposal for an international joint research programme. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Serra, R. (1991a). Important life history aspects of the Chilean jack mackerel, *Trachurus symmetricus murphyi*. Investigacion Pesquera (Chile) 36: 67–83.

Serra, R. (1991b). Long - term variability of the Chilean sardine. In: Proceedings of the International Symposium on the Long - Term Variability of Pelagic Fish Populations and their Environment. T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguchi (eds.) New York: Pergamon Press. pp 165 - 172.

Serra, R., C. Canales and L. Caballero. (2005).Investigación Evaluación de stock y CTP de jurel, 2005. Informe Final. IFOP/SUBPESCA. 43 p. +anexos.

Shaboneyev, I.Y. (1980). Systematics, morpho-ecological characteristics and origin of Carangids of the genus *Trachurus*. J. Ichthyology 20: 15-24.

Sistema Integrado de Información de Comercio Exterior. Jurel en Conserva. Internet report at http://www.siicex.gob.pe/siicex/resources/fichaproducto/109pdf2012Mar15.pdf.

Soldat V.T., Kolomeiko F.V., Glubokov A.I., Nesterov A.A., Chernyshkov P.P. and Timokhin E.N. (2008). Jack Mackerel (Trachurus murphyi) distribution peculiarities in the high seas of the South Pacific in relation to the population structure. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

SPRFMO. (2008). Chilean Jack mackerel workshop. Report of the South Pacific Fisheries Management Organisation (SPRFMO), Chilean Jack Mackerel Workshop, Santiago, Chile, 30 June-- 4 July 2008: 71pp.

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

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.

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

Tilic, I. (1963). Material estadístico sobre la industria peruana de harina de pescado. Inf. Inst. Inv. Rec. Marinos Nº 14: 51p.

Vasilyev, D., A Glubokov and D Kim. (2008). Preliminary estimation of current state of Chilean Jack Mackerel (Trachurus murhyi) stock in the high seas of the South East Pacific. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Vasilyeva, T. E., B. N. Kotenev, V. V. Kryukov, A. N. Kuznetsov, V. L. Mokrushin, V. V. Nekrasov. (1984). Distribution of jack mackerel aggregations in connection with bottom relief and waters circulation in the subantarctic zone of the Pacific ocean. Fishery studies in the open areas of the World Ocean. M.: VNIRO: 10-21. (In Russian).

Vinogradov, M.E.; Shushkina, E.A.; Evseyenko, S.A. (1991). Plankton biomass and potential stocks of the Peruvian jack mackerel in the southeastern Pacific subantarctic zone. Journal of Ichthyology 31: 146–151.

Wyrtki, K. (1967). Circulation and Wter Masses in the Eastern Equatorial Pacific Ocean. Int. J. Oceanolo. & Limnolo. Vol. 1, N°2, p 117-147.

Zhang, M. Y Xu. and C Wang (2008). Genetic variation on mt-DNA Cyt-b sequence of three populations of Chilean jack mackerel, Trachurus murphyi from the Southern Pacific. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Zhang, M., X Zou and Y Zhou. (2008). Report of data collection on jack mackerel in South-East Pacific. Paper presented to the SPRFMO Chilean Jack Mackerel Workshop, Santiago, 30 June – 4 July 2008.

Zuta, S., Tsukayama I.; Villanueva, R. (1983). El ambiente marino y las fluctuaciones de las principales poblaciones pelágicas de la costa peruana. En Sharp, G.D. & J. Csirke (eds) Actas de la Consulta de Expertos para examinar los cambios en la abundancia y composición por especies de recursos de peces neríticos. San José, Costa Rica, 18-29 abril 1983. Una reunión preparatoria para la Conferencia Mundial de la FAO sobre ordenación y desarrollo pesqueros. FAO Fish. Rep./FAO Inf, Pesca (291) vol.2:553p.

Zuzunaga, J. (1986). La ictiofauna: jurel. En: O. A. Mathisen and I. Tsukayama (eds.) Bases biológicas y marco conceptual para el manejo de los recursos pelágicos en el Pacífico Suroriental. Doc. de Pesca No. 001, Organización Latinoamericana de Desarrollo Pesquero. Lima, Perú: 47-50.

Zuzunaga, J. (2013). Conservation and fishery management regulations of Jack mackerel Trachurus murphyi (Nichols 1920) in Peru. In: J. Csirke, R. Guevara-Carrasco y M. Espino (eds). 2013. Ecology, Fishery and Conservation of Jack mackerel (Trachurus murphyi) in Peru. Rev. peru. biol. special issue 20 (1): 107-113. (Volume published in Spanish with titles, abstracts and captions in English).