Report of data collection on Jack mackerel in South-East Pacific

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

1. Vessels and fishing gears

From 2000 to 2007, altogether 11 Chinese fishing vessels have carried fishing operation in SE Pacific water, three of them were dispatched the fishery scientific observers on board. The vessels are the super-factory trawlers, namely “Kai Xin” and “Kai Fu”, belongs to Shanghai Deep-Sea Fishery Ltd. Co., with total tonnage 4407 tons and 7671 tons respectively, their beam width 16.0 and 20 m, engine power 2576kw×2 and 2960kw×2. The third one is 2300 tons factory trawler

"Fu Xing Hai" belongs to Liaoning Deep Sea Fishing Co.

Fishing gear: The middle water trawls of model 960 and model 1248 have been used by the vessels from Shanghai, and the model 1248 trawl was also used by vessel "Fu Xing Hai". The opening of trawl mouth is 56 to 80 meters high with the fishing circle about 960 to 1248 m long.

2. Data collection

Data collected from log book mainly are catch per tow, fishing time and positions, towing speed etc. Environment data about fishing ground are also collected including wind direction and speed, SST, STD etc. which recorded by means of Model XZC2-2 digital aerograph, wind velocity indicator and SBE-37 STD instrument etc. Biological items measured on broad by the random sampling are fork length, body height, width and girth, body weight and net weight without organs, sex, germ cells maturity, contains in the stomach etc. Depth of fish school inhabited in the water and temperature related were recorded by the echo sounder, net sounder and sonar. The otolith collected on board and delivered to the laboratory for appraisal age. The maturity situation of germ cells and stomach containing were observed and sorted in six grades and five grades respectively by the standards of the Chinese marine fish survey. Plankton and botany were collected in predetermined positions, and identified according to marine fishery survey standard.

3. Fishing and survey area

The area of trawling covered the water beyond Chile EEZ to 113°W，from 29°S to 46°S.

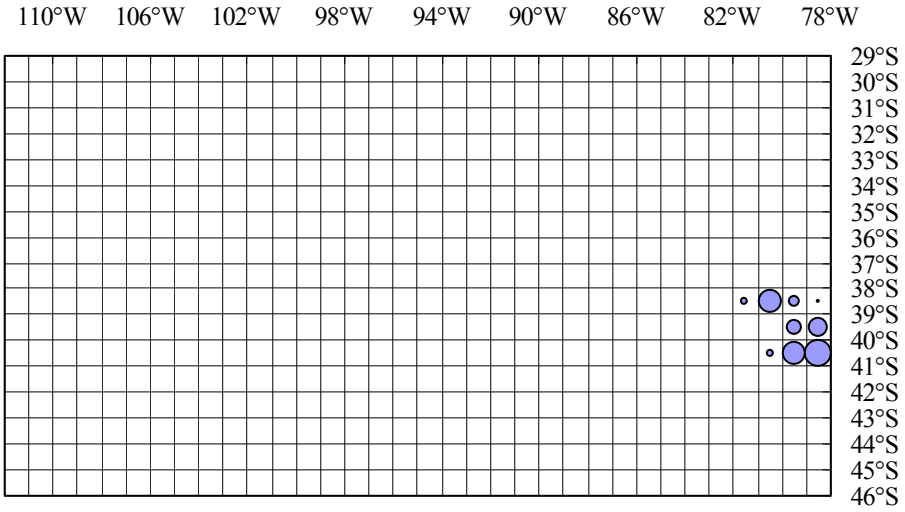

Fig. 1 fishing map of 2000

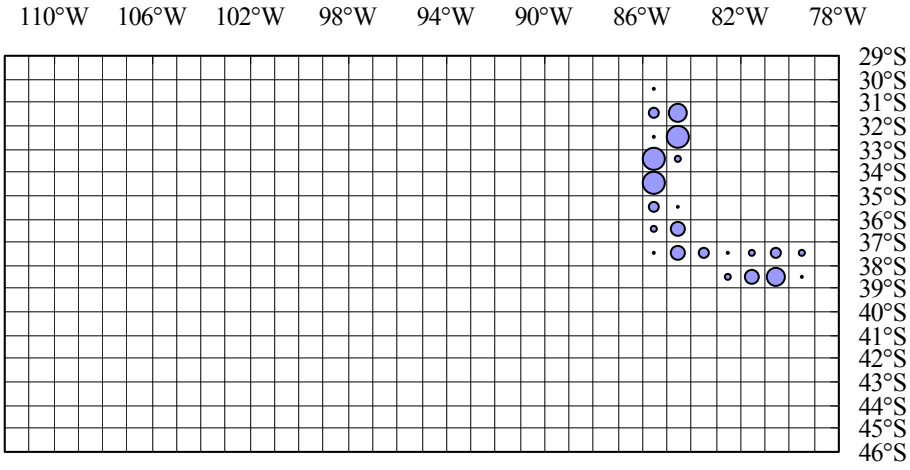

Fig. 2 fishing map of 2001

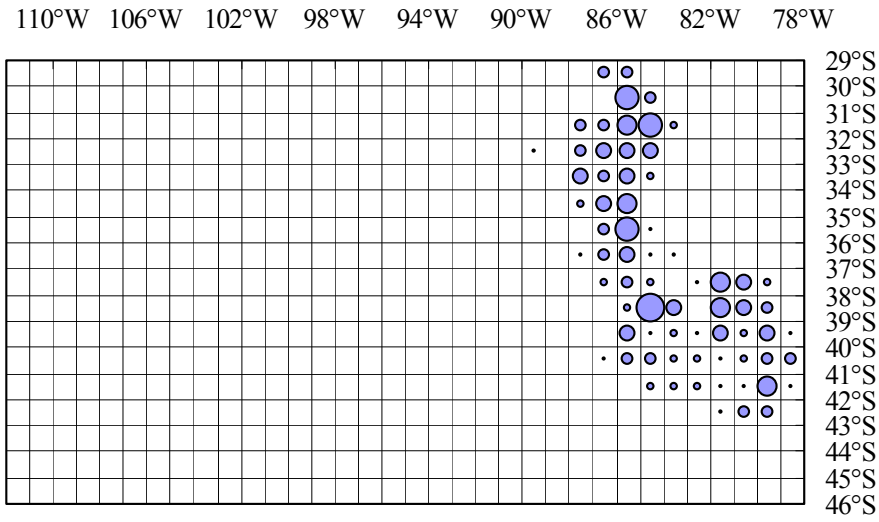

Fig. 3 fishing map of 2002

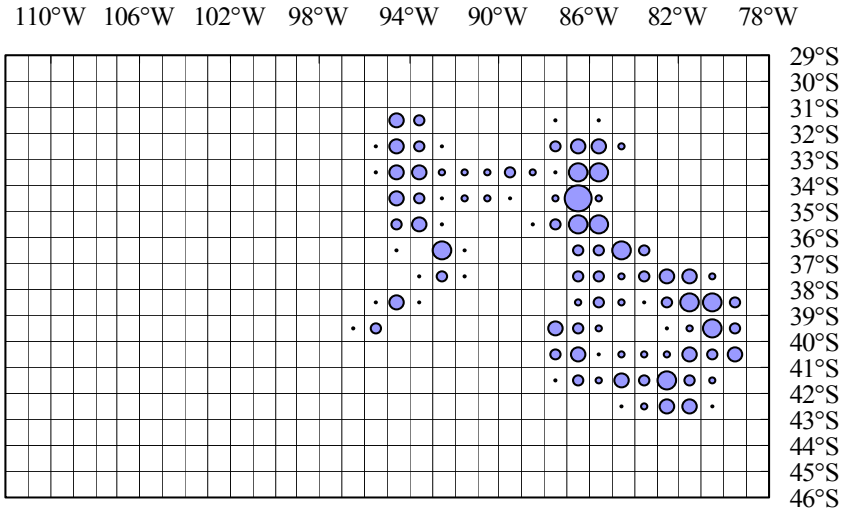

Fig.4 fishing map of 2003

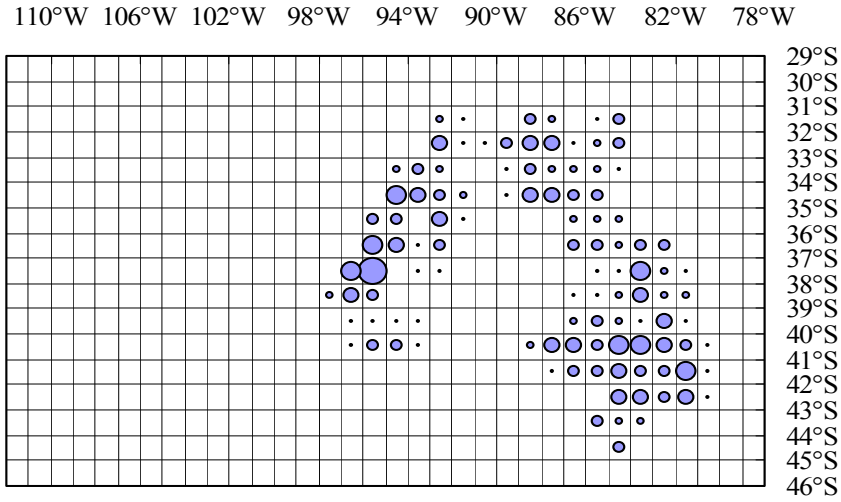

Fig.5 fishing map of 2004

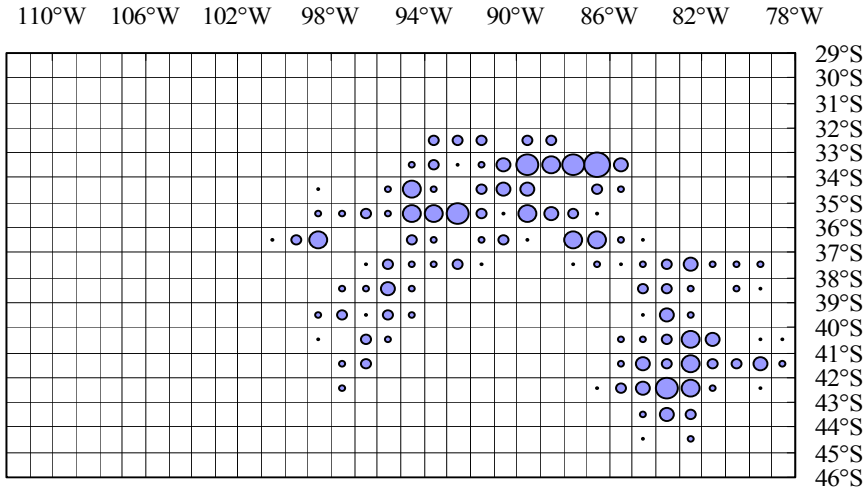

Fig.6 fishing map of 2005

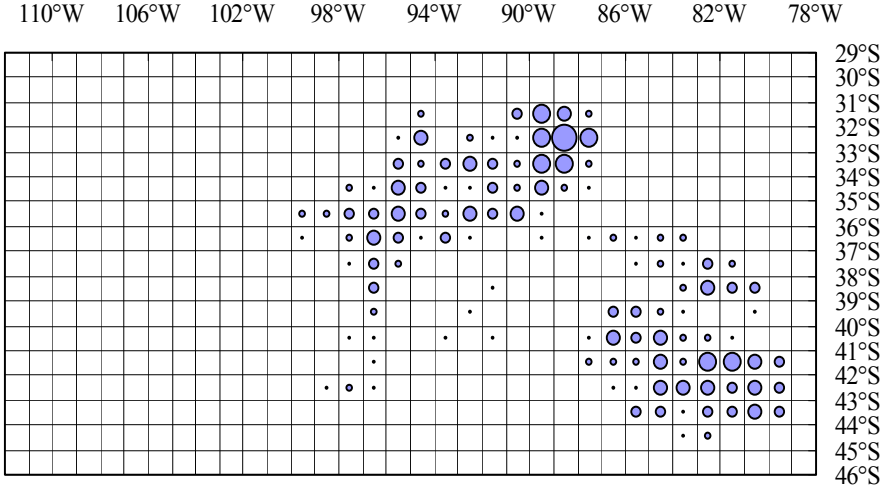

Fig.7 fishing map of 2006

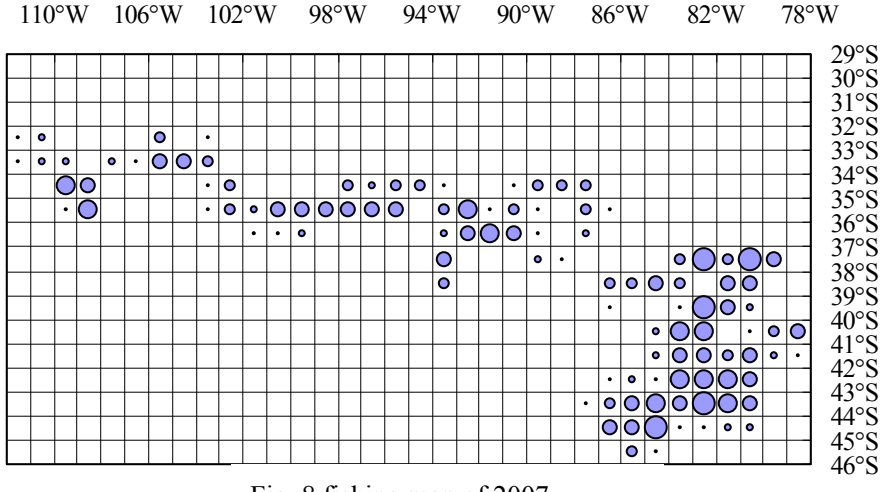

Fig. 8 fishing map of 2007

The sizes of circles in the fishing maps represent the number of the tows in total by Chinese fishing fleet, which show the fishing ground extending towards the west.

Table 1 CPUE（ton/hour）of 8 fishing vessels during 2000-2007

	2000	2001	2002	2003	2004	2005	2006	2007	mean CPUE
CPUE	7.86	7.20	6.39	5.26	5.07	5.95	7.52	6.81	6.21

4. Species in catch

Chile mackerel (*Trachurus murphyi*) is the main target species in the catch. Japanese mackerel (*Scomber japonicus*) as bycatch was found in catch, however, the maximum catch of Japanese mackerel was less than 10-20% in the total catch only found in occasional tows. There are a few of other spices such as pacific scad (*Scomberomorus sierra*), yellowtail (*Seriola laland*), lantrenfishes (*Myctophidae*) etc in the catch. Jumbo flying squid (*Dosidicus gigas*) has been caught since 2006, which is about 5-10% in the catch.

5. Fishing ground

Fig. 9 to Fig. 11 shows the CPUE and mean catch by tows in statistics area 1°×1°. The mean catch per tow (NC) are sorted into three

groups, NC<30t, 30t<NC<50t and NC>50t, which will facilitate to analyze the fish school distribution and indicate the possible fishing ground. The marks with white, gray or black colors in map represent the quantity of catch. The proportion of three groups in catch is 45%, 43% and 11.2% respectively. The group of catch less than 50 tons per tow are mostly located in the east of 97°W, and the big catch, more than 50 tons per tow were found in the west part of 97°W, see fig. 9.

Corresponding above the CPUE is graded as three groups too, i.e. CPUE>10t/h, 10t/h>CPUE>5t/h and CPUE<5t/h, the number of tows of the groups is presented by the size of circle in fig. 11. Their proportions are 14.6%, 36.3% and 49.1% respectively. Obviously, the records from log books show that the catch per hour, which more than 5 tons, is found in the east part of 96°W. the higher CPUE did not show in the west part because a few tows carried out there.

Fig. 10 is total cumulated catch of 8 years in the area by 1°×1°. It shows the main fishing grounds are located at 38-46°S, 79-88°W; 31-38°S, 86-96°W; 32-37°S, the west of 96°W.

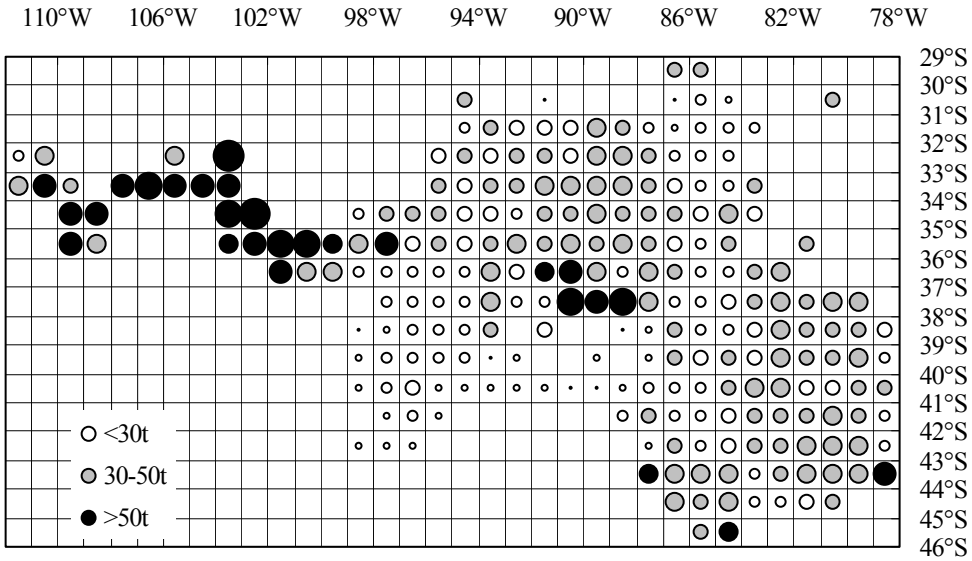

Fig. 9 Mean catch per tow by 1°X1° from 2000 to 2007

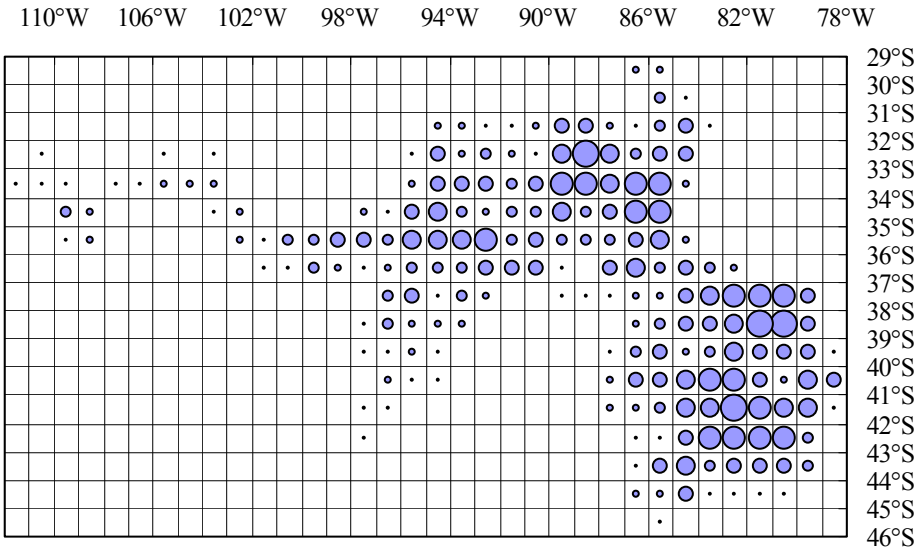

Fig. 10 Catch in 1°X1° from 2000 to 2007

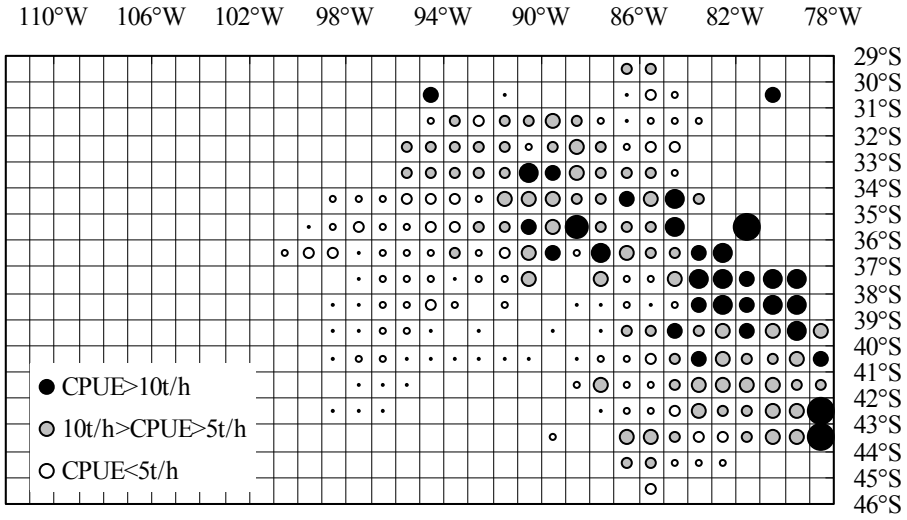

Fig. 11 CPUE in $1^{o}X1^{o}$ from 2000 to 2007

6. Biological characteristic of Chile jack mackerel

Altogether 11,030 samples have been collected, the measurements have been made on board, i.e. fork length (FL), body weight (W), net body weight (W_o), body girth (c), body height (a), body width (b), the germ cells maturity, the stomach contain and fullness etc. 2550 otoliths have been collected too. After statistical processing, some of results are shown as follows:

6-1 fork length and weight

Fig. 12 to fig. 17 shows the relationship between body weight (W in g) and fork length (FL in mm) of Jack mackerel from 2000 to 2007.

Year 2000: $W = 6.5075\times10^{-6}\times FL^{3.0710}$ $R^2 = 9.8617$

Year 2001: $W = 6.9589\times10^{-6}\times FL^{3.0601}$ $R^2 = 9.8376$

Year 2002: $W = 5.6522\times10^{-6}\times FL^{3.0924}$ $R^2 = 9.8721$

Year 2003: $W = 16.3283\times10^{-6}\times FL^{2.9152}$ $R^2 = 9.9285$

Year 2006: $W = 32.7783\times10^{-6}\times FL^{2.8043}$ $R^2 = 9.4081$

Year 2007: $W = 16.6306\times10^{-6}\times FL^{2.9326}$ $R^2 = 9.7467$

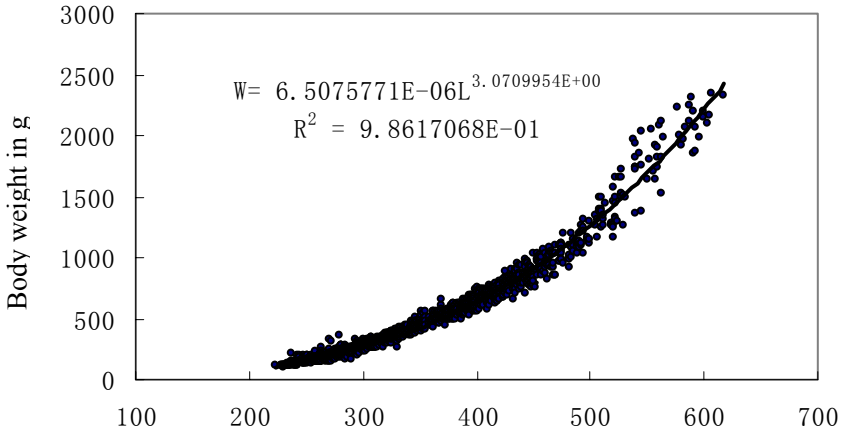

Fig. 12 Relationship between weight and fork length of Jack mackerel body in 2000

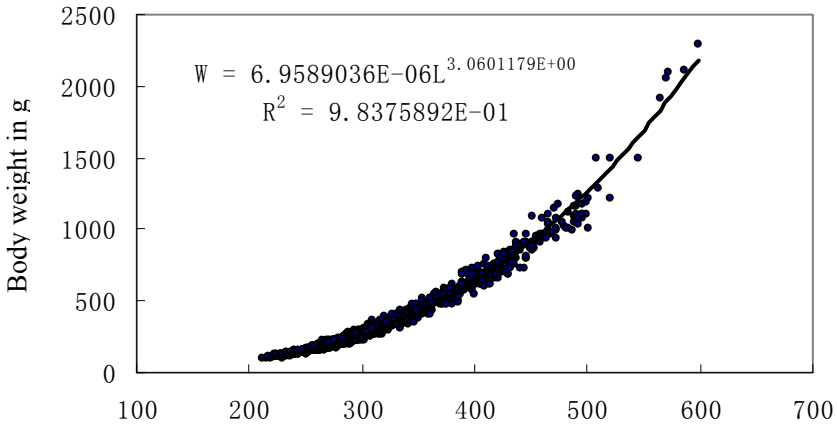

Fig. 13 Relationship between weight and fork length of Jack mackerel body in 2001

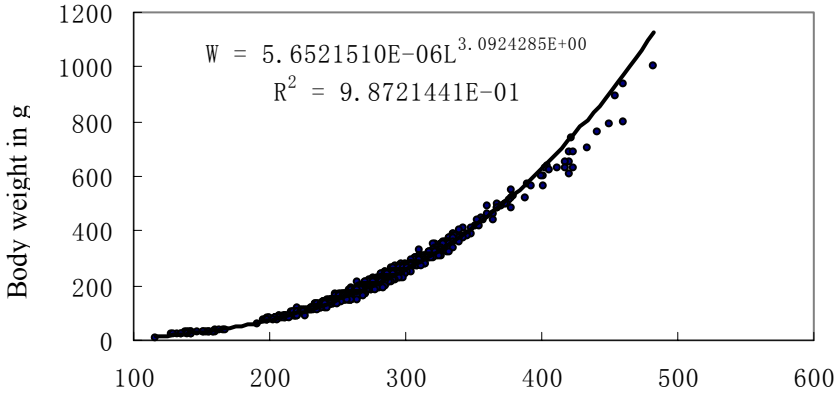

Fig. 14 Relationship between weight and fork length of Jack mackerel body in 2002

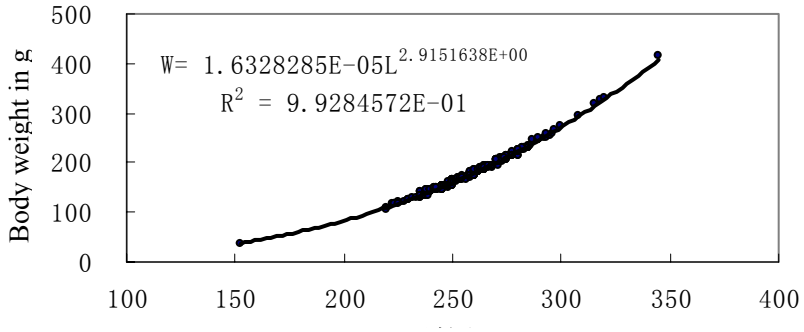

Fig. 15 Relationship between weight and fork length of Jack mackerel body in 2003

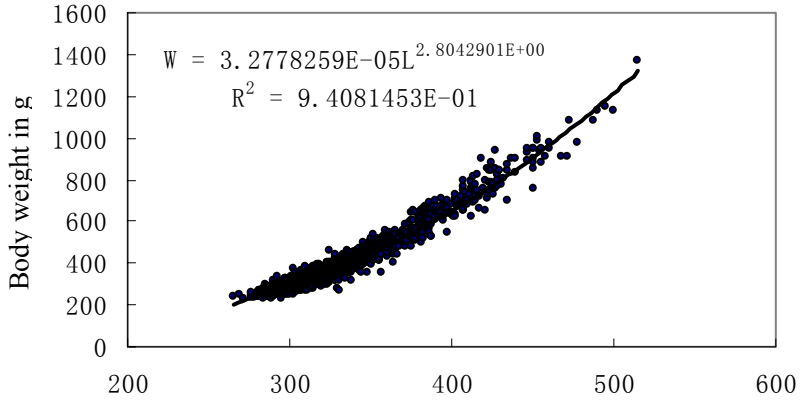

Fig. 16 Relationship between weight and fork length of Jack mackerel body in 2006

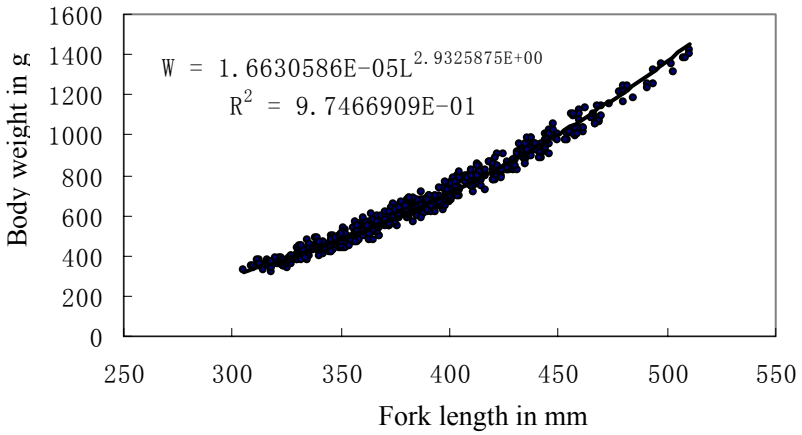

Fig. 17 Relationship between weight and fork length of Jack mackerel body in 2007

Fig. 18 shows the relationship between net weight (without organs) and fork length of jack mackerel in 2000.

$W_o = 6.8983 \times 10^{-6} \times FL^{3.0515}$ $R^2 = 9.8449$

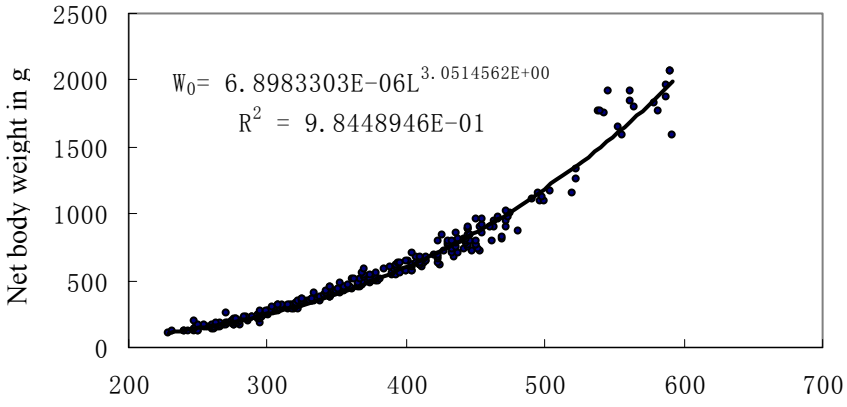

Fig. 18 Relationship between net weight and fork length of Jack mackerel body in 2000

6-2 Relations of fork length with girth C, body height a and body width b

Their relations are shown in fig. 19 to 21.

Year 2000:

C = 0.4812FL - 3.7213 R^2 = 0.965

a = 0.1862FL - 3.6176 R^2 = 0.9397

b = 0.1341FL - 4.3443 R^2 = 0.9518

Year 2001:

C = 0.4900FL - 7.8551 R^2 = 0.9613

a = 0.1887FL - 8.2095 R^2 = 0.9511

b = 0.1299FL - 5.5670 R^2 = 0.9437

Year 2007:

C = 0.5176FL - 5.9051 R^2 = 0.9667

a = 0.1955FL - 8.0351 R^2 = 0.9239

b = 0.1299FL - 2.1230 R^2 = 0.9263

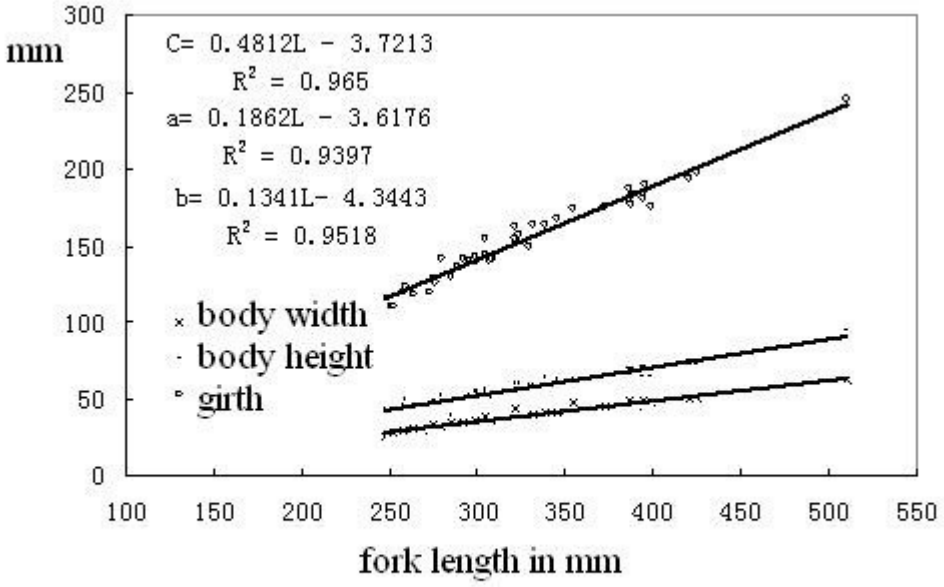

Fig.19 Relations between fork length and girth, body height of Chile jack mackerel in 2000

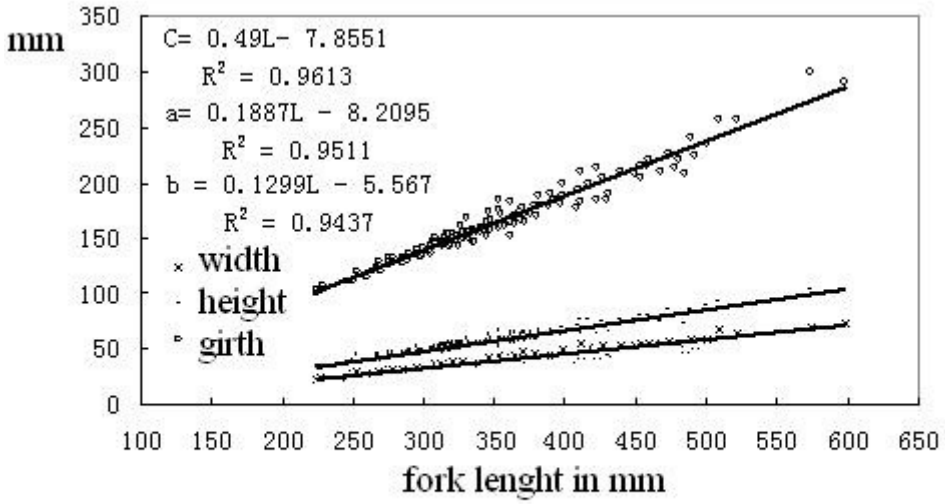

Fig. 20 Relations between fork length and body girth, width and height of Chile jack mackerel in 2001

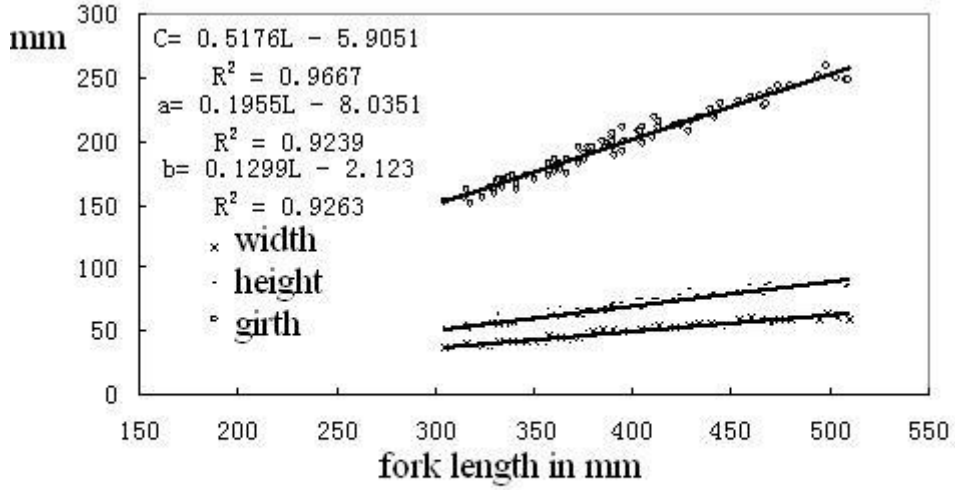

Fig.21 relations between fork length and girth, width and height of body of Chile jack mackerel in 2007

6-3 Depth of jack mackerel school stay

The habitat depths of fish schools recorded by echo sounders are shown in fig. 22, which integrated of data from 31st May/1st June of year 2000 to 2007. Fig. 23 shows the main depth changing with the months. In fact, the Chile jack mackerel distributed from the surface of water to

343 meter in depth, most of them stay at 250 meter and above. Comparison of the depth of schools in varied years shows the habitat depth quite stable having no significant change. Obviously the depth is changing closely related to the seasons. For instance, the fish school mostly concentrated at shallow water, at few hundred meters from sea surface, during April. After that, the fish is going down and habitat water layer is getting deeper. The fish school is rising up again at January at coming year. Jack mackerel has obvious daily migration, upwards at evening and downwards at early morning. They are gathering together at few hundred meters from surface at middle night and disperse into scatter small schools at 50 to 250 meter water layer during daytime.

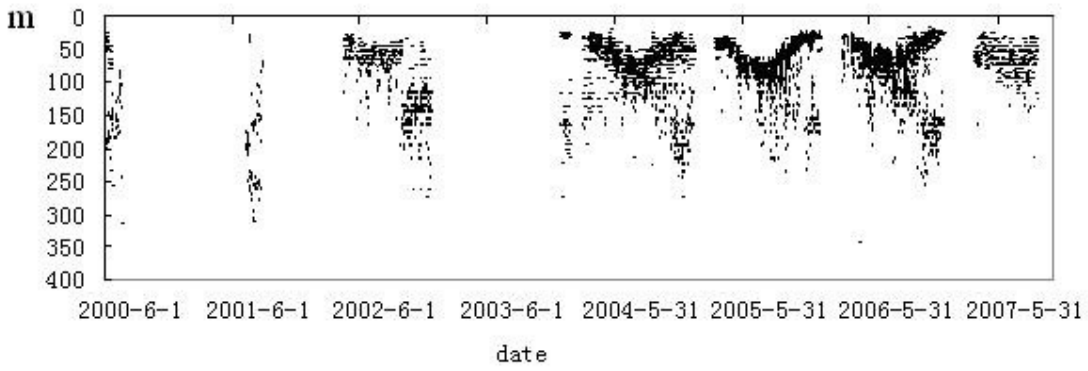

Fig. 22 Habitat depth of Chile jack mackerel

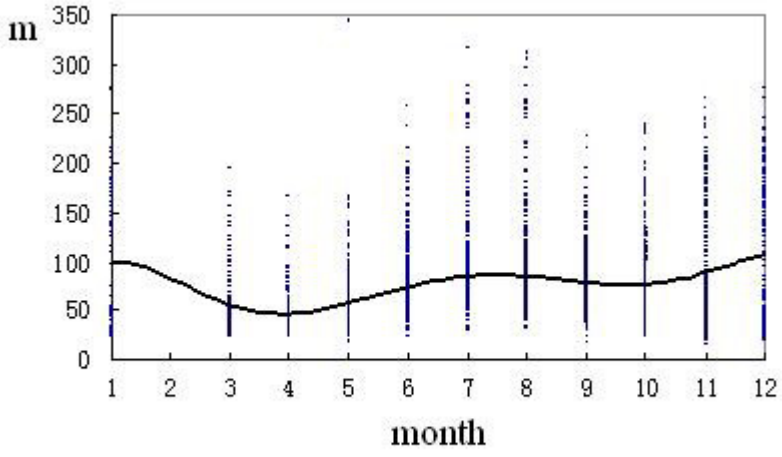

Fig. 23 Habitat depth of Chile jack mackerel

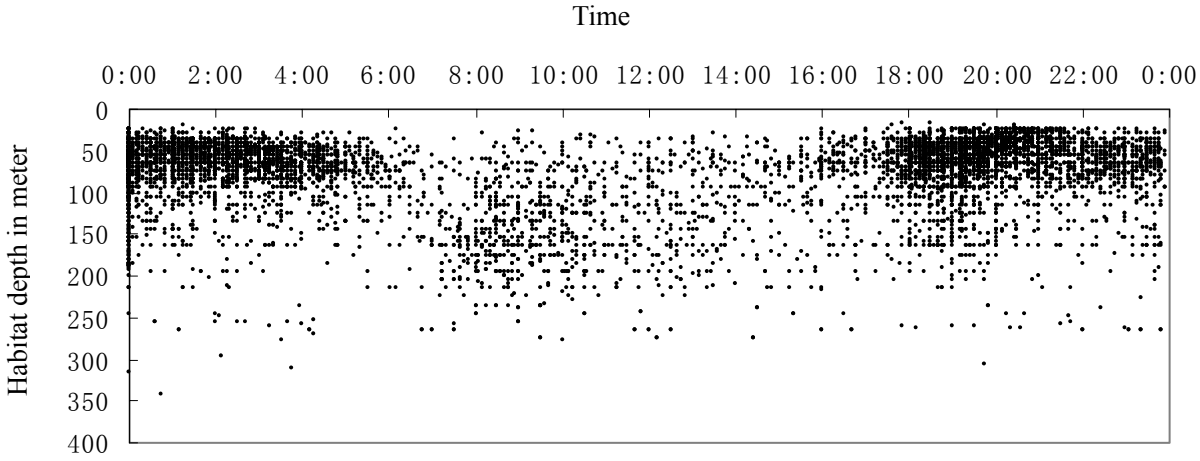

Fig. 24 Habitat depth of Chile jack mackerel by hours

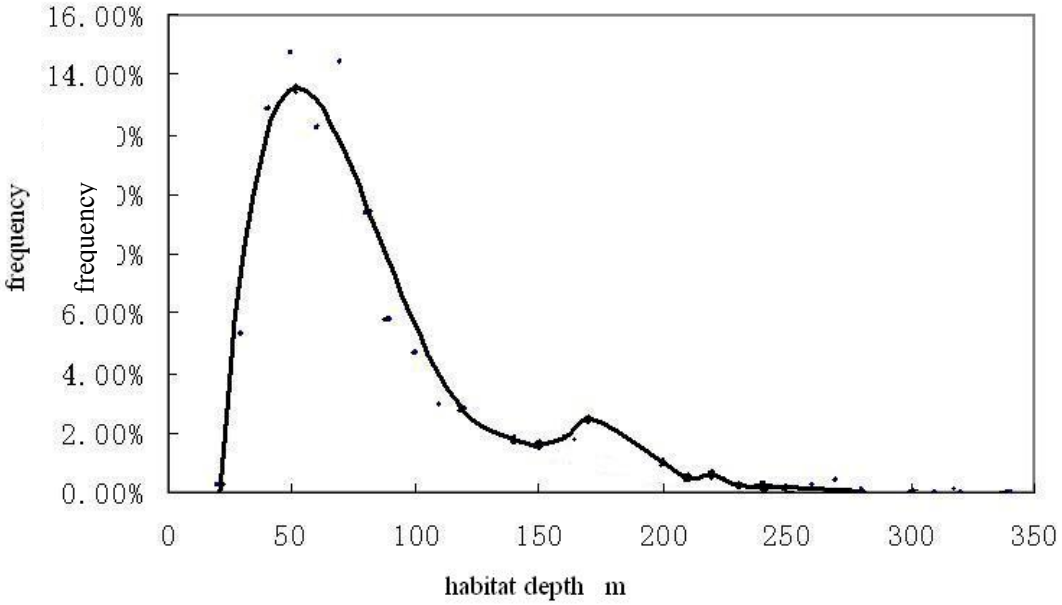

Fig. 25 Frequency of main habitat water layers where Chile jack mackerel existing

Fig. 24 and 25 shown that the jack mackerel schools mainly stay at depth of 25 to 95 meter, in where the frequency of school existing is 74.55%.

6-4 Temperature at habitat water layer of Chile jack mackerel

Fig. 26 shows the water temperature at the layers of fish inhabited integrated from data at May 31st or June 1st from year 2000 to 2007, which indicate that the Chile jack mackerel can be found at the temperature from 6.2 to 18.5°C in wider range and it varied with the season changing. The habitat temperature is higher at March and October, lower at June. During evening to next day morning the fish prefer stay at 12 to 16°C water layer. According the data collected during 8 years the most favorable temperature for fish habitat is between 11.5°C and 16.5°C, which has occurrence frequency 90.57%.

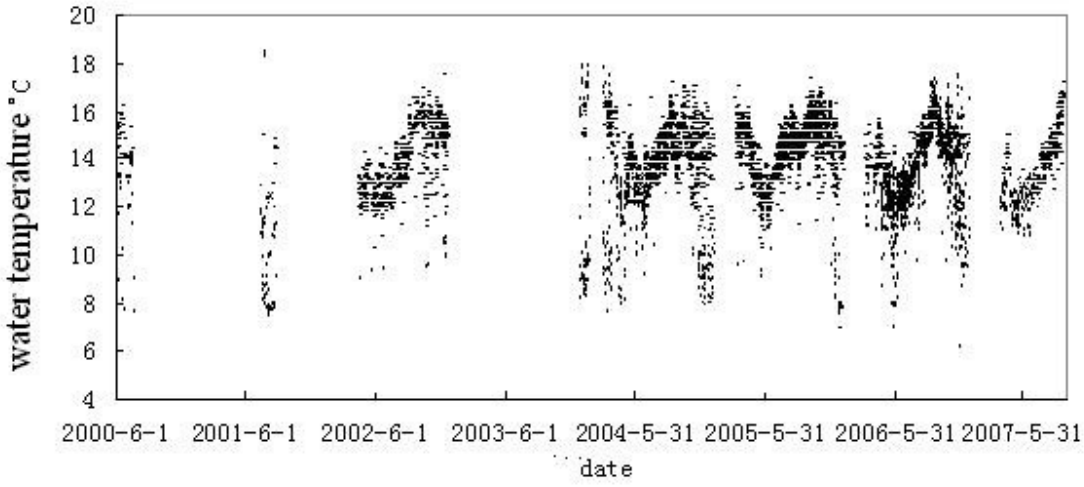

Fig. 26 Water temperature at habitat layer of Chile jack mackerel occurrence

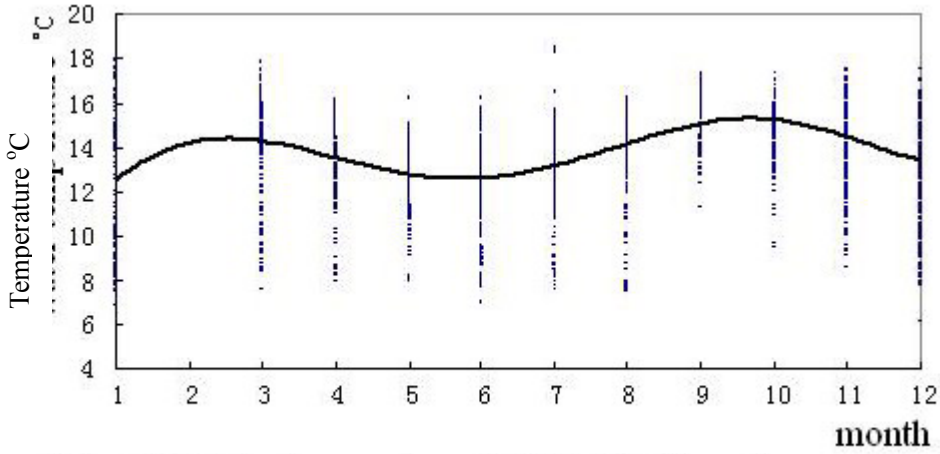

Fig. 27 Water temperature at fish habitat layer by months

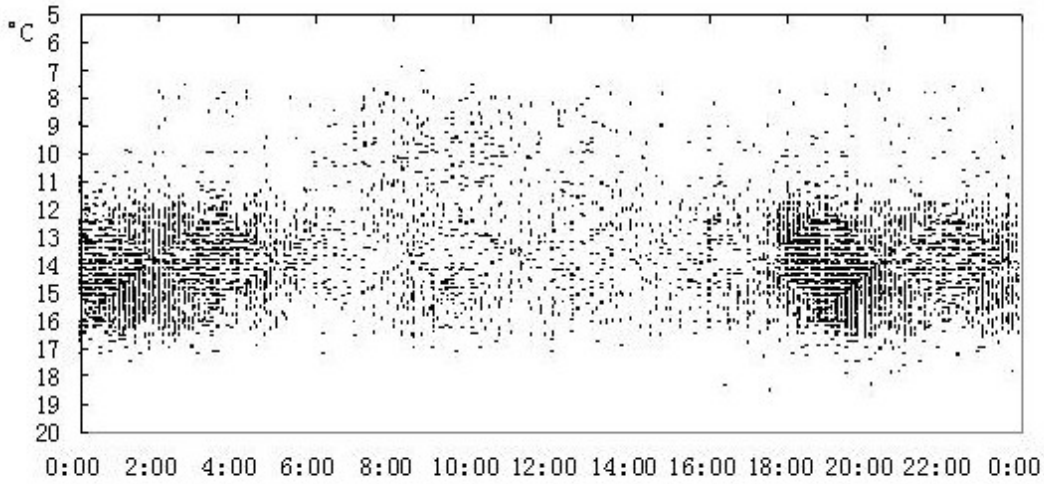

Fig. 28 Water temperature of fish inhabited cumulated at hours

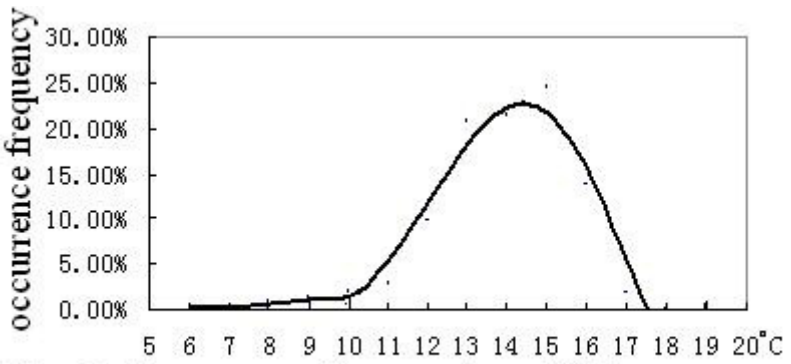

Fig. 29 Frequency of temperature of fish occurrence

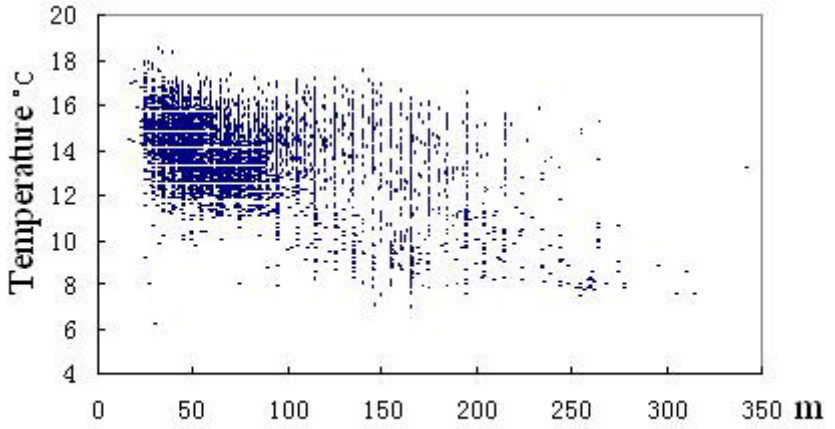

Fig. 30 Depth and temperature at where fish distributed

6-5 Feeding and bait species

Fig. 31 shows the frequency occurrence of the fish with stomach fullness index greater 3, the feeding degrees have fluctuation varied with years, the number of individuals with stomach fullness index 3 and greater is the highest, up to 45.7%, in 2007. and the year 2001 is lowest, 11% only. By monthly analyze the fullness greater 3 is 46.5%, the highest, during April and the lowest appeared at July, which is 12.4% only. By latitude, the data also show that 54% of fish having good feeding at 44.5°S, followed by 42% around 30.5°S, and the lowest happened at 35.5°S, which shows 8% only. By longitude, the area around 79.5°W shows the lowest of fullness index, which only 3% fish have good feed and the highest appeared around 82.5°W, 28% fish having fullness index greater 3, which followed by the fish at 85.5°W, it is 27%. So in general, the area with good feeding condition is located between 40 to 46°S and 82 to 86°W, and the second area is between 30 to 35°S and 84

to 87°W. Chile jack mackerel is less feeding with lower stomach fullness index, the percentage of fish with empty stomach becomes to 51.56% after September due to latency period and ready for reproduction.

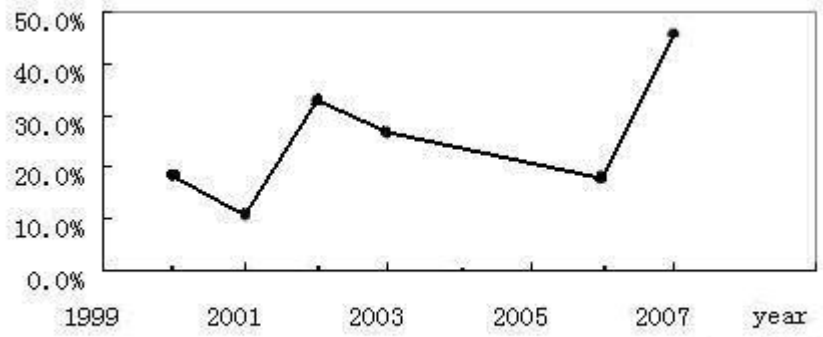

Fig. 31 frequency of stomack fullness index ⩾ grade 3

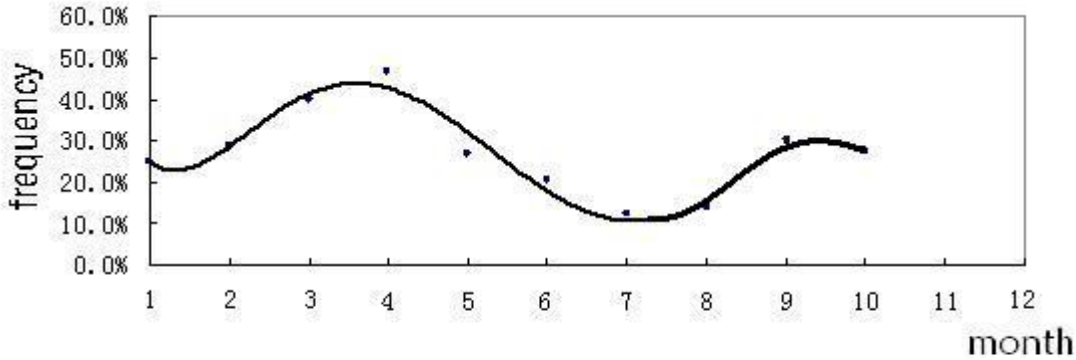

Fig.32 Frequency occurrence of chile jack mackerel with stomach fullness index 3 and greater by months

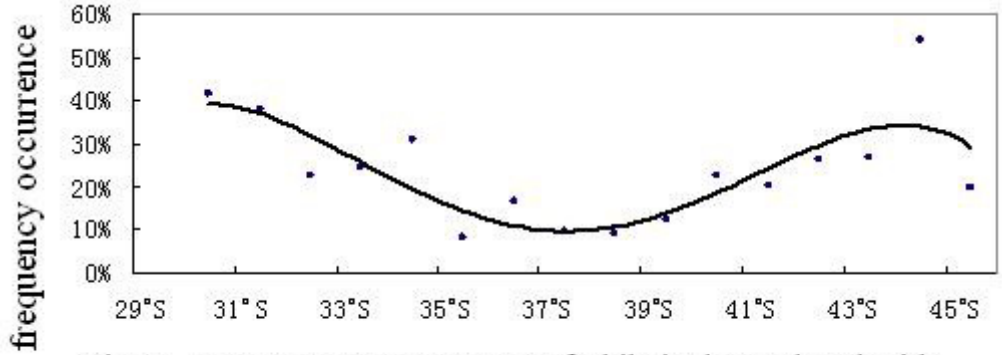

Fig.33 Frequency occurrence of chile jack mackerel with stomach fullness index 3 and greater by latitude

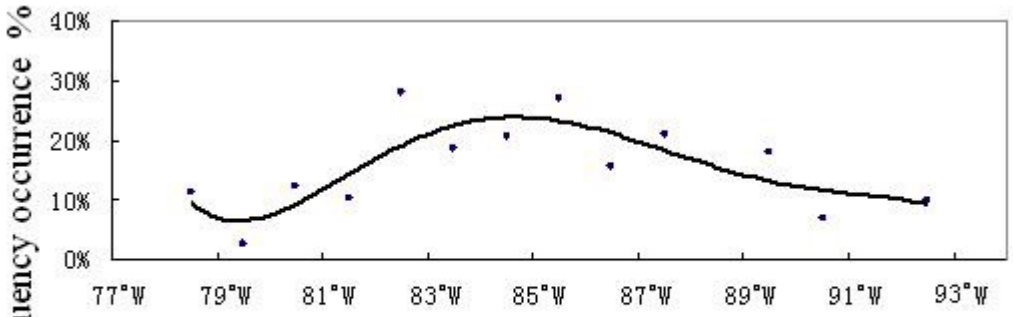

Fig. 34 Frequency occurrence of chile jack mackerel with stomach fullness index 3 and greater by longitude

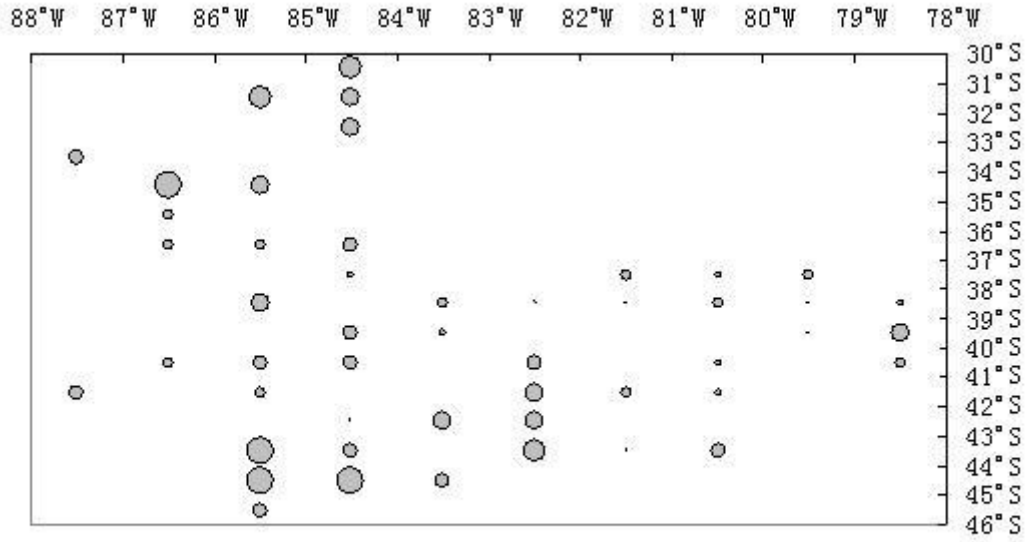

Fig. 35 Distribution of Chile jack mackerel with stomach fullness index 3 and greater

The samples collected shown that the species fed by Chile jack mackerel, and their stomach contain mostly are fish scales, krill (*Euphausiidae*), shrimps and squids etc. The squids can been found out in the catch each tows. A plenty of fish eggs have been found in the stomach of jack mackerel caught at 38°21′S, 80°54′W in 2001. The stomach full with *Salpidae, Salpa thompsoni and Pegea confoederata* has been found in the most of catch in 2006 and 2007. The scales found have been identified in laboratory, the results shown they come from

Indo-Pacific tarpon (*Megalops cyrinoides*), Janpanese flyingfish (*Cypselurus agoo*) etc.

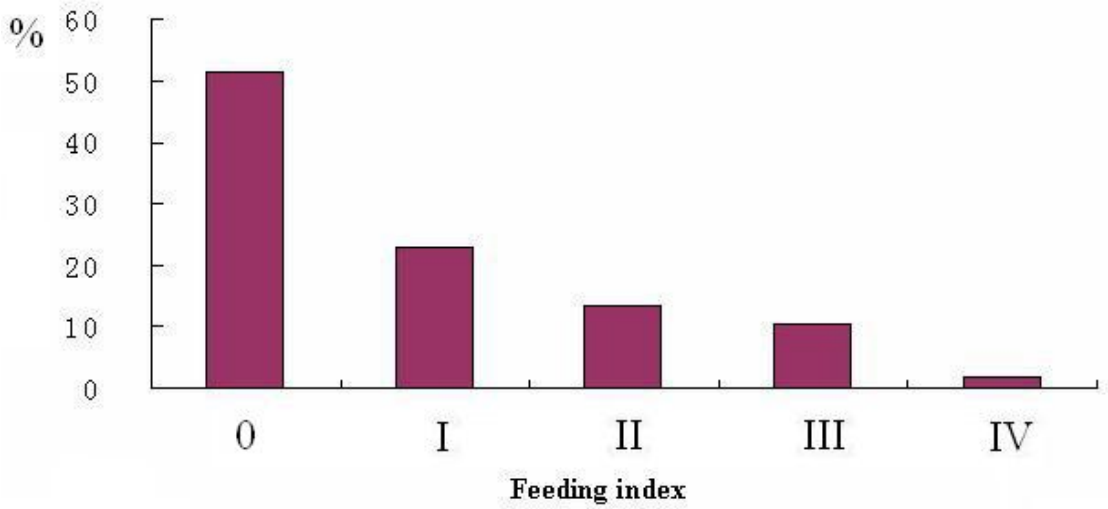

Fig. 36 Feeding situation of Chile jack mackerel in the west part of fishing ground

6-5 Sex ratio and sexual gland

The sex ratio, male/female, is 46.2/53.8, 47.4/52.6, 50:50 at 2000, 2001 and 2002 respectively. The data shows the same sex ratio 40.5/50.5 at both 2006 and 2007. the sex ratio from the sampling of catch shows a greater difference in months, such as higher male/female ratio 61.83/38.17 found in October, and the lowest appeared as 16.67/83.33 in January. This great changing in the sex ratio in the jack mackerel school might be the reproduction strategy for survival.

The distribution of fish based on the sexual gland degree is shown in fig, 37. The data shows the fish becomes sexual latency in June and sexual gland well developed at January. The school with 50% or higher

at sexual stage 3 or higher might be into reproduction soon. So the reproduction period is from November to February mainly.

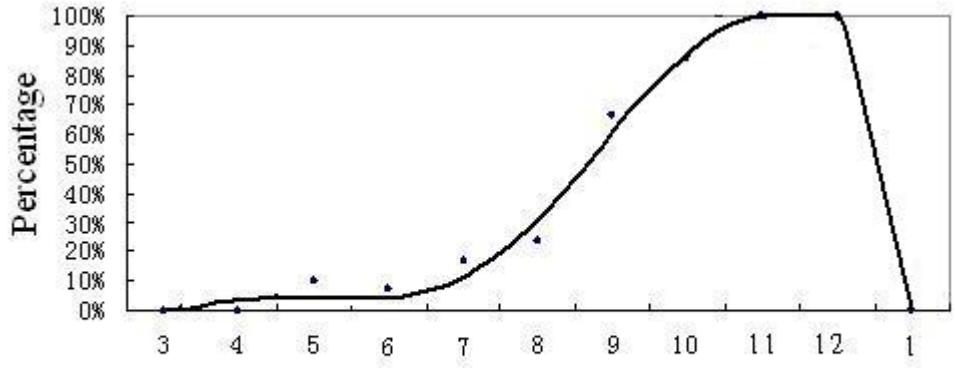

Fig.37 Percentage of sexual gland index 3 and greater of Chile jack mackerel at months

The fish at sexual gland well developed stage are distributed at 30° to 33°S and 57-82% individuals with sex index 3 and greater. The less developed one is located from 41° to 42°S, the fish with sex index 3 is 1% only. On the longitude dimension, the fish school with higher sexual index is at 85° to 86°W and 40.1% individuals are at sexual index 3 and higher. The school with percentage 33.3% is found at 80° to 81°W, but the lowest is 1.9% at 90° to 91°W area.

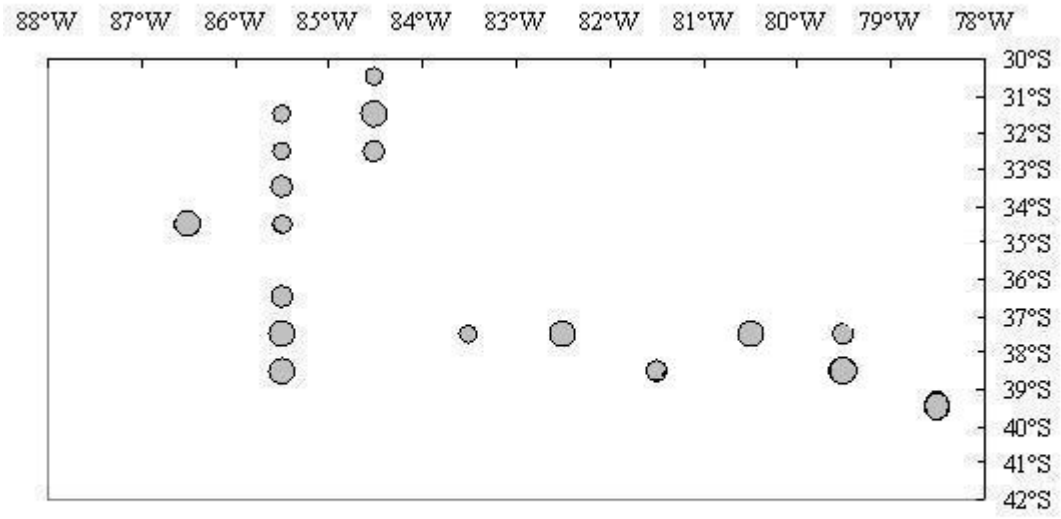

Fig.38 Distribution of sexual gland degree, the circle is 50% more individual is at index 3 or higher

The biological data collected in the area of west part of 96°W during October and November 2007 and their measurements show that the sexual gland are well developed and ready for reproduction, most of them are at IV and V stages, a few individual are already have spawn at VI stage. See fig. 39.

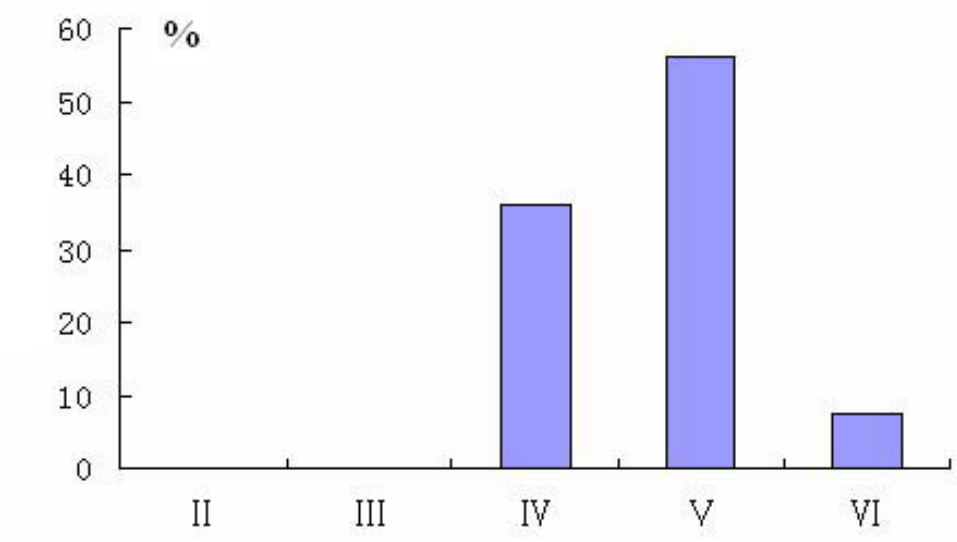

Fig.39 Degree of nomality sexual gulan

6-6 Length frequency and distribution of jack mackerel

FL is 223 to 618 mm in 2000 with body weight 105 to 2340 g, mean FL is 327 mm and Mean BW 404 g. The major FL is 250 to 310 mm group which is 52% in total individuals, see the table 1. The major FL in 2001 is 250-330mm (80.41%), 2002 is 240-300mm (73.74%), 2003 is 230-290mm (91.10%), 2006 is 290-350mm (80.20%) and 2007 is 330-430mm (75.86%)。

Table 1 Mean fork length and body weight of Chile jack mackerel in mm and g

year	Mean FL	Mean BW	Max FL	Max BW	Min FL	Min BW
2000	327	404	618	2340	223	105
2001	302	290	598	2290	212	100
2002	273	206	483	1000	116	10
2003	259	180	345	415	152	35
2006	326	377	515	1370	265	230
2007	386	661	510	1420	305	320

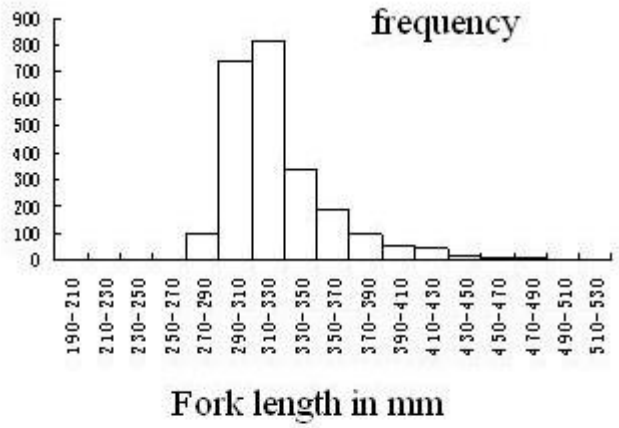

Fig.40 Frequency of fork length distribution in May to August of 2006

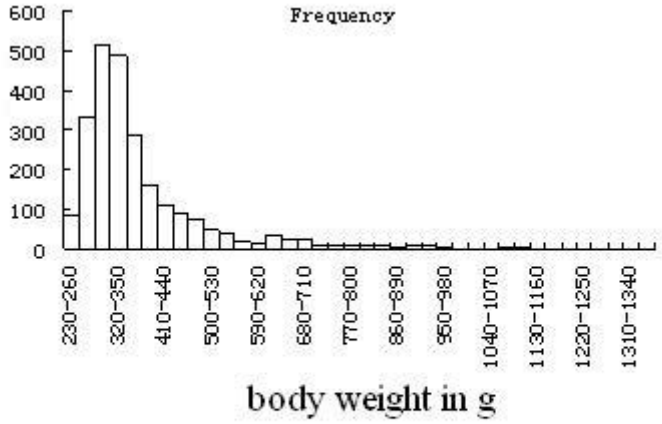

Fig. 41 Frequency of body weight of Chile jack mackerel during May and August of 2006

Table 2 Mean fork length and mean body weight of Chile jack mackerel during May and August

age	<3	3	4	5	6	>6
mean fork length (mm)	285.5979	299.3924	319.2999	373.5564	417.5606	461.0345
mean body weight (g)	270.1546	291.2952	345.4726	545.8182	754.0909	962.0690

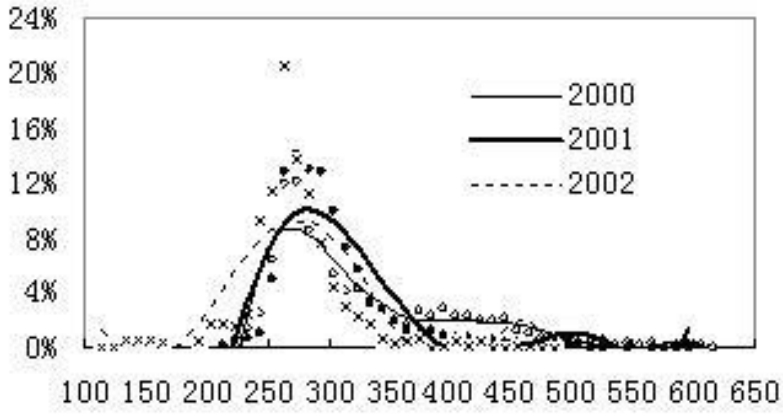

Fig. 42 Frequency of Fork Length during 2000 to 2002

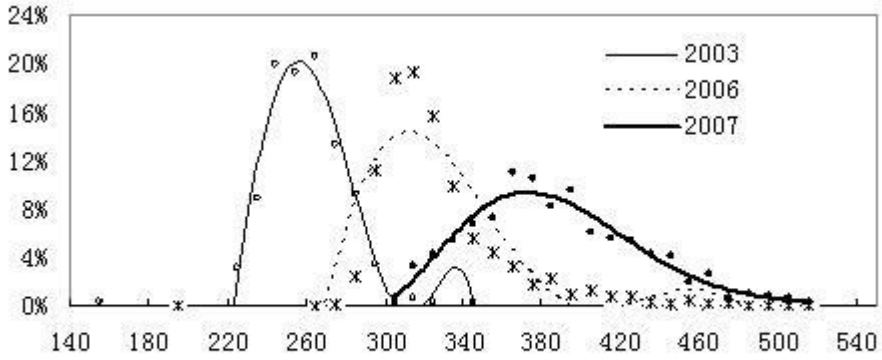

Fig. 43 Frequency of FL in 2003, 2006 and 2007

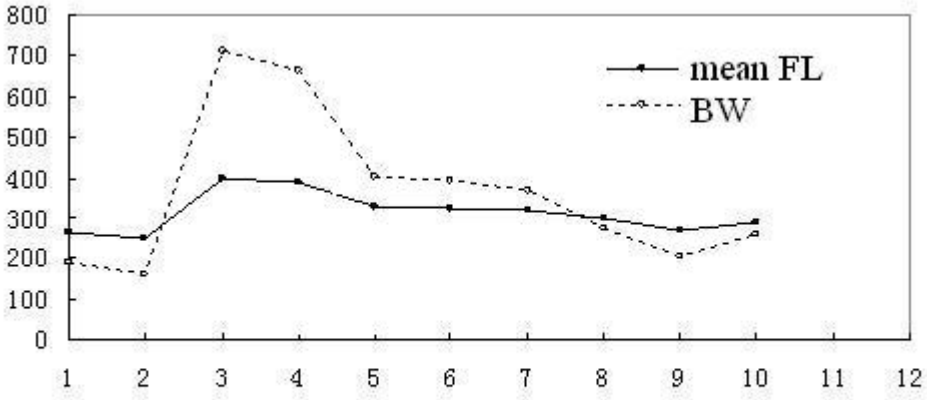

Fig. 44 Mean FL and BW of Chile jack mackerel

Distribution of size of fish school

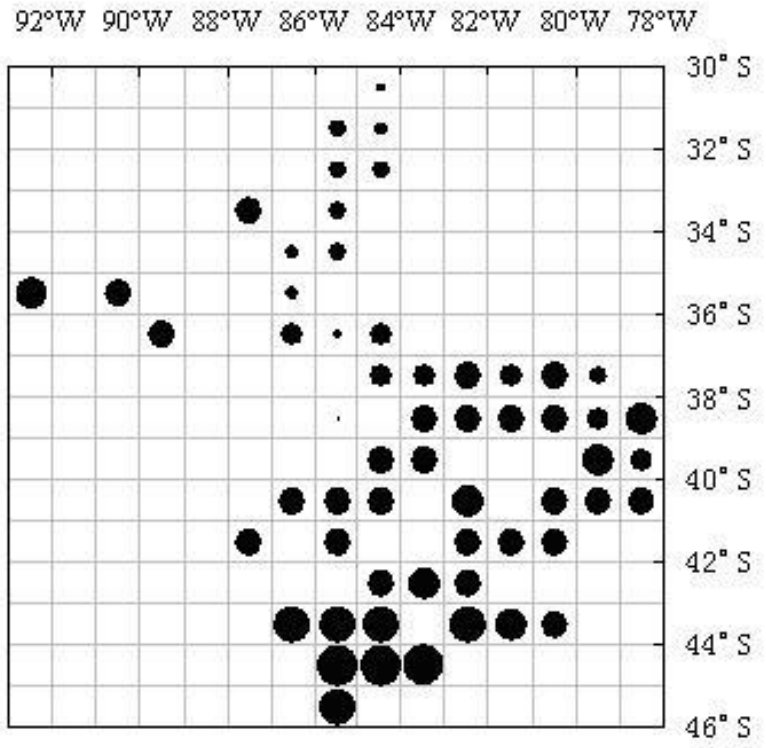

Fig. 45 distribution of FL of Chile jack mackerel

The data in the report is collected and processed by the working group of Shanghai Ocean University, subsidized by the Chile jack mackerel exploitation project and the fishery scientific observer program of MA, China. Prof. Min Zhang is the leader of Jack mackerel exploitation project, Assistant Prof. Xiaorong Zou is in charge the fishery scientific observer program on Jack mackerel. Master degree students, Yongjiu Xu, Liqin Zou, Chenghui Wang and Guoying Shao etc. have collected the most data on board and in lab which made the report available. The captains and crew members in the fish vessels of "Kai Xin", "Kai Fu" and "Fu Xing Hai", all of them made their contributions on the sea trails.

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