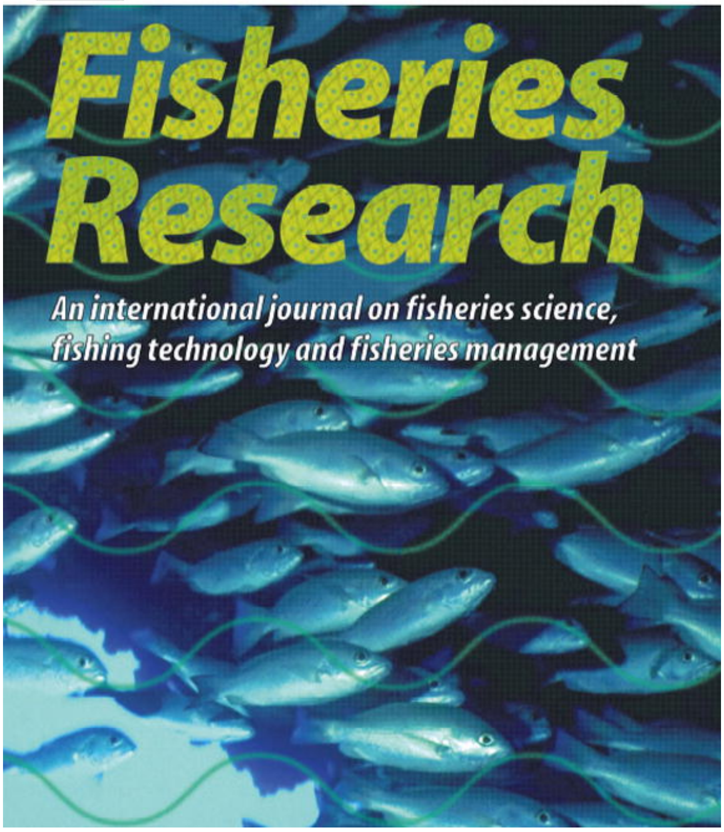
Volume 89, issue 3, March 2008
Completing Volume 89

ISSN 0165-7836



Available online at www.sciencedirect.com
ScienceDirect
Fisheries Research 89 (2008) 211–221
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Review

A review of the development of Chinese distant-water squid jigging fisheries

Xinjun Chen [a,*], Bilin Liu [a], Yong Chen [b]

[a] College of Marine Science and Technology, Jungong Road 334, Shanghai Fisheries University, P.O. Box 67, Shanghai 200090, China
[b] School of Marine Sciences, 218 Libby Hall, University of Maine, Orono, ME 04469, USA

Received 24 February 2007; received in revised form 16 October 2007; accepted 16 October 2007

Abstract

China has developed a major fishing fleet for oceanic squid since 1989, currently having more than 400 squid jigging boats with an annual catch of 250–300 thousand metric tonnes and accounting for about one-sixth of the global oceanic squid production. The main fishing target species include *Ommastrephes bartramii* in the northwestern Pacific, *Illex argentinus* in the southwestern Atlantic, *Dosidicus gigas* in the southeastern Pacific, *Sthenoteuthis oualaniensis* in the northwestern Indian, and *Todarodes pacificus* in the Sea of Japan. The ommastrephidae squid is an opportunist species and vulnerable to environmental fluctuations, making its abundance difficult to assess, forecast and manage. This calls for sharing of scientific information worldwide for better understanding and management of squid fisheries. This study reviews biology, fisheries and resource status of important commercial oceanic squid for the Chinese squid jigging fisheries with a focus on recent literatures published in China.

Keywords: Squid jigging fisheries; China; *Ommastrephes bartramii*; *Illex argentinus*; *Dosidicus gigas*; *Todarodes pacificus*; *Sthenoteuthis oualaniensis*

Contents

1. Introduction 212
2. Japanese common squid in the Sea of Japan 212
   2.1. Jigging fishery 212
   2.2. Biology 213
   2.3. Fishing ground 213
   2.4. Fishing technology 213
3. Neon flying squid in the North Pacific 213
   3.1. Jigging fishery 213
   3.2. Biology 214
   3.3. Fishing ground 215
   3.4. Fishing technology 215
   3.5. Squid abundance and its relationship with marine environment factors 216
4. Argentinus shortfin squid in the southwest Atlantic 216
   4.1. Chinese jigging fisheries 216
   4.2. Biology 216
      4.2.1. Population structure 216
      4.2.2. Sex maturity 217
      4.2.3. Feeding 217

* Corresponding author. Tel.: +86 21 65711303; fax: +86 21 65710389.
E-mail address: xjchen@shfu.edu.cn (X. Chen).

0165-7836/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2007.10.012

4.3. Fishing ground and its relationship with marine environment factors . . . 217
4.4. Fishing technology . . . 217
5. Jumbo flying squid in the southeast Pacific . . . 218
5.1. Jigging fishery . . . 218
5.2. Biology . . . 218
5.3. Fishing ground and its relationship with SST . . . 218
6. Purpleback squid in the Northwest Indian . . . 219
6.1. Jigging fishery . . . 219
6.2. Biology . . . 219
6.3. Fishing ground and its relationship with marine environmental factors . . . 219
6.4. Fishing technology . . . 219
7. Conclusions . . . 220
Acknowledgements . . . 220
References . . . 220

1. Introduction

Since the 1970s, the over-exploitation and collapse of many traditional demersal fisheries resources have lead to large changes in the species composition of world capture fisheries (Rodhouse, 2001). The species with short life cycles such as cephalopod have been continually increasing in their shares in the marine capture fisheries (Chen, 1996a), and are playing a critical role in maintaining or increasing the world capture fisheries production. Of the over 3 million tonnes of cephalopod production, the Teuthoidea squid (including both Ommastrephid and Loliginidae) have the largest share, consisting of 70–80% of the total catch (Chen, 2005). The oceanic squid made the most significant contribution to such an increase (FAO, 2004). More than 10 species of squid has became the main fishing target for the oceanic squid fisheries, including *Todarodes pacificus* in the Sea of Japan, *Ommastrephes bartramii* in the North Pacific, *Illex argentinus* in the southwestern Atlantic, *Dosidicus gigas* in the southeastern Pacific, and *Nototodarus sloani* in the New Zealand waters. These squid species are also the targets of the Chinese distant-water squid jigging fishery (Chen, 2005).

A total of more than 300,000 tonnes of squid are landed annually in recent years by the Chinese squid fishing fleet, accounting for more than one-sixth of the global oceanic squid production. China has one of the largest fishing fleets for oceanic squid. Since 1989, Chinese scientists have conducted a great deal of research on squid in the fields such as squid fishery resource assessment, biology, fishing grounds and fishing technology, and have made great progress in these fields (e.g., Chen, 2000; Chen and Tian, 2005; Chen and Shao, 2006; Chen and Zhao, 2006; Chen et al., 2007a). Because most publications are made in Chinese and there is a limited exchange between China and other countries, much of the work remains unknown to scientists outside China. This prompts us to write this paper to review the research and development of Chinese squid fishery and to share the results with scientists around the world. For this reason, this review is focused on recent literatures published in Chinese which may not be readily available to scientists and managers outside China.

2. Japanese common squid in the Sea of Japan

2.1. Jigging fishery

Japanese common squid, *Todarodes pacificus*, is a commercially important species for Japan, Korea and China (Kang et al., 2005). Its spatial distribution ranges from the Kamchatka Peninsula of Russia to Taiwan of China, and is especially abundant around Japan. The autumn spawning population, mainly distributed in the Sea of Japan, has become the major fishing target since the 1970s. The annual catch from this population by Japan, Korea and China in the Sea of Japan varies between 210 and 320 thousands tonnes since 1995 (Wang and Chen, 2005).

The first Chinese survey of Japanese common squid resources was made for a period of less than 1 month in 1989 in the Sea of Japan (40°–41°45′N and 131°30′–135°20′E) under the Russian jurisdiction (Wang and Chen, 2005). This was the beginning of the Chinese distant-water squid jigging fishery (not including Taiwan provinces; Wang and Chen, 1998). In 1991, a small-scale commercial fishery for this squid started. Fishing season was mainly in the period of June to December and the annual catch was less than 3000 tonnes from 1991 to 1994 (Wang and Chen, 2005). After 1994, because of the large-scale commercial exploitation of Neon flying squid *O. bartramii* in the northwestern Pacific, the squid population in the Sea of Japan became the fishing target during the later fishing season (October–December) with an annual yield less than 10,000 tonnes (Wang and Chen, 2005). The 5-year period (2000–2004) of bilateral fisheries agreements between China and South Korea and between China and Japan were signed, which allows the Chinese squid jigging boats to operate in the regulated regions of EEZ of Japan and South Korea in the Sea of Japan (Le, 2003). The agreement sets the fishing season from October 1 to December 31 for the Chinese squid jigging fishery (Le, 2003). According to the preliminary statistics for the time period of 2000–2004, the annual catch of squid for the Chinese squid jigging fleets reached 1300–4000 tonnes, and the fishing season was mainly from November to December. Since 2005, China has held bilateral meetings with Japan and South Korea annually to determine the number of fishing vessels and total catch allowed for the squid fishery in the Sea of Japan.

2.2. Biology

The squid catch was found to be mainly from the autumn spawning population during June to September from 1989 to 1994 in the central area of the Sea of Japan, which represented about 80% of the total catch (Chen, 1997a). The average mantle length (ML) increased gradually from June to September. In June, the average ML was 21.3 cm, and the dominant ML class was from 19 to 23 cm to which 74.8% of the total catch belonged. In July, the average ML reached 23.6 cm and the dominant ML class was between 21 and 26 cm, accounting for 80.2% of the total catch. The average ML in August and September reached 23.8 and 25.3 cm, respectively. The dominant ML class was from 22.0 to 27.0 cm and from 24.0 to 28.0 cm for August and September, respectively, with 59.7% and 66.7% of the total catch from these two ML classes (Chen, 1997a).

The relationship between ML (mm) and body weight (W, g) can be described as $W = 5.751672 \times 10^{-7} \mathrm{ML}^{2.787}$ ($R^2 = 0.8352$, $P < 0.05$; Yang, 1992). The ratio of female to male squid (F:M) of the catch was 68.3:31.7 in August and 61.4:38.6 in September (Yang, 1992). The smallest size reaching full maturity was 23.0 cm ML. More than 80% male squid in the catch were mature, but only 40% females were found mature after August (Yang, 1992).

Yang (1992) found that the squid is an active predator consuming a wide range of foods. It preys upon zooplankton, anchovy, sardine, *T. pacificus*, and juveniles of many other fish species. During the feeding period, about 75% of the stomachs evaluated were found to be more than half full, and the empty stomach was almost not observed (Yang, 1992).

The basic biology of this squid has been understood through long term studies (Dong, 1991; Wang and Chen, 2005). However, as a animal with short life span, more studies need to be done for a better understanding of ecological roles this squid species plays in the Sea of Japan, impacts of physical and chemical variables on its spawning and feeding grounds, and key ecological factors influencing its larval development and transportation and life history processes.

2.3. Fishing ground

This squid generally makes an annual north–south migration. They moved northwards to 40°–45°N from May to September, and then moved gradually southwards during October to December. According to the log book of the Chinese squid jigging fleets during June to December in 1992 and 1993, the fishing grounds gradually moved northwards from June to August, and were mainly distributed in the latitudes of 37°00′–38°30′N in June, 38°30′–39°30′N in July, and 39°30′–40°30′N in August. The fishing grounds then moved southwards from September to November, and were mainly located in the latitudes of 38°30′–40°00′N in September, 37°00′–39°00′N in October, and 37°00′–38°00′N in November (Wang and Chen, 2005).

The locality of fishing grounds of *T. pacificus* was closely related to the current edge and upwelling (Wang and Chen, 2005). During the period of squid moving northwards, the fishing ground was generally distributed in the warm side of different current confluences. The fishing ground was also distributed around the warm core of current confluence and upwelling areas of continental slope, piles and reefs. During the period of squid migrating southwards, the squid aggregated in the cold mass with tongue stretching from the north (Wang and Chen, 2005).

Yang (1992) found that the squid distribution was closely related to the distribution of zooplankton. The two different currents, Liman Current and Tsushima Current, converged and led to the high concentration of various zooplanktons with the dominant species of *Calanus finmarchicus*, *Amphipoda* and *Sagitta crassa*. This provided suitable biological environment for the formation of fishing ground. The optimum sea surface temperature (SST) of squid schooling ranged from 20 to 23 °C during June and August (Yang, 1992). Environmental conditions in the deep water layer may play an important role in the squid distribution because the squid have a dial vertical movement. Thus, more studies need to be done to identify key environmental variables in the deep water layer that may influence the squid abundance and distribution.

2.4. Fishing technology

Jigging is an effective method for fishing this squid and yields 90% of the total catch in the Japanese squid fishery (Xu, 1992). An auto-machined jigger usually has two jigging lines (diameter 0.75–1.00 mm) equipped with 30 jiggers (Xu, 1992). During the jigging survey in 1990 and 1991, Chen (1996b) reported squid drop-off rates of 5–10%. The low drop-off rates might result from the high breaking strength of squid tentacles which was 7.488 times of its body weight (Chen, 1996b). Xu (1994) found that there was no significant difference in catch rates between white and gray lines ($P = 0.425$), and among the lines of four different diameters (i.e., 0.75, 0.85, 0.9 and 1.00 mm). However, 80 and 90 cm long of jigging lines tended to yield a higher catch rate than 100 cm long of lines ($P = 0.067$). Xu (1992) suggested that the jigger with the colors of yellow and green might help increase the catch rate. The body weights of most individuals in the catch were below 450 g (Wang and Chen, 2005).

3. Neon flying squid in the North Pacific

3.1. Jigging fishery

Neon flying squid, *O. bartramii*, is a large oceanic squid distributed in temperate and subtropical waters of the Pacific, Indian and Atlantic Oceans, and is especially abundant in the North Pacific. This squid has become an important fishing target since 1974. In the 1980s, the total annual catch in both jigging and driftnet fisheries ranged from 150,000 to 350,000 tonnes. However, because the squid driftnet fishery is banned since 1993, the total annual catch dropped to less than 50,000 tonnes (Bower and Ichii, 2005), and further fell to below 20,000 tonnes after 2001 (Wang and Chen, 2005).

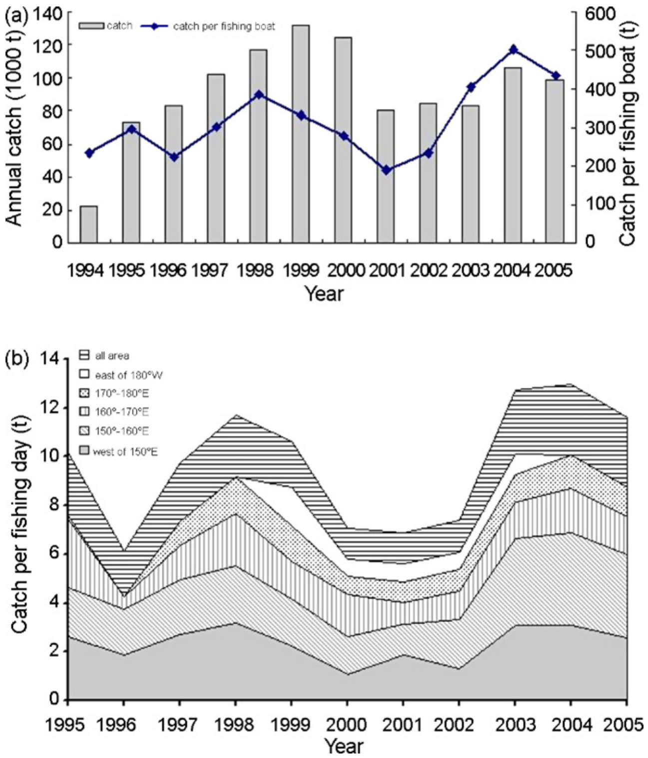


Fig. 1. The annual catch and catch per fishing boat (a) and catch per fishing day (b), of *Ommastrephes bartramii* fished by the Chinese squid jigging boats in the North Pacific during 1995 and 2005.

The first three-year survey on this squid resource by the Chinese squid jigging boats was made in the North Pacific from 1993 to 1995, and the information on squid resources and fishing ground was collected and fishing technology was evaluated in the waters west of 160°E in the North Pacific (Wang and Chen, 1998). A large scale squid jigging fishery started in 1994, and a total of 23,000 tonnes catch was landed. In 1995, the catch was increased to 73,000 tonnes as a result of an increase of fishing vessels. As the new 5-year survey from 1996 to 2000 was completed, the fishing area was expanded eastwards to 170°W (Wang and Chen, 2005), and the fishing season became earlier to the end of April and the beginning of May (Liu and Chen, 2002; Liu et al., 2001). The maximum output in 1999 reached 132,000 tonnes (Fig. 1a). As the Sino-Japanese fishing agreement came into effect since 2000, the Chinese squid jigging boats were prohibited from operating on an important fishing ground (40°–43°N and 147°–150°E). The current fishing area is mainly located in the waters of 150°–165°E and 40°–46°N during August and November for the Chinese squid jigging boats, accounting for more than 65% of the total Chinese squid catch (Chen and Tian, 2006).

3.2. Biology

According to the squid survey during 1993 and 1995 in waters west of 150°E, there existed two cohorts, small groups (S) and large groups (L), with dominant ML classes of 19–21 cm and 26–31 cm (n = 1490), respectively (Wang and Chen, 2005). Chen et al. (2002) also reported that there were two stocks in the area west of 165°E based on a cluster analysis of nine morphological variables.

The squid surveys made during 1993 and 2000 showed that population structure tended to differ in different waters (Table 1). In waters west of 160°E, the average individual ranged from 23 to 27 cm (n = 15613) with the dominant ML of 20–28 cm during June and October (Wang and Chen, 2005). However, in June and July 1997, the average ML reached 35–39 cm (Table 1), which was significantly larger than that in the other years (P < 0.01). The monthly sex ratios of females to males for catch were 1.31:1, 1.42:1, 1.33:1 and 1.35:1 for June to October, respectively. In

Table 1
The mantle length (ML) composition of *O. bartramii* caught by the Chinese squid jigging vessels in the three different waters of North Pacific

Fishing area	Month and Year	ML range (cm)	Dominant ML range (cm)	Percentage (%)	Average ML (cm)	Number of sample
West of 160°E	93.8	15–32	21–25	76	23.1	7246
	94.8	17–40	24–31	69	26.8	2476
	95.8	17–36	21–26	64	24.0	2581
	96.7	17–49	20–24	72	23.2	149
	96.8	16–39	21–28	61	25.1	675
	97.6	21–48	22–26, 37–45	18,48.8	35.7	223
	97.7	22–51	38–43	69.9	38.6	1780
	98.8	21–46	23–28	73	27	74
	98.9	19–47	21–22, 28–29	42,19.7	26.6	96
	98.10	19–31	24–28	80.4	26.2	41
	99.7	18–47	19–28	76.5	24.6	150
	99.8	21–46	23–28	80	26.5	122
160°E–170°E	97.6	20–49	26–42	71.6	39.4	905
	97.7	24–49	38–45	77.7	40.4	54
	98.6	23–53	35–53	71.1	38.2	760
	98.7	30–51	37–43	60.8	40.5	675
	98.10	18–32	21–22, 25–30	16.2,60.4	26.0	43
	99.6	28–43	34–38	65.9	35.8	47
East of 170°E	98.6	33–47	36–41	62.27	37.6	55
	98.7	34–49	38–45	72.72	40.7	44

the waters of 160°–170°E, the squid had the average ML of 35–41 cm ($n = 2441$) and was larger than that in the waters west of 160°E ($P < 0.05$). The sex ratios of females to males were 2.13:1 and 1.91:1, respectively, for the two populations. In October 1998, as new recruits entered into the fishery, individuals in catch were small, compared with those caught during June and September ($P < 0.01$), and the average size was only 26 cm ML ($n = 43$) (Table 1). In the waters of 170°–180°E, their ML's were significantly higher ($P < 0.01$) than those in the area west of 170°E, and the average size reached 37–41 cm ML in the same time period ($n = 99$; Table 1; Wang and Chen, 2005). The samples of squid in different fishing areas were collected by the Technical Group of Chinese squid jigging fisheries since 2004. The squid growth, ML and age composition and life history are currently being analyzed by the authors, which can lead to a better understanding of the biology of this squid.

Wang and Chen (2005) found that *O. bartramii* stomach contents were dominated by myctophids and followed by sardines, mackerel larvae and sauries. Squid species found in its stomach contents were *O. borealijaponicus* and species of *Abraliopsis*. A high proportion of *O. bartramii* was found to be cannibalistic. Crustacean species fluctuated widely between 2% and 18% in the squid stomach contents with higher percentages being observed in young squids. More than 80% of squid in the catch had less than half full stomachs (Wang and Chen, 2005; Sun et al., 2001; Huang et al., 2003).

3.3. Fishing ground

The Chinese squid jigging boats have already become one of the important squid fishing fleets in the North Pacific. Typically, a Chinese squid jigging vessel would leave for the waters of 170°E–175°W, 38°–40°N to fish squid in the middle and late April, and continue to early July. They then gradually moved to the areas of 160°–170°E. From early or middle August, the squid vessels were mainly fishing in the area of 150°–155°E and 40°–42°N, and gradually moved northeast to the waters of 155°–165°E, 42°–44°N in November (Chen and Tian, 2005).

The fishing ground is closely related to the distribution of Kuroshio Current and Oyashio Current (Chen et al., 2003a; Wang et al., 2003). During the squid moving northwards in summer and autumn, it was mainly distributed in the vicinity of Kuroshio front. During the southward spawning migration in winter, the squid were mainly concentrated in the Oyashio front or the warm mass in low SSTs (Wang and Chen, 2005). During 1995 and 2005, Chinese squid jigging vessels mainly fished in the waters of 145°–148°E and 153°–161°E, and the annual output was 70–85% of the total catch (Chen et al., 2003b).

Many studies showed that optimum SSTs for squid varied with months and fishing areas, and there appeared to have the tendency of optimum SST gradually decreasing from west to east (Chen and Tian, 2005). In the waters of 140°–150°E, the monthly optimal SSTs were 17–19 °C, 18–22 °C, 17–19 °C, 13–18 °C and 10–14 °C, respectively, from July to November (Chen, 1997b; Chen and Tian, 2005; Shen et al., 2004). In the waters of 150°–165°E, the monthly optimum SSTs were 12–14 °C, 14–17 °C, 15–19 °C, 14–18 °C, 10–13 °C and 12–15 °C, respectively, for the months of July to November (Chen, 1997b, 1999; Chen and Tian, 2005; Shen et al., 2004). In the waters of 165°–180°E, the optimum SST in June and July ranged from 11 to 15 °C (Chen and Tian, 2005). The squid preferred the habitat in the warm front of 100 or 200 m water layer and its optimum temperature was at 9–10 °C during June and July (Liu and Chen, 2002). In the waters of 180°–170°W, Liu et al. (2001) reported that the fishing ground had a good relationship with the water temperature at the depth of 100 m with an optimal temperature of 10–12 °C.

Previous studies suggested that in the waters west of 160°E, vertical temperature structure played an important role in the formation of fishing ground (Chen, 1995). The fishing grounds usually existed in an area with a thermocline layer found above the 50 m (Chen, 1995). The CPUE (daily catch per fishing vessel) was positively correlated to the temperature changes both in the range of 0 and 100 m and in the range of 0 and 50 m (Chen, 1995). This phenomenon was not obvious in the waters east of 160°E, which might be caused by different marine environmental conditions (Chen and Tian, 2005). There was no interaction of Kuroshio Current and Oyashio Current (Chen and Tian, 2005).

The existence of plankton is a basic condition for the formation of the squid fishing grounds (Chen, 2004). Wang et al. (2003) reported that a skewed distribution function could be used to describe the relationship between chlorophyll-*a* content and the catch in the waters of 150°–165°E and 41°–45°N during August and October, and that the area with chlorophyll-*a* content ranging from 0.15 to 3 mg/m^3 produced 95% of the total catch. Xu et al. (2004) also found that in the waters of 152°E–171°W and 39°–42°N during June and July, the squid tended to aggregate near the areas with the highest abundance (50–100 ind/m^3) of crustaceans (mainly *Copepoda* and *Thaliacea*).

3.4. Fishing technology

The tentacles of large squid often snap during retrievals as the squid breaks the surface, causing the squid to drop from the jigger. Based on the jigging survey from 1993 to 1995, Sun and Chen (1996) reported that the drop-off rate of small squid reached 25–40% for auto machine-jigging and 20% for hand jigging in the waters west of 160°E. While in the waters east of 160°E, the drop-off rate of large squid also reached 25–40% for auto machine-jigging and 30% for hand jiggers (Chen and Huang, 1999). The experiment showed that the breaking strength of squid's tentacle was only 1.874 times of its body weight, which was one of the main reasons resulting in a higher drop-off rate (Chen, 1996b).

This squid were also found to be selective of the color of lines used in jiggers. Sun and Chen (1997) found that the green, light green and light-blue lines used in jiggers could improve the catch of squid, while the orange jigging lines had low catch rates.

Chen et al. (2006) conducted a GAM analysis to find that the moon phase was one of the important factors affecting fishing efficiency. Based on the production statistics in the northern Pacific Ocean during August and October from 1995 to 2000, the catch in the new moon period was 1.16, 1.53 and 1.20 times as high as that of the full moon period, respectively, for these 3 months.

The first experiment on underwater lights began in 1997 in the central North Pacific to fish large squids (body weight of 1–2 kg) inhabiting in the deep water layer (300–400 m) at daytime. Chen (2000) reported that the average catch at daytime reached 0.8 tonnes, the maximum catch was 3.0 tonnes during June and July in 1998 when underwater lights were used, but the drop-off rate increased to between 40% and 60%. The optimal vertical distance between fishing depth and depth of underwater lights ranged from 100 to 150 m (Chen, 2000)

3.5. *Squid abundance and its relationship with marine environment factors*

According to the daily catch of Chinese squid jigging vessels from 1995 to 2005, a high abundance of squid appeared in 1995, 1997–1998, and 2003–2005 with CPUE higher than 2.5 tonnes/day (Fig. 1b). The low squid catches occurred in 2000–2002 with a CPUE of 1.30 tonnes/day (Chen et al., 2003b). CPUE differed in the areas of 140°–150°E, 150°–165°E and 165°–180°E, and the average CPUEs from 1995 to 2001 were 2.41, 1.94 and 1.18 tonnes/day, respectively, for these three areas (Chen and Tian, 2005). The significant difference in CPUE between the west of 165°E and the east of 165°E ($P < 0.01$) might be caused by different marine environmental conditions. In the west of 165°E, the Kuroshio Current and Oyashio Current mixed intensively, which created optimal habitats for the squid, resulting in an increased density of squid schooling in the area (Chen and Tian, 2005).

This squid species, as a short-lived ecological opportunist, typically fluctuated greatly in abundance, responding rapidly to changes in environmental conditions which often play an important role in driving the inter-annual variability and influence both the distribution and abundance of populations. Shao et al. (2005) reported that the CPUE was highest in the year when the quasi-bending of Kuroshio occurred, followed by the years of a small bending of Kuroshio. The lowest CPUE occurred in the years of big bending of Kuroshio (Shao et al., 2005). The squid CPUE was closely related to environmental variables, especially SST on the spawning ground and feeding ground. Such a relationship could be quantified by multiple linear regression equations (Chen et al., 2007b).

Previous studies showed that La Niña event would result in the fall of squid recruitment through the variability of environmental conditions on the spawning ground (Chen et al., 2007b), but El Niño event would lead to the environmental condition favorable to squid recruitment. El Niño/La Niña events also affected squid distribution on the feeding ground, resulting in a northward shift of the fishing ground in the years of La Niña and a southward shift in the years of El Niño (Chen et al., 2007b).

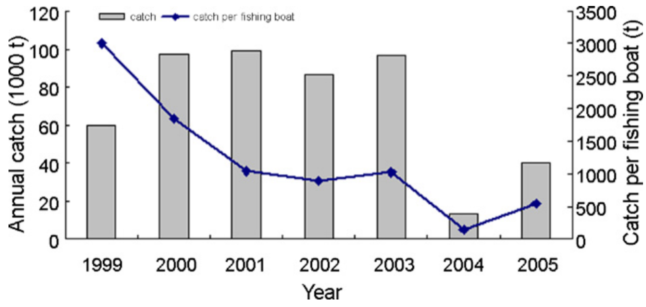


Fig. 2. The annual catch of *Illex argentinus* fished by the Chinese squid jigging boats during 1999 and 2005 in the southwestern Atlantic.

4. Argentinus shortfin squid in the southwest Atlantic

4.1. *Chinese jigging fisheries*

Argentinus shortfin squid, *Illex argentinus*, is a major component of commercial squid fisheries in the southwestern Atlantic. It is widely distributed across the Patagonian Shelf and in adjacent oceanic waters, and could be found in waters between 22° and 54°S (Haimovici et al., 1998). Chinese squid jigging boats fished this squid for the first time in 1997. In 1999 more squid fishing vessels entered into this area, and the annual output reached 60,000 tonnes and the average annual catch per fishing vessel was 3000 tonnes (Wang and Chen, 2005). In 2001 the number of fishing vessels increased to 95 boats with 99,000 tonnes of total catch and an average catch of 1044 tonnes per vessel. In 2004, as its recruitment fell, the squid production decreased dramatically, and the total catch was only 13,400 tonnes for the Chinese squid jigging fleets. The total catch was recovered to 44,000 tonnes in 2005 (Fig. 2).

4.2. *Biology*

4.2.1. *Population structure*

In the high sea during the fishing season from January to May in 2000, the squid in the catch mainly came from the South Patagonic Stock (SPS). Its sizes ranged from 130 to 373 mm ML, and the dominant ML was between 170 and 250 mm, accounting for 55% of the total catch (Ye and Chen, 2002). For the female squid, the ML ranged from 130 to 373 mm ($n = 3613$), and for the male squid, the ML was from 150 to 315 mm ($n = 2514$). The average sex ratio of female to male was 60:40 in the catch during January and May (Ye and Chen, 2002).

For different fishing areas, catch size structure differed greatly (Table 2; Wang and Chen, 2005), which was likely to result from timing of squid recruitment and differences in size structure among the populations. In the high sea, the dominant ML ranged between 160 and 260 mm from January to April. The average ML of squid increased from 196.2 mm in January to 239.0 mm in April (Table 2). The proportion of females reached 70% in January, and decreased gradually to 44.8% in April (Table 3). In the Falkland waters, the dominant ML was between 190 and 340 mm from February to May, and the average ML of squid increased from 227.0 mm in February to 308.9 mm in May (Table 2). The female abundance

Table 2
The mantle length (ML) composition of *I. argentinus* caught by the Chinese squid jigging vessels in the southwestern Atlantic from January to August in 2000

Fishing area	Month	ML range (mm)	Dominant ML (mm)	Percentage of dominant ML (%)	Average ML (mm)
High seas	January	146–290	160–210	80.7	196.2
	February	146–297	170–220	79.8	202.8
	March	158–311	190–240	80.5	230.4
	April	187–345	210–260	74.6	239.0
Around Falkland	February	187–309	190–250	80.9	227.0
	March	198–317	220–280	81.9	256.7
	April	231–341	250–320	83.4	287.3
	May	250–363	280–340	81.1	308.9
EEZ of Argentines	April	255–328	280–320	72.7	295.8
	May	242–366	280–300, 320–350	24.2, 50.0	316.7
	June	130–322	170–210	72.1	202.6
	July	157–358	200–230	52.4	212.4
	August	153–373	210–260	75.4	232.3

tended to be always higher than the male, and the proportion of female ranged between 57% and 69% (Table 3). In the Argentine EEZ, there were three modes in the size frequency distribution from April to August: 180–220 mm, 280–300 mm and 320–350 mm. The monthly average ML varied from 202.6 to 316.7 mm during April and August (Table 2). The proportion of females ranged from 51% to 78% (Table 3; Ye and Chen, 2002).

4.2.2. Sex maturity

On the fishing ground of high sea around 45°S and 60°W during January and April, the SPS squids were in the process of becoming sexual maturity. The female squid attained maturity stages I and II (immature), accounting for 60–82% of the total catch from January to April. For the male squid, 60–93% of the total catch were in maturity stages II (immature) and III (maturing), and the proportion of stage III (maturing) increased gradually (Tang, 2001; Ye and Chen, 2002).

In the Falkland waters, the squids from SPS were also becoming sexual maturing. The sexual maturity of female squid was mainly in stage II, accounting for 45–55% of the total catch from March to May in 2000. The proportion of stage I squid decreased from 50.5% in February to 3.9% in April. For the male squid, the proportion of sexual maturity varied between 42% and 79% (Tang, 2002; Ye and Chen, 2002).

In the Argentine EEZ waters, there was no obvious trend for the maturity of females and males, and the composition of squid in different maturity stages fluctuated greatly between April and August in 2000. After June, individuals were mainly in stages I and II. However, the proportion of squid in maturity stage I for female and male squid decrease from 85.6% and 84.6% in June to 40.8% and 3.1% in August, respectively (Ye and Chen, 2002).

4.2.3. Feeding

Cannibalism was observed in all sizes. The diet of adult squid, *I. argentinus*, consisted mainly of crustaceans (*Euthemisto bispinosa*, *Galatheidea*, *Euphausia*, *Chaetognatha*), juveniles fish (*Merluccius hubbsi*, *Hygophom*) and cephalopod (*I. argentinus*, *Loligo gahi*) (Wang and Chen, 2005).

4.3. Fishing ground and its relationship with marine environment factors

Chinese squid fishing vessels were mainly distributed in waters around 45°–47°S and 59°–60°30′W during January and May. In the high sea, the fishing season usually peaked in February and March, and mainly targeted the SPS. The distribution of fishing grounds showed a close relationship with SST, and the optimum SST on fishing grounds for high CPUE (over 10 tonnes/day per fishing vessel) varied among months: 14–15 °C in January, 13–15 °C in February, 12–14 °C in March, 9–13 °C in April, 8–10 °C in May, and 7–9 °C in June (Liu and Chen, 2004; Chen and Zhao, 2005; Chen et al., 2005a).

4.4. Fishing technology

This squid is relatively small in size and the breaking strength of squid tentacle is similar to that of the Japanese common squid (Wang and Chen, 2005). Thus, its drop-off rate is also low. The

Table 3
The sex ratio of squid, *I. argentinus*, catch caught by the Chinese squid jigging vessels in the southwestern Atlantic from January to August in 2000

Area and month	High seas				Around Falkland				EEZ of Argentines				
	January	February	March	April	February	March	April	May	April	May	June	July	August
Number of sample	854	1328	699	259	310	955	882	577	99	308	222	213	250
Female (%)	70.0	53.1	51.2	44.8	64.5	57.5	66.7	69.0	69.7	77.6	53.2	51.6	60.8
Male (%)	30.0	46.9	48.7	55.2	35.5	42.5	33.3	31.0	30.3	22.4	46.8	48.4	39.2

experiments on the sea showed that different colors of lines used in jiggers had different catch rates, with green jiggers having the highest catch rate. Tang (2001) also suggested that the size of jigger, number of jigger in each fishing line and diameter of fishing line needed to be adjusted according to the size of squid. They also found that underwater lights played a critical role in attracting more squid around the fishing boats and increasing catch rates (Tang, 2001).

5. Jumbo flying squid in the southeast Pacific

5.1. Jigging fishery

Dosidicus gigas, the jumbo flying squid, is distributed from 37°–40°N to 45°–47°S between California and southern Chile, extending westward from the coast to a maximum of 125°–140°W in the Equator (Nigmatullin et al., 2001). Since the early 1990s there has been an increase in industrial vessels, largely from Japan and Korea, fishing off Peru and Central America, resulting in an increase in squid catch from the eastern Pacific Ocean. During June and September in 2001, the Chinese squid jigging industry made their first resources survey of *D. gigas* in the high sea of Peru and Costa Rica (Ye, 2002), followed by commercial production, and its annual catch reached 17,770 tonnes. Because of the poor catch of Argentinus shortfin squid in 2004, a large number of Chinese squid jigging boats moved to offshore waters of Peru after April, and its annual output reached 205,600 tonnes, with an average output of 1728 tonnes per fishing vessel (Fig. 3a).

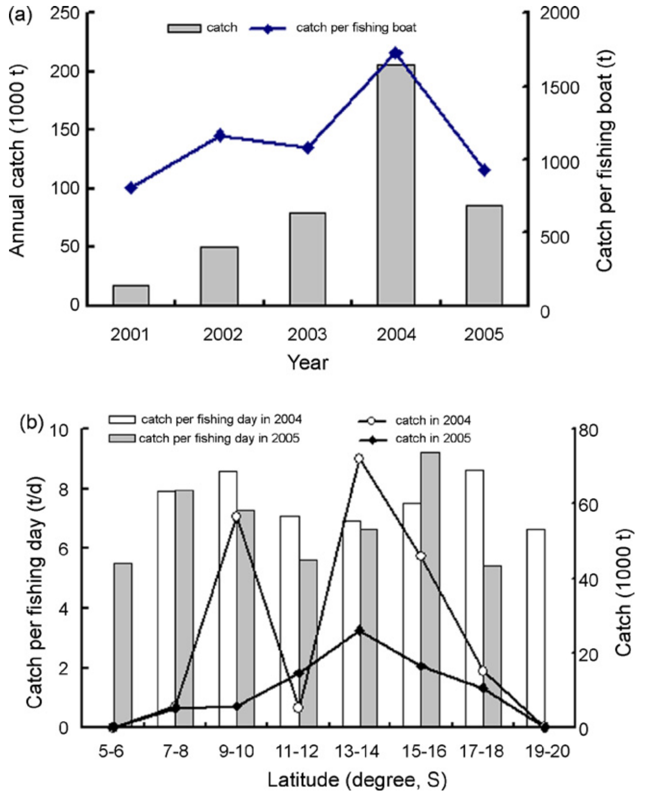


Fig. 3. The annual catch during 2001 and 2005 (a), and catch distribution by latitudes during 2004 and 2005 (b), of *Dosidicus gigas* fished by the Chinese squid jigging boats in the southeastern Pacific.

5.2. Biology

During the first resource survey of *D. gigas* made by the Chinese squid jigging boats in the high sea (5°–16°S and 79°–90°W) off Peru from June to August in 2001, the size range of squid in the catch was large. The ML ranged from 203 to 805 mm and the dominant ML was between 240 and 480 mm. Squid in the dominant ML size class accounted for 80% of the total catch (Ye, 2002). For the male squid, the size of squid varied between 203 and 736 mm ML, and the dominant ML was from 230 to 440 mm, consisting of 80.0% of the total catch. For the female squid, ML ranged from 205 to 805 mm with the dominant ML of 260 to 440 mm, accounting for 74.4% of the total catch. The female squid was more abundant than the male squid in the catch during June and August, and the average ratio of female to male was 2.52:1 (Ye, 2002).

In the high sea (5°–16°S and 79°–90°W) off Peru from June to August, three groups of squid may exist according to the ML composition. Three peaks were observed in the ML composition of male squid catch. They represent three groups with significantly different average MLs ($P < 0.01$): 261 ± 21.5 mm, 381 ± 40.0 mm and 496 ± 110.6 mm (mean ± standard deviation). For the female squid, three peaks were also observed with significantly different average MLs ($P < 0.01$): 289 ± 32.2 mm, 406 ± 57.9 mm and 634 ± 64.1 mm (Ye and Chen, 2007).

The male squid were found to mature at younger ages than the female squid. The initial size at sexual maturity was 374 mm ML for females and 228 mm ML for males (Ye and Chen, 2007). In the high sea (5°–16°S and 79°–90°W) off Peru during June and August, maturity stages III and IV consisted of 84.3% of the all males squid in the catch, but only 47.5% for the female squid (Ye, 2002).

5.3. Fishing ground and its relationship with SST

The production statistics showed that Chinese squid fishing vessels fished in waters from 7° to 20°S all year around, but mainly operated in the waters of 13°–16°S which yielded over 50% of the total catch and an average daily output of 7 tonnes per fishing vessels in 2004 and 2005 (Fig. 3b). The second most productive fishing area was located from 9° to 12°S, which yielded 20–25% of the total catch with an average daily output of 7–9 tonnes/day (Fig. 3b). The combined catch in fishing areas of 5°–6°S and 19°–20°S was less than 0.5% of the total catch (Fig. 3b).

Fishing areas varied among months, and main fishing seasons ranged from May to December. During January and July, the fishing area was mainly concentrated in the waters of 14°–17°S and 80°–84°W in August and 9°–11°S and 81°–83°W in September, and waters south of 14°S in December. The monthly optimal SSTs on fishing grounds were estimated as 23–25 °C from January to April, 21–22 °C in May, 17–20 °C from June to October, and 20–22 °C in November and December (Chen and Zhao, 2006).

6. Purpleback squid in the Northwest Indian

6.1. Jigging fishery

The purpleback squid *Sthenoteuthis oualaniensis* is widely distributed in the equatorial and tropical waters of Indo-Pacific Ocean (Chen et al., 2007a). It is most abundant in the South China Sea and northwestern Indian Ocean. During 2003 and 2005, three scientific fishery surveys for *S. oualaniensis* were undertaken by the Chinese squid jigger vessels in the high sea of the northwestern Indian Ocean (Chen et al., 2007a). In 2005, a small-scale Chinese commercial jigging fishery started, yielding more than 5000 tonnes in production.

6.2. Biology

The female squid tended to be larger than the male squid (Chen et al., 2007a). The largest female squid attained 612 mm ML. During September 2004 and April 2005, the mean ML of the catch was 299 mm for males (ranging 106–462 mm) and 352 mm for females (ranging 106–612 mm), and the dominant MLs were between 260 and 300 mm for males, and 300–360 mm and 480–540 mm for females (Chen et al., 2007a). The size of squid also tended to have large spatial variations, especially in the latitudinal direction. Large squids of over 400 mm ML were mainly located in the north of 18°N, medium squid ranging 300–400 mm ML mainly distributed from 12° to 18°N, and small squid of under 300 mm ML mainly in the south of 12°N. There was no such spatial pattern in size distribution along the longitudinal direction (Ye and Chen, 2004; Chen et al., 2007a). Based on morphological analyses, Random Amplified Polymorphic DNA (RAPD) analyses and analyses of the microstructure of statolith, three groups were identified: spring spawning group, summer spawning group and autumn spawning group (Chen et al., 2007a). The growth patterns of spring spawning group and autumn spawning group could be well described by linear regression models, while summer spawning group by the Gompertz model (Chen et al., submitted for publication; unpublished data). The instantaneous relative growth rates (IRGR) and absolute growth rate (AGR) of ML ranged from 0.18 to 1.06 and from 0.53 to 2.13 mm per day, respectively. The IRGR and AGR of body weight ranged between 0.55 and 3.33, and between 2.23 and 30.67 g per day, respectively. The IRGR and AGR varied with size for a given group, and showed large differences among squids of the same sizes in different groups (ANCOVA, $p < 0.05$; Chen et al., submitted for publication, unpublished data).

The stomach contents included three major groups of preys: juvenile fish, cephalopods and crustaceans, representing 56%, 36% and 8% of the stomach contents by weight, respectively (Ye and Chen, 2004; Chen et al., 2007a). All other species remaining in the stomach contents were identified as *Cypselurus* spp. and *S. oualaniensis*. The cannibalism generally existed in the squids of all sizes. About 70% of the stomachs were less than half full (Chen et al., 2007a).

During the study period from September 2004 to April 2005, the female squid were much more abundant than the male squid, and the sex ratio of females to males for the catch was 30.5:1 (Chen et al., 2007a) which was much higher than that of jigging fisheries of other squids. This might result from using jiggers of large sizes in this fishery. Eighty-eight percent of males in the catch were in maturity stages II (immature), III (maturing) and IV (maturing). For females, only 20% were in maturity stages III or IV (maturing) or stage V (fully mature), but the majority were immature (stages I and II; Chen et al., 2007a).

The large squid tended to have their life span less than one year (Chen et al., 2007a). Squid in the catch had ages ranging from 88 to 363 days, and the dominant ages were between 180 and 270 days, accounting for 81.3% of the total catch. The squid might hatch all year around, with the majority (57.8%) of hatching occurring from March to May (Chen et al., 2007a). Chen et al. (submitted for publication; unpublished data) also found that the highest growth rate was observed in the summer spawning group, followed by the spring spawning group and fall spawning group.

6.3. Fishing ground and its relationship with marine environmental factors

Previous studies suggest that the fishing ground of squid was closely related to the marine environmental variables such as SST, sea surface height (SSH), wind, chlorophyll-*a* and zooplankton (Chen and Shao, 2006). The optimum SST on the fishing ground was 27–28 °C during September and November, and 26–27 °C from December to March in the following year. Most high-yield fishing grounds were distributed in the waters near sea surface height anomalies, SSHA ≤ 0, and the optimal range of salinity in the surface water was from 35.5 to 36.5 (Chen and Shao, 2006; Tian et al., 2006; Yang et al., 2006). On the fishing ground of high daily catch (over 5 tonnes), zooplankton mainly consisted of *Chaetognatha* (average biomass was 9.18 mg/m^3), *Copepoda* (2.32 mg/m^3) and *Mysidacea* (1.38 mg/m^3), and they presented in 86% of all fishing stations (Qian et al., 2006). These three species were also found in the stomachs of squid. Thus they were critical in the formation of fishing ground, and could be considered as indicator species for a squid fishing ground (Qian et al., 2006).

6.4. Fishing technology

The largest squid in weight is more than 6000 g, similar to the Neon flying squid in the North Pacific. Thus, there were high drop-off rates in the fishery. In the first fishing experiment during September and November of 2003, Tian et al. (2004) reported that the average drop-off rate was higher than 45% for machined jiggers, but only 7–12% for hand jiggers when using 2 rows of 1.17 mm diameter jigger. The drop-off mainly resulted from broken tentacles. In the second fishing experiment during September and November of 2004, the jigger with 3 rows of 1.6 mm diameter was used to reduce effectively the drop-off rate to about 10–12% for machined jigging (Chen et al., 2005b). The breaking strength of tentacle was considered as one of main reasons leading to the high drop-off rate of squid, and it was only 1.06 times of its weight and 2.72 times of its five arms (Chen et al., 2005b).

7. Conclusions

China has successfully exploited some important oceanic squids since 1989, including *T. pacificus* around Sea of Japan, *O. bartramii* in the North Pacific, *I. argentinus* in the southwestern Atlantic, and *D. gigas* in the southeastern Pacific and *S. oualaniensis* in the northwestern Indian Ocean. A great deal of progress has been made in oceanic squid research such as fisheries biology, ecology, and fishing technology. The ommastrephidae squid is an opportunist species that plays an important role in the ecosystem and is also vulnerable to environment fluctuations. We should recognize that we still do not fully understand basic biology of the squid and its interactions with its ecosystems. We still lack effective ways to assess and manage the squid resources. Exchange of data and information among countries and regions that are involved in these fisheries can certainly help improve our understanding of these species and fisheries, leading to the development of sustainable squid jigging fishery in the world.

Acknowledgements

We thank Chinese distant-water squid jigging technical group for providing data and information used in this report. This work was supported by the Program for New Century Excellent Talents in University (NCET-06-0437), National Science and Technology Program (2006BAD09A05) and Shanghai Leading Academic Discipline Project (T1101). We would like to thank three anonymous reviewers for their constructive comments.

References

Bower, J.R., Ichii, T., 2005. The red flying squid (*Ommastrephes bartramii*): a review of recent research and the fishery in Japan. Fish. Res. 76, 39–55.

Chen, X.J., 1995. An approach to the relationship between the squid fishing ground and water temperature in the northwest Pacific. J. Shanghai Fish. Univ. 4, 181–185.

Chen, X.J., 1996a. The exploitation and resources of cephalopod in the world. J. Shanghai Fish. Univ. 5, 193–200.

Chen, X.J., 1996b. On the broken strength of *Todarodes pacificus* and *Ommastrephes bartramii* tentacles. J. Shanghai Fish. Univ. 5, 115–118.

Chen, X.J., 1997a. Studies on some biological parameters of *Todarodes pacificus* in the central-southern Japan Sea. J. Fish. Sci. China 4, 29–32.

Chen, X.J., 1997b. An analysis on marine environment factors of fishing ground of *Ommastrephes bartramii* in northwest Pacific. J. Shanghai Fish. Univ. 6, 285–287.

Chen, X.J., 1999. The preliminary study on fishing ground of large-sized *Ommastrephes bartramii* in north pacific waters between 160°E and 170°E. J. Shanghai Fish. Univ. 8, 197–201.

Chen, X.J., 2000. Experiment on fishing large sized squid with underwater light at daytime in the north Pacific. J. Shanghai Fish. Univ. 9, 172–174.

Chen, X.J., 2004. Fisheries Resources and Oceanography. Ocean Press, Beijing, pp. 141–160.

Chen, X.J., 2005. The exploitation and resources of economic cephalopod in the world. World Sci. 3, 25–26.

Chen, X.J., Huang, H.L., 1999. A preliminary study on fishing technique of large-sized *Ommastrephes bartramii*. J. Shanghai Fish. Univ. 8, 170–173.

Chen, X.J., Shao, F., 2006. Study on the resource characteristics of *Symplectoteuthis oualaniensis* and their relationships with the sea conditions in the high sea of the northwestern Indian Ocean. Periodical Ocean Univ. China. 36, 611–616.

Chen, X.J., Tian, S.Q., 2005. Study on the catch distribution and relationship between fishing ground and surface temperature for *Ommastrephes bartramii* in the northwest Pacific Ocean. J. Ocean Univ. Qingdao 35, 101–107.

Chen, X.J., Tian, S.Q., 2006. Temp-spatial distribution on abundance index of neon flying squid *Ommastrephes bartramii* in the northwest pacific using generalized additive models. J. Jimei Univ. 11, 40–454.

Chen, X.J., Zhao, X.H., 2005. The relationship between the distribution of production of squid *Illex argentinus* and sea surface temperature in the Southwest Atlantic Ocean. J. Dalian Fish. Univ. 3, 62–68.

Chen, X.J., Zhao, X.H., 2006. Preliminary study on the catch distribution of *Dosidicus gigas* and its relationship with sea surface temperature in the offshore waters of Peru. J. Shanghai Fish. Univ. 15, 65–70.

Chen, X.J., Liu, B.L., Wang, Y.Z., 2005a. Study on the distribution of production of *Illex argentinus* and its relationship with sea surface temperature in the southwest Atlantic Ocean in 2000. J. Zhanjiang Ocean Univ. 1, 32–37.

Chen, X.J., Liu, B.L., Zhong, J.S. Age and growth of purple back flying squid, *Sthenoeuthis oualaniensis*, based on statolith microstructure in the northwest Indian Ocean. J. Mar. Biol. Assoc. UK, submitted for publication.

Chen, X.J., Tian, S.Q., Qian, W.G., 2006. Effect of moon phase on the jigging rate of *Ommastrephes bartramii* in the north Pacific. Marine Fish. 28, 136–140.

Chen, X.J., Tian, S.Q., Ye, X.C., 2002. Study on population structure of flying squid in northwestern Pacific based on gray system theory. J. Shanghai Fish. Univ. 11, 335–341.

Chen, X.J., Xu, L.X., Tian, S.Q., 2003b. Spatial and temporal analysis of *Ommastrephes bartramii* resources and its fishing ground in the north Pacific Ocean. J. Fish. China 27, 334–342.

Chen, X.J., Zhao, X.H., Chen, Y., 2007b. El Niño/La Niña Influence on the Western Winter- Spring Cohort of Neon Flying Squid (*Ommastrephes bartarmii*) in the northwestern Pacific Ocean. ICES J. Marine Sci. 64, 1152–1160.

Chen, X.J., Zhao, X.H., Liu, J.L., 2005b. Fishing technology of *Symplectoteuthis oualaniensis* in the northwest Indian Ocean. Marine Fish. 27, 200–205.

Chen, X.J., Qian, W.G., Xu, L.X., Tian, S.Q., 2003a. Study on *Ommastrephes bartramii* fishing ground and forecasting model from 150°E to 165°E in the north Pacific Ocean. Marine Fish. Res. 24, 1–6.

Chen, X.J., Liu, B.L., Tian, S.Q., Qian, W.G., Zhao, X.H., 2007a. Fishery biology of purpleback squid, *Sthenoteuthis oualaniensis*, in the northwest Indian Ocean. Fish. Res. 83, 98–104.

Dong, Z.Z., 1991. The Biology of Oceanic Economic Cephalopod in the World. Shangdong Science and Technology Press, Jinan, Shangdong, China, pp. 12–60.

FAO, 2004. Capture production 2002, FAO Yearbook of Fishery Statistics, vol. 94/1, FAO Fishery Information, Data and Statistics Unit. Rome.

Haimovici, M., Brunetti, N.E., Rodhouse, P.G., Csirke, J., Leta, R.H., 1998. *Illex argentinus*. In: Rodhouse, P.G., Dawe, E.G., O'Dor, R.K. (Eds.), Squid Recruitment Dynamics. The Genus *Illex* as a Model. The Commercial *Illex* species Influences on Variability, vol. 376. FAO Fish. Tech. Pap., pp. 27–58.

Huang, H.L., Zheng, Y.J., Cheng, J.H., 2003. Study on the biological characteristics of *Ommastrephes bartramii* in the north Pacific Ocean. Marine Fish. 3, 131–135.

Kang, D., Mukai, T., Iida, K., Hwang, D., Myoung, J.G., 2005. The influence of tiltangle on the acoustic target strength of the Japanese common squid (*Todarodes pacificus*). ICES J. Marine Sci. 62, 779–789.

Le, M.L., 2003. Suggestions on development of Chinese distant-water fisheries. Chin. Fish. Econ. S1, 7–10.

Liu, B.L., Chen, X.J., 2004. Preliminary study on the relationship between the distribution of production of *Illex argentinus* and SST in the southwest Atlantic Ocean in 2001. Marine Fish. 4, 79–83.

Liu, H.S., Chen, X.J., 2002. Study on water temperature distributions and fishing grounds of squid in the north Pacific during May–July in 2000. J. Zhanjiang Ocean Univ. 22, 29–34.

Liu, H.S., Yang, H., Zhang, S.Y., 2001. Preliminary study on seawater salinity and temperature distributions and their relationship with the squid fishing grounds in 175°W–170°W area of north Pacific. J. Shanghai Fish. Univ. 10, 229–233.

Nigmatullin, C.M., Nesis, K.N., Arkhipkin, A.I., 2001. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish. Res. 54, 9–19.

Qian, W.G., Chen, X.J., Liu, B.L., Tian, S.Q., Ye, X.C., 2006. The relationship between fishing ground distribution of *Symplectoteuthis oualaniensis* and zooplankton in the northwestern Indian Ocean in autumn. Marine Fish. 28, 265–271.

Rodhouse, P.G., 2001. Managing and forecasting squid fisheries in variable environments. Fish. Res. 54, 3–8.

Shao, Q.Q., Ma, W.W., Chen, Z.Q., You, Z.M., Wang, W.Y., 2005. Relationship between Kuroshio meander pattern and *Ommastrephes bartramii* CPUE in northwest Pacific Ocean. Oceanol. Limnol. Sin. 5, 111–122.

Shen, X.Q., Fan, W., Cui, X.S., 2004. Study on the relationship of fishing ground distribution of *Ommastrephes bartramii* and water temperature in the northwest Pacific Ocean. Marine Fish. Res. 25, 10–14.

Sun, M.C., Chen, X.J., 1996. Studies on the rate of hooked-off *Ommastrephes bartramii* in the north Pacific. J. Fish. China 20, 144–150.

Sun, M.C., Chen, X.J., 1997. Study on the jig colour selectivity in *Ommastrephes bartramii* fishery. J. Fish. China 21, 210–214.

Sun, M.C., Zhang, S.H., Qian, W.G., 2001. Approach on biological characteristics of *Ommastrephes bartramii* on the central and eastern squid fishing grounds in the north Pacific. Marine Fish. 1, 21–25.

Tang, Y., 2001. The experimental research on the use of hooks and lines in squid, *Illex argentinus*, jigging in the southwest Atlantic Ocean. J. Shanghai Fish. Univ. 4, 26–31.

Tang, Y., 2002. Analysis on biological characteristics of the catch of squid, *Illex argentinus*, jigging in the southwest Atlantic. Marine Fish. 1, 17–22.

Tian, S.Q., Chen, X.J., Yang, X.M., 2006. Study on the fishing ground distribution of *Symplectoteuthis oualaniensis* and its relationship with the environmental factors in the high sea of the northern Arabian Sea. Trans. Oceanol. Limnol. 1, 51–57.

Tian, S.Q., Qian, W.G., Chen, X.J., 2004. Preliminary study on fishing products, fishing rate and jigging-off rate of *Symplectoteuthis oualaniensis* in the northwest Indian Ocean. J. Shanghai Fish. Univ. 13, 224–229.

Wang, W.Y., Zhou, C.H., Shao, Q.Q., Xue, Y.C., Zhang, T.Y., Rong, T.Z., 2003. An application of RS/GIS on study on the migration dynamics of *Ommastrephes bartramii*. High Technol. Lett. 11, 90–93.

Wang, Y.G., Chen, X.J., 1998. The current exploitation of cephalopod resources in the world and the development of Chinese distant-water squid jigging fisheries. J. Shanghai Fish. Univ. 7, 285–287.

Wang, Y.G., Chen, X.J., 2005. The Resource and Biology of Economic Oceanic Squid in the World. Ocean Press, Beijing, pp. 79–295.

Xu, L.X., 1992. Study on the catch rate affected by squid jigger. In: Wang, Y.G. (Ed.), Papers on fishing technology and fishing ground of squid jigging in the Japan Sea (1989–1991). Shanghai Fish. Univ., pp. 1–2.

Xu, L.X., 1994. Effect of colour, thickness and length of nylon fishing line on jigging rate of *Todarodes pacificus* in the Sea of Japan. J. Fish. China. 18, 340–343.

Xu, Z.L., Cui, X.S., Huang, H.L., 2004. Distribution of zooplankton in *Ommastrephes bartramii* fishing ground of the north Pacific Ocean and its relationship with the fishing ground. J. Fish. China 5, 515–521.

Yang, D.K., 1992. Research on the biology of *Todarodes pacificus* and sea conditions in the Japan Sea. In: Wang, Y.G. (Ed.), Papers on fishing technology and fishing ground of squid jigging in the Japan Sea (1989–1991). Shanghai Fish. Univ., pp. 33–44.

Yang, X.M., Chen, X.J., Zhou, Y.Q., Tian, S.Q., 2006. A marine remote sensing-based preliminary analysis on the fishing ground of purple flying squid *Sthenoteuthis oualaniensis* in the northwest Indian Ocean. J. Fish. China 30, 669–675.

Ye, X.C., 2002. Conclusion and analysis on the experimental fishing of *Dosidicus gigas* in the offshore of Peru and Costa Rica in 2001. Marine Fish. 4, 165–168.

Ye, X.C., Chen, X.J., 2002. The study on biology of Argentinus shortin squid, *Illex argentinus*, in the southwest Atlantic. Marine Fish. S1, 46–51.

Ye, X.C., Chen, X.J., 2004. Study of biological characteristics of *Symplectoteuthis oualaniensis* in the northwest Indian Ocean. J. Shanghai Fish. Univ. 13, 316–322.

Ye, X.C., Chen, X.J., 2007. Study of size composition and sex maturity of jumbo flying squid (*Dosidicus gigas*) in the waters off Peru. J. Shanghai Fish. Univ. 16, 347–350.