# Spatio-temporal patterns of crab fisheries in the main bays of Guangdong Province, China

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**Abstract**

Using a semi-balloon otter trawl, crab fisheries in the main bays of Guangdong Province, China, were carried out seasonally. A total of 70 species were found, all belonging to the South China Sea Faunal sub region in the tropical India-West-Pacific Faunal Region. The clustering and nMDS ordination analysis revealed the existence of three groups. Group 1 included Hailing Bay and four bays to its east where typical species were *Portunus sanguinolentus*, *P. pelagicus* and *Charybdis feriatus*. Group 2 included Shuidong Bay and Leizhou Bay where typical species were *P. sanguinolentus*, *P. pelagicus* and *P. hastatoides*. Group 3 was Liusha Bay where typical species were *C. feriatus*, *C. vadorum* and *C. truncate*. The spatial and temporal variations of crab fisheries were mainly associated with characteristics of the sediment, seasonal changes and their own biological characteristics, but not significantly with water depth, temperature, salinity, and the “mid-summer fishing moratorium” conservation measure.

**Keywords**: Crab fisheries, Spatial and temporal distribution, Bays of Guangdong Province, China

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## Introduction

Crabs are not only ecologically important as benthic predators, they are also economically important members of marine and brackish communities found in coastal and estuarine waters (Otto and Jamieson, 2001; Chande and Mgaya, 2003; Baeta et al., 2005). They exhibit complex life histories with stages occurring in both estuarine and fully saline coastal waters (Stone et al., 1992; Carr et al., 2004; Fischer and Wolff, 2006), although relatively few data exist on spatial or temporal determinants of their physical distribution.

Crab fisheries of the coast in the South China Sea appear to have been established as early as the 16th century (Dai et al., 1986), but historically their contribution to traditional fisheries has been underplayed as a result of the relatively small size of commercial catches. In the past several decades, with the world's fish stocks in decline, and crabs accounting for a growing component of marine landings, crab fisheries are being recognized as increasingly important (Morton and Blackmore, 2001; Song et al., 2006; Yu and Yu, 2008).

Guangdong Province abuts the northern part of the South China Sea with 8,400 km of mainland coastline and 450,000 $km^2$ of sea areas, including many bays. These bays represent traditional near-shore crab fishing regions, in which, *Portunus sanguinolentus*, *P. trituberculatus*, and *Scylfa serrata* are the most commercially valued species (Ministry of Agriculture, Farming and Fishery, 1989; Morton and Blackmore, 2001). In recent years, more studies have been carried out on crabs in coastal parts of Guangdong Province, yielding some information about taxonomy, spatial distribution, sex ratio, juvenile recruitment, and reproductive season (Dai et al., 1986; Chu, 1999; Huang, 2008). Still, though, there is a paucity of quantitative information available on the population structure and fisheries in relation to seasonal rhythms. In the present study, some aspects of fisheries resources of crab were investigated, such as the species composition of communities, population biology, and catch rates. The results will provide baseline information that should have some utility for further studies within this area.

## Materials and methods

*Investigation area and sampling protocol*

From the east to the west along the Guangdong coast, a total of 26 stations situated in eight bays were selected for investigation (Fig. 1). The sediment of Shantou Bay (stations A1, A2, A3, A4, and A5) is characterized by muddy and sand-muddy sediment. The seabeds of Honghai Bay (B1, B2, and B3), Daya Bay (C1, C2, C3, C4, and C5), and Dapeng Bay (D1 and D2) are silt-sand with a little clay. The sediment of Hailing Bay (E1, E2, and E3) is dominated by sand and sand-muddy mixed with shell splinter. That of Shuidong Bay (F1, F2, and F3) is medium-coarse sand with a little clay. The floor of Leizhou Bay is mainly composed of fine-medium sand (G1, G2, G3, and G4). The sediment of Liusha Bay (H1 and H2) is mainly fine sand-silt clay. (See Committee of Record of Bays in China, 1998; Committee of Record of Bays in China, 1999.)

Seasonal samples of crabs were collected by boat in spring (April 15-May 15, 2007), summer (July 27-August 30, 2006), autumn (October 26-Novermber 25, 2007), and winter (December 20, 2006-January 20, 2007). A semi-balloon otter trawl with an opening of 10 × 5 m was towed at a speed of 4.6-5.5 km/hr for 30-60min, covering a swept area of about 0.028-0.056 km$^2$. Mesh size at the cod-end of the net was 5 cm when stretched diagonally. A global positioning system (GPS) unit was used to position the station for the start and end points of the trawls. All samples were collected and briefly fixed in 10% formalin or 70% alcohol on board. In the laboratory, all crabs were separated and identified at the species level. Data were standardized to calculate number of crabs captured per km$^2$. Each specimen was individually measured for wet weight (±0.1 g) and carapace width (±0.1 mm), then transferred to 70% ethanol for preservation. Catches, in terms of abundance, biomass and the rate of capture, were standardized to the equivalent of trawling for 60 mins. Water depth, temperature and salinity of the bottom water were determined using a YSI6820 Multi-Parameter Water Quality Logger (YSI incorporated USA) *in situ*.

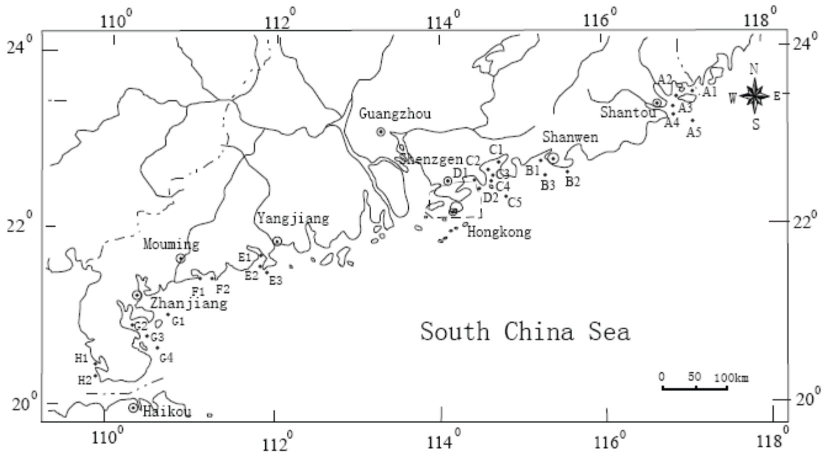


**Figure 1: Locations of stations for the collection of crabs in the main bays in Guangdong Province, China**

*Data multivariate analyses*

Multivariate analyses of crab capture as related to environmental parameters were assessed using the software package PRIMER v 6 (Plymouth Routines in Multivariate Ecological Research). The catch rates of crabs from different bays were examined by cluster analysis for the spatial pattern; non-metric multidimensional scaling (nMDS) was visualized and illustrated in plots. Tests for significance of differences between groups were performed by one-way non-parametric analysis of similarity (ANOSIM). The contribution of each species to similarity within a group or to the total dissimilarity between groups was analyzed using the SIMPER algorithm (Clarke and Gorley, 2006).

## Results

*Environmental features*

The water depths of the bays ranged from 6-32 m. Temperatures of bottom-water fluctuated seasonally with a maximum of 30.2ºC in Shuidong Bay during summer, and a minimum of 16.4ºC in Hailing

Bay during winter. Salinity remained relatively stable in the bays during spring, autumn, and winter, whereas in summer the salinities of Shantou, Hailing, and Shuidong Bays decreased to a minimum of 24.5 ‰ apparently as the result of relatively higher precipitation（Table 1).

**Table 1: Variation in environmental parameters in the main bays along Guangdong Province, China coast**

| Bay | D (m) | Spring | | Summer | | Autumn | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| | | T(℃) | S（‰） | T(℃) | S | T(℃) | S | T(℃) | S |
| Shantou Bay | 7-20 | 22±0.7 | 33.4±1.9 | 24.9±1.6 | 26.9±3.7 | 21.4±0.2 | 32±0.4 | 17.7±0.3 | 34.8±1 |
| Honghai Bay | 10-20 | 22.3±0.9 | 36.2±0.3 | 24.7±0.6 | 34.3±1.1 | 23±0.2 | 32.8±0.1 | 19.5±0.3 | 35.3±0.6 |
| Daya Bay | 7-32 | 21.3±0.9 | 36.2±0.3 | 26±1.8 | 35.1±0.5 | 25±0.8 | 33.2±0.3 | 19.6±0.4 | 35.6±0.5 |
| Dapeng Bay | 17-20 | 20.5±0.5 | 36±0.1 | 25.2±0.9 | 36.5±0.8 | 25.6±0.4 | 33.2±0.2 | 20.2±0.5 | 36.5±0.5 |
| Hailing Bay | 10-22 | 23.4±1.8 | 33.7±0.6 | 29.4±0.2 | 24.5±0.9 | 22.8±0.1 | 31.6±0.2 | 16.4±0.0.2 | 35±0 |
| Shuidong Bay | 6-8 | 24.5±0.2 | 33.5±0.5 | 30.2±0.4 | 25.2±0.4 | 22.8±0.1 | 31.7±0.1 | 17.3±0.1 | 35±0 |
| Leizhou Bay | 10-11 | 25.5±0.4 | 33±0 | 29.5±1.4 | 31±1.4 | 22.7±0.2 | 31±1.1 | 18±0.2 | 33.8±1.2 |
| Liusha Bay | 11-13 | 25±0.2 | 35.3±0.6 | 29.1±0.1 | 34±0 | 23±0.3 | 32.5±0.5 | 18.3±0 | 35±0 |

Legend: D, Water depth; T, Temperature; S, Salinity.



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*Species composition*

In the present investigation, a total of 70 species belonging to 30 genera and 10 families were collected. The Family with the most species number was Portunidae, of which 21 species were collected, followed by Family Leucosiidae (12). Among the bays examined, Shantou Bay had the largest number of species collected (41), followed by Leizhou Bay (35), and Dapeng Bay with the lowest number of crab species collected (20). *Portunus sanguinolentus*, *P. hastatoides*, *Charybdis feriatus*, *C. variegate*, and *C. vadorum* were collected in every bay.

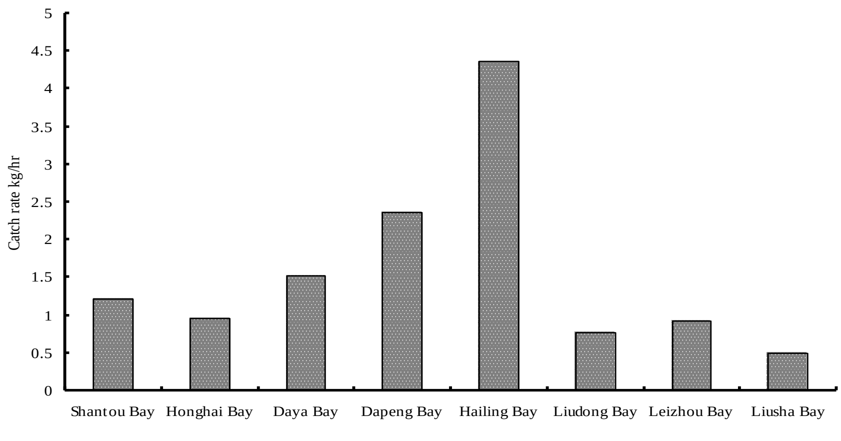


**Figure 2: The annual catch rate of crab in the main bays of Guangdong Province, China**

*The spatial patterns of crab capture*

The annual catch rate of crabs in Hailing Bay was the highest, followed by that in Dapeng Bay. The lowest rate was in Liusha Bay (Fig. 2). Besides *Dorippides facchino* in the Dorippidae family and *Eucrate crenata* in the Goneplacidae family, all other species ranking on the top three of catch rates in each bays belonged to the Portunidae family (Table 2).

**Table 2: The species with the three highest catch rates in each bay as surveyed in Guangdong coast areas, and their average catch rates (kg/hr).**

| Bays | The first species | The second species | The third species |
|---|---|---|---|
| Shantou Bay | *Charybdis feriatus* (0.16) | *Portunus sanguinolentus* (0.14) | *Portunus pelagicus* (0.13) |
| Honghai Bay | *Portunus sanguinolentus* (0.21) | *Portunus pelagicus* (0.17) | *Portunus trituberculatus* (0.16) |
| Daya Bay | *Portunus pelagicus* (0.29) | *Portunus sanguinolentus* (0.21) | *Eucrate crenata* (0.12) |
| Dapeng Bay | *Dorippides facchino* (0.85) | *Charybdis feriatus* (0.54) | *Portunus sanguinolentus* (0.51) |
| Hailing Bay | *Portunus sanguinolentus* (1.04) | *Charybdis affinis* (0.64) | *Portunus pelagicus* (0.57) |
| Liudong Bay | *Portunus sanguinolentus* (0.30) | *Portunus hastatoides* (0.20) | *Portunus pelagicus* (0.05) |
| Leizhou Bay | *Portunus sanguinolentus* (0.29) | *Portunus pelagicus* (0.12) | *Charybdis feriatus* (0.09) |
| Liusha Bay | *Charybdis feriatus* (0.22) | *Charybdis vadorum* (0.13) | *Eucrate crenata* (0.09) |

*The seasonal patterns of crab capture*

The species numbers recorded in spring, summer, autumn and winter were 45, 43, 42 and 29, respectively. The catch rates of crabs in Hailing Bay were the highest in spring, summer and autumn, whereas in winter, the highest catch rate was in Shantou Bay (Table 3). The crabs collected in spring were mainly composed of those species of small size, whereas in summer, autumn and winter, larger species constituted the major proportion of the catch (table 4).

**Table 3: Average catch rates (kg/hr) of crabs in the main bays of Guangdong Province.**

| Region | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Shantou Bay | 0.78 | 0.99 | 2.32 | 1.3 |
| Honghai Bay | 0.48 | 1.12 | 2.04 | 0.22 |
| Daya Bay | 1.32 | 1.04 | 1.76 | 1.97 |
| Dapeng Bay | 6.12 | 0.28 | 1.86 | 1.20 |
| Hailing Bay | 12.1 | 2.09 | 2.87 | 0.44 |
| Liudong Bay | 0.46 | 1.23 | 0.72 | 0.69 |
| Leizhou Bay | 0.29 | 0.30 | 2.77 | 0.34 |
| Liusha Bay | 0.16 | 0.58 | 0.58 | 0.66 |



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**Table 4: The top three species caught and catch rate for each (kg/hr) in four seasons in the main bays of Guangdong Province**

| | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Shantou Bay | *Conchoecetes artificiosus* (0.12) | *Portunus sanguinolentus* (0.31) | *Portunus pelagicus* (0.44) | *Charybdis feriatus*(0.39) |
| | *Charybdis variegata*(0.10) | *Portunus hastatoides* (0.24) | *Charybdis feriatus*(0.27) | *Charybdis affinis* (0.16) |
| | *Portunus haanii* (0.09) | *Doclea japonica* (0.06) | *Portunus sanguinolentus*(0.23) | *Charybdis vadorum* (0.12) |
| Honghai Bay | *Eucrate crenata*(0.28) | *Portunus pelagicus* (0.54) | *Portunus sanguinolentus*(0.72) | *Charybdis feriatus*(0.11) |
| | *Eucrate costata* (0.14) | *Portunus trituberculatus* (0.23) | *Charybdis feriatus*(0.30) | *Portunus trituberculatus* (0.08) |
| | *Philyra globulosa* (0.01) | *Portunus sanguinolentus* (0.14) | *Portunus trituberculatus* (0.30) | *Eucrate crenata*(0.01) |
| Daya Bay | *Eucrate crenata*(0.43) | *Portunus sanguinolentus* (0.28) | *Portunus sanguinolentus*(0.57) | *Portunus pelagicus* (0.76) |
| | *Charybdis vadorum* (0.27) | *Portunus pelagicus* (0.25) | *Portunus trituberculatus* (0.50) | *Dorippides facchino* (0.33) |
| | *Dorippides facchino* (0.11) | *Charybdis anisodon* (0.12) | *Charybdis hongkongensi*(0.25) | *Portunus hastatoides*(0.07) |
| Dapeng Bay | *Dorippides facchino* (3.38) | *Portunus trituberculatus* (0.24) | *Portunus sanguinolentus*(1.00) | *Portunus sanguinolentus*(0.94) |
| | *Charybdis feriatus*(1.69) | *Charybdis japonica* (0.04) | *Charybdis feriatus*(0.38) | *Charybdis feriatus*(0.08) |
| | *Portunus pelagicus* (0.36) | *Parthenope tuberculosu* (0.02) | *Charybdis vadorum* (0.15) | *Dorippides facchino* (0.02) |
| Hailing Bay | *Charybdis affinis* (2.54) | *Portunus sanguinolentus* (1.49) | *Portunus sanguinolentus*(1.98) | *Portunus sanguinolentus*(0.42) |
| | *Portunus pelagicus* (2.25) | *Portunus trituberculatus* (0.38) | *Portunus hastatoides*(0.41) | *Charybdis feriatus*(0.01) |
| | *Eucrate crenata*(2.02) | *Charybdis japonica* (0.06) | *Galene bispinosa*(0.12) | *Charybdis vadorum* (0.01) |
| Shuidong Bay | *Portunus hastatoides*(0.33) | *Portunus sanguinolentus* (0.34) | *Portunus sanguinolentus*(0.37) | *Portunus sanguinolentus*(0.50) |
| | *Charybdis japonica* (0.11) | *Portunus hastatoides*(0.31) | *Portunus hastatoides*(0.16) | *Charybdis affinis* (0.08) |
| | *Eucrate costata* (0.09) | *Portunus pelagicus* (0.16) | *Calappa philargius*(0.14) | *Charybdis feriatus*(0.05) |
| Leizhou Bay | *Portunus sanguinolentus* (0.08) | *Portunus sanguinolentus* (0.08) | *Portunus sanguinolentus*(1.30) | *Portunus sanguinolentus*(0.20) |
| | *Dorippides japonica* (0.05) | *Portunus pelagicus* (0.08) | *Portunus pelagicus* (0.48) | *Charybdis feriatus*(0.18) |
| | *Doclea japonica* (0.05) | *Doclea gracilipes* (0.06) | *Charybdis japonica*(0.23) | *Portunus pelagicus* (0.10) |
| Liusha Bay | *Charybdis feriatus* (0.50) | *Portunus hastatoides*(0.25) | *Charybdis vadorum* (0.52) | *Galene bispinosa*(0.26) |
| | *Charybdis variegate* (0.04) | *Charybdis truncata*(0.18) | *Charybdis feriatus*(0.35) | *Portunus hastatoides*(0.05) |
| | *Charybdis bimaculata* (0.02) | *Portunus gracilimanus* (0.05) | *Portunus hastatoides*(0.07) | *Charybdis feriatus*(0.02) |

*Multivariate analyses of spatial distribution of crabs*

One-way ANOVA revealed that variations in water depth, temperature and salinity did not significantly affect the crab fauna and capture rate (*r* Range between - 0.507 and 0.460, $p>0.05$) in every season.

Bray-Curtis similarity matrices based on abundance, biomass and catch rate were constructed after four root transformation of the data, and then compared using the RELATE routine of PRIMER (Clarke and Gorley, 2006). As a high degree of concordance was observed (*Rs* range 0.657 to 0.902, $p<0.003$), further analysis was performed for catch rate matrix only. To reduce the disturbance of rare species, only those species with catch rate >1% (totally 90.33%) were included in the analysis.

The clustering and nMDS ordination analysis from catch rates revealed the existence (with a similarity greater than





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60%) of three groups: Group 1, Hailing Bay and four bays to its east, in which the typical species were *Portunus sanguinolentus*, *P*. *pelagicus*, and *Charybdis feriatus*. Group 2, Shuidong Bay and Leizhou Bay, with the most typical species being *P*. *sanguinolentu*, *P*. *pelagicus*, and *P. hastatoides*. In group 3, Liusha Bay, the typical species were *C*. *feriatus*, *C*. *vadorum*, and *C*. *truncate* (Figs. 3, 4). The stress values ($s$ < 0.05) indicated that the ordination was sufficient to infer useful results (Clarke and Gorley, 2006). One-way ANOSIM analysis of these groups showed significant overall differences between the groups ($R$=0.968, $P$<0.006), and multiple pairwise tests revealed that the community structures were significantly different between Groups 1 and 2 ($R$=0.945, $P$<0.048). SIMPER analysis showed that the average similarities within Groups 1 and 2 were 65.14 and 75.48, respectively. The average pairwise dissimilarities between groups ranged from 44.73 up to 55.59.

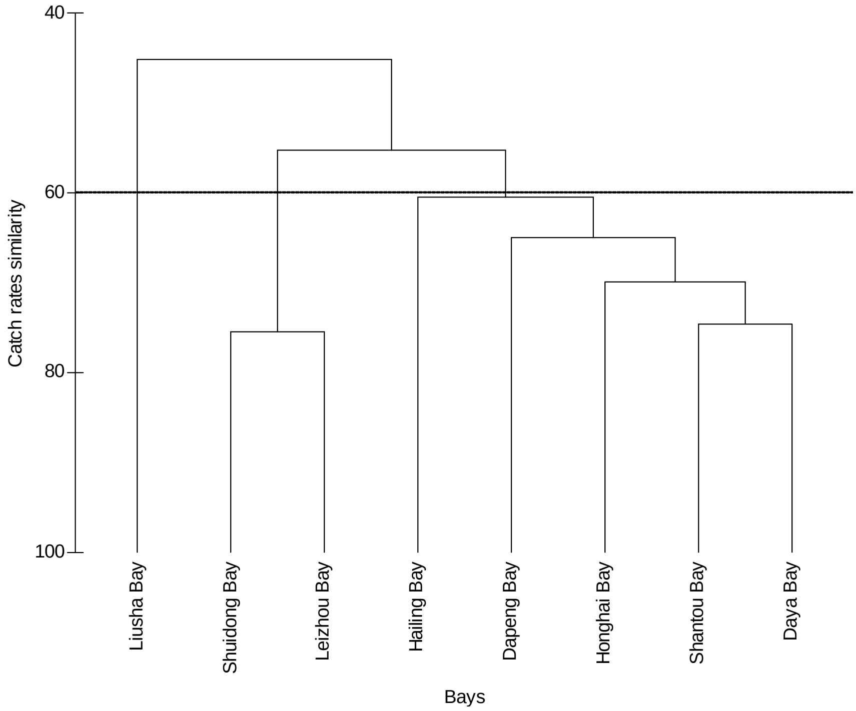


**Figure 3: Cluster of annual-averaged catch rates of crabs from the main bays of Guangdong Province (60% similarity)**



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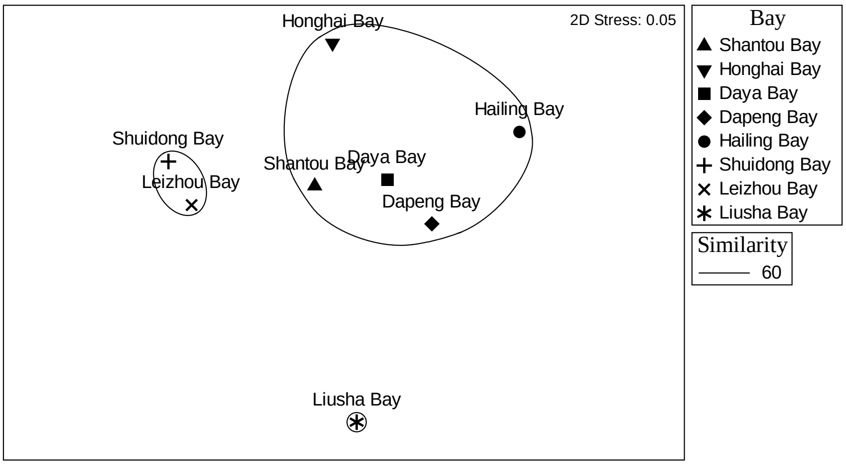


**Figure 4: nMDS ordination plots of spatial variations in annual-averaged catch rates of crabs in the main bays of Guangdong Province (marked groupings have 60% similarity)**

**Table 5: Percentage of crabs captured on different sediment types in the main bays of Guangdong Province**

| Bay | Widely range sediment (%) | Muddy or Muddy-Sandy (%) | Sandy or Sandy-Muddy (%) |
|---|---|---|---|
| Shantou Bay | 47.2 | 38.9 | 13.9 |
| Honghai Bay | 43.5 | 34.8 | 21.7 |
| Daya Bay | 43.3 | 33.3 | 23.3 |
| Dapeng Bay | 50.0 | 33.3 | 16.7 |
| Hailing Bay | 45.8 | 37.5 | 16.7 |
| Shuidong Bay | 57.9 | 31.6 | 10.5 |
| Leizhou Bay | 48.4 | 25.8 | 25.8 |
| Liusha Bay | 45.0 | 30.0 | 25.0 |

**Table 6: Seasonal variations of the average captures of crabs in the main bays of Guangdong Province**

| | Abundance (ind/km$^2$) | Biomass (kg/km$^2$) | Catch rate (kg/hr) |
|---|---|---|---|
| Spring | 3252 | 33.9 | 1.88 |
| Summer | 1236 | 20.2 | 0.98 |
| Autumn | 2390 | 30.4 | 1.85 |
| Winter | 1286 | 14.8 | 0.82 |

## Discussion

*Spatial distribution in catches*

Crabs account for a significant component of the marine fishery production in Guangdong Province, China, and most of them are tropical-subtropical species (Dai et al., 1986). In the present study, the 70 species of crab in the main bays of Guangdong Province are restricted to the tropics and subtropics, the fauna belong to the South China Sea Faunal Sub region in the tropical India West-Pacific Faunal Region, which has a closer relationship with the East China Sea, Southeast Asia, and has a more distant relationship with the Yellow Sea (Shen and Liu, 1963; Dai et al., 1986; Song et al., 2006).

According to a rough estimate (Ministry of Agriculture, Farming and Fishery of China 1989), in the coast of Guangdong Province, *Portunus trituberculatus, P. pelagicus*, and *Scylfa serrata* (dominant in estuarine) are the major crabs captured. In this study, the dominant species were *Portunus sanguinolentus* and *Charybdis feriatus* (which account for 23.1% and 13.0% of the total catch, respectively) rather than *P. pelagicus* and *P. trituberculatus* (comprising 11.4% and 3.6% of the total catch, respectively).

Like other crustaceans, the crabs' mobility is considerable and they can actively choose suitable habitats. Sediment appears likely to be a major factor determining the distribution (Tremblay, 1997; Dionne et al., 2003). *Ovalipes ocellatus* is a common crab that is native to the Atlantic coast of North America, inhabiting only a limited area (about 2,500 $km^2$) in the central part of Northumberland Strait, all of which has a sand or sandy substrate (Voutier and Hanson, 2008). In the central and northern parts of the Taiwan Strait, China, the biomass of crabs was relatively high in the area with fine sand as sediments, while the number of crab species was relatively higher in coarser sand sediments (Fang, 1991). In the present study, the crabs also had a heterogeneous distribution and showed specific habitat preferences. In Hailing Bay, where the sediment was sand and sand-muddy mixed with shell splinter, only 25 species were found, although the biomass and catch were the greatest among all the bays examined. In Shantou Bay, which has muddy and sand-muddy sediment, 41 species of crabs were found, but the overall catch was at an intermediate level. The number of crab species collected in Leizhou Bay, with sandy sediment, was 35 (Committee of Record of Bays in China, 1999). Most of these species favor sand and sandy-muddy substrates, but the catch was very low (Fig. 2, table 5).

Geography and crab biology appeared to be among the main determinants of crab distribution (Nathalie et al., 2007; Nan et al., 2008). For example, *Scylla serrata* inhabits muddy bottoms, mangrove marshes, and river mouths in estuarine environments. It is distributed throughout the Indo-Pacific region, and supports one of the largest crab fisheries in more temperate environments such as China (Overton et al., 1997; Song et al., 2006). *Portunus pelagicus* is distributed throughout the coastal waters of the tropical regions of the western Indian Ocean and the Eastern Pacific, showing a high preference for sub-littoral shallow waters (Sumpton et al., 1994; Chande and Mgaya 2003). *Portunus trituberculatus* is found from Hokkaidō to South India, throughout the


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Malay Archipelago and as far south as Australia, with 98% of the catch of this species off the coast of China (Song et al., 2006). In the present study, the catches of crabs did not show homogeneous distribution, with geographical differences and crab biology being the main determining factors. Except *Portunus sanguinolentus*, *P. hastatoides*, *Charybdis feriatus* and *C. variegate*, which were widely distributed in the Guangdong coast and were abundant in each bay, *Dorippides facchino Portunus trituberculatus*, and *Eucrate solaris* were only collected and abundant in Hailing Bay and three other bays to its east (group 1). Similarly, *Matuta planipes* and *Pseudophilyra albimaculata* in Shuidong and Leizhou bays (group 2); and *Phalangipus hystrix* in Liusha Bay (group 3) had skewed geographic patterns of distribution. In Liusha Bay (group 3), the larger edible crab was sparse, while small crabs such as *Charybdis vadorum* and *Portunus hastatoides* comprised the majority of the catch.

*Seasonal variation in catches*

Because of patterns in feeding, breeding, and over-winter migration, the crab keeps pace with the seasonal changes (Gregg et al., 2001; Woll et al., 2006; Voutier and Hanson, 2008). In Auke Bay, Alaska, The red king crab *Paralithodes camtschaticus* move to deep water in spring after mating and egg extrusion (Stone et al., 1992). In the Gulf of Nicoya, Costa Rica, most spawning of *Callinectes arcuatus* occurs in the dry season from December to April, when egg-laden females migrate from the brackish waters of the upper gulf to high salinity waters in the lower gulf to release their larvae (Fischer and Wolff, 2006). In the spawning season, female *Portunus trituberculatus* migrate to the spawning grounds prior to the males in the Bohai Sea and Yellow Sea, comprising roughly 70% of the catch from March to April. From July to November, male crabs typically exceed the number of females in the catch. They may hibernate during one-third of the winters of their life span (Otto and Jamieson, 2001). In the present study, crab catches also changed seasonally. In winter, the crab species number was reduced by one third in comparison with the other three seasons, and the catch was no more than one half of those in spring and autumn (table 6). In spring, many small and inedible crabs (such as those in the genera *Dorippides* and *Eucrate*) composed the main catches, whereas in summer, autumn, and winter, the main catches consisted mostly of large and edible species. Moreover, summer, autumn, and winter catches of *Portunus sanguinolentus* were dramatically higher than those observed in spring (Table 4).

In the present study, the water depth, temperature and salinity did not significantly affect rates of crab capture in any particular season, because water in all of the bays was very shallow (≤32m), and the bottom water temperature and salinity did not change significantly.

Different from stomatopod, shrimp and fish, in the present survey, the mid-summer fishing moratorium that has been imposed as a conservation measure may not contribute effectively to the protection of the crab from overexploitation (Yu et al., 2008; Huang et al., 2009). Crab abundance in summer was the lowest of the four seasons, and the biomass and catch rate were just above those seen in winter (table 6). It is also noteworthy that alternative





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means of crab hunting including gill-netting and trapping were not forbidden within the closed season by this moratorium.

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