Horseshoe Crabs in Hong Kong: Current Population Status and Human Exploitation

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Abstract An updated survey, using both random transect and walk-through search methods, at 17 shores in Hong Kong in summer and winter showed that juvenile horseshoe crabs (*Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*) were significantly reduced by over 90% in density since 2002. Of the shores where juveniles were found, the highest density of *T. tridenatus* was 0.31 and lowest 0.08 ind 100 m^{-2}. Juvenile *C. rotundicauda* was only found using the walk-through search method, with the highest record of 1.17 and lowest 0.17 ind hr^{-1} $person^{-1}$. The mean prosomal width of juvenile *T. tridentatus* obtained from the walk-through survey varied from 2.6 to 5.5 cm, which corresponded to an age of 4–8 years old. A larger size range for *C. rotundicauda* was, however, noted, from 2.5 to 9.0 cm.

The degree of human exploitation of adult horseshoe crabs (*T. tridentatus*) in Hong Kong was estimated through interviewing 34 seafood restaurants, 150 fish sellers and fish handlers, and fishermen in two local fish wholesale markets over a 13-month study period. A total of 1,023 horseshoe crabs were caught in 2004–2005, with 72% from mainland Chinese waters. Apart from releasing back to sea, an average sale of 17 horseshoe crabs per month was estimated. While the sale of horseshoe crabs was low by comparison with other marine species of economic importance, human exploitation still contributes a potential threat and puts further pressure on the mature population of horseshoe crabs in Hong Kong due to their long maturity period and declining densities of the juveniles.

1 Introduction

Once reportedly abundant on shores in Hong Kong by local villagers in the 1950s, adult horseshoe crabs are rarely found on shores these days. From Mikkelsen (1988), there were records of three Asia-Pacific horseshoe crab

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species, *Tachypleus tridentatus*, *T. gigas* and *Carcinoscorpius rotundicauda* in Hong Kong. More recently, only *T. tridentatus* and *C. rotundicauda* were reported (Chiu and Morton 1999a) and a decline of their presence in the northeastern waters of Hong Kong was also noted (Chiu and Morton 1999b, 2003a). The decline in horseshoe crab populations is not confined to Hong Kong, but has been observed in Japan, Taiwan, and Thailand as well (Sekiguchi 1988; Itow 1998; Chen et al. 2004). It is apparent that the threat for further population decline and possible extinction might be imminent if there are no effective conservation measures to save horseshoe crabs in the Asia-Pacific (Earle 1991).

In Hong Kong, information on species identification (Chiu and Morton 2003b), characteristics of nursery beaches (Chiu and Morton 1999b; Morton and Lee 2003), ecology and biology (Chiu and Morton 1999a), growth and allometry (Chiu and Morton 1999a, 2003a), and behavior of juveniles in the field (Chiu and Morton 2004) and laboratory (Morton and Lee 2003) is available. With continuing urban developments and disturbances to coastal habitats, the threat to the existence of horseshoe crab populations remains apparent. The objectives of this study are to update the current population status on the distribution of juvenile horseshoe crabs at local shores and assess the extent of human exploitation of adult horseshoe crabs in Hong Kong.

2 Materials and Methods

2.1 Population Distribution Study

A total of 17 Hong Kong soft shores were surveyed in this study (Fig. 1), including Tsim Bei Tsui, Sheung Pak Nai, Pak Nai, and two locations at Ha Pak Nai in northwestern New Territories; and San Tau, Shui Hau Wan, Pui O Wan, Tai Ho Wan, Sham Wat, Yi O, Tung Chung, and Hau Hok Wan on Lantau Island, where horseshoe crabs once were reported in abundance (Chiu and Morton 1999b). In eastern waters and on Lamma Island, surveys were also conducted at Luk Keng, Lai Chi Wo, and Pak Kok Wan in northeastern New Territories, and Sok Kwu Wan on Lamma Island (Fig. 1). The 13 shores in northwestern New Territories and on Lantau Island were surveyed in summer from September to November 2004 and in winter from December 2004 to February 2005 while the three shores in northeastern New Territories and one shore on Lamma Island were surveyed from 2005 to 2006. Summer distribution studies in Luk Keng, Pak Kok Wan, and Sok Kwu Wan were carried out from August to October 2005. For Lai Chi Wo in northeastern New Territories, the summer survey was undertaken in June 2006. The winter distribution studies of these four sites were conducted in January 2006.

A transect method as adopted by Chiu and Morton (1999b) was used in this study. At each shore, four horizontal transects were set equally apart from the

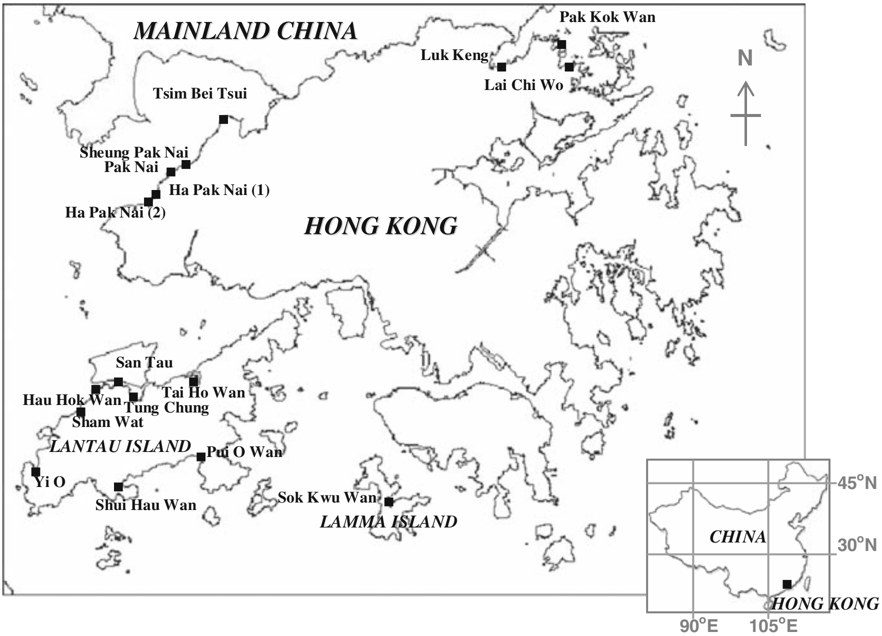

Fig. 1 The 17 survey shores for juvenile horseshoe crabs in New Territories, on Lantau Island and Lamma Island of Hong Kong

lower tidal level at 0.7–1.6 m above chart datum (CD). The length of each transect was similar to the width of the shore, and along each transect five quadrats (8 m $\times$ 8 m) were randomly selected for counting of juvenile horseshoe crabs (Fig. 2). The total survey area on a shore was 1,280 m^2. The number of each horseshoe crab species found on the sediment surface within the quadrat was counted and their prosomal width measured using a Vernier caliper. For survey locations near freshwater streams, the sampling was further stratified by studying additional 20 random quadrats (0.5 m $\times$ 0.5 m) within the stream area. As horseshoe crabs may bury in the sediment and could not be observed by the present sampling method, such bias was assessed by using 20 random quadrats (area of 2 m^2) and each sample was examined by digging sediment up to 5 cm depth in the distribution study in northeastern New Territories and on Lamma Island in 2005–2006. Within each quadrat, sediment temperature, salinity, and dissolved oxygen were also monitored using a glass thermometer, a hand-held refractometer (Model ATAGO S/Mill-E), and an oxygen electrode (YSI Model 58), respectively.

Apart from the transect method, the population density of horseshoe crabs was also obtained by a walk-through survey. At each shore, two persons were involved in search of juvenile horseshoe crabs by walking along the four horizontal transects in a fixed time duration of 3 hours during low tide. All juvenile horseshoe crabs found were counted and the prosomal width of each

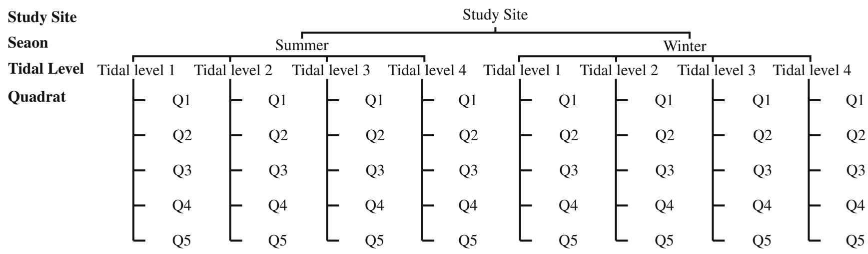

Fig. 2 The transect sampling design for survey of juvenile horseshoe crabs on Hong Kong shores

individual was measured. The data were normalized by calculating the population density per unit search effort, i.e., number of horseshoe crabs/hour/person.

2.2 Human Exploitation Study

A monthly market survey from September 2004 to September 2005 was conducted at 11 popular sites for the sale of seafood in Hong Kong. In total, 34 seafood restaurants and 150 fish sellers were interviewed monthly for information on the sale of adult horseshoe crabs. Monthly interviews of fishermen from two local fish wholesale markets were also carried out, to record if horseshoe crabs were caught in local waters.

2.3 Data Analysis

As the population density data obtained from the transect method did not follow the normal distribution, differences in population density between the survey sites were compared using non-parametric Kruskal–Wallis (KW) test to assess the effects of site, tidal level, and season on the population density of juvenile horseshoe crabs. A Bonferroni adjustment was used to correct for Type I error, and significance for each KW test was evaluated against $\alpha = 0.05$ divided by the number of comparisons being made. Thus, the significance level for each KW test was $P = 0.017$. For data on the hydrological parameters and size of juvenile horseshoe crabs obtained from the walk-through method, data were normally distributed. Hence, a three-way repeated-measures ANOVA was used to address the interacting effects among the survey shores, tidal levels, and seasons on the hydrological parameters and size of horseshoe crabs. No data transformation was used prior to these analyses. When significant differences among treatments were observed, Tukey multiple comparison tests were performed to determine the differences between sites and tidal levels with a significance level of $P = 0.05$. All the statistical analyses were undertaken using software SPSS 11.0.

3 Results

3.1 Population of Juvenile Horseshoe Crabs

Over the survey period, sediment temperature in summer averaged at 29.4 ± 2.2°C, interstitial salinity 25.1 ± 7.2‰, and dissolved oxygen 6.0 ± 1.7 mg l^{-1}, whereas in winter, sediment temperature averaged at 17.0 ± 3.6°C, interstitial salinity 32.5 ± 6.6‰, and dissolved oxygen 7.7 ± 1.4 mg l^{-1}. Temperature varied significantly among the survey shores ($F_{16, 156} = 83.392$, $P < 0.001$), tidal levels ($F_{3, 156} = 8.558$, $P < 0.001$), and seasons ($F_{1, 156} = 5187.483$, $P < 0.001$). Salinity also varied significantly with the sampling shores ($F_{16, 203} = 18.854$, $P < 0.001$), tidal levels ($F_{3, 203} = 5.728$, df = 3, $P = 0.001$), and seasons ($F_{1, 203} = 117.47$, $P < 0.001$). However, dissolved oxygen level in the sediment varied significantly with the survey shores ($F_{15, 170} = 9.241$, $P < 0.001$) and seasons ($F_{1, 170} = 69.180$, $P < 0.001$) but not tidal levels ($F_{3, 170} = 0.471$, $P = 0.703$).

Among the 17 shores, juvenile *T. tridentatus* were only found at 6 shores and no *C. rotundicauda* were noted using the transect method. Figure 3 shows the mean density of juvenile *T. tridentatus* recorded in both summer and winter surveys. In summer, Tsim Bei Tsui and one location at Ha Pak Nai had the highest mean density of 0.31 ± 0.96 and 0.23 ± 0.76 ind 100 m^{-2}, respectively, followed by another location at Ha Pak Nai (0.16 ± 0.48 ind 100 m^{-2}) and San

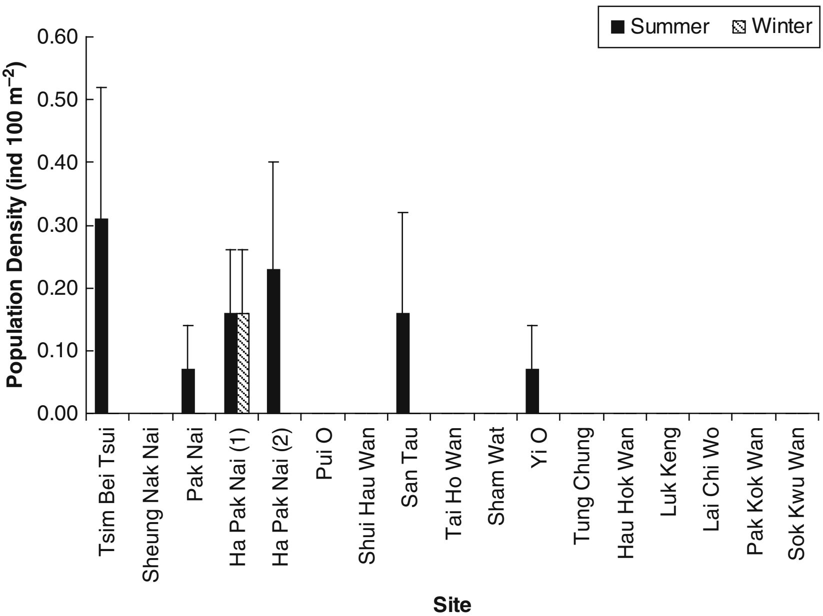

Fig. 3 Mean density (+SE) of juvenile horseshoe crabs (*Tachypleus tridentatus*) recorded by the transect sampling method in the present surveys

Tau (0.16 ± 0.70 ind 100 m^{-2}). Pak Nai and Yi O had the lowest mean density of 0.08 ± 0.35 ind 100 m^{-2} among the six shores. In winter, horseshoe crabs were only found at one site located at Ha Pak Nai with the average density of 0.16 ± 0.48 ind 100 m^{-2}. However, no significant difference in densities was noted among shores (KW test, $H = 29.811$, $P = 0.019$). For spatial variations within shores, the density on the upper shore (tidal level 1) was higher than that on the lower shore (tidal levels 2–4) in both summer and winter (Fig. 4); the differences, however, were not statistically significant (KW test, $H = 1.625$, $P = 0.654$). There was also no significant difference (KW test, $H = 4.554$, $P = 0.033$) in the distribution of horseshoe crabs in the two sampling seasons. The mean density was 0.06 ± 0.39 and 0.01 ± 0.12 ind 100 m^{-2} in summer and winter, respectively. No horseshoe crabs were recorded in stream areas, and no horseshoe crabs were found by the digging method in the distribution study in northeastern New Territories and on Lamma Island.

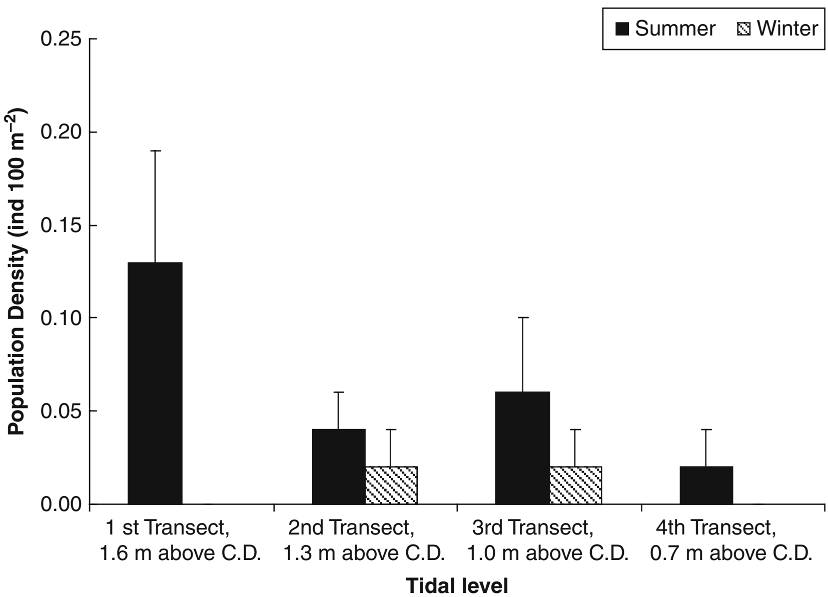

Fig. 4 Mean density (+SE) of juvenile horseshoe crabs (*Tachypleus tridentatus*) found at the four tidal levels (1 = the uppermost transect; 2 = the second transect; 3 = the third transect; 4 = the fourth transect, 0.7 m above chart datum (C.D.)) recorded by the transect sampling method in the present surveys

More individuals of *T. tridentatus* were collected by the walk-through survey than the transect sampling in both summer and winter (Fig. 5). While direct comparison of data was not feasible owing to different sampling efforts, the walk-through survey might be a better strategy to collect sufficient data for

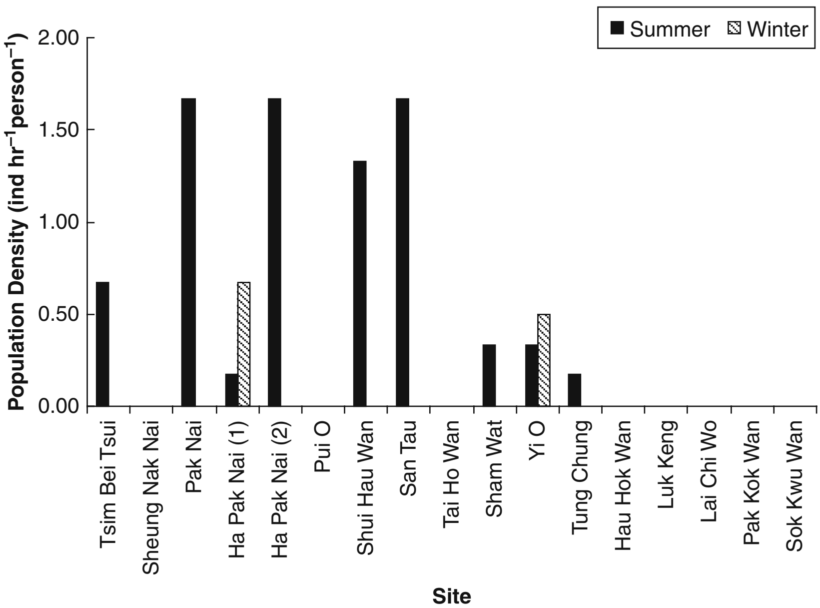

Fig. 5 Population density of juvenile horseshoe crabs (*Tachypleus tridentatus*) found by the walk-through survey

juvenile horseshoe crabs occurring at low densities on local shores. Similar to the transect sampling method, higher densities of horseshoe crabs were found at Tsim Bei Tsui, Ha Pak Nai (2), San Tau, and Pak Nai. No individual was found at Shui Hau Wan by transect sampling but eight individuals were found by the walk-through survey in the summer study. No individual of *C. rotundicauda* was found using transect sampling but 30 and 4 individuals were found in summer and winter, respectively, using the walk-through survey (Fig. 6) with highest densities being found at Tsim Bei Tsui and Pak Nai. Only *C. rotundicauda* was found in northeastern New Territories including Luk Keng and Lai Chi Wo.

Figure 7 shows the mean prosomal width of juvenile *T. tridentatus* obtained from the walk-through survey in both summer and winter. Their mean carapace width varied from 2.6 to 5.5 cm. According to the size–age relationship established by Sekiguchi (1988), these corresponded to an age of 4–8 years old. Horseshoe crabs in Shui Hau Wan had the highest average prosomal width of 5.6 $\pm$ 1.25 cm, while those in Tung Chung had the lowest average prosomal width of 2.7 $\pm$ 0.27 cm (Fig. 7). The size of juvenile *T. tridentatus* did not vary significantly with the survey shores ($F_{8, 35} = 1.721$, $P = 0.128$), seasons ($F_{1, 35} = 0.265$, $P = 0.61$), tidal levels ($F_{3, 35} = 1.048$, $P = 0.383$), or their interaction ($P > 0.05$) as tested by three-way repeated-measures ANOVA. From the present data, the largest average size of horseshoe crabs was collected at 1.3 m above CD and smallest at 0.7 m above CD; the difference, however, was not statistically significant.

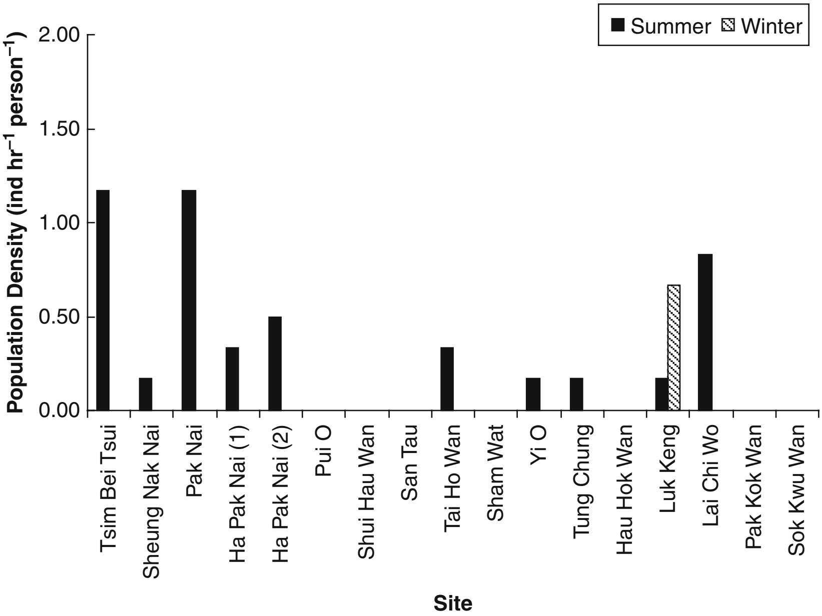

Fig. 6 Population density of juvenile horseshoe crabs (*Carcinoscorpius rotundicauda*) found by the walk-through survey

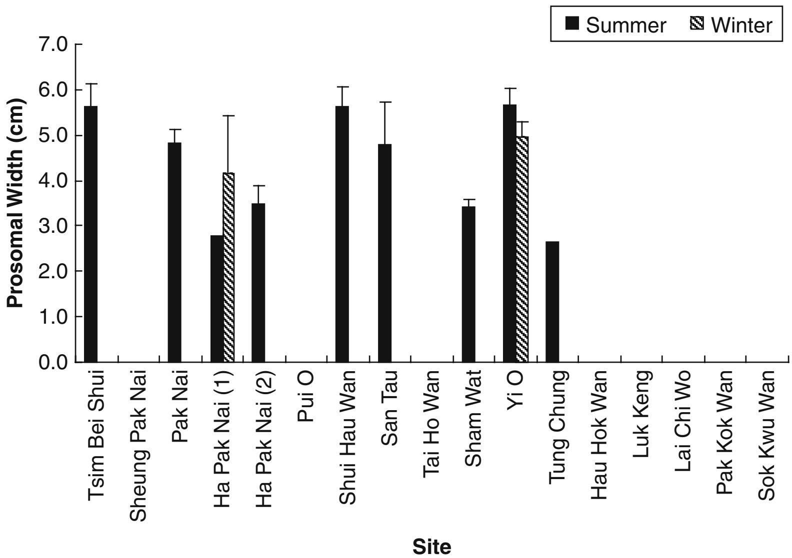

Fig. 7 Mean (+SE) size (prosomal width) of juvenile horseshoe crabs (*Tachypleus tridentatus*) recorded by the walk-through survey at the 17 shores in summer and winter

Figure 8 shows the prosomal width of *C. rotundicauda* obtained at different survey shores and ranged from 2.5 cm (Ha Pak Nai (1)) to 9.0 cm (Lai Chi Wo). The size of horseshoe crabs did not vary significantly with tidal levels ($F_{3,\ 18} = 2.92$, $P = 0.062$), seasons ($F_{1,\ 18} = 14.307$, $P = 0.932$), and their interaction ($F_{1,\ 18} = 0.119$, $P = 0.734$) but varied significantly with the survey shores ($F_{9,\ 18} = 14.307$, $P < 0.001$). From the present data, the largest horseshoe crabs were collected from 1.0 m above CD and smallest at 0.7 m above CD; the difference, however, was not statistically significant.

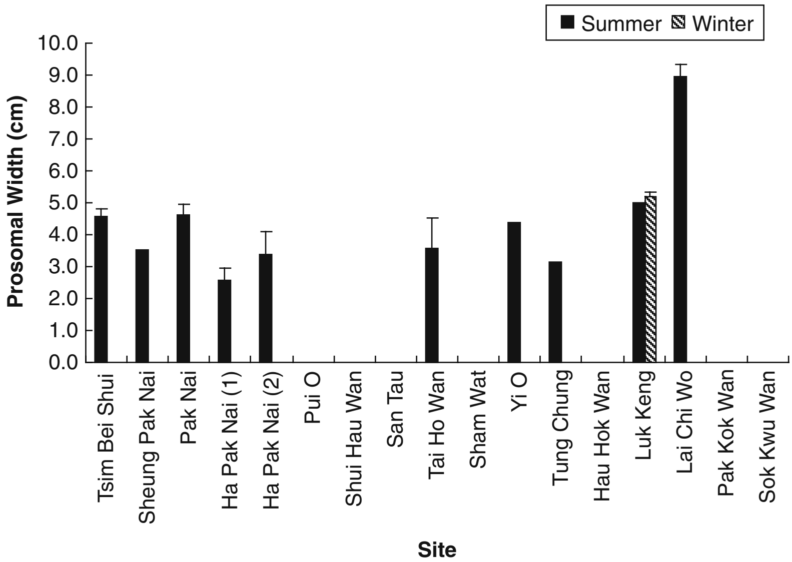

Fig. 8 Mean (+SE) size (prosomal width) of juvenile horseshoe crabs (*Carcinoscorpius rotundicauda*) recorded by the walk-through survey at the 17 shores in summer and winter

3.2 Human Exploitation of Adult Horseshoe Crabs

By interviewing the fish sellers in fish stalls, seafood restaurants, and wholesale markets, we determined that a total of 1,023 adult horseshoe crabs (mostly *T. tridentatus*) were caught throughout the year, from September 2004 to September 2005 (13-month period) (Fig. 9). Most of them were caught by shrimp trawlers, occasionally by netting and cage fishing methods. In terms of seasonal variations, more catch (about 50 ind month^{-1}) was recorded from September to December 2004 than that of the remaining months in 2005 (about 9–10 ind month^{-1}). This result was also confirmed by the interviews with fishermen that more horseshoe crabs were found in the winter than summer time. Of these adult horseshoe crabs, only 32% (332 individuals) were obtained from Hong Kong and 68% (691 individuals) from mainland Chinese waters (Fig. 9). The size ranged from 3 to 60 cm, with an average prosomal width of 30–40 cm and weight of 3 kg.

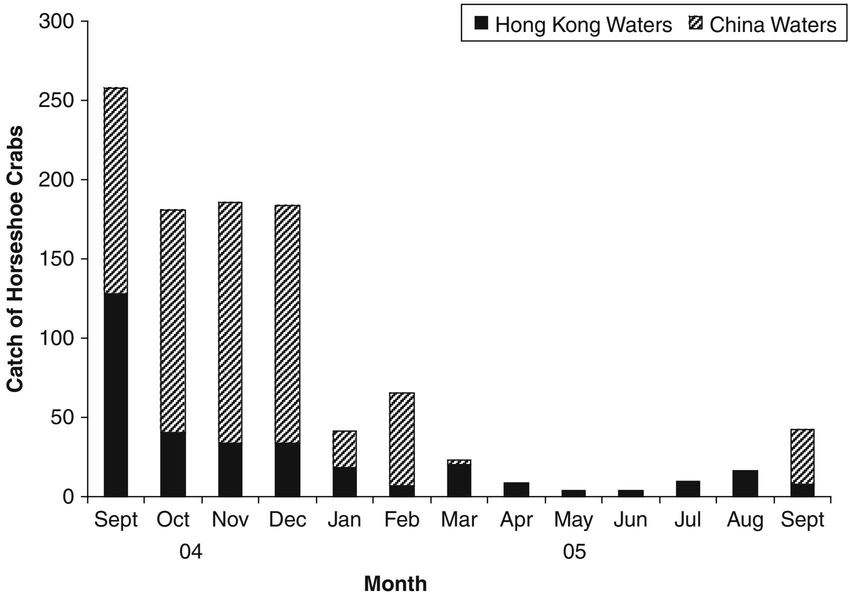

Fig. 9 Number of catch of adult horseshoe crabs (*Tachypleus tridentatus*) from both Hong Kong and mainland Chinese waters, from September 2004 to September 2005

Owing to the low market value and rarity in comparison to other marine economic species such as fish, shrimps, and crabs, about one-third of the horseshoe crabs caught in the trawl net were released immediately back to sea by the fishermen and the remaining two-thirds (about 690 individuals) were retained on board and sold to fish wholesale markets and seafood restaurants in Hong Kong. The present interview surveys noted that the majority (62%) of the adult horseshoe crabs were sold and used for the Chinese traditional 'set-free' rituals at sea, while the remaining (28%) were kept and served as delicacy dishes in local seafood restaurants. 'Set-free' rituals are practices by Chinese Buddhist followers who believe that if they release live animals back to the wild, they will have relinquished their sins of killing animals in their daily life. An average sale of 17 adult (mostly female) horseshoe crabs per month was estimated from the present surveys, with 45% of them being obtained from Hong Kong waters (Fig. 10).

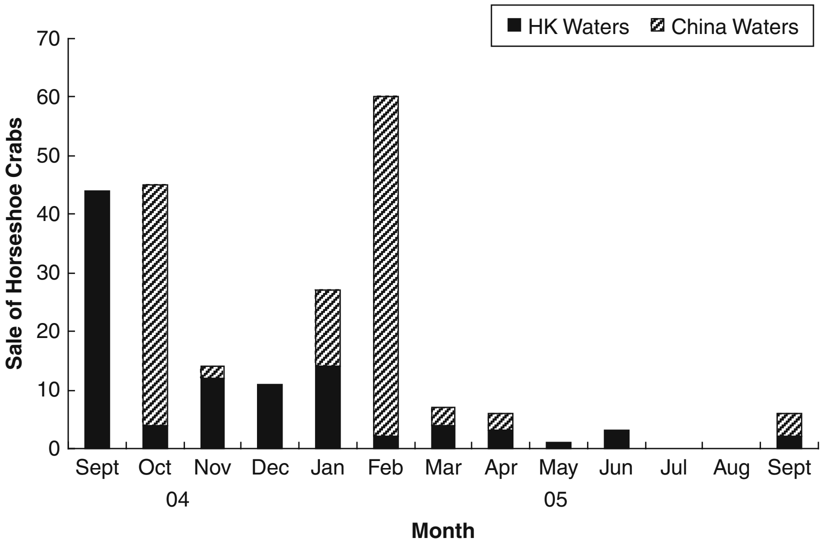

Fig. 10 Estimated sale of adult horseshoe crabs (*Tachypleus tridentatus*) caught from both Hong Kong and mainland Chinese waters for delicacy dishes in Hong Kong seafood restaurants, from September 2004 to September 2005

4 Discussion

4.1 Spatial Variation of Juvenile Horseshoe Crab Population Density

In this chapter, both western and eastern shores of Hong Kong were investigated. Most of the shores where juvenile horseshoe crabs were found are protected from wave action. In particular, those shores on the west of Hong Kong experience lower salinity in the summer owing to increased freshwater discharge from a large river system during the summer rains in mainland China. More juveniles and co-occurrence of *T. tridentatus* and *C. rotundicauda* were noted at some of these shores. The salinity at the eastern shores is relatively oceanic and stable in both summer and winter. In this chapter, only juveniles of *C. rotundicauda* were found at two of the eastern shores.

Local surveys of horseshoe crabs were conducted twice in the past, once in the period of 1995–1998 and once in 2002. In the survey from 1995 to 1998 (Chiu and Morton 1999a), horseshoe crabs were recorded from more mudflat locations than the 17 shores in this chapter (Morton and Lee 2003). Based on the present findings, juvenile horseshoe crabs were still recorded at Tsim Bei Shiu, Pak Nai, and two locations at Ha Pak Nai by the transect sampling method, while few horseshoe crabs were located in Sheung Pak Nai. One shore, Nim Wan, where juvenile horseshoe crabs were found in the previous survey has been developed as a landfill site since 1993.

This study also confirmed the presence of horseshoe crabs on Lantau Island. Based on the present results, horseshoe crabs were found at Shui Hau Wan and San Tau. However, no horseshoe crabs were found on Lamma Island and northeastern New Territories by the transect sampling method, where juvenile horseshoe crabs have been reported using the similar survey method during the study period from 1995 to 1998 by Chiu and Morton (1999a).

4.2 Decline in Juvenile Horseshoe Crab Populations

As compared with previous data, the population density of horseshoe crabs is shown to decline in the past few years. An intensive population distribution study of horseshoe crab was conducted at eight stations along the coast of northwestern New Territories from May to December in 2002 (Morton and Lee 2003), with similar sampling strategies to that of the present survey, i.e., six horizontal transects, from the shoreline down to the lower shore, with a total covering area of 1,200 m^2 (Morton and Lee 2003). In the 2002 study, horseshoe crabs were found at Sheung Pak Nai, Pak Nai, and two locations in Ha Pak Nai, with the densities of 0.10, 1.97, 1.55, and 1.14 ind 100 m^{-2}, respectively. Based on the present data in summer 2004, horseshoe crabs were recorded at all these four stations; however, no horseshoe crabs were found at Sheung Pak Nai by transect sampling, while only the density of 0.08, 0.16, and 0.23 ind 100 m^{-2} were found at Pak Nai and the two locations at Ha Pak Nai. Comparing these data, a sharp decline in horseshoe crab populations by over 90% in the past 2 years is apparent.

Another significant finding in the present survey was that no *C. rotundicauda* was found at all the survey shores in the two seasonal samplings, while this species was found at Ha Pak Nai during the survey from 1995 to 1998 (Chiu and Morton 1999a) and observed along the coast from Sheung Pak Nai to Pak Nai in 2002 (Morton and Lee 2003). In the 2002 intensive survey, only four *C. rotundicauda* were recorded in the 8-month sampling period, from May to December 2002. In this study, no *C. rotundicauda* was found at Sheung Pak Nai, Pak Nai, and Ha Pak Nai. This may imply a significant decline or even disappearance of *C. rotundicauda* within this area. Possible reasons for such declines may be continuing urban developments in the hinterland of the shores and coastal infrastructural projects, leading to habitat destruction and/or degradation and water pollution (Morton et al. 1996). Recently completed and proposed developments on the west of Hong Kong include a bridge link corridor between Hong Kong and mainland China, reclamation for a theme park on Lantau Island, establishment of container port terminals, and construction of a bridge linking west of Hong Kong with other places in mainland China.

4.3 Impact of Human Exploitation of Adult Horseshoe Crabs

There are no data on the population size and habitat range of both adult horseshoe crab species in Hong Kong waters. Potential breeding sites where juvenile horseshoe crabs are found are mostly flat, muddy shores with minimal human disturbances. Anecdotal records on adult populations were from fishermens' accounts based on their by-catch of horseshoe crabs during their trawling activities. Judging from the sharp decline of juvenile horseshoe crab populations on local shores, the sale of adult horseshoe crabs in local seafood restaurants, which seems relatively low as compared to other marine economic species, may be one of the factors for such a population decline in recent years. Based on the results of the market surveys, the sale of horseshoe crabs, especially the gravid females, would reduce production of young, significantly affecting the population due to the long maturity period and low breeding success of the adults in the wild. Human exploitation, therefore, contributes a potential impact and even puts further pressure on the scattered populations of juvenile horseshoe crabs in Hong Kong. While some of the adult horseshoe crabs are caught and kept for display in seafood restaurants, without proper care and food supply, they may eventually die in captivity. This also reduces the number of mature potential breeding horseshoe crabs in the wild and further decreases the chance of successful pair matching and breeding. The traditional 'set-free' ritual also creates a potential threat to the survival of released horseshoe crabs, as they may not be able to adapt to different habitats.

5 Conclusion and Recommendations

This chapter confirmed the sharp decline of juvenile horseshoe crabs (*T. tridentatus* and *C. rotundicauda*) on shores in Hong Kong. Habitat destruction and/or degradation and water pollution caused by continuing urban developments in the hinterland of the shores and coastal infrastructural projects are the possible major factors leading to such declines. While human exploitation of adult horseshoe crabs seemed to be low in comparison to other marine economic species, the sale of adult gravid females as delicacy dishes in seafood restaurants could result in reduction of reproductive pairs in the wild and subsequent decline in mating pairs and success of maintaining viable juvenile populations on the shores. To protect juvenile horseshoe crabs and their nursery grounds, it is proposed that these shores should be designated as Sites for Special Scientific Interest by the Hong Kong government, so that urban developments at these shores can be kept minimal. In the longer term, a comprehensive conservation strategy including public education and awareness, designation of horseshoe crabs as endangered species, ban for human consumption, and introduction of artificial breeding programs should be developed to prevent eventual loss of both *T. tridentatus* and *C. rotundicauda* in Hong Kong waters.

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