Songklanakarin J. Sci. Technol.
31 (4), 373-380, Jul. - Aug. 2009

Songklanakarin Journal of Science and Technology
http://www.sjst.psu.ac.th

Original Article

Seasonal variations in catches and effortsof a small-scale swimming crab trap fishery in the Eastern Gulf of Thailand

Jiraporn Trisak*, Hathaichanok Soasung and Pattama Wongkaew

Department of Fishery Management, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900 Thailand.

Received 13 October 2008; Accepted 10 June 2009

Abstract

Variations in catch per unit effort (CPUE), distributions of size-structure, sex ratio, and spawning female conditions from a fishery were examined to better understand the impact of fishing activities. We collected data from crab fishery, which is a small-scale fishery in Chonburi, an eastern province of Thailand, during October 2006 - September 2007. Both CPUE and size-structure of the swimming crab varied seasonally. Sex ratio from the catch was not 1:1 and the distributions of both male and female varied by season. Even though it is premature to conclude that the stock is overfished, more management measures are recommended to prevent overfishing due to the concern of high proportion of females and the presence of numbers of spawning females in the catches.

Keywords: CPUE, size-structure, sex ratio, swimming crab, small-scale fisheries.

1. Introduction

The swimming crab fishery is one of the most important small-scale fisheries in Thailand. There are many fishing communities in the country that play an important economic role by contributing to the domestic seafood market. Fishing also allows the people in coastal communities to keep their traditional way of life, an element that is diminishing in many societies. Because of its high market price, the swimming crab stock has been heavily exploited. Most of the small-scale fishers have noticed and complained that both catch rate and size of individuals of this species have drastically declined over time. Although fishing has been suspected as the main cause of such reductions, no one has investigated if, or how, the fishery has impacted the swimming crab population.

Data from a fishery, such as catch per unit of effort (CPUE) and catch composition (e.g., size and sex) are basic but important information for fish stock assessment. Scientists use these catch statistics to assess the stock as well as to understand behavior of fishers and how the fishery might affect the stock. Examples are the works of Vignaux (1996a and 1996b), who used commercial catch and effort data to study vessel movements and strategies of the New Zealand hoki (*Macruronus novaezelandiae*) fishery and to investigate spatial distribution of the fish. However, Vignaux did not examine impacts from the hoki fishery.

Traditionally, CPUE has been used as an index of abundance, meaning that the relationship between CPUE and fish stock abundance is a straight line through the origin. An increase or decrease in a stock size can be perceived from the change in CPUE over time. However, this index will be biased if the slope of the relationship is not constant or the line does not pass through the origin. The constant slope denoted as catchability may change temporally and spatially due to many factors, such as changes in fishing fleet efficiency and distribution, and behavior and density of fish, (Richards & Schnute, 1986; Sullivan & Dyner Rebert, 1998; Mauder & Punt, 2004; Mauder *et al.*, 2006). Therefore, most of the studies on CPUE have centered on investigating either the

*Corresponding author.
Email address: jiraporn.t@ku.ac.th

relationship of CPUE and abundance (Gaertner & Dreyfus-Leon, 2004; Hanchet, Blackwell & Dunn, 2005), or factors causing the bias and how to remove them so that CPUE becomes a reliable index (Worthington, Andrew & Bentley, 1998; Battaile & Quinn II, 2004; Campbell, 2004).

We placed our focus on making use of CPUE and other catch information to understand the potential impact of fishing activities. We used the swimming crab fishery as a case study and examined seasonal variations in CPUE, size-structure, sex ratio, numbers of spawning females, and their condition (whether carrying eggs inside or outside the shell). We then incorporated our findings and fishing activity information to explain how the fishery could possibly have an impact on the swimming crab population. We also discuss management implications for the small-scale swimming crab fishery. Specifically, our objectives were 1) to investigate seasonal variation in CPUE; 2) to investigate seasonal variation in population size-structure; and 3) to investigate seasonal variation in the sex of harvested crab, and in the condition of spawning females.

2. Materials and Methods

We conducted 24 surveys to collect information from the fishers in Bang Phra, a coastal village in Chonburi province (Figure 1) from October 2006 to September 2007. A survey was completed within 2-3 days every other week each month. About 12-36 fishers, accounting more than 50% of the fishers who were out fishing during each survey, were interviewed for information on catch (kg) and fishing effort (traps/trip). Also, in each survey we randomly sampled harvested crabs to record their size, sex, and spawning female conditions (eggs inside or outside the shell). Catch per unit of effort (CPUE, g/trap/trip) was calculated from the catch and effort data. All the data were grouped by season (cool, hot, or rainy), based on the 2006 and 2007 announcements of the Thai Meteorological Department, Ministry of Information and Communication Technology. The cool season was from October 15, 2006 to the end of February 2007. The hot season began on March 1 and ended on May 4, 2007, while the rainy season ran from May 5 to October 14, 2007. Accordingly, the data collected from the first survey conducted on October 7, 2006 were excluded from the analysis.

We used four main analyses, seasonal variation in CPUE, in size-structure distribution, in sex and spawning female distributions, and in average carapace length (CL) for males, females and spawning females. All analyses were made with Minitab 15 (Minitab Inc., 2007) and significance tests were at an alpha level of 0.05. For the analysis of seasonal variation in CPUE, we first tested for normality of the CPUE data by the Kolmogorov-Smirnov test. Because CPUE was not normally distributed (KS = 0.116, $p<0.01$) we applied the Kruskal-Wallis test ($\alpha = 0.05$) to examine the difference among seasons.

The carapace length (CL) of an individual was measured to the nearest cm CL. The measurements of carapace length (cm), grouped by season, were used to construct length-frequency diagrams. The difference in size-structure

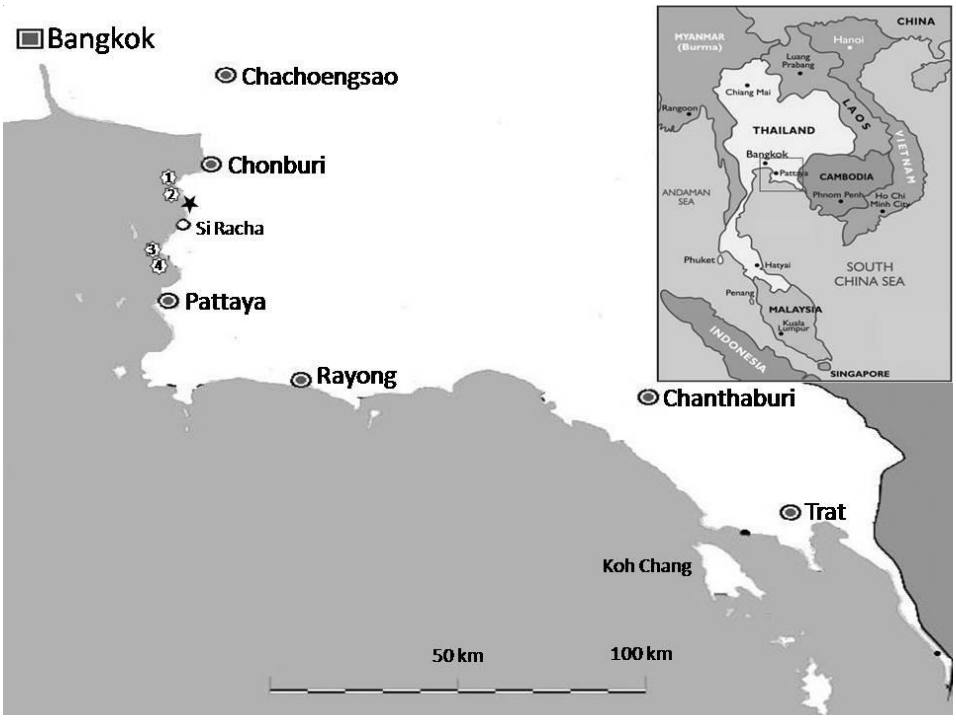

Figure 1. Map of Thailand showing study site, Bang Phra subdistrict (★), Chonburi province, located between 13°21'43" N, 100°58'45"E and 12°58'36"N, 100°54'48"E., and the four fishing grounds, 1 Bang Saen, 2 Bang Phra, 3 Ao Udom, and 4 Bang Lamung.

of the crab population between any two seasons was investigated by the Kolmogorov-Smirnov two-sample test.

For the analysis of sex distribution, we applied Chi square statistics to examine the sex ratio distribution and the seasonal difference of sex distribution. Specifically, the Chi-square goodness of fit test was applied for sex ratio analysis. Meanwhile, a 2 x 3 contingency table was arranged and analyzed to examine associations between the distributions of males and of females and seasons. Similarly, seasonal variation in the distribution of spawning females was also investigated by applying the Chi-square analysis.

In order to examine variation in size of swimming crab caught from the trap fishery, we applied the Kruskal-Wallis test to compare the difference of distribution of CLs among males, females, and spawning females. We further investigated differences in distribution of CLs between any of two seasons using the Mann-Whitney test.

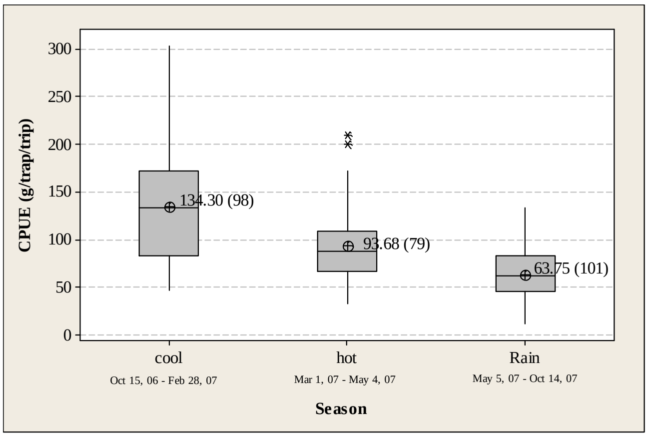

Figure 2. Seasonal variation of CPUE. The labeled numbers represent average CPUE (g/trap/trip), with their sample sizes in parentheses.

3. Results

3.1 Seasonal variation in CPUE

CPUE significantly differed among seasons ($p < 0.001$). The highest average CPUE of 127.89 grams/trap/trip was obtained in the cool season, with averages of 86.55 and 63.75 g/trap/trip for hot and rainy seasons, respectively (Figure 2). However, the estimates of CPUE obtained in the cool season had a wider range than those in the hot and rainy seasons. Catch and CPUE appeared to decline with time (Figure 3) while fishing effort increased (Figure 4).

3.2 Seasonal variation in size-structure

There was evidence that size-structure of the swimming crab caught by the small-scale trap fishery differed among seasons. The length-frequency distribution from the cool season differed significantly from those of the hot and rainy seasons ($p = 0.004$ and $p<0.001$, respectively). The length-frequency distribution also differed between hot and rainy seasons ($p<0.001$).

About 51.4% of the harvest in the cool season was composed of larger individuals than those in other seasons, having CL in the range of 3.9-4.5 cm, with an average of 3.99 cm (Figure 5). Harvested crabs in the hot season had CL in the range of 4.1-4.5 cm, with the average of 3.97 cm. In contrast to the other two seasons, crabs harvested in the rainy season were smaller, with CL ranging from 3.1 to 3.9 cm., and averaging 3.59 cm.

3.3 Seasonal variation in sex ratio and spawning female conditions

The sex ratio of harvested swimming crabs was not

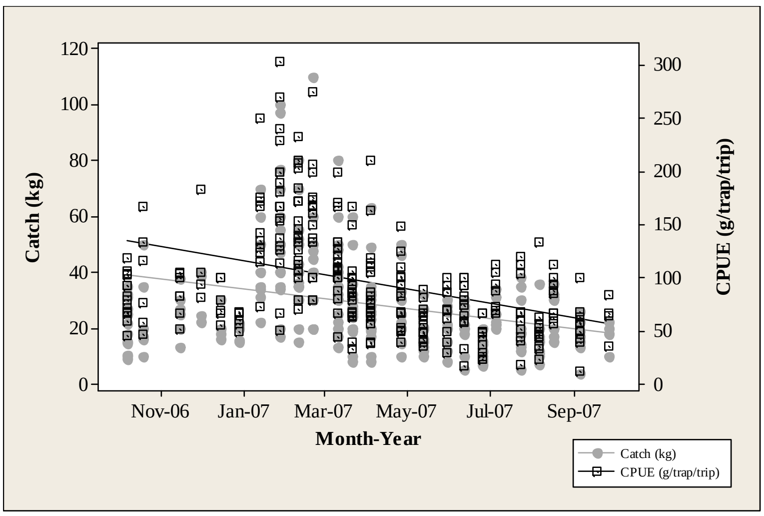

Figure 3. Trends in catch and CPUE.

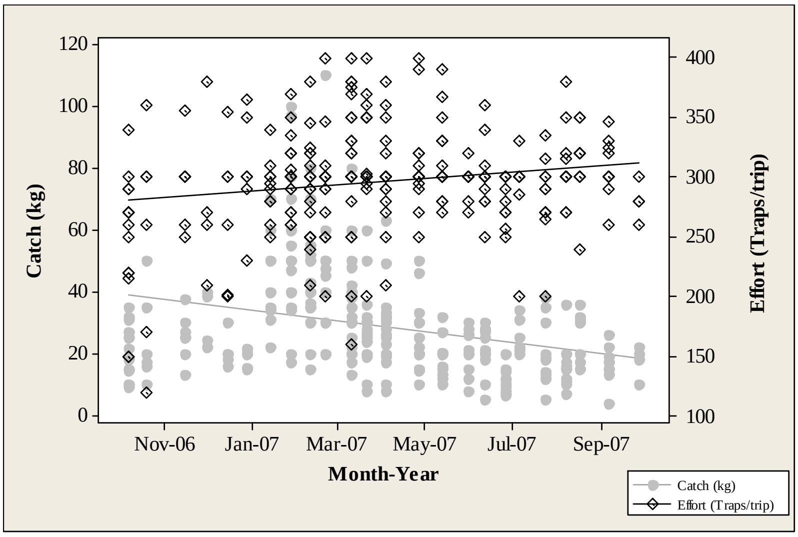

Figure 4. Trends in catch and fishing effort.

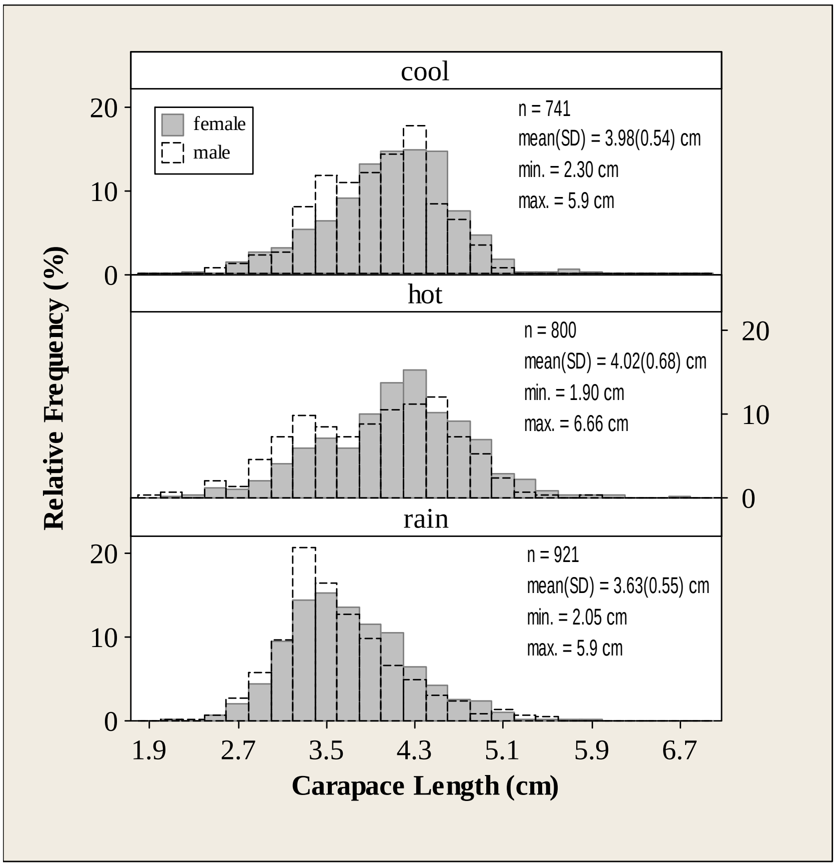

Figure 5. Length-frequency distribution of the harvested swimming crab by sex and by season.

1:1 (χ^2 = 39.54, p<0.001). Additionally, the distributions of both males and females varied seasonally (χ^2 = 15.93, p< 0.001). Accordingly, the female:male ratios were 1.29:1, 1.61:1, and 1.06:1 for the cool, hot and rainy seasons respectively. Females were caught in slightly greater numbers than males in the cool and hot seasons, while the catch in the rainy season had the ratio of female:male close to parity (Figure 6). The highest numbers of females were caught in the hot season, while the highest numbers of males were caught in the rainy season.

Spawning females were harvested in every season. However, there was a significant seasonal variation in spawning female condition (Pearson $\chi^2 = 18.02$, $p<0.001$). The spawning females that carried eggs inside the shell were found most frequently in the cool season, whereas, those that carried eggs outside the shell were found in the highest proportion in the hot season.

3.4 Variation in average size among males, non-spawning females, and spawning females

The Kruskal-Wallis test showed a significant difference of size distribution among male non-spawning female, and spawning female swimming crab ($p<0.001$). The CLs of males and non-spawning females caught from the trap fishery were in a similar range, 1.9-5.8 cm for males and 2.05-5.9 cm for females. Meanwhile, the CL of spawning females ranged from 3.30-6.66 cm. Our further investigation revealed that the distribution of CLs of the males and non-spawning females were not significantly different ($p = 0.63$). However, the CL of spawning females was significantly higher than that of both males and non-spawning females (both with $p< 0.001$) (Figure 7).

4. Discussion

The crabs harvested in the cool and hot seasons had similar size-structure and average size. Nonetheless, CPUE measured in terms of weight of crab per trap per fishing trip in the two seasons differed significantly. The difference in

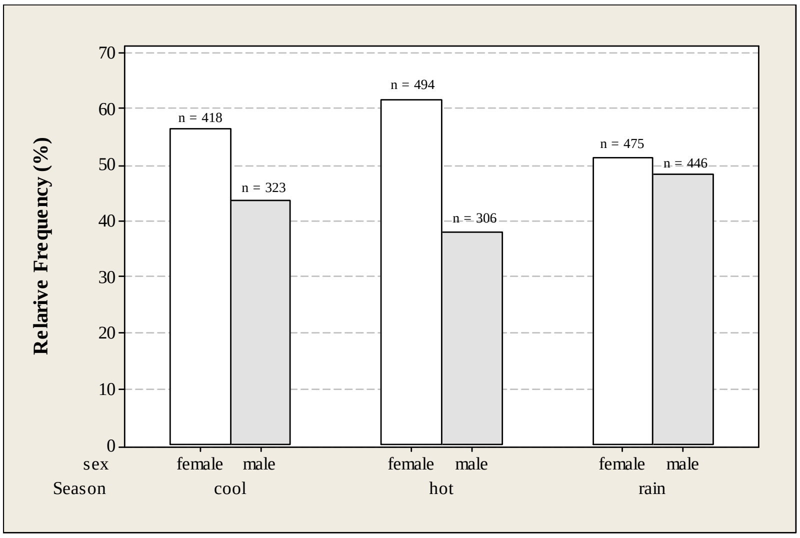

Figure 6. Relative frequencies of sex of sampled swimming crab, by season, where n is the sample size.

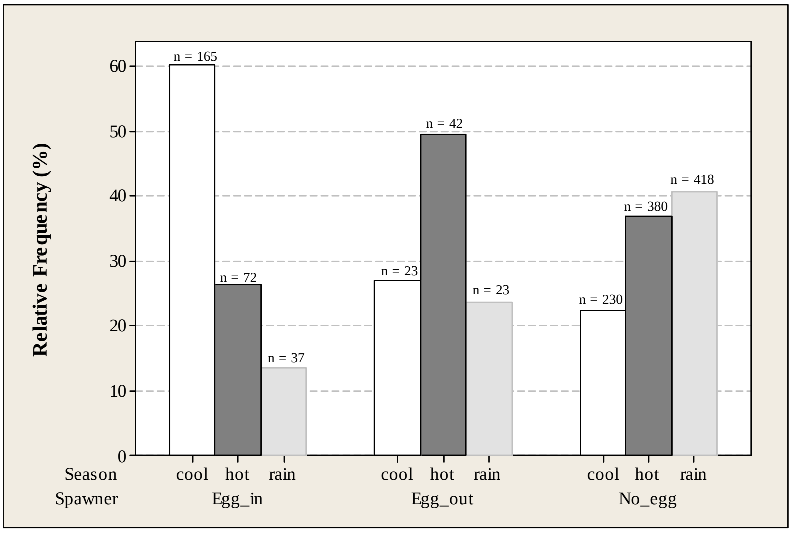

Figure 7. Seasonal variation in the ratio of spawning female conditions, where n is the sample size.

CPUE could presumably be due to changes in population size, given that environmental factors, such as temperature and salinity, which typically influence distribution of crabs, (Kangas, 2000), and consequently affect catchability of fishing gears, were relatively stable over our study period. Meanwhile, the lowest CPUE was obtained in the rainy season, when most of the catch was composed of smaller individuals. This suggests that seasonal variation in CPUE was also due to variation in size-structure.

The presence of spawning females in every season indicates that the swimming crab in Chonburi's fishing grounds spawn all year round, similar to those in other tropical waters (e.g. Sumpton *et al.*, 2003). This stock appears to have its spawning peak in the cool season, suggested by the higher proportion of spawning females in the catch. The data collected on the condition of spawning females indicated that most female swimming crabs released eggs during the hot season. The increased proportion of small crabs in the subsequent rainy season suggests successful recruitment of this species.

The tendency of traps to catch more of one sex than another could be attributable to many factors, including the differences in abundance and in habitat preference of male and female, behavioral changes in both sexes, and the effect of fishing (Kangas, 2000). In the particular case of the Chonburi crab trap fishery, the factors playing an important role in determining catching of a higher numbers of females than of males were inconclusive. However, the results of Bellchambers and de Lestang's study for the swimming crab fishery in the Peel-Harvey estuary, Western Australia (2005), provided convincing evidence for an effect of differences in habitat preferences for males and females. Mature swimming crabs show sexual aggregation over space and time and females prefer the areas with sandy substrate (Kangas, 2000). The different preferences result in the dominant distribution of one sex over another for certain places and times. The swimming crab fishery in the Peel-Harvey estuary caught more males than females except in May when females finished spawning and moved back into the estuary, implying that the estuary is a geographically and characteristically unfavorable habitat for spawning females. In contrast, the Chonburi swimming crab fishery fished in the fishing grounds where the bottom surfaces are mostly sandy. In addition, most of females caught by the fishery were larger than males and had also reached maturity (Figure 5). Taken together with a comparison to the Australian study, the finding that females were caught more than males especially during intensive spawning in the cool and hot seasons while the numbers of catches of females and males were only slightly different in the rainy season, indicates habitat preference of female for the fishing grounds.

Generally speaking, the decreasing trends in catch and CPUE as effort increases from a fishery imply that the population of the targeted species has been declining due to fishing pressure. However, the decreasing trends in both catch and CPUE together with the increasing trend in effort (Figures 3 and 4) from this study can not be used to make the same implications owing to the possibility of short-term variation. The similar pattern could possibly be a coincidence. Additionally, there is insufficient historic and current information about the stock and its fishery, such as fishing morality rate and stock status, so that it is premature to conclude that the stock has declined or is being overfished.

Many crab fisheries prohibit the harvest of females, e.g. Queensland's blue swimmer crab pot fishery (Clarke and Ryan, 2004). In Thailand, harvest of females and spawning females is allowed year-round, except during October to December, when taking females with eggs outside the shell is prohibited. Such a short-term restriction being enforced to a certain group in the population is unlikely to prevent doing

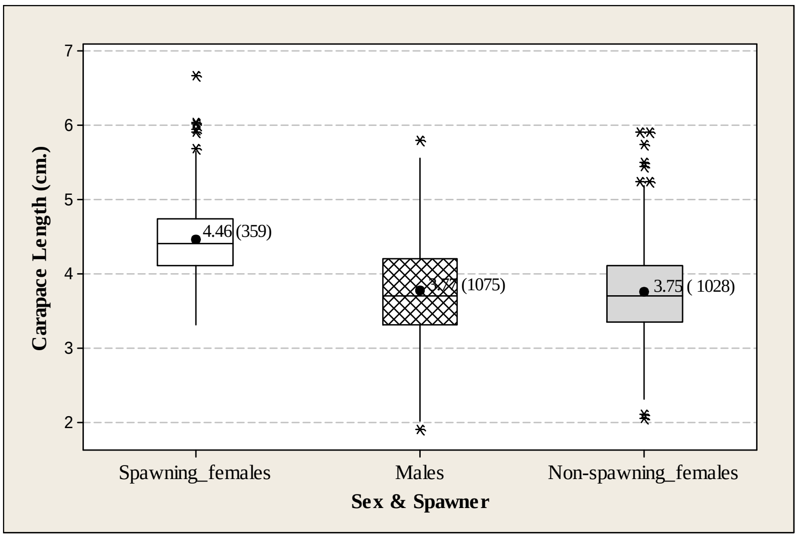

Figure 8. Seasonal variations in average CL of spawning females, males, and non-spawning females. The labeled numbers represent average CL (cm), with their sample sizes in parentheses.

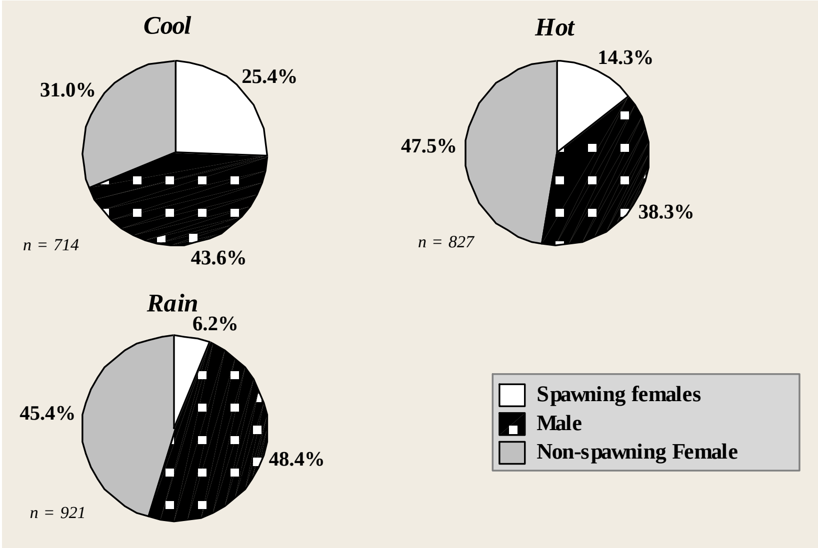

Figure 9. Proportions of harvested spawning females, males, and non-spawning females. by season, where n is the sample size.

harm to the stock, which may be reflected in the higher proportion of females found in the catches in all seasons and, also, the bycatch of egg-bearing females during the restriction. Furthermore, the restriction only covered a small portion of the intensive spawning period, which extends into the hot season (March to early May) (Figure 8). Our interview with the fishers implied that the stock could also be harmed by the fishers' preference for catching spawning females, especially egg-bearing females, as they provide higher biomass than other crabs. In the Chonburi crab fishery, lenient regulations and fishers' preference for spawning females are important pressures on the stock.

If the pattern of catch compositions having larger proportion of females is observed over a long-term, females will be persistently removed from the population. Under this circumstance, when fishing pressure increases the stock could potentially experience growth overfishing, the situation where the recruitment of the stock declins in accordance with the reduction of spawning stock. The current fishing measures that allow the taking of females, including spawning females except egg-bearing females from October to December, could open for a chance of fishing down females to the point where growth overfishing could not be avoided. More management measures need to be enforced to protect females and to ensure the absence of overfishing. For instance, the fishing grounds where spawning females are the most abundant during the peak of spawning should be closed to fishing. Alternatively, the duration of the restriction on taking egg-bearing females should be lengthened so as to protect more females.

Acknowledgements

We wish to express our sincere thanks to the Kasetsart University Research and Development Institute (KURDI) for funding. We are also grateful to Eunice Goetz and David Anderson for their patience and kindness in editing this manuscript. Suggestions and comments from Professor Dr Bill Beamish as well as from anonymous reviewers are also greatly appreciated. Last but not least, our sincere thanks go to the small-scale fishers in Bang Phra fishing village, Si Racha District, Chonburi Province, for their voluntary co-operation and kind contribution.

Reference

Battaile, B.C. and Quinn II, T.J. 2004. Catch per unit effort standardization of the eastern Bering Sea walleye pollock (*Theragra chalcogramma*) fleet. Fisheries Research 70, 161-177.

Bellchambers, L.M. and de Lestang, S. 2005. Selectivity of different gear types for sampling the blue swimmer crab, *Portunus pelagicus* L. Fisheries Research 73, 21-27.

Campbell, R.A. 2004. CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. Fisheries Research 70, 209-227.

Clarke, K. and Ryan, S. 2004. Ecological assessment of the Queensland blue swimmer crab pot fishery. Department of Primary Industries and Fisheries, Queensland Government. 100 pp.

Gaertner, D. and Dreyfus-Leon, M. 2004. Analysis of non-linear relationships between catch per unit effort and abundance in a tuna purse-seine fishery simulated with artificial neural networks. ICES Journal of Marine Science 61, 812-820.

Hanchet, S.M., Blackwell, R.G. and Dunn, A. 2005. Development and evaluation of catch per unit effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise, New Zealand. ICES Journal of Marine Science 62, 1131-1138.

Kangas, M.I. 2000. Synopsis of the biology and exploitation of the blue swimmer crab, *Portunus pelagicus* Linnaeus, in Western Australia. Fisheries Research Report No. 121, 2000, Fisheries Research Division, Western Australia. 22 pp.

Mauder, M.N. and Punt , A.E. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70, 141-159.

Maunder, M.N., Sibert, J.R., Fonteneau, A., Hampton, J., Kleiber, P. and Harley, S.J. 2006. Interpreting catch per unit of effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science 63, 1373-1385.

Minitab Inc. 2006. Minitab 15 Statistical Software. Minitab Inc., State College, Pennsylvania.

Richards, L.I. and Schnute, J.T. 1986. An experimental and statistical approach to the question: Is CPUE an index of abundance? Can. J. Fish. Aquat. Sci. 43, 1214-1227.

Sullivan, P.J. and Dyner, R. S. 1998. Interpreting Pacific halibut catch statistics in the British Columbia individual quota program. Can. J. Fish. Aquat. Sci. 55, 99-115.

Sumpton, W., Gaddes, S., Mclennan, M., Campbell, M., Tonks, M., Good, N., Hadedoorn, W. and Skilleter. 2003. Fisheries biology and assessment of the blue swimmer crab (*Portunus pelagicus*) in Queensland. Project No. 98/117, Department of Primary Industries, Queensland Government. 156 pp.

Vignaux, M. 1996. Analysis of spatial structure in fish distribution using commercial catch and effort data from the New Zealand hoki fishery. Can. J. Fish. Aquat. Sci. 53, 963-973.

Vignaux, M. 1996. Analysis of vessel movements and strategies using commercial catch and effort data from the New Zealand hoki fishery. Can. J. Fish. Aquat. Sci. 53, 2126-2136.

Worthington, D.G., Andrew, N.L. and Bentley, N. 1998. Improving indices of catch rate in the fishery for backlip abalone, *Haliotis rubra*, in New South Wales, Australia. Fisheries Research 36, 87-97.