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Distribution and population dynamics of the edible bivalve species *Meretrix casta* (Chemnitz) in the Dutch canal of Sri Lanka

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Abstract

Meretrix casta is a commercially important clam species in Dutch canal, a slow flowing brackish water body in the western coastal region of Sri Lanka. Its abundance at five sampling sites along a 50 km stretch of the canal, which ranged from 60 individuals m^{-2} to 950 individuals m^{-2}, significantly increased with increasing sand, silt and organic matter content of the bottom sediments. Abundance was negatively correlated with the clay content of the sediments. No significant correlation was recorded between the abundance and environmental parameters such as temperature, salinity, pH and chlorophyll-a content of water. However, abundance was low at the sampling sites with extreme values of salinity (<3 ppt and >40 ppt) and pH (<8.0 and >8.5).

Asymptotic length of the clams ranged from 34 mm to 43.1 mm and the growth coefficient ranged from 0.84 $year^{-1}$ to 1.44 $year^{-1}$. The ranges for total mortality, natural mortality and fishing mortality coefficients were 2.34-3.08 $year^{-1}$, 0.84-1.44 $year^{-1}$ and 1.16-2.24 $year^{-1}$ respectively. The highest asymptotic length was recorded at the site where the abundance was the highest. The lowest natural mortality and the highest fishing mortality were also recorded at this site. Environmental parameters at this site were moderate and never reached extreme values indicating optimum conditions for growth and survival. The mean size at first capture (L_{50}) ranged from 8.3 mm to 24.5 mm while the optimum value for L_{50} ranged from 13.6 mm to 23.3 mm. At four sampling sites, present L_{50} was smaller than the optimum value indicating the exploitation of small individuals. Exploitation rates at two sampling sites were higher than the optimum level indicating over-exploitation of the resource at some places along the canal.

Introduction

Meretrix casta is one of commercially important bivalve species abundant in estuaries, backwaters and bays along the coastline of the Indian Ocean (Quasim 1998). In many regions of India, this species contributes for the livelihood of large number of fisher families (Pruthi 1999, Anon. 2009). The annual yield of *M. casta* from Maharashtra coast has been estimated to be 5000 tons year^{-1} (Quasim 1998). In Vembanad lake system, which is the largest estuarine system in Kerala, *M. casta* is one of the major species contributing to the clam fishery. From this estuarine system, about 31650 tons of clams are harvested annually (Anon. 2009). In Kali, the largest estuarine system of Uttara Kannada coast, which is well known for clam resources, *M. casta* is one of the major species contributing to clam fishery (Pruthi 1999).

In the Puttalam lagoon and Dutch bay in the north western province of Sri Lanka, six species of edible bivalves have been recorded (Dayaratne et al. 1995). However, only three of these are commercially exploited (Kithsiri 1996). These do not include *M. casta*. However, in the Dutch canal which is a lotic brackish water body running more or less parallel to the coastline connecting Kelani river and Puttalam lagoon in the western and northwestern provinces of Sri Lanka, the only commercially important bivalve species of Family Veneridae is *M. casta* (Jayawickrema 1999). Jinadasa et al. (1994) had recorded five species of bivalves in Negombo estuary of which *M. casta* was the most abundant species with a potential harvest of about 10,000 mt per annum.

M. casta is an important test organism which had been widely used to study bioaccumulation and toxicity of heavy metals (Kumaraguru et al. 1980, Patel and Anthony 1991, Karthikeyan and Kumaraswamy 1998, Rajan 1998, Rathabai and Vijayalakshmi 2000, Kumaraswamy et al. 2006) and water soluble fractions of refined and crude oil (Sophia and Balasubramanian 1992). In addition, it could be used as a biological indicator for early detection of pesticide pollution (Devi et al. 2005). It has also been identified as a potential source of antiviral drug as its extracts had shown high antiviral activity when tested with some strains of influenza virus (Chattergi et al. 2002).

Its biology and changes in abundance in some Indian estuaries have been studied in detail (Balasubramaniyan 1993, Harkantra and Rodrigues 2003, Ansari et al. 2007, Arularasan and Kasinathan 2007). It is widely distributed in some brackish water environments in Sri Lanka and is harvested on commercial scale for its shell and flesh (Jayawickrema 1999, Dahanayaka and Wijeyaratne 2006). The shell is used in the lime industry and flesh is used to feed cultured shrimp (Jayawickrema 1999). However, no detail studies are carried out on this species in Sri Lanka. This paper describes the distribution, population dynamics and fishery of *M. casta* in Dutch canal, a slow flowing brackish water body in the north western province of Sri Lanka.

Materials and Methods

Dutch canal runs along the coastal belt of the western and north western provinces of Sri Lanka more or less parallel to the coastline. It has been constructed in the 18th century, connecting the Kelani river to Puttalam lagoon through Negombo and Chilaw lagoons by the Dutch during their colonial regime in Sri Lanka (Infolanka 2009). The 50 km stretch of the canal running from the Pambala to Madurankuliya (7^{o}30′ – 8^{o}00′ N and 79^{o}47′ – 80^{o}00′ E) was selected for this study as there is an artisanal fishery for *M. casta* in this region.

Five sampling sites where *M. casta* is commercially exploited were selected at random for this study. Location of these sampling sites is shown in Figure 1. At each sampling site, water temperature, pH, salinity, chlorophyll-a content, soil texture and soil organic matter content were determined monthly for a period of 10 months from October 1998 to July 1999. Due to the shallowness of water (< 0.7 m in depth), parameters such as temperature, pH, salinity and chlorophyll-a content of water were measured only at the middle of the water column taking samples using a Ruttner sampler. Temperature was measured using a mercury bulb thermometer and salinity was measured using a salinity refractometer. pH was measured using a portable pH meter. Three replicates of 500 ml of water samples from each sampling site were filtered through Whatman GFC circles and the filter papers were immediately wrapped in aluminum foil and preserved in ice for transportation to the laboratory at the University of Kelaniya. In the laboratory, the Chlorophyll-content was determined using a spectrophotometer as described by Marker et al. (1980). Soil texture was determined by thoroughly mixing about 10 g of soil with 50 ml of water in a measuring cylinder and allowing to settle down and then measuring the heights of the silt, clay and sand layers. Soil organic matter content was determined by heating a known weight of a soil sample dried at 100 ^{o}C, for 4 hours at 400 ^{o}C in a muffle furnace and determining the weight loss (Ball 1969). Data were statistically analyzed using two way ANOVA and one way ANOVA followed by Tukey's multiple comparison procedure and the correlation coefficients between variables where appropriate (Zar 1996).

Bivalves were sampled using a 1 m X 1 m quadrate made up of 10 cm wide metal plates connected to each other from their narrow sides. After placing the quadrate on the bottom in such a way that the metal plates penetrated into the substrate, the bivalves on the bottom within the quadrate were handpicked as much as possible. The bottom substrate within the quadrate was then scooped out to a depth of 10 cm. From each sampling site, 5-7 quadrate samples were taken every month. These samples were then subjected to wet sieving using a 3 mm mesh and the bivalves in the samples were collected. The number of individuals of *M. casta* in each sample was recorded. Shell length of a minimum of 75 individuals of *M. casta* selected at random from each sampling site was measured every month to the nearest mm using a Vernier caliper.

Length data were analyzed using FiSAT software package Version 1.0 (Gayanilo et al. 1996) following the procedure described by Amarasinghe and De Silva (1992) and the asymptotic length (L_∞), growth coefficient (K) and total mortality coefficient (Z) of *M. casta* for each sample site were determined. The natural mortality coefficient (M) was determined using M ≈ K approximation (Gayanilo and Pauly 1997). Fishing mortality coefficient (F) was estimated by subtracting M from Z. The exploitation rates (E) were estimated as F/Z (Gulland 1983). Variation of relative yield per recruit with different E values was determined using Beverton and Holt model (Beverton and Holt 1966) incorporated in the FiSAT software package. Variation of mean length at first capture/asymptotic length (L_{50}/L_{∞}) with different E values was also determined and the optimum E and L_{50} values for each site were estimated.

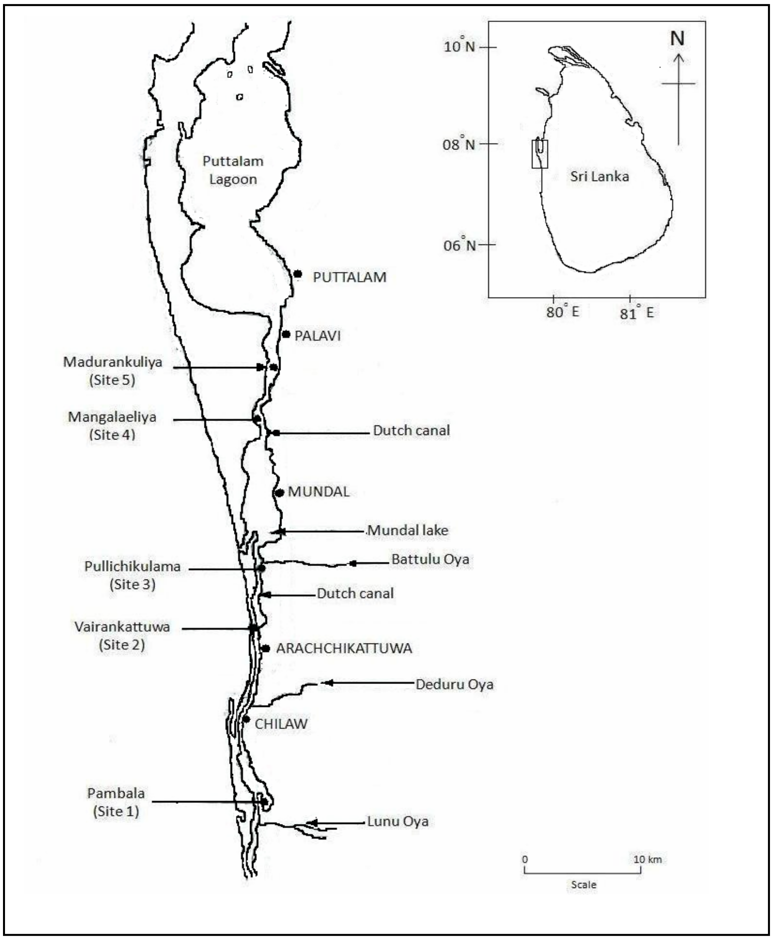

Figure 1. Location of sampling sites

Results

Monthly variation of water temperature, salinity, pH and chlorophyll-a content at each site is graphically shown in Figure 2. Water temperature varied from 28.3 ^{0}C recorded in March and May 1999 at the sampling site 1 to 30.4 ^{0}C recorded in June 1999 at the sampling site 4. High salinity was recorded in all sampling site in September 1998 and the lowest value for salinity, which was 0 ppt, was recorded at the sampling sites 1, 2, and 3 in January and May 1999. The highest salinity, which was 43 ppt, was recorded in October 1998 at the sampling site 5. pH values ranged from 7.1 recorded in May 1999 at the sampling site 5 to 8.8 recorded in June 1999 at sampling site 2. The chlorophyll-a content was high in October and the highest value of 19.9 μg L^{-1} was recorded at the sampling site 2 during this month. The lowest value of 0.3 μg L^{-1} was recorded in March at the same sampling site.

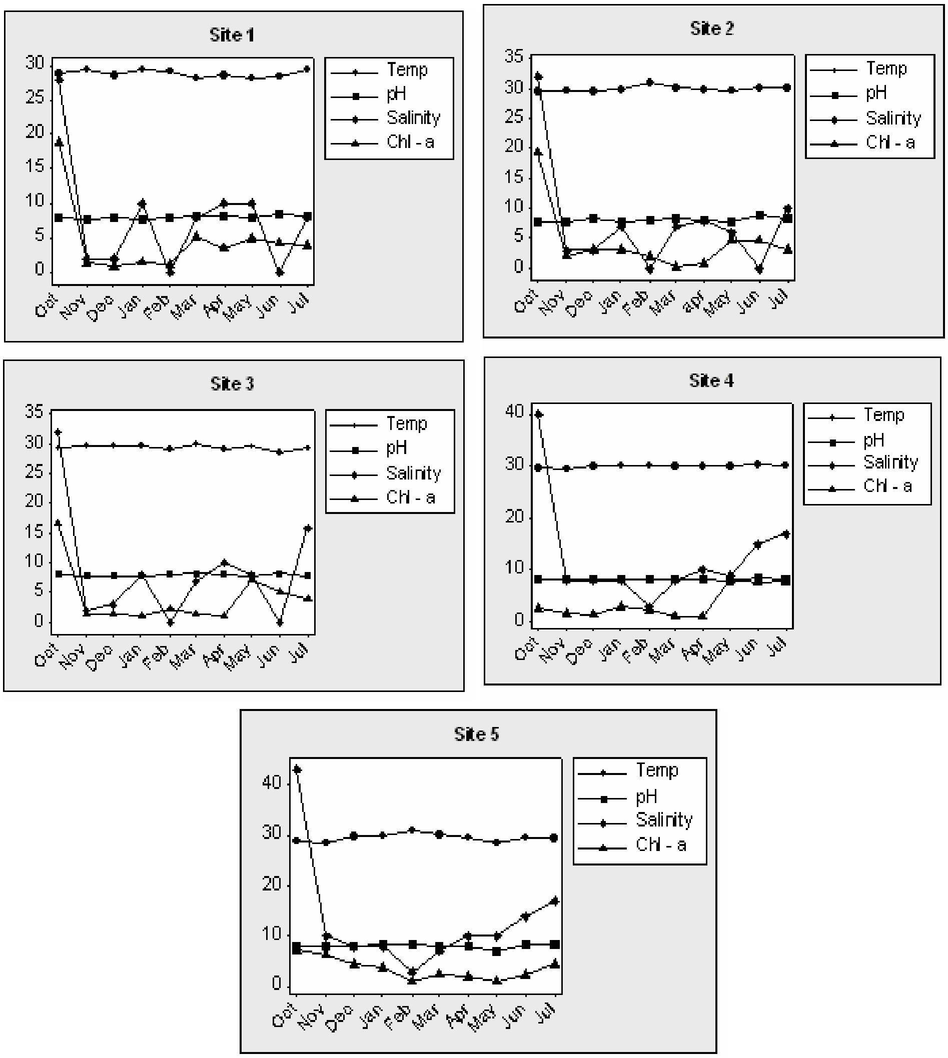

Figure 2. Monthly variation of water temperature (°C), pH, Salinity (ppt) and chlorophyll–a content (μg L^{-1}) at the five sampling sites during the study period.

Mean monthly values for environmental parameters are given in Table 1. Mean values for percentages of sand, silt and clay in the bottom sediments and abundance of *M. casta* are given in Table 2. Mean water temperature of the Dutch canal in different months was not significantly different from each other ($p > 0.05$). However, mean temperature was significantly lower at the sampling site 1 than at other sites ($p < 0.05$). Mean values for Chlorophyll-a content and pH at different sampling sites were not significantly different from each other ($p > 0.05$). Mean salinity at sampling sites 4 and 5 were significantly higher than that of other sites ($p < 0.05$). In October 1998, chlorophyll-a content and salinity were significantly higher than in other months ($p < 0.05$). In February, mean salinity was significantly lower than in other months ($p < 0.05$).

Table 1. Monthly mean values for water temperature salinity pH and Chlorophyll-a content in the Dutch canal during the study period. Values indicated by some superscript in each column are not significantly different from each other ($p > 0.05$).

	Water Temperature(^{0}C)	Salinity (ppt)	pH	Chlorophyll-a content (μg L^{-1})
October 1998	29.3^{a}	35.0^{a}	8.02^{ab}	13.0
November	29.5^{a}	5.0^{bd}	7.96^{ac}	2.6^{b}
December	29.6^{a}	4.8^{bd}	8.06^{ab}	2.3^{b}
January 1999	29.9^{a}	8.2^{b}	8.00^{ab}	2.5^{b}
February	30.2^{a}	1.2^{d}	8.10^{a}	1.8^{b}
March	29.8^{a}	7.4^{b}	8.20^{ab}	2.1^{b}
April	29.5^{a}	9.6^{be}	8.12^{a}	1.7^{b}
May	29.3^{a}	8.6^{b}	7.76^{c}	5.2^{b}
June	29.5^{a}	5.8^{bd}	8.48^{b}	4.8^{b}
July	29.8^{a}	13.6^{ce}	8.16^{a}	4.7^{b}

Mean values for % sand in different sampling sites varied from 82% to 89% while % silt content varied from 2% to 8% (Table 2). The % clay content was 8-10%. There was no significant difference in the mean values for percentages of sand, clay and silt among sampling sites ($p > 0.05$). The % organic matter content in the bottom sediments ranged from 4.2% to 6.5%. Mean value for % organic matter content was significantly higher in sampling site 2 than in other sampling sites ($p < 0.05$).

Mean abundance of *M. casta* varied from 60 individuals m^{-2} recorded at sampling site 3 to 950 individuals m^{-2} recorded at sampling site 4(Table 2). Its mean abundance in sampling site 3 was significantly lower than in other sites whereas the abundance at sampling site 4 was significantly higher than in other sites ($p < 0.05$).

Table 2. Mean values for water temperature, salinity, pH and Chlorophyll-a content of water; % organic matter, % sand, % clay and % silt contents in bottom sediments and abundance of bivalves at each sampling site. Values indicated by the same superscript in each row are not significantly different from each other at 5% level of significance.

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Water Temperature (^{0}C)	28.9^a	30.1^b	29.5^b	30.1^b	29.6^b
Salinity (ppt)	8.7^a	8.3^a	9.6^a	13.3^b	13.7^b
pH	8.0^a	8.1^a	8.0^a	8.2^a	8.1^a
Chlorophyll-a content µg L^{-1}	4.5^a	4.3^a	4.2^a	3.7^a	3.9^a
% organic matter	4.3^a	6.5^b	4.8^a	4.6^a	4.5^a
% sand	88^a	89^a	86^a	85^a	82^a
% clay	8^b	9^b	9^b	9^b	10^b
% salt	4^a	2^a	5^a	6^a	8^a
Abundance (No./m^2)	240^a	520^d	60^b	950^e	360^c

Correlation coefficients between the abundance of *M. casta* and environmental parameters are given in Table 3. The abundance of *M. casta* was not significantly correlated with salinity, pH and Chlorophyll-a content ($p > 0.05$). However, significant correlations were evident between the abundance of *M. casta* and sand, silt, clay and organic matter contents of the bottom sediments ($p < 0.002$). The abundance was positively correlated with the sand, silt and organic matter contents while a negative correlation was evident with the clay content (Table 3).

Table 3. Correlation coefficients between the abundance of *M. casta* and some environmental parameters

Environmental parameter	**Correlation coefficient**	**N**	**p**
Salinity	-0.12	75	>0.05
pH	-0.10	75	>0.05
Chlorophyll-a	-0.14	75	>0.05
% Sand	0.38	75	<0.001
% Silt	0.29	75	<0.002
% Clay	-0.27	75	<0.002
% Organic matter	0.40	75	<0.001

Length frequency distributions of *M. casta* at the five sampling sites together with estimated growth curves are shown in Figure 3. The L_∞, K, Z, M and F values for *M. casta* at different sampling sites are given in Table 4. The highest L_∞, Z and F values and the lowest K and M values were recorded at sampling site 4. The lowest L_∞ was recorded at sampling site 2 while the lowest Z value was recorded at sampling site 3. The highest K and M values and lowest F values were recorded at sampling site 1 (Table 4).

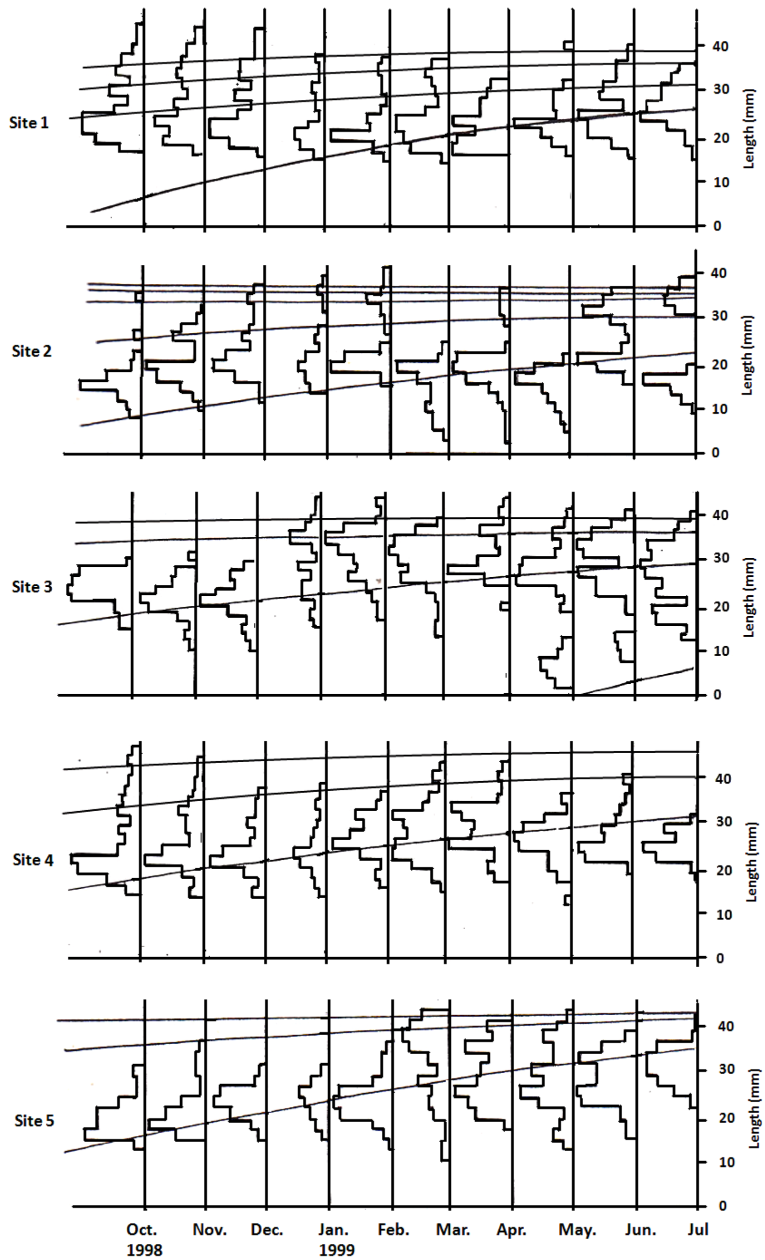

Figure 3. Length frequency distribution of *Meretrix casta* at the five sampling sites together with estimated growth curves.

Present exploitation rate (E), present mean length at first capture (L_{50}), optimum exploitation rate (E_{opt}) and optimum mean length at first capture (L_{opt}) at each sampling site are given in Table 5. Present exploitation rates at sampling sites 1 and 5 were found to be lower than the optimum level where as at sampling sites 2 and 4, the present E values were higher than the optimum values. At sampling site 3, present E value was more or less equal to the optimum value. Present L_{50} values at sampling sites 1, 2, 4 and 5 were smaller than the optimum values and at sampling site 3, it was higher than the optimum value.

Table 4. Asymptotic length (L_∞), Von Bertalanfly growth coefficient (K), total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) of *M. casta* at each sampling site.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
L_∞ (mm)	38.2	34.0	41.1	43.1	36.3
K ($year^{-1}$)	1.44	0.88	1.12	0.84	1.34
Z ($year^{-1}$)	2.60	2.48	2.34	3.08	2.73
M ($year^{-1}$)	1.44	0.88	1.12	0.84	1.34
F ($year^{-1}$)	1.16	1.60	1.22	2.24	1.39

Table 5. Present exploration rate (E), present mean length at first capture (L_{50}), optimum exploration rate (E_{opt}) and optimum mean length at first capture (L_{opt}) at each samples site.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
E	0.5	0.7	0.5	0.7	0.5
L_{50} (mm)	16.1	8.3	24.7	17.0	13.7
E_{opt}	0.7	0.5	0.5	0.6	0.6
$L_{50\,opt}$ (mm)	22.2	13.6	16.0	23.3	20.0

Discussion

Dutch canal is a commercially important lotic water body as it is the source of water for nearly 70% of the shrimp farms in Sri Lanka. About 850 ha of shrimp farms are located on either side of the canal. Shrimp farm effluents are also discharged into this canal which has resulted in various problems such as the spread of shrimp diseases and environmental degradation (Dayaratne et al. 1995, Corea et al. 1995, 1998, Siriwardene 2001).

In the past, fish, crustaceans and mollusks had been exploited from this canal on a commercial scale (Corea et al. 1995). Today, fish and crustaceans are harvested on a subsistence level and the bivalve *M. casta* is harvested on a commercial scale. In some places such as Pambala (Sampling site 1), *M. casta* is harvested throughout the year while in other areas (Sampling sites 2, 3, 4 and 5), it is harvested only from February to July. The monthly catch at each site had been estimated to be 13-30 mt (Jayawickrama 1999).

It has been reported that environmental parameters such as salinity, temperature, sediment texture and organic matter content in the sediments significantly contribute to the abundance of bivalves (Lee 1972). However, during the present study, the abundance of *M. casta* in the Dutch canal was not found to be significantly correlated with salinity and water temperature ($p > 0.05$). The ranges for salinity and water temperature observed in the Dutch canal, i.e., 0-3 ppt and 28.3-30.4^{o}C respectively, may not have a significant influence on the survival and mortality of this species. Narasimham and Laxmilatha (1996) had also reported that *M. casta* could tolerate prolonged low salinities. It has also been reported that *M. casta* is not affected by salinities above 40 ppt (Thangavelu and Poovannam 1994). As observed by Ranade (1964), in low salinities *M. casta* may have closed their valves tightly and borrowed into the substrate to survive and the abundance may not have changed significantly with the variation in salinity from 0 ppt to 43 ppt.

The observed variation in water temperature in the Dutch canal also appears to be too narrow to bring about a significant change in the population size of *M. casta*. Therefore, a significant correlation between the abundance and water temperature could not have been observed. The pH in the Dutch canal also changed within a narrow range, i.e., from 7.1 to 8.8 during the study period. This range also appears to be tolerated well by *M. casta*. Although chlorophyll-a content in water varied within a wide range from 0.3 $\mu g\ L^{-1}$ to 19.9 $\mu g\ L^{-1}$, abundance of *M. casta* was not observed to be significantly correlated with it. Chlorophyll-a content in water is an indicator of abundance of green algae, hence with algal productivity in the water column. However, it appears that the abundance of *M. casta* does not depend on the algal productivity of the water column.

Although the percentages of sand, silt and clay varied in a narrow range, results indicated that the abundance of *M. casta* was significantly correlated with those environmental factors. The abundance increased with increasing sand and silt contents and decreased with increasing clay content indicating that this species preferred benthic habitats with high amounts of sand and silt. Narasimham and Laxmilatha (1996) also reported that *M. casta* thrived on sandy bottoms. Cahn (1951) reported that best substrates for bivalves usually contained 60 – 90 % sand. Silt in a water body results in due to settling down of suspended particles which mainly derive from land based activities. Silt levels in the Dutch canal had increased over the past years mainly due to the effluents discharged from nearby shrimp farms (Corea et al. 1998). These effluents, in addition to containing large amounts of silt, are enriched with nutrients due to decomposition of organic matter such as unutilized food, wastes of shrimp etc. These nutrients may be adsorbed to silt particles resulting in an increase in abundance of these benthic animals with increasing amounts of silt in the benthic sediments.

In the Puttalam lagoon and Dutch bay, located slightly north of the study area (Figure 1), the abundance of bivalves was reported to be highly correlated with the substrate condition (Kithsiri 1996). However, *M. casta* was not recorded in these water bodies although they are contiguous with the

Dutch canal. One of the reasons for this may be the high clay content in the sediments which is above 15% (Kithsiri 1996). In all sampling sites of the Dutch canal, the clay content was found to be less than 15%.

The abundance of *M. casta* was found to be positively correlated with the organic matter content in the substrate. It has been reported the organic detritus contributes to a larger proportion of the diet of bivalve mollusks (Fraga and Vives 1960). Therefore, it appears that the increase in the abundance of the bivalve *M. casta* with increasing amounts of organic matter in the bottom sediments is due to availability of more food

L_{50} of *M. casta* was highest at sampling site 4. At this site, K value was the lowest. K is a measure of the rate achieving L_∞. When L_∞ is large, more time is taken to reach it. Hence K becomes low. L_∞ of *M. casta* in Negombo lagoon had been estimated to be 40 mm (Jinadasa et al. 1999). In Muthukadu backwaters in India it has been estimated to be 42 mm. The values for L_∞ estimated at sampling sites 1, 2 and 5 during the present study were less than 37 mm and at other two sampling sites it was above 41 mm.

The highest L_∞, which was 43.1 mm was recorded at sampling site 4 where the abundance was also the highest. It appears that environmental conditions at this site are highly favorable for *M. casta*. Although abundance was not significantly correlated with pH and salinity, this site recorded the highest mean salinity of 13.3 ppt and the highest mean pH of 8.2. In none of the months, the salinity at this sampling site was below 3 ppt or above 40 ppt. Similarly, pH at this sampling was always between 8.0 and 8.5. Therefore, these ranges appear to be the most desirable for the growth and survival of *M. casta* in the Dutch canal. In addition, the abundance of *M. casta* was found to be significantly correlated with sand, silt and clay contents in bottom sediments. These benthic characteristics may be also have been most favourable at this site because the highest abundance was recorded there. The natural mortality was also found to be the lowest at this sampling site, possibly due to favourable environmental conditions. The highest fishing mortality was observed at this sampling site indicating high fishing pressure. This may also be due to high abundance and presence of large individuals at this site.

At sampling sites 1 and 2, where L_∞ was 38.2 mm and 34.0 mm respectively, salinity was 0 ppt in some months. At the sampling site 5 where L_∞ was 36.3 mm, the mean salinity was 13.7 ppt and in some months it reached a value as high as 43 ppt. In addition, in some months, pH was 7.1. These extreme values may have affected the growth of *M. casta* in these sites resulting in low L_∞. Natural mortality was also found to be high at sampling sites 1 and 5, possibly due to those extreme environmental conditions. However, at sampling site 2, although L_∞ was the lowest, natural mortality was found to be low. More studies on ecological relationships are needed to explain this. The lowest abundance of *M. casta* was observed at sampling site 3. Even though the abundance of *M. casta* was not found to be correlated with salinity, at this sampling site, salinity was 0 ppt in two months and 2 ppt in another month. These extreme environmental conditions may have contributed to low survival of *M. casta* at this site resulting in low abundance. However, even with extreme environmental conditions, L_∞ was estimated to be 41.1 mm at this sampling site. To explain this also more studies are needed. Possibly a combination of other environmental factors may have contributed to this high L_∞.

Yield per recruit analysis indicated that *M. casta* populations at sampling sites 2 and 4 are over-exploited and the fishing effort has to be reduced by about 30% and 15% of the present level respectively. However, at sampling sites 1 and 5, there is a possibility to increase the fishing effort by about 40% and 20% of the present level respectively to obtain the maximum sustainable yield. At sampling site 3, the exploitation rate was more or less at the optimum level. At the sampling sites 1, 2, 4 and 5, present L_{50} is smaller than the optimum value and therefore it appears that small individual are harvested at these sites. Hence it is necessary to increase the L_{50} at these sites. At the sampling site 3, present L_{50} is higher than the optimum value and there is a possibility to catch smaller individuals than those caught at present.

M. casta resource in Dutch canal is very useful to sustain the shrimp farming industry in the area. In addition to providing meat to be used as shrimp feed, it also reduces the suspended solids in shrimp farm effluents (Liyanage et al. 1998). In addition, their shells are used in lime kilns. The clam resource is important economically too as it provides an additional income to the fisher community. Therefore, harvesting this resource at the maximum sustainable level without over-exploitation is very important. A proper management procedure, with the participation of stakeholder community is therefore needed. For such a management procedure, the findings of this study would be very useful.

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