Contribution of Ecological Surveys to Coastal Conservation: A Case in Soft Shore Study

Tai, K.K., S.G. Cheung and P.K.S. Shin*

Department of Biology and Chemistry, City University of Hong Kong, Hong Kong, China

ABSTRACT : Soft shores are particularly vulnerable to human exploitation; however, they exhibit a variety of habitats which provide refuge for a diversity of flora and fauna. This study describes a survey of 13 soft shores in Hong Kong with information on species diversity, sediment characteristics, shore extent, pollution threat, degree of naturalness, linkage with other ecological habitats, and degree of social/economic importance. Data collected were subjected to multivariate statistical analyses, so as to identify shores that have significant ecological status and conservation value for management purposes.

Key words : Coastal conservation, Multivariate statistical analyses, Soft shore

INTRODUCTION

Soft shores, including sandy beaches and muddy habitats, are more vulnerable to destruction than rocky intertidal areas, since soft shores are generally flat and can be easily reclaimed for urban development. A recent review showed that human pressures are one of the major concerns on coastal conservation (Brown and McLachlan 2002). Near-shore eutrophication caused by indiscriminate discharge of domestic sewage and agricultural runoffs also affects soft shores in estuaries and sheltered lagoons to a large extent (Wu 1999; Gowen *et al*. 2000). Yet, the flora and fauna on soft shores are diverse. Brown (2001) estimated over 20 macro- and 600 meiofaunal species present on a typical ocean sandy beach. There is thus a need to implement measures to protect such habitats. This paper describes a survey of soft shores in Hong Kong (24°30 ′N, 114°01 ′E) and how we applied the survey data to evaluate ecological status and conservation value for future management purposes.

MATERIALS AND METHODS

Thirteen soft shores were surveyed on the northeast and southwest of Hong Kong (Fig. 1) at low tide (≈0.5~1 m Chart Datum) in summer 2001. On each shore, a random sampling strategy was adopted, in which 3 transect lines were laid from upper to lower shore zones. Along each transect line, six 0.0625 m^2 quadrat samples of top 5 cm sediment were collected randomly. In addition, 12 similar quadrat samples were obtained randomly between the transect lines. In total, 30 quadrat samples were collected per shore for subsequent faunal analysis in the laboratory. Nine core samples (8 cm diameter, 20 cm length) were also collected on the shore for determination of sediment particle size distribution and organic content. The presence of sea grasses and other habitats such as mangroves and freshwater streams was examined during the shore visits. The extent of collection of clams on the shores by local villagers and visitors was also estimated from counting the number of people involving such activities and their harvests.

In the laboratory, the quadrat sediment samples were sieved through 1 mm mesh and the residues stained with 1% Rose Bengal. Animals were sorted, identified and counted using a dissecting microscope to species level as far as possible. Particle size of the core sediment samples was determined by wet sieving and total organic matter by loss of ignition at 550℃ in a furnace for 6 h (Buchanan 1984). Species diversity (H^*) and evenness (J) of the shore communities were calculated using the formulae by Shannon and Weaver (1963) and Pielou (1966), respectively. Sediment particle size frequency plots were constructed to obtain values on median diameter, inclusive graphic standard deviation, skewness and kurtosis according to Buchanan (1984). The extent area of the shores and their proximity to villages and residential centers were also examined from aerial photos. Data on population within 2 km from the shores were also obtained from the census report.

The community structure among the survey shores was compared by cluster analysis using the Bray-Curtis similarity index and PRIMER software (Clarke and Warwick 2001). The faunal data were 4^{th} root transformed before subjected to cluster analysis. Correlation of the shore community pattern with particle size and organic content data was also carried out using the BIOENV (mat-

This article was presented at the INTECOL meeting (Seoul, August 2002).

* Corresponding author; e-mail: bhpshin@cityu.edu.hk

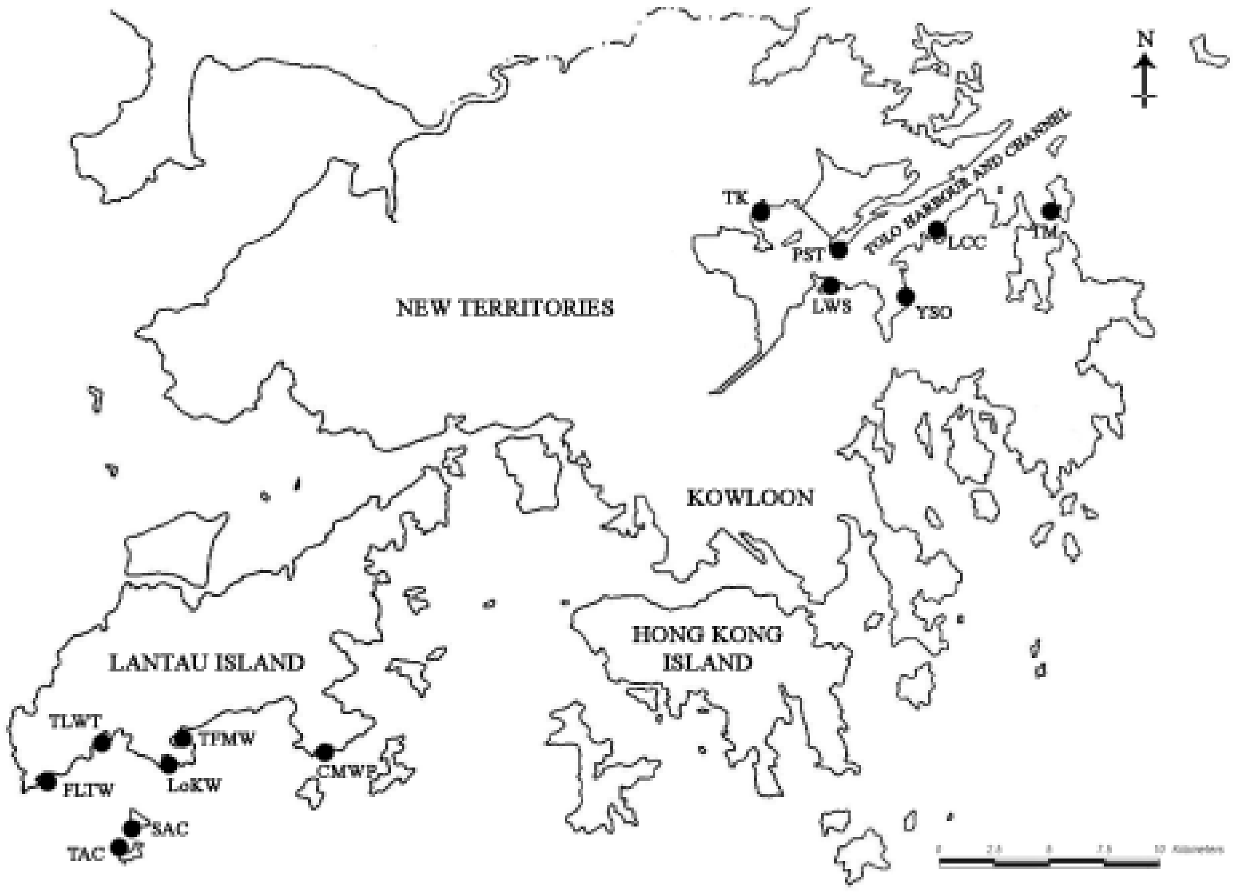

Fig. 1. The soft shores in Hong Kong (LWS-Lok Wo Sha, LCC-Lai Chi Chong, TM-Tap Mun, YSO-Yung Shue O, TK-Ting Kok, PST-Pak Sah Tau, TFMW-Tong Fook Miu Wan, SAC-Siu A Chau, TLWT-Tai Long Wan Tsuen, TAC-Tai A Chau, FLTW-Fan Lau Tung Wan, LoKW-Lo Kei Wan, CMWP-Chi Ma Wan).

ching of biotic to environmental patterns) program from PRIMER. The percent data were arcsine transformed to conform to normality prior to the analyses. To identify shores with distinct conservation value, attributes of biodiversity (as represented by species diversity), pollution threat (as represented by sediment organic content), shore extent (as represented by area at low tide), naturalness (as represented by existence of nearby urban settlements), ecological linkage (as represented by existence of other habitats, e.g., mangroves) and social/economic importance (as represented by human exploitation, e.g., clam harvest) according to Kelleher *et al.* (1995), were subjected to principal component analysis (PCA). Data of each attribute were standardized by dividing the raw data with the mean value prior to analysis.

RESULTS

A total of 9,600 specimens belonging to 68 species were collected, including 46 species of molluscs, 8 polychaetes, 11 crustaceans and 3 species of other animal groups. Molluscs were by far the most dominant, comprising 91.6% of the total specimens recorded. Table 1 shows the biological statistics and sediment characteristics recorded at the 13 shores. In terms of mean species number, LCC had the highest, followed by LWS, YSO and TM, all on northeast of Hong Kong, whereas, in terms of mean individuals, TM registered the highest, followed by TFMW, TK and LWS. Mean species diversity (H') ranged from 0.15 to 2.49 and evenness (J) 0.13 to 0.95. Results of cluster analysis showed two main shore groups, with faunal similarity of >40% (Fig. 2). One group (TK-YSO) was located in the northeast, whereas the other group (TLWT-LoKW) in the southwest of Hong Kong (see Fig. 1). From the results of BIOENV, sediment inclusive graphic standard deviation had the best correlation (Spearman rank correlation = 0.58) to explain the shore groups in Fig. 2.

Table 2 shows the characteristics of the shores from our surveys, according to biodiversity, pollution threat, area extent, naturalness, ecological linkage and social/economic importance. Results of PCA

Table 1. The mean biological and sediment data at the survey shores in Hong Kong (for biological data, N=30; for sediment data, N=9)

Shore[1]	s	N	*H′*	*J*	MDφ	σ	Sk	K_G	TOM (%)
LWS	13.3	838	2.06	0.64	0.38	1.76	0.21	0.81	0.86
LCC	18.7	408	2.49	0.70	0.94	1.59	0.20	0.81	1.45
TM	11.2	1,183	0.73	0.24	0.24	1.78	0.21	0.81	1.50
YSO	12.3	204	2.38	0.76	0.96	1.62	0.20	0.80	1.04
TK	9.1	1,028	1.31	0.46	0.99	1.65	0.20	0.81	0.66
PST	4.8	63.5	1.50	0.68	2.47	0.84	-0.22	1.35	1.50
TFMW	8.0	1,087	1.09	0.40	2.01	0.69	0.03	0.86	1.06
SAC	2.7	7.5	1.53	0.95	-0.77	0.64	0.03	1.09	0.57
TLWT	1.1	5.9	0.47	0.68	1.00	1.09	-0.01	0.91	0.30
TAC	3.2	86.9	0.31	0.17	1.27	1.35	-0.18	0.97	0.32
FLTW	3.2	42.7	1.27	0.71	1.05	1.24	0.09	0.83	1.50
LoKW	2.7	73.7	0.65	0.40	1.97	0.64	-0.11	1.02	0.42
CMWP	1.6	91.7	0.15	0.13	-0.67	0.65	0.06	1.06	0.17

[1] For explanation of shore names, refer to Fig. 1.

s = species number (m^{-2}), N = individuals (m^{-2}), *H’* = species diversity, *J* = evenness, MDφ = median particle diameter, σ = inclusive graphic standard deviation, Sk = skewness, K_G = kurtosis, TOM = total organic matter.

Table 2. The characteristics of survey shores in Hong Kong

Shores[1]	*H′*	TOM (%)	Shore area (m^2)	Population[2]	Mangrove area[3] (m^2)	Clam harvest[4] (ind/month)
LWS	2.06	0.86	54,000	189,870	0	1,800
LCC	2.49	1.45	38,880	3,990	3,100	2,500
TM	0.73	1.50	10,800	436	0	0
YSO	2.38	1.04	52,800	3,990	8,300	0
TK	1.31	0.66	36,000	8,765	87,700	72,000
PST	1.50	1.50	7,200	77	0	0
TFMW	1.09	1.06	201,960	1,557	7,000	5,000
SAC	1.53	0.57	9,600	0	0	0
TLWT	0.47	0.30	18,400	1,055	0	0
TAC	0.31	0.32	3,000	0	0	0
FLTW	1.27	1.50	13,200	125	0	0
LoKW	0.65	0.42	11,600	1,557	0	0
CMWP	0.15	0.17	12,400	2,832	0	0

[1] For explanation of shore names, refer to Fig. 1.

[2] from Census and Statistics Department (2002).

[3] from field observations and Ho (2001).

[4] from field observations and Tam and Wong (2000).

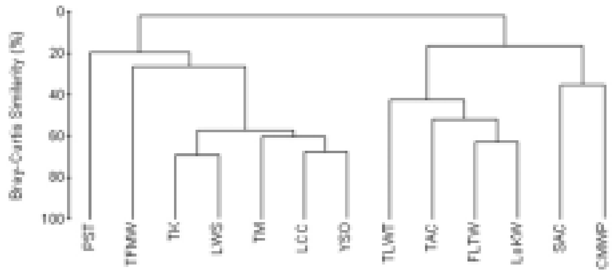

Fig. 2. Dendrogram showing the faunal similarity among survey shores (for explanation of shore names, refer to Fig. 1).

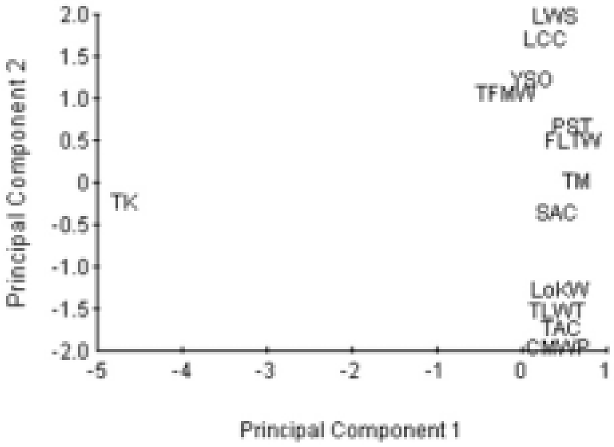

Fig. 3. A graphic plot of the survey shores according to PCA of shore characteristics (for explanation of shore names, refer to Fig. 1).

depicted that the two first principal components (PC1 and PC2) accounted for 63.1% of the data variation. The site TK was clearly separated from other shores along PC1, whereas the other 12 shores were positioned along PC2 (Fig. 3). According to the coefficients of eigenvectors in PCA, the separation of TK from other shores was due to its largest mangrove habitat in adjacent to the shore and heaviest human exploitation of clam populations. For the remaining 12 shores, the separation of sites along PC2 was mainly caused by species diversity and total organic content. Sites with high species diversity and total organic content were plotted with positive value and vice versa.

DISCUSSION

In general, less macrofauna tends to occur in coarser beach sediments (McLachlan 1996). For the present survey, however, mean species diversity of the shores ranged from 0.15 to 2.49, and there is no significant correlation ($p>0.05$) between the diversity values and sediment particle size parameters. Instead, a significant positive correlation ($p<0.05$) is apparent between species diversity and total organic content of sediment. Organic materials provide a source of nutrient to the intertidal benthic fauna and moderate increase in organic content supports a diverse faunal community (Pearson and Rosenberg 1978). The 13 soft shores surveyed in Hong Kong can also be largely separated into two major groups based on faunal similarity. These two shore groups are located in different sectors of Hong Kong waters, one in northeast and one in southwest. Such separation of shore groups is best correlated with the inclusive graphic standard deviation (σ) of the sediment, which reflects the sorting nature of the particle size (Buchanan 1984). The northeastern shore group has significantly higher σ values than the southwestern shore group (*t*-test, $p<0.01$), suggesting that the sediment is poorly sorted (Buchanan 1984). The poorly sorted sediment is also indicative of the low wave and current environment in nearshore waters (Gray 1981). Indeed, the survey shores in northeast of Hong Kong are located within a semi-enclosed embayment, Tolo Harbour and Channel (Fig. 1), which is well protected from the open sea. The shores in southwest, however, are situated on the southern coast of Lantau Island (Fig. 1), which is more exposed to oceanic waves (Morton and Morton 1983).

The present survey identified that molluscs are by far the dominant animals, both in terms of species and individuals, on the soft shores of Hong Kong. Such a high variety of molluscs contributes to a valuable resource in the intertidal areas for human exploitation as bait and/or food source (Brown and McLachlan 2002). Wynberg and Branch (1997) regarded that physical disturbances caused by digging of sediment on the shore may be more deleterious to the ecosystem than the actual removal of target animals. Results of PCA showed that the site TK is distinct amongst the 13 shores, in view of its large mangrove habitat associated with the shore and the heavy removal pressure on its clam populations. The uniqueness of this shore thus warrants careful management to protect the integrity of the ecosystem.

Ecological surveys are essential to ecosystem management as they provide the baseline information on the habitats with respect to their fauna and flora, pollution status, area extent, naturalness, ecological linkage and human activities. These data are important for setting up priorities for conservation purposes (Kelleher *et al*. 1995; Brown and McLachlan 2002). In the present case of soft shores in Hong Kong, results of PCA on such data demonstrated that apart from site TK, other sites are separated along a gradient from high to low species diversity and organic content (Fig. 3). Shores with high diversity values such as LWS, LCC, YSO and TFMW would therefore accord a higher priority in terms of conservation value than shores LoKW, TLWT, TAC and CMWP. The present study illustrated the usefulness of encompassing a multitude of attributes of the habitat characteristics in an ecological survey and the application of PCA in objectively identifying sites that are worth considered in conservation and protection.

ACKNOWLEDGEMENTS

We thanked Harry Chai and Joseph Lo for assistance in the field and laboratory work. This study was supported by the Environment and Conservation Fund and Woo Wheelock Green Fund.

LITERATURE CITED

Brown, A.C. 2001. Biology of sandy beaches. *In* J.H. Steels, S.A. Thorpe and K.K. Turekian (eds.) Encyclopedia of Ocean Sciences, Volume 5. Academic Press, London. pp. 2496-2504.

Brown, A.C. and A. McLachlan. 2002. Sandy beaches ecosystems and the threats facing them: some predictions for the year 2025. Environ. Conserv. 29: 62-77.

Buchanan, J.B. 1984. Sediment analysis. *In* N.A. Holme and A.D. McIntyre (eds.) Methods for the study of marine benthos, 2nd edition. Blackwell Scientific Publications, Oxford. pp. 41-65.

Census and Statistics Department. 2002. Population census 2001. Basic tables for tertiary planning units. Printing Department, Hong Kong Special Administrative Region, Hong Kong.

Clarke, K.R. and R.M. Warwick. 2001. Change in marine communities: An approach to statistical analysis and interpretation, 2nd Edition. Primer-E, Plymouth.

Gowen, R.J., D.K. Mills, M. Trimmer and D.B. Nedwell. 2000. Production and its fate in two coastal regions of the Irish Sea: the influence of anthropogenic nutrients. Mar. Ecol. Prog. Ser. 208: 51-64.

Gray, J.S. 1981. The ecology of marine sediments. An introduction to the structure and function of bottom communities. Cambridge University Press, Cambridge.

Ho, Y.Y. 2001. Effects of human exploitation on soft shore communities. B.Sc. final year project dissertation, City University of Hong Kong, Hong Kong.

Kelleher, G., C. Bleakley and S. Wells. 1995. A global representative system of marine protected areas. Volume VI. South Pacific, Northeast Pacific, Northwest Pacific, Southeast Pacific and Australia/New Zealand. Great Barrier Reef Marine Park Authority, The World Bank and The World Conservation Union (IUCN).

McLachlan, A. 1996. Physical factors in benthic ecology; effects of changing sand particle size on beach fauna. Mar. Ecol. Prog. Ser. 131: 205-217.

Morton, J.E. and B.S. Morton. 1983. The sea shore ecology of Hong Kong. Hong Kong University Press, Hong Kong.

Tam, N.F.Y. and Y.S. Wong. 2000. Hong Kong mangroves. City University of Hong Kong Press, Hong Kong.

Wu, R.S.S. 1999. Eutrophication, water borne pathogens and xenobiotic compounds: environmental risks and challenges. Mar. Pollut. Bull. 39: 11-22.

Wynberg, R.P. and G.M. Branch. 1997. Trampling associated with bait-collection for sandprawns *Callianassa kraussi* Stebbing: effects on the biota of an intertidal sandflat. Environ. Conserv. 24: 139-148.

Perason, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229-311.

(*Received December 9, 2003; Accepted May 10, 2004*)