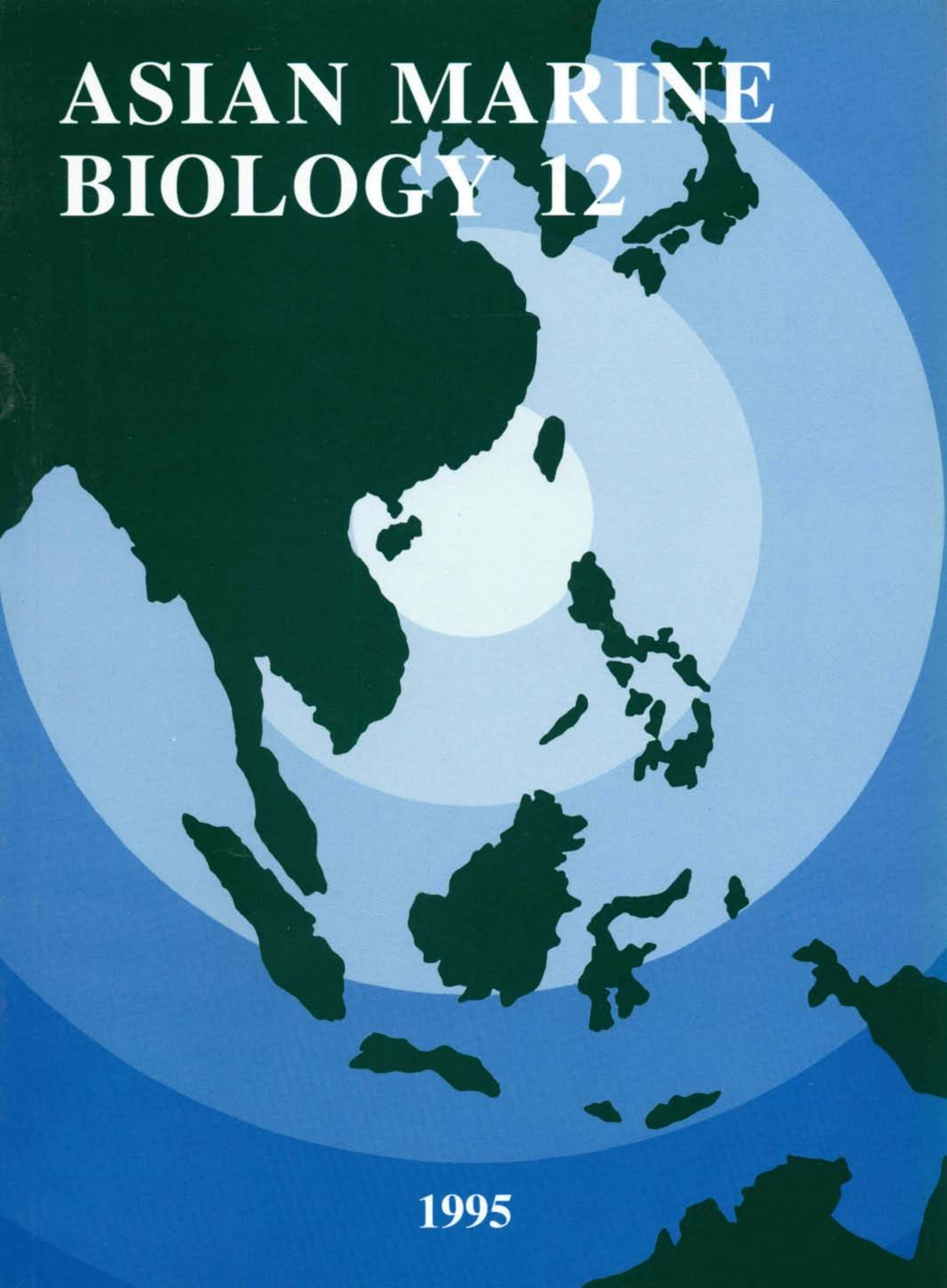
ASIAN MARINE BIOLOGY 12



1995

ASIAN MARINE BIOLOGY 12

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1995

The Marine Biological Association
of Hong Kong

Hong Kong University Press
香港大學出版社

ISBN 962 209 408 2

Printed in Hong Kong by Condor Printing Company Limited

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  (b) to provide opportunity for them to foregather by the holding of meetings, symposia, conferences or other gatherings; and
  (c) to act as a spokesman, when required, on behalf of the interests of marine biology in Hong Kong.
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Shapiro, D.Y. 1981. Size, maturation and the social control of sex reversal in the coral reef fish *Anthias squamipinnis*. *Journal of Zoology, London* 193:105–28.

Tyler, P.A. and Gage, J.D. 1982. The reproductive biology of *Ophiacantha bidentata* (Echinodermata: Ophiuroidea) from the Rockall Trough. *Journal of the Marine Biological Association of the United Kingdom* 62:45–56.

Book references:

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EDITORIAL

This year, 1995, is again significant for the development of marine science in Hong Kong and it reflects the growing interest in the marine environment locally. On 24 November 1994, Hong Kong's Legislative Council debated the first reading of the Marine Parks Bill. This was finally passed into law by the Council on 31 May 1995 and the Marine Parks Ordinance thus became effective on 1 June 1995. This will eventually allow for the designation of proposed marine parks and reserves in Hong Kong. On 10 August 1995, the Country Parks Board was officially retitled the Country and Marine Parks Board with new responsibilities for the proposed marine parks and reserves. At that time too, the Marine Parks and Reserves Working Group, which had been responsible for the drafting of the legislation, was renamed the Marine Parks and Reserves Committee. Established in 1989, with representation on it by the Marine Biological Association of Hong Kong, the working group presented its first report to the Government in 1990. That report, from a short-list of seven sites, selected three, that is, Yan Chau Tong / Li Chi Wo and Hoi Ha Wan, as possible marine parks and Cape d'Aguilar as a marine reserve. Subsequently, extensive consultation took place between the Government and interested parties and the final recommendation to gazette the three areas was made on 1 August 1995, at the last meeting of the working group. Between 1990 and 1995, the working group not only developed the legislation and its associated regulations, but also defined the sea areal extent of the proposed parks and reserves. The only action needed now is designation of the proposed parks and reserves by the Government. After that is accomplished, work can commence to manage them, effectively, for the future generations of Hong Kong people. Two books about the marine parks and reserves, *Hoi Ha Wan* and *An Introduction to the Cape d'Aguilar Marine Reserve, Hong Kong*, can be obtained from the World Wide Fund for Nature Hong Kong and The Swire Institute of Marine Science, respectively.

Another important date in 1995 was 4 September, when the Hong Kong Government agreed to a proposal to designate the Mai Po Marshes, Hong Kong's largest area of mudflats, mangroves, marsh, prawn ponds (*gei wai's*) and fish ponds as a RAMSAR site in recognition of its vital international role as a stopover place for large flocks of migrating waterbirds and resident birds, in particular.

In 1994, The Hong Kong Government sponsored two Ph.D. students based at the Swire Institute of Marine Science (SWIMS), to study the Chinese White dolphin, elsewhere referred to as the Indo-Pacific Humpback dolphin (*Sousa chinensis*), in view of the emerging concern regarding the large number of dead animals (nine in 1994) recorded as strandings in northwestern waters. Such a tragedy was (and is) widely believed to be the result of the developments taking place in the waters to the north of Lantau Island, particularly with regard to the construction of the new airport at Chek Lap Kok and its 10,000 hectare reclamation 'footprint'. Other developments are also taking place in these waters, however, and which, it is now known, are the almost exclusive habitat of the dolphin. Studies now indicate that the population size is around 80 individuals and with nine more adult deaths up to the end of 1995, seven births in 1994, but only four in 1995, one of which has subsequently died, the mortality rate is estimated to be 20% per annum, so that the population will have become locally extinct by the beginning of the next millenium. It has become a matter of the greatest concern that Hong Kong — ranking as eighth in the world league of trading economies, with the sixth highest per capita GDP in the world in 1993 and a budget surplus in 1994 of HK$19.2 billion — cannot protect this species. The dolphin particularly prefers the shallow area of water around a group of three islands, Tree Island, Sha Chau and Lung Kwu Chau, in the furthest northwestern waters of Hong Kong and this was proposed by the Swire Institute of Marine Science researchers as a possible dolphin sanctuary. Regretably, however, the Provisional Airport Authority had already and unknowingly decided that the islands would be the site of a temporary

Aviation Fuel Receiving Facility (AFRF) for the new airport with docking facilities for between 3,000-10,000 tonne tankers, four of which will each week unload aviation fuel for onward transmission to the new airport via submarine pipelines. This temporary facility will require a dredged turning circle and channel for the vessels. The life span of the facility is estimated at between two to seven years, whilst a permanent pipeline is constructed. Notwithstanding, in an attempt to placate conservationists who argued that such a facility was both unnecessary if plans had been made in time to build a permanent facility direct to the airport and that its construction would spell the end of the dolphins, the Government has proposed that a 1,200 hectare area of sea bed around the islands be designated as a marine park.

Although this must be seen as a positive attempt to conserve an important component of Hong Kong's marine life, indeed one that is specifically protected by the Wild Animal Protection Ordinance (Chapter 170, 1976; revised 1992), there is now an emerging view that the proposed park will not be effective in protecting the dolphins. If no developments were planned for the area, there might be a chance that the dolphins could be saved. The AFRF and all the other activities that will, of necessity, grow as this area is developed, along the Planning Department's guidelines, to marry Hong Kong into those other developments taking place in China around the Pearl River delta, must result sooner or later in the local extirpation of the dolphins. The only possiblity for their survival would be the establishment of a much bigger park to the south, west and north of northwest Lantau, ideally extending into Chinese waters also. The Chinese white dolphin is protected by Hong Kong law, by Chinese State Law and is internationally classified as endangered (CITES, Appendix I). It is a remarkable fact that, despite being afforded all this protection, the dolphin will probably become locally extinct and that Hong Kong and China cannot, together, protect it.

Thus, although such local conservation legislation, proposals and achievements are very real, the truth is that, for example, the Mai Po Marshes are still threatened by surrounding developments, the dolphin sanctuary will be one on paper only, corals at Hoi Ha Wan continue to die and, as reported to me just recently, all of the colonies of the coral *Porites lobata* have died in the pool at the proposed Cape d'Aguilar Marine Reserve. Laudable though, therefore, that so much has been achieved, it is now increasingly doubtful that any of the places proposed for designation as marine parks and reserves will actually survive. It is abundantly clear that every existing and proposed marine park and reserve is at the extreme periphery of Hong Kong and that around them developments in China are accelerating, for example, the northern and eastern shores of Mirs Bay and the north shore of Deep Bay. Any Hong Kong proposals, therefore, to protect sensitive marine environments from internal pressures will meet external ones which will grow in ignorance of what the Hong Kong Government is attempting to protect and why.

What is needed is for Hong Kong to be placed within the regional context of southern China so that conservation plans are understood by both the governments of China and Hong Kong. To help achieve this, the Third International Conference on the Marine Biology of the South China Sea is to be convened in Hong Kong by the Marine Biological Association of Hong Kong and the Swire Institute of Marine Science from 28 October to 1 November 1995 (inclusive), at the University of Hong Kong. The conference will hear presentations on and discuss three major topics: (i), Taxonomy and Biological Diversity; (ii), Biology and Ecology and (iii), Coastal Zone Management and Conservation of the Biological Resources of the South China Sea. Interested potential participants should contact the Conference Secretary at the Swire Institute of Marine Science.

At the 13th Annual General Meeting of the Marine Biological Association of Hong Kong, held on 26 May 1995, the following persons were either elected or re-elected to positions on the Council of the Association : Dr S.F. Leung (Vice-chairman), Mr K.F. Leung (Meetings Secretary) and Dr S.G. Cheung, Dr C.K. Wong and Dr P.S. Wong (Councillors). Retiring from the council, Dr S.T. Chiu (Vice-chairman) and Dr R.G. Ong Che and Dr K.H. Chu (Council members) are herein thanked for their contributions to the work of the Association.

Retiring from the Editorial Board of *Asian Marine Biology* after serving for two years is Dr M. Williams and her position has been filled by Dr J.E.N. Veron of the Australian Institute of Marine Science, Queensland, Australia.

Brian Morton

CONTENTS

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COMPETITIVE INTERACTIONS BETWEEN CO-OCCURRING LIMPETS, *CELLANA TOREUMA* (REEVE, 1855) AND *PATELLOIDA SACCHARINA* (LINNAEUS, 1758), ON A ROCKY INTERTIDAL SHORE AT CAPE D'AGUILAR, HONG KONG

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The Swire Institute of Marine Science, The University of Hong Kong, Cape d'Aguilar, Shek O, Hong Kong

Abstract

Intra- and interspecific competitive interactions between co-occurring limpets, *Cellana toreuma* and *Patelloida saccharina*, were investigated on a rocky intertidal shore at Cape d'Aguilar, Hong Kong, between 25 March and 21 May 1993. The two species were caged at densities ranging from natural to 4 times this number on the shore and in different combinations of species, to elucidate possible competitive interactions. *C. toreuma* showed increased mortality and reduced weight at increased densities over a two-month period, due to intraspecific competition. *P. saccharina* showed a slightly reduced weight but no increased mortality at increased densities. The effect of high density on *C. toreuma* was thus greater than that on *P. saccharina*. Tissue weights of *P. saccharina* were affected by an increased density of *C. toreuma*, but not mortality. There was no effect on *C. toreuma* by *P. saccharina* at increased densities. Food supply, i.e., encrusting algae and microalgae, is thought to be the limiting factor for which the species compete.

Introduction

Manipulative field experiments have explored the importance of competition on rocky intertidal shores (Haven 1973; Underwood 1978; Creese and Underwood 1982; Connell 1983; Schoener 1983; Fletcher and Creese 1985). Unlike sessile organisms, grazing limpets are not expected to compete for space but, at high densities, may compete for food (Haven 1973; Underwood 1979; Creese and Underwood 1982; Hawkins and Hartnoll 1983).

Liu (1992; 1993a; b; 1994a; b) has studied the ecology of six species of Hong Kong limpets in terms of the population dynamics, reproductive biology, activity rhythms, consumption rates and grazing effects. Apart from this, little research has been done on the ecology of Hong Kong limpets.

Cellana toreuma (Reeve 1855) and *Patelloida saccharina* (Linnaeus 1758) are prosobranch limpets occupying mid and low intertidal levels on the shores of Hong Kong and graze microalgae, encrusting macroalgae and their spores. *P. saccharina* shows homing behaviour whereas *C. toreuma* is a non-homing limpet and migrates to upper shore levels in winter (Liu 1993b). Both species have a similar docoglossan radula and are capable of scraping into the rock surface (Plate 1). It is hypothesized that: (1) increased mortality and reduced weight may occur at in-creased densities of *C. toreuma* and *P. saccharina* due to intraspecific competition for food, and (2) interspecific competition for food between these two species may be occurring due to closely similar methods of feeding. The present study aimed at investigating such intra- and interspecific interactions between these two co-occurring species of limpet on a rocky intertidal shore in Hong Kong.

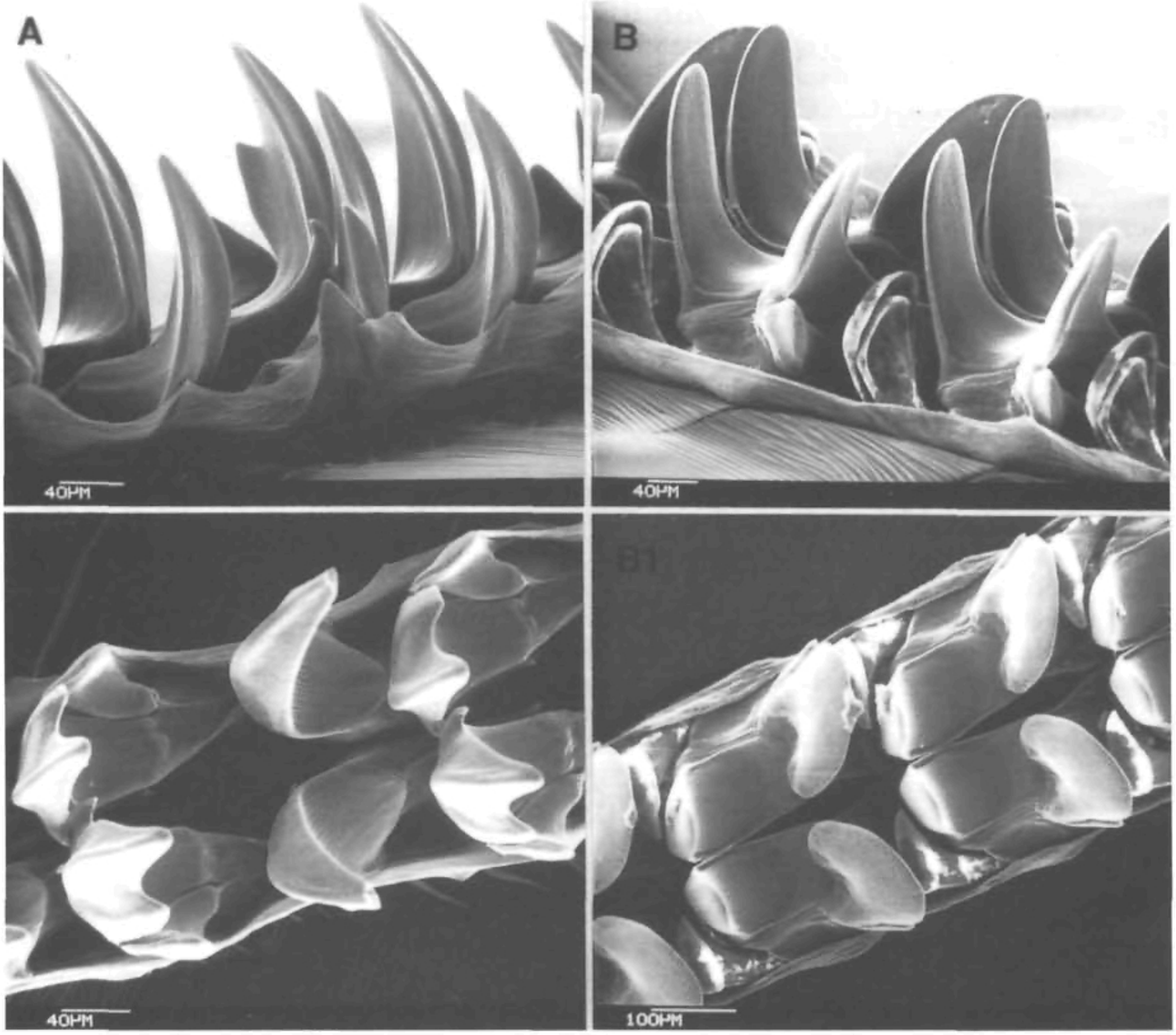

Plate 1. The radulas of A-A1, *Cellana toreuma* and B-B1, *Patelloida saccharina*.

Materials and methods

The study site is located on the northern shore of Lobster Bay at Cape d'Aguilar, Hong Kong Island (Fig. 1) and is exposed to moderate wave action. The study area delineated was between 1 m and 2 m above chart datum. Two co-occurring limpets are common in this area, i.e., *Cellana toreuma* (5.9 individuals. 0.05 m^2, n = 20) and *Patelloida saccharina* (6.1 individuals. 0.05 m^2, n = 20). A few *Siphonaria japonica* (Donovan 1834) and *Patelloida pygmaea* (Dunker 1860) could also be found occasionally.

Cages used in the experiments were made of metal netting of 0.5 x 0.5 cm mesh size and were of 23 x 23 cm, i.e., they enclosed an area of 500 cm^2 and were 4 cm high. The cages were fastened to the rock by metal screws and rawl-plugs. Occasional gaps between the substratum and the base of a cage were sealed with a non-toxic DEVCON wet surface repair putty (UW)

Experiments used a design similar to that of Underwood (1978) and Fletcher and Creese (1985). *Cellana toreuma* and *Patelloida saccharina* were enclosed in cages in various combinations and different densities, i.e., from

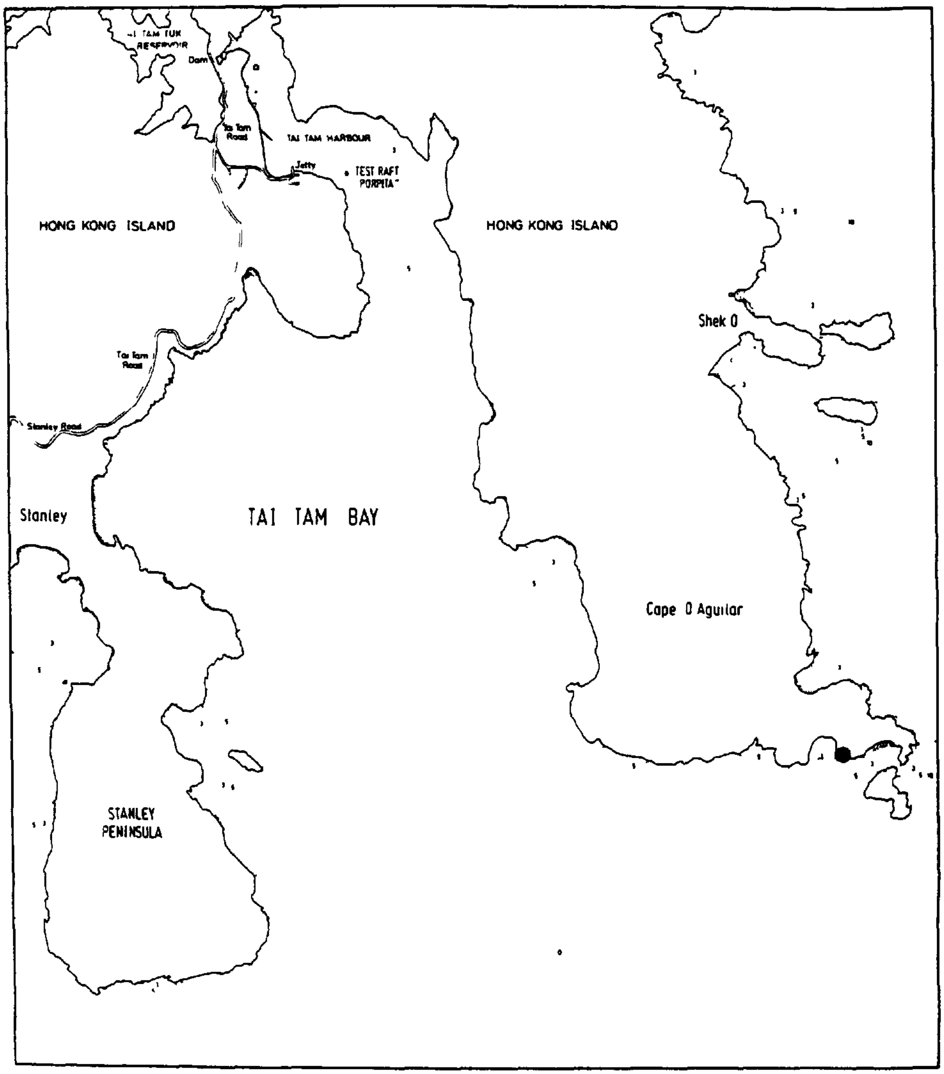

Fig. 1. A map of the southeastern coastal waters of Hong Kong showing the study site.

natural to 4 times the density on the shore (Table 1). Treatments were assigned randomly to the cages. All the treatments were duplicated. Adult limpets were used in the experiments, as such individuals experience little growth (Liu 1994a). Limpets used in this experiment fell into the size ranges of between 27-33 mm for *C. toreuma* and between 14-16 mm for *P. saccharina*. Original individuals used in the experiments were tagged using glue-on polyethylene mollusc tags, with a protective coating of the instant glue Aron Alpha. The mortality of the original individuals of each species in each cage was recorded every week. Dead animals were replaced by similar-sized conspecifics to maintain densities. Replacement animals were marked with red paint so that they would not be sampled finally for determinations of tissue weight and mortality. At the beginning and end of the experiment, a random sample of uncaged adult individuals of each species was collected and shell lengths and tissue weights were obtained to compare with caged individuals in control (natural) densities. At the end of the experiment, all caged animals were removed from

Table 1. ***Cellana toreuma*** **(C) and** ***Patelloida saccharina*** **(P). Experimental treatments.**

				Type of interaction
Total number of limpets	5	10	20	
Experimental treatments	5C	10C	20C	Intraspecific
	5P	10P	20P	Intraspecific
		5C + 5P	5C + 15P	Interspecific
			5P + 15C	Interspecific
Mean shell length (mm)	*C. toreuma*		*P. saccharina*	
Range	27–33		14–16	

the cages and shell lengths and tissue weights were obtained. The experiment was started on 25 March 1993 and continued for two months. A predatory snail, *Morula musiva* (Kiener) occasionally entered the cages and was removed when found

The available food supply for foraging limpets, in terms of biomass and species composition of algae colonizing the rock surface, were investigated. Algal species composition was examined using a light microscope. Algal biomass was determined by chlorophyll a analysis. Six randomly chosen rock samples, each of 10 mm^2, were chipped from the rock surface of each experimental cage and two uncaged plots at the beginning and the end of the experiment. Samples were analysed within 24 hours of collection, usually after overnight storage in an air-tight and light-sealed container placed in a refrigerator (4°C). Chlorophyll *a* was extracted from each set of rock chips using hot methanol (HMSO 1986; Hill and Hawkins 1990). The absorbance of the extract was measured at wavelengths of 665 nm and 750 nm using a PYE UNICAM PU 8600 UV/VIS spectro-photometer. The absorbance value obtained at 750 nm was subtracted from that obtained at 665 nm and this value can be designated A and used as a correction for turbidity. Calculations followed the formula:
The chlorophyll *a* content of the sample

$$= \frac{13.9 \text{ x A x v}}{\text{d x V}} \ \mu\text{g}\cdot\text{cm}^{-2} \text{ (HMSO 1986)}$$

Where A = absorbance
v = volume of solvent in ml
V = area of rock sampled in cm^2
d = cell path length in cm (4.0)
and 13.9 = constant

It is hypothesized that mortality of the same species occurred equally in all cages. This is referred to as the null hypothesis (Ho), and means that the mortality rates between treatments and duplicates should not be different. The question to be asked, then, is whether the observed frequencies deviate significantly from the expected frequencies if the hypothesis is true? A chi-square test was used as an overall measure of deviation to determine whether actual mortalities in the cages differed significantly.

Results

Mortality

The mean mortalities of *Cellana toreuma* and *Patelloida saccharina* at different densities and in different combinations were analysed after a period of two months (Fig. 2). There was an increased mortality of *C. toreuma* at increased densities. The mean mortality of *C. toreuma* reached 30% at high densities (20 individuals. 0.05 m2) but was 10% at lower densities (5 and 10 individuals. 0.05 m^2). *P. saccharina* showed no effect on *C. toreuma* at increased densities. Thus, in the treatments of 5 *C. toreuma* + 15 *P. saccharina*, no mortality of *C. toreuma* was recorded (Fig. 2A). Twenty-three mortalities of *C. toreuma* from 12 cages (6 treatments) were recorded and the observed frequencies (O) are given in Table 2. The null hypothesis (of the same mortality rate in all cages) cannot, therefore, be rejected ($P < 0.25$) (Table 2).

Patelloida saccharina showed little increased mortality at increased densities. At the highest density of *P. saccharina* (20 individuals. 0.05 m^2), mean mortality was only 5% (Fig. 2B). There was also little effect on *P. saccharina* by *Cellana toreuma* at increased densities. For example, at higher densities of *C. toreuma*, i.e., 5 *P. saccharina* + 15 *C. toreuma*, no mortality of *P. saccharina* was recorded (Fig. 2B). There were 6 mortalities of *Patelloida saccharina* from 12 cages (6 treatments) and the observed frequencies (O) are given in Table 3. Again, the null hypothesis (of the same mortality rate in all cages) cannot, therefore, be rejected ($P < 0.25$) (Table 3).

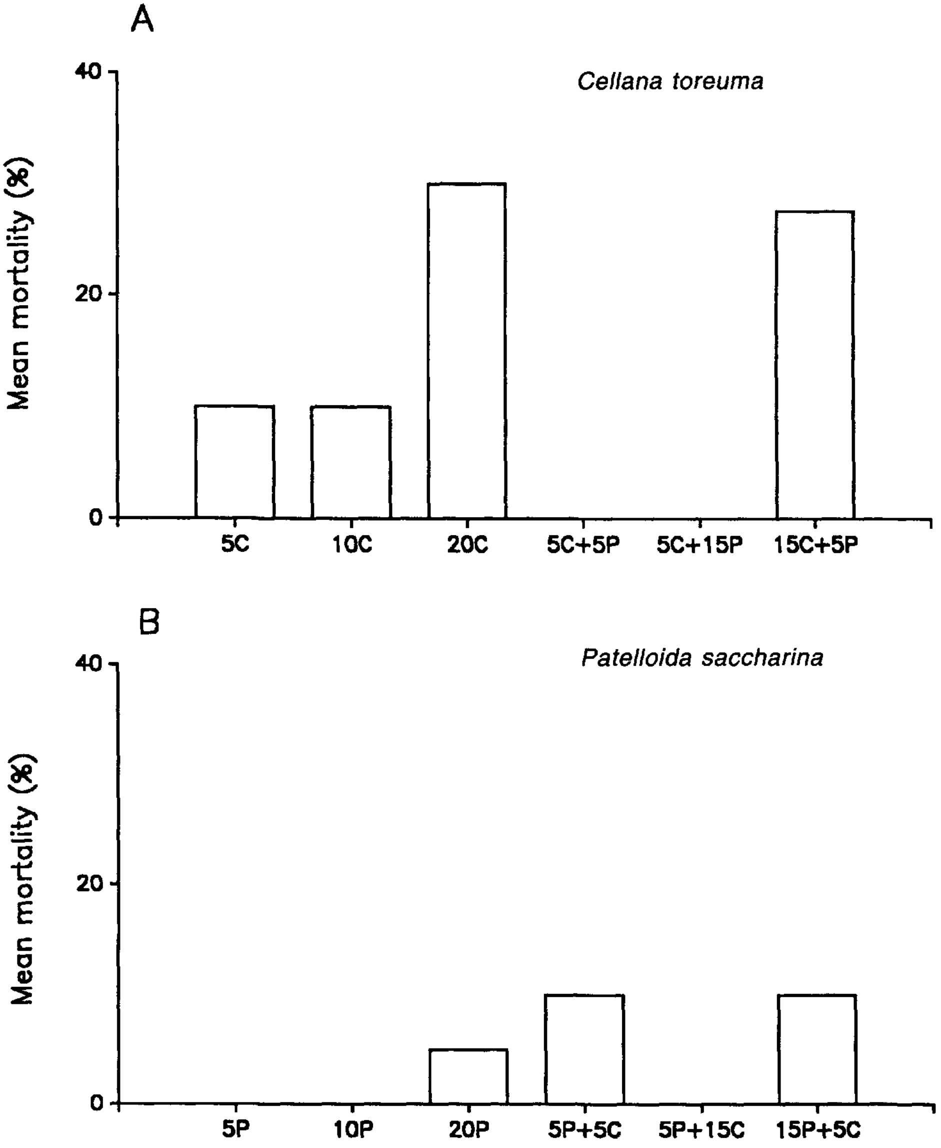

Fig. 2. A, *Cellana toreuma* (C) and B, *Patelloida saccharina* (P). Mean mortalities of individuals at control and experimental densities.

Table 2. Observed frequencies of 23 mortalities of *Cellana toreuma* classified by cage, and subsequent X^2 calculations.

Cages	Observed frequency O	Probability (if Ho true) π	Expected frequency	Deviation (O - E) E = nπ	Deviation squared and weighted $(O - E)^2/E$
5C-1	1	5/120 = 0.042	0.966	1–0.966	0.001
5C-2	0	5/120 = 0.042	0.966	0–0.966	0.966
10C-1	1	10/120 = 0.083	1.909	1–1.909	0.433
10C-2	1	10/120 = 0.083	1.909	1–1.909	0.433
20C-1	7	20/120 = 0.167	3.841	7–3.841	2.598
20C-2	5	20/120 = 0.167	3.841	5–3.841	0.350
5C+5P-1	0	5/120 = 0.042	0.966	0–0.966	0.966
5C+5P-2	0	5/120 = 0.042	0.966	0–0.966	0.966
5C+15P-1	0	5/120 = 0.042	0.966	0–0.966	0.966
5C+15P-2	0	5/120 = 0.042	0.966	0–0.966	0.966
15C+5P-1	3	15/120 = 0.125	2.875	3–2.875	0.005
15C+5P-2	5	15/120 = 0.125	2.875	5–2.875	1.571
	n = 23	1.00	23.0	0	X^2 = 10.221 p-value < 0.25

Table 3. Observed frequencies of 6 mortalities of *Patelloida saccharina* classified by cage, and subsequent X^2 calculations.

Cages	Observed frequency O	Probability (if Ho true) π	Expected frequency E = nπ	Deviation (O - E)	Deviation squared and weighted $(O - E)^2/E$
5P-1	0	5/120 = 0.042	0.252	0–0.252	0.252
5P-2	0	5/120 = 0.042	0.252	0–0.252	0.252
10P-1	0	10/120 = 0.083	0.498	0–0.498	0.498
10P-2	0	10/120 = 0.083	0.498	0–0.498	0.498
20P-1	2	20/120 = 0.167	1.002	2–1.002	0.994
20P-2	0	20/120 = 0.167	1.002	0–1.002	1.002
5P+5C-1	1	5/120 = 0.042	0.252	1–0.252	2.220
5P+5C-2	0	5/120 = 0.042	0.252	0–0.252	0.252
5P+15C-1	0	5/120 = 0.042	0.252	0–0.252	0.252
5P+15C-2	0	5/120 = 0.042	0.252	0–0.252	0.252
15P+5C-1	2	15/120 = 0.125	0.750	2–0.750	2.083
15P+5C-2	1	15/120 = 0.125	0.750	1–0.750	0.083
	n=6	1.00	6	0	X^2 = 8.638 p-value < 0.25

Tissue weights

The ratios of mean dry tissue weight/shell length ($x10^3$) for *Cellana toreuma* were much smaller at increased densities (1.73 for 20 *Cellana*, 2.87 for 15 *Cellana* + 5 *Patelloida* and 3.01 for 10 *Cellana*) (Fig. 3A). There was little effect on *C. toreuma* by *Patelloida saccharina* at higher densities of the latter (5 *Cellana* + 15 *Patelloida*) in terms of tissue weight (3.98). The ratios for *P.*

saccharina were not decreased at higher densities (2.09 at 20 *Patelloida*). There was, however, a strong effect on *P. saccharina* by *C. toreuma* (5 *Patelloida* + 15 *Cellana*), with ratios being smaller (0.88) at increased densities of the latter (Fig. 3B).

The effect of caging at control densities

Random samples of uncaged adult individuals of each species were collected and shell lengths and dry tissue weights were obtained at the beginning and the end of the experiment, for comparison

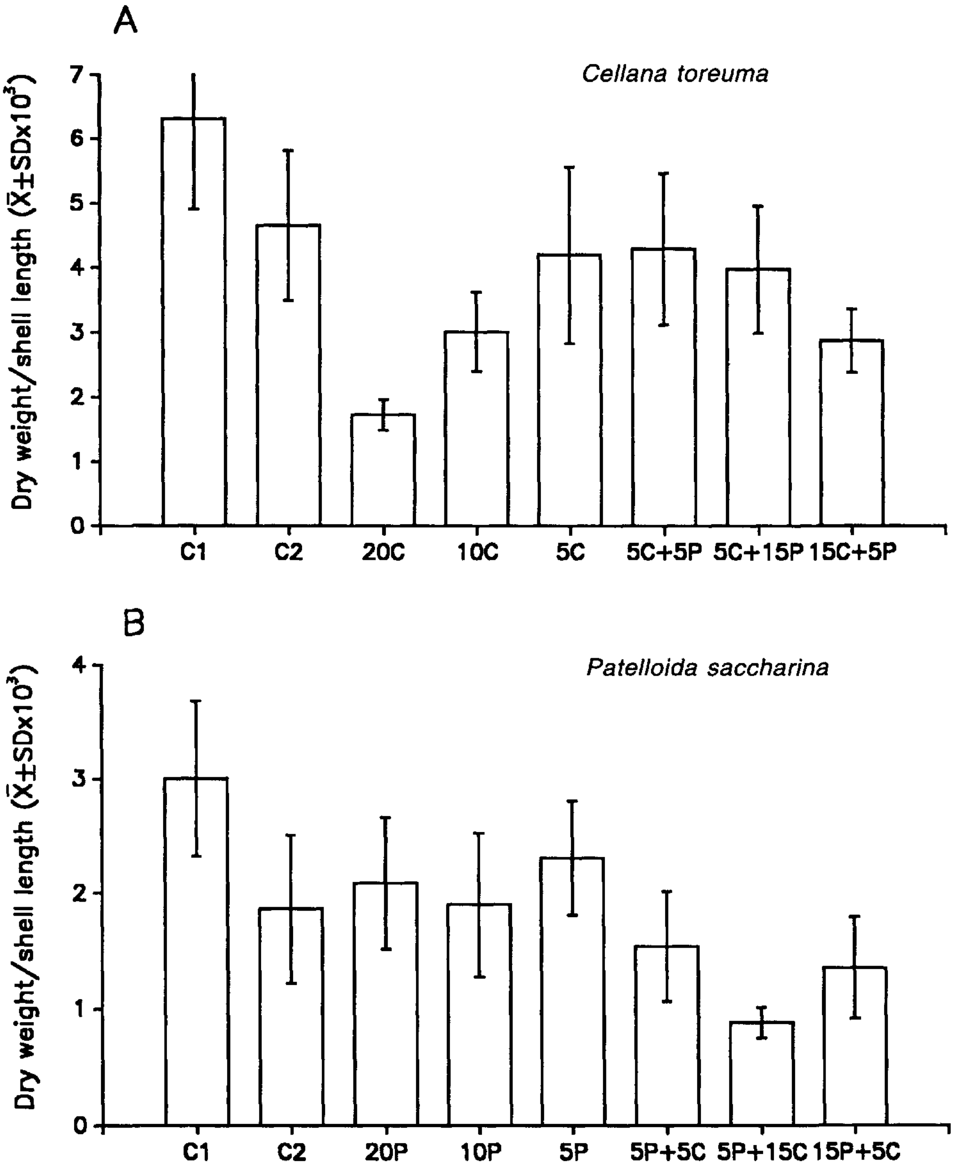

Fig. 3. A, *Cellana toreuma* (C) and B, *Patelloida saccharina* (P). Mean dry weight: shell length ratios (g·mm^{-1}) at various experimental densities (Mean ± S.D.). C1, Uncaged control on 25 March and C2, Uncaged control on 21 May.

with the weight/shell length ratios obtained from individuals in the control (natural) density cages (5 individuals. cage^{-1}). For both *Cellana toreuma* and *Patelloida saccharina*, the mean dry tissue weight/shell length (x 10^3) ratios of the uncaged control animals at the beginning of the experiment, i.e., 6.31 and 3.00, respectively, were significantly greater than the mean ratios obtained for the uncaged, i.e., 4.66 and 1.863, respectively, and caged control animals (5 *Cellana*, 5 *Patelloida*), i.e., 4.20 and 2.31, respectively, at the end of the experiment. There was little difference in the dry tissue weight/shell length ratios between the uncaged and caged control ani-mals at the end of the experiment, i.e., 4.66 vs 4.20 for *C. toreuma* and 1.863 vs 2.31 for *P. saccharina*.

The significant differences in the dry tissue weight/shell length ratios of uncaged individuals at the beginning and the end of the experiment are probably attributable to seasonal changes in algal production (Liu 1993a; 1994a).

Food supply

The available food mainly comprised encrusting algae, *Hildenbrandia prototypus*, *Gomontia* sp., blue green algae and diatoms. The amount of chlorophyll a (μg·cm^{-2}) gives an approximate indication of algal biomass present. Table 4 shows calculated values of chlorophyll a (μg·cm^{-2}) at the beginning and the end of the experiment. Algal biomass was much higher at the beginning (3.10) than at the end (2.04) of the experiment in the uncaged control plots. Such a change is thought to be caused by variations in rates of algal production, which are related to seasonal changes in the physical environment, particularly with regard to temperature and the degree of wetting (Liu 1994a)

Algal biomass decreased abruptly in cages under heavy grazing pressure (20 *Cellana*) after a two-month period, i.e., from 3.14 to 0.64. Algal biomass also decreased in all other cages after a two-month period.

Discussion

This experiment shows that *Cellana toreuma* suffered increased mortality and a loss in tissue-weight due to increases in density above the natural level. There were some small effects due to increased density upon *Patelloida saccharina*. Liu (1993b) showed that *P. saccharina* is a homing species. Homing behaviour may reduce such competition (Mackay and Underwood 1977). *C. toreuma*, therefore, shows stronger intraspecific competition. Fletcher and Creese (1985) have also demonstrated that intraspecific increases in density affected *Cellana tramoserica* more that *Patelloida alticostata*.

Interspecific interactions between *Cellana toreuma* and *Patelloida saccharina* were also examined. Increasing the density of *C. toreuma*

Table 4. Calculated values of chlorophyll *a* (μg·cm^{-2}) at the beginning and the end of the experiment (C, *Cellana toreuma*; P, *Patelloida saccharina*). Mean ± SD. n = 12.

Treatment	Chlorophyll a (μg·cm^{-2}) At the beginning	 At the end
Uncaged control	3.10 (0.48)	2.04 (0.31)
5C	2.96 (0.77)	2.21 (0.27)
10C	3.05 (0.61)	1.17 (0.53)
20C	3.14 (0.32)	0.64 (0.17)
5P	2.87 (0.89)	2.46 (1.13)
10P	3.04 (0.64)	2.15 (0.37)
20P	2.91 (0.21)	1.93 (0.20)
5C+5P	2.73 (0.81)	1.46 (0.36)
5C+15P	2.60 (0.55)	1.43 (0.52)
5P+15C	3.20 (1.02)	0.71 (0.28)

affected individuals of *P saccharina* in terms of a reduction in tissue-weight but little in terms of mortality The former thus appears to be competitively superior to the latter The absence of *C toreuma* resulted in increases in the tissue weights of *P saccharina* (Fig 3A, 20 *Patelloida*, 10 *Patelloida* and 5 *Patelloida*) Increasing the density of *P saccharina* did not, however, affect individuals of *C toreuma* Haven (1973) tested interspecific competition in a habitat where both *Acmaea scabra* and *A digitalis* were common but where the former was smaller than the latter Removal of *A digitalis* from fenced exclosure plots resulted in a significant growth increase in *A scabra*, correlated with pronounced increases in algal food supply Field observations (personal observation) also suggest that the absence of *C toreuma* (or only a few present) results in an increase in the density of *P saccharina* (30 individuals 500 cm^2) The presence of *C toreuma* may effect a reduction in the abundance of *P saccharina* On local shores, however, the densities of *C toreuma* do not occur at high enough levels to eliminate *P saccharina* because of strong interspecific competition for food (Liu, 1994a) and predation (Liu unpublished data) which reduce the numbers of *C toreuma* *C toreuma* affects its own survivorship more than that of *P saccharina* It appears that the major factor allowing coexistence between *P saccharina* and the superior competitor, *C toreuma*, is the effect of intraspecific competition among the *C toreuma* which reduces density below levels at which they can eliminate *P saccharina*

'Asymmetrical competition', where one species adversely affects another but the reciprocal effect is less intense, has been documented for a number of marine organisms (Connell 1961, Dayton 1971, Menge 1972, Underwood 1984) It has also been demonstrated for co-occurring limpets using experimental manipulations (Haven 1973, Stimson and Black 1975, Underwood 1984, Black 1979, Creese 1982, Creese and Underwood 1982, Fletcher and Creese 1985, Garrity and Levings 1985) This study has shown that *Patelloida saccharina* has a relatively small effect on *Cellana toreuma*, while *C toreuma* has a great effect on *P saccharina* and on individuals of its own species

An earlier study by Liu (1992) showed that both *Cellana toreuma* and *Patelloida saccharina* have a docoglossan radula which is capable of scraping into the rock surface, i e, they are able to consume the algal crusts of *Hildenbrandia prototypus* and *Gomontia* sp What are the mechanisms by which *C toreuma*, in experimental cages, outcompetes *P saccharina*? There is no major difference between the radulae of *C toreuma* and *P saccharina*, i e, their abilities to use algal crusts are probably equal and from this point of view neither is a superior competitor The results can only be explained by the fact that while the smaller *P saccharina* has no effect on *C toreuma*, the larger *C toreuma* disturbs the much smaller *P saccharina* by interfering with foraging *P saccharina* is also active only at night when submerged and homes to a scar (Liu 1993b)

Liu (1992) showed that *Cellana toreuma* and *Patelloida saccharina* share a common food resource which is in limited supply Grazing by both *C toreuma* and *P saccharina* at natural densities has a great impact on the colonization and growth of algae Removal of all herbivores resulted in the establishment of opportunistic species of algae, e g, *Acrochaetium robustum*, *Bangia fuscopurpurea*, *Porphyra dentata* and *Ulva lactuca* Shortage of food is the most likely reason for both the intra- and interspecific competition demonstrated in this study, leading to reduced tissue-weight and mortality It is concluded that, in Hong Kong, limpet grazing is strongly limited by algal availability Inter- and intraspecific competition for food increases the mortality and tissue weight loss of *C toreuma* and *P saccharina*

Acknowledgements

I am grateful to The University of Hong Kong for awarding me a Rayson Huang Postdoctoral Fellowship I thank Professor Brian Morton, Director, The Swire Institute of Marine Science, The University of Hong Kong, for the provision of laboratory facilities and work space during the course of this study and for his critical reading of the first drafts of the manuscript of this paper

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Asian Marine Biology 12 (1995): 11–17

FIELD EXPERIMENTS OF PREDATION BY THE MURICID GASTROPODS *THAIS CLAVIGERA* AND *MORULA MUSIVA* ON THE INTERTIDAL BARNACLE *TETRACLITA SQUAMOSA* AT CAPE D'AGUILAR, HONG KONG

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Abstract

Field experiments were undertaken to determine the importance of predation by the muricid gastropods *Thais clavigera* and *Morula musiva* on a population of the barnacle *Tetraclita squamosa* inhabiting a sub-tropical rocky intertidal community in Hong Kong. The effects of *T. clavigera* and *M. musiva* on the prey were tested using experimental cages to exclude the predators. Closed cages containing prey without predators were used to estimate non-predator mortality. Open plots were also used as unmanipulated controls.

Tetraclita squamosa declined in density in open plots throughout the experimental period. Individuals of *T. squamosa* in closed cages showed almost no reduction in density between September 1993 and June 1994 but declined in numbers between June and August 1994. Predator-induced mortality largely occurred in open plots between September 1993 and June 1994, the mean mortality rate during that period being 87.28%. A sharp decrease in numbers of individuals occurred between September and November 1994. Temperature-induced mortality occurred between June and August in all control and experimental plots and when the mean mortality rates in closed cages and open plots were 25.18% and 35.60%, respectively. The latter was accounted for by both temperature and predator-induced mortalities. This indicates that predation intensities in open plots were low during the summer months. Non-predator mortality rate in closed cages was low between September and June (4.55%). The mean annual mortality rate caused by both predation and summer heat in open plots was 91.78%.

On Hong Kong's rocky intertidal shores, predation by *Thais clavigera* and *Morula musiva* at mid-tidal levels generally reduces the abundance of *Tetraclita squamosa*. Predation and summer heat are the major factors affecting the barnacle population and the former is thought to be more significant than the latter.

Introduction

Predation is often considered to be one of the most important processes organizing the structure of rocky intertidal communities (Connell 1975; Paine 1977, 1980). The effects of intertidal muricid gastropods upon their intertidal prey populations, largely mussels and barnacles, have been well studied (Connell 1961, 1970; Menge 1976; Moran 1985a; Fairweather 1985; Abe 1989; Fairweather and Underwood 1991; Morton and Britton 1993).

Rocky shores in Hong Kong are rich in predatory muricids which distribute themselves down the shore into the sub-tidal (Taylor 1980). Higher zoned, intertidal, species, e.g., *Thais clavigera* Kuster and *Morula musiva* (Kiener) feed mostly on oysters and barnacles (Morton and Morton 1983; Taylor 1990). *T. clavigera* occurs on almost every intertidal shore while *M. musiva* is widely distributed on more sheletered rocky shores (Morton and Morton 1983; Tong 1986a). *T. clavigera* and *M. musiva* differ in size with maximum shell heights of 50 mm and 36 mm, respectively (Taylor 1990). They are the main predators on the intertidal shore at Cape d'Aguilar. Abe (1989) showed that small *T. clavigera* mostly feed on the small barnacle *Chthamalus challengeri* whereas large *T. clavigera* mainly on the large barnacle *Tetraclita squamosa japonica*. Large *M. musiva* is the main predator of the mussel *Septifer virgatus*. This author also demonstrated that the seasonal change in prey densities was large and *T. clavigera* showed a marked seasonal pattern of migration.

On most of Hong Kong's rocky shores, the barnacle *Tetraclita squamosa* is dominant at mid-tidal levels and forms the main prey item for muricid gastropods (Morton and Morton 1983). Both *Thais clavigera* and *Morula musiva* are known to feed on *T. squamosa* on the shore at Cape d'Aguilar. Although Tong (1986b) has shown, using gut contents analysis, that *T. clavigera* and *M. musiva* are important predators of the intertidal barnacle *T. squamosa*, almost nothing has been published on the mortality rate of *T. squamosa* as a result of muricid predation.

The present work investigates the effects of predation by *Thais clavigera* and *Morula musiva* on a population of the barnacle *Tetraclita squamosa*. Since high temperatures in mid summer have also been causally linked to mortality of this species (Liu and Morton 1994), it is hypothesized that:

(1) there would be significant differences in the mortality of prey with and without predators;
(2) higher mortality rates may occur in open plots due to predation by muricid gastropods; and
(3) that in closed cages, mortality may occur during the summer months because of heat stress.

A field experiment has been designed to test these hypotheses.

Material and methods

Field experiments were undertaken on the northern shore of Lobster Bay at Cape d'Aguilar, on Hong Kong Island. The shore is exposed to moderate wave action and the study area was delineated between 1 m and 2 m above chart datum. Uncrowded barnacle areas (< 120 individuals·m^{-2}) were chosen to reduce the chance of competition.

Cages used in the experiments were made from metal netting of 0.5 cm mesh size and were 23 x 23 cm in diameter and 4 cm high. The cages were fastened to the rock using metal screws and rawlplugs. Gaps between the substratum and the base of a cage were loosely sealed (to allow for drainage) with a non-toxic DEVCON wet surface repair putty.

Experimental cages were used to exclude all predators (non-predator plots). Open plots as controls were also established using rawlplugs at their corners to allow all predators to gain access to the prey (predator plots). Two treatments were established in eight experimental cages and plots (Table 1). Individuals of *Tetraclita squamosa* used in the experiments were tagged using glue-on polyethylene mollusc tags, with a protective coating of the instant glue Aron Alpha. The experiments commenced on 15 September 1993 and continued for 11 months. The numbers of dead and living individuals of *Tetraclita squamosa* in each experimental plot were recorded every month.

The study area (~ 8 m^2) was visually surveyed for the presence of both *Thais clavigera* and *Morula musiva* every month during the experimental period. Numbers of each species were recorded in the field. Temperature data for the period between September 1993 and August

Table 1. Experimental treatments.

Treatment	Numbers of *Tetraclita squamosa*			
Closed cages	14	7	26	10
Open plots	21	9	59	7

1994 were obtained from the Royal Observatory, Hong Kong.

Results

Figure 1 shows the mean daily maximum and mean air temperatures between September 1993 and August 1994 (Royal Observatory, Hong Kong 1993,1994). Mean daily maximum and mean air temperatures showed a similar pattern and ranged from 19.2°C to 30.4°C and from 17.0°C to 28.0°C, respectively. Peak temperatures were recorded between June and August, i.e., 30.4°C and 28.0°C for mean daily maximum and mean temperatures, respectively.

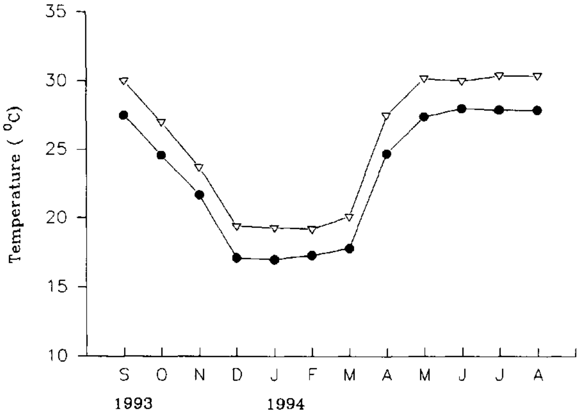

Fig. 1. Mean daily maximum and mean air temperatures (°C) between October 1993 and August 1994 (Records from *Monthly Weather Summary*, between October 1993 and August 1994, Royal Observatory, Hong Kong). • Mean air temperature; ▽ Mean daily maximum temperature

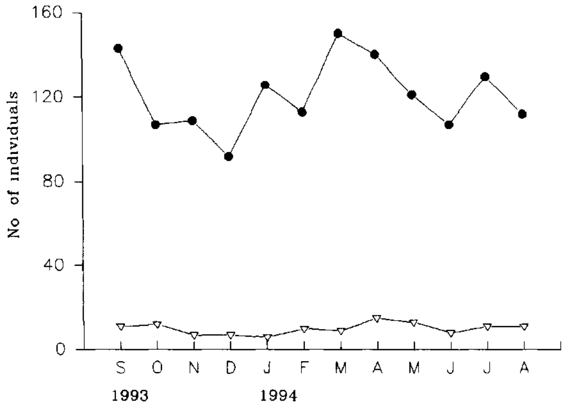

Fig. 2. Densities of *Thais clavigera* and *Morula musiva* at the study site during the experimental period. • *Thais clavigera*; ▽ *Morula musiva*

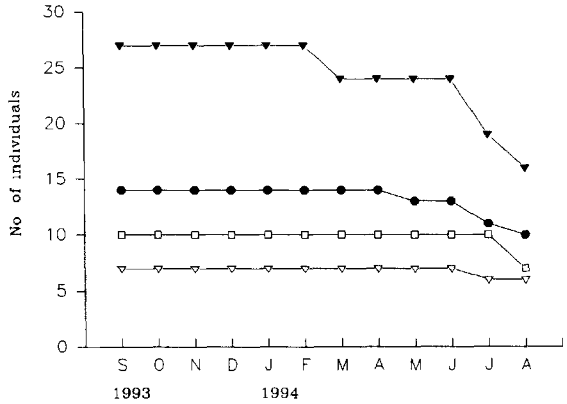

Fig. 3. Mortality rates of *Tetraclita squamosa* in closed cages throughout the experimental period. Initial densities are identified on the left (September 1993) and in Table 1.

The densities of the two species of predators fluctuated throughout the experimental period with a slight decrease in numbers during late autumn and early winter (Fig. 2).

The mortality rates of *Tetraclita squamosa* in all closed cages were low between September 1993 and June 1994 (Fig. 3) when the mean rate was 4.55% (± 5.50) (Table 2). No mortalities occurred in two of these cages between September 1993 and June 1994, i.e., cages with 7 and 10 individuals, respectively. There was a decline in numbers of *T. squamosa* between February and March 1994 in the cage with 27 individuals. This was probably because some of the cages were broken by wave action at this time. There were significant declines in numbers of individuals in all closed cages between June and August 1994 when the mean mortality rate was 25.18% (± 8.40). This decline is thought to be associated with the summer heat. The mean annual mortality rate was 28.40% (± 10.48).

Figure 4 shows the mortalities of *Tetraclita*

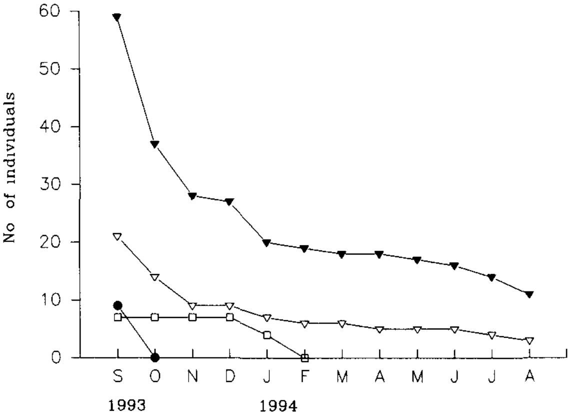

Fig. 4. Mortality rates of *Tetraclita squamosa* in open plots throughout the experimental period. Initial densities are identified on the left (September 1993) and in Table 1.

squamosa in open plots throughout the experimental period. There were gradual declines in numbers of individuals within the plots with 21 and 59 *T. squamosa*, respectively, throughout the experimental period. The mean mortality rate in these two open plots was 35.60% (± 6.22) between June and August 1994, which is slightly higher than the figure for the closed cages. All individuals in the open plot with 9 *T. squamosa* were dead one month after the start of the experiment. Mortalities largely occurred between September 1993 and June 1994 in all the plots and the mean mortality rate during that period was 87.28% (± 14.76). The mean annual mortality rate was 91.78% (± 9.66) (Table 2).

Discussion

Mortality of *Tetraclita squamosa* due to predation by *Thais clavigera* and *Morula musiva* is confirmed by this study. In summer, the mortality rates of *T. squamosa* in all closed cages were slightly lower than those in open plots. This indicates that predation intensities in open plots were low during the summer months and such mortality as did occur probably reflects temperature stress (Liu and Morton 1994). Burrows and Hughes (1989) showed that the natural cycle of foraging and sheltering in the dogwhelk *Nucella lapillus* (Linnaeus) is closely associated with changing weather conditions. In sheltered areas, foraging was limited during periods of sunny and warm weather; in exposed areas, foraging was restricted during periods of strong wave action. Moran (1985b) showed that *Morula marginalba* Blainville forms aggregations in a pool or crevice when environmental conditions are unsuitable for feeding. Menge (1976) also suggested that harsh physical conditions initially reduces the importance of predation (by reducing the effectiveness of predators). Foraging activities of the predators were likely influenced by many physical factors, e.g., temperature and wave action. In the harsher summer environment of Hong Kong, *T. clavigera* and *M. musiva* activities seem greatly restricted by the risks of mortality caused by summer heat. Liu and Morton (1994) showed that *T. squamosa* on the middle shore is thermally stressed in summer when low tides occur in the afternoon in combination with periods of cloudless sunny days and when rock temperatures may climb to ~ 50°C through solar insolation. Although the mean daily

Table 2. Mortality rates of *Tetraclita squamosa* in closed cages and open plots during different experimental periods.

Experimental period	Mean % mortality rate (± S.D.)	
	Closed cage	Open plot
September 1993 - June 1994	4.55 (± 5.50)	87.28 (± 14.76)
June - August 1994	25.18 (± 8.40)	35.60 (± 6.22)
September 1993 - August 1994	28.40 (± 10.84)	91.78 (± 9.66)

maximum air temperature recorded by the Royal Observatory, Hong Kong, shows a peak of 30.4°C in July and August, temperatures may actually climb to 35.2°C in the early afternoon of a hot and sunny day at Cape d'Aguilar (Liu and Morton 1994). High temperatures associated with prolonged periods of emersion in summer could be the most important non-predatory source of mortality in *T. squamosa*.

The temporal variations in densities of *Thais clavigera* and *Morula musiva* are thought to be related to recruitment, variations in environmental conditions and probably seasonal migration (Abe 1989). Such influences, as shown in this study, in variations in the effects of the predators on their prey population, i.e., low predation intensity correlated with low predator densities and harsh environmental conditions in the summer months.

Mortality rates of *Tetraclita squamosa* in all closed cages were extremely low between September and June. This can be interpreted as being due to the exclusion of the predators and confirms that the high mortality rates in all open plots were caused by predation. *Thais clavigera* and *Morula musiva* are important predators on the rocky intertidal shore at Cape d'Aguilar, Hong Kong. Hart and Palmer (1987) showed that large individuals of *Thais emarginata* (>15 mm shell length) exhibit little variation in the locations at which they drill barnacles, and attack the opercular plates more frequently and concentrate their attacks at the suture between the scutal plates. In the absence of predators, e.g., in predator exclusion cages, barnacle mortality rates were low. Although predation has a major influence on community structure, predators are not completely efficient and, occasionally, individuals escape the attentions of the predators. This may explain why these prey species often cover significant areas of space on local exposed shores.

Both *Thais clavigera* and *Morula musiva* were largely found to form aggregations in rock crevices during the low tide period but otherwise ranged widely over the intertidal area. They aggregate when environmental conditions are unsuitable for feeding. Both species were abundant on the shore throughout the year with slightly decreased numbers during late autumn and early winter. This is probably because of reproduction-related mortalities that occur after spawning. Tong (1986a) has shown that recruitment of *T. clavigera* occurs between August and April while *M. musiva* is recruited between September and March. The sharp decrease in the numbers of individuals of *Tetraclita squamosa* in open plots between September and November 1993 is thought to be caused by heavy predation pressure which is also probably related to the reproductive activities of the muricids.

Mortality can be affected by both biological (e.g., predation and competition) and physical (e.g., summer heat and strong wave action) factors. In this study, the temperature-induced mortality rate for *Tetraclita squamosa* in closed cages was 25.18% which accords with figures obtained by Liu and Morton (1994). That study showed that mortality occurred mainly on the middle shore during the summer months, i.e., 23.06% for *T. squamosa* in the sun. This study, however, suggests that the structure of the barnacle population is affected more strongly by biological factors (e.g., predation) than by physical ones (e.g., summer heat) since major declines in abundance can only be explained by mortality from predation. Mortality from physical factors does occur, e.g., summer heat, but is less significant than mortality caused by biological factors, e.g., predation. Other sources of mortality, e.g., competition, were not studied in this work but since the barnacles in the cages were not crowded, this seems unlikely.

Acknowledgements

I am grateful to the University of Hong Kong for awarding me a Rayson Huang Postdoctoral Fellowship. I thank Professor Brian Morton, Director, the Swire Institute of Marine Science, the University of Hong Kong, for the provision of laboratory facilities and work space during the course of this study and for his critical reading of the first drafts of the manuscript of this paper.

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SPATIAL VARIATION IN LARVAL TREMATODE INFECTIONS OF POPULATIONS OF *NODILITTORINA TROCHOIDES* AND *NODILITTORINA RADIATA* (GASTROPODA: LITTORINIDAE) FROM HONG KONG

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Abstract

The incidence of larval trematode (xiphidiocercariae) infections in populations of *Nodilittorina trochoides* and *Nodilittorina radiata* from shores in Hong Kong was investigated during October 1993. Only three species, i.e., *Cercariae minus*, *C. hezuiensis* and *C. tangi* (Trematoda: Plagiorchioidea), were obtained. Two of these species (*Cercaria hezuiensis* and *C. tangi*) are considered to be new to science. Infection rates were low and varied between the sites examined. There was a relatively high incidence of infection at Starfish Bay in the New Territories, as compared to other sites. Populations at some sites on the more exposed southeastern coast of Hong Kong Island had no infected individuals. The incidence of infection appeared similar between the two species of *Nodilittorina*.

Introduction

Littorinid snails are intermediate hosts to a variety of trematode parasites which can influence growth rates, reproduction, behaviour and subsequent survival of their molluscan hosts (see Lauckner 1987 for a review). Infection rates can be as high as > 50 % of the population but can vary greatly between populations and even phenotypes of the same species (Sergievsky 1985). The consequences of trematode infections can, therefore, also vary between populations, resulting in demographic variations between sites. Species of the genus *Nodilittorina* are dominant members of the high shore community and occur in most coastal areas of Hong Kong (Oghaki 1985). Infections by species of xiphidiocercariae (*Cercaria minus*) have previously been recorded from *Nodilittorina vidua* (= *N. millegrana*) (Reid 1992), collected from Starfish Bay in the New Territories of Hong Kong during April 1986 (Tang 1990).

In this study, *Nodilittorina* were collected from nine sites (eight on the southeast coast of Hong Kong Island and one in the New Territories) and the prevalence of parasites in these different populations assessed to investigate spatial variation in parasite loads. Comparison of the data collected in this study and in 1986 from Starfish Bay (see Tang 1990) also allow a brief assessment of temporal variation in infection rates.

Materials and methods

Collections of *Nodilittorina* species were made during October 1993 at nine sites in Hong Kong (Fig. 1). Animals were returned to the laboratory where they were examined by crushing them and dissecting out living larval trematodes. Parasites were observed alive and drawn with the aid of a camera lucida.

Results

Incidence of larval trematode infections in Nodilittorina at different sites in Hong Kong

A total of 6341 specimens of *Nodilittorina trochoides* (Gray) and *N. radiata* (Eydoux and Souleyet) were collected from the nine sites; 5357 snails from the more exposed coastal sites in

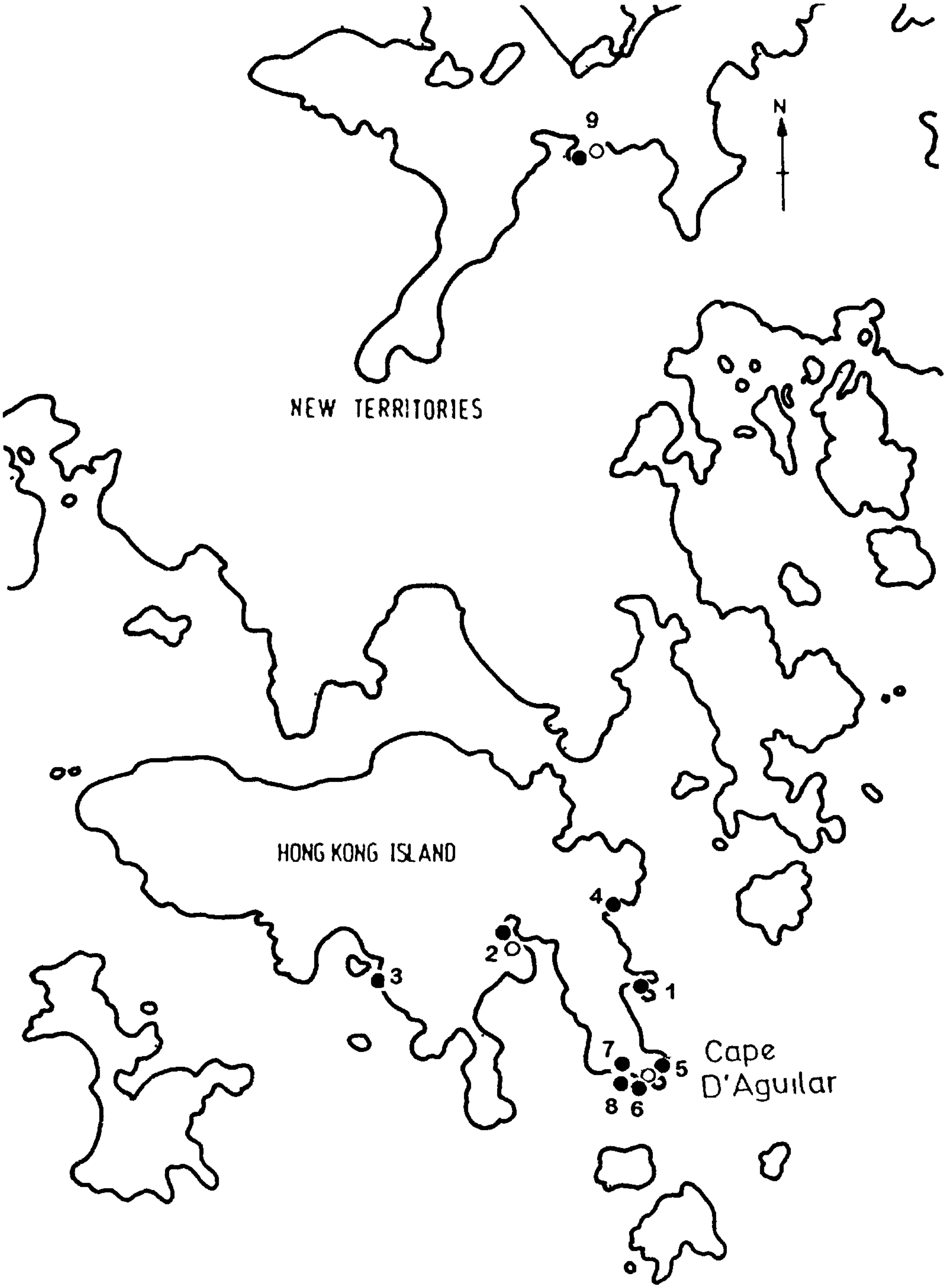

Fig. 1. A map of Hong Kong showing the sampling sites 1, Shek O, 2, Tai Tam, 3, Chung Hum Kok 4, Big Wave Bay, 5, Cape d'Aguilar, 6, Lobster Bay, 7, Telecom Bay, 8, Coral Pool, 9, Starfish Bay (Closed circles = *Nodilittorina trochoides*, Open circles = *Nodilittorina radiata*)

southeastern Hong Kong Island and 984 snails from Starfish Bay in the New Territories.

The majority of specimens were of *Nodilittorina trochoides* (4875 individuals, 4362 from Hong Kong Island and 513 from the New Territories) but 1466 specimens of *Nodilittorina radiata* (995 from Hong Kong Island and 471 from the New Territories) were also examined for larval trematodes. Only three species of xiphidiocercariae, belonging to the Plagiorchioidea, were obtained. All three species of xiphidiocercariae were obtained from *N. trochoides*, but only two species were collected from *N. radiata* at Starfish Bay (Table 1). The xiphidiocercariae obtained from Starfish Bay were *Cercaria minus* Tang, 1990, *Cercaria hezuiensis* sp. nov. and *Cercaria tangi* sp. nov. from *N. trochoides*, and *Cercaria minus* and *Cercaria tangi* from *N. radiata*. The infection rate was quite low (overall rate 1.22 %) although it was slightly higher in *N. trochoides* than *N. radiata* (Table 1).

In contrast, *Nodilittorina trochoides* and *Nodilittorina radiata* from the more exposed coastal areas of Hong Kong Island harboured only one species of xiphidiocercariae (*Cercaria hezuiensis*) and infection rates were 10 times lower (total infection rate 0.112 %, Table 2) than at Starfish Bay. Over 60 % of the *N. trochoides* populations were free of any infection.

Table 1. **The incidence of larval trematode infections of *Nodilittorina trochoides* and *N. radiata* collected from Starfish Bay in the New Territories.**

Mollusc host	N° of snails	Trematode species	N° positive	(%) Infected
N. trochoides	513	*Cercaria minus*	5	0.97
		Cercaria hezuiensis	1	0.194
		Cercaria tangi	1	0.194
Total	513		7	1.365
N. radiata	471	*Cercaria minus*	3	0.637
		Cercaria tangi	2	0.425
Total	471		5	1.062
TOTAL	984		12	1.22

Table 2. **The incidence of larval trematode infections of *Nodilittorina trochoides* and *N. radiata* from different sites on the exposed southeastern coast of Hong Kong Island.**

Site name	Mollusc host	N° of snails	Trematode species	N° positive	(%) Infected
Shek O	*N. trochoides*	587	0	0	0
Tai Tam	–	480	0	0	0
Chung Hum Kok	–	653	0	0	0
Big Wave Bay	–	441	0	0	0
Cape d'Aguilar	–	546	*C. hezuiensis*	3	0.55
Lobster Bay	–	531	*C. hezuiensis*	1	0.19
Telecom Bay	–	530	0	0	0
Coral Pool	–	594	0	0	0
Total		4362	1 species	4	0.091
Tai Tam	*N. radiata*	498	0	0	0
Cape d'Aguilar	–	497	*C. tangi*	2	0.402
Total		995	*C. tangi*	2	0.202
TOTAL		5357	2 species	6	0.112

The morphology of xiphidiocercariae infecting Nodilittorina species

Plagiorchioidea
Cercaria minus Tang, 1990

Cercaria minus has previously been described by Tang (1990) from *Nodilittorina millegrana* (= *N. vidua*) (Reid 1992) collected from Starfish Bay in April 1986. This cercaria may be the larval stage of a species belonging to the Microphallidae (Trematoda). Infection rate was very low. Of 132 individuals of *N. vidua* examined only one was positive (0.76%) for this species of larval trematode (Tang 1990). In the present investigation, this species was recorded from both *Nodilittorina trochoides* and *Nodilittorina radiata* collected from Starfish Bay. Infection rates in these species (0.97% in *N. trochoides* and 0.64% in *N. radiata*) were similar to that previously recorded for *N. millegrana*.

Plagiorchioidea
Cercaria hezuiensis sp. nov.

Specimens of the second xiphidiocercariae, including cercariae and their daughter sporocysts, were obtained from *Nodilittorina trochoides* from Cape d'Aguilar and Lobster Bay on the southeastern coast of Hong Kong Island and from Starfish Bay in the New Territories. At Starfish Bay the incidence of infection was 0.19%. This species of larval trematode was also obtained from the snails collected from Cape d'Aguilar and Lobster Bay on Hong Kong Island where infection rates were 0.55% and 0.19%, respectively (Tables 1 and 2).

Morphological characteristics of the cercaria and daughter sporocyst

Daughter sporocyst (Fig. 2B). Cyst-shaped body is between 0.23–0.71 mm in length and between

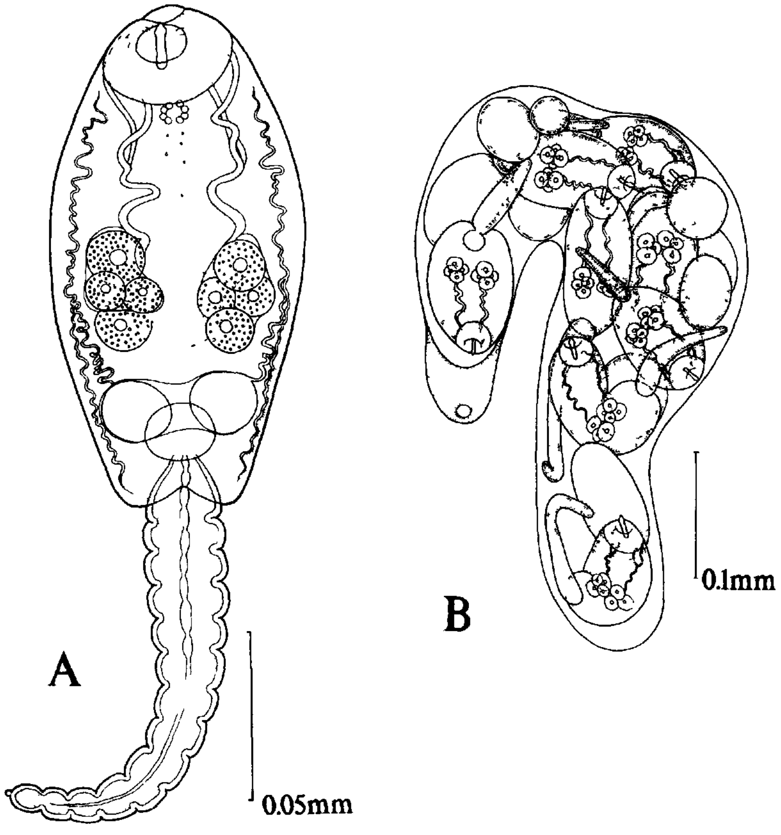

Fig. 2. A, Cercaria of *Cercaria hezuiensis* sp. nov. and B, sporocyst of *Cercaria hezuiensis* sp. nov.

0 11-0 21 mm in width (alive), containing between 7–20 germ balls and cercariae in different developmental stages A round birth opening is present at the tip of the body

Cercaria (Fig 2A) Body relatively large, 0 15–0 19 x 0 055–0 074 mm in living specimens Tail measures between 0 132–0 141 mm long and between 0 020–0 025 mm wide at the upper part of the tail when contracted Oral sucker, between 0 032–0 038 mm in diameter Stylet lanceolate, between 0 015–0 017 mm in length and 0 004 mm in width Prepharynx absent Pharynx, oesophagus and acetabulum are all unclear There are four pairs of penetration gland cells, the two smaller cells lie parallel between the larger two and are situated lateral to the unclear acetabulum which appears as a cell mass at mid-body, their ducts coil, run forward and open at the tip of the body and at the edge of the stylet sac The excretory bladder consists of three round cysts, the basal cyst of the bladder is between 0 015–0 020 mm in diameter, and the two anterolateral cysts are each about 0 015–0 020 x 0 015–0 021 mm in length and width An association between the two anterolateral cysts can be seen Primary left and right collecting vessels arise from the left and right anterolateral cysts of the bladder, respectively, and each divides into anterior and posterior excretory capillaries at about 2/5 of the body length from the posterior end of body

The morphology of this cercaria closely resembles the cercaria of *Gynaecotyle nassicola,* (Microphallidae) (Cable and Hunninen, 1938) (Rankin 1940), which develops in *Nassa obsoleta* Both are monostomatous xiphidiocercariae of the *ubiquita* group of Sewell (1922) and possess similar larval structures, such as the number of penetration gland cells, the same lancet-shaped stylet, an unclear acetabulum, and a similarly shaped excretory bladder *Cercaria heuzuiensis* is different from the cercaria of *G nassicola* in several important aspects, e g , the *G nassicola* cercaria has a longer stylet (0 025 mm in length) and a shorter tail (only about 1/2 of body length), a different arrangement of penetration gland cells (of which the two smaller gland cells are behind the larger two) and different species of molluscan hosts The above characteristics distinguish the cercaria of *G nassicola* from the present xiphidiocercaria from Cape d'Aguilar which is considered to be a new species This species is named *Cercaria hezuiensis* sp nov to record the place of its discovery, the proposed marine reserve at Cape d'Aguilar which is also the site of The Swire Institute of Marine Science

Plagiorchioidea

Cercaria tangi sp nov

This third xiphidiocercariae was only obtained from *Nodilittorina radiata* collected from Cape d'Aguilar and Starfish Bay Infection rates were low for both sites (Cape d'Aguilar = 0 43%, Starfish Bay = 0 40% (Tables 1 and 2) All the infected snails contained mature sporocysts and cercariae The worms differ from other xiphidiocercariae thus far collected

Daughter sporocyst (Fig 3B) The daughter sporocyst of this species is sacculate There are numerous germ balls and developing cercariae in the body cavity of the sporocyst The total length and width is between 0 32–0 92 x 0 16–0 29 mm The anterior end of the daughter sporocyst is bluntly narrow with an external opening located at the tip

Cercaria (Fig 3A) This species of xiphidiocercariae possesses an elongate tail The body is between 0 135–0 141 x 0 05–0 055 mm in length and width in living individuals The tail is between 0 120–0 153 mm in length and 0 018–0 020 mm wide at the base The stylet is triangular with a sharp anterior end and wide round base, elongate and bowed, between 0 016–0 018 mm in length and between 0 006–0 008 mm wide at its base Oral sucker, between 0 029–0 032 mm in diameter Prepharynx absent Pharynx, 0 008 x 0 010 mm The acetabulum, between 0 028–0 035 mm in diameter, is located centrally just posterior to the equatorial line of the body There are only two pairs of penetration gland cells which are lateral to the acetabulum The excretory bladder is oval and between 0 026–0 028 x 0 018–0 020 mm in length and width It is surrounded by many cells whose function is unknown Two small cysts, of between 0 008–0 010 x 0 007–0 009 mm, can sometimes be seen at the anterolateral sides of bladder, from which arise the primary collecting vessels

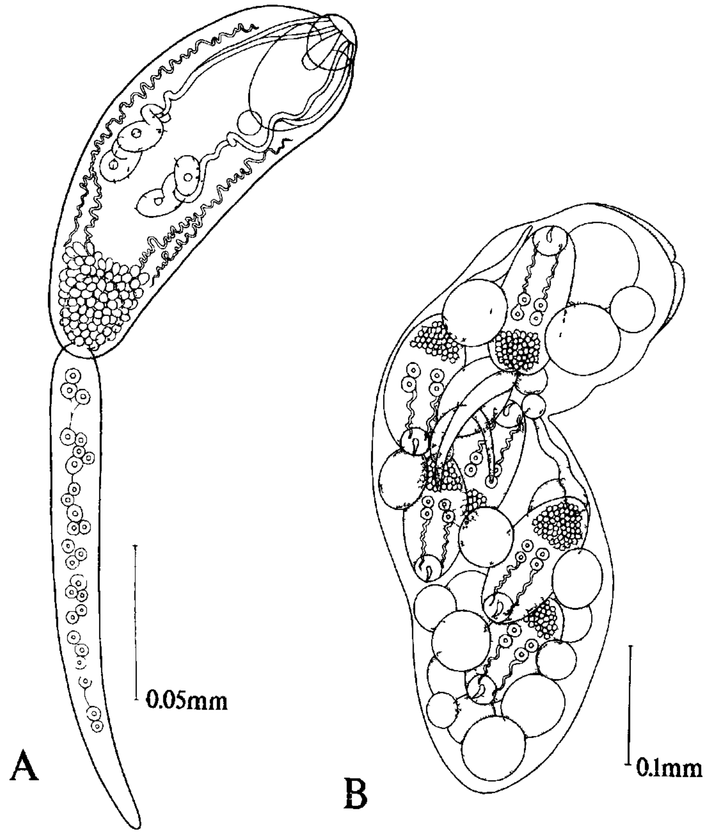

Fig. 3. A, Cercaria of *Cercaria tangi* sp. nov. and B, sporocyst of *Cercaria tangi* sp. nov.

This species of xiphidiocercarial cercariae is similar to the cercaria of *Maritreminoides caridinae* (Yamaguti and Nisimura, 1944) (Chen 1957) belonging to the Microphallidae (Trematoda). They both possess the same number (only two pairs) of penetration gland cells. There are, however, important differences between these species, e.g., the molluscan host of *M. caridinae* in which the cercariae develop is a freshwater mollusc, *Oncomelania nosophora,* as opposed to the marine *Nodilittorina radiata.* The two species of cercariae also differ in the shape of stylet, the length of tail and the structure of the excretory bladder. In the cercaria of *M. caridinae*, the tail is shorter than the body and its excretory bladder is V-shaped. A comparison with all recorded species of xiphidiocercarial cercariae shows this Hong Kong xiphidiocercaria to be unique and so the author names it *Cercaria tangi* sp. nov. in memory of my respected and beloved father, the late Professor Tang Zhong-zhang (C. C. Tang) who left us in July 1993.

Discussion

To date, five species of xiphidiocercariae have been obtained from marine molluscs in Hong Kong. Of these, three species were obtained from the genus *Nodilittorina.* The other two species are *Cercaria spelotremoides* (Tang 1990) parasitizing the digestive glands of *Cerithidea rhizophorarum* collected from Three Fathoms Cove in the New Territories, and *Cercaria armata* (Tang 1990) parasitizing *Clypeomorus pellucida* collected from mangrove areas in the New Territories.

Xiphidiocercarial cercariae are a relatively large group of larval trematodes belonging to many families of the Trematoda Four of the five species collected from Hong Kong are similar to the cercariae of some species of Microphallidae, whose adults parasitize fish, birds and mammals The first intermediate hosts of these species are molluscs and their second intermediate hosts include crayfish, crabs and amphipods The fifth species, *Cercaria armata*, may be the larval stage of a species belonging to the genus *Macroderoides* (Allocreadiidae) which parasitize fish The life cycles and adult stages of these species are largely unknown

Infection rates at the different sites were low (never > 1 5 %) as compared to infection rates in some populations of other littorinids, e g , *Littorina obtusata* from Russia, > 50 % infection rates (Sergievsky 1985), *Littorina littorea* from the United Kingdom, > 90 % infection rates (James 1968) This may reflect the high shore character of the local nodilittorinids as compared to pool dwelling *L littorea* and fucoid inhabiting *L obtusata* both of which spend longer periods immersed when infection rates would be maximal Other populations of these species do have much lower infection rates (Sergievsky 1985) Variation in infection rates between populations at different sites was small, given the low prevalence of infections *Nodilittorina trochoides* from six sites showed no infection at all as did *N radiata* from Tai Tam Such low incidences are surprising as many of these sites support large populations of birds and crabs

The incidence of *Nodilittorina* infection collected from Starfish Bay in the New Territories were compared between April 1986 and October 1993 Infection rate was similar (0 757 – 1 062 %) and *Cercaria hezuiensis* was never recorded from *N radiata*, although *Cercaria tangi* was recorded in 1993 but not in 1986 It appears that trematode infections do not play a large role in the ecology of high shore nodilittorinids on Hong Kong shores as suggested for these parasites in other species of littorinid which live lower on the shore in more temperate regions

Acknowledgements

The author sincerely thanks Professor Brian Morton for providing facilities at the Swire Institute of Marine Science for this investigation The author also thanks Dr G A Williams of the same Institute for comments on the manuscript and providing and identifying the species of *Nodilittorina* collected from the beaches in Hong Kong and Mr Robin Kennish, Mr Mak Yiu Ming and Mr James Hui who also collected snails

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COMMUNITY STRUCTURE OF SCLERACTINIAN REEFS IN THE BAITYLONG ARCHIPELAGO (SOUTH CHINA SEA)

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Abstract

Preliminary investigation of fringing reefs at nine localities in the western part of the Baitylong Archipelago, Vietnam, were made along line transects to 15 m depth. The area studied is characterized by alluvial sediments discharged by many rivers, water temperature falling to 16°C in winter and rainy season salinities of 28–30‰. Two morphological types of reef occur: structural and unstructural, both showing distinct vertical zonation in terms of species composition and community structure. A comparison of the Baitylong Archipelago reefs with reefs of central and southern Vietnam, Gulf of Thailand and other Pacific reefs reveals an affinity in terms of species composition and reef morphology. One hundred and forty-two species of Scleractinia belonging to 43 genera were identified, 80 species and 15 genera of which have not hitherto been reported from the Gulf of Tonkin.

Introduction

The Baitylong Archipelago is located in the north of the Gulf of Tonkin and consists of chains of linearly elongate islands made up of broken carbonaceous, weakly metamorphosed, limestone. As a result of marked erosive processes, they form complex morphostructures with abrasive bays and fiords deeply incising the islands. The shore is extremely rugged, steeply inclined and filled with debris. The underwater topography is a weakly inclined, aggradative, plain alternating with surface terraces at depths of 6, 9 and 11 m and numerous patches of truncated bedrock. Numerous rivers discharging into the Gulf of Tonkin (especially the two large rivers, Thaibinh and Honga) transport much suspended organic and mineral material and make coastal waters turbid. In the rainy season, salinity drops to between 28–30‰ coinciding with periods of large tidal fluctuations (to - 3.5-3.7 m). Coral communities over large areas of emergent reefs perish under the freshening effect of the heavy rain. Water temperature also falls to 16–18°C in winter (Gurjanova 1972; Yet 1989). Such physical extremes affect the coral communities. In the western part of the gulf, however, there are the well-known national reserves of Kat'ba Island and Halong Bay about which virtually nothing is known. One study (Yet 1989) reports that reefs occur here in groups in closed and open bays or in passages between islands. There is one publication on the distribution of coral reefs in the northern Gulf of Tonkin (Latypov and Malyutin 1990). Data on the coral fauna and the state of reefs lying close to the boundary of the northern tropics will thus be of special interest and this is a study of such communities.

Material and methods

A study of coral communities and reef structure was conducted east of Kat'ba Island, the largest of the islands of the Baitylong Archipelago. This area is situated about 30 km from the mouth of the Thaibinh River (Red River) and about 2° from the Tropic of Cancer. Distribution of corals was studied on five islands using transect and quadrat techniques (Loya and Slobodkin 1971). Nine transects with each metre distance marked, were made of the outer and inner sides of the islands, inside straits, bays and fiords in areas of rocky, rubble-covered and sandy coastlines (Fig.1). The degree of substratum cover by corals, numbers of colonies and density of dominant species were calculated for each transect (Maragos and Jokiel 1976). Qualitative samples of coral species were collected from each physiographic zone at depths of 1, 2–3, and 5–7 m. A total of about 400 samples of coral were collected and 142 species, belonging to 43 genera, were determined. Corals were identified by the author using the following publications (Veron and Pichon 1976,1979,1982; Latypov 1990,1992).

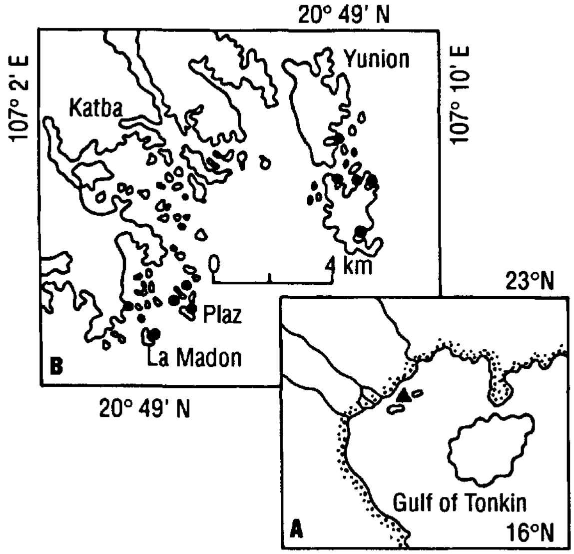

Fig. 1. A, Location of Baitylong Archipelago in the Gulf of Tonkin (▲). B, Map showing the study area and location (black circles) of the transects.

Results

Morphology and zonality

Different islands, their sides and bays have various morphological profiles and patterns of reef zonation. Small islands and their bays have structureless coral reefs built by settlement of individuals or groups of colonies, rarely by bioherms (Fig.2). Reef deposits form only a veneer; they do not form the reef framework and match the natural profile of the bottom which consists, for the most part, of large pieces of rock rubble and, rarely, of dead coral fragments. The

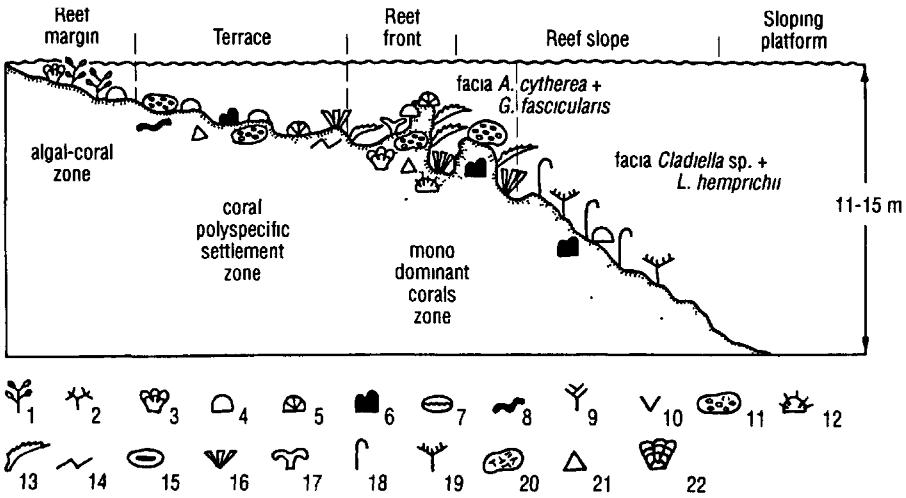

Fig. 2. Reef profile and distribution of abundant macrobenthos on an unstructured reefs. 1, *Sargassum polycystum;* 2, *Gracilaria verrucosa*; 3, *Padina australis*; 4, *Porites*; 5, *Favia, Favites*; 6, *Goniopora stokesi*; 7, *Cypraea tigris*; 8, *Holothuria atra*; 9, *Acropora nobilis*; 10, *Turbinaria peltata*; 11, *Galaxea fascicularis*; 12, *Diadema setosum*; 13, corymbose *Acropora*; 14, *Echinopora lamellosa*; 15, *Fungia*; 16, *Lobophyllia hemprichii*; 17, *Cladiella* sp.; 18, *Ellisella* sp.; 19, *Verrucella umbraculum*; 20, *Pavona cactus*; 21, *Trochus niloticus*; 22, *Echinophyllia aspera.*

morphology of such reefs is affected strongly by the underlying topography and only a reef slope is distinct

Reefs with a distinct morphological zonation occur in closed bays of the larger islands on an organic substratum A shallow-water boat channel with the rare occurrence of individual coral colonies and a small lagoon has a reef flat The inner reef flat is externally cut with numerous channels and cavities (Fig 3) The reef front is not defined morphologically Only at the junction between the reef flat and the reef slope, are coral deposits more cemented Transverse channels are better pronounced and the numbers of massive colonies increase along this part of the reef The reef slope is short and sheer, with a distinctive spur-and-groove system Numerous colonies of scleractinians, alcyonarians and gorgonians are grouped into bioherms or longitudinal polyspecific settlements

Coral community characteristics

Unstructured reefs Along the coast, for a distance of 20–40 m and at a depth to 1 m, occurs an algal-coral zone dominated by macrophytes i e , *Sargassum, Padina, Asparagopsis* and *Turbinaria*, crusts of the zoanthid *Palythoa* and individual small massive and encrusting colonies of the scleractinians *Porites, Leptoria, Goniastrea, Pavona* and *Hydnophora* The substratum is covered with algae for no more than 10% (rarely 40% in some areas) with *Sargassum polycystum* or *Asparagopsis taxiformis* dominant Corals cover between 7–15% of the substratum with *Galaxea fascicularis, Leptastrea transversa* and *Porites lobata* dominant, the latter forming flat microatolls up to 1 5 m across At 40–60 m off the coast and with increasing depth to 2 m, the numbers and abundance of scleractinians increase (Table 1) Colonies of *G fascicularis* and *P lobata* grow to 1 5 m across and to 0 5 m high The algae *A taxiformis*, and *S polycistum* also occur here The degree of substratum covered with corals reaches 40% with *P lobata, G fascicularis* and *Pavona decussata* dominant

Between 70–80 m offshore, the bottom drops from 3 to 9–11 m The depth change occurs either gradually or by two to three sharp steps An associated change takes place in species composition and pattern of coral settlement on the reef slope Large (up to 2 m across) colonies of *Galaxea, Lobophyllia*, plate-like *Acropora, Montipora*, and plate-like encrusting *Echinopora, Echinophyllia, Mycedium, Pachyseris* and the lamellar-funnel form of *Turbinaria* are dominant Massive colonies of *Porites* occur on the upper and middle parts of the reef slope (1 5–2 m in height) Species richness increases two fold Many genera are represented by 2 to 3 species and the genera *Acropora, Montipora* and *Porites* by between 5 to 20 species A reef slope community is formed by scleractinians and the alcyonarians *Cladiella, Lobophytum, Sarcophyton, Gorgonia* and *Ellisella*, which occur either as individual colonies or as groups The degree of coral cover

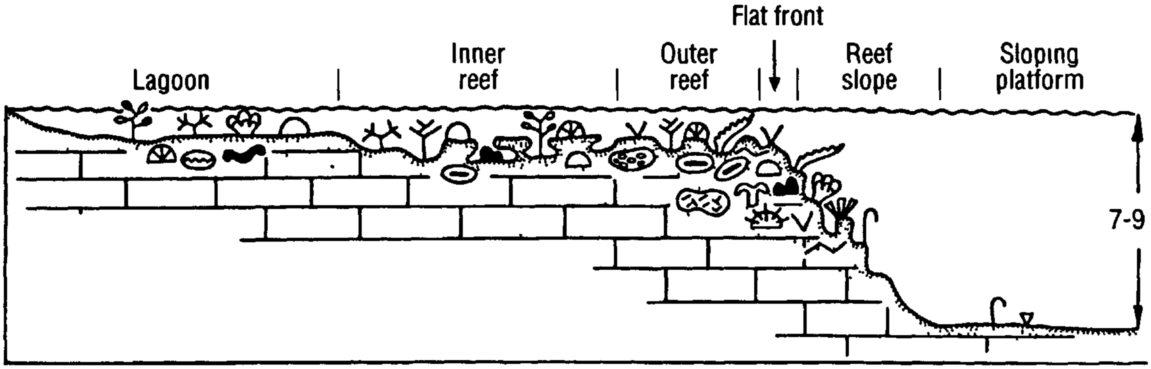

Fig. 3. Reef profile and distribution of abundant macrobenthos on a structural reef Hatched areas reef limestone

Table 1. Distribution of Scleractinia on reefs of the Baitylong Archipelago and other regions of the South China Sea. 1-4, islands of the Baitylong Archipelago (1, Plaz; 2, La Madon; 3, Yunion; 4, Pe); 5, Paracel Islands; 6, Gulf of Thailand; 7, Con Son and Tchu Islands(South China Sea).

	Species	1	2	3	4	5	6	7
1.	*Stylocoeniella quenteri* Bassett-Smith		+	+	+	+	+	+
2.	*Psammocora contigua* (Esper.)		+	+	+	+	+	+
3.	*P.digitata* M.- E. & H.		+		+	+	+	+
4.	*P.nierstraszi* Van der Horst	+			+	+		
5.	*P.profundacella* Gardiner	+	+	+	+		+	+
6.	*Astreopora myriophthalma* (Lamarck)	+		+	+	+		+
7.	*Montipora aequituberculata* Bernard			+	+	+	+	+
8.	*M.caliculata* (Dana)		+	+	+		+	+
9.	*M.danae* M.- E. & H.		+	+		+		
10.	*M.digitata* (Dana)			+	+	+		+
11.	*M.hispida* (Dana)	+	+	+	+	+	+	+
12.	*M.informis* Bernard		+	+	+	+		
13.	*M.nodosa* (Dana)		+	+	+	+		
14.	*M.spongodes* Bernard	+	+			+	+	+
15.	*M.tuberculosa* (Lamarck)	+	+	+		+	+	+
16.	*M.turtlensis* Veron & Wallace	+	+	+				
17.	*M.turgescens* Bernard		+		+	+	+	+
18.	*M.undata* Bernard	+		+		+	+	+
19.	*M.venosa* (Ehrenberg)	+	+					
20.	*Acropora humilis* (Dana)	+	+	+	+	+	+	+
21.	*A.samoensis* (Brook)	+	+	+				
22.	*A.digitifera* (Dana)	+	+	+		+	+	+
23.	*A.robusta* (Dana)	+	+		+	+	+	+
24.	*A.nobilis* (Dana)	+	+	+	+	+	+	+
25.	*A.formosa* (Dana)		+			+	+	+
26.	*A.acuminata* (Verrill)	+	+	+		+		
27.	*A.valenciennesi* (M. - E. & H.)	+	+			+		
28.	*A.microphthalma* (Verrill)	+	+		+	+	+	+
29.	*A.austera* (Dana)	+	+					+
30.	*A.aspera* (Dana)			+	+	+	+	
31.	*A.pulchra* (Brook)			+	+	+	+	+
32.	*A.millepora* (Ehrenberg)		+		+	+	+	+
33.	*A.selago* (Stutter)	+		+		+		
34.	*A.yongei* Veron & Wallace	+		+				
35.	*A.cytherea* (Dana)	+	+	+	+	+	+	+
36.	*A.hyacinthus* (Dana)	+	+	+	+	+	+	+
37.	*A.glauca* (Brook)	+	+	+	+			
38.	*A.lutkeni* Crossland	+						
39.	*A.divaricata* (Dana)	+	+	+		+	+	+
40.	*Pavona cactus* (Forskål)		+	+	+	+	+	+
41.	*P.clavus* (Dana)	+	+	+			+	+
42.	*P.decussata* (Dana)	+	+	+	+	+	+	
43.	*P.explanulata* (Lamarck)	+	+	+	+	+	+	
44.	*Leptoseris mycetoseroides* Vaughan	+	+	+		+		+
45.	*Pachyseris rugosa* (Lamarck)		+	+		+		+
46.	*P.speciosa* (Dana)	+	+	+	+	+		+
47.	*Pseudosiderastrea tayamai* (Yabe & Sug.)	+	+	+	+	+	+	
48.	*Coscinaraea columna* (Dana)	+	+	+	+	+	+	+
49.	*Fungia repanda* Dana	+	+			+		

(to be continued)

50.	*F.fungites* (Linnaeus)			+	+	+	+	+
51.	*F.corona* Doderlein	+		+	+			
52.	*F.granulosa* Klunzinger			+	+			
53.	*F.danai* M. - E. & H.	+	+	+	+	+	+	+
54.	*Halomitra pileus* (Linnaeus)			+	+			
55.	*Sandalolitha robusta* (Quelch)	+		+	+	+	+	+
56.	*Lithophyllon undulatum* Rehberg	+	+			+	+	+
57.	*L.mokai* Hoeksema	+				+		
58.	*L.bistomatum* Latypov	+	+					
60.	*Podobacia crustacea* (Pallas)	+	+	+	+	+	+	+
61.	*Alveopora allingi* Hoffmeister			+	+		+	+
62.	*Goniopora columna* Dana		+		+	+	+	+
63.	*G.djiboutiensis* Vaughan	+			+	+	+	+
64.	*G.stokesi* M.- E. & H.			+	+		+	
65.	*G.stutchburyi* Wells	+	+	+	+		+	+
66.	*Porites australiensis* Vaughan	+	+	+	+		+	+
67.	*P.lobata* Dana	+	+	+	+	+	+	+
68.	*P.lutea* M.- E. & H.	+	+	+	+	+	+	
69.	*P.solida* (Forskål)		+					
70.	*P.mayeri* Vaughan	+	+	+	+	+		+
71.	*P.murrayensis* Vaughan	+	+			+	+	+
72.	*P.stephensoni* Crossland	+	+	+	+	+	+	
73.	*P.densa* Vaughan	+	+	+			+	
74.	*P.species* 1		+		+			
75.	*Barabattoia amicorum* E.- M. & H.		+	+		+	+	
76.	*Favia speciosa* (Dana)	+	+	+	+	+	+	+
77.	*F.pallida* (Dana)	+		+	+	+	+	+
78.	*F.laxa* (Klunzinger)	+		+		+	+	+
79.	*F.favus* (Forskål)	+	+			+	+	+
80.	*F.maritima* Nemenzo	+	+	+	+			+
81.	*F.rotumana* (Gardiner)		+			+	+	+
82.	*F.matthai* Vaughan		+			+	+	+
83.	*F.maxima* Veron, Pichon & Best	+	+	+	+	+	+	+
84.	*Favites abdita* (Ellis & Solander)	+	+	+	+	+	+	+
86.	*F.chinensis* (Verrill)		+			+	+	+
87.	*F.flexuosa* (Dana)	+	+	+	+	+	+	
88.	*F.complanata* (Ehrenberg)	+	+			+		+
89.	*F.pentagona* (Esper)		+				+	
90.	*Goniastrea retiformis* (Lamarck)		+	+	+	+	+	+
91.	*G.aspera* (Verrill)	+		+	+	+	+	
92.	*G.favulus* (Dana)		+		+			
93.	*Platygyra daedalia* (Ellis & Solander)	+	+	+	+	+	+	+
94.	*P.lamellina* Ehrenberg	+	+	+	+	+	+	+
95.	*P.pini* Chevalier	+	+				+	+
96.	*P.sinensis* M.- E. & H.	+	+	+		+	+	+
97.	*Australogyra zelli* (Veron,Pichon & Best)		+					
98.	*Oulophyllia crispa* (Lamarck)			+			+	+
99.	*Hydnophora exesa* (Pallas)	+	+	+	+	+	+	+
100.	*H.microconos* (Lamarck)	+	+	+	+	+	+	+
101.	*Montastrea valenciennesi* M.-E.& H.	+	+	+		+		+
102.	*Plesiastrea versipora* (Lamarck)	+	+	+	+	+	+	+
103.	*Leptastrea purpurea* (Dana)	+	+	+	+	+	+	+
104.	*L.transversa* Klunzinger	+	+	+	+	+	+	
105.	*L.pruinosa* Crossland			+			+	
106.	*Cyphastrea chalcidicum* (Forskål)	+		+		+	+	+
107.	*C.serailia* (Forskål)	+	+	+	+	+	+	+

(to be continued)

108.	*C.mycrophthalma* (Lamarck)	+				+	+	
109.	*Echinopora lamellosa* (Esper)	+	+	+	+	+		+
110.	*E.gemmacea* (Lamarck)	+	+	+	+	+		
111.	*Oulastrea alta* Nemenzo	+	+		+	+	+	
112.	*O.crispata* (Lamarck)	+	+				+	+
113.	*Galaxea fascicularis* (Linnaeus)	+	+	+	+	+	+	+
114.	*G.astreata* (Lamarck)	+		+		+		+
115.	*Merulina ampliata* (Ellis & Solander)	+	+	+	+	+		+
116.	*Symphyllia recta* (Dana)	+		+	+	+		+
117.	*S.radians* M.-E. & H.	+		+	+	+	+	+
118.	*S.agaricia* M.-E. & H.		+	+	+	+		
119.	*S.valenciennesi* M.-E. & H.		+				+	+
120.	*Lobophyllia corymbosa* (Forskål)			+		+	+	+
121.	*L.hemprichii* (Ehrenberg)	+	+	+	+	+	+	+
122.	*L.hattai* Yabe, Sug.& Eguchi	+	+	+	+	+	+	+
123.	*Cynarina lacrymalis* (M.-E. & H.)	+	+	+				
124.	*Pectinia lactuca* (Pallas)			+		+		+
125.	*P.paeonia* (Dana)	+	+	+	+	+		+
126.	*Echinophyllia aspera* (Ellis &Sol.)	+	+	+	+	+		+
127.	*E.echinata* (Saville-Kent)	+	+	+	+			+
128.	*E.orphensis* Veron & Pichon	+	+	+	+			+
129.	*Oxypora lacera* (Verrill)	+	+	+		+		+
130.	*Mycedium elephantotus* (Pallas)	+	+	+	+	+		+
131.	*Turbinaria frondens* (Dana)		+	+	+	+	+	+
132.	*T.mesenterina* (Lamarck)	+	+	+	+	+	+	
133.	*T.peltata* (Esper)	+	+	+	+	+	+	+
134.	*T.reniformis* Bernard	+	+	+	+		+	+
135.	*T.stellulata* (Lamarck)			+	+		+	
136.	*T.bifrons* Bruggemann		+	+				
137.	*Dendrophyllia japonica* Rehberg		+	+			+	
138.	*D.cornigera* (Lamarck)		+					+
139.	*D.aculeata* Latypov		+					+
140.	*Balanophyllia cummingii* M.-E.& H.		+	+			+	
141.	*Tubastrea aurea* (Quoy & Gaimard)	+	+	+	+	+	+	+
142.	*T.micranthus* (Ehrenberg)	+	+	+	+	+	+	+
	Totals	78	86	80	72	83	73	81

increases to between 70–80% and to 100% in places with large (to 3 m) colonies of *G. fascicularis, P. lobata, Acropora cytherea* and *Lobophyllia hemprichii.*

The reef slope community is divided distinctly into two facies, i.e., ***Acropora cytherea* + *Galatea fascicularis*** on the upper part of the reef slope and ***Cladiella* sp.+ *Lobaphyllia hemprichii*** on the lower. Towards the base of the reef slope (to a depth of between 8–10 m) scleractinian richness and individual numbers decreased. The genera *Goniopora, Lobophyllia, Podobacia, Echinopora, Oxypora, Pectinia* and *Turbinaria*, were most common here as individual colonies covering between 3–5% of the substratum surface.

Structural Reefs. Boat channels between 2 to 10 m wide were generally free of macrobenthos, with single algae, *Padina* and *Sargassum*, and small crusts of the *Leptastrea, Porites, Galaxea* and *Favia.* The inner reef flat consisted of coralogenic flat cemented crusts and branching colonies of *Acropora, Montipora* or *Pavona* and massive heads of *Porites*, which here formed monospecific strands. Living corals were represented by rare colonies (between 5–12 individuals·m^{-2} no more than 10 cm across) of massive encrusting forms of *Leptastrea, Porites, Platygyra, Galaxea, Pavona, Favia* and *Favites.* Macrophytic algae occurred among the corals. Between 40 to 50m offshore, the total number of colonies increased to 15–20·m^{-2}. Colonies of branched *Pavona cactus, Acropora pulchra,* *Acropora millepora* and *Montipora digitata* formed small areas of monospecific settlements and massive *P. lobata* formed numerous microatolls. There were also crusts of *Palythoa* with areas of up to several square metres and small algal mats of *Gracilaria* up to 1.5 m^2. The external reef flat was cut with longitudinal and cross grooves occupied mainly by encrusting and massive colonies (between 10–14·m^{-2}) of *G. fascicularis, P. cactus, F. speciosa, P. lobata, Hydnophora exesa.* Single fungiids, *Fungia danai* and *Sandalolitha robusta,* were dominant. The external part of some reef flats were between 21–60% covered by monospecific stands of *P. cactus,* other areas had a 10–30% covering of *M. digitata* or an up to 54% covering of different species of *Acropora,* i.e., *A. pulchra, A. cytherea, A.millepora, A.nobilis.* At the edge of the reef flat, the number of massive and encrusting colonies of *Pavona, Favia, Favites, Echinopora* and *Symphyllia* increased to 25–30·m^{-2} and single *Fungia* and *Sandalolitha* formed accumulations of between 4–6·m^{-2}. Species of *Pectinia, Mycedium, Merulina, Turbinaria, Sinularia* and *Cladiella* also occurred. The degree of coral cover on the reef flat was between 60–70%.

The reef slope was steep, with numerous grooves and spurs densely inhabited by different corals. On the upper part of the reef slope, *Acropora* species, i.e., *A.cytherea, A.hyacinthus, A. humilis, A. aspera* and *Montipora* species, i.e., *M. danae, M. aequituberculata, M. hispida* were dominant. Widespread here were large massive colonies of *Porites, Galaxea, Lobophyllia* and *Favia. Goniopora stokesi* occupied areas of hundreds·m^{-2}, and accumulations of Fungiidae, up to 15–45·m^{-2}, were dominated by *Fungia danai.* Coral cover reached 70–100%. The lower part of the reef slope (> 3–5 m) was occupied mainly by massive scleractinians and encrusting, plate-like, forms. Most widespread were species of *Lobophyllia, Symphyllia, Echinophyllia, Turbinaria, Favia, Favites,* and *Montipora* with, as usual for this part of the reef slope, *Merulina, Micedium, Pachyseris, Pectinia, Podobacia,* and the alcyonarians *Sinularia, Sarcophyton,* and the gorgonian *Ellisella* and *Antipatharia.* At a depth of between 9–10 m, only single scleractinian and gorgonian corals occurred.

Discussion

The reefs on the western part of the Baitylong Archipelago lie at the northern boundary of the distribution of Vietnamese corals and are subject to the strong currents of large and small rivers that discharge silt laden waters, reduce salinity and reduce temperature in winter. In spite of such extreme conditions, the reefs of this region have a relatively high species richness and a high degree of similarity with other Vietnamese reefs and those of the Indo-Pacific (Table 1 and Fig.4). The reefs studied had 65.1% species in common with reefs of Cape Danang and the Thyam Islands of central Vietnam and 59.4% of species in common with the reefs of southern Vietnam (Tchu and Con Son Islands and others). The island reefs of the South China Sea (Paracel Islands, Nanh Sha and others) have 55% of species in common with the Baitylong Archipelago. More than two-thirds of the coral species are common to the coral faunas of the Gulf of Tonkin and the Gulf of Thailand (62.3%).

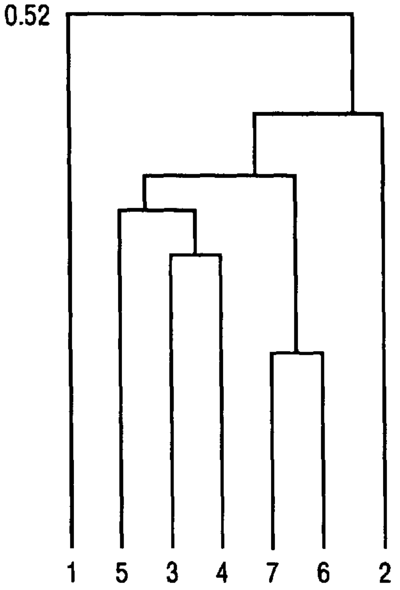

Fig. 4. Dendrogram resulting from clustering of Jaccard similarity coefficients between species compositions of corals in different reefs of the South China Sea. 1-7: localities are the same as in Table 1.

Acroporidae form monospecific stands and occupied frequently large reef areas they create the high coral diversity (28 5% of species composition) as with the majority of Indo-Pacific reefs (Indonesia - 29 7%, Australia - 34%, Thailand - 27 7%)

Investigated reefs were characterized by massive reef building corals Massive colonies of *Porites lobata* and *P lutea* occurred from the littoral zone to the lower part of the reef slope They formed large colonies between 1 5–2 5 m across and more than 1 m high or occurred as accumulations of colonies of different sizes (18–25 m ^{2}) that covered between 75–100% of the substratum Generally, *Porites* colonies dominated the reef flat and the upper part of the reef slope and often formed microatolls Massive *Porites* with continuous settlements have also been recorded from similar situations in the Gulf of Thailand (Latypov 1986, Sakai *et al* 1986) Massive *Porites* are known to form zones in turbid waters of the Singapore reefs (Chou and Teo 1985), the Great Barrier Reef (Potts *et al* 1985), and the east coast of Africa (Hamilton and Brackel 1984) Zones of *P lutea* were also reported in low illumination habitats for deeper parts of the base of the reef slope in the Red Sea (Loya 1972) I have recorded zones of *P lutea* and *P lobata* on the lower part of the reef slope at a depth of 25 m in the Seychelles (Coetivy and Aldabra Islands) where a decrease in light intensity is perceptible from a depth of 18–20 m

A subdominant group among the scleractinians of the Baitylong Archipelago is *Galaxea fascicularis* which forms massive colonies with an area between 3–5 m ^{2} and monospecific stands of between 12–15 colonies m ^{2} on the outer reef flat zone and at 2–3 m ^{2} on reefs with no obvious pattern of zonation The large corallites of this coral, which are able to remove fine sediment (Spencer-Davies *et al* 1971) are well adapted to turbid waters and form extensive encrusting or massive colonies and monospecific stands in different areas of the Seychelles and Maldive Islands and the east coast of Africa (Taylor 1968, Spencer-Davies *et al* 1971, Hamilton and Brackel 1984) Additionally, it is known that *Galaxea* species are most aggressive among scleractinians in terms of interspecific competition and can form large monospecific reefs (Sheppard 1979)

A wide distribution of large encrusting plates of *Echinophyllia, Echinopora, Micedium, Pectinia, Lobophyllia, Pachiseris, Podobacia* and *Turbinaria* is typical of the Baitylong Archipelago reefs These corals, with large surfaces up to 3 m across, absorb light falling from above and are capable of removing sediment Accordingly, they occupy niches in all reef zones from the littoral to between 9–11 m depth Usually, such corals settle on the lower part of the reef slope at a depth of between 18–30 m In the study area they also occur at a shallower depth of between 1–9 m A series of experiments and direct observations on reefs have shown thinning of colonies and a predominance of plate colonies with decreasing light intensity (Goreau 1963, Porter 1976, Fricke and Meischner 1985) Zones of monospecific stands or abundance plate-like colonies of *Echinopora, Pachyseris* and the plate or funnel forms of *Turbinaria* occur in limited light conditions (from 30 to 2% FAR) at great depth and in shaded shallow waters of South Vietnam (Latypov 1986, Titlyanov *et al* 1988)

Another peculiar feature of the reefs of the western part of the Baitylong Archipelago is the formation of structured and unstructured reefs While structural reefs have their own physiographic zones and limestone framework, unstructured reefs only follow the geomorphological profile of the underwater slope Conversely, unstructured reefs of Baitylong show a clear vertical zonation in terms of species composition and community structure which are, in principle, similar to those on structural reefs (Fig 5) Communities of unstructural reefs were similar to the lagoon, reef flat and reef slope communities of structural reefs (Wainwright 1965, Pichon 1981, Sheppard 1982, Latypov 1990, Sorokin 1990) and, in their morphological relationship, they are as if in a middle stage of coral succession to a 'specialized community' (Hubbard 1974, Pichon 1974)

The mass development of corals either in models of coral community succession (Connell and Slatyer 1977) or in the formation of reefs on artificial substrata (Schuhmacher 1977) and in reefs at different stages of development (Hubbard

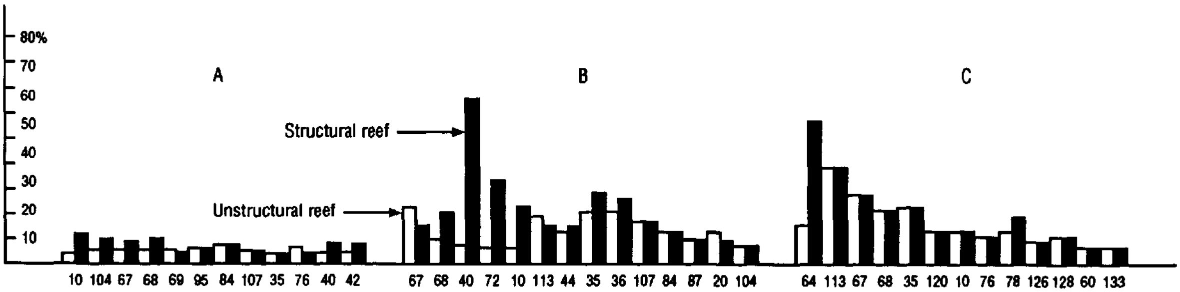

Fig. 5. Histograms of degree of cover and rank order of abundant species demonstrating the affinity of species composition and coral community structure in the same zone of different reef types A, inner reef flat, B, outer reef flat, C, reef slope 10, 35, 113 numbers of species from Table 1

1974, Loya 1976) must follow a phased formation of a cover by biogenic deposits in which corals are pioneer settlers Colonies of certain species settle and gradually give rise to multispecific settlements (Hubbard 1974) that form, with time, the primary coral layer (Pichon 1974, 1981) When such a reef crust is formed, more species settle and the primary framework of the reef grows vertically to the intertidal level (Fig 6) A porous framework of cemented benthic organisms is formed, which are mostly dead A young fringing reef forms with a reef flat adjacent or almost adjacent to the shore (Pichon 1981, Latypov 1987a) In time and in the course of erosive and sedimentation processes, there is a transfer of deposits from the deep zones to shallower ones and *vice versa* The areas of 'living' and 'dead' reef extend, reef deposits grow thicker and morphological zonation develops (Fig 6C,D)

Unstructured reefs of the Baitylong Archipelago represent a stable ecosystem adapted to low light intensity in strongly turbid and eutrophic waters The reefs have stable species composition and community structure in the same zones on different reefs (Figs 2–5) The reefs are characterized by high species diversity (more than a third of all Pacific scleractinian species) Their limestone framework is at the stage of 'framework building' (Sheppard 1982) when cementation of sediments and the filling of reefogenous deposits occur It is rather difficult to distinguish such reefs from real structural reefs or the different developmental stages of reef like 'coral layers'

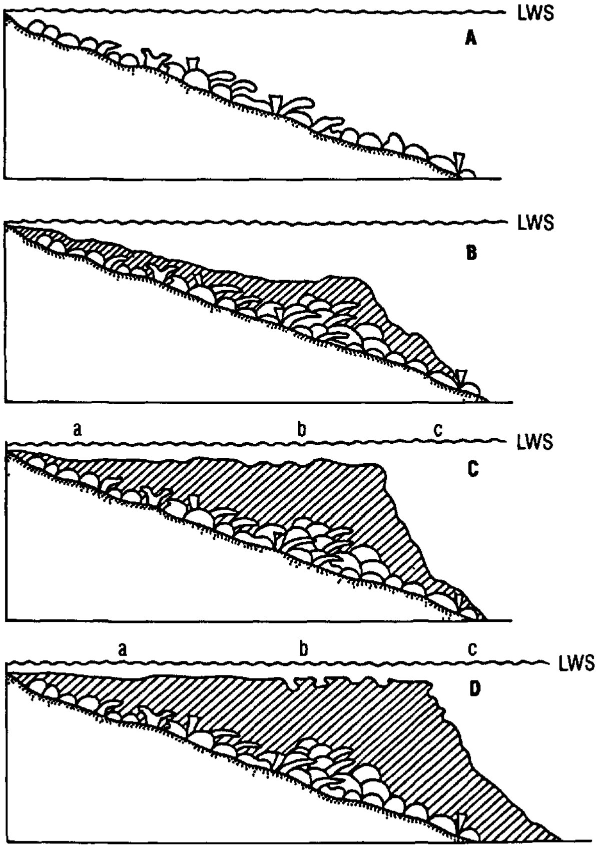

Fig. 6. Different stages of development of a coral reef A, superficial layer of corals on a solid substratum B, Primary framework stage C, Young fringing reef with formative zonation D, Structural reef with clear zonation (a, lagoon, b, reef flat, c, reef slope partially after Pichon 1974)

and 'specialized settlements' and may need a new term Such encrusting reefs, along with the usual structural reefs, are widespread along the shores of Vietnam (Latypov 1982, 1987b, Latypov and Malyutin 1990) Their development is associated with a monsoon climate, constant turbidity, periodic dilution by fresh water and, hence, the periodic destruction of a large number of corals These encrusting reefs form on rocky and rubble-boulder substrata or in turbid conditions and are also known from other regions (Roberts 1972, Zhuang *et al* 1983, Trible and Randall 1985, Latypov 1986, Sakai *et al* 1986) Unfavourable conditions are, on the whole, less continuous than favourable ones and reefs can, therefore, recover and survive The composition and distribution of coral communities on encrusting reefs, forming heterotrophic internal and autotrophic external components of an integral ecosystem (Sorokin 1990) do not differ from such on reefs in terms of a clear pattern of zonation (Latypov 1987b, 1990)

The reefs of the western part of the Baitylong Archipelago, as in the whole of the Gulf of Tonkin, with a high degree of similarity in terms of species composition and distribution of reef-building scleractinians and abundant species diversity (more than one-third of the entire faunistic scleractinians of the Pacific Ocean), in comparison with many other areas of the Indo-Pacific region, are organically part of the Indonesian-Philippine centre of reef formation

Acknowledgement

The author thanks Irina A Barsegova for her help in the preparation of the English text of this paper

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Asian Marine Biology 12 (1995): 39–52

AGE, GROWTH AND ALLOMETRIC RELATIONSHIPS IN *SEPTIFER VIRGATUS* (BIVALVIA: MYTILIDAE).

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Abstract

Age and growth of *Septifer virgatus* (Wiegmann) from six physically contrasting sites on a wave-exposed rocky shore at Cape d'Aguilar, Hong Kong were determined from the pattern of tidally induced microgrowth bands present in the outer nacreous layer of the shell. These bands exhibit a distinct seasonal pattern in their deposition with groups of widely spaced bands alternating with groups of narrower bands produced during periods of reduced linear growth. Two obvious groups of narrowly spaced bands are deposited annually, one during the winter (February to March) when seawater temperatures are at their lowest, the other during the summer (July to August) when mussels are probably subjected to elevated levels of physiological stress. Maximum growth was recorded amongst low shore and shallow subtidal mussels whilst the slowest growth rate occurred in mussels located in high intertidal pools. The maximum estimated age of *S. virgatus* within the six study populations ranged between 4 and 6 years. Significant intersite variations in shell allometry are reported whilst within each population shells become proportionately wider, more elongate and lighter with overall increase in body size.

Introduction

The evolution of the heteromyarian wedge-shaped shell (the typical mussel form) associated with the neotenous retention of the byssus (Seed 1990; Morton 1992) has enabled mytilid mussels to exploit successfully hard or semi-consolidated substrata in coastal and estuarine environments throughout the world. Wherever conditions for attachment and growth are favourable, mussels frequently become the dominant space-occupying organisms (Seed and Suchanek 1992). Mussel beds are characteristically highly productive assemblages (Leigh *et al.* 1987) and as structurally complex entities also provide extensive habitats for a wide range of associated fauna (Suchanek 1985; Ong Che and Morton 1992; Peake and Quinn 1993; Lintas and Seed 1994).

The genus *Mytilus* is widely distributed throughout the cooler waters of both northern and southern hemispheres (Seed 1992 and references therein) but in tropical and subtropical latitudes is replaced by other zone-forming genera such as *Perna* and *Septifer* though *Mytilus galloprovincialis* Lamarck is now known to have been recently introduced into Hong Kong waters (Lee and Morton 1985). Unlike their temperate counterparts, however, these warmer-water mussels have generally been much less intensively studied. Whilst both *Perna viridis* (Linnaeus) and *Septifer virgatus* (Wiegmann) are widespread throughout the coastal waters of Hong Kong, the local distribution of these two mytilids rarely overlaps. Thus, whereas *P. viridis* predominates in the low intertidal and shallow subtidal zones in sheltered, often heavily polluted, waters such as Tolo and Victoria Harbours (Huang *et al.* 1985), *S. virgatus* occurs principally at higher tidal levels on outer wave-exposed shores (Lee and Morton 1985).

In this paper we present some preliminary data concerning the age structure and growth characteristics of *Septifer virgatus* populations from several contrasting habitats on a wave-exposed shore at the southernmost tip of the Cape d'Aguilar peninsula in Hong Kong. These populations are those previously investigated by Seed and Brotohadikusumo (1994) in their study of the spatial variation in the molluscan fauna associated with *S virgatus*

Materials and methods

Random samples of between 219 and 1745 individuals of the finely ribbed *Septifer virgatus* were collected from six physically contrasting sites at Cape d'Aguilar, on the southeastern tip of Hong Kong Island during April 1992 Here, as on wave-exposed shores elsewhere in Hong Kong, *S virgatus* forms a conspicuous dense band approximately 1 0 m wide in the mid littoral zone which expands and narrows with changes in local topography, at other shore levels, *S virgatus* occurs either in scattered groups or as isolated individuals (Morton 1995)

Two locations were selected, one a severely wave-swept rocky promontory, the other only a few metres away, but located immediately inside a narrow inlet and thus receiving considerably more protection from the full force of the breaking waves At each location, random clumps of mussels were collected from the upper and lower margins of the main *Septifer* zone At the wave-exposed location, however, where *S virgatus* was more prolific, samples were also collected from small high shore rock pools and from a point just below low water of spring tides where isolated clumps of larger coralline-encrusted individuals occurred, particularly in the rock crevices

In the laboratory, samples were sorted and shell lengths (maximum anterior-posterior dimension) measured to the nearest 0 1 mm using vernier calipers and the resulting length-frequency distributions separated into their component size classes following the method described by Bhattacharya (1967) Sub-samples, each of 50 mussels, from six populations and covering the size range from approximately 10 mm to the largest individuals present in the sample, were then selected and the shells scrubbed to remove any adhering sediment or encrusting organisms Shell length, height and width of each individual (Fig 1, A) were measured, again to the

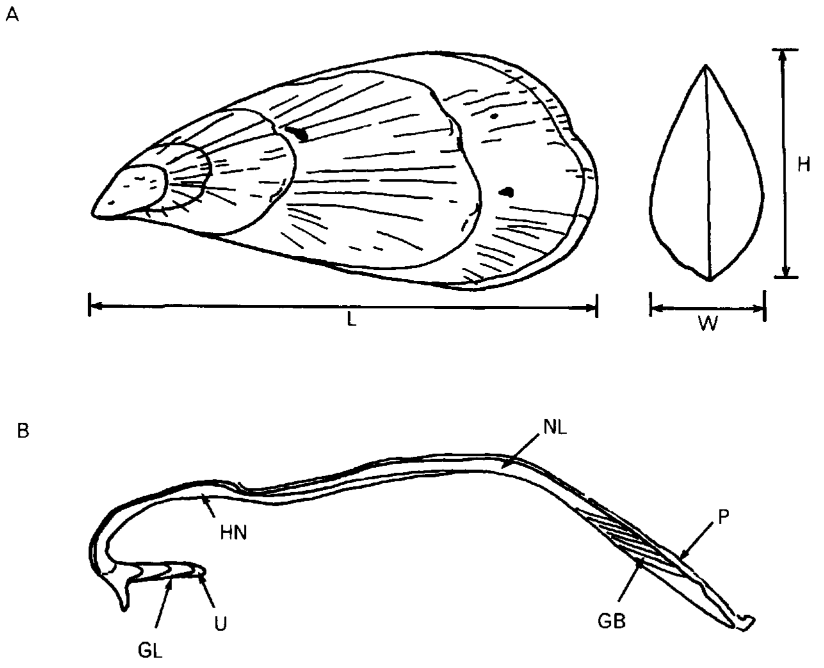

Fig. 1. A Diagram of *Septifer virgatus* showing the measured shell dimensions, height (H), length (L) and width (W) B Schematic section through a shell valve, (GB), tidal microgrowth bands, (GL), growth lines, (HN), homogeneous nacre, (P), periostracum, (NL), outer nacreous layer, (U), umbo

nearest 0 1 mm, and the flesh removed by brief immersion in boiling water Shells and wet flesh (blotted dry) were weighed separately and the flesh then oven dried to constant weight at 60°C All weighings were made to 0 01 g on a top loading balance These data were then examined for evidence of differential growth by testing each pair of size variables x and y for their fit to the allometric equation ($y = ax^b$) which, when logarithmically transformed, becomes ($\log_{10} y = \log_{10} a + b \log_{10} x$) The constants a (intercept) and b (slope) were estimated by regression analysis and pairs of size variables between the six populations compared, using a two-way ANOVA with a covariate, after having first established homogeneity of variance among residuals For a fuller explanation of allometric growth in mussels, see Seed and Richardson (1990)

The internal shell structure of each individual was observed using acetate peel replicas of polished and etched radial sections of resin embedded shell valves Ten of the largest *Septifer* shells from each sample were embedded in Metaset resin (Buehler U K Ltd) and sectioned along the main growth axis using a diamond saw Particular care was taken that each section passed through the umbonal region of the shell (Fig 1B) Each cut radial shell surface was ground on successively finer grit 'wet and dry' paper then on alumina grit, optical grade 50, before finally polishing the cut shell surface on a cloth soaked in household metal polish (Brasso) The polished surfaces were then etched in 0 01M HCl for 25 minutes and acetate peel replicas of these surfaces prepared Once dry, these 'peels' were mounted between a slide and coverslip and viewed under a light microscope

Microgrowth bands visible in the outer nacreous layer (Fig 2) of intertidal *Septifer* are similar in appearance to the tidally induced bands previously described in the shells of intertidal *Mytilus edulis* Linnaeus (Richardson 1989) In *M*

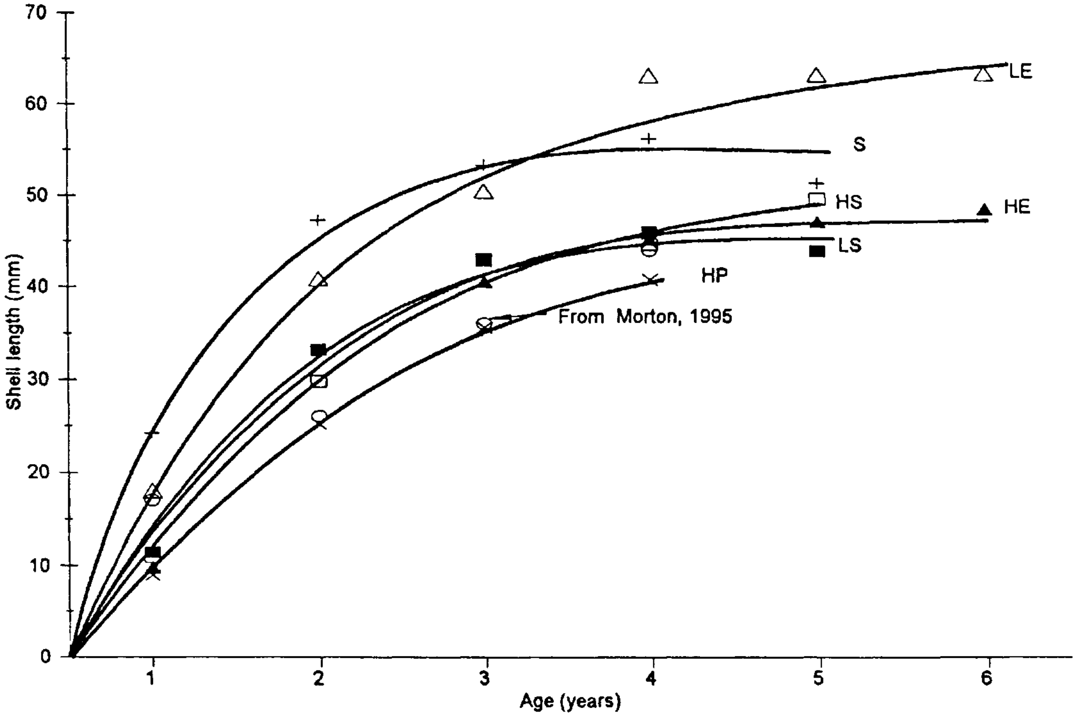

Fig. 2. Growth curves for six populations of *Septifer virgatus* at Cape d'Aguilar, exposed low shore (LE △), subtidal (S +), sheltered high shore (HS □), sheltered low shore (LS ■), exposed high shore (HE ▲), high shore pool (HP X), curves fitted using the von Bertalanffy growth equation (O) growth curve estimated from size frequency data for a low shore wave-exposed population (Morton 1995)

edulis these bands exhibit a distinct seasonal periodicity in their deposition with groups of narrower bands produced during winter when linear shell growth is substantially reduced The overall pattern of banding in *Septifer* is similar except that here there is evidence of two periods of reduced shell growth each year, one occurring during the winter months and another, less marked growth reduction, during the summer Twice yearly periods of reduced shell growth have previously been reported for *S virgatus* (Morton 1995) as well as for other Hong Kong mytilids such as *Perna viridis* (Lee 1985) Our interpretation of the periodicity of these bands in *Septifer* was confirmed subsequently by counting the number of bands between successive periods of reduced growth and showing that these broadly coincided with the number of tidal emersions during the same period The position of the prominent winter group of bands was marked on the coverslip using a permanent marker pen and the linear distance between the umbo and each mark measured using vernier calipers Using these data, the age of each individual could be established and population growth curves constructed Data were fitted to the von Bertalanffy growth function ($L_t = L\infty\ (1 \quad e^{kt})$) and the growth constant (k) and asymptotic maximum shell length ($L\infty$) determined using the Fisheries Programme 'Fishparm'

Results

The arrangement of the different shell layers in *Septifer virgatus* is illustrated in Figure 1B and Plate 1 The shell consists of an outer proteinaceous periostracum (P) (Plate 1F) protecting the surface of the outer nacreous shell layer (NL) (Plate 1C-F) from bacterial decay whilst the inner shell layer is composed of myostracal-type prisms (Plate 1B) (Taylor *et al* 1969) Growth patterns are visible in several areas of the shell In the outer nacreous layer, fine microgrowth bands run approximately parallel to the growing edge of the shell (Plate 1D) while prominent growth lines are present in the inner shell layer (Plate 1B) and in the region of the umbo (Plate 1A) Plate 1C shows the biannual deposition of the narrowly spaced bands in the outer nacreous layer of a young, fast-growing individual, separated by periods of somewhat faster shell growth In older shells, where growth is much slower, these two zones of narrowly spaced bands are generally somewhat less obvious Plate 1A and B show the appearance of growth lines in the umbonal region and inner shell layer respectively Four clear growth lines are evident in the umbonal region (Plate 1A) whereas in the inner shell layer these lines branch or coalesce along the shell section (Plate 1B) Whilst the periodicity of these prominent growth bands remains to be determined, similar bands described for other bivalves are known to be annual (Lutz 1976, Anwar *et al* 1990, Richardson *et al* 1990)

The age of individual mussels was estimated from the growth bands in the outer nacreous layer, whilst the number of growth lines in the umbonal region and inner shell layer were used as independent measures of age Figure 2 shows the linear growth rate of *Septifer virgatus* at Cape d'Aguilar For comparison, the growth rate estimated from the modal progression of size-frequency distributions of an October settlement of *S virgatus* at this locality (Morton 1995) is also illustrated Individuals from the lower zone of the wave-exposed location and those collected subtidally, exhibited the fastest growth whereas individuals from the slightly more protected sites and those from the upper zone at the wave exposed location, had somewhat slower but similar rates of linear shell growth Individuals from the high shore pools had the slowest growth rate which was comparable to that previously reported by Morton (1995) The maximum asymptotic size ($L\infty$) and the growth constant (k), together with their standard errors, are presented in Table 1 The wave-exposed low shore population had a low k value (0 609 ± 0 118) and the highest asymptotic length (66 46 ± 4 57 mm), indicating a relatively slow approach to a large final body size The subtidal and sheltered low shore populations, in contrast, had the highest k values (1 338 ± 0 866 and 0 982 ± 0 376, respectively) and the second highest and the lowest asymptotic shell lengths (55 55 ± 5 50 and 47 16 ± 4 45 mm, respectively) The von Bertalanffy constants for the other populations

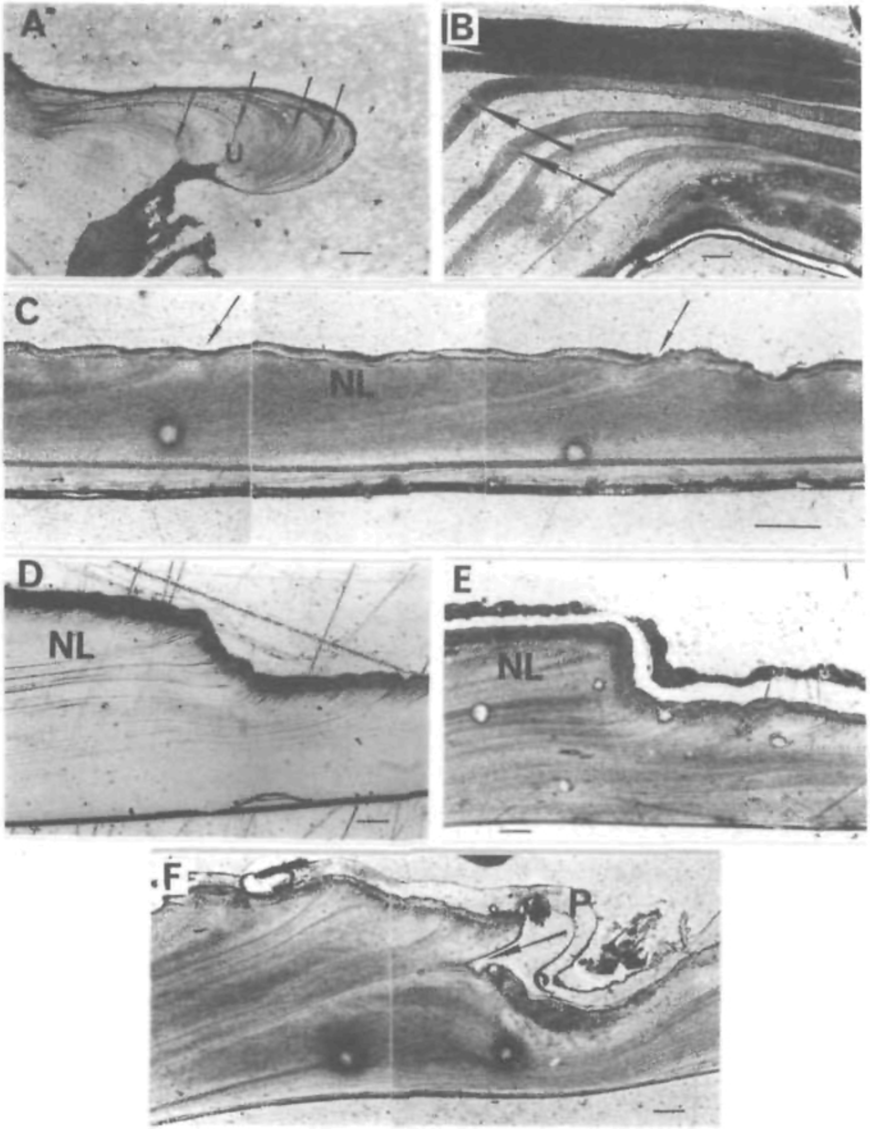

Plate 1. Photomicrographs of acetate peels of *Septifer virgatus* shell sections. A. Growth lines (arrowed) in the umbo region (U). B. Growth lines (arrowed) in the homogeneous nacre layer. C. Groups of narrowly spaced bands in the outer nacreous layer (NL) of a subtidal mussel; two distinct groups of bands (arrowed) are separated by more widely spaced bands. D. and E. Groups of narrowly spaced tidal growth bands in the outer nacreous shell layer (NL). F. Narrowly spaced growth bands (left of figure) and a sudden growth disturbance resulting in a prominent cleft in the shell (arrowed), (P), periostracum.
All scale bars = 200 μm.

were intermediate between these values (Table 1).

Tables 2 and 3 summarize the relationships between various combinations of size variables in terms of the constants b (slope) and a (intercept) of the allometric equation. Shell height was negatively allometric with respect to shell length in all six populations. Shell width generally increased at a relatively faster rate than shell

Table 1. The growth constant (k) and asymptotic shell length (L_∞) estimated from the von Bertalanffy growth function for *Septifer virgatus* from Cape d'Aguilar, Hong Kong.

Site		k (± SE)	L_∞ mm (± SE)
(i)	Wave exposed		
	high shore	0 929 ± 0 210	47 48 ± 2 89
	low shore	0 609 ± 0 118	66 46 ± 4 57
	high pool	0 501 ± 0 336	50 74 ± 1 70
	subtidal	1 338 ± 0 866	55 55 ± 5 50
(ii)	Sheltered		
	high shore	0 665 ± 0 253	52 13 ± 6 50
	low shore	0 982 ± 0 376	47 16 ± 4 45

length although this relationship departed from isometry only in the case of the high shore pool population Shell width was consistently positively allometric with respect to shell height These results indicate that with increase in body size, the shell of *Septifer virgatus* tends to become proportionately wider and more elongate Shell weight in all populations was negatively allometric relative to shell length indicating that the shell becomes proportionately lighter with increasing size, possibly reflecting the greater degree of physical abrasion experienced by the larger, and presumably older, individuals Dry flesh weight was isometrically related to shell length except for individuals from the high shore populations at both the wave-exposed and sheltered locations where this relationship was one of negative allometry and positive allometry respectively Dry flesh weight increased at a relatively faster rate than shell weight (positive allometry) except for high shore individuals at the wave-exposed location, where these two variables were negatively allometric (Table 2) Overall, these data suggest that high shore individuals from the wave-exposed locality are in somewhat poorer condition than those from the other study sites A comparison of the slopes and intercepts (Table 2) estimated using regression analysis of pairs of these size variables indicates that significant intersite differences in shell dimensions and soft body tissues exist between *S virgatus* samples

When analysed by the Bhattacharya (1967) method, these *Septifer virgatus* populations could be resolved into either four, i e , high pool, low exposure, subtidal (Fig 3B and C) or five, i e , high sheltered, high exposure, low shelter (Fig 3A) overlapping size classes While it is possible that these may represent dominant year classes, there is little or no correspondence between the mean size of these cohorts and the mean size at age estimated from analyses of microgrowth patterns, which suggest that up to six year groups may be present within the Cape d'Aguilar population (Fig 3) Some of these year classes, however, particularly those comprising older individuals, may be only poorly represented

In general the mean shell length of individual size (= age?) classes was smaller than the mean length at age obtained from microgrowth patterns, even amongst those populations where the size frequency distributions were most clearly polymodal (Fig 3C) This lack of coincidence between these mean values will of course be due, at least in part, to differences in the time at which these populations were sampled (April) and the time when the annual winter growth bands are deposited within the shell matrix (February to March)

Discussion

Size-frequency distributions within some bivalve populations are characteristically polymodal, each mode representing an individual year class By estimating the mean size of these modal

Table 2. Coefficient of allometry[1] for various combinations of size parameters together with interpopulation comparisons[4] in *Septifer virgatus* from Cape d'Aguilar, Hong Kong

Dependent variable[2] ($\log_{10}$)	Independent variable[3] ($\log_{10}$)	Sheltered		Wave-exposed				F values[4]	
y	x	high	low	high	low	subtidal	pool	slopes	intercepts
Height	Length	0 804*	0 775*	0 717*	0 712*	0 775*	0 822*	7 11†	–
Width	Length	1 060 ns	1 030 ns	1 020 ns	0 997 ns	1 030 ns	1 050*	3 15†	–
Width	Height	1 250*	1 270*	1 350*	1 340*	1 270*	1 200*	0 97	0 62
Shell Weight	Length	2 770*	2 710*	2 770*	2 450*	2 710*	2 680*	9 57†	–
Dry Flesh Weight	Length	3 250*	2 960 ns	2 500*	3 010 ns	2 990 ns	2 930 ns	6 19†	–
Dry Flesh Weight	Shell Weight	1 170*	1 090*	0 878*	1 150*	1 100*	1 080*	7 62†	–

[1] *The coefficient b in the allometric equation*

[2,3] The variables y and x respectively in the allometric equation

* Relationships which depart significantly from isometry at $p < 0\ 05$

ns not significant

[4] ANOVA with covariate, † analysis significant at $p < 0\ 05$ ($F = 2\ 21$ at 5,229 df)

Table 3. Regression constants for various combinations of size parameters in *Septifer virgatus* from Cape d'Aguilar, Hong Kong.

Dependent variable[1] ($\log_{10}$)	Independent variable[2] ($\log_{10}$)	Sheltered						Wave-exposed											
y	x	high			low			high			low			subtidal			pool		
		a[3]	b[4]	r[5]	a	b	r	a	b	r	a	b	r	a	b	r	a	b	r
Height	Length	0.027	0.804	0.942	0.059	0.775	0.961	0.105	0.717	0.947	0.165	0.712	0.959	0.059	0.775	0.958	0.004	0.822	0.946
Width	Length	-0.494	1.060	0.974	-0.444	1.030	0.969	-0.438	1.020	0.963	-0.338	0.997	0.959	-0.444	1.030	0.902	-0.470	1.050	0.973
Width	Height	-0.449	1.250	0.929	-0.464	1.270	0.934	-0.502	1.350	0.909	-0.546	1.340	0.921	-0.464	1.270	0.884	0.393	1.200	0.920
Shell Weight	Length	-3.800	2.770	0.983	-3.750	2.710	0.989	-3.880	2.770	0.981	-3.380	2.450	0.917	-3.640	2.710	0.969	-3.690	2.680	0.983
Dry Flesh Weight	Length	-5.610	3.250	0.966	-5.170	2.960	0.975	-4.580	2.500	0.916	-5.240	3.010	0.964	-5.050	2.990	0.950	-5.180	2.930	0.952
Dry Flesh Weight	Shell Weight	-1.140	1.170	0.974	-1.080	1.090	0.975	-1.070	0.878	0.882	-1.070	1.150	0.910	-1.020	1.100	0.965	-1.150	1.080	0.949

[1] [2] The variables y and x respectively in the allometric equation.

[3] [4] The constants b (slope) and a (intercept) respectively in the allometric equation.

[5] r = correlation coefficient.

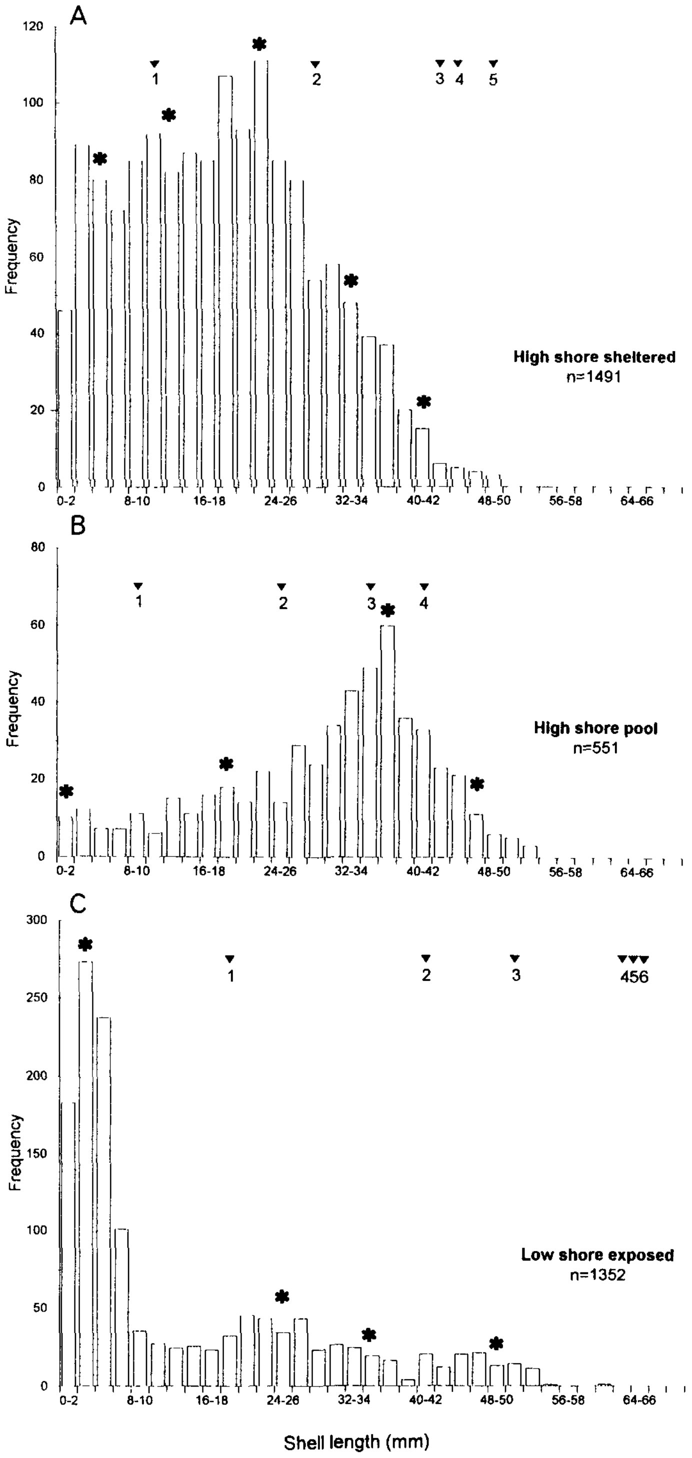

Fig. 3. Size frequency distributions of A, high shore sheltered; B, high shore pool and C, low shore exposed populations of *Septifer virgatus* at Cape d'Aguilar. Asterisks denote mean values of individual size classes, arrow symbols the estimated age (yrs) determined from microgrowth bands in population sub-samples.

distributions, mean population growth rates can be assessed. This, however, is usually possible only when annual recruitment is relatively restricted and where growth rates of individuals within each cohort are fairly uniform (Cerrato 1980). Where recruitment is temporally more extended and individual growth rates are slower and more variable, as in many mussel populations, size classes may overlap to such an extent that size-frequency distributions are of limited value for estimating population growth rate (Kautsky 1982; Richardson *et al.* 1990) (Fig. 3). Moreover, although such distributions have previously been used to estimate mussel growth (Bayne and Worrall 1980; Rodhouse *et al.* 1984) they can only provide a measure of the average growth of individuals within the population, and such estimates may have been substantially modified by size-specific mortality (Seed and Richardson 1990).

Morton (1995) followed successive cohorts of *Septifer virgatus* which recruited onto the shore at Cape d'Aguilar and concluded that although this population comprised six size (year) classes, the majority of individuals within the population probably had a life span of between four and five years. This broadly supports the findings of an earlier investigation in which *Septifer* from Victoria Harbour were estimated to be up to six years of age (Morton 1991). Similarly, in the present investigation, no individuals over six years old were found, strongly suggesting that this could be the normal longevity of *Septifer* in Hong Kong waters. However, Morton (1995) has speculated that some of the large solitary mussels (>60 mm) collected from the low intertidal zone at Cape d'Aguilar may have the potential to live for much longer periods and could possibly be up to twelve years of age.

The absence of old *Septifer virgatus*, particularly from the high shore populations, stands in marked contrast to previous reports for. *Mytilus edulis* in temperate waters where many small, slow-growing, individuals at higher tidal levels may live for over 20 years (Seed 1969). No *S. virgatus* greater than four years of age were found in the high shore pools (Fig. 3). Water temperatures in excess of 40°C have been recorded in mid shore pools at Cape d'Aguilar during July (Liu and Morton 1994) and these temperatures would almost certainly be exceeded in pools at higher tidal levels. Such temperatures are close to those which induce heat coma (44.5°C) in *S. virgatus* (Liu and Morton 1994). It seems likely, therefore, that the unfavourable conditions prevailing in these pools would result in high levels of mortality, especially during summer. Liu and Morton (1994), however, have shown that mortality of *S. virgatus* in mid shore pools was actually lower than for conspecifics on the adjacent open rock surface.

Surface growth rings resulting from seasonal changes in shell deposition have previously been used with varying degrees of success to determine the age of mussels (Seed and Richardson 1990). Although growth rings on the shell surface of *Septifer virgatus* are well defined, external rings in mytilids are often unreliable indicators of age as they can arise not only from seasonal variations in shell growth, but also from environmental disturbance and physiological state (Richardson *et al.* 1980; Richardson 1993). In the present investigation, the age of individual mussels and, thus, population growth rates, were estimated from microgrowth bands present in the outer nacreous layer. Radial shell sections revealed a clearly marked annual pattern in the deposition of these tidally induced bands, with two groups of narrowly spaced bands representing periods of reduced linear growth, produced each year. Whilst one of these groups appears to be associated with low sea water temperatures during winter (February to March), the other appears to be related to a period of post-reproductive stress aggravated by particularly high temperatures during summer (July to August). Our data are, therefore, wholly consistent with earlier reports that two surface growth rings are deposited annually in *S. virgatus*, one in winter, the other separating two phases of gonad maturation and spawning in summer (Morton 1991, 1995). Although coupling between reproductive activity and periods of reduced shell growth has previously been described for other bivalves, e.g., *Spisula solidissima* (Dillwyn) (Jones *et al.* 1978) and *Donax trunculus* (Linnaeus) (Ramón *et al.* 1995), no such correspondence between reproduction and growth was observed in

Chamelea gallina (Linnaeus) (Ramón and Richardson 1992)

For many intertidal marine organisms, including mussels (Seed and Suchanek 1992 and references therein), growth rate is typically inversely correlated with tidal level, thus reflecting the progressively reduced feeding times with increasing aerial exposure Maximum growth rates of *Septifer virgatus* at Cape d'Aguilar occurred amongst low intertidal and shallow subtidal individuals at the more wave-exposed locality, whereas the slowest growth rate, which was comparable to that previously reported by Morton (1995) from analysis of size-frequency data was recorded amongst individuals from the shallow high-shore pools (Fig 3) Although permanently submerged, these pool individuals will presumably periodically experience high seawater temperatures, fluctuating salinities and reduced oxygen levels during periods of particularly calm weather in the summer months

Significant intersite variability in the allometric relationships between *Septifer virgatus* populations has been demonstrated Furthermore, the general pattern of growth at each of the study sites is for individuals to become proportionately wider and more elongate with an overall increase in body size, strongly suggesting that such changes in shell form have adaptive significance The development of a more elongate shell elevates the posterior feeding currents above those of neighbouring conspecifics, whilst increase in shell length and width relative to shell height will effectively enhance physical stability Our results are therefore strikingly similar to those previously described for *Mytilus* (Brown *et al* 1976, Seed 1978, 1980) which, like *S virgatus*, also occurs in densely packed assemblages on wave-exposed rocky shores

Acknowledgements

The authors are grateful for the following financial support C A R (Royal Society travel grant), R S (British Council), R O (British Council and the Swire Educational Trust) and N A B (Unesco) We are particularly grateful to Professor Brian Morton, Director of the Swire Institute of Marine Science (SWIMS), The University of Hong Kong, for his hospitality and provision of facilities during our visit

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Asian Marine Biology 12 (1995): 53–68

FURTHER STUDIES ON THE SUBTIDAL MACROBENTHIC COMMUNITY OF TAI TAM BAY, HONG KONG

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Abstract

This paper presents the results of a second phase of investigations of the subtidal macrobenthic community at Tai Tam Bay, Hong Kong. Bimonthly benthic sampling at three stations was undertaken from March 1989 to January 1991 using a Van Veen grab. Species assemblages were segregated by hierarchical classification into three communities, i.e., those supported by a silt-clay bottom at the inner bay station, a sand bottom at the outer bay station and a mixture of silt-clay and sand at the middle of the bay. The inner bay was characterized as the *Sigambra tentaculata* – *Veremolpa scabra* – *Aglaophamus toloensis* community, the outer bay as the *Corophium* sp. 1– *Hyale grandicornis* – *Branchiostoma belcheri* community and the transition zone as the *Chaetozone* spp. – *Ampelisca cyclops* – *Mediomastus californiensis* community on the basis of their Biological Index of Dominance averaged over four years of sampling. Dominant species at each station are listed. The five most abundant species at the middle and outer bay stations comprised between 28 and 48 % of the total abundance indicating weak dominance, in contrast to the inner bay station. Species diversity during the sampling period averaged 2.76, 4.46 and 4.36 at the inner, middle and outer bay stations, respectively. Evenness and species richness averaged 0.70, 0.90, 0.84 and 2.62, 4.69, 5.73 at the three stations, again respectively. Seasonal variations in diversity index were correlated with summer recuitment of some species.

Water quality of Tai Tam Bay showed a general improvement in 1989-1991, as compared with 1987-1989, evidenced by the increased species diversity index for the bay as a whole, the lack of inflection in log-normal plots of species abundance and the increased number of low abundance species. The comparatively lower diversity index in the inner bay and the continued dominance of *Sigambra tentaculata*, an indicator of moderate pollution, however, remain as points of concern for the fragility of the Tai Tam Bay system. Continued monitoring of the area is recommended and a list of indicator species which occur in the intermediate abundance groups and which could be the focus of monitoring is provided.

Introduction

Tai Tam Bay (22°13' N, 114°14' E) is a dog-leg shaped inlet on the southern coast of Hong Kong Island. It was gazetted as a Site of Special Scientific Interest (SSSI) in 1974 (Agriculture and Fisheries Department 1974) to supposedly protect the diversity of intertidal communities occurring there. Situated in the eastern region of the Southern Water Control Zone, declared by the Hong Kong Government in August 1988, it lies between the Stanley and the Cape d'Aguilar peninsulas. At the tip of the latter is the Cape d'Aguilar SSSI, Hong Kong's first proposed marine reserve.

A collaborative study between The University of Hong Kong and the Environmental Protection Department of the Hong Kong Government was undertaken from February 1987 to January 1989 which established the baseline environmental status of Tai Tam Bay with regard to water quality and sediment chemistry (Lui 1991), the subtidal macrobenthic community (Ong Che and Morton 1991) and phytoplankton dynamics and productivity (Chan *et al.* 1991). The studies found the bay waters to be generally 'clean'. A potential problem of eutrophication was, however, suggested by the lower benthic species diversity indices and higher chlorophyll *a* values at the innermost bay station. The studies recommended continued monitoring to delineate long-term trends in the area, but at a reduced number of stations, i.e., three instead of five, in part to determine if such a minimized data set could still monitor the bay's benthic community effectively.

This study is a response to that recommendation and reports upon a further two-year investigation of the subtidal macrobenthic community of Tai Tam Bay. Ecological studies have been undertaken in the area over a period of 15 years and their findings are discussed in an attempt to define overall trends in environmental quality.

Materials and methods

Collection and treatment of samples

Bimonthly sampling was carried out on board the marine monitoring vessel of the Environmental Protection Department of the Hong Kong Government, for two years from March 1989 to January 1990 (designated 1989 in this paper) and from March 1990 to January 1991 (designated 1990). Three replicate samples were obtained with a Van Veen grab (0.5 m^2) from three stations, i.e., Stations 1, 4 and 5 of the 1987-1989 study (Ong Che and Morton 1991) in Tai Tam Bay and situated in the inner, middle and outer regions of the bay, respectively. The locations of the stations are identified in Lui (1991, Fig. 1) as SM31, SM34 and SM35, respectively. Samples were washed on board through a 0.5 mm sieve and the residue preserved in 5% neutral formalin stained with Rose Bengal. Sorting procedures were as described in Ong Che and Morton (1991). Specimens were identified using the reference collection lodged at The Swire Institute of Marine Science, The University of Hong Kong.

Dominant species

Species were ranked according to their contribution to the percentage numbers of total individuals in the pooled two years' samples. Dominant species were also selected by means of the Biological Index of Dominance (B.I.D.) (Fager 1957). This method determines the relative abundance of the species using rank-score analysis on a 5-point system. In a given sample, the most abundant species was given 5 points, the next most abundant 4 points and so on. The points for each species over the entire study period were totalled and the species ranked

Seasonal trends

Species diversity (*H'*), Evenness Index (*J'*) (Pielou 1966) and Species Richness (*D'*) (Margalef 1958) were calculated as follows :

$$H' = -\sum_{1}^{S} \frac{N_i}{N} \ln \frac{N_i}{N}$$

$$J' = \frac{H'}{\ln S}$$

$$D' = \frac{S - 1}{\ln N}$$

where N_i is the number of individuals in the i-th species, N the total number of individuals in a sample and S the total number of species. Seasonal variations in diversity indices were examined by plotting them against time for each station.

Community patterns and seasonal differences in species composition were further analysed using agglomerative hierarchical classification. The data were logarithmically transformed (ln (x + 1)) before clustering. Similarity between station – time groups was calculated using squared Euclidean distances. Clustering utilized the group – average linkage which defines the distance between two clusters as the average of the distances between all pairs of cases in which one member of the pair is also a member of one of the clusters. This method differs from other linkage methods in that it uses information about all pairs of distances and not just the nearest (nearest neighbour technique) or the farthest (farthest

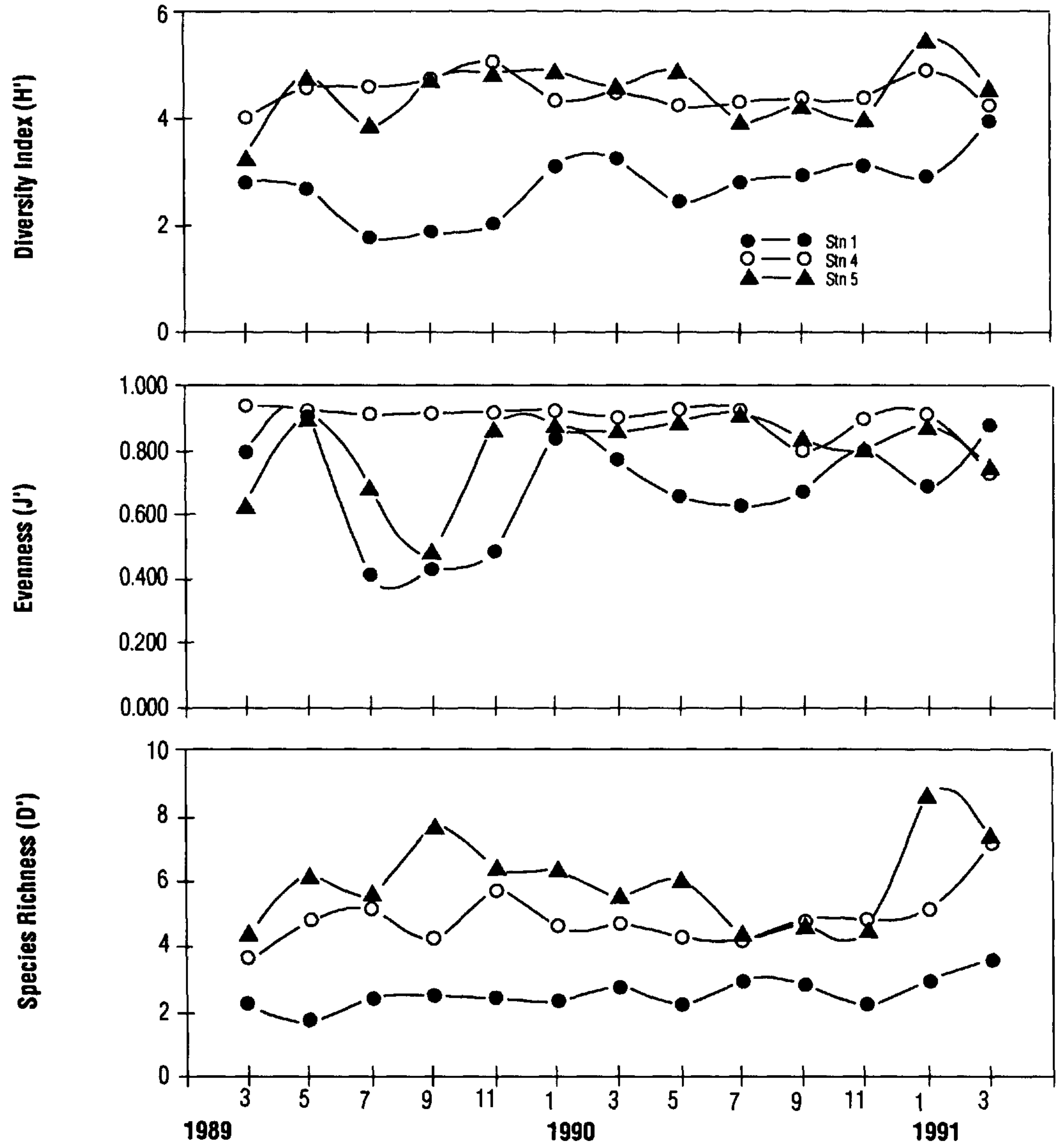

Fig. 1. Seasonal variations in Species Diversity (*H'*), Evenness (*J'*) and Species Richness (*D'*) at three stations in Tai Tam Bay, Hong Kong.

neighbour technique) (Clifford and Stephenson 1975; Norusis 1988).

Log-normal plots

The 'health' of the Tai Tam benthic communities was examined by the method of Gray and Mirza (1979). Log-normal plots of the cumulative percent of species in different geometric classes (x 2 scale) were constructed for inner, middle and outer bay stations, i.e., stations 1, 4 and 5, using the combined faunal data for each year. Plots were also made using the percentage number of species on the ordinate in order to identify the species in the community which occurred in intermediate numbers and which could serve as potential indicators of pollution (Pearson *et al.* 1983).

Results

Faunal analysis

The 5741 individuals collected from three stations within Tai Tam Bay were distributed among 85 species of which annelids, molluscs and arthropods together comprised more than 82% of the total number of individuals and more than 90% of the total number of species recorded. Table 1 shows the percentage distribution of species and individuals among the major taxa at the three stations.

Table 1. Percentage numbers of species (A) and of individuals (B) recorded for different faunal groups sampled in 1989 - 1990 at three stations within Tai Tam Bay.

A. Numbers of species (%)

	Stations		
	1	4	5
Polychaeta	77	60	50
Mollusca	15	5	8
Crustacea	8	25	35
Others	0	10	7

B. Numbers of individuals (%)

	Stations		
	1	4	5
Polychaeta	78	67	34
Mollusca	20	2	3
Crustacea	2	28	45
Others	0	3	18

Dominant species

Table 2 lists the dominant species, ranked by their percentage representation in the pooled samples and by the Biological Index of Dominance (B.I.D.) obtained for stations 1, 4 and 5 in 1989 - 1990. The five most dominant species at Station 1 were the same in 1989 and in 1990. Dominance ranking, based on the two methods used, differed, however. Numerical abundance of *Veremolpa scabra* decreased from 67.6 % to 16.6% while that of *Minuspio* sp. and *Sigambra tentaculata* increased from 6.3% to 32.6 % and from 3.5% to 8.2%, respectively. This may be due to the bias arising from high catches of some species in some seasons. The ranking of the five dominant species at Station 1 remained unaltered between the 1989 and 1990 sampling years on the B.I.D. scale.

In contrast, community dominants at Station 4 changed between 1989 and 1990. In 1989, all of the dominant species except one were polychaetes, whereas in 1990, polychaetes comprised only half of the dominant species list. Interestingly, the five most abundant species at this station made up only 28% of the total numbers sampled, indicating their weak dominance. The remaining 72% of the individuals recorded comprised species occurring in the low abundance spectrum.

Community dominants at Station 5 were mostly non-polychaete species. Half of these were amphipods. The change in the dominant taxa between Stations 1, 4 and 5 correlates with a shift in substratum type from mud in the inner bay to sand in the outer. While absolute ranking changed between the two sampling years, the dominant species selected by the two methods remained largely the same. Similar to the observation noted for Station 4, the community recorded at Station 5 comprised many 'rare' species.

Diversity indices

Table 3 shows the mean, median, maximum and minimum values of Species Diversity, Evenness and Species Richness at the three stations in Tai Tam in 1989 and 1990. Mean diversity ranged from 2.52 and 3.01 in the inner bay and increased to 4.44 and 4.29 at the outer bay in 1989 and 1990, respectively. T - tests comparing diversity indices between years indicate, however, that differences were not significant.

Species diversity over the two-year sampling period averaged 2.76, 4.46 and 4.36 at Stations 1, 4 and 5, respectively. According to the criteria used by Jhingran *et al.* (1989), Station 1 within Tai Tam Bay is moderately polluted ($H' = 1 - 3$) while Stations 4 and 5 enjoy clean waters ($H' > 3$). Evenness averaged in the same way showed greatest equitability at Station 4 ($J' = 0.90$) as compared with 0.70 at Station 1 and 0.84 at

Table 2. Dominant species ranked on the basis of percentage representation in pooled samples and on the Biological Index of Dominance (B.I.D.). A, 1989; B, 1990.

A 1989

Station 1	%	Cumulative %	B I D
Veremolpa scabra (Hanley, 1845)	67 6	67 6	1
Minuspio sp	6 3	73 9	2
Aglaophamus toloensis (Ohwada)	4 1	78 0	3
Sigambra tentaculata (Treadwell, 1941)	3 5	81 5	2
Chaetozone spp	2 1	83 6	4
Theora lata (Hind, 1944)			5
Station 4			
Sigambra tentaculata (Treadwell, 1941)	7 5	7 5	1
Aglaophamus toloensis (Ohwada)	7 4	14 9	3
Sternaspis scutata (Renier, 1807)	5 1	20 0	2
Chaetozone spp	4 4	24 4	5
Mediomastus californiensis (Hartman, 1944)	4 3	28 7	
Ampelisca cyclops			4
Station 5			
Corophium sp 1	18 2	18 2	2
Hyale grandicornis	14 6	32 8	1
Branchiostoma belcheri (Gray)	6 4	39 2	4
Prionospio sp	4 8	44 0	5
Golfingia misakiana (Ikeda, 1904)	4 0	48 0	3

B 1990

Station 1	%	Cumulative %	B I D
Minuspio sp	32 6	32 6	2
Veremolpa scabra (Hanley, 1845)	16 6	49 2	1
Aglaophamus toloensis (Ohwada)	9 6	58 8	2
Sigambra tentaculata (Treadwell, 1941)	8 2	67 0	3
Chaetozone spp	5 5	72 5	4
Copepoda spp			5
Station 4			
Ampelisca cyclops	7 1	7 1	2
Chaetozone spp	6 5	13 6	1
Mediomastus californiensis (Hartman, 1944)	5 7	19 3	1
Aglaophamus toloensis (Ohwada)	5 0	24 3	4
Sigambra tentaculata (Treadwell, 1941)	4 0	28 3	
Amphipoda sp 8			3
Caprella aequilibra			4
Prionospio saccifera (Mackie and Hartley)			4
Golfingia misakiana (Ikeda, 1904)			5
Station 5			
Corophium sp 1	9 8	9 8	
Hyale grandicornis	5 4	15 2	4
Podocerus sp	5 1	20 3	1
Ophiura kinbergi (Ljungman)	4 1	24 4	2
Prionospio sp	3 5	27 9	
Branchiostoma belcheri (Gray)			3
Ampelisca cyclops			5

Table 3. Mean, median, maximum and minimum values of Species Diversity (*H'*), Evenness (*J'*) and Richness (*D'*) at three stations (1, 4 and 5) in Tai Tam in 1989 - 1990. T-test results comparing diversity values between years are also presented.

	Diversity		Evenness		Richness	
	1989	1990	1989	1990	1989	1990
Station 1						
Mean	2.52	3.01	0.66	0.73	2.37	2.87
Median	2.70	2.96	0.76	0.66	2.80	2.95
Maximum	3.26	3.98	0.91	0.82	1.75	3.66
Minimum	1.78	2.49	0.41	0.66	2.43	2.29
t-test	-1.28	n.s.	-0.74	n.s.	-1.89	n.s.
Station 4						
Mean	4.48	4.44	0.92	0.87	4.26	5.12
Median	4.58	4.36	0.92	0.91	4.59	4.85
Maximum	5.08	4.93	0.94	0.93	5.71	7.26
Minimum	4.01	4.27	0.91	0.74	2.14	4.25
t-test	-0.72	n.s.	1.32	n.s.	-1.90	n.s.
Station 5						
Mean	4.44	4.29	0.80	0.87	6.03	5.43
Median	4.75	4.28	0.87	0.88	6.20	4.71
Maximum	4.92	5.51	0.90	0.97	7.69	8.72
Minimum	3.27	2.70	0.63	0.75	4.36	2.19
t-test	-0.50	n.s.	-1.65	n.s.	0.28	n.s.

Station 5. The two-year averages of species richness for the outer bay Stations 4 and 5 were 4.69 and 5.73, respectively, which are almost double that recorded for Station 1 (*D'* = 2.62).

Figure 1 presents graphs of Species Diversity, Evenness and Species Richness over time. Species diversity indices at the outer stations (4 and 5) were consistently higher throughout the year, as compared with the inner station (1). A parallel trend was obtained for species richness, with the highest values being recorded from Station 5 and the lowest from Station 1, throughout the year. Evenness was relatively constant at Station 4, with only a slight decline in September 1990 and March 1991. In contrast, Stations 1 and 5 showed greater fluctuations. The reductions in evenness which occurred in summer (July to September) at these stations were more pronounced in 1989 than in 1990. Recruitment of some species in summer, e.g., *Veremolpa scabra* and *Minuspio* sp. at Station 1, and *Corophium* sp. 1 and *Hyale grandicornis* (= *Hyale* sp. 1, Ong Che and Morton 1991) at Station 5 accounted for the decrease in evenness during this period. Counts of *V. scabra* and *Minuspio* sp. peaked at 293 and 385 individuals·sample^{-1}, respectively, at the height of the summer recruitment. Relative abundance of *Corophium* sp. 1 and *H. grandicornis* reached 174 and 132 individuals·sample^{-1}, respectively. A less pronounced fall in evenness in March 1991 at Station 5 resulted from high catches of *Hyale* sp. 2 (188 individuals·sample^{-1}, *Musculus nanus* (140), *Podocerus* sp. (123) and *Iphinoe* cf. *sagamiensis* (168) all of which are recruited in winter.

Figure 2 compares the mean Species Diversity Index for the whole of Tai Tam Bay over a period of 15 years. Species diversity, as reported in the first study on the Tai Tam benthos (Shin 1977), averaged 3.90 in 1975. Diversity decreased to 3.32 in 1987-1988 (Ong Che and Morton 1991) and a return to original levels is recorded in the present

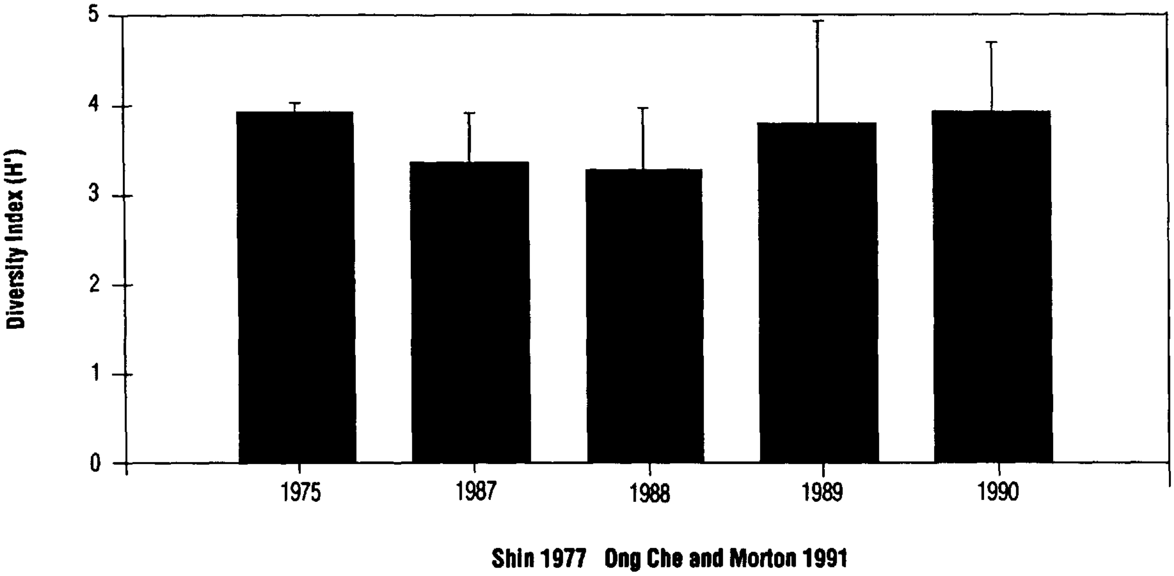

Fig. 2. A comparison of Species Diversity Indices (*H'*) of the Tai Tam Bay macrobenthic community reported upon in this and previous studies over a period of 15 years.

study (*H'* = 3.86). Following the criteria specified in Jhingran *et al.* (1989), Tai Tam Bay has, therefore, experienced generally good water conditions over the past 15 years.

Hierarchical clustering

Results of the hierarchical classification of the 1989 - 1990 species abundance data are presented in Figure 3. The similarity index on the ordinate axis has been converted to rescaled distance where smaller distances indicate greater similarity.

The present analysis of data obtained from three stations with three replicates each has verified the community patterns defined by the classification of the 1987 - 1988 faunal data obtained from five stations with five replicates each (Ong Che and Morton 1991). Stations were segregated (cfr. station column, Figure 3), indicating differences in the species composition of the three areas of the bay, i.e., Station 1 in inner Tai Tam, Station 5 in outer Tai Tam and Station 4 in between these two areas. This segregation correlates well with the substratum type occurring at these three sections of the bay, i.e., silt–clay, sand and mixed silt–clay and sand, respectively.

Some interspersion of contiguous stations occurs, however, reflecting an overlap in species distributions between stations. The mid-bay transition community (Station 4) showed greater species overlap with the inner bay mud community than with the outer bay sand community. This suggests that the benthic communities of Tai Tam Bay are not strictly delimited and conform to the concept of communities as a continuum of species distributions (Gray 1981). The presence of such community gradients within the bay is also reflected in the clustering schedule which shows many small increments in distance, that is, clustering of similar groups.

The analysis of station, replication and time (month, year) groups shows that replicates were representative of the area sampled. The three replicate samples were clustered in consecutive steps in 18 out of the 114 clustering stages while two out of the three replicates were similarly grouped in 30 out of the 114 steps (cfr. replicate column, Figure 3).

No strong seasonal differences in species composition were apparent from the classification results. Seasonal cycles in benthic communities

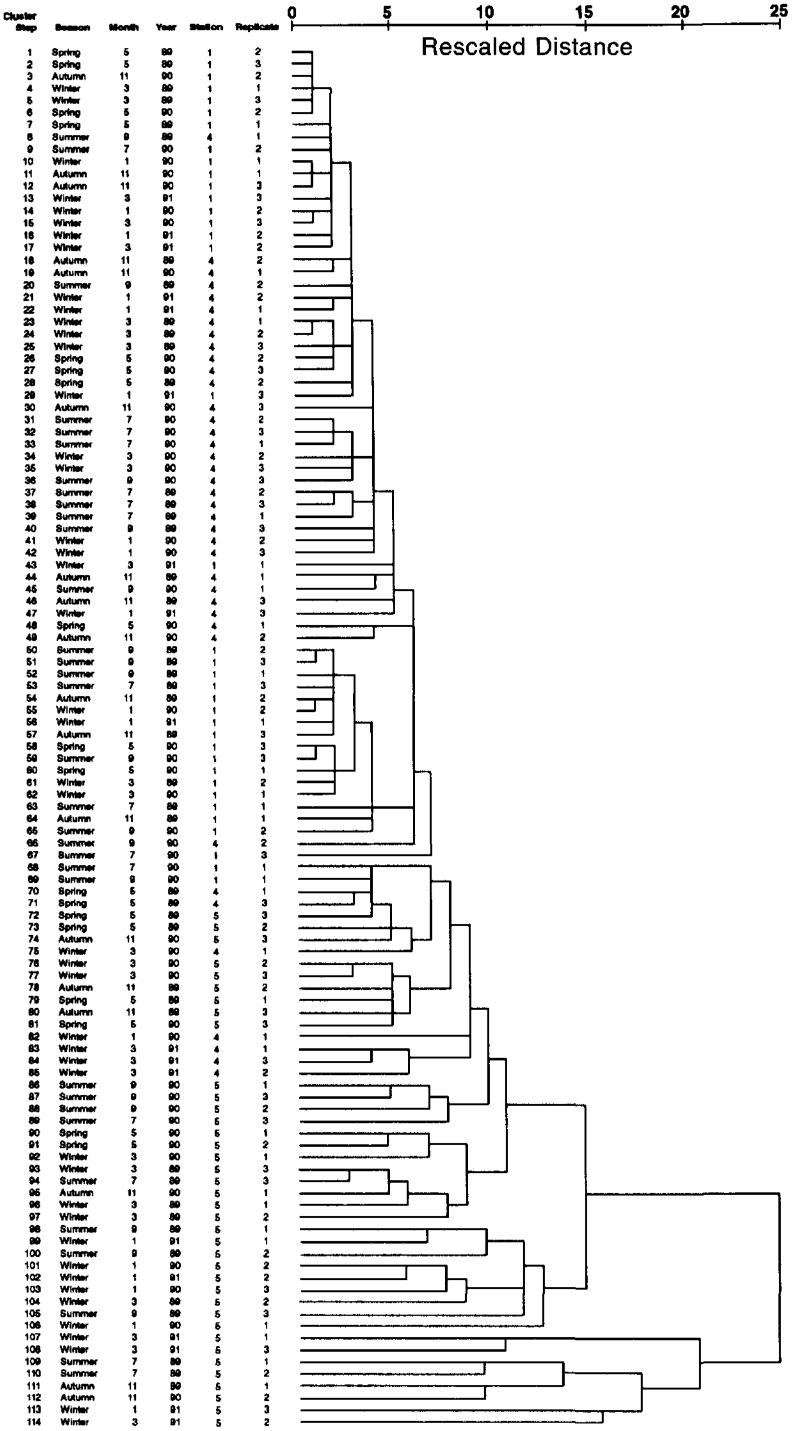

Fig. 3. Hierarchical agglomerative classification analysis of station - replicate - time (months, years) groups within Tai Tam Bay. Squared Euclidean distances on the ordinate have been rescaled to fall within the range 1 - 25. Smaller distances indicate greater similarity.

are strongly influenced by annual variations in temperature, light, primary production and related factors (Gray and Mirza 1981). In subtropical Hong Kong, water temperatures in three seasons (winter, spring and autumn) are similar and fall within a narrow range (15.5-21.1°C). Distinctly higher temperatures occur in summer (25.2-28.1°C). Thus, in the classification analysis, winter, spring and autumn samples are generally unsorted and species assemblages may only be different between the cooler times of the year and summer (cfr. season and date columns, Figure 3).

Log-normal plots

Log-normal plots of the cumulative percentage of species in different geometric classes are shown in Figure 4 for the 1989 - 1990 data from Stations 1, 4 and 5. A single, steep, slope was obtained for all the stations in both years. The number of geometric classes was low, ranging from six at Station 4 to a maximum of eight at the other two stations.

Figure 5 presents log-normal plots of the number of species against the number of individuals·species^{-1} in geometric classes for the consolidated faunal data (1987 - 1990) from Stations 1, 4 and 5 at Tai Tam. The time series plots show a log series distribution with the majority of the species being represented by one individual·sample^{-1} (geometric class 1). The range of geometric classes decreased from between 8 to 10 in the 1987 - 1988 sampling period to between 6 to 8 in 1989 - 1990, indicating that fewer species in the higher abundance classes were recorded during the second phase of sampling .

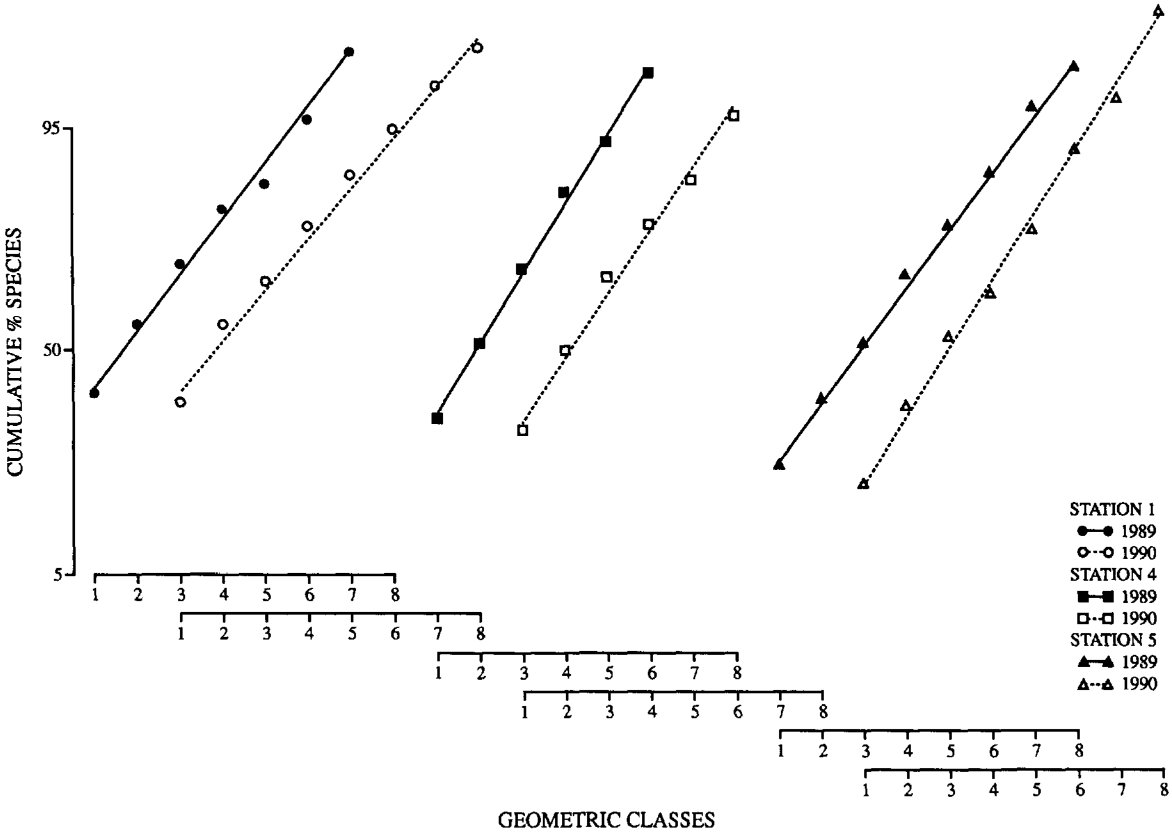

Fig. 4. Log-normal plots of individuals·species^{-1} sampled in the 1989 - 1990 survey of three stations (1, 4 and 5) in Tai Tam Bay.

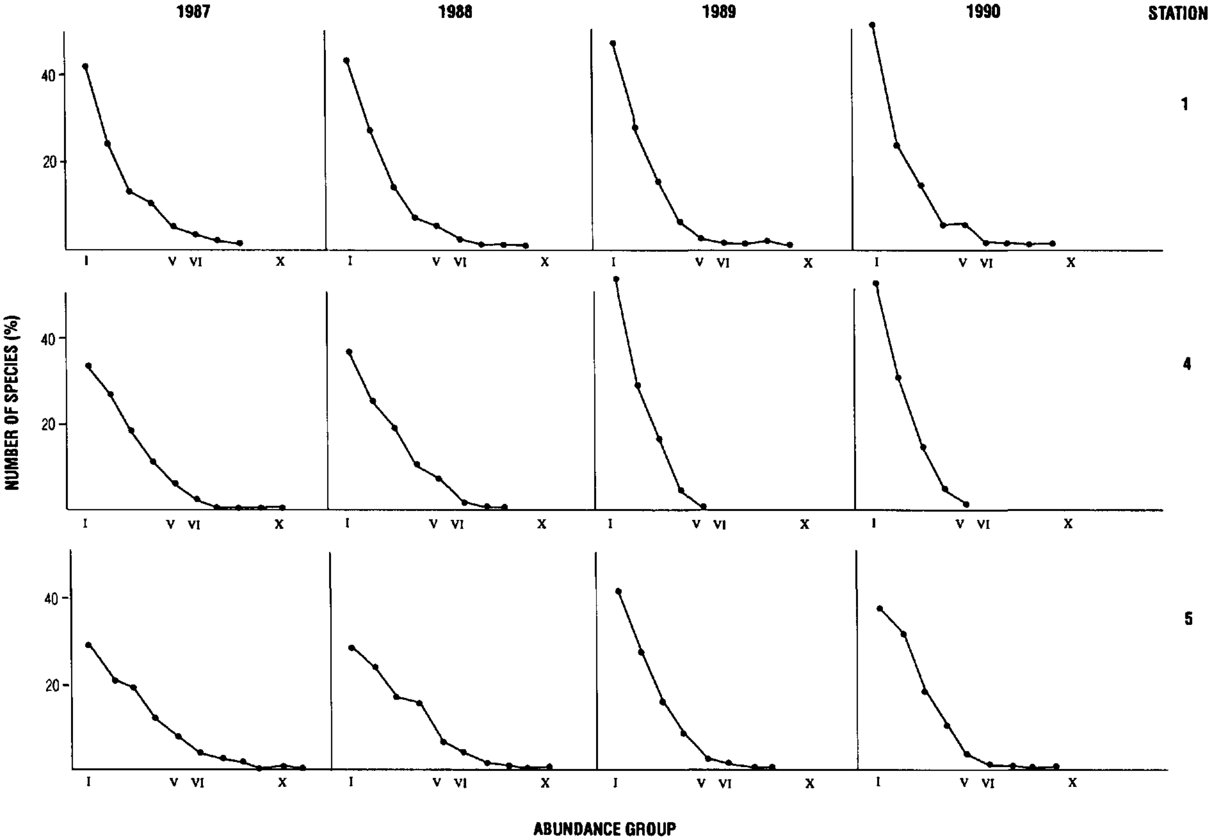

Fig. 5. Plots of percentage number of species in different geometric classes for the faunal data obtained from two surveys of Tai Tam Bay in 1987 - 1988 and 1989 - 1990.

When the lower abundance groups were compared over the two sampling periods, more species were recorded in low numbers (geometric classes I to IV) in 1989 - 1990. Looking at the bay as a whole, therefore, 37 to 53% of the species recorded fall in geometric class I in 1989-1990 in contrast to between 28 to 43% in 1987-1988. Similarly, the percentage of species in the intermediate abundance group (geometric classes V and VI) decreased over the two sampling periods at both Stations 1 and 5, i.e., from 5% to 1% and from 8% to 1%, respectively. This change was even more obvious at Station 4 where no species had a relative abundance greater than 32 individuals·sample^{-1} (geometric class VI) in 1989-1990.

Pearson *et al.* (1983) noted that unpolluted areas are characterized by a concentration of species in the low abundance groups and that no species occur in geometric classes higher than VII. The Tai Tam log-normal plots reflect this situation, especially in 1989-1990.

The species in abundance classes V and VI are listed in Table 4. None of these species has been reported to be pollution indicators. Some related species are, however, known to have wide ecological requirements and are indicators of environmental perturbation. Examples of such related species are *Chaetozone setosa*, *Lumbrinereis latreilli* and *Prionospio malmgreni* (Food and Agriculture Organization 1986).

Table 4. Species in abundance classes V and VI at the three stations in Tai Tam Bay sampled in 1989-1990.

	Geometric class V (16-31 individuals·species^{-1})	Geometric class VI (32-63 individuals·species^{-1})
Station 1		
1989	*Minuspio* sp. *Pseudopolydora* sp.	*Veremolpa scabra*
1990	*Minuspio* sp. *Chaetozone* spp. *Pseudopolydora* sp. *Sigambra tentaculata* *Aglaophamus toloensis*	*Veremolpa scabra* *Prionospio saccifera*
Station 4		
1989	*Mediomastus californiensis* *Chaetozone* spp. *Aglaophamus toloensis*	
1990	*Ampelisca cyclops* *Caprella aequilibra*	
Station 5		
1989	*Campylaspis angularis* *Corophium* sp. 1 *Glycera alba* (Fauvel, 1923) *Hyale grandicornis* *Loimia medusa* *Lumbrinereis nagae* (Gallardo, 1968) *Minuspio* sp. *Ophiura kinbergi* *Podocerus* sp. *Prionospio* sp. *Golfingia misakiana*	*Branchiostoma belcheri*
1990	*Branchiostoma belcheri* *Ampylaspis angularis* *Corophium* sp. 1 Amphipoda sp. 1 *Hyale grandicornis* *Mactra* sp. 1 *Podocerus* sp. *Prionospio* sp. *Colelepis* sp. *Stenothoe* sp.	*Caprella aequilibra*

Discussion

Community structure

Benthic communities have traditionally been characterized by the dominant species occurring in them. According to Petersen (1915) who undertook the first quantitative study on the marine benthos of Northern Europe, these community-characterizing species should have two traits, that is, either numerical or biomass dominance, and a recurring presence within the community.

In their study of the spatial distribution of the infaunal benthos of Hong Kong, Shin and Thompson (1982) delineated five communities using agglomerative hierarchical classification. They declined to name these five communities after the three most dominant species, however, because of low fidelity. Several of the dominant species occurred in more than one of the five community groupings.

In the present study, low fidelity was also observed, resulting from communities not being delineated by rigid boundaries. A few of the dominant species selected by percentage representation in pooled samples and by their Biological Index of Dominance ranking were recorded from more than one station. The abundance of these species at the different stations differed, however. *Prionospio* sp., for example, comprised ≈ 20% of the total individual numbers at Station 1 but less than 3% at Station 5. Conversely, *Stenothoe* sp. comprised ≈ 18% of the total abundance at Station 5 in contrast to ≈ 4% at Station 1.

Brown (1984) discussed the relationship between species abundance at different spatial scales and niche size. According to Brown, a species is most abundant at the centre of its niche and decreases in numbers towards the edge. The intergradation of communities within Tai Tam Bay need not, therefore, invalidate characterizing these communities after the dominant species. Communities can be named after the dominant species which occur at the centre of their niches.

The Biological Index of Dominance (B.I.D.) ranking of Fager (1957) selects the numerically important and recurring species *sensu* Petersen. By taking the mean of the B.I.D. ranks of the five most dominant species over the four sampling years at each station, the communities at the three stations within Tai Tam Bay can be named (Table 5). Station 1, in the inner bay can be characterized as the *Sigambra tentaculata – Veremolpa scabra – Aglaophamus toloensis* community (in the order of decreasing dominance), Station 4, in the transition zone, as the *Chaetozone* spp. – *Ampelisca cyclops – Mediomastus californiensis* community and Station 5, in the outer bay, as the *Corophium* sp. 1 – *Hyale grandicornis – Branchiostoma belcheri* community. The communities thus named reflect high fidelity.

In a study on the benthic communities of Tolo Harbour and Mirs Bay, Shin (1990) delineated three major location groups by agglomerative hierarchical classification, representing different infaunal communities in Tolo Harbour, Tolo Channel and Mirs Bay. Although the animal assemblages in these three locations showed intergrading dominance of species, the fidelity of key species in characterizing the particular location was high. Thus, the urchin *Schizaster lacunosus*, the ophiuroid *Ophiura kinbergi* and the venerid bivalve *Paphia undulata* were confined to Mirs Bay, the polychaetes *Prionospio ehlersi* and *Lagis koreni* to Tolo Channel and the polychaetes *Sigambra tentaculata, Minuspio cirrifera, Tharyx* sp. and *Leonnates persica* to Tolo Harbour.

Of the polychaetes dominant in Tolo Harbour, two are associated with areas of environmental stress. *Minuspio cirrifera* has been regarded as an indicator species of moderate organic pollution at Oslofjord, Norway, by Mirza and Gray (1981) and at Victoria Harbour, Hong Kong, by Thompson and Shin (1983). *Sigambra tentaculata* has also been reported in great numbers in an anoxic basin at Golfo Dulce, Costa Rica by Nichols-Driscoll (1976). The presence of these pollution indicator species in Tolo Harbour, together with information from other studies describing environmental deterioration in the area (Wong, *et al.* 1977; Thompson *et al.* 1982, Wu 1982; Hodgkiss and Chan 1983; Morton 1985) led Shin (1990) to conclude that the benthic infauna of Tolo Harbour represented a stressed community.

In the present study, both *Sigambra tentaculata* and *Minuspio* sp. are recorded as dominant species in the inner Tai Tam Bay area (Table 2). This interesting parallel in the pollution indicating polychaete species occurring at inner Tolo Harbour and inner Tai Tam Bay suggests that the environmental changes which have been affecting the Tolo Harbour infaunal community may be operating at inner Tai Tam Bay as well, albeit at a less intense degree.

Species richness was consistently lower in the inner bay (Station 1) compared to the outer bay (Station 5) during the two phases of sampling spanning four years. Lui (1991) reported temperature stratification of the water column in Tai Tam during the summer months and that this

Table 5. Consolidated dominant species list at Tai Tam Bay. The five most dominant species and the mean B.I.D. ranks are shown. Ties were given average ranks and species not among the top five that year were given an arbitrary rank for calculation of the mean B.I.D. rank.

Station 1	1987	1988	1989	1990	Mean
Veremolpa scabra	1		1	1	3 5
Minuspio sp	2 5		2 5	6 8	
Aglaophamus toloensis	3		2 5	4	3 4
Chaetozone spp			5	5	8 0
Theora lata	5	4 5	6	6 6	
Copepoda sp				6	9 8
Nephtys polybranchia (Southern, 1921)	2	1			6 2
Prionospio saccifera		4 5			9 4
Merisca sp		2			8 8
Diastolopsis sp 1		6			9 8
Station 4					
Sigambra tentaculata			1		11 5
Aglaophamus toloensis			3	6	9 8
Sternaspis scutata			2		11 8
Chaetozone spp	3	3	5	1 5	3 1
Mediomatus californiensis		1		1 5	8 1
Ampelisca cyclops		2	4	3	6 0
Amphipoda sp 8				4	12 2
Caprella aequilibra				6	11 5
Prionospio saccifera				6	11 5
Golfingia misakiana				8	12 0
Stenothoe sp	1				11 5
Prionospio sp	2				11 8
Magelona crenulifrons		4			12 2
Nephtys polybranchia	5	5			10 0
Diastolopsis sp 1		4			12 2
Station 5					
Corophium sp 1	3	1	2		4 2
Stenothoe sp	2	2			6 5
Diastolopsis sp 1		3			9 0
Ampelisca cyclops	1	4		5	5 2
Prionospio sp		5	5		8 0
Branchiostoma belcheri	5 5		4	3	5 8
Hyale grandicornis	5 5		1	4	4 3
Veremolpa scabra	4				9 2
Golfingia misakiana			3		9 0
Podocerus sp				1	8 5
Ophiura kinbergi				2	8 8

was more pronounced in the inner bay as compared with the outer Stratification of the water column restricted vertical oxygen transfer, resulting in a depletion of bottom water oxygen levels Periodic subtidal anoxia, exacerbated by poor tidal flushing in the inner bay could be limiting for the community there and thus account for the lower species diversity recorded from this station

The Tai Tam subtidal macrobenthos provides a rich fauna for taxonomic study Jiang and Xu (1992) reported upon a new mollusc collected during this study, *Circe* (*Laevicirce*) *hongkongensis* sp. nov. The polychaete *Prionospio* sp. may also be an as yet undescribed species (Mackie, personal communication). The taxonomic status of many invertebrate species in this total Tai Tam Bay community remains to be clarified.

Ecological monitoring

The water quality of Tai Tam Bay, as reflected in the data presented here of an overall increase in benthic species diversity, apparently showed a general improvement during the second phase of benthic sampling in 1989-1990. Log-normal plots of the cumulative percentage of species in the different geometric classes showed a single steep slope at all stations for both years. In addition, most of the species occurred in the low abundance groups. These two facts, together with the increased mean species diversity index, are believed to support the notion of improved water conditions in the inlet.

The Environmental Protection Department of the Hong Kong Government reported that the Water Quality Objectives (WQO) in the Southern Water Control Zone, which includes Tai Tam Bay, had largely been achieved in 1989 and 1990. The dissolved oxygen profile showed fairly well oxygenated waters with annual mean D.O. levels, even in summer, measuring more than 50% saturation. Levels of inorganic nitrogen, organic nitrogen, inorganic phosphate and mean surface chlorophyll *a* during this period were all below the cut-off criteria for eutrophication, i.e., 0.1 $mg{\cdot}l^{-1}$, 0.3 $mg{\cdot}l^{-1}$, 0.3 $mg{\cdot}l^{-1}$ and 10 $\mu g{\cdot}l^{-1}$, respectively. The mean B.O.D. value was equal to 1 $mg{\cdot}l^{-1}$ and *E. coli* counts were similarly low. Government reports attribute the improved water conditions and the significant reduction in observed red tides to the successful implementation of the livestock waste control scheme in the gazetted water control zone (Environmental Protection Department, Hong Kong 1990).

In a concurrent study of the phytoplankton dynamics of Tai Tam Bay, Chiu *et al.* (1994) reported that chlorophyll *a* levels in 1989 - 1990 ranged from 0.40 to 32.31 $\mu g{\cdot}l^{-1}$ at the surface and from 0.33 to 33.91 $\mu g{\cdot}l^{-1}$ at the bottom. Two of their study sites (SM31 and SM34) are the same as Stations 1 and 4 of this study. At both stations, from July 1989 to March 1991, the measured chlorophyll *a* content of both surface and bottom waters was less than the eutrophication level set by the Environmental Protection Department of the Hong Kong Government, i.e., 10 $\mu g{\cdot}l^{-1}$. The only substantially higher chlorophyll *a* level was measured at the last sampling date of their study, i.e., May 1991 (> 30 $\mu g{\cdot}l^{-1}$ at Station 1 and > 15 $\mu g{\cdot}l^{-1}$ at Station 4 for both surface and bottom waters). This was parallelled by the higher ammonium - nitrogen content measured in May 1991 which increased beyond the range observed during the early part of their study. No unusual increase in May 1991 was obtained for nitrate-nitrogen and ortho-phosphate content in the study of Chiu *et al.* (1994).

Although Tai Tam Bay waters are considered to have exhibited a general improvement in water quality during this second phase of monitoring, the continued dominance of *Sigambra tentaculata*, an indicator of moderate pollution (Shin 1990) and the marginal species diversity index recorded in this study for the inner bay (Station 1) remain as points of concern signalling the fragility of the Tai Tam Bay system. In addition, the high chlorophyll *a* levels reported upon by Chiu *et al.* (1994) in May 1991 indicate fertile water conditions. In view of the ecological importance of this site, its close proximity to Cape d'Aguilar, the only proposed marine reserve in Hong Kong and the gazetting of sludge and construction waste dumping sites off southeastern Hong Kong, both of which may affect the marine biota of this site, further long-term monitoring of the area is recommended.

Much of the baseline information on the Tai Tam subtidal macrobenthic community have been collated in this and a previous study (Ong Che and Morton 1991). These relate to species assemblages, community structure, species numbers and abundance, diversity indices, seasonal patterns and log-normal plots.

The present study has demonstrated that the three-station-three-replicate programme yielded results comparable with those obtained in the first study using a five-station-five-replicate protocol. Any sampling programme for the long-term monitoring could, thus, employ such a reduced sampling effort Sampling frequency might also be reduced to an annual survey of the area in the autumn months when no major recruitment is recorded to occur in the overall macrobenthic assemblage Such a sampling programme conforms to the traditional practice of researchers who have used between two and five replicates station ^{1} (Holme and McIntyre 1984, Burd *et al* 1990)

Pearson *et al* (1983) recommends monitoring species present in the intermediate abundance groups (geometric classes V and VI) According to those authors, such species are good indicators of population change and generally either increase or decrease markedly in numbers following disturbance to the community Monitoring such species is more cost-effective as compared with monitoring either the commonest or dominant species, the enumeration of which is labour-intensive Frequent sampling would also be required for the latter method since dominant species are typically opportunistic and exhibit large fluctuations in abundance over short time intervals in rapid response to any form of disturbance The long-term benthic monitoring of Tai Tam Bay could, therefore, focus on those species in the intermediate abundance groups, as listed in Table 4

The sampling programme here proposed would be cost-effective and should be sufficient for the purposes of assessing future man-induced degradation of the sea bed in the Southern Water Control Zone, which includes Tai Tam Bay

Acknowledgements

We thank the staff of the Environmental Protection Department, Hong Kong Government and the crew of the *Dr Catherine Lam* for their help in sample collections

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OCCURRENCE OF THE BARNACLE *BALANUS AMPHITRITE* DARWIN ON THE SHELLS OF THE PREDATORY GASTROPOD *THAIS CLAVIGERA* KUSTER AT CAPE D'AGUILAR, HONG KONG

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Abstract

Settlement of *Balanus amphitrite* on the shells of the predatory gastropod *Thais clavigera* is here first recorded from Hong Kong. At Cape d'Aguilar, 30% of *T. clavigera* examined were used as a substratum by *B. amphitrite* on a semi-exposed shore and 58% on an exposed shore. In the settlement behaviour of *B. amphitrite*, there may be a preference for the shells of predatory snails. It may also be that *B. amphitrite* settles randomly but that only those attached to the shells of *T. clavigera* survive, the rest dying, perhaps through muricid predation or by limpet grazing.

Introduction

A wide variety of hosts are used by barnacles, e.g., crustaceans, bryozoans, sponges, corals, molluscs and starfish (Foster 1982, Morton 1988, Rainbow 1990, Jones 1992). Foster (1982) studied the shallow water barnacles of Hong Kong and recorded 41 species. Of these, 25 were associated with other animals (living substrata). Sixteen were non-commensal barnacles, i.e., not especially associated with living substrata but attached to rocks, shells and other hard objects, mostly in the intertidal zone. Jones (1992) reported upon *Balanus trigonus* attaching to the starfish *Anthenea flavescens* in Hong Kong while Cai and Huang (1993) reported upon species of *Chelonibia patula* attaching to the subtidal crabs *Charybdis cruciata* and *Portunus pelagicus*, also in Hong Kong, and more significantly, in terms of this study, investigated *Balanus amphitrite* Darwin attaching to the shells of the intertidal bivalve *Xenostrobus atrata* (attachment rate 86%).

Balanus amphitrite has been widely reported from Hong Kong (Foster 1982, Rainbow 1990, Cai and Huang 1993). It is frequently found attached to the hulls of ships and also occurs on either intertidal and upper subtidal stones and rocks (Harding 1962, Utinomi 1970). Cai and Huang (1988) reporded that *B. amphitrite* attaches gregariously to natural substrata, but attaches to *Xenostrobus atrata* shells singly (74.5%). Foster (1982) showed that *B. amphitrite* is not associated with living substrata, i.e., it attaches to rocks and shells. There is no information available on the settlement of *B. amphitrite* on gastropod hosts.

Preliminary field observations indicated the regular occurrence of *Balanus amphitrite* on the shells of the predatory snail *Thais clavigera* on both exposed and semi-exposed shores at Cape d'Aguilar, Hong Kong. The species richness of the molluscan fauna at Cape d'Aguilar is high, and thus a wide variety of molluscan shells can be utilized for the settlement of *B. amphitrite*. Large populations of *Tetraclita squamosa* also occur at Cape d'Aguilar. This species is distinctive in terms of shape and size, the large surface area providing space for epizoites. Their shells are, however, rarely used by *B. amphitrite*. It is hypothesized that in the settlement behaviour of *B. amphitrite*, there is a local preference for the shells of predatory snails. This may be advantageous in the avoidance of predators, because *T.*

squamosa suffers heavy predation pressure on the shores of Cape d'Aguilar, Hong Kong (Liu, unpublished data). Alternatively, young *B. amphitrite* settling on the shells of *T. squamosa* are quickly consumed, as elsewhere on the shore and the only safe residence is the back of the predator.This study examines the occurrence of *Balanus amphitrite* on a wide variety of molluscan shells at Cape d'Aguilar, Hong Kong, to determine habitat choice between different hosts.

Materials and methods

Two sites were chosen for study. Site 1 was located on the northern shore of Lobster Bay on the westen shore of Cape d'Aguilar and is exposed to moderate wave action. Site 2 was exposed to strong wave action on the easten shore of Cape d'Aguilar, Hong Kong Island (Fig. 1). Sampling areas were located between 0.5 m and 2.0 m above chart datum, i.e., the middle and

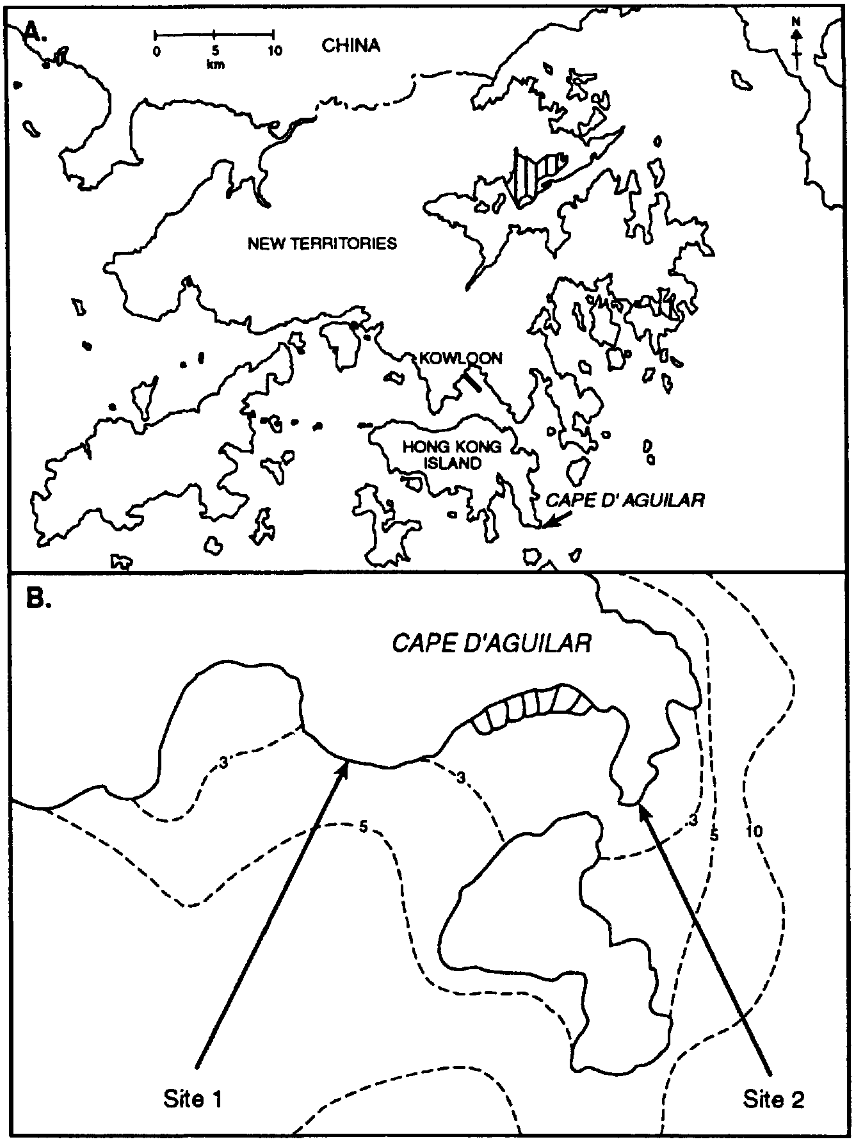

Fig. 1. A, a map of Hong Kong showing the location of Cape d'Aguilar; B, the location of the two study sites at Cape d'Aguilar

lower parts of the shore. Areas of 0.9 m^2 were sampled by removing all gastropods from ten 30 x 30 cm squares at each site. The numbers of individuals of each species. 0.09 m^2 were recorded and the shell length of each individual was measured to the nearest 0.5 mm with vernier calipers. Barnacle settlement on each shell was recorded in terms of either the presence or absence of individuals of *Balanus amphitrite*. The numbers of *B. amphitrite* on each host were counted and their shell lengths measured, again to the nearest 0.5 mm. This work was undertaken during October 1993.

Results

Table 1 shows the percentage frequency of each species used as a substratum by *Balanus amphitrite* from the semi-exposed shore in Lobster Bay at Cape d'Aguilar. A total of 46 individuals of *Thais clavigera* were examined and 14 of these (30%) were used as a substratum by *B. amphitrite.* The total number of *B. amphitrite* occurring on their hosts was 60. Additionally, 641 individuals of *Tetraclita squamosa*, 29 individuals of *Cellana toreuma*, 159 individuals of *Patelloida saccharina*, 2 individuals of *Nerita albicilla* and 18 individuals of *Liolophura japonica* were examined, but only 1 individual of *C. toreuma* was used as a substratum by *B. amphitrite*. From the exposed eastern shore at Cape d'Aguilar (Table 2), 47 individuals of *T. clavigera* were examined and 27 of these (58%) were used as a substratum by *B. amphitrite*. The total number of *B. amphitrite* recorded from their hosts was 88. Additionally, 1436 individuals of *T. squamosa*, 53 individuals of *C. toreuma*, 3 individuals of *P. saccharina* and 18 individuals of *L. japonica* were examined but none of these was used as a substratum by *B. amphitrite*. A narrow range of gastropod species was settled upon by B. amphitrite at both sites, i.e., almost wholly *T. clavigera*. The mean shell lengths of *B. amphitrite* were 5.3 mm on the semi-exposed shore and 3.9 mm on the exposed shore.

The frequency of occurrence of different numbers of *Balanus amphitrite* on *Thais clavigera* hosts are shown in Figure 2. One individual may occur on one host shell but there may also be a number of individuals, up to a maximum of 12, occurring on one shell. The percentage frequency of occurrence of one individual of *B. amphitrite* on one host was the highest at both semi-exposed and exposed sites, i.e., 28% and 37%, respectively. Only one shell from the exposed site hosted 12 individuals of *B. amphitrite* (4%).

Figure 3 shows the relationship between *Thais clavigera* host size and numbers of attached barnacles. At site 1, i.e., the semi-exposed shore, there was a positive relationship between host size and numbers of attached barnacles. At site 2, i.e., the exposed shore, there was no strong relationship between host size and numbers of barnacles.

Discussion

The present work shows that Cape d'Aguilar supports a population of *Balanus amphitrite* which largely occurs on the shells of the predatory snail *Thais clavigera.*

Differential settlement means that larvae do not settle randomly but settle instead on specific sites as a result of complicated interactions with environmental factors. Bourget (1989) listed 12 environmental factors which have been shown to influence the settlement of intertidal barnacles. These factors include light quality, background illumination, surface angle, surface contour, surface texture, tidal currents, wave action, water depth, shore level, the presence of conspecifics, bacterial film and algae.

From an examination of 37 large clusters of the gooseneck barnacle, *Pollicipes polymerus*, Chia (1989) showed that 81% of juveniles are attached to the peduncles of adults. *Pollicipes* larvae do not settle on either etched or smooth glass slides with or without bacterial films. Mapstone *et al.* (1984) have shown that the intertidal limpet *Patelloida mufria*, of all visible sizes, actively selects *Austrocochlea constricta* in preference to other available gastropods. This preference is not explained by the relative shell area of *A. constricta* but by the increased probability that *P. mufria* would be in pools during low tide, since this is the primary habitat of this potential host.

Table 1. The percentage frequency of each species used as a substratum by *Balanus amphitrite* from a semi-exposed shore at Cape d'Aguilar, Hong Kong.

Host	Frequency	% Frequency	No. of host examined	Total number of *Balanus* found	Shell length of host (mm) Mean ± S.D.	Max.	Min.	Size
Thais clavigera	14	30	46	60	16.2 (5.15)	25.6	6.3	46
Tetraclita squamosa	0	0	641	0	23.0 (8.43)	35.4	8.7	60
Cellana toreuma	1	4	29	2	17.3 (3.30)	22.4	12.1	29
Patelloida saccharina	0	0	159	0	11.8 (2.28)	15.3	5.9	33
Nerita albicilla	0	0	2	0	17.5	19.3	15.6	2
Liolophura japonica	0	0	18	0	29.0 (4.42)	35.6	20.5	18

Shell length of *Balanus* :	Mean ± S.D.	Max.	Min.
	5.3 (1.71)	8.5	1.5

Table 2. The percentage frequency of each species used as a substratum by *Balanus amphitrite* from an exposed shore at Cape d'Aguilar, Hong Kong.

Host	Frequency	% Frequency	No. of host examined	Total number of *Balanus* found	Shell length of host (mm) Mean ± S.D.	Max.	Min.	Size
Thais clavigera	27	58	47	88	21.3 (2.92)	27.4	16.7	47
Tetraclita squamosa	0	0	1436	0	17.4 (8.68)	32.4	5.1	57
Cellana toreuma	0	0	53	0	13.0 (4.35)	20.0	5.0	23
Patelloida saccharina	0	0	3	0	9.4 (0.32)	9.8	9.2	3
Liolophura japonica	0	0	18	0	34.1 (4.99)	44.3	24.0	18

Shell length of *Balanus:*	Mean ± S.D.	Max.	Min.
	3.9 (1.36)	8.2	1.3

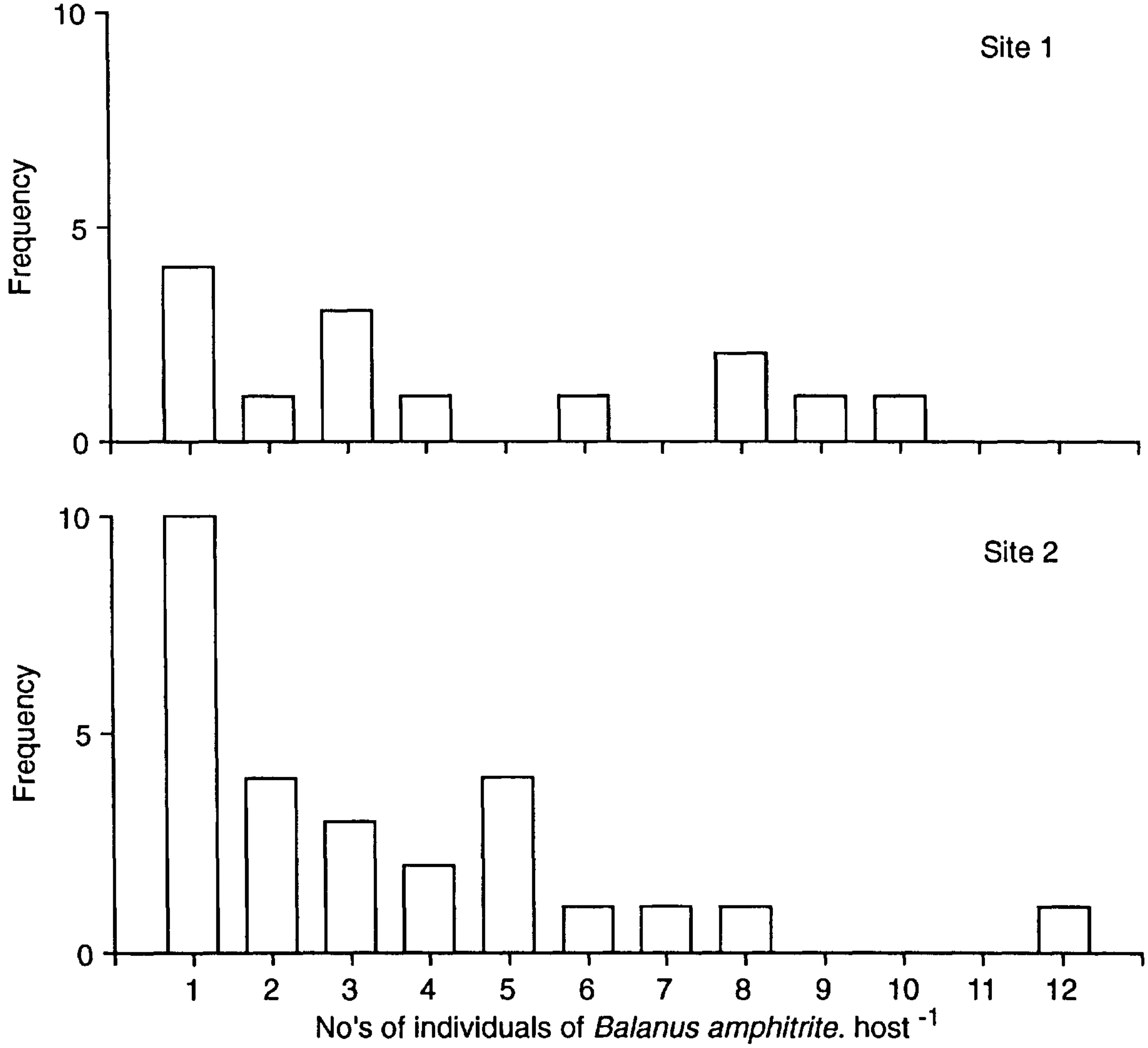

Fig. 2. Frequency histograms of the numbers of *Balanus amphitrite* on each individual of *Thais clavigera* Site 1, semi-exposed shore, Site 2, exposed shore

At Cape d'Aguilar, Hong Kong, *Tetraclita squamosa*, *Cellana toreuma* and *Patelloida saccharina* are under heavy predation pressure by *Thais* and *Morula* (B Morton and J D Taylor, pers comm , Liu 1995) It seems that the settlement of *B amphitrite* on the shells of predatory snails may be advantageous in the avoidance of predation, even if the barnacle *T squamosa* and the limpet *C toreuma* offer more areas of potentially habitable surface for *Balanus amphitrite* Vermeij *et al* (1987) showed that the suspension-feeding calyptraeid limpet-like gastropod *Crepidula adunca* is protected from predation by the sea-star *Leptasterias hexactis* by virtue of its close fit on the host shell and by the effective escape response of the host trochid, *Calliostoma ligatum*

The settlement of *Balanus amphitrite* could be either differential or uniform *B amphitrite* may not settle randomly, i e , they prefer to settle on the shells of *Thais clavigera* *B amphitrite* may choose shells of predatory snails rather than

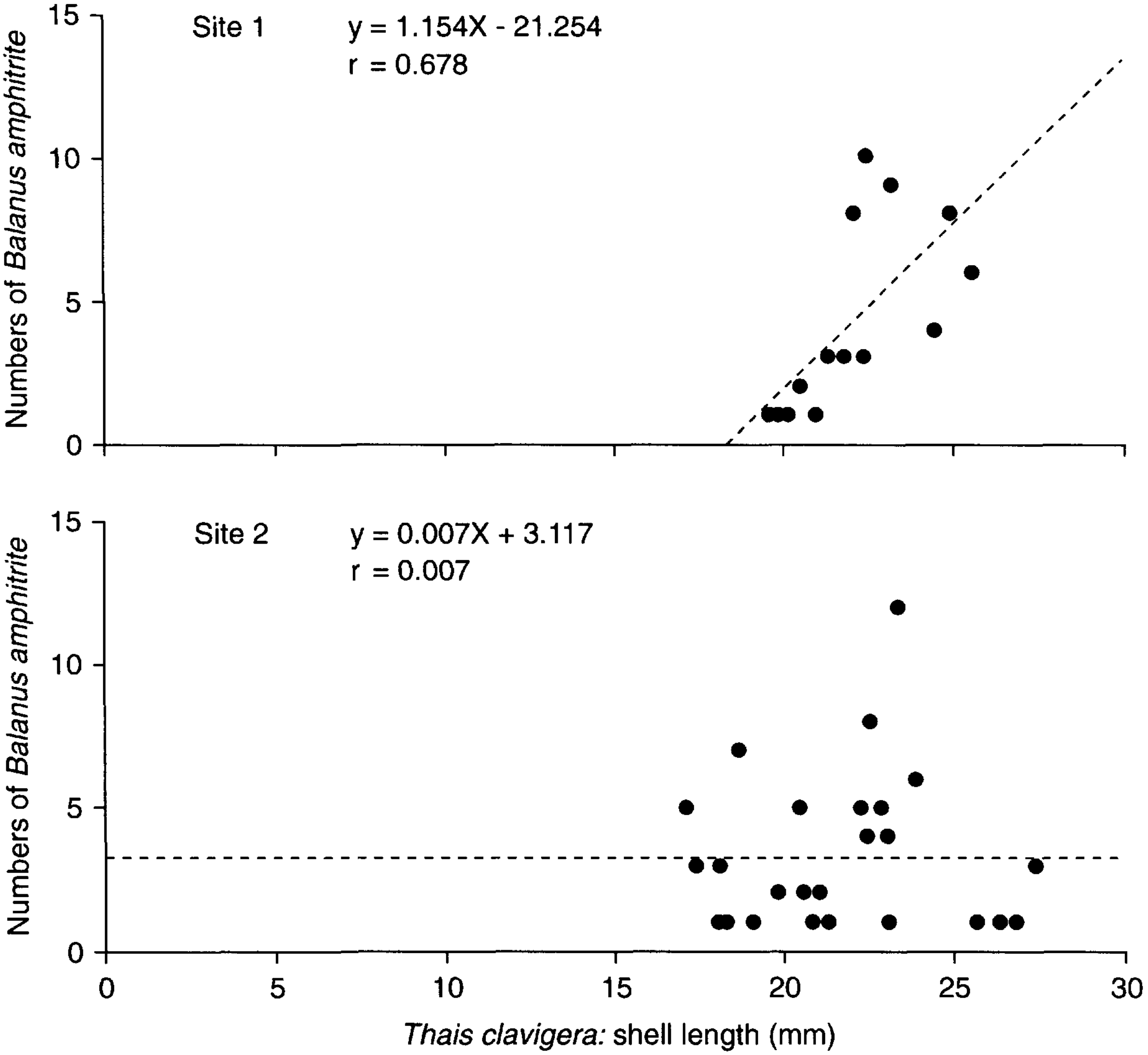

Fig. 3. The relationship between host size and numbers of attached individuals of *Balanus amphitrite* . Site 1, semi-exposed shore; Site 2, exposed shore.

the shells of other gastropods. It may also be that *B. amphitrite* settles randomly but only those attached to the shells of *T. clavigera* survive, the rest dying, perhaps through predation by the muricids themselves (Morton and Morton 1983; Tong 1986; Taylor 1980, 1990) or from grazing by limpets (Lewis, 1954; Connell, 1961; Branch, 1981). These authors all record that limpets reduce the survival of post-settlement barnacles. Petraitis (1983) demonstrated that the periwinkle *Littorina littorea* strongly affects the abundance of the barnacle *Balanus balanoides*. At high densities, *L. littorea* appears to dislodge newly-settled barnacle cyprids. Experiments on the larval settlement of *B. amphitrite* would clarify this point. Settlement of B. amphitrite on the shells of the predatory gastropod *T. clavigera* may help us understand adaptation and natural selection.

Balanus amphitrite is known to form associations with other organisms. Table 3

Table 3. Published records of Mollusca-barnacle associations.

Mollusca host	Barnacle	Reference
Pecten maximus (scallop)	*Balanus balanoides*	Barnes 1953
Chlamys opercularis (scallop)	*Balanus balanoides*	Barnes 1953
Anadara subcrenata (clam)	*Balanus cirratus*	Cai and Huang 1984
Anadara granosa (clam)	*Balanus cirratus*	Cai and Huang 1984
Perna viridis (mussel)	*Balanus trigonus*	Cai and Huang 1988
Mytilus crassitesta (mussel)	*Balanus trigonus*	Cai and Huang 1988
Xenostrobus atrata (mussel)	*Balanus amphitrite*	Cai and Huang 1993
Saccostrea cucullata (oyster)	*Balanus amphitrite*	Rainbow 1990
Septifer virgatus (mussel)	*Balanus amphitrite*	Liu, pers. observation

Table 4. Gastropod hosts used by other species.

Gastropod host	Species	Reference
Batillaria spp.	*Crepidula walshi* (limpet-like snail)	Yipp 1980
Lunella coronata	"	"
Nassarius hepaticus	"	"
Calliostoma ligatum	*Crepidula adunca* (limpet-like snail)	Vermeij *et al.* 1987
Batillaria zonalis	*Patelloida (C.) lampanicola* (limpet)	Morton 1980, 1988
Austrocochlea constricta	*Patelloida mufria* (limpet)	Mapstone *et al.* 1984

identifies the literature published on Mollusca-barnacle associations. The molluscan hosts are typically bivalves, e.g., scallops, clams, mussels and oysters. There is no information available about the settlement of barnacles on gastropod hosts, which are, for example, widely used by other animals, e.g., limpets (Table 4).

We did not investigate the differences between the shells of *Thais clavigera* and the shells of other gastropods in terms of surface texture, surface contour and bacterial film. Maki *et al* (1988) showed that bacterial films generally inhibited attachment of larval *Balanus amphitrite.*

Acknowledgements

JHL is grateful to The University of Hong Kong for awarding her a Rayson Huang Postdoctoral Fellowship. We thank Professor Brian Morton, Director, The Swire Institute of Marine Science, The University of Hong Kong, for the provision of laboratory facilities and work space during the course of this study and for his critical reading of the first drafts of the manuscript of this paper.

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AN ANNOTATED CHECKLIST OF CETACEANS RECORDED FROM HONG KONG'S TERRITORIAL WATERS

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Abstract

There are records for Hong Kong territorial waters either suggesting or confirming the presence of fifteen species of Cetacea three members of the Balaenopteridae (Minke whale, Bryde's whale and Fin whale), one of Phocoenidae (Finless porpoise), one of Physeteridae (Pygmy sperm whale), and ten of Delphinidae (Bottlenose dolphin, False killer whale, Fraser's dolphin, Indo-Pacific humpbacked dolphin, Long-beaked common dolphin, Pantropical spotted dolphin, Spinner dolphin, Striped dolphin, Rough-toothed dolphin and Risso's dolphin) Of these, only two appear to be present year round in Hong Kong waters the Indo Pacific humpbacked dolphin and the Finless porpoise

Introduction

Hong Kong is situated adjacent to the mouth of the Pearl River on the south coast of the Chinese province of Guangdong (Fig 1) The first western records of cetaceans in Hong Kong date from 1637, when the adventurer Peter Mundy reported that 'the porpoises here are as white as milke, some of them ruddy withall' (Carnac-Temple 1919) This was what is now known to be the 'local' population of Indo-Pacific humpbacked dolphin, *Sousa chinensis* (Osbeck, 1765) Based on his own observations during voyages in the eighteenth century, Osbeck (1765) classified similar animals he found in Hong Kong as a species new to science, the Chinese white dolphin Since then and until relatively recently, little has been done to study Hong Kong's cetacean populations Official sighting and stranding reports first began to be assembled by the Agriculture and Fisheries Department of the Hong Kong Government in 1973 Body measurements (albeit incomplete) of stranded carcasses date from 1985 Reports were made largely by government employees until the World Wide Fund for Nature Hong Kong established, in 1989, a scheme to prompt members of the public to report details of their casual sightings The initial findings from these various programmes suggested that the waters of Hong Kong, surprisingly, were frequented by several cetaceans, including at least two resident species (Morton *et al* 1992) the Indo-Pacific humpbacked dolphin, known locally as the Chinese white dolphin, and the Finless porpoise, *Neophocaena phocaenoides* (Cuvier, 1829) It was in the climate of awareness created by WWF's high-profile public reporting programme, together with lobbying from conservation organizations, that the Hong Kong Government initiated a study of cetaceans in Hong Kong waters, including the threats facing them and possible mitigations to those threats This study is being undertaken by a full-time research team at the Swire Institute of Marine Science The University of Hong Kong

The following is a list of species occurring in Hong Kong The correct classification of sightings and stranding data can only be confirmed, however, in cases where there are either voucher specimens or unambiguous photographs of the animals The reliability of other reports is unconfirmed The taxonomy used here follows Honacki *et al* (1982), Barnes *et al* (1985), Perrin (1989) and Heyning and Perrin (1994)

English common names follow Perrin (1989) Details on which CITES appendix the species appear in are from Klinowska (1991)

Species Accounts

Order Cetacea Brisson, 1762
Suborder Mysticeti Flower, 1864
Baleen whales
Family Balaenopteridae (Gray, 1864)
Rorquals
Subfamily Balaenopterinae (Gray,1864)
Balaenoptera acutorostrata Lacepède, 1804
Minke whale
[CITES Appendix I]

Minke whales occur throughout the world's seas They are mainly oceanic but sometimes come close to shore Wang (1984a, 1991a, 1993) has reported Minke whales from the Bohai, Yellow, East China and South China Seas As would be expected from their cosmopolitan distribution, Minke whales have been reported from Hong Kong waters There are currently three recognised populations of this species (Omura 1975) and the whales described in Hong Kong were probably members of the population known to winter off the coast of Japan (*Balaenoptera acutorostrata davidsoni* Scammon, 1872) There have been several unsubstantiated reports of Minke whales in Hong Kong waters and one confirmed sighting of two individuals in Sai Kung (Anonymous 20 May 1991) There have been only two Minke whale strandings since records began to be kept (Fig 1, Table 1) The first was near Crooked Harbour, Lai Chi Wo (26 February 1978) and the second at Tin Sam, Tai Po (3 February 1982)

Balaenoptera edeni Anderson, 1878
Bryde's whale
[CITES Appendix I]

This whale occurs in oceanic and, occasionally, in coastal waters in warm temperate and tropical climates In the North Pacific, the species is limited to waters south of 30°N (Vidal *et al* 1993) Chinese researchers report Bryde's whales in theYellow Sea, the East and South China Seas, and the waters around Taiwan (Yang 1976, Wang 1984a, 1991a,b, 1993, Chou 1994)

One cetacean carcass washed up in Hong Kong has been tentatively identified as a Bryde's whale from photographic evidence (S Leatherwood pers comm) The carcass was found in Tung Wan on Cheung Chau Island (18 September 1992) (Fig 1, Table 1) A second, confirmed, Bryde's whale carcass was discovered in Tolo Harbour Channel on 22 November 1994 (Plate 1)

Balaenoptera physalus (Linnaeus, 1758)
Fin whale
[CITES Appendix I]

This is a cosmopolitan, but usually pelagic, species It occurs in cooler waters during the summer months and warm waters in winter The species shows less distinct migrations than some other types of great whale

Fin whales are known to winter in the Bohai Sea , the East and South China Seas and the Yellow Sea (Wang 1978, 1984a, 1991a, 1993) as well as in the Sea of Japan There are six recognized populations worldwide The East China Sea Fin whales are thought to be a resident and distinct population, as are those in the Yellow Sea (Evans 1987) These whales presumably migrate northwards during the summer months

There has been only one reported Fin whale stranding (Table 1) , at Ming Sang wharf, Victoria Harbour, on 12 April 1955 (Romer 1958) The whale was an infant, only six to seven weeks old, and the preserved skeleton of the whale is now mounted and resides outside the Swire Institute of Marine Science (Morton *et al* 1992)

Family Eschrichtiidae
Ellerman and Morrison-Scott, 1951

Eschrichtius robustus (Lilljeborg, 1861)
Gray whale
[CITES Appendix I]

Although there have been no recent sightings, Gray whales are believed to have frequented Hong Kong waters in the past 'Dragon' bones in several temples in the territory are believed to come from

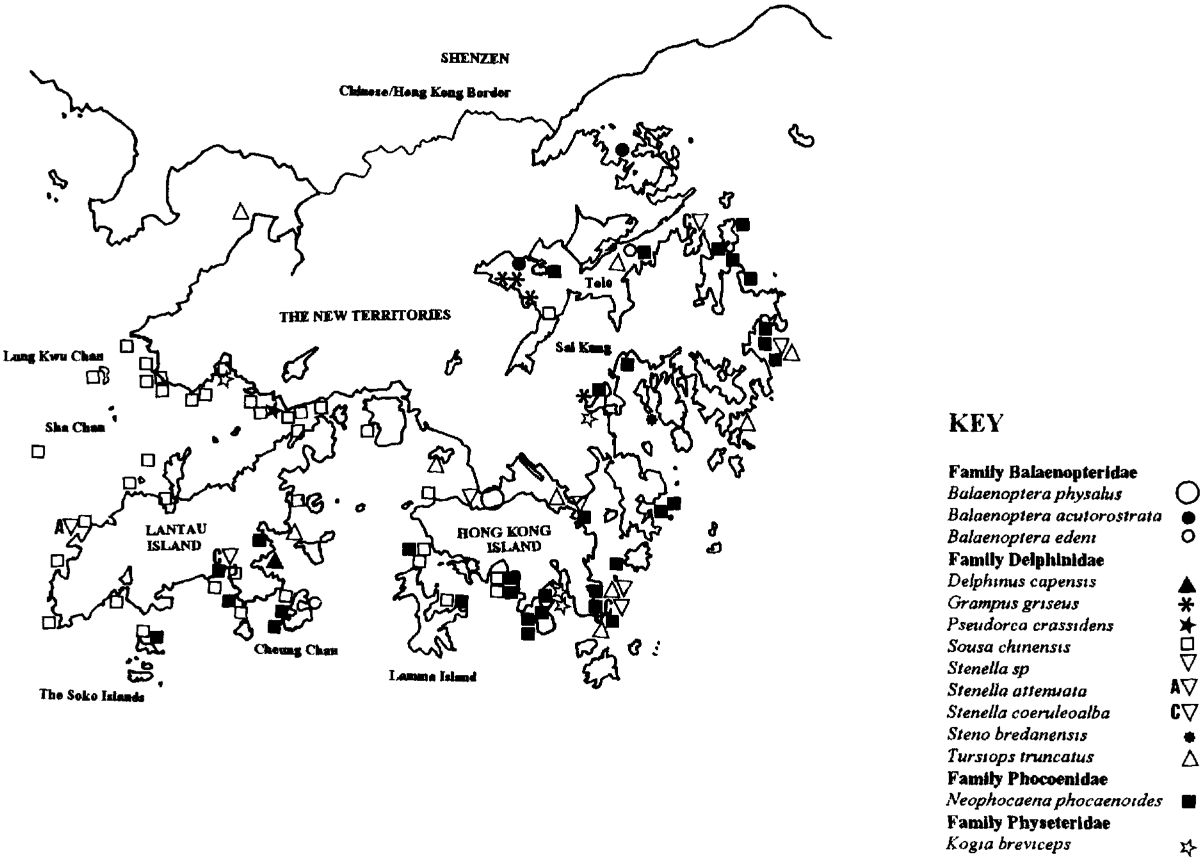

Fig. 1. Map of Hong Kong showing the locations of cetacean strandings.

Gray whales historically hunted by locals. There are currently two extant gray whale populations. The most abundant occurs in the Eastern Pacific. The second, smaller (and most relevant to Hong Kong), Gray whale population winters in the Yellow Sea and the East and South China Seas near Korea, spending the summers in the Sea of Okhotsk (Andrews 1914; Blokhin *et al.* 1985; Brownell and Chun 1977; Wang 1984a, 1991a, 1993). This population has also been reported off the coast of Taiwan (Yang 1976; Wang 1991b; Chou 1994). Hunted until 1966, the Korean population is now estimated to number between 200-300 individuals (Evans 1987).

When flourishing, this population was abundant in the South China Sea near Hong Kong. Wang (1984b) documents a Gray whale captured from nearby Guangdong Province, which was at that time a breeding ground for whales. Daya Bay (Fig. 2), to the east of Hong Kong, was once a calving site for Gray whales. Because of over-whaling, this stock is now believed to be locally extinct.

Suborder Odontoceti Flower, 1867
Toothed whales
Superfamily Delphinoidea (Gray, 1821)
Family Delphinidae Gray, 1821
Marine dolphins
Subfamily Delphininae (Gray, 1821)
Delphinus spp. Linnaeus, 1758
Common dolphins
[CITES Appendix II]

Dolphins of this genus have a wide distribution and occur in both warm temperate and tropical offshore waters. Common dolphins occur throughout the Indian Ocean and, in the Pacific,

Plate 1. A Bryde's whale (*Balaenoptera edeni*) stranded in Tolo Channel, 22 November 1994.*Credit: E.C.M. Parsons.*

their distribution extends from central Japan southward to Australia and New Zealand. Common dolphins have been seen in the Bohai, Yellow and East and South China Seas as well as off the coast of Taiwan (Yang 1976; Wang 1984a, 1991a, b, 1993; Chou 1994; Zhou *et al.* 1995).

The genus *Delphinus* currently contains two species: *Delphinus delphis* (Linnaeus, 1758) and the newly recognized Long-beaked common dolphin, *Delphinus capensis* (Heyning and Perrin, 1994). It should be noted that for stranding and distribution records prior to 1994, all Common dolphins were assumed to be *D. delphis.*

Although there was a highly publicised visit of a pod of approximately 50 Common dolphins to Victoria Harbour (20 February 1978) and one individual was captured near Kwun Tong in 1954 (Romer 1958), there has only been one Common dolphin stranding (Plate 2) reported from Hong Kong (Fig.1, Table 1). It occured at Shap Long, south of Mui Wo on Lantau Island (3 May 1989). From photographs of the dolphin it was suggested (S. Leatherwood and W. Perrin pers. comm.) that the animal was a member of the newly defined species *Delphinus capensis* or the putative species *Delphinus tropicalis.*

Grampus griseus (G. Cuvier, 1812)
Risso's dolphin
[CITES Appendix II]

This species is widely distributed in both tropical and temperate climates, in all waters. The range extends southwards from the Kuril Islands in the North Pacific, to New Zealand, southern Australia and Tasmania. The species is also quite abundant in the Indian Ocean (Leatherwood *et al.* 1984; Alling 1986), especially in the northern and western reaches and deeper coastal waters (Kruse *et al.* 1991), extending southwards to Australia

Table 1. Summary of cetaceans stranded in Hong Kong's territorial waters [1973-1993]

Species	Date	Location	Length	Sex	Tooth Count		Notes
			(point-to-point)		Upper jaw	Lower jaw	
1973							
Stenella sp	(25-10-73)	Lei Yue Mun, New Territories	+	+	+	+	Stab wounds
1975							
Sousa chinensis	(8-1-75)	Picnic Bay, Lamma Island	+	+	+	+	Caught by gill net
1978							
Balaenoptera acutorostrata	(26-2-78)	Crooked Harbour, Lai Chi Wo, New Territories	+	+	+	+	
Stenella sp	(1-3-78)	No Records	+	+	+	+	
Neophocaena phocaenoides	(4-3-78)	Ma Shi Chau, Tolo Harbour, New Territories	+	+	+	+	
Neophocaena phocaenoides	(4-11-78)	West Tai Long Bay, Sai Kung, New Territories	+	+	+	+	
1980							
Sousa chinensis	(2-7-80)	Castle Peak, New Territories	+	+	+	+	
Tursiops truncatus	(26-11-80)	Shek O Wan, Hong Kong Island	+	+	+	+	
1982							
Balaenoptera acutorostrata	(3-2-82)	Tin Sum Chuen, Tai Po, New Territories	+	+	+	+	
Steno bredanensis	(7-3-82)	East Sharp Island, Port Shelter, New Territories	+	+	+	+	
Neophocaena phocaenoides	(11-3-82)	Shek O Wan, Hong Kong Island	+	+	+	+	
Neophocaena phocaenoides	(26-11-82)	Lamma Island	+	+	+	+	Drowned in gill net
1983							
Sousa chinensis	(11-4-83)	Chung Sha Beach, Lantau Island	+	+	+	+	
Pseudorca crassidens	(19-4-83)	Tai Lam Chung, Tuen Mun, New Territories	+	+	+	+	
Neophocaena phocaenoides	(14-7-83)	Brick Hill, Deepwater Bay, Hong Kong Island	+	+	+	+	
Tursiops truncatus	(20-7-83)	Shap Long Wan, Silvermine Bay, Lantau Island	+	+	+	+	Live stranding, treated and released
Neophocaena phocaenoides	(7-12-83)	Po Toi O Bay, Sai Kung, New Territories	+	+	+	+	
1984							
Neophocaena phocaenoides	(5-1-84)	Chung Chau	+	+	+	+	Drowned in gill net (distinct wounds)

(to be continued)

Table 1 *(continued)*

Species	Date	Location	Length	Sex	Tooth Count		Notes
1985							
Stenella sp	(15-2-85)	Shek O Wan, Hong Kong Island	+	+	+	+	
Stenella sp	(13-3-85)	Ham Tin Beach, Tai Long Bay, Sai Kung, New Territories	250	+	40(r)	36(r) /46(l)	
Neophocaena phocaenoides	(13-3-85)	Ham Tin Beach, Tai Long Bay, Sai Kung, New Territories	161	+	+	+	Circular wound on head
Tursiops truncatus	(26-3-85)	Sheung Pak Nai, Deep Bay, New Territories	+	+	+	+	Live stranding on mud flat, towed out and released
Sousa chinensis	(18-6-85)	Deep Water Bay, Hong Kong Island	+	+	+	+	
1986							
Kogia breviceps	(6-1-86)	Tai Tam Bay, Hong Kong Island	216	+	0(r) /0(l)	13(r) /12(l)	Haemorrhagic enteritis, cause of death hypovolumaeia
Grampus griseus	(2-6-86) Tai Po,	Kwong Fuk Estate, Mouth of Lam Chuen River New Territories	260	M	3(r) 2(l)	3(r) / 3(l)	Live, died later
Grampus griseus	(3-6-86)	Mouth of Lam Chuen River, Tai Po, New Territories	278	+	+	+	
Grampus griseus	(3-6-86)	Mouth of Lam Chuen River, Tai Po, New Territories	275	M	0(r) /0(l)	3(r) /3(l)	
Grampus griseus	(6-6-86)	Cheung Shue Tan, Tai Po Kau, New Territories	275	M	3(r) /(3(l)	0(r) /0(l)	
Sousa chinensis	(24-6-86)	Butterfly Bay, Tuen Mun, New Territories	+	+	+	+	
Sousa chinensis	(28-6-86)	Pui O, Lantau Island	215	M	64	59	
Sousa chinensis	(22-7-86)	Lung Kwu Tan, Tuen Mun, New Territories	220	M	35	30	
Tursiops truncatus	(8-8-86)	Pak Lap Wan, Sai Kung, New Territories	240	M	24	24	
Kogia sp	(21-10-86)	Tuen Mun, New Territories	+	+	+	+	Live, treated and released
1987							
Sousa chinensis	(2-1-87)	Nim Shue Wan, Lantau Island	240	M	29	49	
Neophocaena phocaenoides	(10-1-87)	Wah Fu Estate, Near Aberdeen, Hong Kong Island	+	+	+	+	
Sousa chinensis	(31-1-87)	Sha Lo Wan, Lantau Island	+	+	+	+	
Sousa chinensis	(9-2-87)	Nim Shue Wan, Lantau Island	+	+	+	+	
Neophocaena phocaenoides	(6-6-87)	Repulse Bay, Hong Kong Island	175	F	+	+	
Stenella attenuata	(14-12-87)	Po Chue Tam, Lantau Island	175	+	35	35	

(to be continued)

Table 1 *(continued)*

Species	Date	Location	Length	Sex	Tooth Count		Notes
1988							
Stenella coeruleoalba	(10-5-88)	Pui O, Lantau Island	198	F	43(l)	37(l)	
Sousa chinensis	(5-8-88)	North of Lantau Island	+	+	+	+	
Sousa chinensis	(27-8-88)	Wah Fu Estate, Near Aberdeen, Hong Kong Island	215	M	33(r) /32(l)	31(r) /31(l)	
Sousa chinensis	(2-9-88)	Shek Pik, Lantau Island	181	M	30(r) /31(l)	31(r) /30(l)	
Grampus griseus	(3-9-88)	Pak Sha Wan, Sai Kung, New Territories'	260	M	0(r) /0(l)	4(r) /(4(l)	
Sousa chinensis	(23-12-88)	Sai Tso Wan, Tsing Yi, New Territories	+	+	+	+	
1989							
Neophocaena phocaenoides	(6-1-89)	Siu Sai Wan, Chai Wan, Hong Kong Island	92	F	0(r) /0(l)	0(r) /0(l)	Juvenile
Neophocaena phocaenoides	(22-1-89)	Pik Sha Wan Beach, Sai Kung, New Territories	80	M	0(r) /0(l)	0(r) /0(l)	Juvenile
Neophocaena phocaenoides	(15-2-89)	Nam She Beach, Sai Kung, New Territories	145	+	13(r) /13(l)	15(r) /15(l)	
Neophocaena phocaenoides	(27-2-89)	Sok Kwu Wan, Picnic Bay, Lamma Island	+	+	+	+	
Neophocaena phocaenoides	(23-3-89)	Lai Chi Chong, Sai Kung, New Territories	75	M	0(r) /0(l)	0(r) /0(l)	Juvenile
Delphinus delphis	(3-5-89)	Shap Long, Lantau Island	183	M	47(r) /49(l)	46(r) /46(l)	
Sousa chinensis	(3-7-89)	Castle Peak, New Territories	217	M	58	62	
Stenella coeruleoalba	(3-7-89)	Outlying Pier, Central, Hong Kong Island	+	+	45	45	
Sousa chinensis	(19-7-89)	Lamma Island	+	+	+	+	Fluke missing
Sousa chinensis	(5-8-89)	Tsing Lung Tau, New Territories	90	+	0(r) /0(l)	0(r) /0(l)	Juvenile
1990							
Neophocaena phocaenoides	(18-3-90)	Tap Mun Beach, New Territories	150	F	15(r) /14(l)	18(r) /19(l)	
Neophocaena phocaenoides	(19-3-90)	Tap Mun Pier, New Territories	148	F	16(r) /16(l)	16(r) /15(l)	
Sousa chinensis	(17-4-90)	Pak Kok, Lamma Island	200	+	+	+	
Sousa chinensis	(13-6-90)	Tuen Mun Ferry, New Territories	240	M	+	+	
Sousa chinensis	(2-7-90)	Tai Lam Marine Police Base, New Territories	235	M	34(r) /28(l)	31(r) /30(l)	
Neophocaena phocaenoides	(23-11-90)	Tung Lung Island, New Territories	165	+	+	+	
Neophocaena phocaenoides	(23-11-90)	Tung Lung Island, New Territories	85	M	+	+	Juvenile
Neophocaena phocaenoides	(31-12-90)	Tai Wan, Sai Kung, New Territories	118	+	16(r)	17(r)	
1991							
Neophocaena phocaenoides	(14-1-91)	Between Kau Lau Wan & Tap Mun, New Territories	148	F	+	+	
Neophocaena phocaenoides	(6-2-91)	Tai Long Wan, New Territories	148	+	28	36	
Sousa chinensis	(17-5-91)	Castle Peak, Tuen Mun, New Territories	297	+	+	+	
Sousa chinensis	(23-5-91)	Castle Peak, Tuen Mun, New Territories	210	+	+	+	
Kogia breviceps	(19-8-91)	Tai Tam Bay, Hong Kong Island	+	+	+	+	

(to be continued)

Table 1 *(continued)*

Species	Date	Location	Length	Sex	Tooth Count		Notes
1992							
Neophocaena phocaenoides	(18-3-92)	Hairpin beach, Stanley, Hong Kong Island	130	+	+	+	
Stenella coeruleoalba	(27-6-92)	Hoi Ha Wan, Sai Kung, New Territories	230	+	+	+	
Balaenoptera edenii		(18-9-92)	Tung Wan, Cheung Chau flukes		1000+	+	+ +
Kogia breviceps	(3-10-92)	Marina Cove, Sai Kung, New Territories	200	+	+	+	Injured & died later
Sousa chinensis	(30-11-92)	Yi O, Lantau Island	250	+	23(l)	18(l)	
Neophocaena phocaenoides	(3-12-92)	Rocky Bay, Shek O, Hong Kong Island	+	+	+	+	
Neophocaena phocaenoides	(13-12-92)	Shek O, Hong Kong Island	78	F	0(r) /0(l)	0(r) /0(l)	Juvenile
1993							
Sousa chinensis	(7-2-93)	Off Des Voeux Rd, North of Hong Kong Island	180	M	72	64	
Neophocaena phocaenoides	(28-3-93)	Pui O, Lantau Island	100+ flukes	+	+	+	
Neophocaena phocaenoides	(6-5-93)	Mui Wo, Lantau Island	140	+	+	+	
Sousa chinensis	(25-5-93)	Tai Kwai Wan, Cheung Chau	150	+	+	+	
Sousa chinensis	(15-6-93)	Stove Beach, Tai Lam Chung, Tuen Mun, New Territories	130	+	60	34	
Neophocaena phocaenoides	(17-6-93)	Stanley Beach, Hong Kong Island	175	F	+	+	
Neophocaena phocaenoides	(19-6-93)	St Stephen Beach, Stanley, Hong Kong Island	165	+	+	+	
Sousa chinensis	(6-7-93)	Stove Beach, Tai Lam Chung, Tuen Mun, New Territories	110	+	+	+	
Sousa chinensis	(24-7-93)	Butterfly Beach, Tuen Mun, New Territories	200	+	+	+	
Sousa chinensis	(27-7-93)	Fan Lau Sai Wan, Lantau Island	150	+	+	+	
Neophocaena phocaenoides	(23-8-93)	Mong Tung Wan, Lantau Island	180	+	+	+	
Neophocaena phocaenoides	(22-12-93)	Stove Beach, Shek Koo Chau, Near Cheung Chau	71	F	0	0	Juvenile
1994							
Neophocaena phocaenoides	(17-1-94)	Stanley, Hong Kong Island	+	+	+	+	
Sousa chinensis	(27-01-94)	Tung Chung Pier, Lantau Island	155	M	29(r)/29(l)	+	Juvenile, cause of death concussive blast?

(to be continued)

Table 1 *(continued)*

Species	Date	Location	Length	Sex	Tooth Count		Notes
Tursiops truncatus	(23-04-94)	Cape d'Aguilar, Shek O, Hong Kong Island'	+	+	+	+	
Sousa chinensis	(28-04-94)	Castle Peak, Tuen Mun, New Territories	+	M	+	+	
Sousa chinensis	(12-6-94)	Sea Ranch, Lantau Island	181	F	+	+	Fins sliced off
Sousa chinensis	(16-6-94)	Lung Kwu Chau, North of Lantau Island	+	+	+	+	Dead juvenile with mother in attendance, resighted on 22-6-94, still accompanied by mother
Sousa chinensis	(16-6-94)	Repulse Bay, Hong Kong Island	+	+	+	+	
Stenella coeruleoalba	(17-7-94)	Tai Long Wan, Hong Kong Island	234	+	84	86	
Neophocaena phocaenoides	(30-7-94)	Tai A Chau, Soko Islands	155	+	+	+	
Sousa chinensis	(9-9-94)	Off Chek Lap Kok Island, North of Lantau Island	+	+	+	+	
Sousa chinensis	(26-9-94)	Sea Ranch, Lantau Island'	+	+	+	+	Juvenile
Sousa chinensis	(19-10-94)	Tai A Chau, Soko Islands'	+	+	+	+	
Neophocaena phocaenoides	(4-11-94)	Lung Ha wan, Clearwater Bay, New Territories	137	+	+	+	
Balaenoptera edenii	(22-11-94)	Tolo Harbour, New Territories	904	F	N/A	N/A	Caught in anti-smuggling cable
Tursiops truncatus	(25-11-95)	Seal Sai Wan, Hong Kong Island	293	M	21(r)/20(l)	21(r)/17(l)	
Tursiops truncatus	(27-11-94)	'Tai Long Wan, Hong Kong Island	+	+	+	+	
Tursiops truncatus	(11-12-94)	Tolo Harbour, New Territories	+	+	+	+	
Tursiops truncatus	(4-12-94)	Stonecutter's Island	244	F	+	+	
Neophocaena phocaenoides	(16-12-94)	Clearwater Bay, New Territories	82	F	0	0	Juvenile
Sousa chinensis	(23-12-94)	Yam O, Lantau Island	222	M	31(r)/32(l)	31(r)/31(l)	

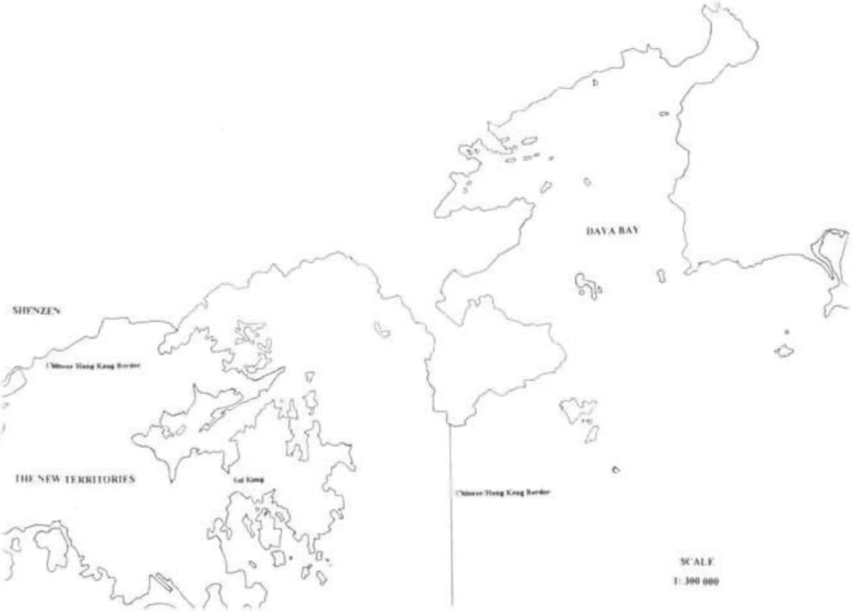

Fig. 2. Map showing the location of Daya Bay, adjacent to Hong Kong.

Plate 2. A Long-beaked common dolphin (*Delphinus capensis*) stranded at Shap Long, Lantau Island, 3 May 1989. *Credit: Agriculture and Fisheries Department, Hong Kong Government.*

Table 2. A summary of cetacean strandings in Hong Kong's territorial waters (1973-1994)

Year	*Sousa chinensis*	*Neophocaena phocaenoides*	Other species
1973	0	0	*Stenella* sp
1974	0	0	
1975	1	0	
1976	0	0	
1977	0	0	
1978	0	2	*Stenella* sp *Balaenoptera acutorostrata*
1979	0	0	
1980	1	0	*Tursiops truncatus*
1981	0	0	
1982	0	2	*Balaenoptera acutorostrata* *Steno bredanensis*
1983	1	2	*Pseudorca crassidens* *Tursiops truncatus* [Live]
1984	0	1	
1985	1	1	2 *Stenella* sp *Tursiops truncatus* [Live]
1986	3	0	*Kogia breviceps* *Kogia* sp [Live] 4 *Grampus griseus* [1 Live] *Tursiops truncatus*
1987	3	2	*Stenella attenuata*
1988	4	0	*Grampus griseus* *Stenella coeruleoalba*
1989	3	5	*Stenella coeruleoalba* *Delphinus capensis*
1990	3	5	
1991	2	2	*Kogia breviceps*
1992	1	3	*Stenella coeruleoalba* *Kogia breviceps* *Balaenoptera edeni*
1993	6	6	
1994	9	4 5	*Stenella coeruleoalba* *Balaenoptera edeni* *Tursiops truncatus*
TOTAL	38	35	2 *Balaenoptera acutorostrata* 2 *Balaenoptera edeni* 1 *Delphinus capensis* 5 *Grampus griseus* [1 Live] 4 *Kogia* sp [1 Live] 1 *Pseudorca crassidens* 9 *Tursiops truncatus* [2 Live] 9 *Stenella* sp 1 *Steno bredanensis*

and South Africa Even though they are distributed at low densities, they are gregarious, occurring in groups of up to 4000 but usually less than 50 animals (Leatherwood *et al* 1980, Kruse *et al* 1991)

Although widely distributed, the species does not occur in as large numbers as *Stenella* spp and Common dolphins Locally they have been seen around Taiwan (Yang 1978, Wang 1991b, Chou 1994, Zhou *et al* 1995) and in both the East and South China Seas (Wang 1991a, 1993, Zhou *et al* 1995) There have been five reported strandings in Hong Kong (Fig 1, Table 1) Four occurred within a few days of each other in same area, Chung Shue Wan in Tolo Harbour The first, a carcass of a 2 6 m male, was discovered on 2 June 1986 On the following day there was a live stranding of a 2 78 m Risso's dolphin with a carcass found later the same day The third carcass washed up three days later on 6 June The fifth reported stranding was in Pak Sha Wan, Sai Kung on 3 September 1988

Lagenodelphis hosei Fraser, 1956
Fraser's dolphin
[CITES Appendix II]

The distribution of this pelagic species is essentially tropical Fraser's dolphins have been recorded from eastern Australia to Japan and Taiwan, as well as in the Indian Ocean from Sri Lanka, Madagascar and South Africa (Leatherwood and Reeves 1983) There have also been reports from scattered locations in the Atlantic The species was first recorded from Sarawak in the South China Sea (Fraser 1956) and can be found in the East and South China Seas as well as in Taiwan (Wang 1993, Zhou *et al* 1995) There has been, to date, only one stranding of a Fraser's dolphin in Hong Kong, it occurred on 31 May 1995 in Tai Po, the New Territories

Lagenorhynchus obliquidens Gill, 1865
Pacific white-sided dolphin
[CITES Appendix II]

This species is primarily an inhabitant of the cool temperate waters of the northern Pacific Although Wang (1991a, 1993) records this species in the South China Sea there are no recorded strandings within Hong Kong's territorial boundary Hammond and Leatherwood (1984) mention a large herd of this species Victoria Harbour in Winter 1982-1983 This was, however, based on second hand reports and should be disregarded (S Leatherwood pers comm)

***Stenella* spp.**
Spotted, Striped and Spinner dolphins
[CITES Appendix II]

Due to the difficulty in identifying stranded stenellids to species it is highly probable that several stranded carcasses have been misclassified Bearing this in mind, the complete records of *Stenella* spp strandings are here treated as a single genus rather than three separate species

All three pantropical stenellids occupy warm temperate and tropical waters and share much the same distribution *Stenella attenuata* (Pantropical spotted dolphin, Gray, 1846) is primarily oceanic and is one of the most commonly occurring species in its range It is recorded from the South and East China Seas (Wang 1984a, 1991a, 1993, Zhou *et al* 1995), Taiwan (Yang 1976, Wang 1991b, Chou 1994, Zhou *et al* 1995) and near Japan In the Indian Ocean, it occurs from the Seychelles southwards to southern Australia and New Zealand There are several geographic variants of the species and the coloration of Indo-Pacific animals is varied and complicated (Leatherwood and Reeves 1983), making them easily confused with other stenellid species when not seen close up

Stenella coeruleoalba (Meyen 1833), the Striped dolphin, is also oceanic, but it also comes inshore in some areas The species is found throughout the Indian Ocean, while in the Pacific it extends from Japan to Taiwan (Yang 1976, Wang 1984a, 1991a,b, 1993, Chou 1994), the East and South China Seas (Zhou *et al* 1995) and southwards to Australia's southern tip

The third stenellid species recorded from Hong Kong waters is *Stenella longirostris* (Gray, 1828) This species is usually oceanic but can be coastal Its range in the Indian Ocean extends from the northernmost reaches to southern Australia and South Africa Both China and Taiwan have records of the species (Wang 1991a, b, 1993; Chou 1994; Zhou *et al.* 1995). In 1993, illegally caught Spinner dolphin carcasses were intercepted by the Hong Kong Government. These had been landed off the coast of Hainan, China, adding this locale to their range.

Two unidentified stenellids have been washed up in Hong Kong. One was found on the south side of Hong Kong Island, at Shek O (15 February 1985) and the second was at Tai Long Wan on the south side of Lantau Island (13 March 1985) (Fig.1, Table 1). A carcass reported on 14 December 1987 at Po Chue Tam, Lantau Island, was identified as *Stenella attenuata* by Agriculture and Fisheries officers. Also on Lantau Island, the first of the four known *Stenella coeruleoalba* strandings was washed up at Pui O on 10 May 1988 (Plate 3). The other three strandings were in Central (3 July 1989), Hoi Ha Wan (27 June 1992) and Shek O (17 July 1994). Although, to date, no Spinner dolphins have stranded in Hong Kong, live animals have been sighted (L.J.Porter pers. obs.).

Tursiops truncatus (Montagu, 1821)
Bottlenose dolphin
[CITES Appendix II]

Tursiops truncatus is a cosmopolitan species occurring in coastal and offshore waters in all but the polar and sub-polar seas. In the western Pacific, the distribution extends from Japan to Australia and New Zealand. Bottlenose dolphins occur throughout the Indian Ocean and as far south as South Africa and southern Australia. They also occur in waters adjacent to Hong Kong, Taiwan and China (Yang 1976; Wang 1984a, 1991a,b, 1993; Chou 1994; Reeves *et al.*1995; Zhou *et al.* 1995). At present, all bottlenose dolphins are conservatively assigned to *Tursiops truncatus*. However, there are recognizably

Plate 3. A Striped dolphin (*Stenella coeruleoalba*) discovered on 10 May 1988 at Pui O, Lantau Island. *Credit: Agriculture and Fisheries Department, Hong Kong Government*

different 'ecotypes' in many areas, including the western Pacific (Walker 1981; Scott and Chivers 1990). Bottlenose dolphins in Hong Kong include slender, longer-snouted, and spotted coastal forms (often refered to as *Tursiops aduncus*) and heavier-bodied, larger-snouted and less spotted offshore forms (often refered to as *Tursiops gilli*).

There have been two live strandings of Bottlenose dolphins in Hong Kong (Fig.1). The first occurred on 20 July 1983, in Sha Long Wan, Silvermine Bay (Lantau Island). The second was an animal which foundered on mud flats at Sheung Pak Nai, Deep Bay (26 March 1985). A stranded carcass was found at Pak Lap Wan, Sai Kung on 8 August 1986. Further carcasses (Fig.1, Table 1) have been found on the south side of Hong Kong Island, in Shek O (26 November 1980), and nearby Cape D'Aguilar (23 April 1994). Sightings of live Bottlenose dolphins were recorded at Cape D'Aguilar two weeks after this latter carcass was discovered (Parsons pers. obs.). During the closing months of 1994 there were four more strandings. One was an unconfirmed carcass in Tai Long Wan, Hong Kong Island (27 November 1994) which was said to be badly decomposed, but from the carcass descriptions offered, the animal was most probably a Bottlenosed dolphin (D. Clarke pers. comm.). The other three carcasses were found in Siu Sai Wan (25 November 1994) and near Stonecutters Island (4 December 1994) and Tolo Harbour (11 December 1994)(Fig. 1). The Siu Sai Wan and Stonecutters Island carcasses were measured and necropsied and from preliminary examination were deemed to be members of an offshore ecotype (Leatherwood pers. comm.) (Plate 4).

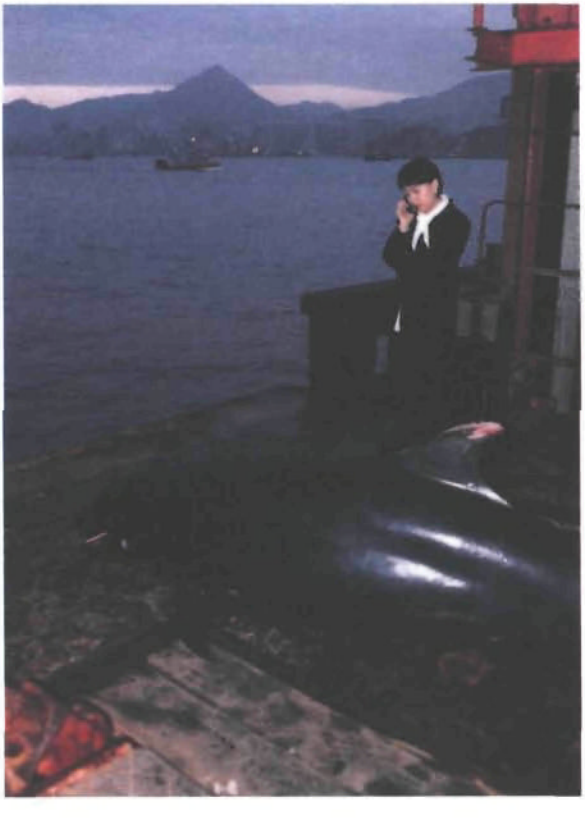

Plate 4. A Bottlenose dolphin (*Tursiops truncatus*) reported on 25 November 1994 at Siu Sai Wan, Hong Kong Island. *Credit: S. Leatherwood*

Subfamily Globicephalinae (Gray, 1866)
Pseudorca crassidens (Owen, 1846)
False killer whale
[CITES Appendix II]

This is a widely distributed species (Leatherwood and Reeves 1983) which is found in offshore warm temperate and tropical waters, including the Indian Ocean (Leatherwood *et al.* 1991) and the Pacific. The species' range extends from Japan and the Red Sea south to New Zealand and South Africa. They are thought to prefer deep, offshore, warm temperate and tropical waters. They are known to occur around Taiwan (Yang 1976; Wang 1991b; Chou 1994) Wang (1984a, 1991a, 1993) and Zhou *et al.* (1995) also document them from the Bohai, Yellow and East and South China Seas. There has been only one carcass found in Hong Kong, in Tai Lam Chung on 19 April 1983.

Subfamily Steninae (Fraser and Purves, 1960)
Sousa chinensis (Osbeck, 1765)
Indo-Pacific humpbacked dolphin
[CITES Appendix I]

At present the genus *Sousa* is split into two main species of Humpbacked dolphin. The first is *Sousa teuszii*, the Atlantic Humpbacked dolphin (Kukenthal 1892), occurring coastally in tropical west Africa. The second main species is the Indo-Pacific Humpbacked dolphin, *Sousa chinensis*. The classification of the latter is confused and disputed. Leatherwood and Reeves (1983) recognize two distinct morphs: one west of India with the 'hump' after which the dolphins are named, the second to the east and south of India, individuals of which are much lighter in colour and do not posses such a defined 'hump'. Pilleri and Gihr (1974) suggested that *Sousa chinensis* should be split into several species: the freckled *Sousa lentiginosa* (Owen, 1866), and *Sousa plumbea* (Cuvier, 1829), both extending in range from East Africa to Thailand; *Sousa borneensis* (Lydekker, 1901), dwelling in the coastal waters of Borneo and Australia; and *Sousa chinensis* in Chinese waters. Zhou (1980a) and Ross (1984) suggested that a separate species for *S. lentiginosa* was not valid, but that *S. plumbea* should be treated as a separate species, or as Ross *et al.* (in press) argue, a sub-species. The latter is a dark, humpbacked dolphin occurring from East Africa to the Suez and along the coast to East India. This leaves the species *Sousa chinensis* (or sub-species *S. c. chinensis*; Ross *et al.*, in press), ranging from Sumatra to the East China Sea, including the Pearl River delta, and southwards to the northern and eastern coast of Australia.

The species usually occurs in warm, shallow (less than 20 m deep) waters. They are often associated with mangroves, river deltas and, estuaries, as they can tolerate brackish waters. Chinese researchers have documented Humpbacked dolphins in the East and South China Seas (Wang 1982, 1984a, 1991a, 1993; Zhou *et al.* 1995), with their northern Chinese limits in Zhejiang Province. They have also been known to swim several kilometres up rivers, including the Minjiang and Jiulong rivers in Fujian Province as well as the Pearl (Wang 1982) and Shenzen rivers (D. Melville pers. comm.) in Guangdong Province. They are reported to be abundant in Xiamen, especially between February and May (Z.G. Huang pers. comm.; Wang 1984a).

Together with the Finless porpoise, the Indo-Pacific humpbacked dolphin is the only truly resident cetacean species in Hong Kong (Plates 5 and 6). Known locally as Chinese white dolphins, the animals notable for their coloration. The calves are usually grey. They lighten with age, leading to white or pink adults which often have either grey or blue mottling and spots. The lightening in coloration as the animal grows older often begins with the dorsal fin, a phenomenon also seen in Australian animals (G. Ross pers. comm.). Their mating season appears to be from August to September (E.C.M. Parsons and L.J. Porter pers. obs.), which is later than the May to June breeding season noted by Wang (1982) for the Xiamen population.

Between the records started in 1973 and the end of 1994 there were 38 reported strandings of *Sousa chinensis* in Hong Kong (Table 1, Fig.1) and numerous sightings of live dolphins. The habitat of the dolphins is restricted. To date, they can consistently be found near Castle Peak (Tuen Mun) and the islands of Lung Kwu Chau and Sha Chau. They sometimes occur to the south (Fan

Plates 5 and 6. Regular sightings of identified individuals have confirmed that *Sousa chinensis* is resident in Hong Kong. *Credit: L.J. Porter*

Lau and the Soko Islands) and north (Tai O and near Chek Lap Kok airport) of Lantau Island. In September 1994, a large number of sightings was collected from the east of Lantau, at Cheung Chau, Mui Wo and Peng Chau. These sightings added all the coastal waters of Lantau to the known localized distribution, for this part of the year at least. Melville (1976) also records them off Pak Nai, Deep Bay as well as near Lamma Island. These sightings were, however, when the size of the population was considerably larger and possibly more widespread than it is at present.

Steno bredanensis (G. Cuvier, *in* Lesson, 1828)
Rough-toothed dolphin
[CITES Appendix II]

This is not a particularly abundant species, although stranding data suggest a widespread distribution. It is known to occur from northern Japan to Australia in the Pacific Ocean and from the Gulf of Bengal and the Gulf of Aden southwards to South Africa and Western Australia. The species usually swims far offshore in deep waters of the warm temperate and tropical mid-Pacific. Rough-toothed dolphin distribution includes both Chinese and Taiwanese waters (Yang 1976; Wang 1984a, 1991a, b, 1993; Chou 1994; Zhou *et al.* 1995). A solitary carcass washed aground on East Sharp Island, Port Shelter on 7 March 1982 (Fig.1, Table 1).

Family Phocoenidae (Gray, 1825)
Porpoises
Neophocaena phocaenoides (G. Cuvier, 1829)
Finless porpoise
[CITES Appendix I]

This is the second of the two truly resident Hong Kong small cetaceans (Plate 7). Although on

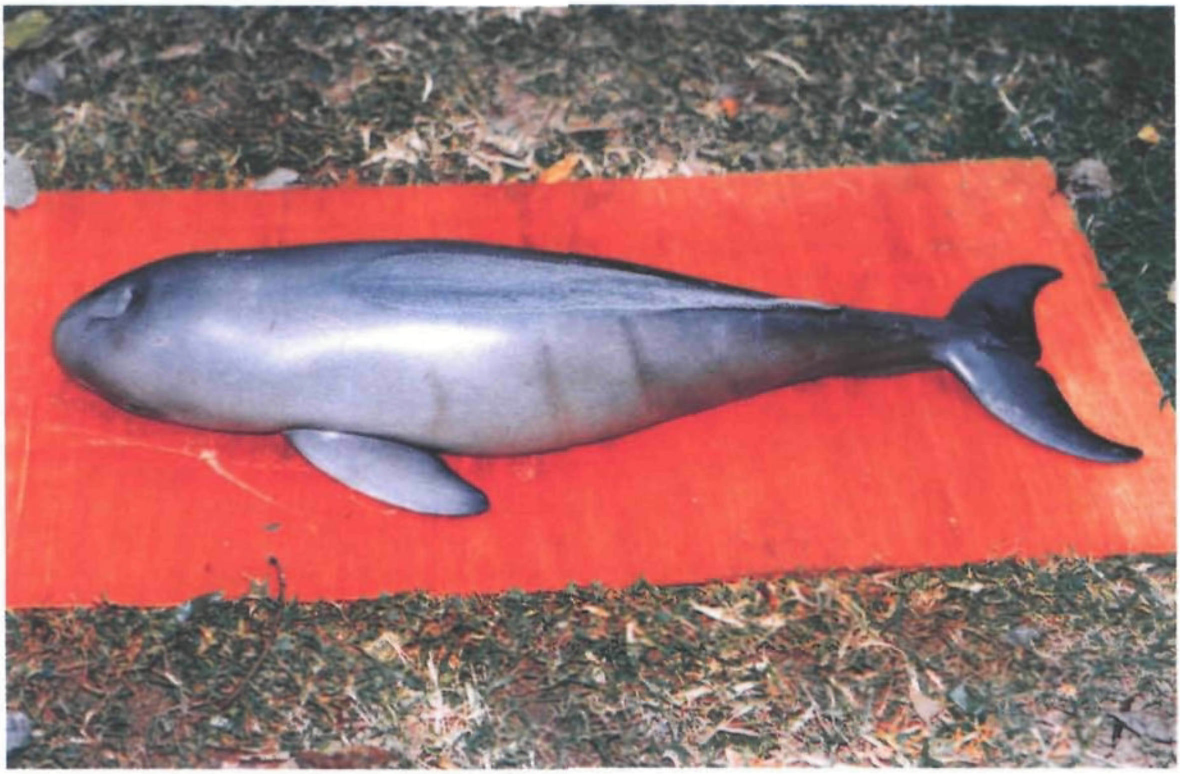

Plate 7. Hong Kong's second resident cetacean species, the Finless porpoise (*Neophocaena phocaenoides*). This stranding was reported on 13 December 1992 at Shek O, Hong Kong Island. *Credit: Agriculture and Fisheries Department, Hong Kong Government*

dolphin surveys in Hong Kong, several light-grey or even khaki coloured (L J Porter pers obs) animals have been seen, most individuals are black (E C M Parsons pers obs) The Finless porpoise normally dwells in warm, shallow, coastal waters of Southeast Asia Their range extends from northern Japan (Kasuya and Kureha 1979, Shirakihara *et al* 1992), southwards around Taiwan (Yang 1976, Wang 1991b, Chou 1994), China (Wang 1984a,c, 1991a, 1992a,b, 1993, Gao and Zhou 1993, Zhou *et al* 1995), Korea, Pakistan (Harrison and McBearty 1974), and through to the Persian Gulf (Tomlin 1967, Pilleri and Gihr 1974) There are also unconfirmed sightings off the eastern coast of Africa (Martin 1990) They also occur within river systems, including the Yangtze River (Chen *et al* 1980, Zhou *et al* 1980b, Wang 1984c, 1992a,b) There have been three populations of *N phocaenoides* identified around China the Yangtze River population, a Yellow Sea population and a South China Sea population (Gao 1991, Wang 1992a,b, Gao and Zhou 1993a) Finless porpoises stranded in Hong Kong display the wide dorsal groove characteristic of the South China Sea stock

It is possible that Finless porpoises in Hong Kong are migratory So far, porpoises have been recorded from the southern part of Lantau and the Soko Islands at the beginning and end of the year (E C M Parsons pers obs), a distribution which is echoed in stranding data (Fig 1, Table 1) Strandings have also occurred in the Sai Kung region during this period, although as yet there have been no sightings of live animals in this area

During the spring and summer months, the porpoises possibly move to waters south of Hong Kong Island There have been sightings of porpoises near Po Toi and Waglan Island during this period This change in distribution may be linked to their breeding cycle, as Gao and Zhou (1993b) reported that the South China Sea population of Finless porpoises gives birth from June to March, with a peak between August and December As of December 1994 there were 35 recorded Finless porpoise strandings in Hong Kong (Fig 1, Table 1) The carcasses are often of juveniles (7 cases of 25 stranding records) with no teeth and measuring less than 1m in length

Superfamily Physeteroidea (Gray, 1821)
Sperm whales
Family Physeteridae (Gray, 1821)
Subfamily Kogiinae (Gill, 1871)
Kogia breviceps (de Blainville, 1838)
Pygmy sperm whale
[CITES Appendix II]

These whales are dwellers of most deep oceanic waters in the temparate and tropical Pacific (Leatherwood and Reeves 1983, Caldwell and Caldwell 1989, Chantrapornsyl *et al* 1991) They are not often seen , owing to low density or cryptic behaviour The species has been recorded from the coast of Taiwan (Yang 1976, Wang 1991b, Chou 1994, Zhou *et al* 1995) and the East and South China Seas (Wang 1991a, 1993, Zhou *et al* 1995)

There has been one live stranding of a Pygmy sperm whale in Hong Kong, at Tuen Mun (21 October 1986) Three stranded carcasses have also been discovered Two were found in Tai Tam Bay on 1 June 1986 and on 19 August 1991 Sightings of living *Kogia* were reported in these areas over a period of several weeks (A Leung pers comm), which is unusual considering their deep oceanic distribution The third carcass was discovered in Marina Cove, Sai Kung on 3 October 1992 (Plate 8)

Acknowledgements

We wish to thank the World Wide Fund for Nature Hong Kong for allowing us access to their cetacean sightings reports and assistance with our project Thanks also go to the staff of the Agriculture and Fisheries Department of the Hong Kong Government, especially Mr Y K Chan and Mr C C Lay for their help with the project and with collating cetacean stranding records Also to Wei Lee Tsai and Oscar Lee for kindly assisting with the Chinese references Last, but not least, our gratitude to T Jefferson, S Leatherwood and Professor Brian Morton for their advice and assistance with the editing of this paper

Plate 8. A Pygmy sperm whale carcass reported on 3 October 1992 at Marina Cove, Sai Kung. *Credit: Agriculture and Fisheries Department, Hong Kong Government*

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ODYSSEYLANA SIRENKOI: A NEW GENUS AND NEW SPECIES OF CIROLANID ISOPOD FROM THE SOUTH CHINA SEA (CRUSTACEA: ISOPODA)

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Abstract

Odysseylana sirenkoi, new genus and species of cirolanid isopod is described, based upon a specimen collected off Tkhu Island, South China Sea, at a depth of 300 m *Odysseylana* gen nov is characterized by an extended frontomedial margin of the head, elongate, pentagonal, anteriorly acute, frontal lamina, lamellar, non-opercular pleopod 1, quadrate pleopod 1 peduncle, deep rounded notch in the very narrow distal end of the pleotelson and slender, long, conical uropod exopod These features distinguish the new genus from similar genera such as *Conilera* and *Politolana*

Introduction

During an expedition cruise of the research vessel *Odyssey* in summer 1984 to the South China Sea, Dr B I Sirenko collected a new species of cirolanid isopod A combination of features has not allowed the author to ascribe this species to any genus hitherto described In this paper, a new genus *Odysseylana* is established It belongs to the *Conilera* group (Bruce 1986, Wetzer *et al* 1987) or the Conilerinae Kensley and Schotte, 1989, which are characterized by the following features antenna 1 peduncle articles 3 and 4 subequal in length, pereopods 1-3 with merus and ischium produced distodorsally, abundant long setae on posterior pereopods, no ornamentation on the body somites, frontal lamina usually flat and narrow

The holotype is deposited in the Zoological Institute, Russian Academy of Sciences, St Petersburg Abbreviations used ZIN- Zoological Institute, Russian Academy of Sciences

Systematics

Family Cirolanidae Dana
Odysseylana gen nov

Type species *Odysseylana sirenkoi* sp nov , by monotypy Diagnosis Body elongate, straight side in dorsal view about 4 times as long as wide Dorsum of body smooth, pleotelson only with stout plumose dorsal setae Head smaller than first pereonite, frontomedial margin extended and covering basis of antenna 1 Pereonite 1 longer than pereonite 2 All five pleonites visible dorsally, not fused, widening from 1 to 4 Lateral margin of pleonite 5 overlapped by those of pleonite 4 Pleonites in ventral view broader than pleopod 1 peduncle Pleotelson triangular, narrower than pleonite 5, posterior margin narrowed, with rounded notch in which are set spines and plumose marginal setae, pleotelson lateral margins concave, denticulated, with plumose marginal setae Pleotelson dorsal surface with two broad rows of stout plumose setae

Antenna 1 peduncle articles 1-3 progressively longer, flagellum shorter than peduncle Antenna 2 peduncle articles 1-3 short, 4-5 long, 4 longest Frontal lamina not visible in dorsal view, pentagonal, about 2 5 times as long as basal width, straight-side, anterior margin acute Clypeus and labrum sessile Mandibles with prominent spine row and molar process Maxilla 1 outer endite with stout spines, inner endite with 3 stout circumplumose spines Maxilla 2 with all lobes well developed Maxilliped palp articles 2-5 with both margins setose, endite with 3 coupling hooks and prominent plumose setae

All pereopods slender Dorsal surface of basis slightly concave with scattered short and long setae Pereopods 1-3 with merus weakly and ischium markedly expanded distodorsally Pereopods 4-7 with ischium, merus and carpus broader distally, provided with long spines and setae All pereopods with very small secondary unguis on dactylus

Pleopod 1 lamellar, not operculates, remaining pleopods with lateral margins not adjacent to the pleonites, peduncle about as long as broad, pleopod 1 rami subequal in length, endopod almost half as wide as exopod Pleopod 2 appendix masculina inserted basally, longer than endopod Peduncles of all pleopods with long distolateral seta Peduncles of pleopods 4 and 5 with small lobes on lateral margin, pleopod 5 endopod only without plumose marginal setae Uropod exopod slender, conical, longer than endopod, extending beyond apex of pleotelson Endopod narrowed apically, with lateral margin concave Both rami with plumose marginal setae and spines

Etymology. Name is formed from the name of the research vessel *Odyssey*, from which the specimen was collected and the ending *-lana* to indicate family affinity The gender is feminine

Remarks *Odysseylana* belongs to the *Conilera* group on the basis of general morphology, body shape, antennae, pereopods, elongate frontal lamina and pleopod 1 peduncle The triangular pleotelson and uropod endopod shape of *Odysseylana* are similar to those of *Conilera* (Montagu, 1804) *Conilera* differs in having an indurate, operculate first pair of pleopods, almost completely encapsulating ventrum, flat, short uropod exopod (Fig 6 C, D), more slender frontal lamina (about five times longer than basal width) with a semicircular anterior projection and pereopods 1-3 merus distodorsally more prolonged Quadrate pleopod 1 peduncle, arrangement of pleopods, when the first ones do not cover the following, slender, long uropod exopod share this genus with *Politolana* Bruce, 1981 *Politolana* differs from *Odysseylana* in having frontal lamina more slender and rounded anteriorly, ischium and merus of pereopods 1-3 distodorsally more strongly prolonged, appendix masculina arising sub-basally or sub-medially, endopod of uropod with a notch on the lateral margin, pleotelson with lateral margins convex *Conilera* and *Politolana* have no species with the frontomedial margin of head extended and covered basis of antenna 1 In both *Conilera* and *Politolana* antenna 2 has peduncle article 1-2 short, 3-5 long, article 5 is longest and differs from antenna 2 of *Odysseylana* with peduncle articles 1-3 short, 4 and 5 long, with article 4 longest In *Odysseylana* pleonites in ventral view are broader than pleopod 1 peduncle, whereas *Conilera* and *Politolana* (and of most cirolanid genera) have the ventral part of the pleonites markedly narrower than pleopod 1 peduncle *Odysseylana* is separated from the all other genera of the *Conilera* group by the deep rounded notch in the very narrow distal end of the pleotelson and setation of its dorsal surface, conical uropod exopod, 3 coupling hooks on maxilliped endite Only one cirolanid genus has non-flat (cylindrical) uropod exopod, i e , *Atarbolana* Bruce and Javed, 1987, but *Atarbolana* is otherwise very different from *Odysseylana*

Odysseylana sirenkoi sp nov
(Figs 1-6)

Material examined Holotype N 1/69411, male, 10 45 mm long, South Vietnam, off Tkhu Island, 10 46'N 109 43'E, depth 300m 25 August 1984, RV *Odyssey*, coll B I Sirenko

Description of male holotype

Body (Fig 1) Total body length 10 45 mm, maximum width 2 70 mm, length 3 83 width

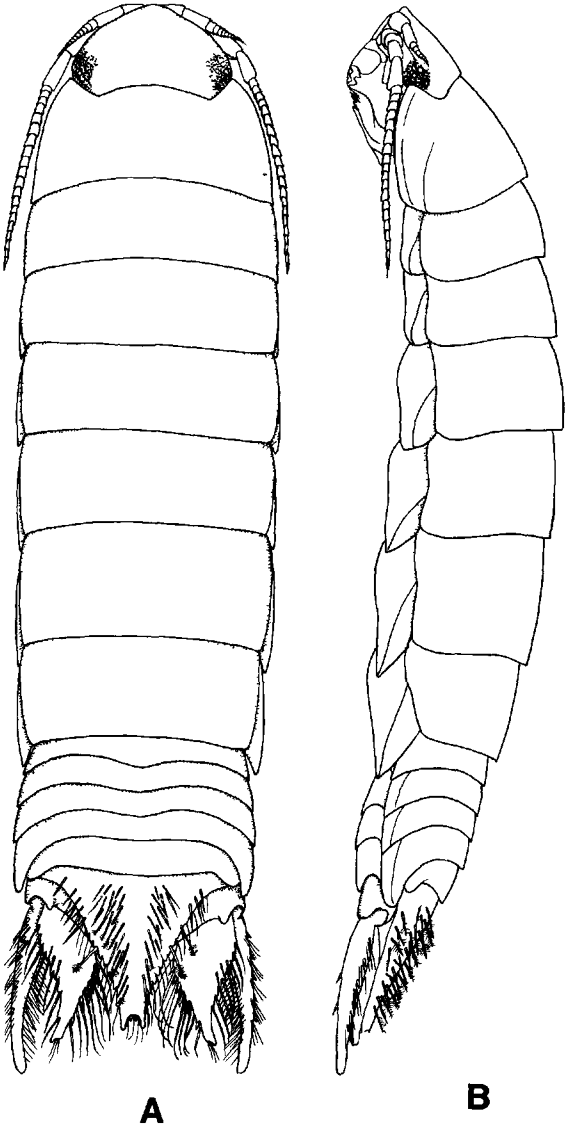

Fig.1. *Odysseylana sirenkoi* sp.nov. Male, holotype. A, dorsal view; B, lateral view.

Body elongate, dorsally vaulted, straight-side. Head 1.8 times as wide as medial length; frontomedial margin extended, covering basis of antenna 1. Eyes with remnant of cuticular ommatidial facets. Pereon outline smooth, pereonite 6 longest, 2 and 3 shortest, remainder subequal in length. Coxae 2-4 with curved carina; coxae 5-7 with more pronounced, but less curved, medial carina extending diagonally from median plate to posterolateral acute angle. Epimera of pleonite 4 longer than preceding plate, posteriorly extended, rounded and laterally bent.

Pleotelson width 1.26 length, pleotelson length 0.14 body length, anterior margin width 6.6 posterior margin width; posterior notch with 4 spines and plumose marginal setae; lateral margins concave, denticulate, with plumose marginal setae and without spines; dorsal surface with two broad, dense rows of stout plumose setae. Frontal lamina (Fig. 2 A, B) not visible in dorsal view, 2.4 times as long as wide, pentagonal, straight sided, anterior margin acute. Clypeus triangular, 4.2 time as wide as long, laterally very elongate and slender, laterally surpassing the labrum; labrum weakly concave on posterior margin.

Antenna 1 (Fig.2C). Not extending to end of antenna 2 peduncle. Length 0.08 body length. Antenna 1 peduncle 4-articulate, article 4 minute, with two feather bristles. Peduncle article 1 and 2 are subequal in length and fused, with two distomedial setae, article 3 narrower but longer than preceding ones, article 3 length 0.77 article 1 and 2 combined. Ten flagellar articles with a row of long and slender aesthetascs and a group of short simple setae.

Antenna 2 (Fig.2D). Extending back to posterior margin of pereonite 2, with 5 peduncular and 19 flagellar articles. Length 0.28 body length, peduncle article 1 broadest; article 2 shortest, without setae; article 3 subequal in length to first and second articles together, with 3 distal simple setae; article 4 longest and broadest, with 13 long plumose setae; article 5 narrowest, slightly shorter than article 4; flagellar articles with tuft of lateral simple setae.

Mandibles (Fig.2F). Spine row with 9 or 10 stout spines, molar process long, triangular, with an anterolateral row of small strong acute teeth. Palp length 0.86 mandibular body length. Article 1 and 2 subequal in length, article 1 slender, with 1 distal seta; with 20 simple and pectinate setae; last article with 15 pectinate setae.

Maxilla 1 (Fig.2E). Outer endite with 13 spine-like setae, inner endite 0.61 outer.

Maxilla 2 (Fig.2H). Innermost endite shortest and broadest, with numerous simple and 3 circumplumose setae, medial endite with 14 and outer endite with 5 spine-like setae.

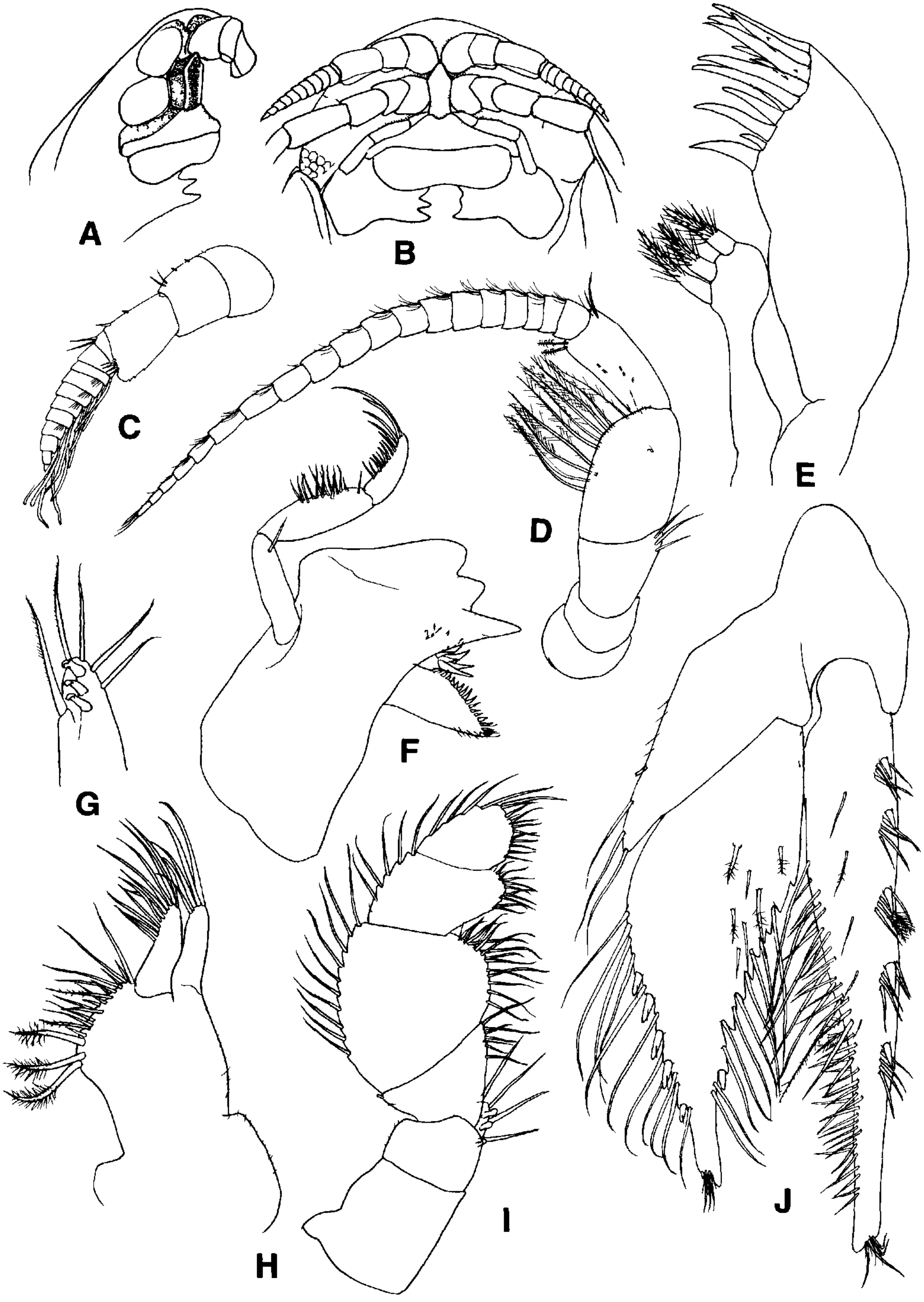

Fig.2. *Odysseylana sirenkoi* sp nov Male, holotype A, ventrolateral view of frontal lamina, clypeus and labrum, B, ventral view of antennae 1, antennae 2, frontal lamina, clypeus, labrum and mandibles, C, antenna 1, D, antenna 2, E, maxilla 1, F, right mandible, G, maxilliped endite, H, maxilla 2, I, maxilliped, J, uropod

Fig.3. *Odysseylana sirenkoi* sp.nov. Male, holotype. A, peropod 1 with enlargement of dactylus; B, pereopod 2 with enlargement of dactylus; C, pereopod 3; D, pereopod 4.

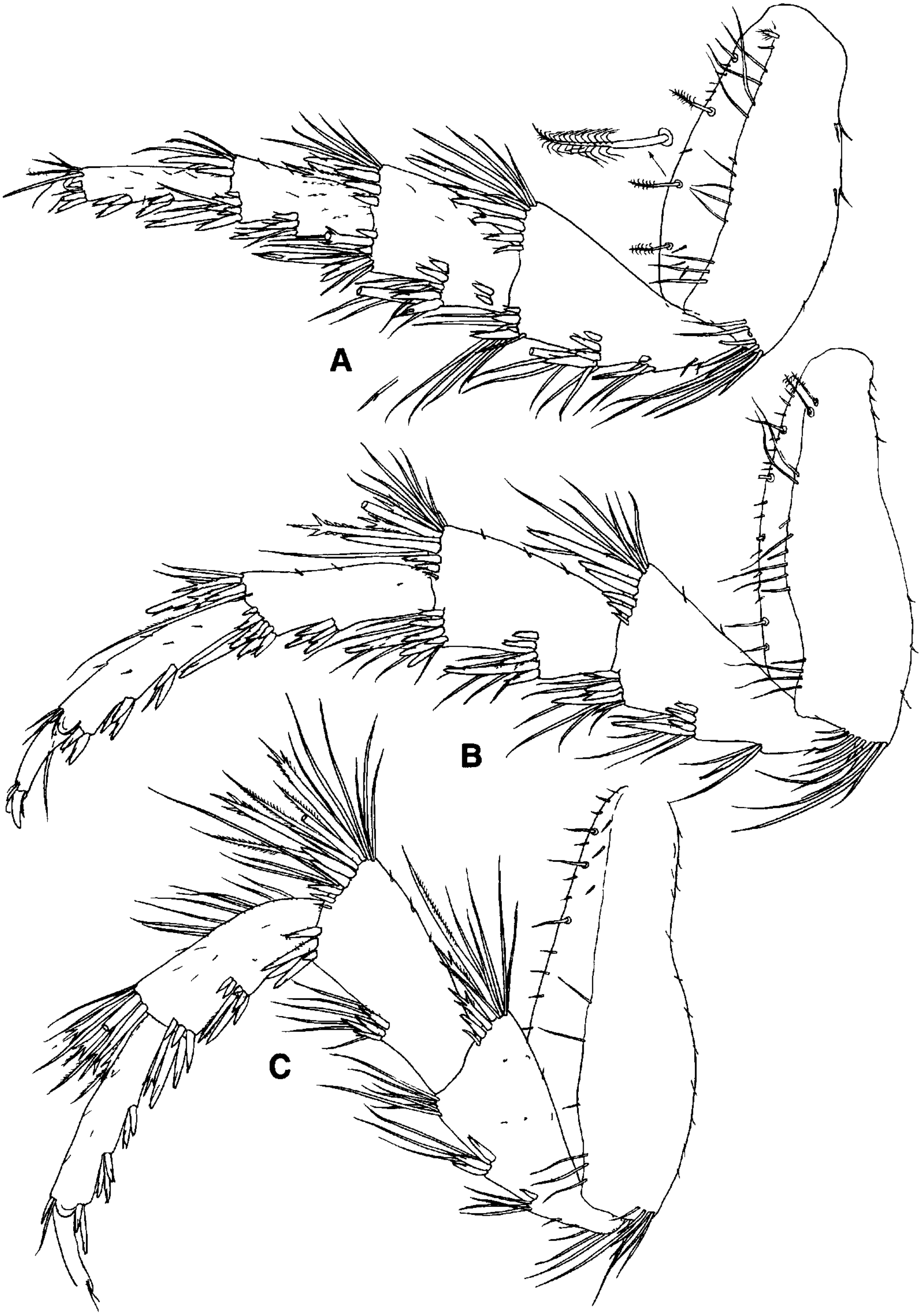

Fig.4. *Odysseylana sirenkoi* sp nov Male, holotype. A, pereopod 5; B, pereopod 6, C, pereopod 7

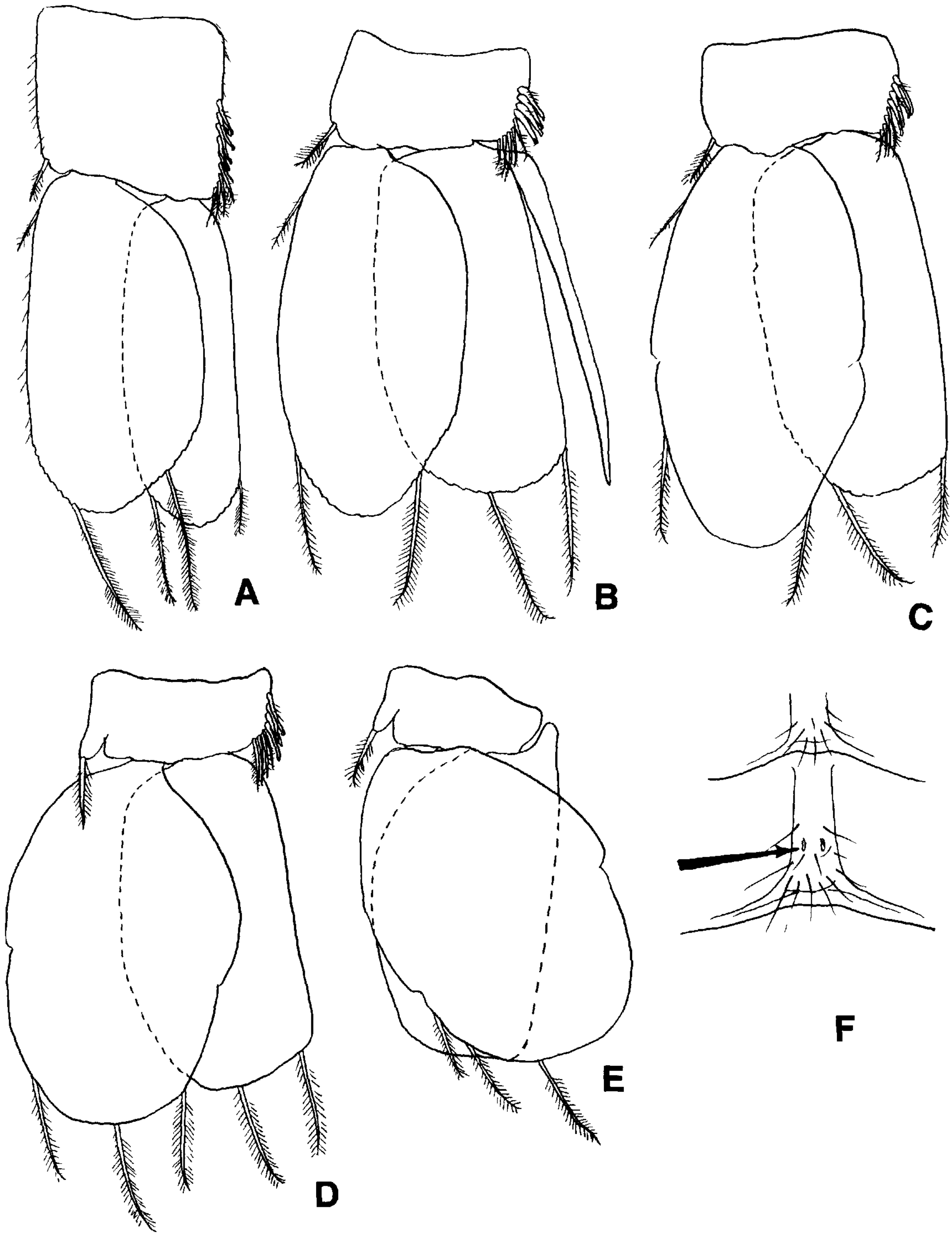

Fig.5. *Odysseylana sirenkoi* sp.nov. Male, holotype. A-E, pleopods 1-5; F, penes on sternite 7.

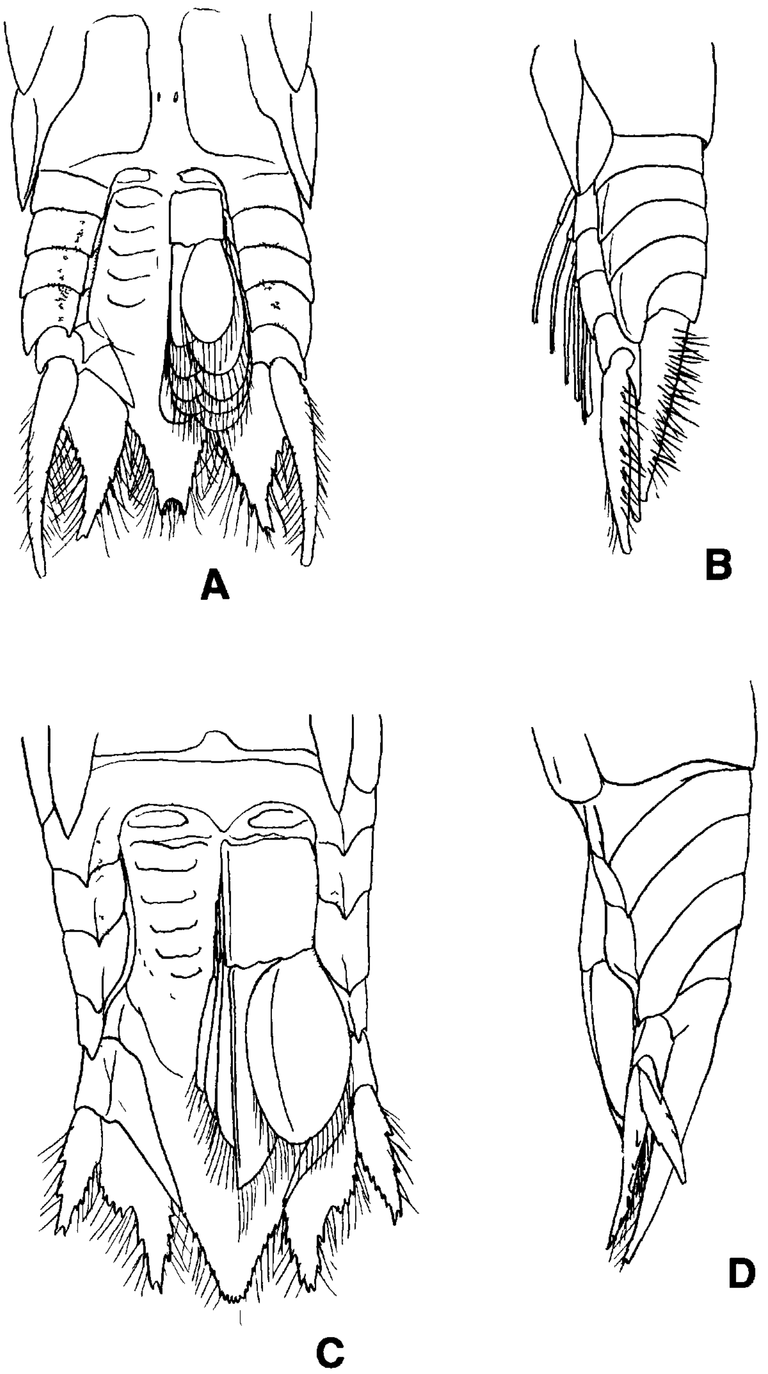

Fig.6. *Odysseylana sirenkoi* sp nov Male, holotype A, pleon, ventral view, B, pleon, lateral view, *Conilera cylindracea* female from Naples, Italy C, pleon, ventral view, D, pleon, lateral view

Maxilliped (Fig 2 I, G) Endite with 3 coupling hooks and 5 long plumose setae Palp article 1 shortest, subrectangular, article 2 subtriangular, with long simple setae medially, article 3 longest and broadest, with eighteen medial and eleven lateral long simple setae, article 4 about half as long as third, with 13 medial and 5 lateral setae, last article subequal in length, but narrower than article 4, with twenty-two long simple setae

Pereopod 1 (Fig 3A) Basis with numerous dorsal small and long simple setae and eleven long distoventral setae, ischium with seven long simple ventral setae, two stout sensory distoventral spines, six distomedial and nine distodorsal long setae, merus with six stout long and six shorter sensory spines on broad ventral surface and six distodorsal long simple setae, carpus with five bifid distoventral setae, propodus with three stout bifid and one simple ventral setae, very stout sensory spine and five simple setae distoventrally, dactylus with six simple setae distally Pereopods 2 and 3 (Fig 3B, C) similar to pereopod 1, but spines of ischium, merus and carpus larger, merus narrower and longer, carpus narrower and shorter than in pereopod 1, ischium and merus with additional sensory spines distodorsally

Pereopods 4-7 (Figs 3D and 4A-C) Essentially similar, but all articles increased in length Basis with two dorsal rows of simple and plumose setae Ischium, merus and carpus with groups of sensory spines and long simple setae along ventral margin and a group of spines and long setae distodorsally (for details of setation see Figs 3 and 4) Propodus with 3 groups of 2-3 sensory spines on ventral margin and 3-4 simple and plumose setae distodorsally

Penes (Fig 5F) Well separate, flattened

Pleopod 1 (Fig 5A) Peduncle as long as broad, endopod almost half as wide as exopod Peduncles of remaining pleopods almost half as long as first Pleopods 1-4 peduncle with four coupling hooks and 4-5 plumose setae distomedially

Pleopod 2 (Fig 5B) Appendix masculina long and slender, tapering, extending slightly past endopod apex, not reaching beyond swimming setae of rami, endopod subrectangular

Pleopod 3 (Fig 5C) Similar to 2, but exopod slightly broader Pleopods 3-5 exopod (Fig 5C-E) with partial suture only

Uropod (Fig 2 J) Rami extending beyond apex of pleotelson Exopod 1 26 times as long as endopod, slender, conical, lateral side with five groups of 4-5 short plumose setae and 1 stout spine in each, medial side with row of long plumose setae Endopod proximally 1 8 times as broad as exopod, tapering distally, lateral margin concave, roughly serrate with fifteen plumose setae Medial margin with five sensory spines and twelve long plumose setae Apexes of both rami obliquely truncate, with tuft of setae

Remarks. This species is known only from the single specimen It is distinguished from other Cirolanidae by the generic characters

Etymology. The species is named for marine biologist Dr B I Sirenko, from ZIN, who collected this specimen

Acknowledgements

I thank Dr N L Bruce and Professor O G Kussakin for their critical comments on the first draft of the manuscript of this paper

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RECORDS OF CUVIER'S BEAKED WHALES *(ZIPHIUS CAVIROSTRIS)* FROM TAIWAN, REPUBLIC OF CHINA

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Abstract

Recent strandings and previous records of Cuvier's beaked whale, *Ziphius cavirostris*, in Taiwan are described The chronology and distribution of the events and the external morphology and appearance, stomach anatomy and contents, and reproductive characteristics of specimens are presented

Introduction

Cuvier's beaked whale or the Goose-beaked whale (*Ziphius cavirostris* Cuvier, 1823) is probably the most cosmopolitan member of the Ziphiidae However, a global review revealed no published accounts from the waters surrounding Taiwan, even though there are numerous records from the waters of Japan and parts of southeast Asia and Australia (Heyning 1989) The paucity of information from Taiwan more likely reflects limited research effort or poor documentation of specimens rather than a lack of animals We present information on nine strandings in Taiwan between late 1991 and late 1994, and mention three specimens collected prior to 1990 Seasonality of occurrence, reproduction and diet are discussed

Chronology and location of stranding events

On 26 November 1991, a live 575 cm male was found on a beach at Houlung, Miaoli County, northwest Taiwan Newspaper accounts stated that the whale returned to the sea but stranded again an hour later and died The eyes and both erupted teeth were removed by local residents Five scars or wounds on the body were reported, they may have been inflicted by parasites (see later) The complete skeleton (except the teeth) is at the National Museum of Natural Science (NMNS-10)

Two animals stranded alive on a beach in Hualien County, northeast Taiwan on 3 February 1993 Positive identification was made by the authors from high quality, newspaper, photographs Sexes are uncertain, but light pigmentation around the head of one suggests that it was male (see Heyning 1989) After unsuccessful rescue attempts with heavy machinery, both animals died and were butchered for sale by local residents The masses were estimated by the residents at 3000 kg (the probable male) and 2000 kg No samples were obtained from either

Two more animals stranded alive on the same beach early in the morning on 24 January 1994 The larger (approximately 7 m long), still partially immersed, was pushed back to sea successfully by a bulldozer It was probably a male judging from rescuers' descriptions of visible teeth at the tip of the lower jaws The smaller whale was stranded higher on the beach and died after unsuccessful attempts to return it to the sea (Plate 1A) She was

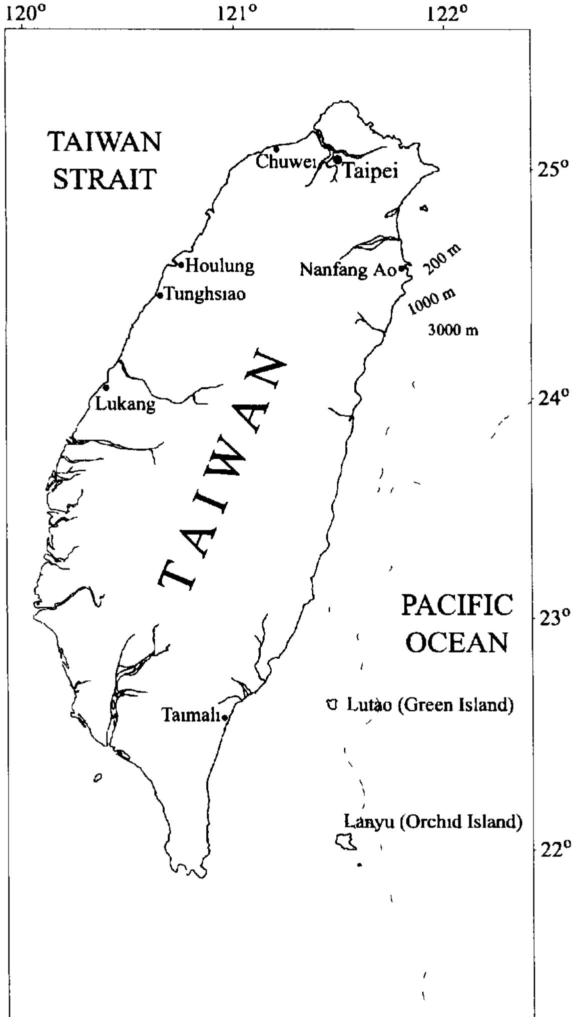

Fig. 1. Map of the study area with locations and depth contours.

468 cm long and weighed 1410 kg (measured by a truck-scale). This represents only the tenth Cuvier's beaked whale for which mass has been determined. This specimen was transported to the National Museum of Natural Science for dissection; the skeleton (HU-94-01) is being prepared for the museum collection.

Two weeks later, on 11 February 1994, a whale stranded on Lutao (Green Island), Taitung County, southeast Taiwan. Its species was determined from photographs. Although length and sex were not reported, light pigmentation around the head and evidence from photographs that teeth may have been removed from the tip of the mandibles suggest it was a male.

Further south, on Lanyu (Orchid Island), Taitung County, a female stranded alive on 1 April 1994 in a rocky tidal pool; she died a few hours later. When we arrived the following day, she was floating and her body was curled with the flukes submerged to almost a metre depth making an accurate measurement of the total length impossible. She was approximately 560 cm in length and pregnant with a 210.5 cm long male foetus (Plate 1B). Because of severe abrasion to the skin, the pigmentation pattern of the adult could not be determined. The female's skull was retrieved and is being prepared at the National Museum of Natural Science (LY-94-01).

The skull and lower jaws of another specimen, also found on the shores of Lanyu, are kept at the Institute of Academic Sinica. No other data are available.

The most recent stranding was of a 560 cm female which came ashore on 27 September 1994 at Taimali, Taitung County, southeast Taiwan. She was necropsied at the National Museum of Natural Science, and the skeleton is being prepared for the collection (TD-94-01).

Other records

Two specimens were described by Yang (1976). An approximately 600 cm male stranded on a beach at Lukang, Changhwa County, central western Taiwan, on 19 October 1961. Its weight was reported as 1852 kg (no information available on the weighing method). Yang also mentioned that a specimen was captured near Hengtseng (location details were not mentioned) but provided no other information.

On 12 May 1987, researchers of the National Taiwan Ocean University (previously known as National Taiwan College of Marine Science) discovered a carcass at the fishing port of Nanfang Ao, Ilan County, northeast Taiwan. Length and

Plate 1. Photographs of *Ziphius cavirostris* stranded along the beaches of Taiwan. A, HU-94-01; B, foetus of LY-94-01.

sex were not determined, but photographs of the head allowed positive identification Only the mandibles were collected, they are stored in the collection of the National Taiwan Ocean University (NTOUI)

Distribution

The Taiwan Strait consists of shallow continental shelf waters with a maximum depth of approximately 200 m On the Pacific coast of Taiwan, however, water drops to depths of 1000 m less than 3 km from shore and greater than 3000 m within 4 or 5 km of shore Seven of the nine strandings reported in this paper occurred on the Pacific coast within a few kilometres of water depths greater than 1000 m This is consistent with the findings of Nishiwaki and Oguro (1972), who examined data on catches of Cuvier's beaked whales in the Japanese whaling records The Houlung and Lukang strandings may be unusual, as these sites are more than 150 km and 250 km, respectively, from the nearest water of 1000 m depth The Houlung animal stranded alive, so that it is unlikely ocean currents alone were responsible for bringing it to this location Two very fresh Dwarf sperm whales (*Kogia simus*) also stranded in this area, one on the beach of Tunghsiao, Miaoli County (Chou 1989), the other further north on a beach near Chuwei, Taoyuan County (unpublished data) The presence of these two deep water, teuthophagous, species along the west coast of Taiwan is peculiar and deserves further attention Catch data from regional fisheries during the period of these stranding events may provide insight, for example, prey species in the stomachs of stranded whales can be compared with fisheries catches to test the hypothesis that dense aggregations of cephalopods attracted the whales into relatively shallow waters they do not usually inhabit

All strandings occurred during non-summer months, most (five of nine) happened in winter This pattern may reflect seasonal differences in abundance, weather conditions, or prey availability The harsher weather in the winter may increase the likelihood of stranding Current data are too sparse for more than speculation

The number of Cuvier's beaked whales found stranded in 1994 (five) is substantially higher than that in other years, i e , 1991, 1992 and 1993 Furthermore, the most recent stranding, as of November 1995, was that of TD-94-01 in September 1994

External morphology and appearance

The external morphology of specimens reported in this paper was consistent with the description of the species by Heyning (1989) The flukes lacked the distinct median notch seen in most cetaceans, but frequently a slight median indentation, resembling a notch is present, we observed this in the flukes of NMNS-10, TD-94-01 and HU-94-01 (Plate 2A) However, both LY-94-01 and her calf exhibited a small median lobe (Plate 2B)

Coloration of most ziphiids is poorly described owing to the poor condition of most stranded specimens The pigmentation of all adult specimens reported in this paper was consistent with that described by Heyning (1989) The male foetus of LY-94-01 was uniformly light gey (slightly darker dorsal surface and lighter ventral surface) with a contrasting dark patch around the left eye (Plate 2B) The skin was too badly abraded to confirm the same colour pattern on the right side

All specimens had many healed, white, oval scars Some also had partially healed and fresh scars that were still bleeding (Plate 2C) These scars, which were 4–5 cm along the major axis and 3–4 cm along the minor axis, were consistent with descriptions of scars on other ziphiids which have been attributed to parasitism by lampreys or Cookie-cutter sharks (probably *Isistius* sp) (Mead *et al* 1982)

The mean body length of the four Taiwan adult specimens which stranded and for which length measurements were available, was 541 ± 49 (SD) cm This was significantly shorter ($p < 0$ 05, df = 191) than the mean body length (592 ± 50 (SD) cm) of specimens reported in the Japanese whaling records calculated from data presented by Nishiwaki and Oguro (1972) The whaling industry was likely biased towards harvesting larger animals Selected measurements (as

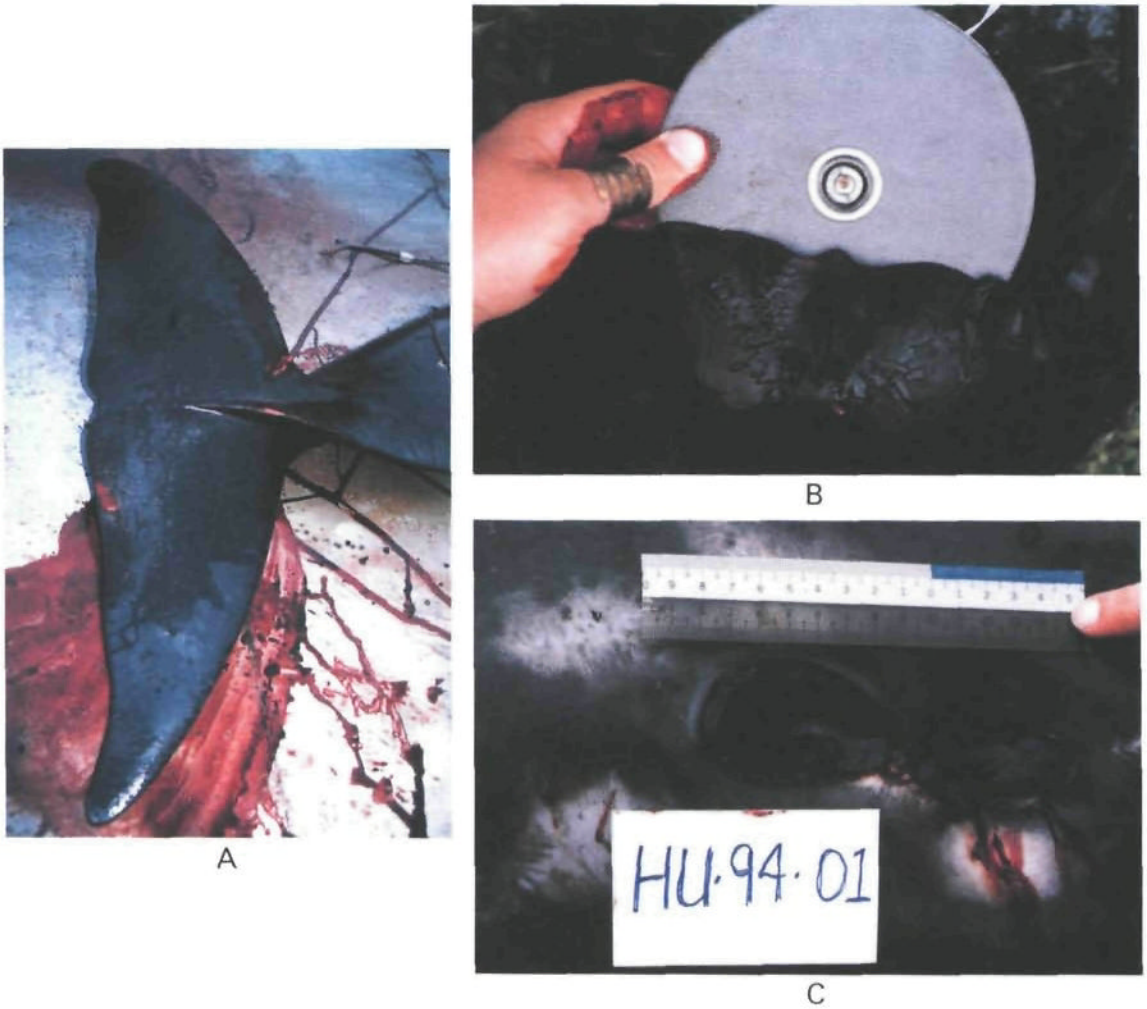

Plate 2. Some characteristics of *Ziphius cavirostris* stranded along the beaches of Taiwan. A, a slight median notch in the flukes of HU-94-01; B, a small median lobe in the flukes of the foetus of LY-94-01; C, scars found on the body of HU-94-01 (presumed to be inflicted by lampreys or Cookie-cutter sharks).

percentage of the total body length) of some specimens are presented in Table 1. Values for 13 measurements of Taiwan specimens were more than one standard deviation from the means reported by Heyning (1989). Four were greater than two standard deviations. Differences in measurements may result from different positions of the animals when measured, researcher experience, and error in data recording or transcription, e.g., the snout to the anterior insertion of the flipper measurement of NMNS-10 was nine standard deviations below the mean and impossible morphologically; they may also indicate that more variation exists in the morphology of this species than previously observed.

Stomach contents

The stomach anatomy of the Taiwan specimens was consistent with the description by Mead (1993). The variation in the number of main and

Table 1. Comparisons of morphometric measurements as a percentage of total length between the Cuvier's beaked whales of Taiwan and reported means.

Measurement	Catalogue Code				Reported
	NMNS-10	HU-94-01	LY-94-01	TD-94-01	means (SD)
Snout to anus	69 4	69 7	–	71 7	68 0(3 9)
Snout to urogential aperture	59 8	–	–	–	58 9 (–)
Snout to urogential aperture	–	62 5	–	66 2	67 6 (–)
Snout to umbilicus	–	49 7	–	47 9	46 9 (–)
Snout to tip of dorsal fin	63*	68 3	69 4	67 6	67 6(3 2)
Snout to ant insertion of flipper	6 4**	19 6*	–	21 7	21 9(1 6)
Snout to blowhole	11 7*	7 8**	11 0	7 8**	10 3(1 0)
Snout to eye	11 7	10 7	12 7*	10 7	11 5(1 1)
Snout to ear	15 8	12 7	–	–	12 6 (–)
Snout to gape	6 3	5 3	7 3	5 7	5 1 (–)
Fluke width	27 5	30 4*	24 6	25 3	27 1(3 1)
Fluke length	8 3	8 3	7 4	7 7	7 5 (–)
Dorsal fin height	4 2	4 9	3 8	4 4	4 3(0 7)
Dorsal fin base length	6 3	8 7*	8 0	9 8*	6 9(1 5)
Flipper length (anterior)	11 3	11 5*	10 6	10 3	10 8(0 6)
Flipper length (posterior)	9 7**	7 9	7 0*	7 9	7 8(0 7)
Flipper width	3 5	3 3	2 6	2 8	3 0(0 5)

from Heyning (1989) for males for females
*one SD from mean **two SD from mean

pyloric chambers for Taiwan specimens are shown in Table 2

The stomachs contained copious amounts of fluid, cephalopod beaks and crustacean parts (Table 2) The stomachs of TD-94-01 also contained fish otoliths possibly from a member of the Macrouridae All prey species have yet to be positively identified However a preliminary examination of beaks indicated that the contents in the stomachs of LY 94-01 contained *Enoploteuthis chuni Pholidoteuthis* sp , *Octopoteuthis* sp , *Histioteuthis*?, Mastigoteuthidae or Chiroteuthidae, and Ommastrephidae Detailed analysis of the stomach contents will require a regional reference collection of cephalopod beaks This was started recently

Reproduction

Little information was obtained from the Taiwan specimens LY 94-01 was the only pregnant female The foetus was 210 5 cm long and male We believe the pregnancy was in the late stages since the estimated length at birth for this species is 270 cm (Mead 1984) Foetal folds were observed on the left side indicating that the foetus was curled up with the left side facing inward (Plate 1B)

Table 2. Summary of the anatomy and contents of the stomachs of Cuvier's beaked whale from Taiwan waters.

	HU-94-01	LY-94-01	TD-94-01
Main			
Number of chambers	1	1	2
Amount of fluid and hard parts (g)	465	2695	1000 ± 100
Contents	empty	21 cephalopod beaks and crustacean parts	32 cephalopod beaks 3 fish otoliths and crustacean parts
Pylorics			
Number of chambers	7	9	10
Amount of fluid and hard parts (g)	–	5930	7200 ± 100
Contents	1 cephalopod beak and crustacean parts	42 cephalopod beaks, crustacean parts and a wooden stick (approx 15 cm long)	543 cephalopod beaks 2 fish otoliths crustacean parts and 5 to 6 soft, flaky rocks

Discussion

As indicated by the number of specimens presented, the lack of information on the occurrence of Cuvier's beaked whales in Taiwan is probably not due to a lack of animals, but rather reflects research effort This is likely a common species along the east coast of Taiwan where a water depth of greater than 1000 m is near shore The favourable ocean bathymetry of eastern Taiwan presents an opportunity to further our understanding of this and other ziphiids Increased effort in collection of biological information on stranded individuals in Taiwan will contribute greatly to our sparse knowledge of these deep-diving and rarely encountered cetaceans

Acknowledgements

We would like to thank J Chen, W L Tsai and S Y Chu for assistance in the field, W Walker for the preliminary examination of the stomach contents of LY-94-01 and T Jefferson for providing information on the mandibles of NTOU1 Constructive and detailed criticism of early drafts of the manuscript from S Leatherwood, E Secchi, L L Yang and an anonymous reviewer was appreciated greatly This research was made possible by grants from the Council of Agriculture of Taiwan, R O C to L S C Photographs were provided by J Y W

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Asian Marine Biology 12 (1995) 119–139

RECORDS OF SMALL CETACEANS IN CHINESE WATERS: A REVIEW

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Abstract

There are confirmed records of 22 species of small cetaceans in Chinese waters (including Hong Kong, Macau, and Taiwan) The list includes a few cold temperate species and nearly all of those warm temperate and tropical species known from the Indo-Pacific region Three species previously reported (Irrawaddy dolphin, Short-beaked common dolphin, and Harbour porpoise) are herein removed from the list, based on a critical review of information supporting the identifications One or more of these three, as well as additional species of beaked whales, may ultimately be shown to occur in Chinese waters In China, small cetaceans of many species are suffering from problems associated with habitat loss/degradation and kills in fisheries Effective conservation efforts are needed to avoid the loss of stocks and even species

Introduction

China[1] is bordered by the Bohai, Yellow, East China and South China seas, adjacent to the western North Pacific (Fig 1) China's Extended Economic Zone is large, and it has a coastline of over 18,000 km, not including that of the more than 5,000 islands on the continental shelf and slope and in oceanic waters Chinese fisheries rank among the most productive anywhere, with worldwide annual marine catches of > 10 million tonnes Extensive fisheries are known to operate in most coastal provinces and interactions between fishery operations and cetaceans are known to occur Figure 2 is a map of Taiwan

The extensive coastline of China is inhabited by a large number of species of small cetaceans Other than work on the population status and biology of the Baiji (*Lipotes vexillifer* Miller) and, to a lesser extent, the Finless porpoise (*Neophocaena phocaenoides* [Cuvier]), there has been little directed work on the small cetaceans of China In the past few years, however, many research projects on marine cetaceans in mainland China, Taiwan and Hong Kong have been initiated and one for Macau is being planned (Perrin in press) Parsons *et al* (1995) recently provided a checklist of cetaceans in Hong Kong Several species of China's marine dolphins and both its species of freshwater small cetaceans are known to be caught incidentally in fisheries throughout the region (Zhou and Wang 1994, Chou *et al* 1995) However, very little is known about the impacts of human activities on the small cetaceans of China This paper reviews published information on the occurrence of each of the species recorded, presents some unpublished data, and discusses the current conservation status of small cetaceans in China

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[1] In this paper, we use the term China to refer to the geographical region including mainland China, Taiwan, Hong Kong and Macau

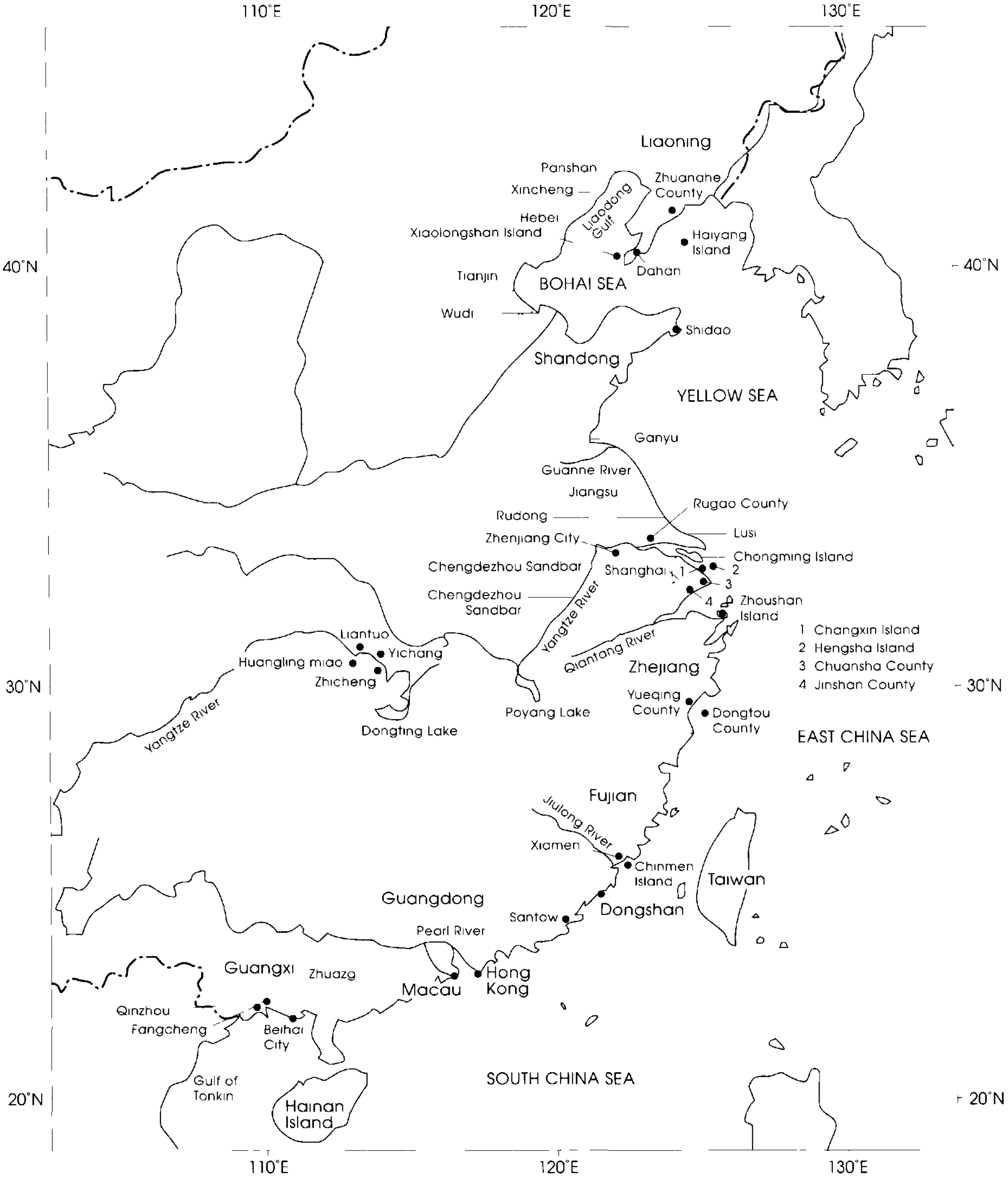

Fig. 1. Map of Chinese waters, showing some of the place names mentioned in the text.

Fig. 2. A map of Taiwan showing some of the place names mentioned in the text.

Known species and their distributions

Examination of the published and unpublished literature indicates that 25 species of small cetaceans have been reported from Chinese waters. Twenty-two of these have been confirmed (Table 1). Of these, 13 have been recorded on both sides of the Taiwan Strait, four from mainland provinces and territories only, and five from Taiwan only. Chinese records of Irrawaddy dolphins (*Orcaella brevirostris* (Gray)), Short-beaked common dolphins (*Delphinus delphis* Linneaus), and Harbour porpoises (*Phocoena phocoena* (Linneaus)) are provisionally rejected, because of a lack of convincing evidence for their occurrence. However, all three are found along adjacent sections of coastline (Short-beaked common dolphins and Harbour porpoises to the north (Perrin in press), and Irrawaddy dolphins to the southwest (Lloze 1973) and may eventually be found to be a part of the cetacean fauna of China.

For most offshore species, we have only scattered stranding records, which are not indicative of their true ranges; we have therefore not provided distribution maps for these species. Although one or more stocks have been identified for at least 8 of the 21 species occurring in Chinese waters (Perrin and Brownell 1994), little is known about their geographic variation in China, except for the Finless porpoise and Bottlenose dolphin. Studies of stock structure are badly needed for most species of cetaceans that occur in the region.

Pygmy sperm whale: Kogia breviceps (de Blainville)

Pygmy sperm whales (Plate 1A) are represented in Chinese waters by reports of at least eight specimens, stranded in Taiwan at Keelung, Dashi, Tungkang, Kaohsiung, the Penghu Islands and Yehliu (Yang 1976; Chou *et al.* 1995; Chen *et al.* 1995). There are also at least three stranding records from Hong Kong (Parsons *et al.* 1995). It is possible that some of these reported specimens of *K. breviceps* were specimens of *K. simus*.

Dwarf sperm whale: Kogia simus Owen

Dwarf sperm whales (Plate 1B) are known only from off the coast of Taiwan, although they probably also occur elsewhere in Chinese waters. A female was found dead on the beach of Miaoli County, Taiwan, in June 1986 (Chou 1989). A skull collected from Suao[2] was deposited in the collection of the National Taiwan Ocean University (NTOU) (Mizue 1988; Wang, P. 1991). There are two recent stranding records, one each from Ilan and Taoyun, Taiwan (Chou *et al.* 1995).

Cuvier's beaked whale: Ziphius cavirostris Cuvier

A male Cuvier's beaked whale was found stranded on the beach at Lukang, Taiwan, in October 1961 (Yang 1976). The skull of this specimen is now

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[2] The so-called Suao fish market is actually located in the small village of Nan Fang Au, just south of Suao. Presumably, most or all records reported from Suao are actually from this fish market.

Table 1. Areas of confirmed records of small cetaceans in Chinese waters.

	Region							
Species	SCS	ECS	YS	BS	YR	T	HK	M
Kogia breviceps	X	X				X	X	
Kogia simus		X				X		
Ziphius cavirostris	X	X				X		
M densirostris		X				X		
Mesoplodon ginkgodens	X	X	X			X		
Orcinus orca	X	X	X	X		X		
Globicephala macrorhynchus	X							
Pseudorca crassidens	X	X	X	X	X	X	X	
Feresa attenuata	X	X				X		
Peponocephala electra	X	X				X		
Sousa chinensis	X	X			X		X	X
Steno bredanensis	X	X	X			X	X	
Lagenorhynchus obliquidens		X						
Grampus griseus	X	X				X	X	
Tursiops truncatus	X	X	X	X		X	X	
Stenella attenuata	X	X				X	X	
S longirostris	X	X				X		
S coeruleoalba	X	X				X	X	
Delphinus capensis	X	X				X	X	
Lagenodelphis hosei	X	X				X	X	
Neophocaena phocaenoides	X	X	X	X	X	X	X	
Lipotes vexillifer					X			

Region abbreviations SCS, South China Sea, ECS, East China Sea, YS, Yellow Sea, BS, Bohai Sea, YR, Yangtze River, T, Taiwan territorial waters, HK, Hong Kong territorial waters and M, Macau territorial waters

housed at the Tawian Fisheries Research Institute, Kaohsiung (TFRIK) (Jefferson pers observ) Several specimens were also obtained from Suao and Hengchun, Taiwan (Yang 1976, Wang, P 1991) There are records of six recent strandings from Taiwan, at Miaoli, Hualien, Lu Tao, Lan Yu, and Taitung (Chou *et al* 1995, Chen *et al* 1995)

Baird's beaked whale: Berardius bairdii Stejneger

A complete skeleton of a Baird's beaked whale is housed in the Zhejiang Museum of Natural History (Wang Yu pers comm) A museum staff member said it was collected by the Zhoushan Marine Fisheries Company at the end of the

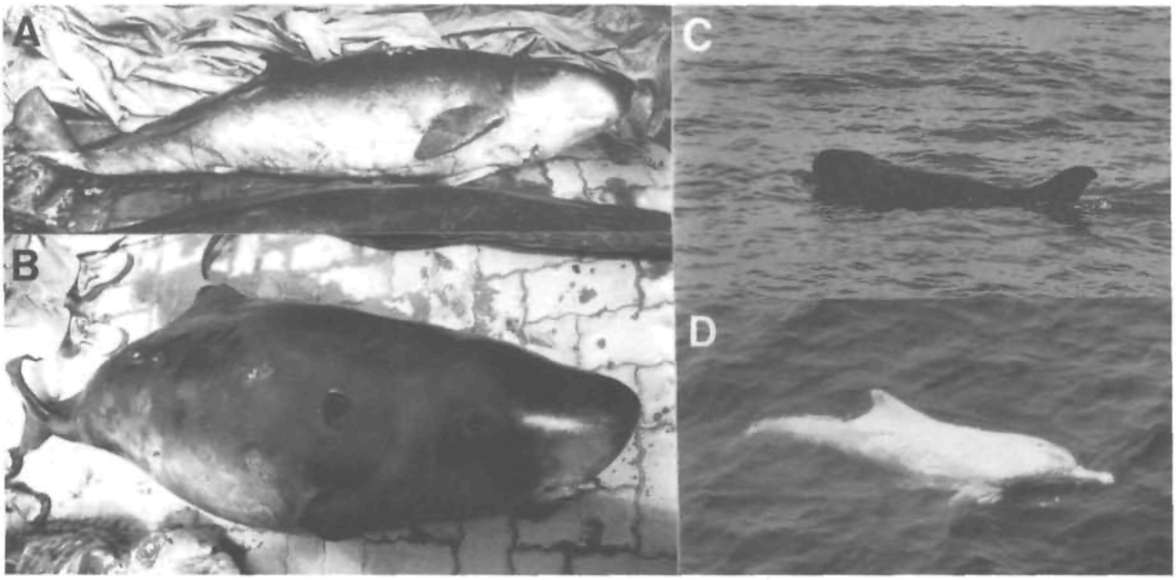

Plate 1. A, Pygmy sperm whale from the east coast of Taiwan; B, Dwarf sperm whale from the east coast of Taiwan; C, False killer whale observed off Hualien, Taiwan, on 19 June 1995; D, Indo-Pacific hump-backed dolphin off Hong Kong.

1950s, but the collection locality is not known, and it may not have come from China. Baird's beaked whale is primarily a cold temperate species and it probably does not occur off southern China, Hong Kong, Macau, or around Taiwan. It may, however, occur seasonally in colder, northern, waters.

Blainville's beaked whale: *Mesoplodon densirostris* (de Blainville)

Blainville's beaked whales have been recorded along the Chinese mainland and Taiwan. A specimen was found stranded at Changxin Island, Shanghai, in the estuary of the Yangtze River, in 1994 (Zhou unpubl. data). Two specimens were found at the fish markets in Peikang and Tungkang, Taiwan, in 1968 (Kasuya and Nishiwaki 1971; Yang 1976).

Ginkgo-toothed beaked whale: *Mesoplodon ginkgodens* Nishiwaki and Kamiya

A female Ginkgo-toothed beaked whale was found stranded on the Yellow Sea coast at Zhuanghe County, Liaoning Province, in August 1980 (Shi and Wang 1983). Local fisheries around the Penghu Islands and Xiaoliuqiuyu Island, Taiwan, took two specimens in the early 1960's (Yang 1964, 1976). Another specimen was found at the fish market in Kaohsiung, Taiwan, in 1969 (Yang 1976). There is also a single record of a whale of this species having been taken by commercial whalers in southern Taiwan (Yu 1995).

Other beaked whales (Ziphiidae)

Although there are confirmed records thus far of only two species of *Mesoplodon* from Chinese waters, it is likely that other species occur there. For example, photographs of a beaked whale skull from Taiwan (Yang 1976: fig. 22), identified by the author as a Blainville's beaked whale, show what is probably another species of *Mesoplodon*, possibly a Hubbs' beaked whale (*M. carlhubbsi* Moore) or a Stejneger's beaked whale (*M. stejnegeri* True).

It should be noted that several sightings and possible captures of Bottlenose whales (*Hyperoodon* sp.) have been made in the tropical Indo-Pacific (Leatherwood *et al.* 1992; Perrin in press; R. L. Pitman pers. comm.), and it is feasible that Bottlenose whales could occur in China.

Irrawaddy dolphin: *Orcaella brevirostris* (Gray)

The occurrence of the Irrawaddy dolphin in the coastal waters of Taiwan was reported by Chou (1994), from interviews with fishermen We consider these to be cases of mistaken identity, however There is no convincing evidence that dolphins of this species occur around the island of Taiwan, and it is best not to consider Taiwan as part of their range

Sightings of two pods of small, blunt-headed dolphins in Hong Kong were reported as Irrawaddy dolphins (Viney 1993) However, we also consider these records unreliable Irrawaddy dolphins are known from southern Vietnam, there are suggestions that they also occur in the Red River in the north, but there are no confirmed records north and east of Vietnam (see Smith *et al* 1995)

Killer whale: *Orcinus orca* (Linneaus)

Killer whales have been recorded from Chinese waters as follows from Xiaolongshan Island (Shedao Island), near Dalian City, Liaoning, in the Bohai Sea (Wang 1979), from Haiyang Island, Liaoning, and Shidao, Shandong, in the Yellow Sea (Wang 1979, Shi and Wang 1983), and from Zhoushan Island, Zhejiang, in the East China Sea (Wang 1984) They have also been reported from Pingtung and Kaohsiung, Taiwan, in the East China Sea, and from the South China Sea (Yang 1964, 1976) There is also a record, supported by photographs, of a Killer whale having been taken by commercial whalers in southern Taiwan (Yu 1995)

Short-finned pilot whale: *Globicephala macrorhynchus* Gray

There is only one known record of Short-finned pilot whales from Chinese waters This was a stranding at Xisha, Hainan Province, in July 1991 (Wang 1993) Miyashita *et al* (1995) reported a sighting from oceanic waters off the east coast of Taiwan, just outside the border of our study area Presumably these animals are more common than the scarcity of records indicates

False killer whale: *Pseudorca crassidens* (Owen)

False killer whales (Plate 1C) have been recorded from the Bohai, Yellow, East China, and South China seas There are records from the waters off Liaoning, Shandong, Zhejiang, Fujian, and Guangxi Zhuang provinces (Wang 1990, Zhou *et al* 1982), Taiwan (Nishiwaki and Yang 1961, Yang 1976), and Hong Kong (Parsons *et al* 1995) They reach estuaries and occasionally enter rivers in the Chinese mainland Tens of animals were reported 50 km up the Guanhe River, Jiangsu Province, on 16 June 1994, solitary individuals were discovered 220 km and 300 km up the Yangtze on 13 February 1991 and 2 March 1991, respectively (Zhou unpubl data), and three were reported 30 km up the Qiantang River, Zhejiang Province, in April 1957 (Zhou *et al* 1982) A False killer whale swam into the harbour at Taichung, Taiwan, in 1986 and died despite attempts to save it (Jeng 1986) There have been additional strandings in recent years in Taiwan (Chou *et al* 1995), and many small groups were observed at sea off Hualien, east coast of Taiwan, on 19 June 1995 (Jefferson unpubl data)

The largest directed kills of False killer whales in Chinese waters were by the drive fishery in the Penghu Islands, Taiwan Dozens of whales were driven into a fishing port on the Islands and captured in March 1990, along with unspecified numbers in previous years Six of the animals were bought by Ocean World in Yehliu, Taiwan, in 1990 for display The killing and capturing of cetaceans has been banned in Taiwan since August 1990

Pygmy killer whale: *Feresa attenuata* Gray

The skull of a Pygmy killer whale was collected from Suao, Taiwan, in 1987 (Mizue 1988, Wang, P 1991) Recently, a pod of between 10 and 20 whales of this species swam into a navy harbour in southern Taiwan and remained there for many days before swimming back out to sea (R Chen and J Y Wang pers comm)

Melon-headed whale: *Peponocephala electra* (Gray)

Specimens of the Melon-headed whale were found at fish markets in Peikang, Tungkang, and Kaohsiung, Taiwan, in the 1950s and 1960s (Yang 1976) It is now known that the mass stranding of 109 small cetaceans at Hengchun, Taiwan, originally reported as Harbour porpoises, was actually a herd of Melon-headed whales (Yang 1976, H Yang pers comm) There are three recent Taiwanese records, from Tainan and Kaohsiung (Chou *et al* 1995, Chen *et al* 1995)

Indo-Pacific hump-backed dolphin: *Sousa chinensis* (Osbeck)

Indo-Pacific hump-backed dolphins (Plate 1D) inhabit waters off the coast of the Chinese mainland, from the Gulf of Tonkin to the estuary of the Yangtze River (Fig 3) They are present year round in Hong Kong waters (Parsons *et al* 1995) and Xiamen Harbour and in the Gulf of Tonkin (Beibu Gulf) (Wang and Sun 1982) They are known to occur in Macau (O Pinto, Museo Maritimo de Macau, pers comm) and there are reports, at least from the past, from reliable observers of sightings in other parts of the Pearl River (also called the Zhujiang River) Delta (Zhou *et al* 1980, Zhou 1991, D Melville pers comm , L J Porter pers comm) There are records from the coastal waters of Guangxi Zhuang, Guangdong, and Fujian provinces (Huang *et al* 1978, Wang and Sun 1982) A female was found stranded on the beach in Yueqing County, Zhejiang, on 19 February 1995 (Zhou unpubl data) A male was captured near Hengsha Island, in the Yangtze estuary, in September 1982 (Huang and Fu 1984) The known northern limit of 32°N is represented by a female found on the river bank in Rugao County, in February 1987, 220 km from the mouth of the Yangtze (Zhou 1991) There are no records from the island of Taiwan, but they do occur off the mainland coast around the Chinmen Islands (Chou *et al* 1995)

Rough-toothed dolphin: *Steno bredanensis* (Lesson)

Rough-toothed dolphins are distributed in the East China and South China seas A female was found stranded on the beach of Chuansha County, Shanghai, in October 1973 (Huang 1980) A carcass of this species washed aground on East Sharp Island, Hong Kong, in March 1982 (Parsons *et al* 1995) Two rough-toothed dolphins, collected in Taiwanese waters, were found at the fish markets in Keelung and Kaohsiung in the 1950s and 1960s (Yang 1976) There is a skull from an animal collected at the Suao fish market in 1987 at the NTOU (Mizue 1988) and another from Lukang is at the TFRIK (Jefferson pers observ)

Pacific white-sided dolphin: *Lagenorhynchus obliquidens* Gill

The only Pacific white-sided dolphin specimen reported in Chinese waters was a female taken from the East China Sea, beyond the mouth of the Yangtze River in 1958 (Huang and Tang 1979) The second-hand report by Hammond and Leatherwood (1984) of a sighting in Hong Kong is well south of the species' known range (Leatherwood *et al* 1984) and was almost certainly a mis-identification It is unlikely that White-sided dolphins occur this far south along the Chinese coast

Risso's dolphin: *Grampus griseus* (Cuvier)

Five specimens of Risso's dolphins (Plate 2A) were found in Keelung, Tungkang, and Kaohsiung, Taiwan, in the 1950s and 1960s (Yang 1976) In Hong Kong, strandings of four individuals in June 1986 and one individual in September 1988 were recorded (Parsons *et al* 1995) A female Risso's dolphin was collected on the beach in Dongtou County, Zhejiang Province, in August 1988 (Wang, Y 1991) Five additional

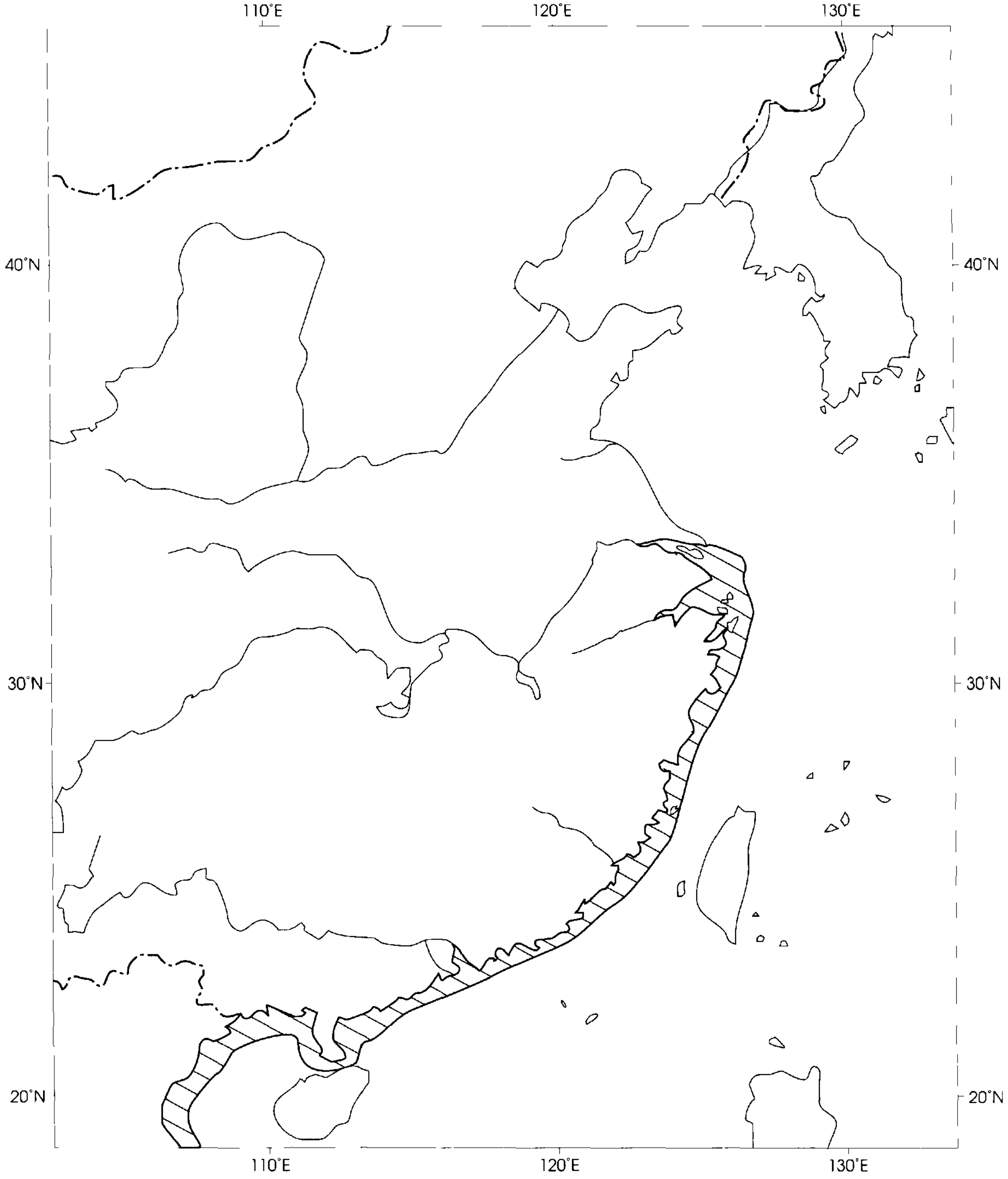

Fig. 3. Approximate distribution of the Indo-Pacific hump-backed dolphin in Chinese waters.

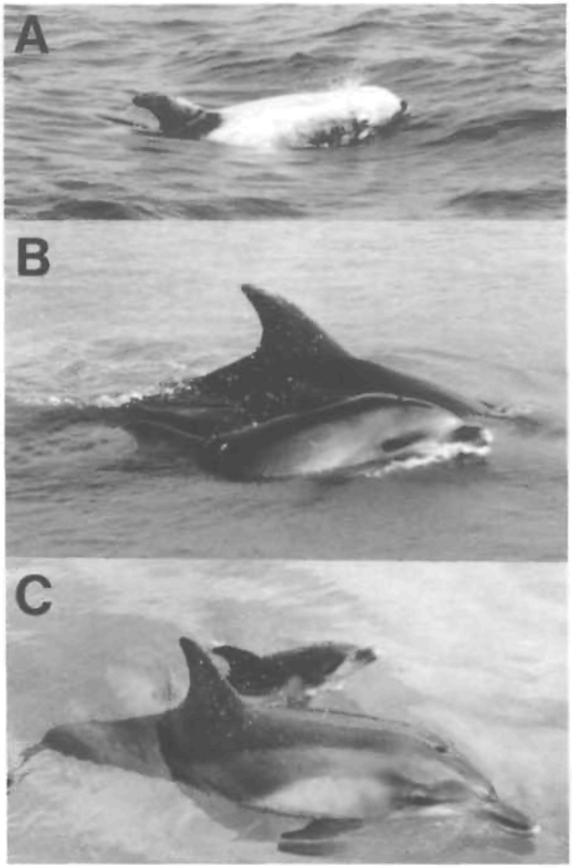

Plate 2. A, Risso's dolphin observed off Hualien, Taiwan, on 18 June 1995; B, captive *truncatus*-type bottlenose dolphins captured off Shakang, Penghu Islands, Taiwan; C, captive *aduncus*-type bottlenose dolphins captured near the Penghu Islands, Taiwan.

Taiwanese records have been reported, from Taipei, Pingtung, and Tainan (Chou *et al.* 1995; Chen *et al.* 1995). At the NTOU, there is also a skull of this species, collected from the Suao fish market (Mizue 1988). Several small herds of Risso's dolphins were observed off Hualien, Taiwan, on 18 and 19 June 1995 (Jefferson unpubl. data).

Bottlenose dolphin: *Tursiops truncatus* (Montagu)

Bottlenose dolphins are widely distributed in Chinese waters (Fig. 4). A larger form (*truncatus*- or *gilli*-type — Plate 2B) and a smaller form (*aduncus*-type — Plate 2C) are recognized (Zhou 1987; Wang *et al.* 1995). The former occurs in the Yellow, Bohai, and East China seas. The latter occurs in the South China and East China seas (Zhou and Qian 1985). Bottlenose dolphins have been recorded from Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Guangxi Zhuang provinces and from Hong Kong (Meng *et al.* 1981; Shi and Wang 1983; Wang 1990; Zhou 1965, 1987; Zhou *et al.* 1982; Zhou and Wang 1994; Parsons *et al.* 1995). All of the specimens stranded in Hong Kong have been of the *truncatus*- or *gilli*-type (Leatherwood pers. observ.).

The largest directed kill of Bottlenose dolphins in Chinese waters was in the drive fishery in the Penghu Islands, Taiwan (Chen *et al.* 1976). Some individuals taken in the drives were sold to oceanaria in the 1980s for display (Hammond and Leatherwood 1984; Reeves *et al.* 1994). Both forms occur sympatrically around the Penghu Islands, where there is both shallow and moderately deep water (Wang *et al.* 1995). Bottlenose dolphins have also been recorded from Keelung and Tungkang, Taiwan (Yang 1976). For all sufficiently documented records from the east coast of Taiwan, where water depths drop off quickly, the specimens appear to be of the larger *gilli*-type (Jefferson pers. observ.).

Pantropical spotted dolphin: *Stenella attenuata* (Gray)

Pantropical spotted dolphins (Plate 3A) are distributed in the South and East China seas. Specimens were caught about 300 km southeast of Shantou in 1978 (Zhou *et al.* 1980) and off Qinzhou, Guangxi Zhuang, in 1988 (Wang 1990). A dolphin carcass from Keelung was reported by Yang (1976) to have been a specimen of *Stenella frontalis*, but the published photos show that it is was a Pantropical spotted dolphin. A carcass, apparently of this species, was found in December 1987, on Lantau Island, Hong Kong (Parsons *et al.* 1995). Spotted dolphins are also known from Taiwanese waters, based on several recent strandings (Chen *et al.* 1995; Chou *et al.* 1995)

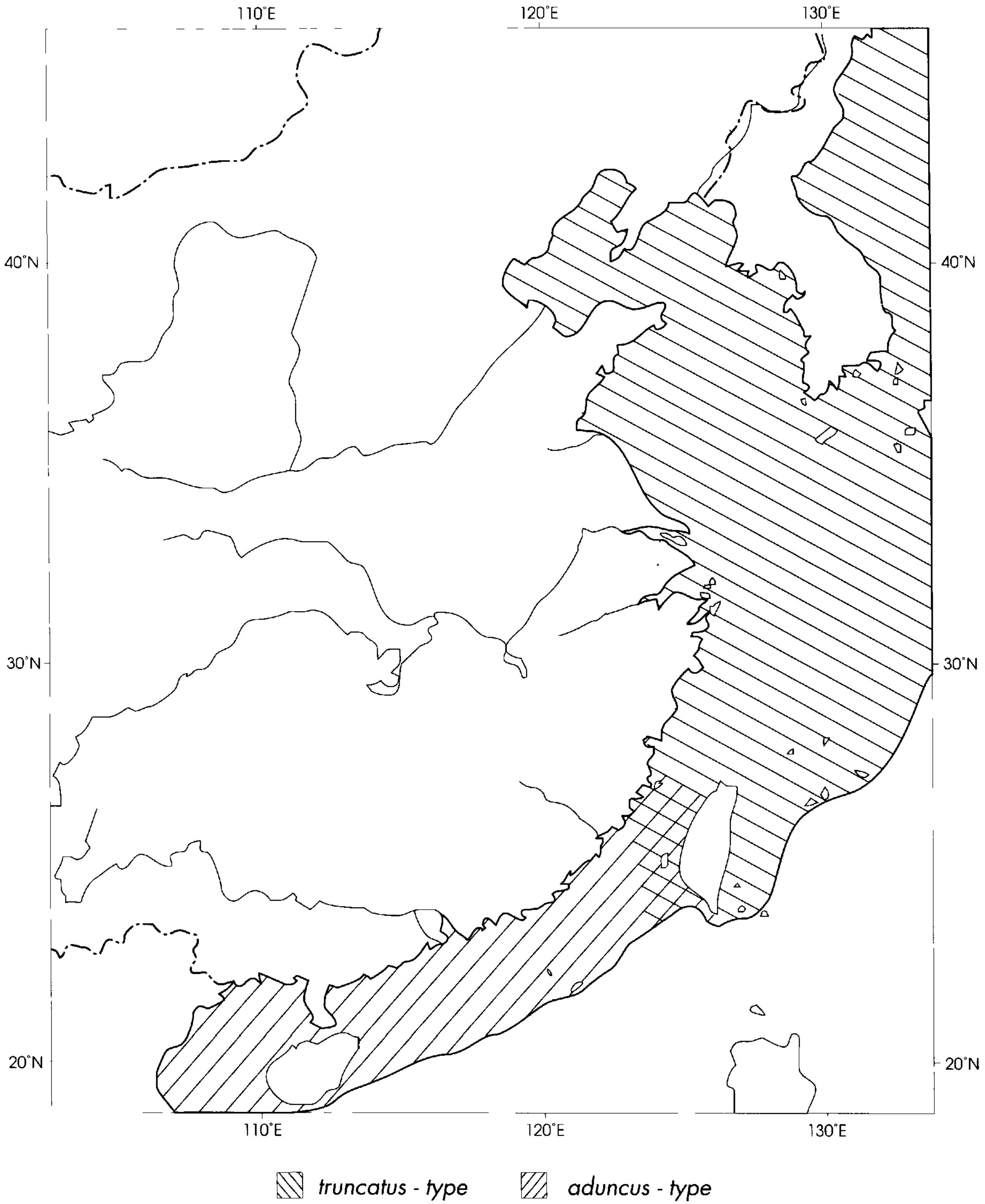

Fig. 4. Approximate distribution of two types of bottlenose dolphin in Chinese waters.

and from captures by fishermen (Mizue 1988). Two herds were observed a few kilometres off the coast of Hualien, northeast Taiwan, on 19 June 1995 (Jefferson unpubl. data). This appears to be one of the most common species of oceanic small cetacean off the east coast of Taiwan.

Spinner dolphin: *Stenella longirostris* (Gray)

Two specimens of Spinner dolphins (Plate 3B) were captured off the coast of Fangcheng County, Guangxi Zhuang, in the Gulf of Tonkin in 1988 (Wang 1990). Illegally caught Spinner dolphin carcasses from Hainan Island were intercepted in Hong Kong in 1993 (Parsons *et al.* 1995). For Taiwan, there are stranding records of Spinner dolphins from Kaohsiung (Yang 1976), Ilan (Chou *et al.* 1995), and an unknown locality (Chen *et al.* 1995). Three skulls in the collection of the NTOU were collected at the Suao fish market, Taiwan (Mizue 1988). Dolphins of this species were frequently encountered just a few kilometres off the coast of Hualien, Taiwan, during two days of vessel surveys in June 1995 (Jefferson unpubl. data). From observations of live animals at sea and from examination of several skulls, it is clear that Taiwanese Spinner dolphins are not of the dwarf form, but of the pantropical subspecies, *S. longirostris longirostris* (see Perrin 1990).

Striped dolphin: *Stenella coeruleoalba* (Meyen)

A male Striped dolphin was found at the fish market in Suao, Taiwan, in 1964 (Yang 1976). The collection of the NTOU in Taiwan also contains the skull of a Striped dolphin collected at the Suao fish market (Mizue 1988). There have been four Striped dolphin strandings in Hong Kong, one each in 1988, 1989, 1992, and 1994 (Parsons *et al.* 1995).

Common dolphins (*Delphinus* spp.)

Currently two species of common dolphins are recognized, the Short-beaked common dolphin (*Delphinus delphis* Linneaus) and the Long-beaked common dolphin (*D. capensis* Gray — Plate 3C) (Heyning and Perrin 1994). Groups of tens to hundreds of common dolphins have been recorded from the Bohai and Yellow seas along the coast of the Chinese mainland (Wang 1984). Two specimens were captured from the northern Yellow Sea in 1963 and 1978 and are housed in the Dalian Natural History Museum (Shi and Wang 1983). An adult female was killed in the Gulf of Tonkin in 1976 (Zhou *et al.* 1980). Five specimens were collected from Beihai City, Guanxi Zhuang, between 1981 and 1988, and two were captured in the same area in 1981 and 1985

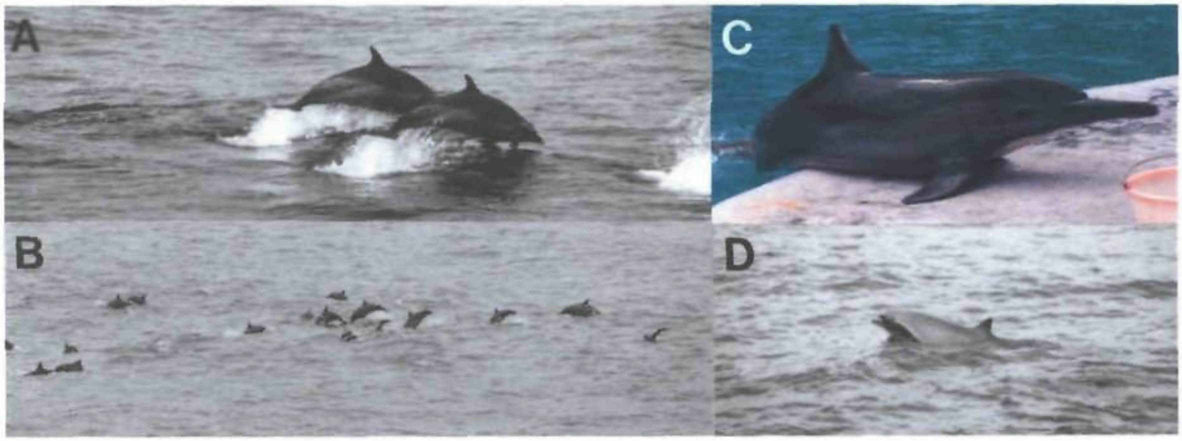

Plate 3. A, Pantropical spotted dolphins observed off Hualien, Taiwan, on 19 June 1995; B, part of a herd of Spinner dolphins off Hualien, Taiwan, on 18 June 1995; C, captive Long-beaked common dolphin captured off the Penghu Islands, Taiwan; D, Fraser's dolphin observed off Hualien, Taiwan, on 19 June 1995.

(Wang 1990) All of the seven *Delphinus* skulls measured by Zhou (including the specimen in Zhou *et al* 1980) had ratios of rostral length to zygomatic width outside the range of *D delphis*, and are presumably of the long-beaked species The single confirmed specimen of a common dolphin from Hong Kong also appears to be referable to *D capensis* (Parsons *et al* 1995) There are several reports of both *D delphis* and *D capensis* from Taiwan (Yang 1976, Chen *et al* 1995, Chou *et al* 1995), but the specimens have not been re-examined to confirm their specific identity since the taxonomy of the genus was clarified (Heyning and Perrin 1994) Both records from Taiwan that can be identified to species, i e , a single animal reported by Mizue (1988) and an individual captured alive at the Penghu Islands and held in captivity at Ocean World for several years (R Chen pers comm), appear to be Long-beaked common dolphins In addition, van Bree and Gallagher (1978) and Kasuya (1973) reported specimens of Long-beaked common dolphins from Taiwan

Short-beaked common dolphins are not yet known to occur in Chinese waters All of the confirmed records are of exceedingly long-beaked animals, either an extremely long-beaked variety *of D capensis*, or members of the nominal species *D tropicalis* (van Bree and Gallagher 1979) The taxonomic status of the *tropicalis* form has not yet been established (Heyning and Perrin 1994) Clarification will require study of additional specimens, ideally coupled with genetic work

Fraser's dolphin: *Lagenodelphis hosei* Fraser

Single specimens of Fraser's dolphins (Plate 3D) were found at the fish markets in Kaohsiung and Tungkang, Taiwan, in 1969 (Tobayama *et al* 1973, Yang 1976) There are three skulls of Fraser's dolphins in the NTOU collection, all from Suao (Mizue 1988) One herd of this species was observed during a cetacean observation cruise off the coast of Hualien, Taiwan, on 19 June 1995 (Jefferson unpubl data) In addition, there was a recent stranding of this species in Hong Kong (Parsons *et al* 1995)

Harbour porpoise: *Phocoena phocoena* (Linneaus)

The accuracy of the record of Harbour porpoises from Hengchun, Taiwan (Yang 1964) was doubted by the same author (Yang 1976), and this species was subsequently deleted from the list of Chinese cetaceans (Zhou 1986, 1991) We now know the original record to have been a mis-identification of the Melon-headed whale (Yang 1976 fig 17) Reports of the species in Taiwan, provided by fishermen (Chou 1994), are also considered to involve identification errors We think it unlikely that this cold temperate species occurs in Chinese waters

Finless porpoise: *Neophocaena phocaenoides* (Cuvier)

The Finless porpoise (Plate 4A) inhabits waters off the coast of mainland China from the Gulf of Tonkin, in the South China Sea, to the Liaodong Gulf, in the Bohai Sea (Fig 5) Three subspecies have been described, based on morphological differences (Gao 1991, Gao and Zhou 1995), and these designations are supported by preliminary analysis of mitochondrial DNA (cytochrome *b*) sequences (Wang 1995) The Yangtze Finless porpoise (*N p asiaeorientalis*) occurs in the middle and lower reaches of the Yangtze River and its adjacent lakes This is the only Finless porpoise population known to inhabit freshwater The estimated population size of the Yangtze Finless porpoise is about 2,700 individuals (Zhang *et al* 1993) The northern Finless porpoise (*N p sunameri*) inhabits the Bohai, Yellow and East China seas The southern Finless porpoise (*N p phocaenoides*) inhabits the South China Sea and the southern part of the East China Sea This latter subspecies is also distributed sparsely throughout Hong Kong waters (Parsons *et al* 1995)

Yang (1976) reported on a Finless porpoise that was collected from Tainan, north of Kaohsiung, Taiwan, in 1958 One specimen of this species was recovered from the Penghu Islands, Taiwan, in 1987, and is now in the NTOU collection (Mizue 1988), another from the same

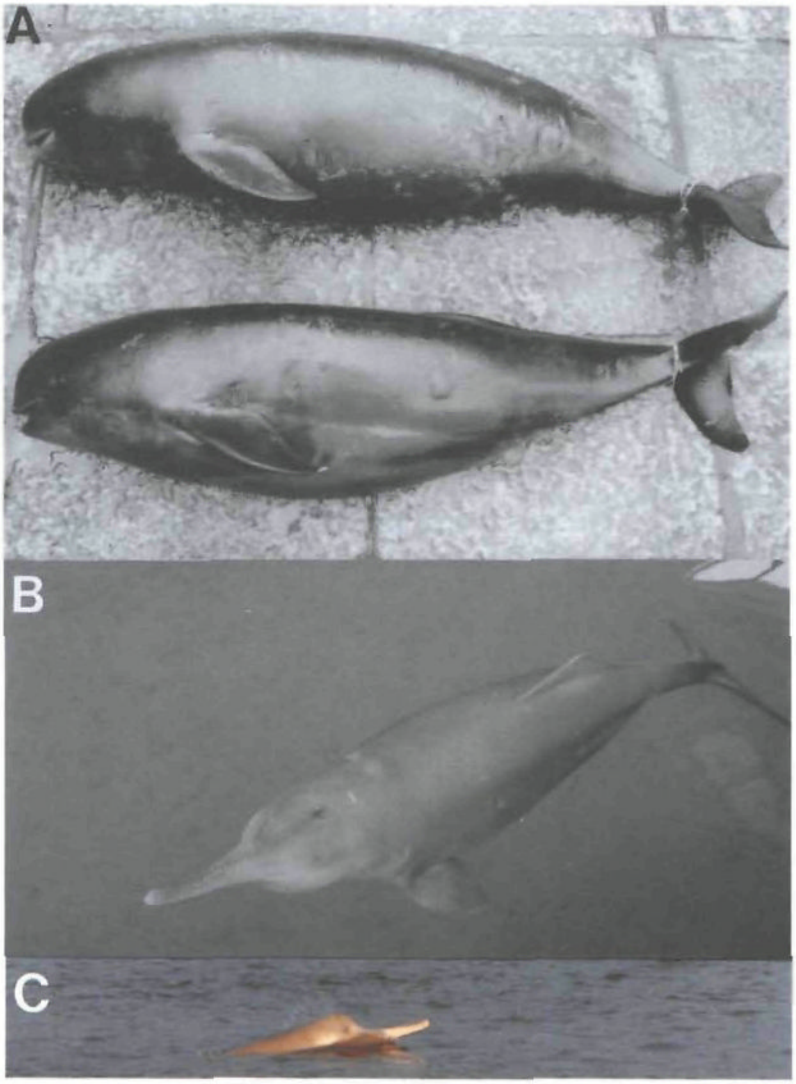

Plate 4. A, Finless porpoises captured in gillnets off mainland China; B, captive Baiji 'Qi Qi' at the Wuhan Institute of Hydrobiology; C, free-ranging Baiji in the Yangtze River.

locality is at the TFRIK (Jefferson pers. observ.). There are two additional stranding records, from Hsinchu and an unknown locality in Taiwan (Chou *et al.* 1995; Chen *et al.* 1995). Finless porpoises, which are shallow water animals, probably do not occur off the east coast of Taiwan, where deep water is found immediately offshore.

Baiji: *Lipotes vexillifer* Miller

Baiji (Plate 4B,C) are found mainly in the mainstem of the middle and lower reaches of the Yangtze River, although individuals might occasionally enter some tributary lakes during intense flooding (Fig. 6). In the 1940s, the uppermost records in the Yangtze River were at Huanglingmiao and Liantuo, in the Three Gorges area. In the 1970s and 1980s, however, the upper limit was no farther upstream than Zhicheng, Hubei (Chen and Hua 1989; Zhou *et al.* 1977). Results of recent surveys of almost all the species' previous range, Shanghai to Yichang, suggest that

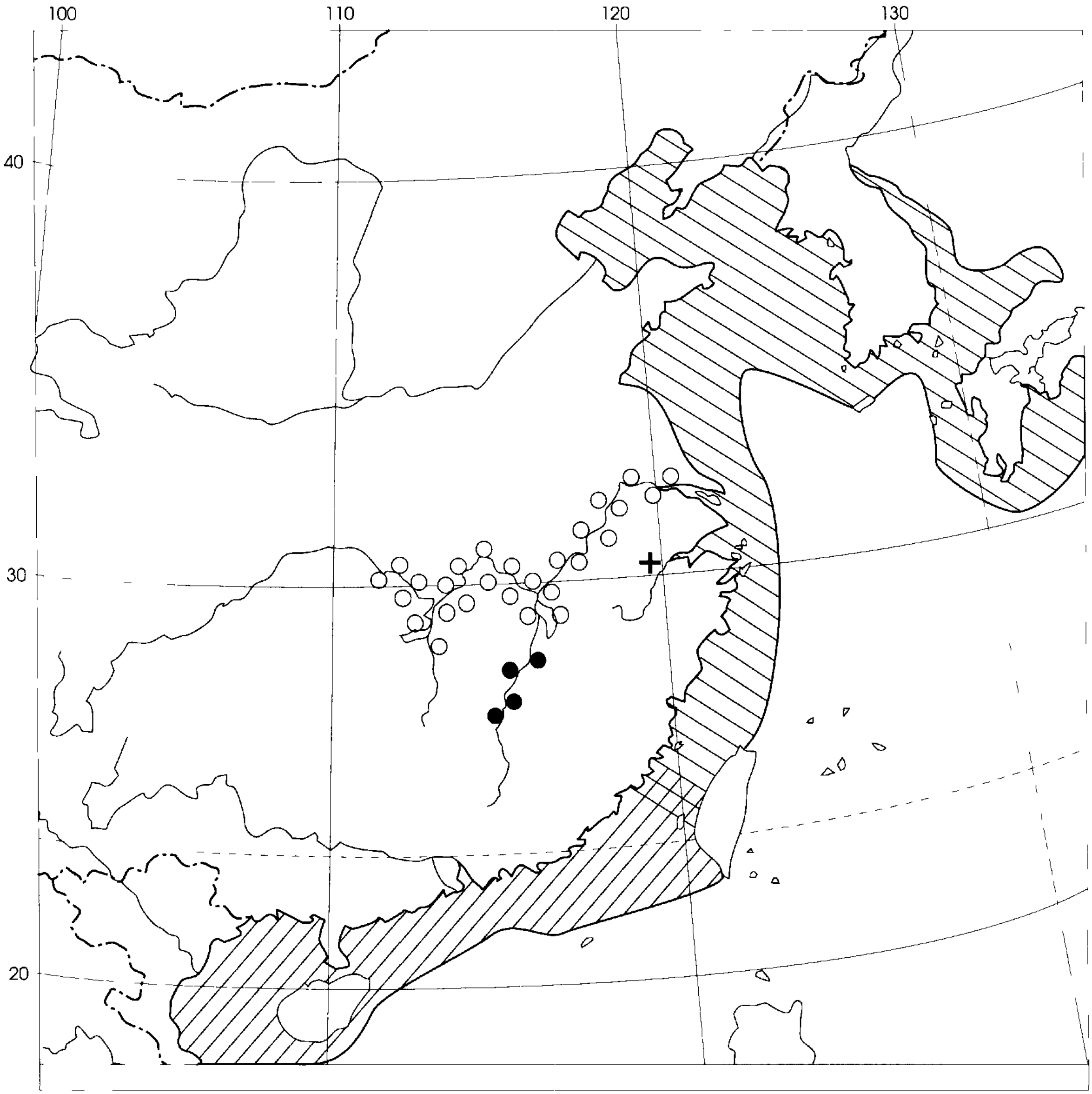

Fig. 5. Approximate distribution of the three described subspecies of the finless porpoise in Chinese waters.

▧ *N. p. sunameri* ▨ *N. p. phocaenoides* ○ *N. p. asiaeorientalis*

● Locality where *N. p. asiaeorientalis* is recorded occasionally

+ Locality where *N. p. sunameri* is recorded occasionally the range is continuing to contract and that the population is very small and is still declining (Liu *et al* in prep) At the lower end of the river, specimens of Baiji were obtained at the Yangtze estuary, off the eastern end of Chongming Island, Shanghai, in the 1950s and 1960s Baiji were also seen in the Qiantang River during the great flood of 1955 (Zhou *et al* 1977), but disappeared from that area after the construction of a hydropower station in 1957 (Zhou 1989)

Exploitation and conservation of small cetaceans in Chinese waters

Dolphin fisheries began in the Penghu Islands, off the west coast of Taiwan, in ancient times Dozens, perhaps hundreds, of small cetaceans — mostly Bottlenose dolphins, but also False killer whales and dolphins of a few other species — were taken annually by drive, harpoon, and gillnet fisheries The largest recorded catch by the drive fishery was 1,200 individuals in January 1956 (Chen *et al* 1976) The catch declined to a few tens of animals per year in 1989 and 1990 The Taiwanese Wildlife Conservation Law of 1989 was amended in August 1990, making the capture of cetaceans illegal in Taiwan (Mok *et al* 1992) Despite this, the last drive occurred in the winter of 1992-1993 Many of the fishermen involved, however, were prosecuted and all of the animals were released alive

The Taiwanese legislation has now apparently been effective in eliminating the Penghu drive fishery However, during a recent two-month visit to Taiwan, Jefferson saw evidence that direct captures of cetaceans still occur (harpoon wounds on some animals), at least off the east coast of Taiwan In addition, incidental catches of small cetaceans in gillnets and longlines continue, apparently unabated Taiwanese government officials in the Council of Agriculture contend that the problem has been solved by passage of the new law In reality, it is likely that this law has little or no effect on the actions of most fishermen Incidental catches (arguably involving more species of small cetaceans than the drive fishery at the Penghu Islands ever did) continue to occur Until an observer programme is established and the law is rigorously implemented, and sustainable catch limits are imposed, the problem of human-caused mortality of small cetaceans in Taiwan cannot be considered solved Such a programme may actually be easy to initiate because all vessels in Taiwan are required to check in with government officials upon leaving and returning to port

No direct exploitation of small cetaceans is known to occur in other parts of China When one considers the number of fishermen and the extent of the coastline, it seems likely that some direct exploitation has occurred, and still does occur, in other Chinese waters Hong Kong fishermen have been reported to capture dolphins in the Gulf of Tonkin and sell them to local residents (Parsons *et al* 1995) Passive fishing gear and incidental catches of small cetaceans in Chinese waters were reviewed by Zhou and Wang (1994) Finless porpoises, False killer whales, Bottlenose dolphins and common dolphins are known to be caught incidentally in the fisheries It is probable that other species are taken as well

Finless porpoises are probably killed in considerable numbers, recorded incidental catches suggest that dozens, perhaps hundreds, have been caught annually in gillnets, driftnets, trammel nets, stow nets and pound nets along the coasts of Liaoning, Hebei, Shandong, Jiangsu and Fujian provinces Finless porpoises are known to be taken in various gillnet fisheries throughout their range (Zhou and Wang 1994, Jefferson and Curry 1994) Usually the carcasses of entangled Finless porpoises are sold to local people for use as livestock feed Individuals of the Yangtze Finless porpoise are caught incidentally in rolling hook longlines and encircling gillnets The latest recorded death of a Yangtze Finless porpoise, of which we are aware, was a rotting carcass found on the river bank of Zhenjiang City, Jiangsu Province, on 28 May 1995, and that of a northern Finless porpoise a newborn found on a dyke along the coast of Jinshan County, Shanghai, on 29 June 1995 (Zhou unpubl data)

Baiji are killed by rolling hook longlines, gillnets, and fish traps in the Yangtze River and some individuals are known to have been killed by explosives and by collisions with boat hulls and propellers (Zhou and Li 1989, Chen and Hua

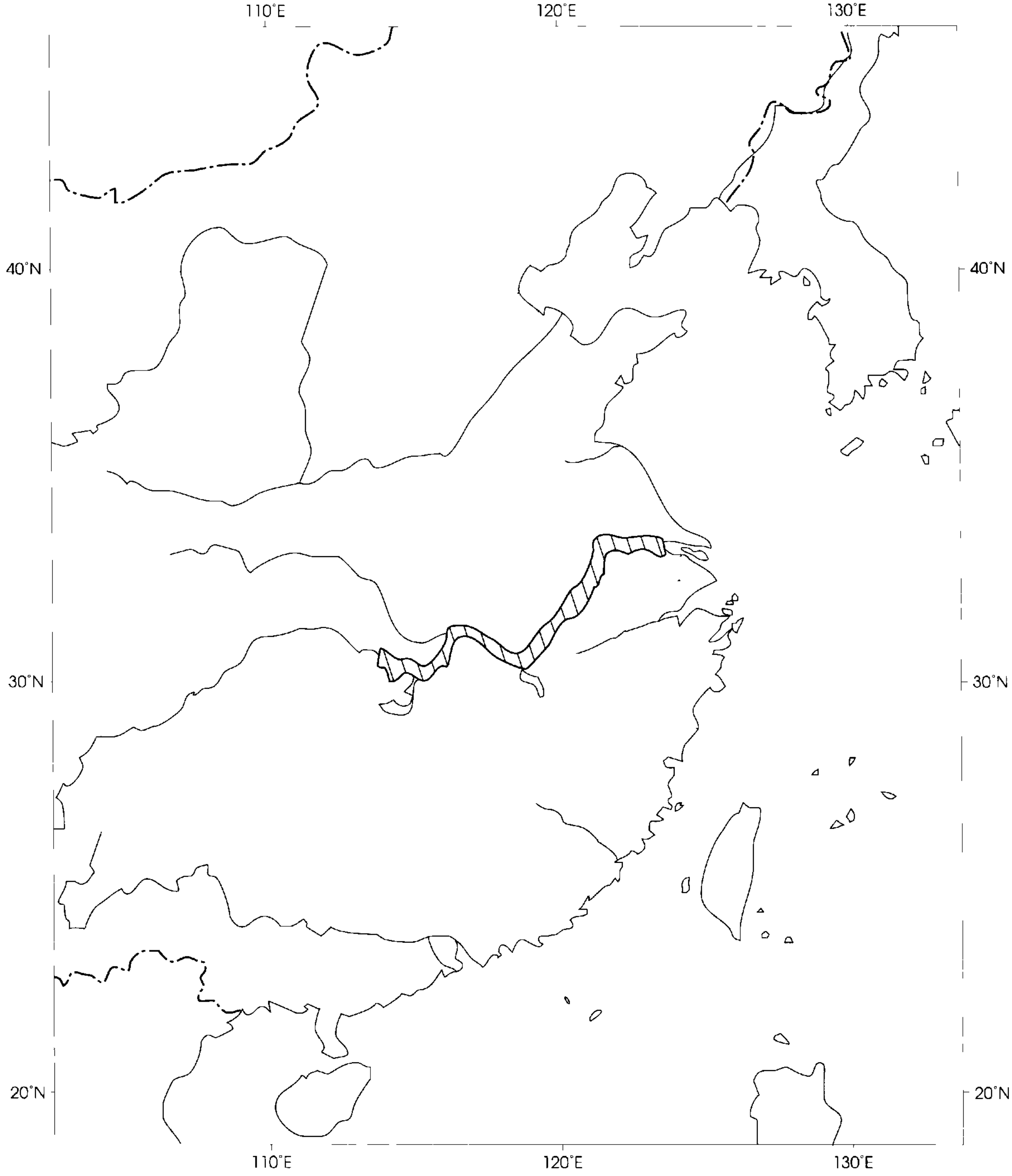

Fig. 6. Approximate distribution of the Baiji in Chinese waters.

1989) Perrin and Brownell (1989) reported that, in the past, some dolphins stranded on sandbars were beaten to death by local residents No directed exploitation is known, although capture teams from the Institute of Hydrobiology and Tongling Seminatural Reserve are actively searching for Baiji to live capture for captive breeding programmes (Liu *et al* in prep)

There are no reliable population estimates for Baiji and the best that can be surmised from the various reports of surveys is that rates of encounter and, presumably, also numbers, have declined precipitously since the late 1970s, and that the population is 'small and presumably still declining' (Zhou *et al* 1994) The first rigorously designed and conducted surveys covered most of the river between Shanghai and Yichang in the last quarter of 1994 They used three vessels, a ship in mid-channel and a ship along each shore, and only five animals were seen This suggested to the participants that the population numbered fewer than 100 individuals, perhaps no more than a few dozen (Liu *et al* in prep)

Live captures and removals of small cetaceans must be included in assessments of the effects of exploitation To date, as far as we know, only a few Baiji, Finless porpoises, and Bottlenose dolphins have been live-captured in mainland China waters for either display or research In Taiwan, although there has been no live-capture fishery, Bottlenose dolphins and False killer whales have been purchased for display in association with the former drive fishery at the Penghu Islands The number of species that have been affected by live-removals is thus far relatively small There is, however, the potential for greatly increased future impacts, as we are aware of at least nine dolphinariums under construction in mainland China (one each in Qingdao, Shanghai, Guangzhou, Shenzen, Wuxi, Xiamen, and Dalian and two in Beijing) and two additional ones in Taiwan (Taichung and Keelung)

The Chinese Government at various levels has enacted a series of laws and provisions to protect wildlife including small cetaceans (Zhou 1992) The capture, killing, selling, or buying of the national key protected aquatic animals, including Baiji, is strictly prohibited Most of the provinces along the mainland coast and in the Yangtze River have issued either their own laws or regulations for the implementation of the national laws and regulations In Taiwan, there is now legal protection for all cetaceans But, in China, as elsewhere, laws have little or no effect if people do not know about them and if they are not enforced humanely and consistently

The wide variety of cetaceans that occur along the various coastlines and rivers of mainland China, Taiwan, Hong Kong, and Macau represent a valuable natural treasure They can only be conserved for future generations with education and laws suited to the needs of humans and wildlife alike We hope that public officials and citizens will take note of this fact and push for strict and effective measure to conserve all cetacean species in Chinese waters

Acknowledgements

Thanks to X Xu and G Yang for assistance in Zhou's field work We appreciate the efforts of G Chen, R Chen, L Chou, J Y Wang, and H Yang for their hospitality when Jefferson was in Taiwan and E Huang for assistance in locating records and for translation of several papers L Porter and R Chen provided photos for the plates Support for some of the work described in this paper came from the World Nature Association, National Taiwan Ocean University, National Taiwan University, Hong Kong's Airport Authority, Ocean Park Conservation Foundation, and the IUCN/SSC Cetacean Specialist Group We thank C Leatherwood for typing an earlier draft, B Wang and C Mok for preparing the figures, and Professor Brian Morton and an anonymous reviewer for comments on the manuscript

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Appendix I. List of place names mentioned in the text, which have multiple spellings.

Spelling used in Taiwan	*Spelling used in Mainland China*
Kaohsiung	Gaoxiong
Tungkang	Donggang
Keelung/Chilung	Jilong
Dashi	Daxi
Lukang	Lugang
Pingtung	Pingdong
Peikang	Beigang
Taipei	Taibei
Hsinchu	Xinzhu
Hualien	Hualian
Ilan	Yilan
Taichung	Taizhong
Taitung	Taidong
Taoyun	Taoyuan
Yehliu	Yeliu
Lu Tao	Ludao Island
Chinmen	Jinmen