The use of mixed fish feed in Hong Kong's mariculture industry

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Wild fishes are widely used in Southeast Asian countries as feed for the mariculture industry. Although a considerable volume is involved, its species composition, fish body size and volume are rarely known. There are some concerns that heavy use of wild fishes, or mixed fish feed, could adversely affect marine ecosystems and constituent species and hence, its widespread use might not be sustainable. This study provides the first in-depth examination of feed component species used in the Hong Kong mariculture industry. Its aims were to identify the species of fish used as fish feed, to determine the average sizes and weights of fish taken, test for seasonal patterns and estimate the approximate annual volume involved. The Hong Kong mariculture industry is used as a case study; the issue of the sustainability of current practices is discussed in local and regional contexts.

The Mariculture Industry in Hong Kong

In Hong Kong, mariculture activities began in the late 1960s, mainly among retired fishermen. Production expanded rapidly until 1997 (Wong 1995, Wilson 1997). Mariculture in Hong Kong involves rearing marine fish from wild caught fry to marketable size in cages suspended from floating rafts. This process usually takes about 1.5-2 years, on average, depending on species (Li 1996). The major cultured species are groupers, Serranidae, and sea bream, Sparidae, which command relatively higher market values than common foodfishes in the local market. Until recently, the mariculture industry contributed about one fourth to one fifth of the domestic live marine fish supply (Wilson 1997, Lee *et al*. 2001) for home use and medium-priced restaurants (Li 1996). Production recently, however, has dropped to about 1,000 t annually.

Mixed fish feed (MFF) has been used in the Hong Kong mariculture industry since commercial culturing began and is still the feed type most widely used today (Wilson 1997, Willmott 2000). The source of this feed is mainly from local trawlers, purse seiners and the Fish Marketing Organization (Wilson 1997). MMF, more commonly referred to as trash fish, refers to the feed comprised solely of wild fish used to feed cultured carnivorous species. In general, there are no specific requirements regarding the type of fish or fish sizes used. Nevertheless, the fish involved tend to be relatively small and consist either of juveniles of commercially important species or small pelagic fishes (Willmott 2000). In Hong Kong, the feed is dominated by the Clupeidae, Carangidae, Leiognathidae, Engraulidae, Siganidae and Scombridae, although the actual species and size composition are not known (Wilson 1997, Sadovy 1998).

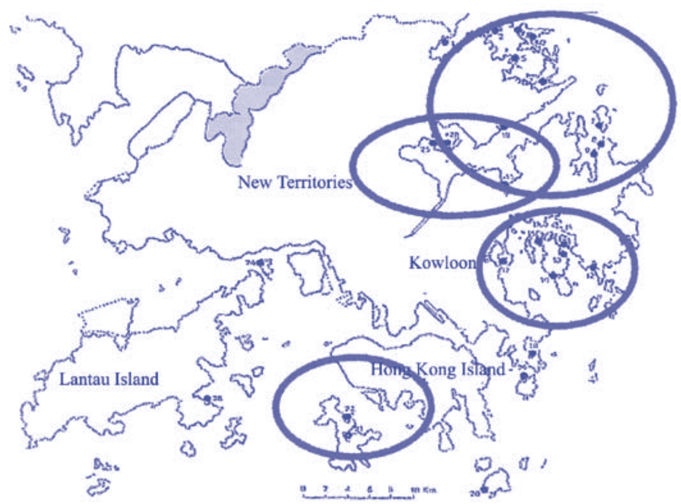

Fig. 1. Distribution of marine fish culture zones in Hong Kong. (Dots within a circle refer to the zones grouped into one specified area) (AFCD, http://www.afcd.gov.hk/fisheries/eng/images/6-3-2p1b.jpg)

Survey Design

There are 26 designated mariculture zones in Hong Kong with about 1,300 licensed operators (Agriculture, Fisheries and Conservation Department homepage: http://www.afcd.gov.hk/fisheries/fish_e.htm). Most of the zones are located in sheltered, inshore areas of eastern Hong Kong waters (Figure 1). The number of farms in the different zones varies, and each is owned by a licensed mariculturist. The total area available for fish culture and, hence, the number of fish cages per farm, varies according to the conditions specified in each license. In general, most farms are small in scale with 1 to 2 rafts covering 250 m and are operated on a family basis (Chu 2002).

In this study, eight out of the 26 mariculture zones were selected for sampling, based on the locations and sizes of the zones. The eight zones selected were widely spread and covered farms in all parts of Hong Kong.

To determine if there is any seasonal difference in MFF

(Continued on page 8)

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in terms of species composition, samples were collected in summer (May, August and September) of 2002, and winter (December 2002 to early March) of 2003. Although June and July are usually the months when seawater temperatures are highest (HKO 2000), those months were excluded from the study because of a two month fishing moratorium in the South China Sea outside Hong Kong that begins in June. Only gillnetting, long lining and hand line fishing are allowed during that period (EFB 2000). Since most of the fish used as feed are caught by trawlers that work inside and outside of Hong Kong waters, sampling of MMF had to be stopped during the fishing moratorium to minimize the possibility of collecting fish from different sources among seasons because of changes in areas fished by fishing vessels. Sample collection was also stopped between late January and early February because of the Chinese Lunar New Year Festival, when most fishermen stay in port with their families for several weeks. Only a few fishermen go fishing shortly after the festival and, hence, the supply of MFF is less than that at other times. Alternatives, such as frozen fish and dry pelleted feed, are used in that period by mariculturists.

The same sampling box size of 15*x*8*x*8 cm^3 was used throughout the study to standardize the sample volume. With the oral permission of mariculturists, the samples were collected randomly from containers, pans or plastic containers, of fish feed at each farm; farmers do not sort the fish by species or size prior to feeding. A pilot study was performed in March 2002 at the Lo Tik Wan mariculture zone and the results indicated that the cumulative number of fish species found began to level off after sampling six boxes. Nine boxes were selected, therefore, to ensure a representative sample for species composition in this study. In data analysis, the nine boxes were pooled to constitute one sample.

During each sampling season, winter or summer, each zone was sampled twice with at least three weeks between each visit. During each visit, nine boxes of fish were collected whenever possible. It was sometimes impossible to collect nine boxes of fish during a single visit and, in such cases, additional visits were made within 1-3 days of the original visit so that the sampling target of nine boxes was achieved.

The fish were identified to species whenever possible, with their standard length, total length and wet weight measured to the nearest mm and g, respectively. Those that were difficult to identify to species, because of poor condition or small size, were assigned to genus. The parameter standard length was omitted for some individuals (37.3 percent) owing to poor body condition. Fish identification was based on 1) *Fishes of Japan with Pictorial Keys to the Species* (Nakabo 1993); 2) *The Fishes of the Japanese Archipelago* (Masuda *et al*. 1992); 3) *Fishes of Taiwan* (Shen 1982); and 4) *Reef Fishes of Hong Kong* (Sadovy and Cornish 2000).

Data Analyses

The Shannon-Wiener Index (H') was calculated using the formula (Zar 1999):

$$-\sum p_i \, Ln\,(p_i),$$

where p_i is equal to the number (or weight) of individuals of a species group divided by total number (or weight) of individuals within a sample of nine fish boxes.

The index (H') takes the number of species and their relative abundance into account. The larger the index value, the richer the species diversity indicated. The minimum and maximum values are 0 and *Ln* (number of species categories in a sample), respectively.

To test for significant differences in MFF species composition (H') by season and determine whether feed availability to the culturist varies by season, ANOVA was performed at the 0.05 significance level. Normality and homogeneity of variance (Bartlett's test) were checked to ensure that the data were in the appropriate form for the statistical test selected, and the data transformed as necessary.

MFF composition was summarized by family and species for both seasons combined. That gave an overall picture of types and volumes of fish involved. Only the more plentiful species, having a percentage share of five percent or more in terms of abundance and weight, are presented in the results, by species.

To obtain an overall picture of the size of fish involved in MFF, the mean total lengths of species sampled in MFF were calculated for both seasons and the overall size distribution was plotted by pooling all data. Standard length was not used as it was sometimes unobtainable due to poor fish condition. The total length frequency distributions of the 10 most abundant species found in each season were also plotted (Appendixes 1 and 2). For pelagic fishes, for which maturity sizes are not known, a rough estimate was used based on the rule of thumb that fish reach sexual maturity when they grow to approximately half of their maximum body length. This works especially well for clupeid species (Blaxter and Hunter 1982).

Results

About 10 percent of the samples collected could not be identified to species because of their bad condition. They were classified as unknown species within the assigned family.

A total of 109 finfish species from 38 families were identified with a few families dominating by both number and weight (Table 1, Figure 2**)**. Eighty-nine species from 32

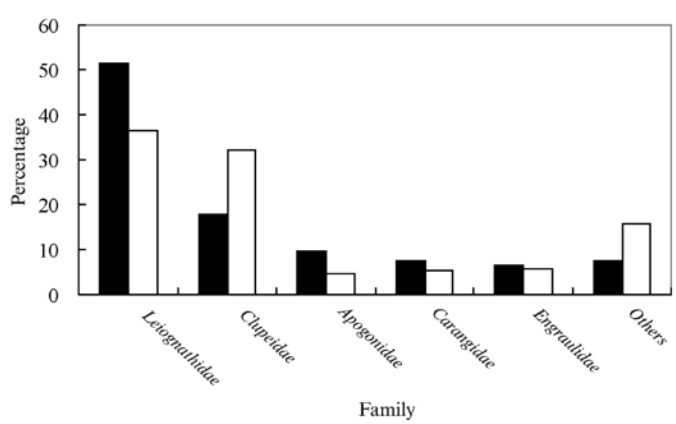
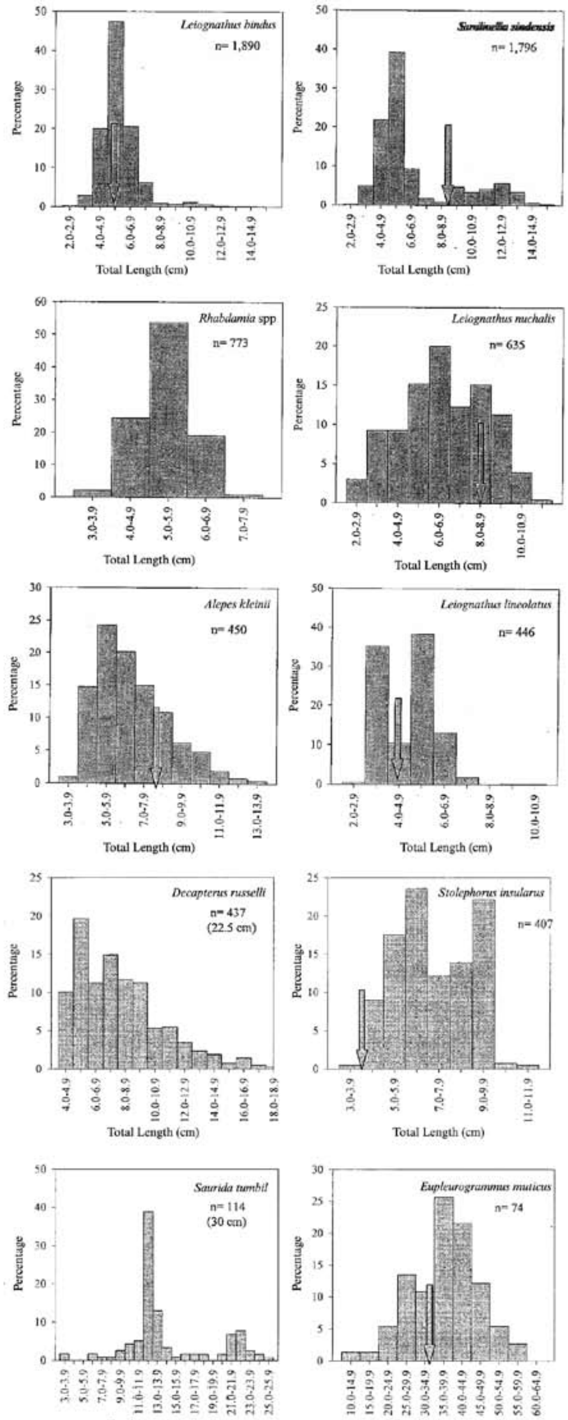
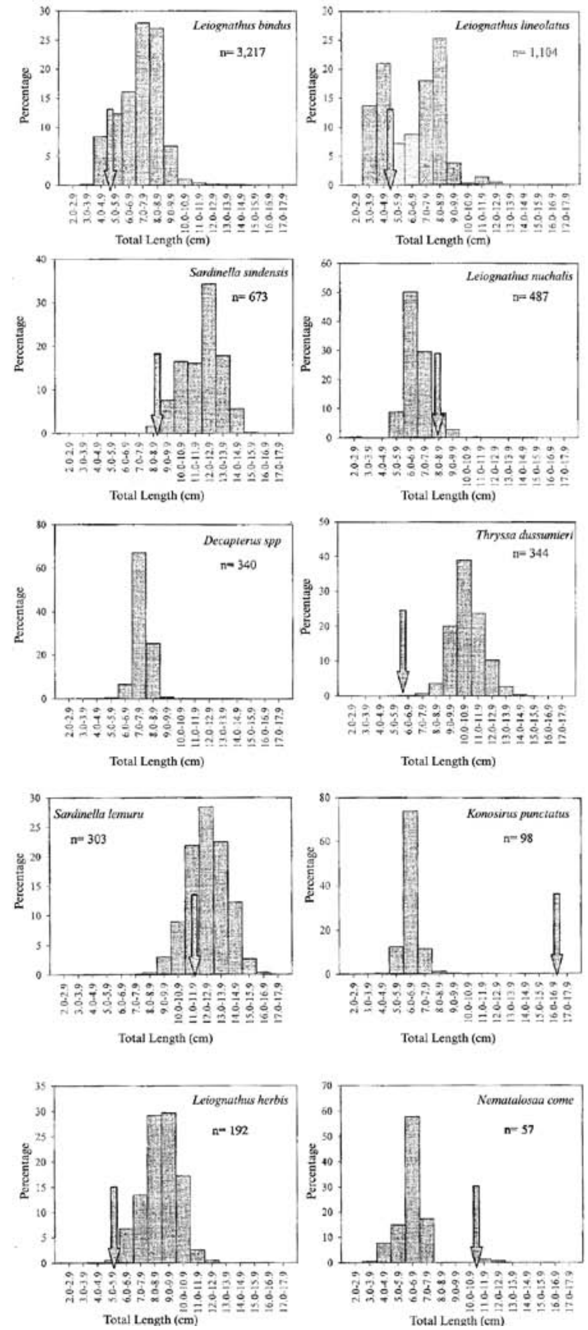


Fig. 2. Percentage of mixed fish composition in all 2002/3 samples by family (dark bar: number of individuals, n= 16,847 individuals; light bar: weight, n=109,781.9 g) (others refer to all the species listed in Table 1).



Appendix 1. Length frequency plots of the 10 most abundant species in summer sample 2002 (arrow/ number in brackets refers to maturity size).



Appendix 2. Length frequency plots of the 10 most abundant species in winter 2002/3 (arrow/number in bracket refers to the maturity sizes).

families were classified as minor MFF components, having a percentage of occurrences in the summer of less than one percent each, either in terms of number of individuals counted or by weight. There was no significant difference in MFF species composition by season. This means that the fish farmer has supplies of similar species throughout the year (Figures 3 and 4).

At the family level, Leiognathidae (pony fish) and Clupeidae (herrings) were the most abundant components, comprising 51 percent and 18 percent of the total number of individuals counted (Figure 4). Carangidae (jacks), Apogonidae (cardinal fish) and Engraulidae (anchovies) accounted for a further seven, nine and seven percent, respectively. Those five families accounted for about 91 percent of the total number of individuals counted. When analyzed by weight, a similar picture emerged, with those five families accounting for about 84 percent of total weight. Synodontidae (lizardfishes) and Trichiuridae (cutlassfishes) accounted for six percent and four percent in terms of weight.

The lengths and weights of MFF species are summarized

Table 1. A summary list of the composition, mean total length and weight of species of fish found in mixed fish feed samples in 2002/3 (s refers to summer sample; w refers to winter sample)

Family	Species		n	Total Length (cm)	Weight (g)
Ambassidae	*Ambassis urotaenia*	*s*	7	4.99	1.07
Antennariidae	*Antennarius spp*	*s*	*1*	9.20	17.70
Aploactinidae	*Erisphex pottii*	*w*	1	10.50	8.50
Apogonidae	*Apogon aureus*	*s*	2	7.15	6.40
	Apogon carinatus	*s*	41	6.25	3.80
		s	37	11.40	23.12
	Apogon fasciatus	*w*	15	5.16	3.87
	Apogon kiensis	*w*	1	8.30	8.20
		s	152	6.80	3.55
	Apogon lineatus	*w*	2	8.90	9.55
		s	25	6.03	3.30
	Apogon quadrifasciatus	*w*	1	11.20	15.10
	Apogon semilineatus	*s*	183	8.48	5.58
	Apogon spp	*s*	108	6.19	2.53
	Rhabdamia spp	*s*	773	5.37	1.47
		w	58	8.02	4.43
	Rhadadamia cypselurus	*w*	199	6.46	2.73
Atherinidae	*Atherinomorus lacunosus*	*s*	30	1.94	2.11
	Hypoatherina valenciennei	*w*	4	9.30	5.48
Bothidae	*Chascanopsetta lugubris*	*s*	1	11.00	15.90
	Engyprosopon grandisquama	*s*	25	9.93	11.24
	Engyprosopon spp	*w*	4	10.70	13.28
	Psettina iijimae	*w*	8	12.41	17.30
Bregmacerotidae	*Bregmaceros lanceolatus*	*w*	14	6.84	2.08
	Bregmaceros mcclellandi	*w*	2	6.00	1.10
	Bregmaceros spp	*s*	86	7.48	2.49
Callionymidae	*Calliurichthys japonicus*	*w*	18	8.86	4.18
	Repomucenus richardsonii	*w*	2	9.65	4.20
	Callionymus japonicus	*s*	24	10.56	7.42
Carangidae	*Alepes kleinii*	*s*	450	6.54	3.15
	Carangoides praeustus	*s*	6	12.57	10.77
	Decapterus macrosoma	*w*	1	9.00	8.80
	Decapterus russelli	*s*	437	8.05	6.31
	Decapterus spp	*s*	15	6.11	2.18
		w	340	7.67	4.41
	Megalaspis cordyla	*w*	3	9.37	10.43
	Scomberoides tol	*w*	3	12.43	11.97
	Selaroides leptolepis	*w*	3	9.73	11.43
Champsodontidae	*Champsdon snyderi*	*w*	80	8.86	6.67
Clupeidae	*Konosirus punctatus*	*w*	98	18.43	63.66
	Nematalosa come	*s*	31	16.30	48.17
		w	57	16.98	47.10
	Nematalosa japonica	*w*	25	17.46	60.26
	Sardinella albella	*w*	28	12.24	22.16
	Sardinella lemuru	*w*	303	12.47	17.07
	Sardinella sindensis	*s*	1,796	6.83	4.17

Family	Species		n	Total Length (cm)	Weight (g)
		w	673	11.94	15.19
Congridae	*Ariosoma spp*	*w*	9	24.93	11.59
	Conger myriaster	*w*	2	22.60	15.00
	Gnathophis spp	*s*	7	8.04	8.47
		w	6	25.77	17.23
	Rhynchoconger spp	*s*	35	15.33	6.33
Engraulidae	*Encrasicholina devisi*	*s*	36	8.55	4.79
	Encrasicholina heteroloba	*w*	24	7.50	2.99
	Encrasicholina punctifer	*w*	67	6.64	2.08
	Stolephorus insularis	*s*	407	6.92	2.72
	Thrissa dussumieri	*s*	219	8.29	8.58
		w	344	10.67	8.36
Fistulariidae	*Fistularia commersoni*	*s*	20	29.56	9.27
		w	1	25.00	7.30
Gerreidae	*Gerres filamentosus*	*s*	2	8.90	4.25
		w	2	10.50	18.70
Leiognathidae	*Gazza minuta*	*w*	1	9.00	9.4
	Leiognathus berbis	*w*	192	8.87	9.23
	Leiognathus bindus	*s*	1,890	5.65	2.75
		w	3,217	7.25	5.54
	Leiognathus brevirostris	*s*	9	8.14	6.39
		w	61	8.17	7.67
	Leiognathus dussumieri	*w*	4	8.55	8.93
	Leiognathus equulus	*w*	37	8.65	9.59
	Leiognathus lineolatus	*s*	446	4.84	1.55
		w	1,104	6.51	4.80
	Leiognathus nuchalis	*s*	635	6.64	4.61
		w	487	6.88	4.15
	Leiognathus spp	*w*	9	7.52	5.64
	Leiognthus rivulatus	*s*	212	7.01	5.03
	Secutor insidiator	*s*	*1*	10.00	11.80
		w	83	11.29	17.70
`	*Secutor ruconius*	*s*	101	3.75	0.95
		w	156	6.36	4.37
Lophiidae	*Lophiomus setigerus*	*w*	1	27.0	189.70
Menidae	*Mene maculata*		*w*	412.83	28.48
Monacanthidae	*Cantherhines fronticinctus*	*w*	1	8.60	10.20
	Paramonacanthus sulcatus	*s*	4	9.05	13.08
Mugilidae	*Liza affinis*	*w*	9	16.58	40.50
	Mugil cephalus	*s*	21	14.91	31.37
Mullidae	*Upenus japonicus*	*s*	99	8.13	6.83
		w	11	9.48	9.75
Nemipteridae	*Nemipterus bathybius*	*w*	15	6.74	5.04
	Nemipterus japonicus	*s*	6	11.55	21.17
		w	1	19.00	0.00
	Nemipterus virgatus	*s*	12	11.58	9.73
		w	1	12.00	8.30
Nettastomatidae	*Saurenchelys fievaster*	*s*	3	25.43	16.30

Family	Species		n	Total Length (cm)	Weight (g)
	Saurenchelys spp	*w*	6	31.20	8.48
Ophidiidae	*Hoplobrotula armata*	*w*	2	13.00	18.30
Pinguipedidae	*Parapercis pulchella*	*s*	1	13.50	21.90
	Parapercis sexfasciata	*w*	11	11.06	9.21
Platycephalidae	*Grammoplites scaber*	*w*	5	12.78	7.76
	Onigocia macrolepis	*s*	1	8.90	6.80
	Rogadius asper	*s*	1	11.00	12.80
		w	2	7.30	2.70
Pomacentridae	*Chromis spp*	*w*	2	11.30	20.05
	Pomacanthus spp	*w*	5	11.26	20.26
	Stegastes obreptus	*s*	2	14.30	36.50
	Teixeirichthys jordani	*s*	7	4.70	1.67
	Unidentified spp	*s*	14	5.15	2.26
Priacanthidae	*Priacanthus macracanthus*	*s*	27	4.57	1.80
Sciaenidae	*Collichthys lucidus*	*s*	1	9.70	7.30
	Johnius amblycephalus	*w*	2	12.45	21.60
	Johnius belengerii	*s*	26	10.17	10.89
Scombridae	*Scomberomorus commerson*	*s*	6	10.38	19.82
Scorpaenidae	*Scomber japonicus*	*w*	9	13.33	19.92
	Apistus carinatuis	*s*	1	9.50	9.60
		w	2	7.95	7.80
	Minous monodactylus	*w*	2	10.60	21.30
	Pterois lunulata	*s*	1	13.00	18.40
		w	3	7.57	4.60
Siganidae	*Siganus spp*	*s*	1	14.80	33.70
Sparidae	*Evynnis cardinalis*	*s*	58	9.96	12.71
Sphyraenidae	*Sphraena flavicauda*	*s*	29	10.63	5.37
Synodontidae	*Saurida gracilis*	*s*	12	10.44	7.91
	Saurida tumbil	*s*	114	14.71	30.87
		w	3	15.77	28.33
	Saurida undosquamis	*w*	58	14.20	17.41
	Synodus jaculum	*s*	61	7.33	3.25
	Synodus spp	*s*	25	8.01	9.12
	Synodus variegates	*s*	5	8.16	5.98
	Trachinocephalus myops	*s*	28	13.90	31.85
		w	3	11.57	14.07
Teraponidae	*Terapon jarbua*	*s*	3	6.37	3.67
Trichiuridae	*Eupleurogrammus muticus*	*s*	74	37.81	33.55
		w	3	18.00	4.07
Triglidae	*Trichiurus lepturus*	*w*	40	37.76	34.37
	Lepidotrigla spp	*s*	3	5.97	2.00
	Lepidotrigla spp	*w*	1	14.40	40.40

by season with length frequency distributions given for the 10 most abundant species by season (Appendixes 1 and 2). The mean total length of all individuals, combined, in the summer MFF was 7.1 cm (SD = 4.3) and the mean weight of individuals was 4.7 g (SD = 8.6; Table 2). The length frequency distribution is left skewed, as most individuals were relatively small (Figure 5).

The mean total length of all individual in the winter feed sample was 8.6 cm (SD = 5.2) and the mean weight of individuals found in the feed was 8.4 g (SD = 10.4; Table 3). The length frequency distribution is left skewed, as most individuals were relatively small (Figure 6).

Immature fish are often used as fish feed in the local mariculture industry because of the overall sizes of fish typically included in MFF. In the summer season, six out of the 10 most abundant species, by number of individuals, were taken from the sea as feed when they were immature according to approximate estimates of maturation size (Appendix 1). In the winter sample, three of the 10 most abundant species were removed from the sea when they were still probably immature (Appendix 2).

Table 2. Mean total length and weight for the 10 most abundant species in summer 2002 samples.

Species	Number	Total Length (cm)	Weight (g)
Leiogrnathus bindus	1,890	5.65	2.75
Sardinella sindensis	1,796	6.83	4.17
Rhabdamia spp.	773	5.37	1.47
Leiognathus nuchalis	635	6.64	4.61
Alepes kleinii	450	6.54	3.15
Leiognathus lineolatus	446	4.84	1.55
Decapterus russellii	437	8.05	6.31
Stolephorus insularis	407	6.92	2.72
Saurida tumbil	114	14.71	30l87
Eupleurogrammus muticus	74	37.81	33.55

Discussion

Mixed fish feed used by local mariculturists is mainly comprised of small pelagic fishes, with mean total lengths and weights of 7.1- 8.6 cm and 4.7- 8.6 g in summer and winter. There are no significant seasonal differences in species composition. Fishes from the families Leiognathidae and Clupeidae dominate the MFF by both weight and number. This is consistent with a report that in Hong Kong, Clupeidae, Leiognathidae, Engraulidae and Carangidae harvested by the capture fishery usually were sold to the mariculture industry as trash fish (Wilson 1997). Many of the fish involved are unlikely to have attained sexual maturation.

Large amounts of small pelagic fishes are removed from the wild using the current fish feeding system in Hong Kong and elsewhere in the region, including Mainland China, Thailand and Taiwan. The volumes removed are proportional to the operational scale of the mariculture industry. For example, in Hong Kong, the minimum estimated volume of fish used as fish feed on local farms was about 9,700

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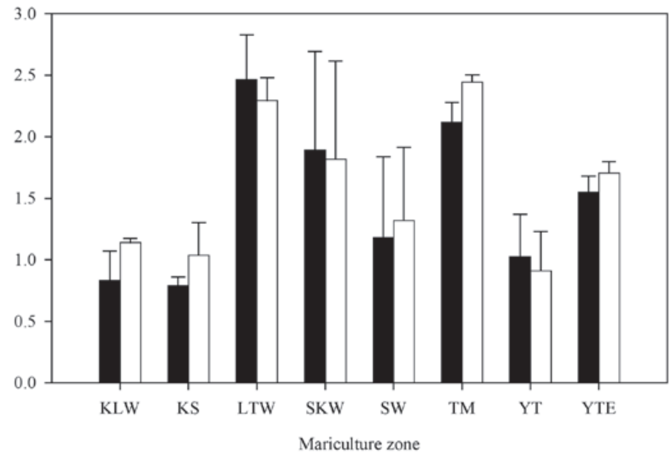

Fig. 3. Shannon-Wiener Index (H') for species abundance by zone in summer 2002 (n=16) (± 1 SE) (dark bar: number of individuals; light bar: weight) (KLW: Kai Lung Wan; KS: Kau Sai; LTW: Lok Tik Wan; SKW: Sok Kwu Wan; SW: Sham Wan; TM: Tap Mun; YT: Yim Tin; YTE: Yim Tin East).

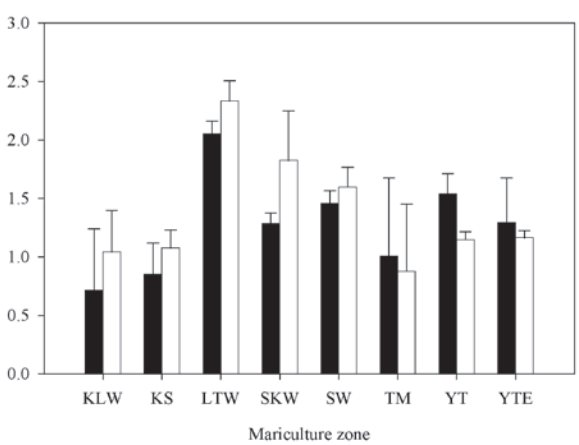

Fig. 4. The Shannon-Wiener index (H') for species abundance by zone in winter 2002/3 (n=16) (dark bar: number of individuals; light bar: weight) (± 1 SE) (KLW: Kai Lung Wan; KS: Kau Sai; LTW: Lok Tik Wan; SKW: Sok Kwu Wan; SW: Sham Wan; TM: Tap Mun; YT: Yim Tin; YTE: Yim Tin East).

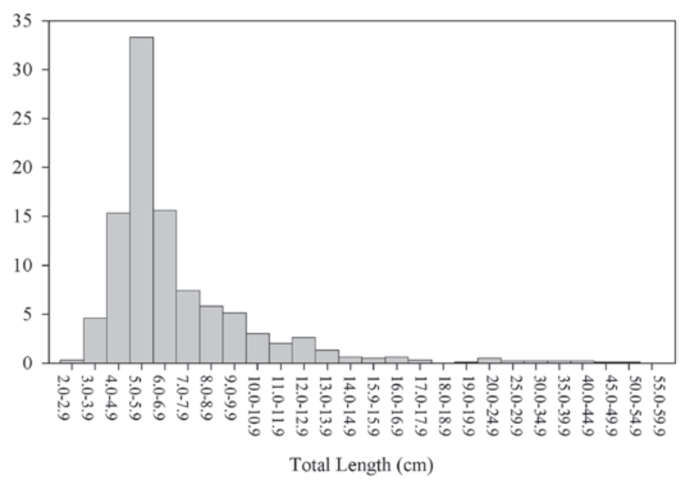

Fig. 5. Length-frequency distribution of all individuals found in the summer mixed fish feed samples with all species combined (n=8,686).

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tons in 2002, based on mariculture production of 1,211 tons and a food conversion ratio of 8:1. This implies that about 5 percent of the locally landed capture fishery production (which comes from both Hong Kong waters and the northern South China Sea; 169,790 t in 2002) was used as fish feed locally. The amount of fish used as MFF was higher before 2002 because mariculture production was higher. For example, in the mid 1990s, it is estimated that about one tenth of all marine fish caught by the local fishing fleet was used as MFF (AFD 1996). It should be noted that the volume of fish being used as feed is likely to be underestimated using the above conversion rule, as there is fish mortality throughout the growout process, a loss not factored into the final mariculture, or feed consumption, production volume. AFCD has been unsuccessful in converting mariculturists from MFF to pellet-based feed (Chau 2004).

The current feeding practice of using MFF to feed cultured fish is considered inappropriate as a long-term solution to feeding cultured fish because:

- Its use exacerbates the pressure of overfishing owing to the economic value of these small fishes.
- There are unknown effects on marine the ecosystem because of the removal of large volumes of small pelagic fishes from the sea.
- Some species are important for direct human consumption.
- Economic perspective.

Exacerbating Overfishing

Hong Kong waters are overfished (ERM 1998, Cheung 2001). The use of small pelagic and demersal fishes as feed exacerbates the overfishing problem as it has created an economic value for them, so fishing continues. In the past, MFF provided a useful route for non-target fish caught incidentally. Likewise, none of the fish caught in China have been discarded since the mid-1990s as all unwanted catches are taken either to the growing aquaculture industry as feed or used as part of the fish meal processing industry (Zhou and Ye 1996). Such usage has sustained the operation of the capture fishery even as the proportion of fish, often as human food, declines. Because of the considerable sale of bycatch, fishing continues. Wilson (1997), ERM (1998) and Cheung (2001) reported that purse seine fishermen operating in northeast Hong Kong caught fish especially for the mariculture industry. Trawl operators tend to use small mesh trawls to catch smaller fish as they found that there is heavy demand for small fish on mariculture farms as feed (ERM 1998). Hence, the need for MFF stimulates fishing with smaller nets, placing additional pressure on already overexploited natural fish stocks. Moreover, given the demand for MFF, there is little incentive to develop or employ fishing methods that are designed to avoid bycatch.

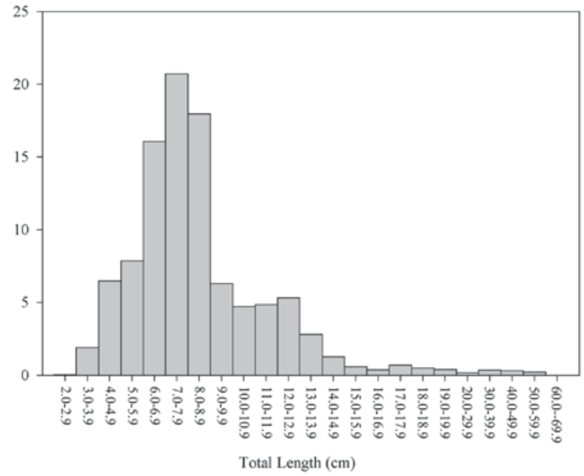

Fig. 6. Length-frequency distribution of all individuals found in the winter mixed fish feed samples with all species combined (n=8,161).

Table 3. Mean total length and weight for the 10 most abundant species in winter 2002 samples.

Species	Number	Total Length (cm)	Weight (g)
Leiogrnathus bindus	3,217	7.25	5.54
Leiognathus lineolatus	1,104	6.51	4.80
Sardinella sindensis	673	11.94	15.19
Leiognathus nuchalis	487	6.88	4.15
Decapterus spp.	*340*	7.67	4.41
Thryssa dussumieri	344	10.67	8.36
Sardinella lemuru	*303*	12.47	17.67
Leiognathus berbis	192	8.7	9.23
Konosirus punctatus	98	18.43	63.66
Nematalosa come	57	16.98	47.10

Unknown Impacts on Marine Ecosystems

While the consequences of removing large volumes of small fish from the wild on marine ecosystems are not known (Emerson 1999), there is agreement that it is likely to have negative impacts upon fish populations and food web interactions, especially if biological overfishing is already occurring (Crowder and Murawski 1998). At the population level, although these fishes are generally fast-reproducing and short-lived, massive removals from the sea could ultimately diminish their ability to replenish populations. This problem worsens if MFF comprises significant numbers of fishes prior to maturity, as is the case in Hong Kong. At the ecosystem level, the dominant component of MFF is small pelagic fishes, which are potential food sources for the larger, commercially valuable predatory fishes and other marine predators (Crowder and Murawski 1998, Emerson 1999). Removing them could increase the competition among larger predators, shift the relative abundance of different species in the food chain and, hence, alter trophic interactions (Crowder and Murawski 1998).

Diminishing the Source of Potential Food Fish Supply

Many of the fish species found in MFF in Hong Kong are edible. Fish in the families Mugilidae, Synodontidae, Trichiuridae, Nemipteridae and Sparidae constitute as much as 21 percent by weight in summer samples. The feed might also include potential foodfish for the future. When demand for foodfish increases and catches decline, people are willing to accept new, alternative species as foodfish. In Malaysia, for example, many of the former trashfish species, including Synodontidae, are now collected and processed into fishery products such as fish balls, for human consumption (Chee 1996). In Australia, one study found that any fish with a total length of 13 cm or more, has the potential to become food for humans (Pender *et al*. 1992).

Economic Perspective

As the demand for both mixed fish and fishmeal as feed increases, their price is likely to increase as availability becomes more limited. As feed cost already contributes to more than half of the industry's operational cost (Hassan *et al*. 1989), the increase in feed prices would further increase production costs, and may ultimately make production unviable.

The use of MFF has been associated with disease outbreaks that are likely to have negative economic consequences in two ways. Excess uneaten MFF can increase nutrient loading in localized culture areas, which may then degrade water quality and stimulate the disease outbreak (Donaldson *et al.* 2003). Diseases can also be transmitted directly from MFF to cultured fish.

In Hong Kong, there have been gradual changes in both the species composition and sizes of fish landed since 1950 and the fishery is overexploited (ERM 1998, Cheung 2001). As a result, there has been a marked shift in catch composition from large, slow growing to small fast growing fishes. Fishermen are spending less time fishing within local waters and go further into the South China Sea, because of the continuing reduction of catch within local waters (Cheung 2001). While improved fishing technology and intensified fishing are clearly associated with overfishing (Cheung 2001), the increased use of MFF might also have played a role, although there is no evidence to support a direct relationship. Landings of small pelagic species, particularly fishes in the families Clupeidae and Engraulidae increased sharply between 1975 and 1978/79, stabilized for about five years, then started to decrease (Cheung 2001). At the same time, the mariculture industry expanded rapidly, requiring large volumes of fish as fish feed. The steady decline in landings of small pelagic fishes since the early 1990s further suggests that that group of fishes is overexploited (Cheung 2001).

MFF is not only used in Hong Kong but also in other Asian countries, including Thailand, Malaysia, Japan, Mainland China and Taiwan where also there is evidence that heavy use of feed fish species deplete their populations. In Thailand, species from the family Leiognathidae contribute a large proportion of bycatch and are used as fish meal (Clucas, 1997). In Japan, fishes including sardines (*Sardinops melanostica*), jack mackerel (*Trachurus japonicus*) and sand lance (*Ammodytes personatus*) are landed in large quantities and have been used as fish feed since the 1980s (Watanabe *et al.* 1989). In China and Japan small pelagic fishes are increasingly scarce (Watanabe *et al.* 1989, Liufu Yongzhong 2002). In Malaysia, fishes of the family Leiognathidae dropped from 13 percent to three percent by weight in the catch landings after 18 years of trawling (Chan and Liew 1986). In areas where small pelagic fishes, including Atlantic herring, *Clupea harengus*, and Pacific sardine, *Sardinops* spp., are the principal catch targets for human and animal food, their populations have been depleted to low levels and have not recovered (Beverton 1990). Hence, the implications of using bycatch as mixed fish feed should not be underestimated.

Based on the above considerations, the continued and heavy use of MFF, in the long term, would appear to be an inappropriate fish feed goal from biological, ecological and economic perspectives. Finding a nutritionally adequate cost-effective diet is regarded as one of the two major constraints for the global development of the aquaculture industry (Boonyaratpalin 1997). While it is known that massive volumes of mature, but small fish are being used as feed in Hong Kong and other Asian countries including Taiwan, Japan and Thailand, the exact volume is unknown. Measures, including recording the volume of fish being removed as feed and regular fishery stock assessment, including minimum size/volume to be used, should be taken to evaluate the impacts of such removals on marine ecosystems and factored into management programs.

In general, the limited availability of the small fish supply as feed is likely to become one of the main constraints to the mariculture industry (Boonyaratpalin 1997). If this problem cannot be solved effectively, perhaps it is time to reconsider whether or not carnivorous fish are appropriate for aquaculture. To address the demand for fish protein, it is possible to shift the focus to herbivorous fish culture, thereby reducing demand for small pelagic fish as feed.

The team trash fish should be avoided, as the fish involved in MFF are not necessarily valueless. They are important not only due to their market value for mariculture, their potential as food fish, but also due to their role in the marine ecosystem. Those small pelagic fishes typically belong to lower trophic levels and are important food sources for species in the upper levels, including those with higher human food value. Using the term trash fish gives people a wrong perception that those fish are without worth and that removing them in large volumes is of little or no consequence.

Notes

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FMO is a non-profit organization operating all the seven wholesale fish markets in Hong Kong.

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