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Reconstructed catches in waters administrated by the Hong Kong Special Administrative Region

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RECONSTRUCTED CATCHES IN WATERS ADMINISTRATED BY THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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ABSTRACT

This paper aims to reconstruct comprehensive fisheries catch statistics from 1950 to 2010 in Hong Kong waters. The catch reconstruction was based primarily on data from landings statistics from the United Nations Food and Agriculture Organization (FAO). These data were then corrected for under-reporting and shift in fishing grounds using information collected from interviews with fishers and government fisheries officers, and data collected from sporadic surveys. The estimated total catch from Hong Kong waters increased from 5,200 t in 1950 to a peak of 31,400 t in 1979, then dropped to around 13,200 t in 2010. Artisanal catches decreased from the late 1950s to the late 1990s (with a small peak in catches in 1988), then increased to a steady amount in the 2000s. Since most fishing boats were un-mechanized before the mid-1950s, artisanal catch dominated the total catch during that period. Total discards also decreased from the 1980s to now. This is essentially because of the assumption of a lower discard rate. However, the assumed decrease in discard rate coincides with the decrease in total catch and expansion of mariculture in Hong Kong, as well as the increase in proportion of miscellaneous catches. Recreational fishing surprisingly contributed a considerable amount of total catches in Hong Kong. Thus, reconstructed total catches for Hong Kong in its own EEZ are 3.2 times the portion of the data reported by FAO on behalf of Hong Kong that was deemed to be caught inside the EEZ. However, it should be noted that there is a high degree of uncertainty in the estimated data as a result of the wide confidence range of the source data and the assumptions made. Nevertheless, cross-validations among different information sources show that the estimations agree in general with the actual trend in development of the fisheries in Hong Kong waters.

INTRODUCTION

Hong Kong is a Special Administrative Region (SAR) in the People's Republic of China, where it has a high degree of autonomy in all matters except for foreign relations and military defense. From the mid 19th century to 1997, Hong Kong was a British colony. Hong Kong is situated along the southeastern coast of China on the eastern shores of the Pearl River estuary. The waters administrated by Hong Kong, hereafter called Hong Kong waters, with an area of around 2,097 km^2 (Figure 1), are influenced by the outflow of freshwater from the Pearl River in the west, and oceanic currents in the east (Mortan and Mortan 1983). There are more than 800 species of marine fishes recorded in Hong Kong waters (Ni and Kwok, 1999).

Fishery resources in Hong Kong waters were mainly exploited by trawls (pair trawl, stern trawl, shrimp trawl, hang trawl), purse seine, gillnet, fish trap, hook and line (hand-line and long-line), as well as other gears such as cast net and spear gun (mainly by recreational divers) (Lin, 1949; AFD, 1986, 1987; Cook *et al.*, 1997; ERM, 1998). Similar to other tropical reef fisheries, mixed species stocks were exploited. As Hong Kong waters are influenced by the oceanic currents in the east, and the freshwater influx from the west, both reef and estuarine species are well represented in the catches.

The government fishery landing statistics are a comprehensive fisheries dataset which records the amount of fish landed and the corresponding wholesale price in the Hong Kong government wholesale markets [Fish Marketing Organization (FMO)] since 1948 (FMO, 1950 to 1998). The FMO markets were established primarily to ensure orderly marketing of fishes in Hong Kong. However, there has never been a systematic assessment of fishery landings from Hong Kong waters. The fish landed by the fishers are from both within and outside Hong Kong waters, and the landing statistics are not divided according to different fishing grounds. Moreover, though fishers are legally restricted to land fresh fish in FMO markets, results from this survey showed that fishers are increasingly landing their catches elsewhere. This is reported to be a result of better prices and more efficient auction procedures in other non-FMO markets, as well as these markets being closer to the fishing grounds being used. Additionally, fishers are not required to land live fish and invertebrates in the FMO. Thus landing statistics, without adjustments for these differences, are invalid for use in fishery assessments of Hong Kong waters.

This paper aims to reconstruct more complete fisheries catch statistics from 1950 to 2010 in Hong Kong waters. The analysis is based on Cheung and Sadovy (2004) that provided a reconstruction of fisheries catches in Hong Kong waters from 1950 to 1997. Here, I used the methodology described in Cheung and Sadovy (2004) and landings statistics from the United Nations Food and Agriculture Organization (FAO) to extend the catch reconstruction to 2010. Furthermore, I attempted to estimate the amount of landings from artisanal fishing. Here, artisanal fishing is defined as fishing boats that are un-mechanized or smaller than 12 m, and fish in inshore waters of Hong Kong. I also estimated the amount of recreational catches and discards from fisheries.

METHODS

Background of Hong Kong fisheries

Before and immediately after World War II, fishing boats were largely un-mechanized Chinese junks (Cheung and Sadovy, 2004). Wind-driven sailing junks were used and the major fishing grounds included Hong Kong waters, the Pearl River Estuary, and the coast of Southern China. The importance of the marine capture fisheries to the economy of Hong Kong in the pre-war period is revealed in a note in the Hong Kong Colonial Report (Hong Kong Government 1938):

> "*The fisheries of Hong Kong, from the point of view of the general economy of the Colony and of the number of persons connected directly and indirectly with this form of production, are the most important of the local industries...*"

Dramatic changes in the local marine capture fisheries took place in the latter half of the 20th century. Following heavy casualties in fishing communities and destruction of gear from the Sino-Japanese war, there was major rehabilitation and reconstruction of the marine capture fisheries. The government took control of the wholesaling of fishes from private wholesalers and government grants and loans were given to the fishers to repair or purchase new fishing gear (AFD, 1948). Since the 1950s, the government has encouraged mechanization of the fishing vessels by introduction of new technology and provision of grants and loans to fishers. From 1950 to 1970, the percentage of mechanized fishing vessels in Hong Kong increased from a few percent to more than 90 percent (AFD, 1950-70). Modern trawlers were introduced in the 1960s to replace the traditional style trawlers (Stather, 1975). At the same time, other fishing technologies, such as onboard refrigeration, sonar fish-finder, and other navigation technology were developed which greatly improved the capability to fish for extended periods and to extend fishing grounds further offshore (AFD, 1986).

The improvement in fishing technology can also be illustrated through the changes in net material over the past 50 years. In the early half of the 20th century, the only net-making material used in Hong Kong was China grass (*Boehmeria nivea*, Gaud) (Lin, 1949). Nets made of China grass required frequent drying and preservation after each fishing trip. Since nylon monofilaments were introduced as net and line-making material in the late 1950s, a considerable amount of time was saved from preserving the nets. Nylon monofilaments soon took over from China grass and became widely used by Hong Kong fishers (AFD, 1957). Moreover, the introduction of advanced technology such as the mechanized hauler (AFD, 1971), sonar fish-finder and global positioning system (GPS), greatly increased the efficiency of fishing, and reduced travelling time to and from fishing grounds.

From the mid-1970s to the 1980s, various signs of overfishing were reported. Anderson (1970), in his study on the life of fishers in Castle Peak Bay, Hong Kong noted that:

> "*Classic marks of overfishing exists: the small average size of catches in the most heavily worked areas, the relative abundance of trash fish, the year-by-year reduction of catch in proportion to effort expended*."

Reconstructed catch-per-unit-effort in Hong Kong waters shows rapid decrease in the late 1960s (Cheung and Sadovy, 2004). Such reduction of CPUE matched tightly with those reported from the interviewed fishery officers (Cheung 2001).

Meanwhile, Leung and Lee (1987) noted a change of fishing grounds from the southwest of Hong Kong in 1973, northeastward to 20 degrees N latitude in the late 1970s and eventually to between 25 degrees N and 28 degrees N in the 1980s, i.e., even further from Hong Kong. The shift might partly have been a result of the declaration of the Exclusive Economic Zone (EEZ) in the mid-1970s by neighbouring countries and the imposition of the trawling ban in waters less than 40 m deep along the coastline by China since 1979 (Leung and Lee, 1987). Despite continued expansion of the fishing grounds, local Hong Kong waters continued to be intensively exploited (ERM, 1998).

Intensive and largely unrestricted fishing has resulted in severe depletion of the fishery resources in Hong Kong waters (Cheung and Sadovy, 2004). Recent stock assessments suggested that 12 out of 17 assessed commercial species were over-exploited, the rest being fully exploited (Pitcher et al., 1998). Indeed the 17 species assessed by Pitcher et al. (1998) were mostly low trophic level fishes and invertebrates, being the only groups for which representative samples could be obtained. The majority of traditionally fished predatory food fishes were not included in the assessments as so few were sampled. Moreover, of the eight species of groupers (Serranidae) considered to be common in the 1960s, five are no longer regularly encountered in markets (Chan, 1968; Sadovy, 1998). The previously abundant yellow croaker (*Larimichthys crocea*, Sciaenidae), which used to aggregate to spawn in the Pearl River Estuary (Chu, 1960), has disappeared as a major local catch. The commercially valuable giant croaker (*Bahaba taipingensis*, Sciaenidae), its range limited to the coast of southern China, has disappeared from commercial fishery catches (Sadovy and Cheung, 2003). Local depletions or extirpations of a variety of reef fishes have been indicated (Sadovy and Cornish, 2000; Cheung, 2001) and ecosystem modelling of the Hong Kong marine ecosystem suggests that this is now dominated by small fishes and invertebrates more resilient to high fishing intensity (Pitcher *et al.*, 2002). In addition to overfishing, marine resources are threatened by coastal development such as reclamation, dredging, dumping, and industrial and domestic pollution (Morton, 1989, 1996).

By the 1990s, besides the commercially valuable species, a considerable amount of less valuable species, including substantial amounts of juveniles of demersal and pelagic species, were also being caught, especially by bottom trawlers (Sadovy, 1998). Historically, most small fish were taken as by-catch in local trawl fisheries and discarded. Since the 1980s, this by-catch was used as feed for fish in mariculture (Wilson, 1997; Sadovy, 1998). Moreover, juveniles of valuable species such as sea bream (Sparidae), mainly red pargo (*Pagrosomus major*), gold-lined sea bream (*Rhabdosargus major*), groupers (Serranidae) and snappers (Lutjanidae) were captured to supply the mariculture industry locally or sent

to Japan as fingerlings for grow-out (Johannes and Riepen, 1995; Cook *et al.,* 1997; Wilson, 1997; Sadovy, 1998).

Catch reconstruction

A. Correction of landings data in official statistics

Since time-series data of catch were not available, an indirect method of annual landings estimation using FMO landings data (FMO, 1950-1998) was employed. These data, which include fishery landings from Hong Kong-based vessels that fish both inside and outside Hong Kong waters, were categorized into generic groups (Table 1). Moreover, fishers often do not land their catch at the FMO, despite being required to do so by law (at least for fresh fish), and such catches go unreported. To estimate catch by Hong Kong vessels in Hong Kong waters only, first of all, the mean proportions (P) of catch sold through FMO in the 1950s, 1970s and 1990s were estimated from interviews with fishers. Assuming a linear change of P from the 1950s to the 1990s, values of P in the intervening years were interpolated. Unreported landings outside the FMO were corrected by the equation:

$$Lc_{i(y)} = Lg_{i(y)}/(1-P_{(y)})$$

where *Lc* and *Lg* represent the corrected and original government landings (tonnes) of generic group *i* in year *y* respectively.

The fisheries landings statistics for Hong Kong reported in FAO appear to have accounted, to some extent, for the bias inherent in the FMO landings data. When the FAO and the original FMO landings statistics from 1950 to 2010 were compared (Figure 2), reported landings in FAO statistics are an average of 1.2 times the FMO data in the 1950s. The FAO to FMO landings discrepancy increased continuously to an average of 3.2 times in the 1990s. However, no published documentation on the methodology of such a correction was found. Since FAO data are the internationally recognized statistics, the catch reconstruction presented here uses FAO data as the reported landings baseline.

B. Reconstructing landings from 1950 to 2010

The major generic groups caught by interviewed fishers in 1950, and their major fishing grounds, were determined. The proportion of catch of each taxonomic group from Hong Kong waters to total catch from all areas by fishery sector was estimated (methods and detailed results presented in Cheung 2001).

Landings by species in 1996-97 and 2001-2002 were estimated by the Agriculture, Fisheries and Conservation Department AFCD through an extensive interview programme (port survey) (AFD, unpublished report) and categorized into the generic groups listed in the FMO landing statistics. The relative proportions of the port survey-estimated catches to the FMO and FAO landings statistics by taxon groups (small pelagic fishes, all other fishes, invertebrates) during these two time period were calculated.

Assuming a linear change of the proportion of Hong Kong waters landings to those recorded in FMO and FAO landing statistics from 1950 to 2010, a time-series dataset of landings from Hong Kong waters was estimated. The taxonomic composition of the generic groups reported in the landings statistics is based on (AFD unpublished data, see Table 1).

Artisanal catch

I estimated catches from artisanal fisheries based on the estimated proportions of landings from mixed-gear vessel types from the Port Surveys and the historical change in number of this type of fishing boat. Artisanal fishing (defined here as by un-mechanized or small i.e., <12 m boats that fish almost exclusively in Hong Kong waters) was common before the 1960s when most fishing boats were still un-mechanized, and more recently, by the mixed-gear fisheries that employed a mixture of gillnet, lines, purse seine and traps depending on the target species, fishing grounds and season. Firstly, estimates of the proportion of un-mechanized fishing vessels were obtained from AFD annual reports. Secondly, fishing vessels in the miscellaneous (mixed-gear type) categories operating in Hong Kong waters were estimated from the 1996-97 and 2000-2001 Port Surveys (unpublished data). Thirdly, changes in the number of miscellaneous fishing vessels from 1950 to 1996 were obtained from AFD annual reports (1950 – 1996). Changes between 1996 to 2001 were assumed to be linear and the proportion of miscellaneous vessels became stable from 2001–2010. Furthermore, I calculated the proportion of catch per unit of mixed-gear fishing boat relative to other fishing boat types. These were then used to calculate the changes in proportions of catch from mixed-gear fishing boat by multiplying the proportion of boats by the proportion of catch per boat and the total catch in that year. Since un-mechanized fishing boats included mixed-gear fishing boats, the maximum between the proportion of catches from un-mechanized and mechanized fishing boats were used to represent artisanal catches.

Recreational fishing

The estimation of recreational catch from Hong Kong waters was based on an unpublished survey commissioned by WWF Hong Kong (Andy Cornish, unpublished data) and demographic data. Firstly, the recreational fishing survey estimated the population of Hong Kong residents that participated in recreational fishing in 2001-2002. They divided the frequency of participation into three categories: one time or more per year, four times or more per year, and twelve times or more per year. To be conservative,

I used the lower limit of these categories to calculate the total recreational fishing trips per year by Hong Kong residents in 2001-2002. I also calculated the proportion of total population that participated in recreational fishing in each frequency category. Assuming that recreational fishing participation rate and the proportion in different participation frequency remained constant from 1950 to 2010, I multiplied the total population of Hong Kong from 1950 – 2010 with the participation rate to estimate the total number of recreational fishing trips per year. Assuming that the average catch per trip was 500 g of fish (Sumaila *et al.* 2007), I estimated the annual recreational fishing catch from 1950-2010.

Discards

Discards were estimated based on regional and global published discard rates (Kelleher 2005). Globally, the average discard rate was estimated to be 7% of the total landings, while a country-specific rate for China was estimated to be 0.5% only. However, a literature review by Cheung (2001) suggested that discards of low value catch were more common before the 1980s. From the 1980s, the increasing demand for fish feed used in mariculture farms in Hong Kong created a market for this previously discarded by-catch (Cao et al. 2015). Thus, I assumed that before 1980, the average discard rate in Hong Kong equaled the global average (i.e., 7%), while discard rate decreases to 0.5% from 1980 to 1990 and remained at that level since.

RESULTS AND DISCUSSION

Total reported volume of landings from Hong Kong fishing fleets changed considerably between 1950 and 2010 (Figure 3). The estimated landings from Hong Kong waters increased from an average of 2,300 t·year^{-1} in the 1950s to 9,000 t·year^{-1} in the 1970s, then dropped to around 2,800 t·year^{-1} in the 2000s. Overall, around 10% of corrected landings reported by FMO or FAO were originated from Hong Kong waters (Cheung 2001).

Reported landings of major commercially important demersal and pelagic groups increased consistently from the 1950s to 1990, but decreased rapidly thereafter (Figure 4). Such trend is consistent between reconstructions that are based on FMO and FAO data.

Unreported industrial landings followed the same trend as reported commercial data, increasing from 440 t·year^{-1} in the 1950s to a peak of almost 18,000 t in 1988. Catches rapidly declined thereafter and averaged 5,700 t·year^{-1} in the 2000s.

Unreported artisanal catches decreased from the late 1950s to 1977, increased to a small peak in 1988 and decreased again in the 1990s, before increasing and stabilizing in the 2000s. Most fishing boats were un-

mechanized before the mid-1950s, therefore, artisanal catch dominated the total catch during that period (Figure 4a). As the fishing fleets gradually become mechanized, the proportion of catches from artisanal fishing decreased rapidly from the 1950s. However, as noted in Cheung and Sadovy (2004), following the depletion of fisheries resources, many fishers shifted from larger-scale, more cost-intensive fishing back to smaller scale inshore fishing since the 1990s. Thus, the proportion of artisanal fishing catches increased.

Total discards also decreased from the 1990s to now (Figure 4a). This is mainly driven by the assumption of a declining discard rate. However, the assumed decrease in discard rate coincides with the decrease in total catch and expansion of mariculture in Hong Kong, as well as the increase in proportion of miscellaneous catches (Figure 4b). It is suggested that the depletion of local fisheries resources since the 1980s prompted the development of mariculture as alternative livelihoods (Cheung 2001). The demand of previously non-valuable miscellaneous catches that consisted mostly of juvenile and pelagic fishes increased to supply the local mariculture farm as fish feed. Such changes sustained the continued operation of many fishing boats in Hong Kong waters.

Surprisingly, recreational fishing contributed a considerable amount of total catches in Hong Kong. I estimated that recreational fishing amounted to approximately 11% of catches from the 2000s (Figure 4a). This is partly because of the increased population that participated in recreational fishing and the decreases in commercial catches. The major targeted species, according to the recreational fishing survey (Andy Cornish, unpublished data), were grouper, seabream, snapper, sea perch, rudderfish, trevally, grunt and tuna-like fishes. Currently, marine recreational fishing is not regulated/managed in Hong Kong, except the prohibition of use of destructive methods. As recreational fishing contributed to a large proportion of catches in Hong Kong, it should be managed and regulated.

One of the major limitations of fishery studies in Hong Kong, and in the Indo-Pacific in general, is the lack of accurate time-series catch data (Blaber, 1997). In the present study, an attempt was made to use the best available information to reconstruct time-series catch and effort data on Hong Kong waters over the latter part of the 20th century. However, it should be noted that there is a high degree of uncertainty in the estimated data as a result of the wide confidence range of the source data and the multiple assumptions made. Nevertheless, cross-validations among different information sources show that the estimations agree in general with the actual trend in development of the fisheries in Hong Kong waters with at least an order-of-magnitude accuracy.

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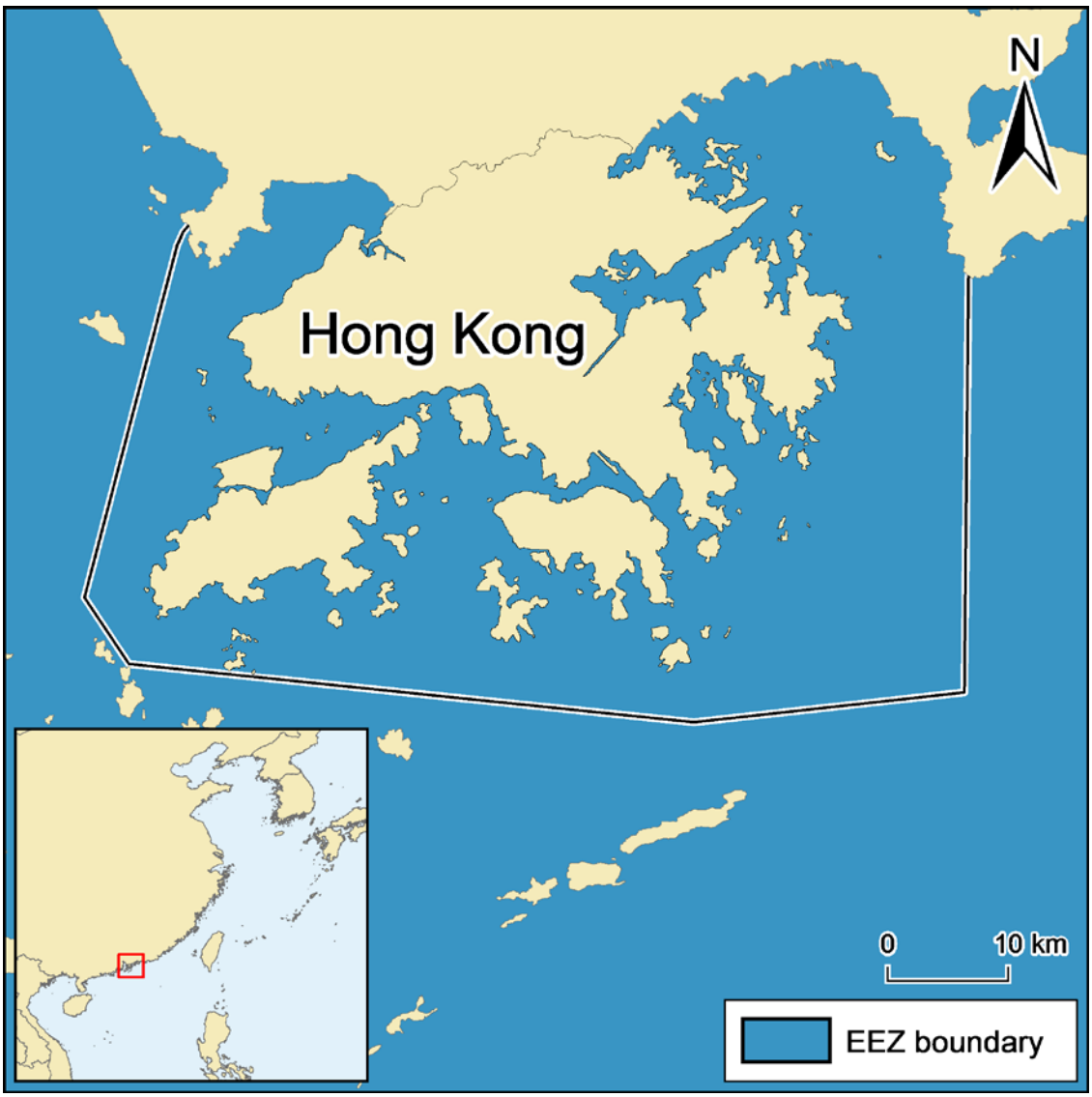

Figure 1: Map of Hong Kong, its shelf (to 200m depth) and Exclusive Economic Zone (EEZ).

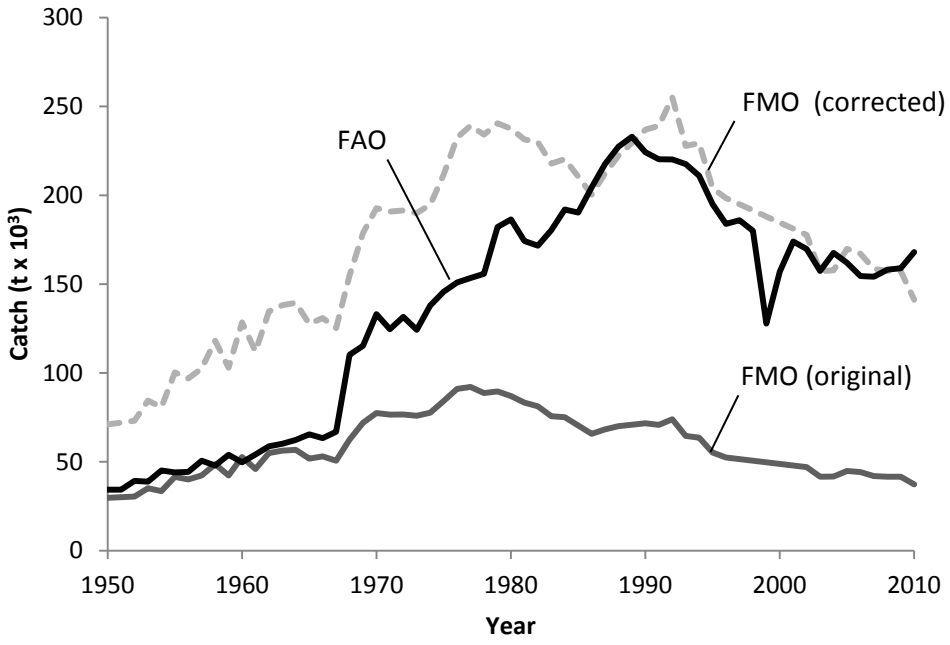

Figure 2. Landings statistics reported by the UN Food and Agriculture Organization (FAO, black line), by the Hong Kong Fish Marketing Organization (FMO original, grey line) and by FMO corrected for unrecorded landings (FMO corrected, dashed line).

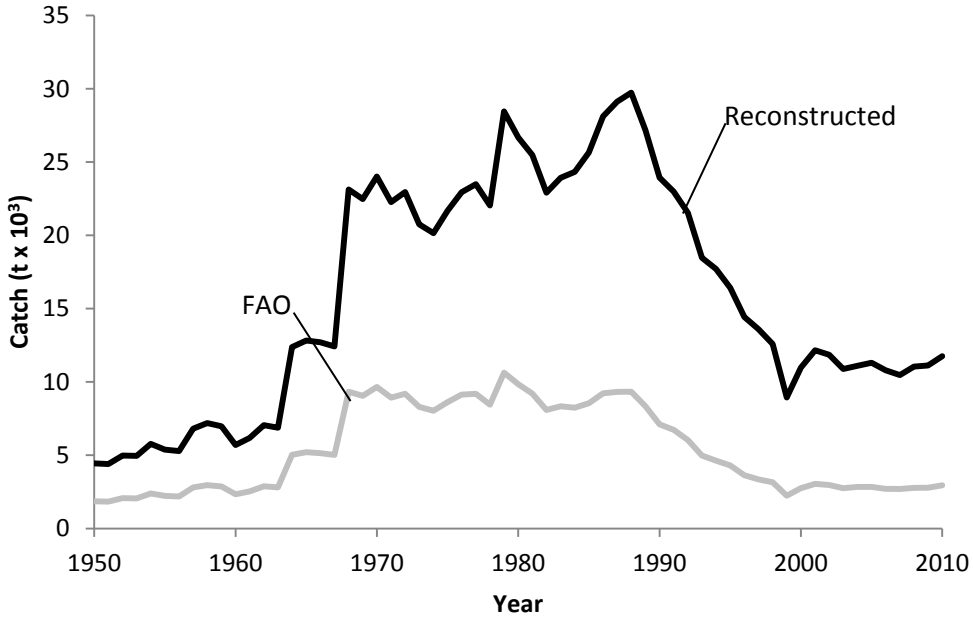

Figure 3. Estimated landings from Hong Kong waters only based on data from FAO (grey line, and reconstructed catch (dotted line).

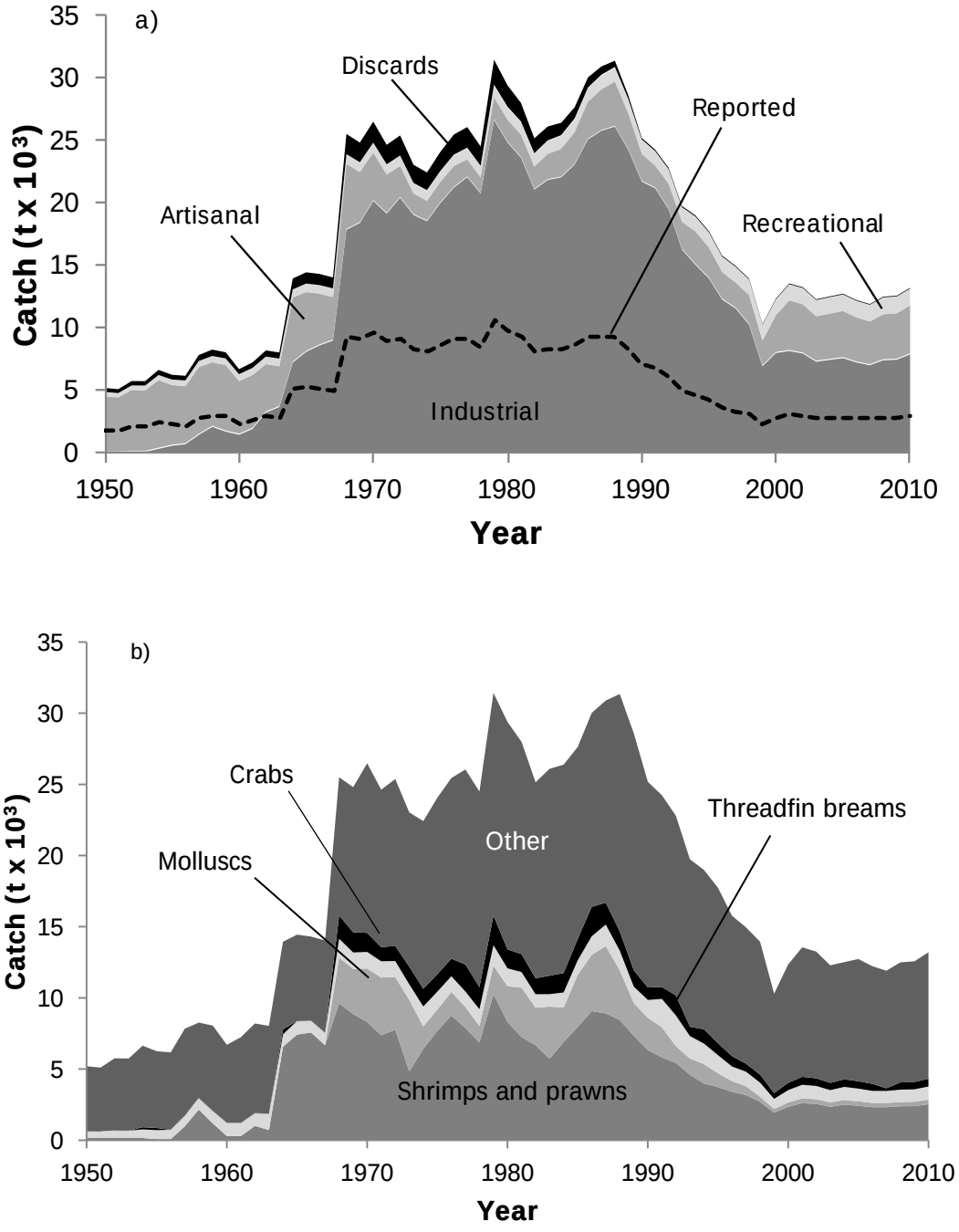

Figure 4. Reconstructed total catches for Hong Kong's EEZ equivalent waters, 1950-2010, by a) fishing sector with discards treated separately, and FAO reported data overlaid as a dashed line and b) major taxonomic grouping. 'Other' consists of 28 additional taxonomic categories.

Table 1. List of generic groups in the FMO landing statistics (1970-1999), and the corresponding taxa in the results of AFD Port Survey 1996-97. (Synonyms, as used in the Port Survey report in brackets).

Generic groups in FMO landing statistics	Taxa in Port Survey
Pelagic fishes	
Anchovies	*Engraulis japonicus* (*Stolephorus zollingeri*); *Stolephorus heterolobus* (*heteroloba*)
Crevalles	*Alepes djedaba* (*Caranx kalla*); *Alepes melanoptera* (*Caranx malam*); *Caranx* spp.;
Pomfrets	*Parastromateus* (*Formio*) *niger*; *Pampus* (*Stromateoides*) *argenteus; Pampus chinensis* (*Stromateoides sinensis*); *Pampus* (*Stromateoides*) spp.
Mackerels	*Scomberomorus commersoni*; *Scomberomorus guttatus*; *Scomber japonicus*; *Rastrelliger kanagurta*; *Scomberomorus* spp.;
Round herrings	*Dussumeria* spp.; *Hilsa* spp.; *Thrissa* spp.;
Sardines	*Sardinella jussieu*; *Sardinella aurita*; *Sardinella* spp.;
Scads	*Decapterus lajang*; *Trachurus japonicus*
Tuna-like species	*Thunnus* spp.
Demersal fishes	
Bigeye	*Macrocephalus spp.*
Conger-pike eels	*Muraenesox cinereus*; *Muraenesox talabonoides*; *Muraenesox* spp.;
Croakers	*Pennahia* (*Argyrosomus*) *pawak*; *Argyrosomus spp.; Collichthys lucidus* (*lucida*); *Johnius belangerii* (*belengeri*); *Nibea albiflora*; *Argyrosomus* (*Nibea*) *japonicus* (*japonica*); *Protonibea* (*Nibea*) *diacanthus, Pseudosciaena crocea*
Goatfish	*Parupeneus* spp.;
Groupers	*Cephalopholis boenak* (*pachycentron*); *Epinephelus akaara*; *Epinephelus areolatus*; *Epinephelus awoara*; *Epinephelus bruneus* (*brunneus*); *Epinephelus chlorostigma*; *Epinephelus fasciatomaculatus*; *Epinephelus tauvina*; *Epinephelus* spp.
Hair-tails	*Trichiurus lepturus* (*haumela*)
Lizard fish	*Saurida tumbil*; *Saurida* spp.
Melon Seed	*Psenopsis anomala*
Horsehead	*Branchiostegus spp.*
Seabreams	*Acanthopagrus* (*Mylio*) *berda*; *Acanthopagrus* (*Mylio*) *latus*; *Acanthopagrus* (*Mylio*); *Acanthopagrus* (*Mylio*) spp.; *Pagrus* (*Chrysophrys major*); *Rhabdosargus sarba*
Snappers	*Paracaesio* sp.; *Lutjanus argentimaculatus*; *Lutjanus johnii* (*johnii*); *Lutjanus lutjanus* (*lineolatus*); *Lutjanus russellii* (*russelli*)
Soles	*Cynoglossus semilaevis*; *Cynoglossus trigrammus*; *Cynoglossus* spp.; *Paralichthys olivaceus*
Threadfin breams	*Nemipterus virgatus, Nemipterus japonicus*
Other fishes	Fishes in Port Survey 1996-97 and 2000-01 that are not included in this list
Invertebrates	
Crabs	*Charybdis cruciata*; *Charybdis natator*; *Portunus pelagicus*; *Portunus trituberculatus*; *Portunus sanguinolentus*; *Scylla serrate.*
Cuttlefish	*Sepia pharaonis*; *Sepia* spp.;
Lobsters	*Panulirus versicolor*;
Shrimps	*Acetes japonicus*; *Acetes* spp; *Metapenaeus affinis*; *Metapenaeus joyneri*; *Metapenaeus* spp.; *Metapenaeopsis barbata*; *Metapenaeopsis palmensis*; *Parapenaeopsis hungerfordi*; *Parapenaeopsis tenella*; *Penaeus japonicus*; *Penaeus merguiensis*; *Penaeus penicillatus*; *Penaeus* spp.; *Slpheus* spp.; *Solenocera crassicornis*; *Trachypenaeus curvirostris*; *Anadara brotoni*.
Squid	*Loligo edulis*; *Loligo* spp.; *Sepioteuthis lessoniana*
Other Invertebrates	*Babylonia lutosa*; *Babylonia* spp.; *Harpiosquilla harpax*; *Octopus* spp.; *Oratosquilla oratoria*; *Oratosquilla* spp.; *Pinna bicolor*; *Tapes philippinarum; Tapes* spp.; Urchin.