Analysis of a 131-year longitudinal dataset of the Eurasian otter *Lutra lutra* in Hong Kong: implications for conservation

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Abstract Hong Kong is one of the busiest metropolises, and the Eurasian otter *Lutra lutra* is one of its most threatened species. We collected published data for 1890–2020 to document changes in local otter abundance and distribution over time. The 108 records revealed new distribution data and showed that decline began as early as the 1930s. The local Eurasian otter is strongly associated with coastal and alluvial wetlands, and its last refugium, the Yuen Long floodplain draining the Mai Po Inner Deep Bay Ramsar Site, has always been a critical habitat. Our analysis suggests that hunting is unlikely to be a major cause of the otter's decline. Rather, dependence on lowland wetlands makes it particularly susceptible to habitat loss caused by increasing urbanization. Auxiliary infrastructures and water pollution have also exacerbated wetland degradation to the detriment of otters and their prey. There is a need for greater cooperation amongst government agencies and landowners to guarantee otter survival: priority steps include the establishment of additional and interconnected wetland reserves, better stakeholder engagement and enforcement efficiency to tackle entrenched pollution problems, and flood prevention schemes that preserve or restore functional riverine ecosystems within critical otter habitats. The current otter distribution range has been earmarked for development in a government-led mega urbanization plan; the plight of the local Eurasian otter needs to be widely publicized to garner stakeholders' support and galvanize immediate conservation actions across society.

Keywords Critical habitat, Eurasian otter, historical ecology, hunting, *Lutra lutra*, pollution, population trend, urbanization

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Introduction

The Eurasian otter *Lutra lutra* has the widest distribution of all extant otter species, with a range stretching across Europe, Asia and North Africa (Hung & Law, 2016). Although the once-threatened European population is recovering (Ledger et al., 2022), it is generally considered rare in Asia and the future of these eastern populations is not secure (Loy, 2018; Yoxon & Yoxon, 2019). Despite the species' threatened status in Asia, little research has been conducted on its ecology and threat processes in the region (Zhang et al., 2018; Basnet et al., 2020; Zhang & Fan, 2020). The Global Otter Conservation Strategy (Duplaix & Savage, 2018) identified a number of goals and associated objectives and actions to protect otters, among which Actions 2.3 and 2.4 under Objective 2 (Locality-based implementation of conservation) and Actions 4.2 and 4.3 under Objective 4 (Strategic research) call for the identification and protection of critical otter habitats, and synthesis of otter records to determine historical and current distributions (Duplaix & Savage, 2018).

Although the Eurasian otter is categorized as Near Threatened on the IUCN Red List (Loy et al., 2022), the species has undergone substantial population and range reductions in East Asia (Sasaki, 2016; Li et al., 2017; Li & Chan, 2018; Zhang et al., 2018; Chang et al., 2019; Han & Shi, 2019; Jang-Liaw et al., 2023), except in South Korea (Jo et al., 2020). This general trend is echoed in the Hong Kong Special Administration Region, which is a metropolis with one of the highest human population densities and some of the busiest ports. Hong Kong was one of the first places in Asia to afford legal protection to the Eurasian otter; together with the Chinese pangolin *Manis pentadactyla* it was listed as a protected species in 1936. However, little published information is available on the local Eurasian otter, with only a few brief general accounts in early natural history publications (e.g. Herklots, 1951; Marshall, 1967a; Lance, 1976; Hill & Phillips, 1981). Scientific studies of Hong Kong's terrestrial mammals only began in the 1990s and the status of the Eurasian otter remained obscure, with only occasional reports from the Mai Po Nature Reserve and the surrounding Deep Bay area (Goodyer, 1992; Reels, 1996; Shek, 2003, 2006; Suen, 2003; Shek et al., 2007). The first scientific research on Hong Kong otters was not completed until 2021, in which only seven individuals were genetically identified in a 2-year field study throughout its known local range, with Mai Po Nature Reserve and adjacent wetlands highlighted as the core habitat (McMillan et al., 2022). Despite being considered a species of high conservation priority (Fellowes et al., 2002; Shek, 2003), there is no

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active conservation programme targeting this population (Agriculture, Fisheries and Conservation Department, 2014a; Kadoorie Farm and Botanic Garden, 2018).

Historical data sources such as newspapers, archival documents, and traditional and local ecological knowledge have been increasingly used as an alternative approach for assessing species' population trends and ecosystem changes over time when conventional ecological data are lacking (Lotze & McClenachan, 2013; Thurstan et al., 2015). They can also be useful for identifying critical habitats of threatened species to inform conservation management (Hiddink et al., 2019; Moore & Hiddink, 2022). McMillan et al. (2019) used local ecological knowledge to collect data on the past and current distribution of otters in Hong Kong but were unable to provide a long-term, Hong Kong-wide overview because of a lack of community memory pre-1950 and the limited geographical coverage of their interview study. Here we systematically review and collate all otter records in scientific publications, books, local newspapers and other popular publications from 1890 to 2020, and reconstruct a longitudinal pattern of temporal and spatial changes in otter abundance and distribution in Hong Kong. We also explore possible causes of the population collapse and recommend key conservation actions.

Study area

Hong Kong is a 1,100 km² coastal city at the mouth of the busy Zhujiang (Pearl) River Delta in subtropical China. The topography is hilly, with flatlands limited to narrow coastal strips; most housing and other developments for the >7 million residents are concentrated on 25% of the land. Hong Kong has a coastline of $>1{,}200$ km and many sheltered bays have dense, although stunted, mangrove formations, especially along the western coastline, which receive discharge from the Zhujiang River, with salinity approaching that of fresh water in the rainy season. The only substantial alluvial landscape is the Yuen Long floodplain, drained by the Deep Bay Basin, supporting Hong Kong's largest wetland ecosystem and comprising rivers, marshes, reedbeds, aquaculture ponds, mangroves and mudflats. Hong Kong has been inhabited for at least 6,000 years and all ecosystems have been degraded, but 40% of the land area, mainly the hilly interior, is protected for nature conservation (Dudgeon & Corlett, 1994). Although many forest-dependent and large mammals have been lost, the remaining fauna includes 14 medium- to large-sized non-volant wild mammal species, many of which have recovered from previous population crashes following the establishment of an extensive protected area system in the late 1970s (Shek et al., 2007).

Methods

For otter-related newspaper articles, we reviewed Hong Kong newspapers on the WisersOne database and the Old Hong Kong Newspapers Collection in the Multimedia Information System of the Hong Kong Public Library using the search term 'otter' and the Chinese character for otters (獺). We also searched the archive of the *South China Morning Post*, a local English-language newspaper founded in 1903. We also searched Google Scholar (2022) and Google Books (2022) with the search terms 'otter', 'lutra' or '獺', paired with 'Hong Kong' or the Chinese characters '香港'.

We also reviewed (1) annual reports of the Hong Kong government, (2) wildlife records in *Porcupine!*, a newsletter of the University of Hong Kong on local biodiversity, (3) literature about local natural history, natural environment and wildlife, and (4) documents submitted to the Hong Kong government's Environmental Protection Department under the Environmental Impact Assessment Ordinance. We also searched for place names containing 'Otter', '獺' or 'Chat' (the Cantonese romanization of the character '獺') using GeoInfo Map (2022).

For each record, the perceived local otter abundance was coded using a four-tier classification system modified from similar studies (Fortibuoni et al., 2010; Al-Abdulrazzak et al., 2012; Alleway & Connell, 2015; Al-Abdulrazzak & Pauly, 2017): common (commonly seen or no evidence of reduced abundance), present (present but with evidence of reduced abundance), rare (severely reduced abundance and already disappeared from some localities), and absent (no longer in existence). Not all occurrence accounts could be coded as some simply reported a sighting event, or only reported otter abundance in a specific location. We graphed the average otter abundance rank for each decade over the 131-year study period to produce a longitudinal trend of otter population change. Some researchers have suggested that the Asian small-clawed otter *Aonyx cinereus* may also occur in Hong Kong (Foster-Turley & Santiapillai, 1990; Wang & Xie, 2009) but without any supporting evidence. Therefore, 'otter' refers here to the Eurasian otter. For locality names mentioned in the text, see Fig. 1.

Results

A total of 14,231 otter-related newspaper articles were examined. After removing false positives resulting from optical character recognition errors in the digital databases, irrelevant articles and dubious records, we retrieved 27 otter records for Hong Kong from 1890 to 2020. Eighty-one additional records were located from other sources; literature citing published information already collected was excluded. The year of publication was reported for those items that did not specify the year of record.

Seven of the 108 reports declared the otter extinct in Hong Kong. For those reporting its continued presence, a drastic reduction in range and abundance is evident. This can be divided into three phases: Phase I is pre-1933, during

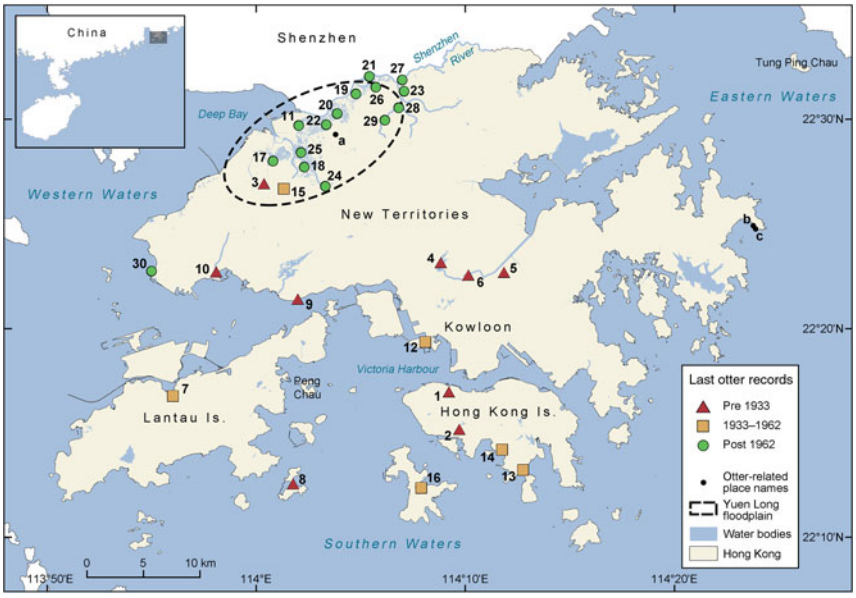

FIG. 1 Eurasian otter *Lutra lutra* records in Hong Kong during 1890–2020. 1, Central; 2, Aberdeen; 3, Ping Shan; 4, Shing Mun; 5, Sha Tin*; 6, Shing Mun River*; 7, Lantau Island*; 8, Cheung Chau Island*; 9, Tsuen Wan Ka Loon Tsuen; 10, Castle Peak*; 11, Mai Po and Deep Bay; 12, Stonecutters Island*; 13, Stanley; 14, Repulse Bay; 15, Yuen Long*; 16, Lamma Island Picnic Bay; 17, Tin Shui Wai-Fung Lok Wai; 18, Nam Sang Wai; 19, Lok Ma Chau; 20, San Tin; 21, Hoo Hok Wai; 22, Mai Po San Tsuen-Tam Kon Chau; 23, Sandy Ridge; 24, Kam Tin; 25, Tai Sang Wai; 26, Ma Tso Lung; 27, Lo Wu; 28, Long Valley-Ho Sheung Heung; 29, Kwu Tung; 30, Tap Shek Kok; a, Chat Ling (獺嶺); b, Chat Ngam (獺岩); c, Chat Wan (獺灣). *Location point is approximate

which the otter was reported to be relatively common until the first report of decline; Phase II is 1933–1962, when the otter population progressively declined and its range contracted; Phase III is post-1962, when the otter was on the brink of local extirpation, with a highly localized distribution. Figs 1 & 2 summarize all otter records in Hong Kong during the 131-year period; Supplementary Table 1 details the 108 records. Our extensive newspaper search revealed only three deliberate killings of local otters in 131 years. The species' legal status was highlighted in 23 reports.

Historical otter distribution

The first otter report in our study period was one killed in Central, Hong Kong Island in 1898. Since then, the species has been reported from Kowloon, the New Territories and several offshore islands (Fig. 1). Although there are three records from hilly areas (Aberdeen, Shing Mun and Shing Mun River), otters were predominantly reported from lowland wetlands, including coastal waters, beaches, mangroves, marshes, mudflats, rivers, fishponds and intertidal shrimp ponds locally known as *gei wai*. Among the 70 records with specific locations, 56 (80%) were clustered in the Yuen Long floodplain, and the records span the 1900s to 2019, suggesting it is the critical otter habitat in Hong Kong. We found no unequivocal evidence of otters occurring in the eastern marine waters of Hong Kong dominated by oceanic waters from the South China Sea.

Of the seven otter-related place names located, Chat Ling (meaning Otter Ridge) is adjacent to Mai Po Nature Reserve in the Yuen Long floodplain, supporting the notion that place names can be a biogeographical indicator of the historical distribution of fauna (e.g. Cox et al., 2002; Tattoni, 2019), and four were likely to be named for the resemblance of a landscape feature to the otter's appearance or based on animal-related fung shui principles in Chinese culture or for other unrelated reasons (Iu, 2012). We were unable to ascertain whether the remaining two locations (Chat Wan and Chat Ngam, meaning Otter Bay and Otter Rock) in eastern Hong Kong waters are associated with former otter occurrence.

Bunbury (1909) reported otters in 'Ping Shan, New Territories'. However, in his revised edition, the location became 'Ping Chau, New Territories' (Bunbury, 1913). Historically, there were two outlying islands named Ping Chau in Hong Kong; one is near Lantau and is now known as Peng Chau, the other is in the oceanic eastern waters and is now known as Tung Ping Chau (Fig. 1). The different localities given in the two editions have caused some confusion among local otter researchers regarding whether otters occurred in the eastern waters of Hong Kong (McMillan et al., 2019, 2022). Although the possibility of otters occurring on these islands cannot be excluded, we think it likely that Ping Chau is a typographical error. Ping Shan was a popular location for early travellers and naturalists (e.g. Hurley, 1897; Heywood, 1938; Herklots, 1951), including Bunbury, and is within the Yuen Long floodplain.

The otter sightings on Stonecutters Island in 1948 are of special interest; the description of the animal, seen repeatedly, leaves no doubt that it was an otter. Together with the 1898 sighting from Central, this confirmed otters occurred in the busy Victoria Harbour until at least the late 1940s. Otter reports from Sha Tin, Shing Mun and Shing Mun River are also notable, as these are the only records from catchment basins emptying into the eastern waters of Hong Kong. Herklots (1951) stated that otters used to occur on Hong Kong Island but could find no recent records. Ye (1958) noted that otters occurred in Stanley and

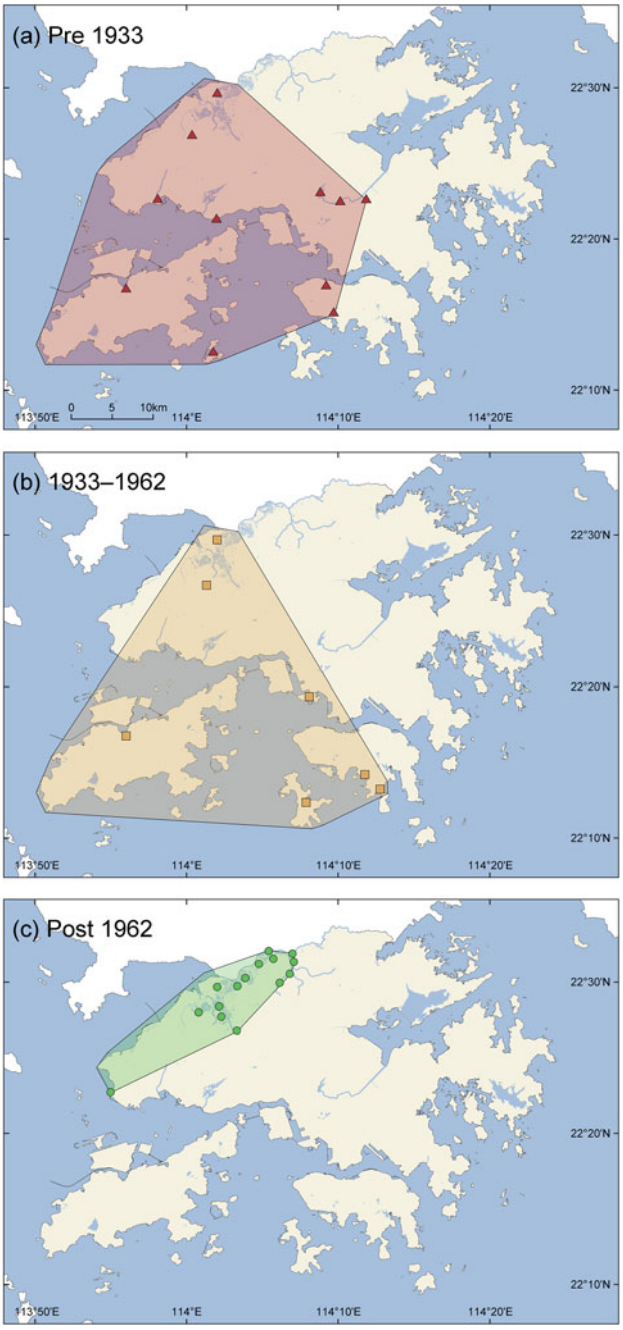

FIG. 2 Distribution of the Eurasian otter in Hong Kong (a) pre-1933, (b) 1933–1962 and (c) post-1962.

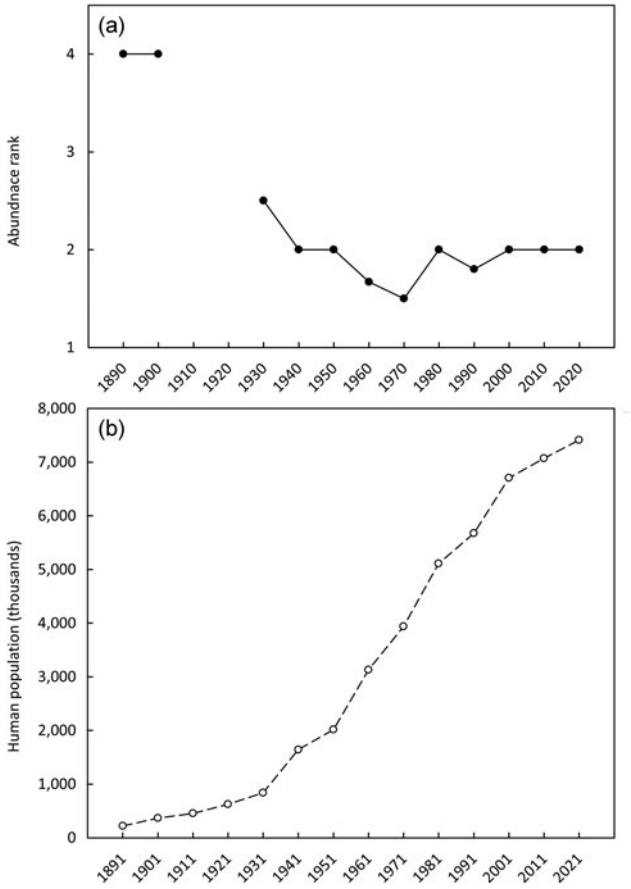

FIG. 3 Decadal changes in (a) the perceived abundance of the Eurasian otter during 1890–2020 (1, absent; 2, rare; 3, present; 4, common), and (b) the human population of Hong Kong during 1891–2021 (Census and Statistics Department, 1972, 1992, 2021). No data were available for perceived otter abundance in the 1910s and 1920s.

Repulse Bay in the less developed parts of Hong Kong Island, but were rare. A newspaper article on an otter sighting at Repulse Bay in 1961 is the last otter report from Hong Kong Island. An otter was reported from neighbouring Lamma Island in the following year but it was found tied with a rope on a beach, and the possibility of it being caught elsewhere cannot be ruled out. This record suggests otters could have survived in the southern waters up to the early 1960s.

All otter records from Lantau, a rural area and the largest island of Hong Kong, with many mangrove-lined bays, were brief and no specific locations were given (Peplow, 1930; Peplow & Barker, 1931; The Government of Hong Kong, 1948; Herklots, 1951; Ye, 1958; Webb, 1961). Nonetheless, with contemporary records from adjacent Cheung Chau Island, Castle Peak and Tsuen Wan, we assume otters once occurred throughout Lantau in suitable habitats. Webb (1961) claimed local otters were mainly found on Lantau.

Change in otter abundance

According to local naturalist Geoffrey A. C. Herklots (1902–1986), the former Governor of Hong Kong, Sir Cecil Clementi (1875–1947), recalled seeing otters frequently when he was a cadet during 1899–1900 (Lethbridge, 1970). Kershaw (1908) noted that otters occurred on Hong Kong Island and were common in the New Territories. Bunbury (1909, p. 17) also mentioned otters were seen 'in great numbers on dark nights in the autumn'. The decline of local otters was first mentioned by Herklots in 1932, and

progressive disappearance was reported in subsequent decades (Heywood, 1938; The Government of Hong Kong, 1948, 1950; Melville & Morton, 1983). In a review of Hong Kong mammals, Vincent H.C. Jarrett (c.1895–1973) described that otters were 'fairly common in certain localities . . . must be very rare now on Hong Kong (Island) itself, if still existent' (Jarrett, 1933, p. 1). The fact that the otter became legally protected in 1936 also indicates an early detectable decline. There were no otter records in the first 2 decades of Phase III, with most literature describing the otter as extremely rare and probably extinct. In the 1980s, some anecdotal reports from fishers of otter vocalizations in the western waters resurfaced, and the species' persistence was confirmed in 1986 in Mai Po Nature Reserve (Fig. 3a).

Discussion

Our study provides the first longitudinal overview of the distribution and abundance of the Eurasian otter in Hong Kong, revealing that the species was more widespread and common in historical times. Considering the presumed much lower observation effort and coverage in the first half of the 20th century, the species was most likely underreported. The local otter population started to decline around the 1930s, much earlier than previously estimated (McMillan et al., 2019), and experienced progressive population and range reductions in subsequent decades. The otter population declined further from the 1960s, and only a remnant population now persists, in Mai Po Nature Reserve and the surrounding Deep Bay area.

Although our historical approach provides new insights into this threatened population, there are inherent limitations to our data: (1) not all newspapers published in the study period have been digitized and included in searchable databases, and there are missing issues and pages; our search was therefore not exhaustive, (2) although dubious records have been excluded, not all records are verifiable as detailed descriptions of many sightings are lacking, and (3) it is impossible to quantify differences in observation effort in space and time, which is likely to have resulted in some biases in the distribution pattern and perceived otter abundance. Nevertheless, we believe that our expansive review, spanning 131 years, reflects the longitudinal trend of the local otter population.

Our findings show that the local otters are strongly associated with coastal alluvial wetlands, which is unsurprising given that the hillside watersheds of Hong Kong are small and probably cannot sustain otter populations. The Yuen Long floodplain is probably the only wetland ecosystem in Hong Kong extensive enough to offer sufficient resources to support resident breeding otters, and is likely the local source population. Hong Kong's extensive protected area system mainly conserves headwaters and hillsides, and few alluvial and coastal habitats have statutory protection (Dudgeon & Corlett, 1994; Yip et al., 2004; Agriculture, Fisheries and Conservation Department, 2014a). Land-use change in rural lowlands has been a major conservation challenge for Hong Kong (Jim, 1996; Agriculture, Fisheries and Conservation Department, 2014a), and apart from the 380 ha Mai Po Nature Reserve and the nearby 61 ha Hong Kong Wetland Park, the majority of otter habitats are unprotected and privately owned, and thus subject to heavy anthropogenic pressures.

Causes of otter decline

In the absence of archives on otter status, environmental issues and hunting records for Hong Kong, key drivers of the otter's local range reduction and population decline cannot be unequivocally established. We can, however, look at the major threats to otter survival from a global perspective based on the IUCN Red List, and assess the severity of these threats in the local context, offer some interpretation of the population collapse and make informed conservation recommendations.

Of the major threats to the Eurasian otter identified by Loy et al. (2022), habitat loss and degradation, hunting and pollution are possible contributing factors in Hong Kong. As elsewhere in South China, wildlife hunting and consumption used to be common in Hong Kong, resulting in defaunation of the local countryside (Marshall & Phillips, 1965; Lance, 1976; Lau et al., 2010). Some researchers have attributed the decline of local otters to hunting (Marshall, 1967a,b; Melville, 1980; Foster-Turley & Santiapillai, 1990; McMillan et al., 2019); however, we only found three reports of deliberate killings in 131 years. Local folklore and natural historian Kow Choy Iu, who worked in the conservation sector during 1955–1990, suggested that although local fish farmers might kill otters in retaliation for taking fish, otters were not commonly targeted by local game hunters (K.C. Iu, pers. comm., 2023). Many traditional game species, such as the northern red muntjac *Muntiacus vaginalis*, wild boar *Sus scrofa*, similar-sized carnivores such as the mainland leopard cat *Prionailurus bengalensis* and masked palm civet *Paguma larvata* were heavily hunted and threatened with local extinction (Marshall & Phillips, 1965; Marshall, 1967a,b; Lance, 1976), but have benefited from better protection and are now widespread and common (Shek, 2006; Shek et al., 2007; Pei et al., 2010; Yang et al., 2022; authors unpubl. data). Even the Chinese pangolin and Chinese three-striped box turtle *Cuora trifasciata*, widely hunted in Hong Kong and elsewhere, remain relatively widespread in Hong Kong compared with the otter (Lau et al., 2000; Pei et al., 2010). Thus, we believe hunting was not a major driver of the otter's decline in Hong Kong.

The otter is a resilient species and can live in human-dominated landscapes provided that healthy riverine and/or coastal ecosystems are available (White et al., 2013;

Jo et al., 2020). Urbanization leads to the direct loss of otter habitat, and has been reported to be a major driver of local otter decline (McMillan et al., 2019, 2022). Hong Kong was a modest trading port with a human population of 368,987 in 1901; the population swelled to > 1.6 million in 1941 and reached 3.1 million in 1961 (Census and Statistics Department, 1972; Fig. 3b). With high housing pressure, the government initiated a new town development programme in the early 1970s to relocate urban populations to rural districts, resulting in the reclamation of shallow bays at Tsuen Wan, Sha Tin, Castle Peak (renamed Tuen Mun in 1973), Tseung Kwan O and North Lantau (Tung Chung), and the urbanization of the alluvial lowlands of Tai Po, Fanling/Sheung Shui, Tin Shui Wai and Yuen Long. By the end of the 1990s, c. 3 million people were housed in nine new towns (Information Services Department, 2000), of which at least seven were once inhabited by otters.

To tackle recurring flooding, the Hong Kong government developed large-scale flood control schemes throughout the lowlands, including the Yuen Long floodplain (Wu, 2003). Channelization projects in Hong Kong involve heavy engineering with concrete reinforcement, and these concrete-lined flood channels are impoverished wildlife habitats (Chan, 2001; Chan & Dudgeon, 2001; Agriculture, Fisheries and Conservation Department, 2014b). The meandering 18 km Shenzhen River, the largest river basin in Hong Kong with prime otter habitats, was engineered and shortened to a 13.5 km drainage channel (Drainage Services Department, 2020). A Hong Kong-wide study of lowland freshwater fishes reported that > 44% of the surveyed river stretches had been channelized (Chan, 2001). The potable and irrigation reservoirs throughout Hong Kong's hillsides impounded all sizeable river systems with auxiliary catchwaters to intercept neighbouring stream flows, which greatly affected the downstream flow regime and estuarine ecosystem (Dudgeon, 1996; Chan, 2001). These extensive waterway engineering projects have resulted in a substantial loss of otter habitats in Hong Kong.

Water pollution has been identified as a major cause of otter decline in Europe and Asia (de Silva, 2011; Ledger et al., 2022), and it has been suggested that contamination by polychlorinated biphenyl (PCB) affects otters in Hong Kong (Foster-Turley & Santiapillai, 1990; Liang et al., 1999). Before 2001, municipal sewage from the burgeoning human population was discharged into Victoria Harbour with minimal pre-treatment (Watson & Watson, 1971; Morton, 1989; Drainage Services Department, 2009). Pollution was further aggravated by an industrial boom and the thriving livestock industry from the 1950–1960s, causing severe pollution in waterways and nearshore waters (Binnie and Partners, 1973, 1974; Tanner et al., 2000; Tang et al., 2008). Approximately 40% of the waterways in the New Territories, including all major rivers in the Yuen Long floodplain, were classified as either polluted or badly polluted (Binnie & Partners, 1974). The timeline for the rising human population and worsening environmental problems appears to align with the widespread disappearance of the otter across Hong Kong.

Conservation recommendations

The insights from this study are crucial for improving the management of the small otter population and the aquatic ecosystems of Hong Kong. The sustained and severe anthropogenic impacts in the under-protected lowland wetlands have negatively affected otter survival and may also explain the failure of the otter population to increase despite the general trend of wildlife recovery.

If extinction of the Eurasian otter in Hong Kong is to be prevented, a multifaceted conservation project must be devised and implemented. Firstly, public and government support for otter conservation must be garnered and conservation action galvanized (Hong et al., 2017; Khoo & Lee, 2020). This is particularly crucial with the looming Northern Metropolis development mega-plan recently released by the Hong Kong government (Information Services Department, 2021), which will drastically modify the rural landscape of the Yuen Long floodplain, home to a globally important Ramsar Site and the last local otters. This plan covers the whole Yuen Long floodplain and aims to develop housing, economic centres and related infrastructures for 2.5 million residents and create > 0.5 million jobs. A holistic nature-positive land-use plan must be developed to balance economic development and nature conservation, and ensure ecologically sensitive areas are preserved. Secondly, otters travel long distances in search of shelter, prey and/or mates (Erlinge, 1967), and coastal alluvial wetlands are under-represented in Hong Kong's protected area system. Although the Hong Kong government has pledged to establish additional nature/wetland conservation parks in the Northern Metropolis, interconnecting eco-corridors must be built between these otter habitats. Thirdly, in the Yuen Long floodplain it is imperative to design and/or restore functional riverine ecosystems and re-establish connectivity with riparian wetlands to enhance these critical habitats for local otters. The restoration and maintenance of environmental flow for the extensive reservoir catchwater system should also be explored, so as to restore healthy estuarine ecosystems across a wider area. Fourthly, the Deep Bay Basin continues to be subject to domestic and industrial pollution, mainly from private properties; improving stakeholder engagement and law enforcement efficiency is essential to address the recurring pollution.

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Author contributions Both authors contributed equally.

Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards.

Data availability The data supporting the findings of this study are available within the article and its supplementary material.

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