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Hong Kong's Indo-Pacific Humpback Dolphins (*Sousa chinensis*): Assessing Past and Future Anthropogenic Impacts and Working Toward Sustainability

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Abstract

Within the past several decades, Indo-Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong have gone from being virtually unknown to being probably the best-studied dolphin population in Southeast Asia. Essentially nothing was known of their status prior to 1993, but they are now understood to be part of a large population (> 2,000 individuals) that inhabits the Pearl River Estuary of southern China. Approximately 130 to 200 dolphins occurred within Hong Kong's boundary in the late 1990s and early 2000s, but the numbers have declined since then, with currently only about 65 to 70 dolphins found within the region at any one time. Despite an ambitious management scheme by the Hong Kong Agriculture, Fisheries, and Conservation Department, mostly involving Hong Kong's Environmental Impact Assessment (EIA) legislation, the dolphins appear to be at risk locally. A series of recommendations are hereby made to encourage improved management of these animals and include (1) management at the population level; (2) better assessment of cumulative impacts; (3) protection of critical habitat, especially along the west coast of Lantau Island; and (4) management with "teeth." If these suggested approaches are vigorously followed, I remain optimistic about the future of humpback dolphins in Hong Kong. Historical data show us that these animals can indeed recover from anthropogenic impacts but only if important habitat areas receive better protection than they are getting at present.

Key Words: Asia, conservation, delphinid, small cetaceans, management, population biology, Indo-Pacific humpack dolphin, *Sousa chinensis*

Introduction

Hong Kong is a major global tourism destination, financial center, and shipping and transportation hub. It is not generally considered a major wildlife hotspot, but the local population of Indo-Pacific humpback dolphins (*Sousa chinensis*, known locally as "Chinese white dolphins") are well known and some would even say famous in Hong Kong. The dolphins have been a prominent focal point for most of the local environmental groups in Hong Kong since the early 1990s (Leatherwood & Jefferson, 1997). This is when local news media began to publish and broadcast speculative stories of their imminent demise as a result of the new Hong Kong International Airport (HKIA), which was being built on mostly reclaimed land in the northwestern waters of the territory, just north of Lantau Island (Figure 1). The animals' image received another strong boost when they were chosen by the departing British Government to be the mascot of Hong Kong's reunification with mainland China (this event is often called "the handover") in 1997.

Unfortunately, there has been a great deal of misinformation and misinterpretation of facts about these animals in the past 25 years (see Leatherwood & Jefferson, 1997; Karczmarski et al., 2016). The public is routinely subjected to false or strongly misleading information by the Hong Kong news media (which is highly commercialized, very competitive, and much more "tabloid" than "journalistic" in nature), often stating the dolphins are endangered or will go extinct soon (Leatherwood & Jefferson, 1997). This is very unfortunate as the dolphins need effective management based on sound scientific knowledge, and the environment of misinformation and false beliefs have made that difficult to achieve. This article attempts to summarize what is known of the past and present status of Hong Kong's humpback dolphins, to assess the prospects for their long-term survival, and to recommend some changes in how they are managed that will help to facilitate their long-term persistence.

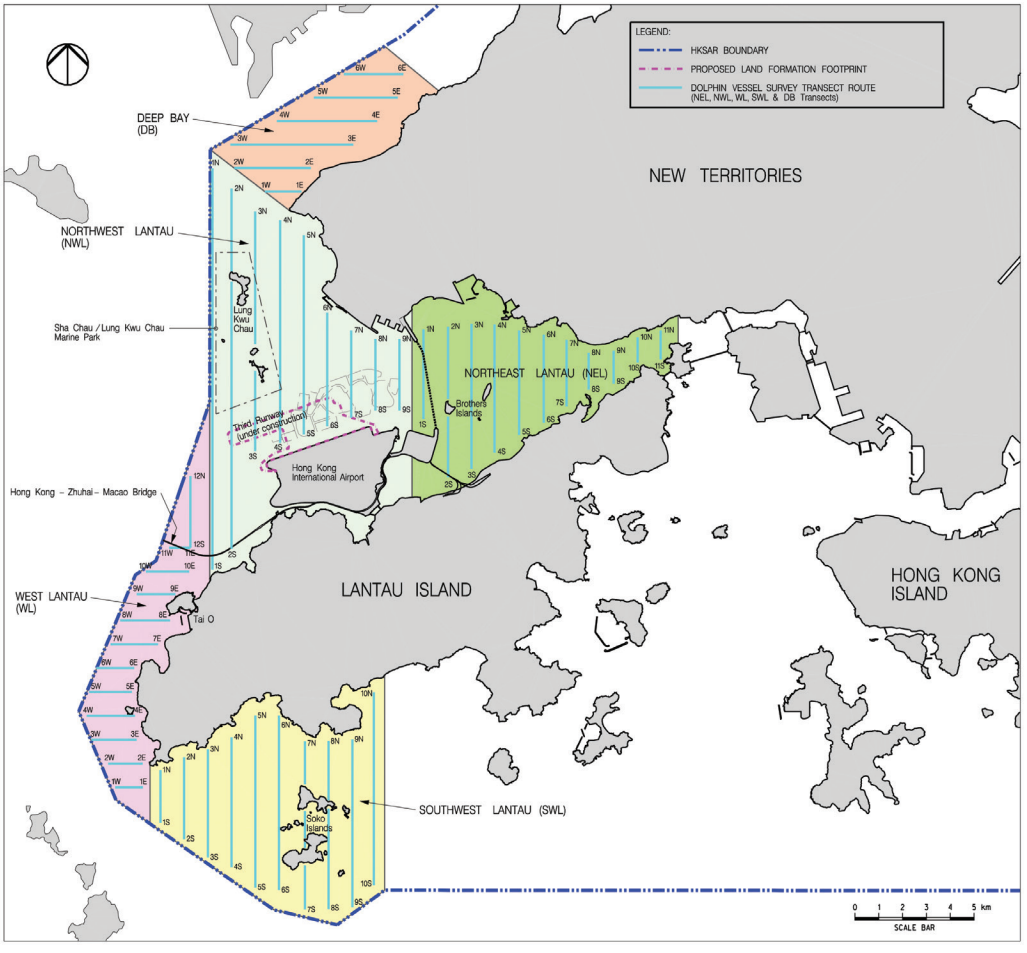

Figure 1. Map of Hong Kong, showing the location of the places where Indo-Pacific humpback dolphins (*Sousa chinensis*) have regularly occurred in recent years, the survey areas and transect lines, and the Hong Kong International Airport (HKIA) and expanded Third Runway System (currently under construction)

History of Humpback Dolphin Scientific Study

Scientific study of humpback dolphins in Hong Kong began in the early 1990s, spurred by concerns over the impacts of the construction of the new HKIA at Chek Lap Kok. Previous to this, *Sousa chinensis* was almost unknown in the scientific literature for the area, except for a few brief mentions. Osbeck (1771) reported sighting what is assumed to have been this species in the Canton River just west of Hong Kong in November 1751. In fact, a later translation of this pre-Linnaean account serves as the type description for the species *Sousa chinensis* (see Jefferson & Rosenbaum, 2014). Romer (1955), in the first scientific report on the cetaceans of Hong Kong, did not even mention the species, referring only to common dolphins (*Delphinus* sp.), Indo-Pacific finless porpoises (*Neophocaena phocaenoides*), and the fin whale (*Balaenoptera physalus*) (though there is some question as to whether this specimen may have actually been of another species of *Baleanoptera*; see Jefferson & Hung, 2007). Mörzer-Bruyns (1971) reported that he had never seen *Sousa* in Hong Kong and was of the opinion that the water was too cold for it.

In February 1974, an unpublished report from Ocean Park (a commercial oceanarium) staff reported a sighting of *Sousa* northeast of Chek Lap Kok by an Ocean Park trainer, and the Hong Kong Marine Police reported two additional sightings of unidentified cetaceans at Fan Lau and at Tung Chung (which were probably *Sousa*, based

on what we now know about the species). The first published reports of the species in Hong Kong were from Melville (1976), who detailed two sightings—in January 1976 in the West Lamma Channel, and in February of the same year in Deep Bay. Abel & Leatherwood (1985) reported a number of additional sightings of humpback dolphins in Hong Kong's western waters from May to August 1978 (see next section for details of these sightings). A mother and calf pair were reportedly observed repeatedly in Tai Tam Bay in 1980/1981 (apparently between the months of June to October), and the calf was live-captured by fishermen and taken to Ocean Park but was subsequently released to be reunited with its mother (Hammond & Leatherwood, 1984). Starting in 1975, the newly established stranding recovery program coordinated by the government's Agriculture, Fisheries, and Conservation Department (AFCD) began to document stranding records of humpback dolphins in Hong Kong.

Finally, in the early to mid-1990s, dedicated studies of the dolphins began, through the impetus of concerns about the impacts of Hong Kong's new international airport development (Jefferson & Leatherwood, 1997; Parsons, 1997; Porter et al., 1997; Porter, 1998; Jefferson, 2000). Since that time, studies have continued and intensified so that now this population qualifies as perhaps the most well-known and best-studied of all dolphin populations in Southeast Asia (see Jefferson & Rosenbaum, 2014; Karczmarski et al., 2016).

Population Abundance/Status

Historical (Pre-1995)

Until research by the University of Hong Kong started in 1993, virtually nothing was known of the status of *Sousa chinensis* in Hong Kong other than that the species did occur there. The set of sightings that resulted from a series of surveys dedicated to searching for dolphins by Grant Abel and colleagues from Ocean Park in 1978 provides an interesting historical perspective. The sightings generally were in line with what we know of the dolphins from the 1990s (when dedicated work began), both in terms of locations and general behavior of the animals (see Table 1 & Figure 2). This is suggestive of some long-term stability, though it should be pointed out that other information could suggest that the dolphins' range in the 1970s and 1980s may have extended further east than it did in the 1990s. The reported sightings of *Sousa* in Tai Tam Bay (southeast Hong Kong

Table 1. Historical Indo-Pacific humpback dolphin (*Sousa chinensis*) sightings in Hong Kong by G. Abel; NWL = Northwest Lantau, NEL = Northeast Lantau, WL = West Lantau, and PRE = Pearl River Estuary.

Date	Location	Area	Group size	Calves?	Activities	Boat assoc.	Notes
8 May 78	Lung Kwu Chau	NWL	6	Yes	?	No	Elusive group
8 May 78	North of Chek Lap Kok	NWL	6	Yes	Playing	No	Possibly same group as earlier in day
8 May 78	Brothers Islands	NEL	1	No	Traveling	No	
9 May 78	Lung Kwu Chau	NWL	30 to 40 (35)	?	Feeding	Trawlers	Feeding around trawlers in several subgroups over 1 km area
4 July 78	Off Tai O	WL	2	No	Playing	No	
6 July 78	Off Tai O	WL	1	No	Basking/ eating	No	
31 July 78	South of Tai O	WL	3	No	Feeding	?	
4 Aug 78	Lung Kwu Chau	NWL	6 to 8 (7)	Yes	?	?	
31 Aug 78	PRE, west of Sha Chau	PRE	15	Yes	Feeding	Trawlers	Feeding around trawlers
4 Sept 78	South of Tai O	WL	1	?	Feeding	?	Trawlers fishing in the area
25 Oct 78	Off Tai O	WL	1	No	Feeding	No	
26 Oct 78	Off Tai O	WL	3	Yes	Feeding	Pair trawlers	"Two adults, one baby inside one trawler's net"
27 Oct 78	West of Tai O	WL	6+	No	Traveling	Pair trawlers	All adults, traveling heading south

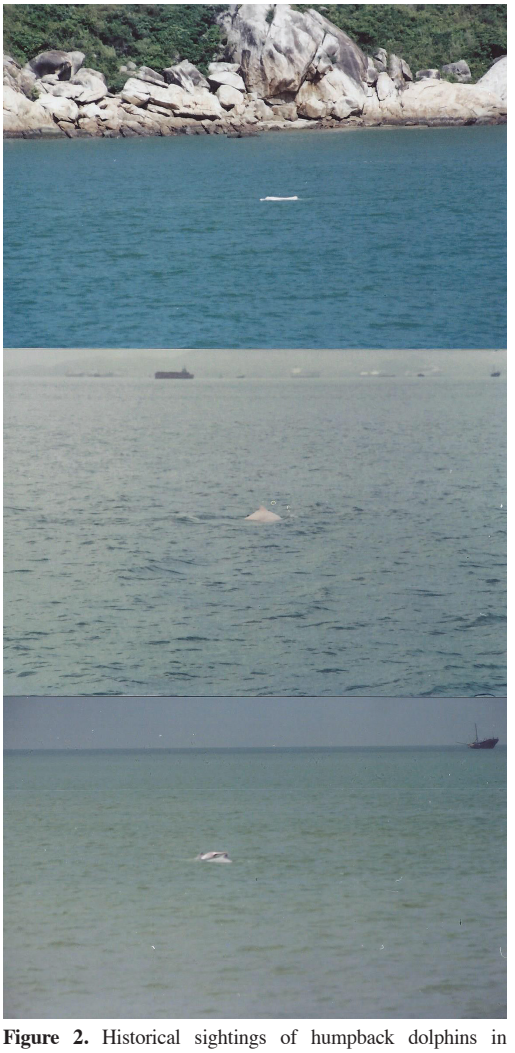

Figure 2. Historical sightings of humpback dolphins in Hong Kong's western waters, May to August 1978 (Photographs by G. Abel)

Island) and the West Lamma Channel, both areas where they are extremely rare today, may support this, but there is a great deal of uncertainty about this point (see Figure 1 in Jefferson & Hung, 2007).

Dedicated dolphin surveys from 1993 to 1995 by two then-Ph.D. students from the University of Hong Kong, using photo-identification and other techniques, established that humpback dolphins were primarily found in Hong Kong's western waters, that there was some residency (through repeated sightings of identified individuals), and that numbers within Hong Kong were likely relatively low, reported to be about 85 individuals (Parsons, 1997; Porter, 1998). It was also established that the dolphins occurred in the estuarine zone associated with the Pearl River, and there was a suggestion made that there were two "subpopulations" north and south of Lantau Island, with no mixing between them (Porter et al., 1997). However, sighting effort was not taken into account in these studies, and there was no attempt to develop a statistically rigorous abundance estimate through either mark-recapture or line-transect methods, so the true status of the "population" remained unknown. Public concerns about the impacts of airport construction, which at the time were not being properly monitored or mitigated, were growing, and there was much speculation in the popular press about the dolphins being a species unique to Hong Kong and the animals being pushed to extinction by the start of the new millennium (for a discussion, see Leatherwood & Jefferson, 1997).

Recent (1995 to 2014)

In November 1996, through the newly established Marine Park Ordinance, the Hong Kong Government established the first marine protected area for dolphins in Hong Kong, the 1,200-ha Sha Chau/Lung Kwu Chau Marine Park (Wong, 1998). This was partly in response to worries about the effects of the new airport and, in particular, the building of an aviation fuel receiving facility (AFRF) at Sha Chau, an area that had been identified as critical habitat for the dolphins (Hofmann, 1995; Porter et al., 1997).

Beginning in September 1995, a long-term dolphin-monitoring program was established by the author, working in collaboration with the Ocean Park Conservation Foundation (funded first by the Airport Authority, and later by the AFCD), using systematic line-transect survey methods (with supplemental photo-identification data) to quantitatively monitor the population's numbers, distribution, and habitat use in Hong Kong. At the same time, a refined stranding monitoring program was set up to obtain information on marine mammal mortality and to collect samples for various life history and ecological studies. This monitoring has continued up to present day by the Hong Kong Cetacean Research Project (population surveys) and Ocean Park Corporation (strandings), though with some variation in the extent and intensity of survey effort over the years.

During this time period (late 1990s), it was determined that Hong Kong's dolphins were not a unique population (as had often been assumed by the media and some local researchers) but that they were actually part of a much-larger population that was centered on the Pearl River Estuary (hereafter called PRE). Most of the range was shown to occur in mainland waters of Guangdong Province but, in addition to Hong Kong, also including waters of

the Macau Special Administrative Region (SAR) (Jefferson, 2000).

Systematic, long-term line-transect surveys of the dolphins in Hong Kong have now provided a 22+ year time series to examine how dolphin use of the different regions of Hong Kong has changed over the years (see Appendix A for a summary of methods). The first full year of our surveys indicated that about 160 dolphins occurred within the territory in 1996 (Figures 3-6). Within North Lantau waters (Figure 3), dolphin numbers declined dramatically from 1996 to 1998 (this was during the final phases of the original airport construction and completion of the AFRF at Sha Chau); and then after the airport opened in mid-1998, numbers recovered from 1999 to 2003 (in fact, in 2001 to 2003, North Lantau numbers returned to near "baseline"; and overall numbers in Hong Kong were at their peak of > 175 dolphins), but dolphin numbers in Hong Kong have been on a steady decline since (Figures 3 & 7). The alarming drop from 2011 to 2015 corresponds well with the construction phase of the massive Hong Kong/Zhuhai/Macau Bridge (HZMB), which has impacted the dolphins both within their major habitats in Hong Kong as well as in habitats stretching all the way across the PRE (Figure 3).

In West Lantau (the area with the highest densities of dolphins in Hong Kong), numbers declined from 2002 (the first year with reasonably precise estimates) through 2012 but may be showing some evidence of increasing again starting in 2013 (and this general increase in use of West Lantau is also supported by the work of Hung, 2017; Figure 4). Southwest Lantau showed some evidence of a declining trend from 1997 to 2000, then a possible increase from 2001 to 2004, and then a steady decline through 2008 (Figure 5). There is evidence from my estimates, as well as those of Hung (2017), of a slightly increasing trend from about 2009. Finally, Deep Bay is an area that has often been ignored when discussing Hong Kong dolphin habitats (see discussion by Chan & Karczmarski, 2017). However, Deep Bay, while never a dolphin hotspot, has often contained a significant number of dolphins in its southern reaches, especially just north of Black Point. There is no evidence of a long-term trend in Deep Bay, but the numbers there fluctuate from year to year, with an average of about five to six dolphins present in most years (Figure 6).

Current (2015 to 2017)

From 2015 to 2017, there has been possible indication of a stabilization of dolphin numbers in Hong Kong (and in North Lantau, specifically; Figures 3 & 7). The estimate for 2017 is slightly higher than the corresponding 2016 estimate, though it is too early to tell if this is indicative of a long-term stabilization or even recovery of numbers. I would not expect a significant recovery to occur until after construction work for HKIA's expansion to a Third Runway System (3RS), which is expected to be completed in the early 2020s.

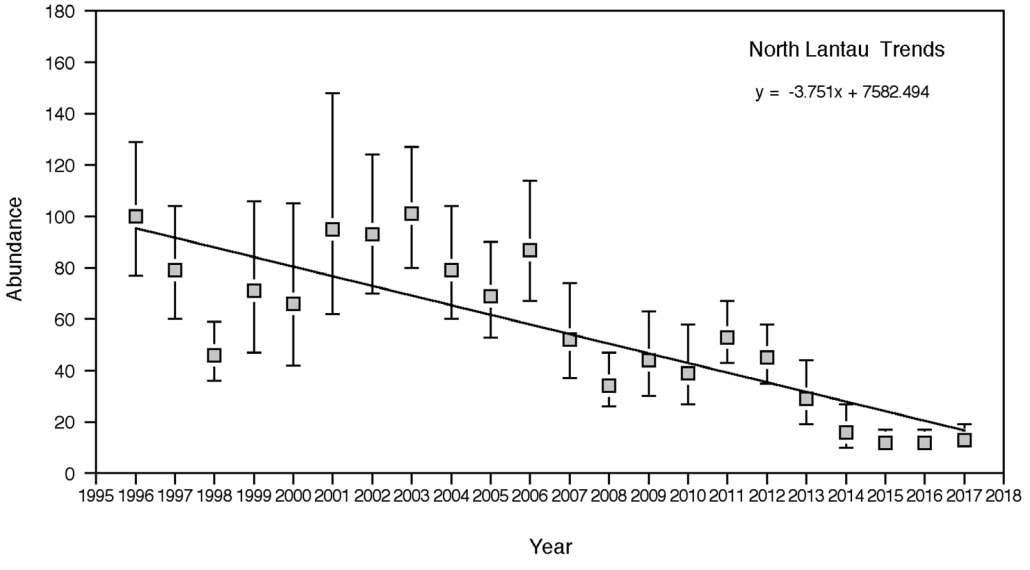

Figure 3. Long-term trends in abundance of humpback dolphins in the North Lantau area (note that this area includes both the Northeast and Northwest Lantau areas), 1996 to 2017

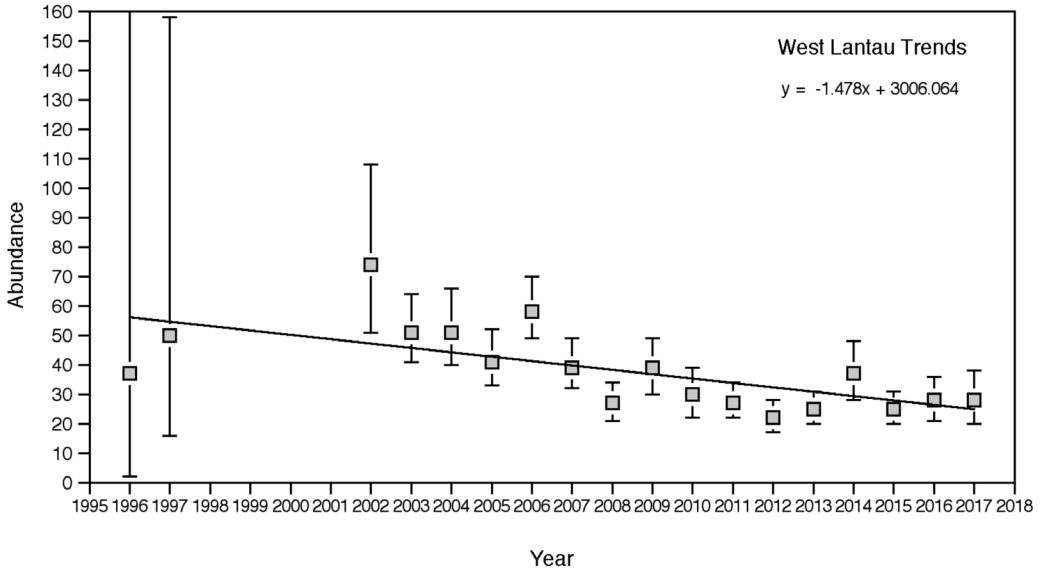

Figure 4. Long-term trends in abundance of humpback dolphins in the West Lantau area, 1996 to 2017

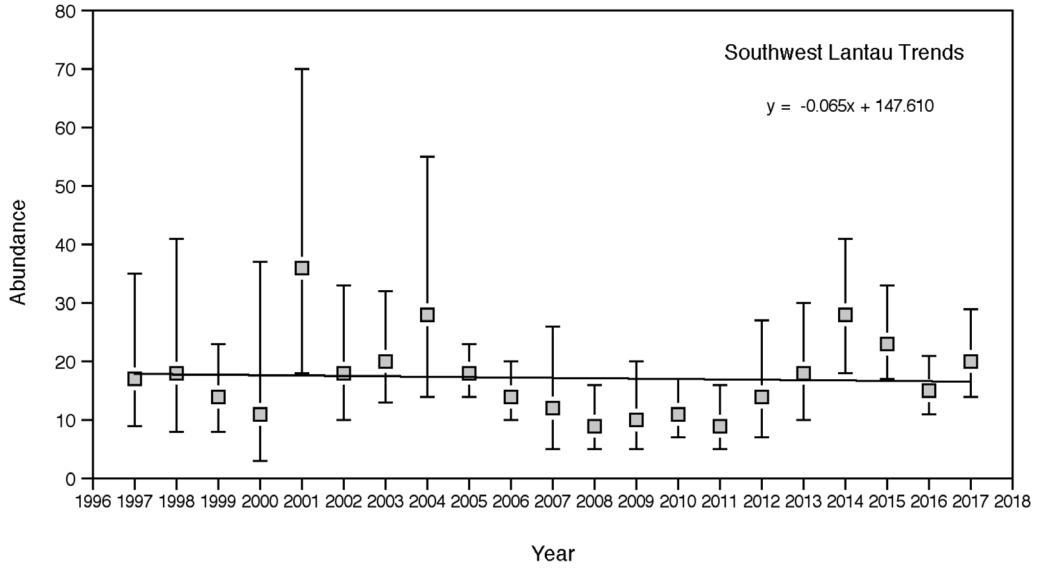

Figure 5. Long-term trends in abundance of humpback dolphins in the Southwest Lantau area, 1997 to 2017

One thing that is apparent from the above analyses is that, despite the overall trend in size of the PRE population (see below), dolphins using Hong Kong waters shift around among different areas, both within and outside of Hong Kong, most likely in response to disturbance from noisy anthropogenic activities (like intense vessel traffic, land reclamation work involving dredging and rock fill, and other marine construction activities; see Figure 7). These shifts are indeed examples of adaptive behavior as they presumably reduce the negative effects that individual dolphins experience. They also must be viewed as negative impacts (on a population level), however, since they appear to encourage dolphins to avoid areas of previously favored habitat, and this may have

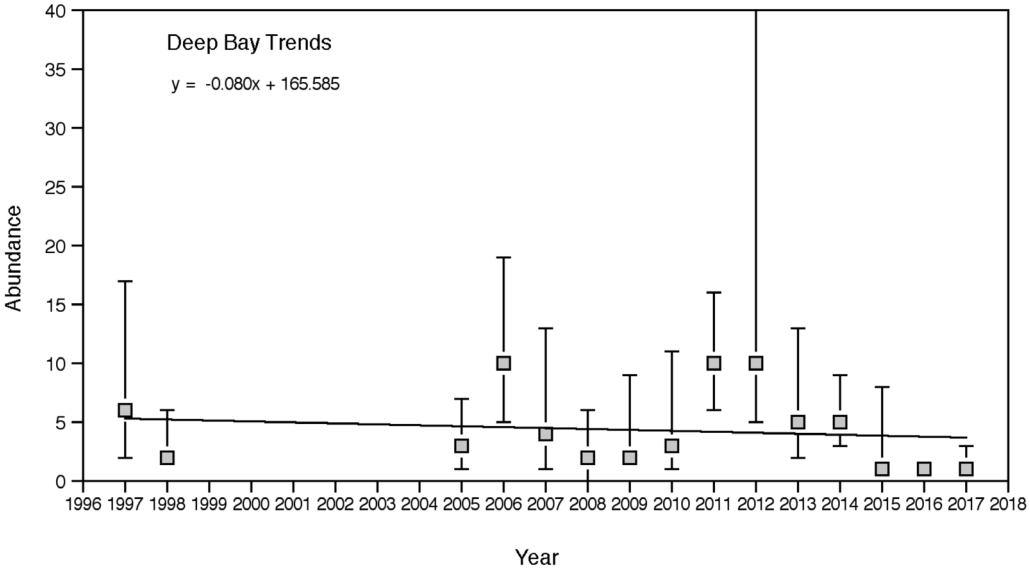

Figure 6. Long-term trends in abundance of humpback dolphins in the Deep Bay area, 1997 to 2017

detrimental effects on feeding, socializing, and reproductive activities.

Strandings of humpback dolphins in Hong Kong average 9.5/year but with strong yearly fluctuations (Figure 8). The numbers have shown some evidence of a slight negative trend since the collection of reliable records started in 1996 (Figure 8). It is likely that many dolphins that die in mainland waters drift onto Hong Kong shorelines (considering the currents and shoreline topography of the area), making stranding rates of questionable value as direct indicators of the status of the Hong Kong "subpopulation." Since there are limited places for the stranded specimens to end up on shorelines, they may be more indicative of the mortality levels of the overall PRE population, though this remains unknown.

Recent demographic studies based on photo-identification indicate that at least 368 individual dolphins rely on waters within Hong Kong's boundary as part of their home range (Chan & Karczmarski, 2017). Although Chan & Karczmarski (2017) suggested that declining line-transect abundance estimates in recent years may be largely the result of methodological inadequacies, I disagree. The "shortcomings" of the work by AFCD contractors (e.g., Hung, 2017) are not limitations of the line-transect method itself but, instead, stem from problems with the application, interpretation, and presentation of the results (see Chan & Karczmarski, 2017, for an explanation). However, both the work of Hung (2017; despite the stated inadequacies) and the current work described herein provide strong evidence that numbers of dolphins in Northwest and Northeast Lantau have declined dramatically in the past decade or so (with Northeast Lantau currently having almost no daytime use by dolphins). The exact role that increased historical human occupation, and land and water development over the last several thousand years have played in the current dolphin population status is debatable (see Lin et al., 2016), but there is little doubt that current threats (especially vessel traffic, fishing net and line entanglement, and habitat loss from coastal development) are unsustainable, and the need for more effective conservation of this population is clear (see Jefferson et al., 2006, for a summary of diagnosed causes of death for Hong Kong humpback dolphins).

Current Management Framework

Hong Kong Government Approach

In Hong Kong, management of dolphins and porpoises is the responsibility of the AFCD, although other government departments (e.g., Environmental Protection Department, Civil Engineering and Drainage Department, and Marine Department) are often involved to a lesser extent for certain issues. Active management began in about 1993/1994 with the first dedicated studies of the species locally, and a large number of management efforts have been directed toward the dolphin population since that time (much less have been aimed at the partially sympatric finless porpoises; see Jefferson, 2000; Jefferson & Smith, 2002). Jefferson et al. (2009) provided a

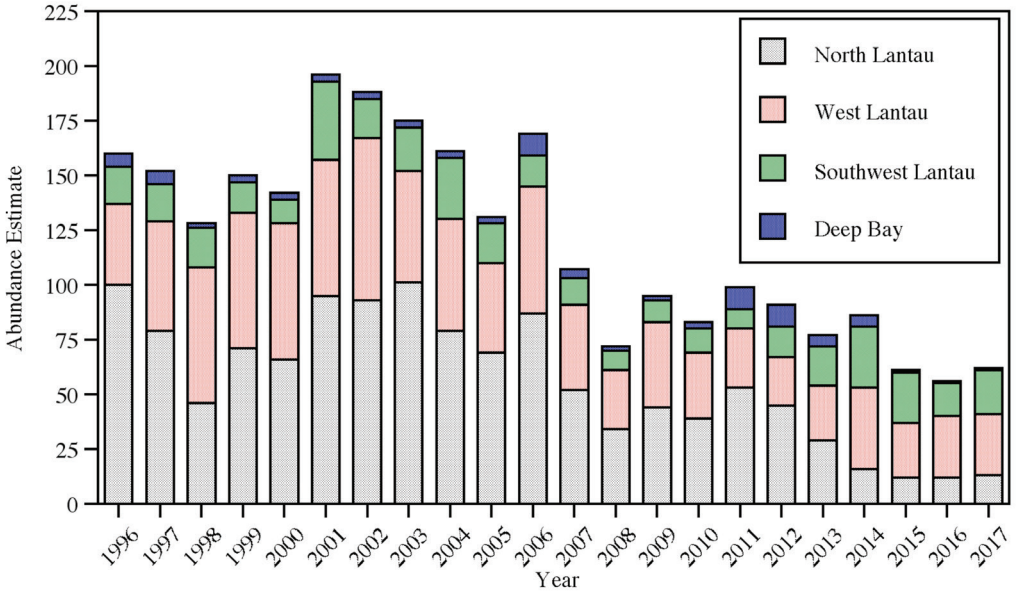

Figure 7. Overall abundance of humpback dolphins in Hong Kong waters, 1996 to 2017

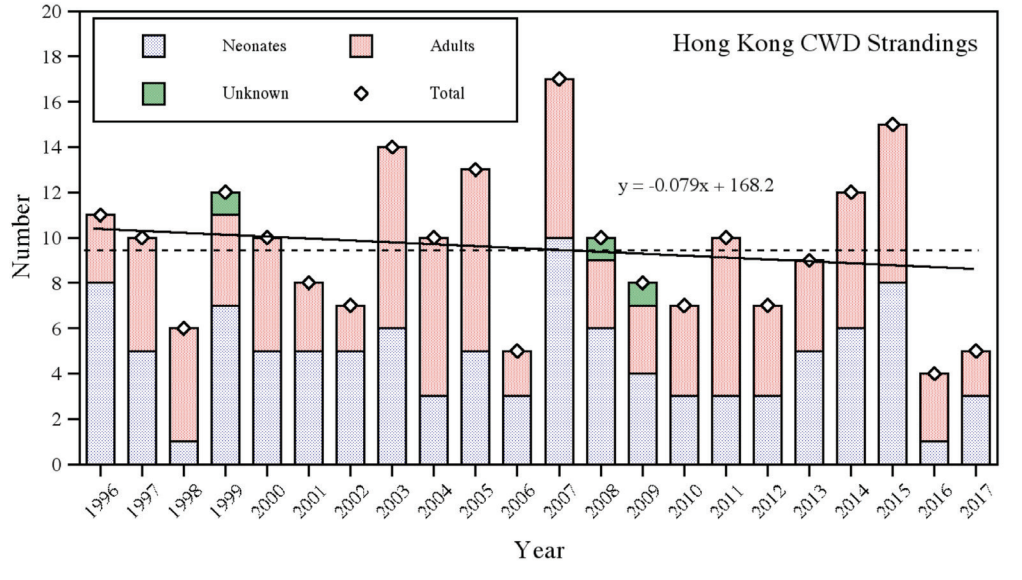

Figure 8. Strandings of humpback dolphins in Hong Kong, 1996 to 2017; dashed line is the long-term average, and solid line is the best-fit linear regression line.

useful review of the overall Hong Kong dolphin management strategy and philosophy.

Contribution of the Environmental Impact Assessment Process

Management of dolphins in Hong Kong has largely taken place through the Environmental Impact Assessment (EIA) process, which is relatively well developed compared to that in most Southeast Asian countries (Jefferson et al., 2009). Hong Kong's EIA Ordinance governs marine construction and development activities (e.g., airport development and expansion; bridge construction; creation of port facilities and container terminals;

creation of "mud pits" for dumping contaminated mud; sewage outfalls; and reclamations for theme parks, housing blocks, and other uses). The focus is on the impacts that occur during the construction stages of projects, although there is usually also some effort directed at examining operational phase impacts, at least during the first few years of operation. Shipping and fishing fall largely outside the EIA process, however.

In fact, Hong Kong's humpback dolphins are probably more extensively involved in EIA evaluations than any other small cetacean population in the world and certainly within Southeast Asia (Jefferson et al., 2009). Many marine development projects focus a very large portion of their effort and resources on predicting, mitigating, and compensating for impacts on dolphins, and to a lesser extent, finless porpoises.

Problems with the Approach

The Hong Kong government deserves major kudos for its dolphin monitoring efforts over the past 22 years. There has been consistent, long-term monitoring of the dolphins within Hong Kong waters, the program has been well funded, and support has been given to make the results transparent and amenable to publication in the scientific literature. However, one problem with the approach is that the heavy emphasis on use of the EIA process to manage the dolphins means that there are impacts from other threats that do not undergo EIA scrutiny and approval. For instance, increases in vessel traffic from shipping or expanded ferry traffic; water and air pollution, especially from sources that are outside Hong Kong; and fishing net entanglement are often underappreciated and almost always neglected.

Although the small cetacean monitoring work conducted in Hong Kong since 1995 provides one of the most consistent and intensive longitudinal datasets for examination of dolphin population status in Southeast Asia (and possibly the world), the resulting data and information have not always been put to use wisely to provide effective management of the animals, and the number of dolphins present in Hong Kong has declined steadily over the past decade or so. This has happened despite cautionary statements and warnings by many people, including the researchers actually conducting the dolphin monitoring work (e.g., see Porter, 1998; Jefferson, 2000; Hung, 2008; Jefferson et al., 2009; Karczmarski et al., 2016).

In my opinion, this situation has resulted from a series of factors, some of which are largely outside the AFCD's control (mainly a strong societal and governmental desire for ever-increasing industrialization and development and a concomitant lack of emphasis on the importance of a healthy, sustainable natural environment) but some of which are within the agency's ability to change. I shall discuss those issues that are amenable to change below and make some suggestions for how the management program can be improved.

Recommendations to Achieve Sustainability

Management at Population Level

Stocks are units that are used for management of wildlife populations (Wang, 2017). Ideally, a stock should be a demographically distinct "population" (in the traditional sense of the word), although this is not always the case, often due to incomplete knowledge and/or political/logistical constraints. So far, the AFCD has managed dolphins in Hong Kong at the level of the "subpopulation" that occurs within the Hong Kong Special Administrative Region boundary, largely because when these dolphins began to be managed in the early 1990s, there was virtually nothing known of them outside of Hong Kong. However, now, nearly a quarter century later, we have learned that Hong Kong represents just the very eastern portion of the range of a large population of dolphins that spans across the PRE (and includes Hong Kong SAR, Macau SAR, and mainland Chinese waters) (Jefferson, 2000; Chan & Karczmarski, 2017). The range of these animals may extend as far west as the Moyang River Estuary, suggesting that the true PRE population is even larger than previously thought. Hong Kong is only a small part of that range and at any one time contains less than 10% of the total population. As such, management of just the dolphins that are within the Hong Kong SAR boundary is not going to be effective. Management must occur at the level of the biological population, and this will require much better communication, cooperation, and collaboration with authorities on the mainland Chinese side (as well as those in Macau). There is strong public support for ensuring that dolphins remain a part of Hong Kong's fauna in the future, and the government is publicly committed to this goal. Further, the waters of Hong Kong, despite being a small portion, are very important for the conservation of the PRE population as a whole (Chan & Karczmarski, 2017).

Accounting for Cumulative Impacts

Cumulative impacts have become a major issue in the last decade as we learn that the effects of human activities are not simply the sum of all the impacts of individual projects or actions but, rather, that the effects on dolphins are often additive, multiplicative, and/or synergistic (see Jefferson et al., 2006). Although this has been recognized by AFCD since at least the early 2000s,

little has been done to advance the science of cumulative impact assessment in Hong Kong. EIA Ordinance regulations require that cumulative impacts be discussed in EIA reports, but this often represents little more than a listing of the individual projects that will occur in the general area and time period of interest.

In fact, cumulative impact assessment is an advanced science, and much work has been done in other areas and on other species/issues to develop proper cumulative impact assessment methods. The use of computer modeling and GIS can provide huge advances in our ability to evaluate cumulative impacts, but despite repeated recommendations by the author to hold workshops and support the development of such methods in Hong Kong, this has not happened. Recent efforts to examine cumulative impacts scientifically, while commendable (Marcotte et al., 2015), have provided little insight into the issue. We are now in the unenviable position in which nearly everyone involved in EIA work on Hong Kong dolphins recognizes that cumulative impacts are where the most serious issues lie, and yet we go on year after year essentially ignoring this "elephant in the room."

Protection of Critical Habitat

Marine protected areas (MPAs) are seen as an important conservation measure for cetaceans worldwide (Hoyt, 2011). Recent studies indicate that dolphins in the eastern PRE prefer rocky, undisturbed coastlines, such as those along western Lantau Island, Lung Kwu Chau, and Neilingding and Sanjiao Islands (the latter two in mainland waters; Or, 2017). Most of these areas are not currently protected (Figure 9). Only two very small MPAs have been designated in Hong Kong for dolphin conservation so far—the Sha Chau/Lung Kwu Chau Marine Park (SCLKCMP) and Brothers Marine Park (BMP)—and both are now areas with dramatic declines in dolphin densities in the last few years (and the BMP actually has very few dolphins using it at present). This may change in the future, but the fact is that the most important dolphin habitat in Hong Kong (that stretching along the entire west coast of Lantau Island from north of Tai O to around Fan Lau) is still completely unprotected. This is despite first being identified as critical habitat in 1998 (20 years ago) and repeated recommendations by local environmental groups and AFCD's own consultants (including myself, L. J. Porter, and S. K. Hung) to designate protected areas along the entire western coast of Lantau Island.

Although two new marine parks (which limit development, restrict harmful fishing, and slow vessel traffic to 10 kts or less) are scheduled to come online very soon (the Soko Islands and Southwest Lantau Marine Parks; Figure 9), all dolphin experts who have done work on the Hong Kong animals agree that these are inadequate to the goal of protecting critical dolphin habitat in Hong Kong (Karczmarski et al., 2016). To do so, there needs to be an interconnected matrix of MPAs (including perhaps some with more stringent protection measures than a "marine park") which covers the entire region of western Lantau Island and the area around Fan Lau. The area needs to cover from the shoreline to at least a kilometer or two offshore and protect both core feeding/calving/nursing areas as well as travel corridors or routes that dolphins use to move between them. The upcoming marine parks should also cover the area between Fan Lau and the Soko Islands, which would require rerouting high-speed ferries between Hong Kong and Macau to south of the Soko Islands. Recently, some progress has been made in restricting high-speed ferries in the North Lantau area as part of the mitigation for the HKIA's Third Runway development. In late 2015, a Speed Control Zone was established by the Airport Authority, which now requires their high-speed ferries traveling to cities to the west to move through a specified channel at much slower speeds of < 15 kts (as opposed to previous speeds of up to 40 kts!); all vessels are tracked with AIS, and violations are followed up with offenders given warnings or other disincentives (Figure 10). I see this as a valuable mitigation measure that will likely reduce disturbance to the dolphins and will undoubtedly reduce injuries and deaths from vessel collisions (see Jefferson et al., 2006, for information on vessel impacts). This new measure may be partly responsible for the apparent stabilization of dolphin numbers in North Lantau, and we hope to see similar protective measures implemented in the South Lantau area as well. Several concrete proposals have been put forth by local nongovernmental organizations (NGOs) and researchers recently to encourage AFCD to do this, but so far little appears to have changed.

A very ambitious proposal for a protected area matrix, involving both marine parks and more stringently protected marine reserves, has been set out by Karczmarski et al. (2016, Figure 8, p. 52). Although the proposal as presented may be very difficult to achieve (due to challenges from stakeholders who do not want human activities restricted), I believe that working toward a model such as this should be vigorously undertaken. Science-based MPAs focused on protecting current high-value habitat, as well as recovering previously important habitat areas (such as Northeast Lantau Island) and incorporating strong linkage corridors among the core regions, are probably

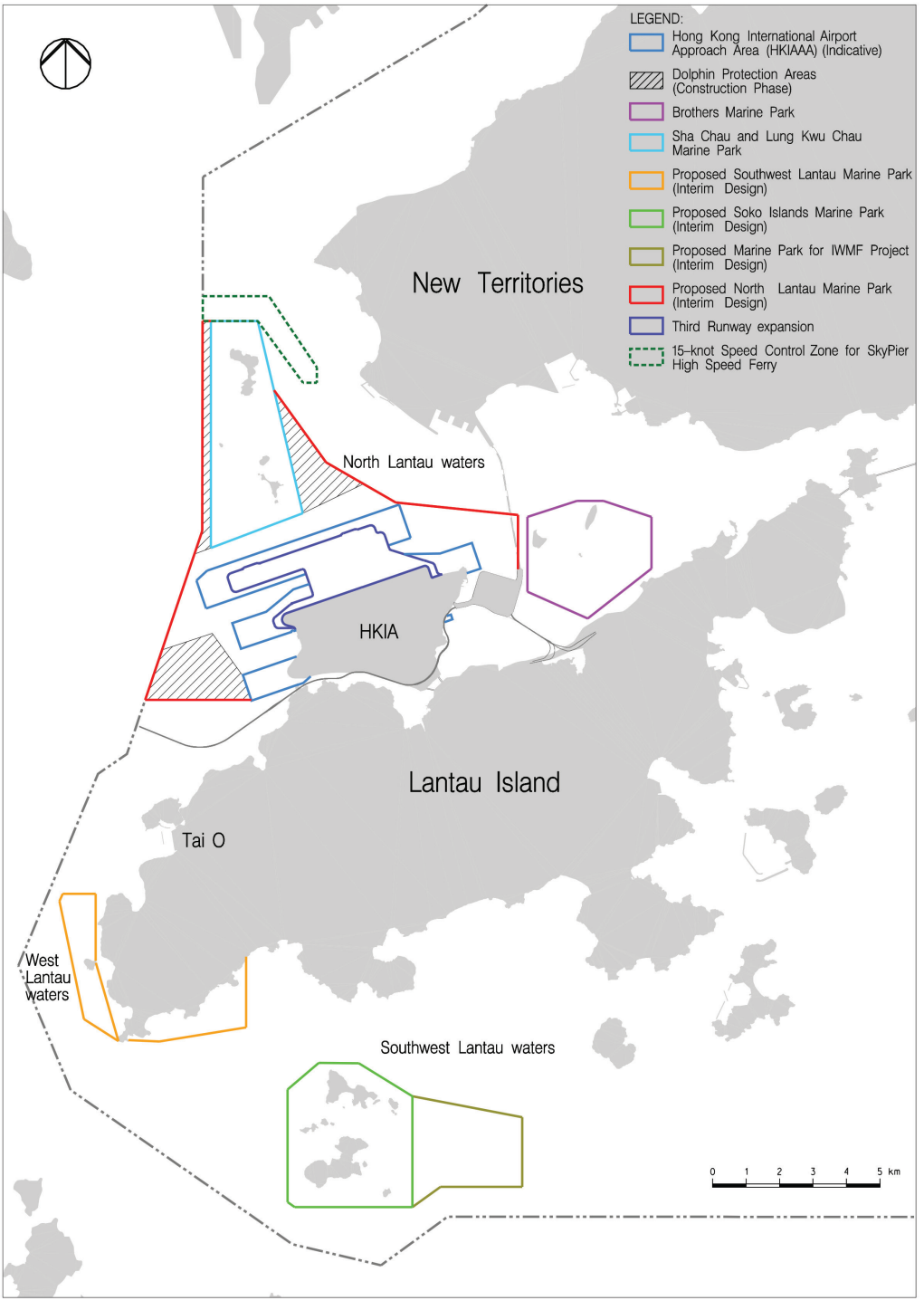

Figure 9. Current and planned marine parks, along with other protected areas in western Hong Kong, designated primarily for the protection of humpback dolphins and finless porpoises (*Neophocaena phocaenoides*)

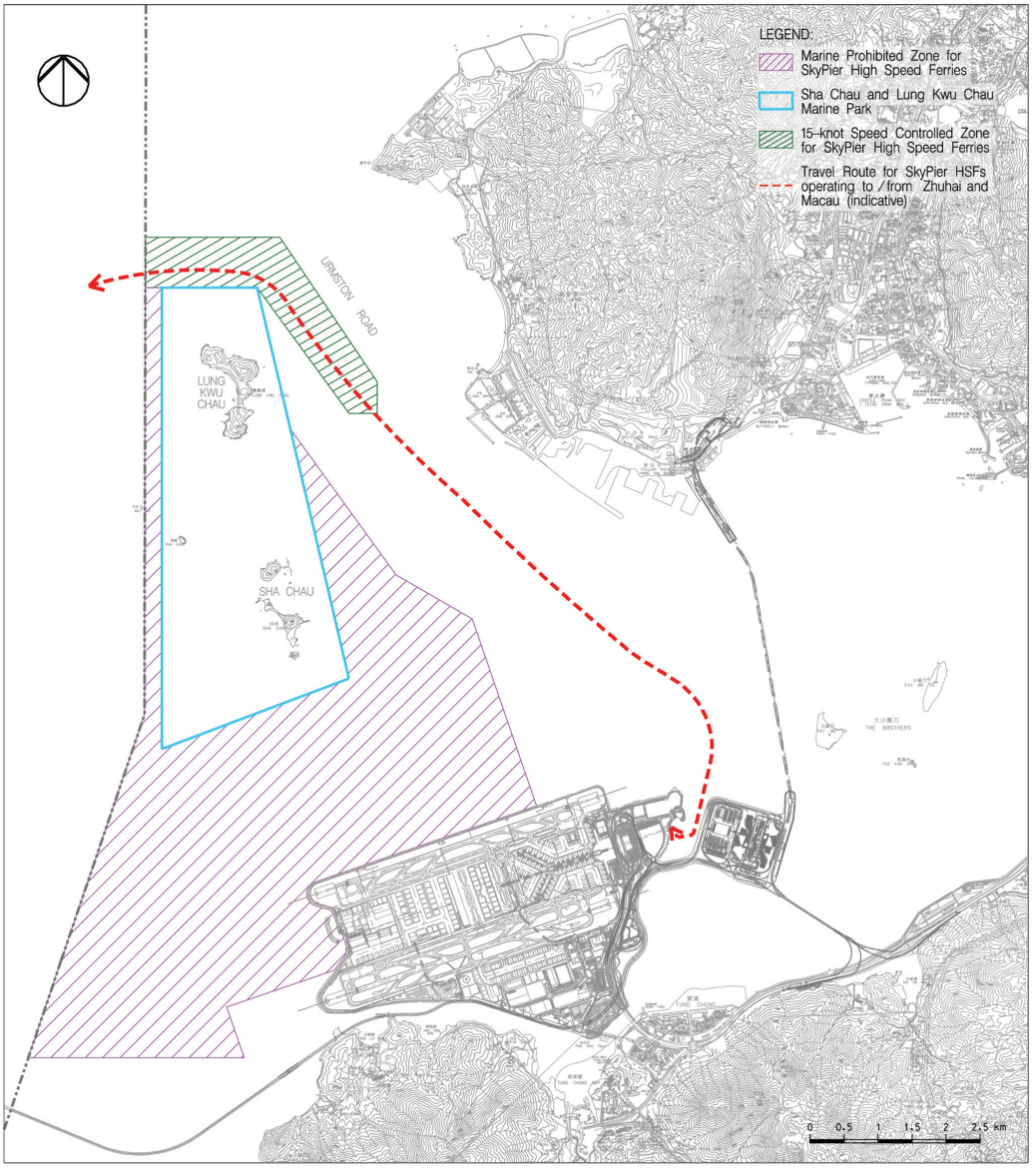

Figure 10. The Speed Control Zone, which was instigated as a mitigation measure to reduce impacts of high-speed ferries transiting from the Sky Pier at HKIA to cities to the west of Hong Kong

the best hope for stabilizing and even reversing the negative trend in dolphin numbers that is currently happening. Some progress toward this goal will come with the completion of the marine construction for a new third runway at the HKIA when the Hong Kong Airport Authority (HKAA) will establish a large marine park covering most of the North Lantau area outside of the Urmston Road shipping lane (Figure 9).

Management "with Teeth"

Finally, management of dolphins in Hong Kong must take on a more active, aggressive role. The AFCD fisheries and conservation officers have significant enforcement capabilities, but in the past, AFCD has hesitated to "flex its muscles" for the most part. Management is conducted largely in a passive way; as an example, there has been a Code of Conduct for dolphin-watching

operators in Hong Kong for over 20 years, which has remained a voluntary code, even in the face of evidence that many small-scale dolphin-watching operators out of Tai O were routinely harassing dolphins, putting short-term profits above what is good for the dolphins (Ng & Leung, 2003). This attitude is also visible at government meetings in which AFCD officials often sit quietly and avoid engaging in controversial discussions. It is my belief that this must change, and AFCD should not be afraid to use its considerable enforcement capability to develop a more aggressive and effective dolphin conservation plan.

The Future . . .

While Hong Kong's dolphin population is, without a doubt, facing serious threats and is in trouble, it is not nearly in as bad of shape as many other cetacean populations and even species (e.g., vaquitas [*Phocoena sinus*], Atlantic humpback dolphins [*Sousa teuszii*], North Atlantic and North Pacific right whales [*Eubalaena* spp.], and North Island Hector's dolphins [*Cephalorhynchus hectori maui*]), which are facing possible extinction in the next decade or two (see Reeves, 2018; Jefferson, in press). Indo-Pacific humpback dolphins in the PRE (of which the Hong Kong dolphins are a part) likely still number over 2,000 animals, and recent demographic modeling suggests that the overall population is declining at a rate of about 2.46% annually (Huang et al., 2012). At that rate, they would not be in danger of extinction for about three generations (about 80 years), with the most likely scenario resulting in extinction more than 100 years in the future (Huang et al., 2012), so there is indeed time to work out a solution. However, there is no reason for complacency. Karczmarski et al. (2016, 2017) argue that the population is heading toward a critical point and that it is in danger of local extinction if effective conservation measures do not rapidly reverse the current negative population trend. Dolphins have drastically reduced their use of some Hong Kong waters in recent years, and while there is likely to be some rebound in numbers once heavy development ceases (if it does) and critical habitat is protected (if it is), there is still evidence that the overall population is losing habitat and is in decline, both from factors that cause direct mortality (e.g., vessel collisions, environmental pollution, and fisheries bycatch) as well as those that reduce survival and calf production (e.g., habitat loss and degradation, and excessive underwater noise). It seems that all researchers who have studied these dolphins in recent years more or less agree on these points.

Hong Kong and China should not wait until this species is critically endangered to enact relevant protection measures (as happens so often). The time to do so is now while the population is still relatively large, a reasonable amount of suitable habitat still remains, and reproduction is occurring at rates that can result in increases in numbers. A great deal has been learned about the animals in the past quarter century, and now is the time to put that impressive set of information to full use by developing sound, workable, science-based management and recovery programs, which are collaborative in nature between mainland and Hong Kong (and Macau) authorities. If this is done soon, and there are sincere efforts to provide the protection these animals deserve and to achieve a reasonable balance between conservation and development, then I remain optimistic that the dolphin population in Hong Kong can be saved from a path leading to local extinction (see Appendix B for a summary of some cases in which populations of small cetaceans have recovered in the presence of improved environmental conditions). It is unlikely that it will ever be able to recover to levels from when it was a "pristine" population, but it can persist in the long-term . . . maybe even prosper and potentially increase to reoccupy some of the habitats that have been recently "abandoned." This is probably the best we can hope for. With interested stakeholders working together to keep sustained pressure on the Hong Kong government, all the while aided by science-based knowledge, this appears to be a real possibility.

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Appendix A
Analysis Methods for Line-Transect Estimation

For information on survey methods, see Jefferson & Leatherwood (1997) and Jefferson (2000). I used both conventional distance sampling (also known as CDS) and a more sophisticated approach, multiple covariate distance sampling (known as MCDS), to estimate humpback dolphin abundance for the waters of western Hong Kong. The latter approach is generally preferred as it uses information on environmental factors that are likely to affect detection probability (such as variables describing sighting conditions) and often (though not always) produces estimates with higher precision (i.e., lower variances and CVs). Prior to analysis, I filtered data to use only sightings and effort collected in conditions of Beaufort sea state 3 or less. Filtered data were assembled into *Excel*™ spreadsheets for preparation of the input files that were analyzed using *Distance*, Version 6.2, software, Release 1 (Thomas et al., 2010).

To aid in sample size issues, data from all areas known to be used as significant dolphin habitat in Hong Kong (Northeast, Northwest, West, and Southwest Lantau and Deep Bay) were used in calculating a pooled detection function and average group size for each year (data were not pooled across years). Sighting rates were stratified by each survey area and were not pooled. Four different key function/adjustment combinations were used to model the data (half-normal with cosine and hermite polynomial adjustments, and hazard-rate with cosine and simple polynomial adjustments), and the most appropriate model (based on the minimum value of Akaike's Information Criterion) was selected for the final estimates. Beaufort sea state was used as a co-variate in the MCDS analyses.

There are three different datasets currently available to examine CWD density and abundance by line-transect methods in Hong Kong:

1. AFCD long-term dataset (hereafter called AFCD) from late 1995 to present and covering all survey areas in Hong Kong

2. Hong Kong-Zhuhai-Macau Bridge dataset (HZMB) from 2014 to present and covering NEL, NWL, and WL

3. Third Runway dataset (3RS) from late 2015 to present and covering DB, NEL, NWL, WL, and SWL (plus AW)

The first two sets of data were collected by a team from the Hong Kong Cetacean Research project (HKCRP; under contracts to AFCD and CEDD), and the third set of data were collected by a team from Mott MacDonald (under contract to the Airport Authority). All teams used the same basic methods developed by the author in the mid-1990s for small cetacean line-transect surveys in Hong Kong (Jefferson & Leatherwood, 1997; Jefferson, 2000).

Estimates of density and abundance (and their associated coefficients of variation) were calculated using the following standard formulae:

$$D = \frac{n\, f(0)\, E(s)}{2\, L\, g(0)}$$

$$N = \frac{n\, f(0)\, E(s)\, A}{2\, L\, g(0)}$$

$$\hat{CV} = \sqrt{\frac{\hat{\text{var}}\,(n)}{n^2} + \frac{\hat{\text{var}}\,[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\text{var}}\,[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\text{var}}\,[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D = density (of individuals), n = number of on-effort sightings, $f(0)$ = detection function evaluated at zero distance, $E(s)$ = expected average group size (using size-bias correction in *Distance*), L = length of transect lines surveyed on effort, $g(0)$ = trackline detection probability, N = abundance, A = size of the study area, CV = coefficient of variation, and *var* = variance.

In some of the early years of the study, due to funding limitations, survey effort was not conducted in certain subareas; and to obtain estimates of numbers for the whole of Hong Kong, we needed to have estimates for those areas. In these few cases with missing data, we used the mean of the point estimates from the two years immediately before and after as a proxy (see Figure 7). The estimates presented are based on relatively even coverage throughout all 12 months of the year; thus, seasonal changes are accounted for in the annual estimates.

Appendix B

Case Studies of Harbor Porpoise Populations that Have Recovered After Establishment of Effective Protection Measures

The issue of whether dolphins in Hong Kong can re-occupy habitat that was previously inhabited but currently not used and also "recover" previous habitat areas has been a controversial one in Hong Kong in recent years, with some arguing that it is not possible or likely. Therefore, some review of cases wherein such recoveries have been well documented seems to be of value.

Harbor porpoises (*Phocoena phocoena*) are found in the cooler waters of the North Pacific and North Atlantic Oceans. In the latter half of the 20th century, in some European waters of the North Sea and especially areas of France, Germany, and the Netherlands, harbor porpoises underwent dramatic declines in abundance and areas of occupancy; there have been recent "comebacks" in many of these areas (Smeenk, 1987; Camphuysen, 1994, 2004; Reijnders et al., 1996; Addink & Smeenk, 1999; Thomsen et al., 2006; Jung et al., 2009). In North America, two places along the U.S. West Coast, namely San Francisco Bay, California, and Puget Sound, Washington, showed similarly dramatic declines of harbor porpoises. These latter cases are discussed in some detail below.

San Francisco Bay

Harbor porpoises were known to occur regularly in San Francisco Bay, a large estuarine system with a relatively deep connection to the ocean, until the 1940s when they mysteriously disappeared (although they remained relatively common in nearby open waters of the central California coast and Gulf of the Farallones; Carretta et al., 2017). Throughout the latter half of the 1900s, porpoise records inside San Francisco Bay were rare, largely relegated to occasional strandings (Keener, 2011; Stern et al., 2017).

The reasons for harbor porpoise disappearance in the bay have been linked to various anthropogenic disturbances, including massive shoreline development, land reclamation, dredging, and general industrialization (Stern et al., 2017). The roles played by bycatch in fishing gear (especially gillnets to which harbor porpoises are known to be particularly susceptible; Jefferson & Curry, 1994) and pollution are not certain, although it seems likely they both played a part. Military impacts were also probably important, as during World War II, a large anti-submarine net system was deployed across the opening to the bay, just inside the Golden Gate. Though circumstantial, the timing of placement of this net system correlates well with the apparent disappearance of porpoises from the bay (Stern et al., 2017).

Starting in about 2008, harbor porpoise records inside the bay began to increase, and an observation platform set up on the Golden Gate Bridge recorded over 5,800 porpoises in the bay between 2011 and 2014, with porpoises being observed on 96% of the 169 observation days (Stern et al., 2017). On average, 34.4 porpoises were seen per day. Sightings occurred throughout the year, and calves and foraging behavior were both regularly seen, with calves accounting for about 10% of individuals observed. Although the specific conditions that led to the porpoises' recovery in San Francisco Bay are not known with certainty, Stern et al. (2017) have implicated reduced pollution levels, improved water quality, and increased productivity leading to better foraging opportunities as likely key factors. Without a doubt, the removal of the anti-submarine netting after World War II, as well as recent reductions in nearshore gillnetting operations in the area, would also have been important.

Puget Sound

A very similar situation occurred in Puget Sound, a large inshore estuarine complex of bays, channels, and fjords in Washington State, near the U.S. border with Canada. Harbor porpoises had been well known throughout most of the sound through the 1940s (Scheffer & Slipp, 1948). Although little attention was paid to porpoises after World War II, by the 1960s and 1970s, it had become apparent that harbor porpoises had been greatly reduced in Puget Sound; and at that time, only occurred regularly near Admiralty Inlet, the very northern boundary of the sound, where it connects with the Strait of Juan de Fuca.

Again, the factors responsible for the decline are not precisely known as marine mammal science was in its infancy in the mid-1900s, and surveys to document distribution at this time were almost non-existent. However, in reviewing the situation, Jefferson et al. (2016) suggested several possible categories of factors that could have been

involved: bycatch (mostly in gillnets), disturbance from vessels and industrial noise, pollution, habitat loss and degradation (largely related to coastal development and land modification), and competition with the partially sympatric Dall's porpoise (*Phocoenoides dalli*). All of these factors correlate reasonably well with the disappearance (and later recovery; see below), except for disturbance, which seems to have increased during the last several decades (at a time when recovery was occurring).

In the early 2000s, opportunistic harbor porpoise records inside Puget Sound showed some evidence of an increase, and seabird aerial surveys conducted by the Washington Department of Fish and Wildlife and Cascadia Research Collective documented an increasing trend in porpoise sightings from 1994 to 2014 (Evenson et al., 2016). A comprehensive set of aerial surveys of Puget Sound and adjacent waters, conducted from 2013 to 2016, provided clear-cut evidence of the harbor porpoise "recovery." Porpoises were observed throughout the year, in virtually every portion of Puget Sound, and calves and foraging behavior were seen frequently (Jefferson et al., 2016). During the surveys, 1,063 harbor porpoise groups were observed, and line-transect analyses of the survey data yielded an average seasonal abundance (excluding winter) of 2,387 porpoises (CV = 39%) in the sound. Spring was the peak season, with over 4,000 porpoises estimated to occur in that season. The similarities with the San Francisco Bay situation are, in many ways, fascinating, particularly in terms of the timing of both the initial decline and later "recovery." There may be some common elements here that can provide lessons for how other marine mammal populations can be restored to a healthier condition.