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Wader use of an eco-engineered drainage channel in Hong Kong

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In this study I present data on wader abundance and diversity over a five-year period following the construction of an eco-engineered flood relief channel in Hong Kong. The concrete channel has hollow cells in its bed which allow retention of a silt/mud substrate. Twenty wader species have been recorded in the channel and both wader diversity and abundance have shown an increasing trend over time. The channel offers foraging opportunities to waders, which can be particularly important during winter and migration periods. The cellular concrete appears to provide microhabitats in the channel bed and this seems to be preferable compared with a homogenous concrete lining with no ecological niches.

Keywords

waders

engineered channel

habitat loss

watercourse enhancement

INTRODUCTION

Globally, lowland rivers and watercourses often require training or modification in order to alleviate flood risks or as a result of development (Gleick 2003, Palmer *et al.* 2005). These engineering works often lack the ecological niches that a natural system provides (Leader 2009) and likely lose their value as foraging or resting sites to birds. Through a combination of the application of simple techniques and an awareness of the potential opportunities that currently exist, creation and enhancement of modified watercourses or other wetlands can result in habitats with high conservation value (Gilbert & Anderson 1998). Whilst the relationship between waders and these modified channels and/or artificial wetlands has been studied for tidal systems (Cooper 1997, Kwok & Dahmer 2006, Lai *et al.* 2007, Green *et al.* 2015), there is currently little information available for eco-modified channels that are not subject to tidal influence.

Waders along the East Asian-Australasian Flyway currently face a very fast rate of habitat loss which is strongly associated with anthropogenic habitat change (Sutherland *et al.* 2012, HKBWS 2015, Piersma *et al.* 2016). Wetlands of the northwest New Territories in Hong Kong are particularly important for migrating and wintering waders (Anon. 2015a, b), but several lowland rivers have been channelized or modified due to increased urbanisation and development (Cheung *et al.* 2010, HKBWS 2013). Most lowland rivers in Hong Kong are small, narrow and sinuous, and channelization not only destroys riverine habitats but also affects adjacent wetland habitats (Kwok & Dahmer 2006). The extent to which channelizing a stream reduces its ecological value depends on the construction techniques used, and even organically polluted channelized lowland streams with extensive bankside vegetation can be remarkably rich in birdlife, if sufficiently undisturbed (Leader 2009). Waders are typically associated with intertidal habitats, coastal areas or freshwater wetlands and little information on their use of engineered channels is available (Kwok & Dahmer 2006, Lai *et al.* 2007). As the landscape becomes more urbanised, information on wader use of these novel habitats will be very valuable for efforts to achieve some ecological benefit from anthropogenic habitat change (Cooper 2006). For example, the Hong Kong Government is looking to revitalise water bodies in large-scale drainage improvement works by integrating environmental and ecological considerations into the detailed design of drainage infrastructure (Drainage Services Dept. 2015). Here I present the findings of an independent study of wader abundance and diversity in an eco-engineered channel in Hong Kong over a five-year period and report on the species using this man-made habitat. Observations from this study may be applicable to sites elsewhere in East Asia, as well as other parts of the world, and help guide more suitable design and appropriate maintenance of engineered channels in order to benefit waders.

METHODS

Study site

The San Tin Eastern Main Drainage Channel (STEMDC) in the northern New Territories of Hong Kong Special Administrative Region (22°30'24.02"N, 114°04'25.73"E) is in close proximity to the border with Shenzhen, People's Republic of China (Fig. 1). The STEMDC is directly adjacent to the boundary of the Inner Deep Bay and Shenzhen River Important Bird Area (Birdlife International 2015), being particularly important for migrating and

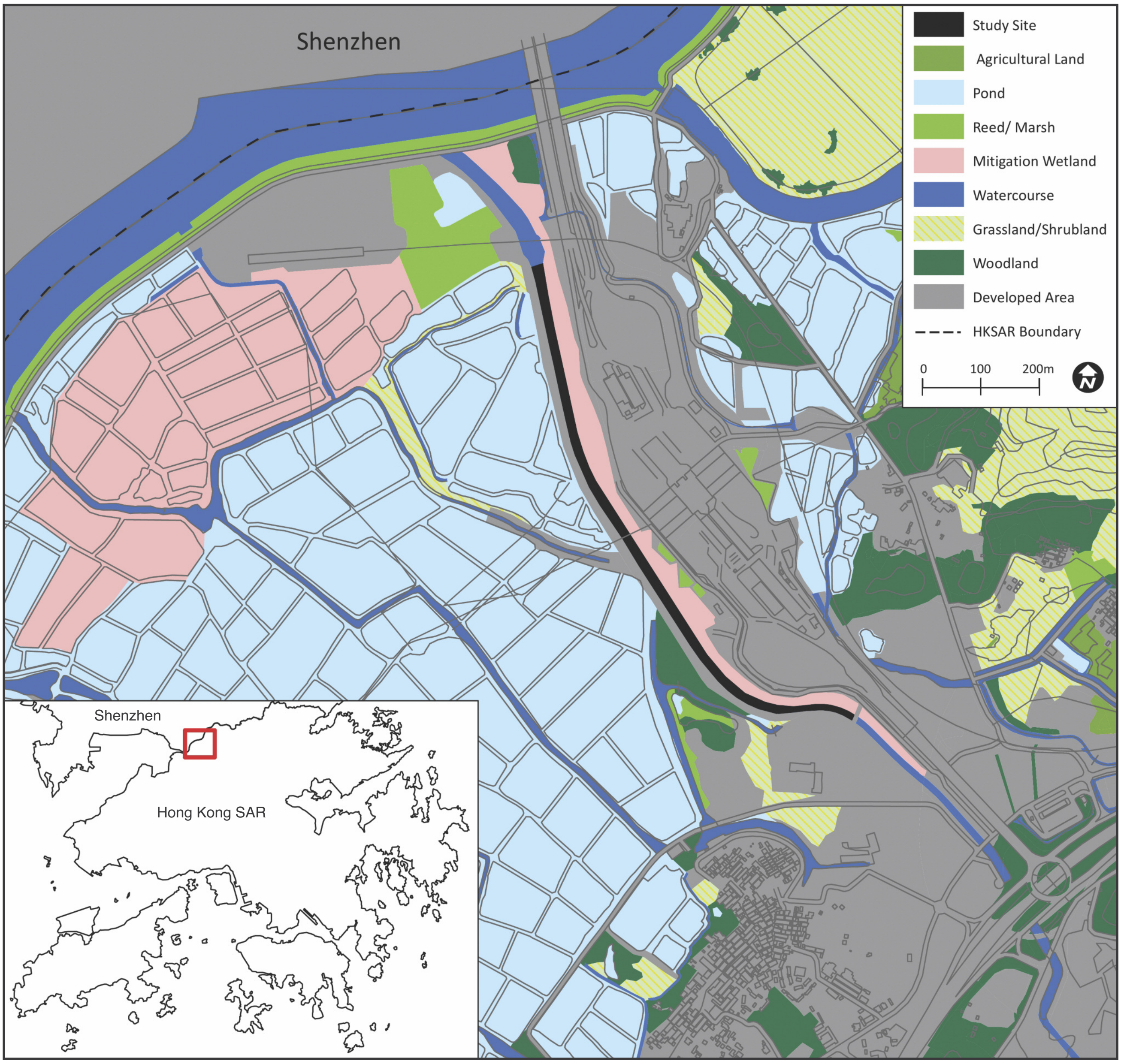

Fig. 1. Location of the study site, the San Tin Eastern Main Drainage Channel, Hong Kong Special Administrative Region, China.

wintering waders on the East Asian-Australasian Flyway (Conklin *et al.* 2014).The STEMDC was developed to alleviate flooding problems with construction being completed in September 2006 (Drainage Services Dept. pers. comm.; Fig. 2), resulting in the loss of commercial fishponds, small streams and marsh. Currently, the adjacent habitats to the west are dominated by commercial freshwater fishponds and to the east by a linear artificial freshwater wetland and extensive road infrastructure (Fig. 1).

The STEMDC is a large trapezoidal channel 2.2 km in length, 50 m wide and slopes down to a channel bed width of *ca.* 20 m. An inflatable dam and pumping station at the confluence with the tidal Shenzhen River allow controlled discharge of collected floodwaters. The deflation and inflation of the dam is automatically controlled by the water levels in the STEMDC. Discharge happens when water levels reach >2.2 m PD (Hong Kong Principle Datum, which is 1.23 m below mean sea level), occurring three to eight times per year, though there will always be some shallow water retained in the upstream channel section (Drainage Services Dept. pers. comm.). The channel bed and banks are lined with a series of 'grassed concrete slabs' (hereafter 'cellular concrete') each of which is 1 m square, 100 mm thick and includes nine 200 x 200 mm hollow cells (Fig. 3). Unlike regular slabs commonly used for channel beds, the hollow cells promote the settlement of sediments and establishment of vegetation (Fig. 4).

The STEMDC receives a regular flow of water throughout the year which peaks in the summer months when water levels rise significantly (>1 m deep) submerging much of the channel bed (Fig. 2A), which becomes subject to siltation. Once water levels drop, through mechanical discharge or seasonal changes, ruderal vegetation (e.g. *Sesbania* sp.) and wetland plants (e.g. *Ipomea* sp.) rapidly become established in the shallow margins and exposed channel bed. The embankments are dominated by tall stands of the exotic tree *Leucaena leucocephala*. There is no programme for vegetation management or sediment removal from the channel. This work is conducted when required, approximately twice per year, usually in the drier months when water levels are lower (Drainage Services Dept. pers. comm.; Fig. 2B).

Alongside the eastern length of the channel is a 3.70 ha linear, artificial wetland developed as a mitigation measure for the loss of a small watercourse and fishponds (Drainage Services Dept. 2003, Ove Arup & Partners 2013; Fig. 1). This artificial wetland comprises a series of small ponds, with areas of open water (up to 2 m deep) and marsh habitats (10–15 cm deep) and gently sloping bunds which dry out in the winter months (Environmental Resources Management 1999). A small *Phragmites* reedbed (<0.5 ha) is also present and forms the mitigation measure for the infrastructure development to the east (BBV 1999). These artificial wetlands, ranging from 5–40 m wide, are not considered here. Their proximity to the STEMDC may influence some of the wader species present, although generally, the size and shape of this neighbouring wetland, combined with the fact that it is enclosed by tall screening trees, likely limit its use by large numbers of waders.

Fig. 2. San Tin Eastern Main Drainage Channel before (A) and after (B) sediment and vegetation removal. Note piles of silt/mud on right in B.

Wader surveys

A total of 47 counts were made between October 2007 and December 2012, covering more than five years and including all months of the year, though not at regular intervals (average counts per month = 3.9, range 1–7). Counts were made by direct observation using 10 x 42 binoculars primarily from a vehicle. All waders using the channel and the embankments were identified to species level and counted. Observations were made commencing from a road bridge at the upstream section of the STEMDC for a distance of *ca.*1,400 m up to the inflatable dam. Counts were started at about 07:30h, and lasted 30 minutes.

Birds along this channel are tolerant to vehicular traffic, but given the distance from the road to the channel (<20 m), they will readily flush when a human (on foot or bicycle) is in sight. The vehicle therefore acted as a hide, reducing disturbance to foraging waders, though periodically there would be a need to exit the vehicle to make more detailed observations dependent on vegetation cover (although always in close proximity to the vehicle). Double counting was avoided as birds were rarely flushed (low volume of pedestrian traffic during counting hours) but when this happened those that settled back in the channel were easily observed and not counted again.

Statistical analysis

For the purposes of this study, winter period was defined as October to March. In order to compare wader abundance across winters, a Kruskal-Wallis test was used as the count data were not normally distributed. Diversity indices for each of the six winter periods, encapsulating both the number of species and number of individuals, were calculated using the Shannon-Weaver Diversity Index (H'). Diversity indices for summer count data have not been produced given the low numbers of waders present in Hong Kong during this period of the year (Anon. 2015b). However, annual variation in abundance at the study site was calculated as the average number of waders present each month.

RESULTS

Ten wader species were recorded in the first survey in October 2007 and the number increased steadily to reach 20 species (first counted in October 2012) over the study period (Fig. 5).

The most frequently encountered species were Wood Sandpiper and Little Ringed Plover, both recorded during 40 or more counts (Table 1). Other regularly recorded waders included Green Sandpiper (34 counts), Common Greenshank and Common Sandpiper (both 33 counts), Common Snipe (32 counts) and Black-winged Stilt (29 counts; Table 1). Greater Painted-snipe, a resident breeder, was recorded on 14 occasions. This species is highly cryptic and largely crepuscular (Hayman *et al.* 1986) so overall figures may not necessarily be representative of its presence or abundance. Wood Sandpiper was also the most numerous of all species recorded. Pied Avocet was recorded in high numbers, as were Common Snipe and Black-winged Stilt (Table 1).

Numbers of waders in the STEMDC were lower during the summer months (May–July) than the winter months (Fig. 6) and much higher abundance was recorded during migration periods, particularly in March/April and September/October, though the number of counts during spring migration was rather low (Fig. 6).

Wader diversity appears to have increased over the five-year study (Fig. 7), although sample sizes in some winters were relatively low (e.g. 2010). Wader abundance also increased during the study period, following an upward trend after 2009, though this was not statistically significant ($H_{(5)} = 10.813$, $P = 0.055$).

Table 1. Wader species recorded in STEMDC across the five-year study period (Oct 2007–Dec 2012) ordered by frequency of occurrence. Status key: A = Abundant, C = Common, LC = Locally common, U = Uncommon, S = Scarce or Rare; M = Migrant, PM = Passage Migrant, P = Present all year, R = Resident, W = Winter Visitor. Note that Pintail Snipe *Gallinago stenura* and Swinhoe's Snipe *G. megala* cannot be separated in the field (Leader & Carey 2003).

Common name	Scientific name	Status in Hong Kong (Welch 2015)	First recorded at STEMDC	Number of counts recorded	Average number of birds per count		Maximum count	Month of maximum count
					Counts with species recorded	All counts		
Wood Sandpiper	*Tringa glareola*	CM, W	Oct 2007	45	31.02	27.92	145	Oct 2007
Little Ringed Plover	*Charadrius dubius*	CP	Oct 2007	40	9.03	7.22	32	Mar 2012
Green Sandpiper	*Tringa ochropus*	CM, W	Oct 2007	34	5.62	3.82	13	Aug 2009
Common Greenshank	*Tringa nebularia*	AW, M	May 2008	33	3.94	2.60	12	Nov 2008
Common Sandpiper	*Actitis hypoleucos*	CP	Oct 2007	33	3.09	2.04	7	Aug 2009
Common Snipe	*Gallinago gallinago*	CW, M	Jan 2008	32	17.22	11.02	63	Oct 2012
Black-winged Stilt	*Himantopus himantopus*	CW, M	Oct 2007	29	19.34	11.22	61	Oct 2007
Greater Painted-snipe	*Rostratula benghalensis*	LCR	Oct 2007	14	2.36	0.66	7	May 2009
Temminck's Stint	*Calidris temminckii*	CM, M	Oct 2007	14	6.86	1.92	22	Oct 2007
Marsh Sandpiper	*Tringa stagnatilis*	AW, M	Oct 2010	13	6.46	1.68	28	Oct 2012
Pintail/Swinhoe's Snipe	*Gallinago stenura/megala*	C/S PM	Jan 2008	10	5.70	1.14	17	Feb 2009
Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	UM, RW	Oct 2007	4	1.50	0.08	2	Oct 2007
Common Redshank	*Tringa totanus*	APM, W	Oct 2007	4	8.50	0.68	18	Sep 2012
Pied Avocet	*Recurvirostra avosetta*	AW	Mar 2012	3	49.67	2.98	92	Mar 2012
Grey-headed Lapwing	*Vanellus cinereus*	LCW	Oct 2010	3	3.00	0.18	4	Oct 2012
Spotted Redshank	*Tringa erythropus*	CPM	May 2010	3	1.33	0.08	2	Oct 2011
Long-toed Stint	*Calidris subminuta*	CPM, SW	Oct 2010	2	1.50	0.06	2	Oct 2010
Pacific Golden Plover	*Pluvialis fulva*	CM, W	Oct 2012	1	1.0	0.02	1	Oct 2012
Kentish Plover	*Charadrius alexandrinus*	AW, SM	Oct 2012	1	1.0	0.02	1	Oct 2012
Ruff	*Philomachus pugnax*	SPM, RW	Oct 2007	1	1.0	0.02	1	Oct 2007

Fig. 3. Detail of cellular concrete slab, showing hollow cells and Common Snipe probing in accumulated silt.

Fig. 4. Channel bed showing cellular concrete and colonisation by aquatic vegetation and grasses.

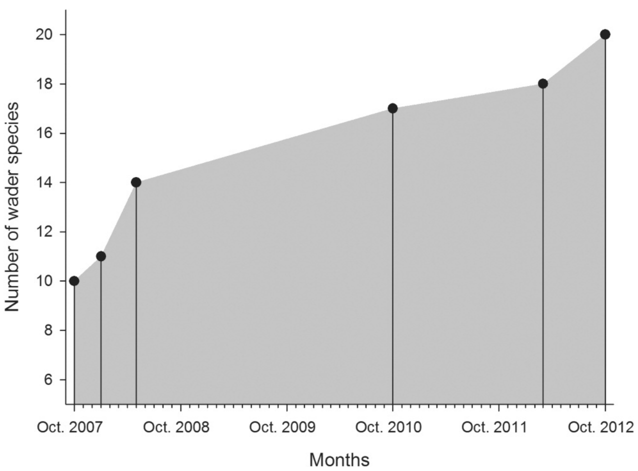

Fig. 5. Cumulative number of wader species over the five-year study period (Oct 2007–Dec 2012). The total number of species had been reached by October 2012, and only counts with new species are shown (filled circles). The shaded area represents species increase though time.

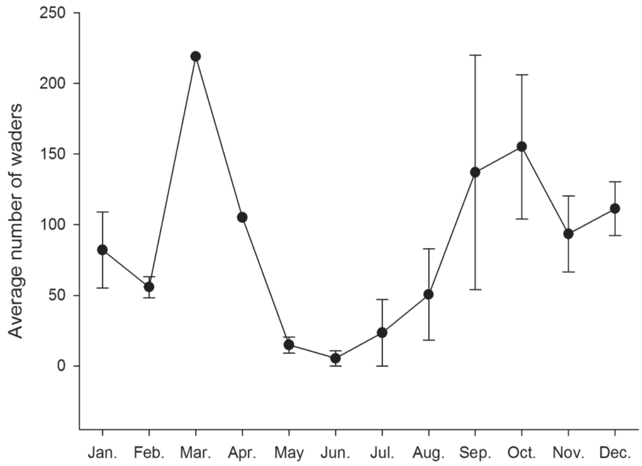

Fig. 6. Monthly average number of waders (±SE) recorded in STEMDC across a five-year period (Oct 2007–Dec 2012). March and April were only counted once; the rest were counted 2–7 times.

DISCUSSION

Across the five-year study a total of 20 wader species were recorded using the new habitats created by the STEMDC. In a separate 12-month survey carried out as part of the environmental impact assessment prior to the channelization project, only a single wader species (Pheasant-tailed Jacana) was recorded in the area extending 50 m on either side of the course of the STEMDC (Environmental Resources Management 1999). After the STEMDC construction, the wader community became more diverse and abundant as the microhabitats within the STEMDC established over the course of the years. Waders used the channel primarily for foraging, though some species also used it as a daytime roost site, e.g. *Gallinago* snipe (pers. obs.).

Many of the waders recorded in this study, including Black-winged Stilt, Little Ringed Plover and Wood Sandpiper, exploit a range of freshwater habitats (Carey *et al.* 2001) and the wader community recorded here is typical of other inland wetlands in Hong Kong, namely the extensive fishponds of the New Territories (Leader 2009). Those aquaculture ponds are known to be of considerable value as foraging habitat for birds, including waders, particularly when they are drained down (Lai *et al.* 2007, Leader 2009). The microhabitats present within the STEMDC appear to provide similar foraging opportunities and resources as drained fishponds. The fishponds to the west of the study site stretch almost continuously for about 5 km as far as the intertidal mudflats of Inner Deep Bay, and it is likely that the STEMDC forms part of a wide foraging area used by a suite of wader species. Common Greenshanks and Common Redshanks fitted with

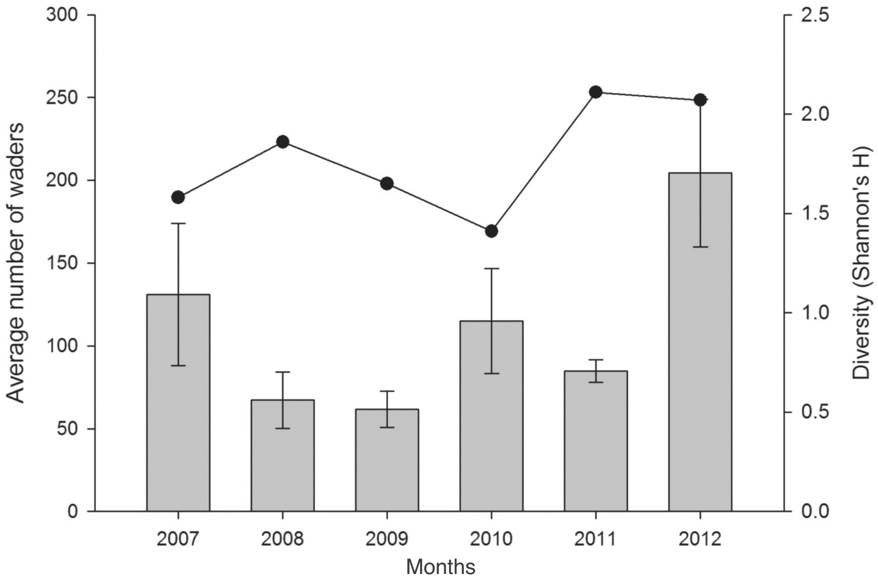

Fig. 7. Average number (±SE) of waders (columns) and Shannon-Weaver Diversity Index (filled circles and line) for six consecutive winter periods (Oct–Mar) on the STEMDC. Sample size (number of counts) for each winter period is: 2007–2008 (3); 2008–2009 (6); 2009–2010 (6); 2010–2011 (2); 2011–2012 (7); 2012 (3).

leg-flags at other locations, 4 km and 7.5 km away, have been recorded on the STEMDC, which indicates some level of movement between wetland sites within northwest Hong Kong. Unfortunately, these flags did not have alphanumeric inscriptions so more detailed information about the movements of these birds could not be deduced.

Of the nine species that were infrequently recorded (i.e. on less than five occasions; see Table 1), four are not usually recorded on fishpond habitats (Common Redshank, Spotted Redshank, Pacific Golden Plover and Kentish Plover) and one is scarce in Hong Kong (Ruff; Carey *et al.* 2001), indicating that the STEMDC also serves wader species with other requirements. Habitats that suit Pheasant-tailed Jacana and Grey-headed Lapwing occur irregularly in the STEMDC: Pheasant-tailed Jacana was recorded when dense rafts aquatic vegetation were present, and Grey-headed Lapwing was only recorded after complete clearance of bankside vegetation left short swards. The habitat within STEMDC also appears suitable for Long-toed Stint and Pied Avocet though only a low number of records of each species were obtained. The reason for this is unknown, though both species were recorded for the first time towards the end of the study. The later records of Pied Avocet (approximately five years after the completion of construction) and the apparent overall increase in species diversity may coincide with the longer-term establishment of freshwater benthic invertebrates in the channel bed. Pied Avocet is abundant on the intertidal mudflats of Inner Deep Bay *ca.* 5 km to the west and numbers have significantly increased in Hong Kong in recent years (Welch 2015). It could therefore be expected for the species to have occurred in the channel in earlier surveys, but this was not the case.

Engineered channels can offer suitable habitats to waders, particularly when sediment has been allowed to accrete in the channel bed (Page & Shuford 2000). Kwok & Dahmer (2006) suggest that the effectiveness of 'grasscrete' (a cellular reinforced concrete system with voids similar to that in the STEMDC; see Fig. 3) to provide bird habitat in flood control channels is limited, though it is still recommended as an alternative to bare concrete or coarse rubble embankments. The incorporation of a cellular concrete lining along the bottom and banks of the channel appears to provide suitable foraging habitat for waders in the STEMDC and seems to be preferable to box or trapezoidal concrete channels without features. The cellular concrete allows the accumulation of a muddy substrate, creating microhabitats throughout the base of the channel, and enabling the establishment of aquatic macrophytes and rank grasses, even following top layer sediment removal. Whilst invertebrates were not studied here, it is likely that chironomids and oligochaetes colonized quickly following completion of the channel's construction. The inclusion of cellular concrete in the channel bed likely acts as a reservoir for benthic invertebrates, and waders have been observed feeding in the channel both during and following the mechanical removal of sediments. It is not known what prey waders were feeding on during the observations and any future studies of eco-engineered flood channels would do well to incorporate benthic sampling as part of a longer term monitoring project.

Given that observations were only made early in the morning, a full understanding of the daily use of the channel cannot be provided. Likewise, the frequency of observations does not allow for any estimate of turnover to be deduced, which could potentially show that a much larger total number of waders uses the STEMDC. Additionally, no measurements of water quality or sediment pollution are taken for this watercourse (Drainage Services

Dept. & Environmental Protection Dept. pers. comm.), though visual observations suggest that water quality is poor and only a low diversity of pollution-tolerant aquatic invertebrates are present. The only fish species observed were North African Catfish *Clarias gariepinus* and Nile Tilapia *Oreochromis niloticus*, both of which are introduced and tolerant of low water quality (Lee *et al*. 2004, Fishbase 2016). By combining benthic sampling, water quality and wader behaviour measurements, a more detailed understanding could be reached of the role eco-engineered channels have as buffers of wader habitat loss. This would be very valuable for assessing their conservation potential.

Whilst there is no doubt that retention of natural lowland watercourses and wetland habitats would be preferential to creating artificial habitats, this is not always possible and where artificial watercourses are needed there are opportunities to design channels sympathetically to wetland birds. In Hong Kong, the STEMDC offers foraging opportunities to waders, particularly to those that are wintering or stopping while on migration. The cellular concrete appears to offer some structural diversity and microhabitats in the channel bed and is preferable to a homogenous concrete lining with no ecological niches. By regulating the timing of sediment clearance, the potential of STEMDC as an area for wader conservation could be further enhanced. To do so, sediment clearance should be conducted outside of migration seasons (Page & Shuford 2000) and in some cases, the breeding season, as there is potential for these periods to overlap for some species, e.g. Greater Painted-snipe. Although the clearance of the STEMDC channel is conducted on an *ad hoc* basis, it may be prudent to establish a longer-term management plan to reduce potential impacts at key periods of the year.

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REFERENCES

Anon. 2015a. *Monthly Waterbird Monitoring Biannual Report 2 (October 2014 to March 2015), Mai Po Inner Deep Bay Ramsar Site Waterbird Monitoring Programme 2014–15*. Report by the Hong Kong Bird Watching Society to the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Anon. 2015b. *Monthly Waterbird Monitoring Biannual Report 1 (April to September 2015), Mai Po Inner Deep Bay Ramsar Site Waterbird Monitoring Programme 2015–16*. Report by the Hong Kong Bird Watching Society to the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Binnie Black & Veatch HK Ltd. (BBV). 1999. *Expansion of Kiosks and Other Facilities at Lok Ma Chau Boundary Crossing: Final Environmental Study Report*. Report to Hong Kong SAR Government.

BirdLife International. 2015. *Important Bird Areas factsheet: Inner Deep Bay and Shenzhen River catchment area*. Downloaded 3 Oct 2015 from: *http://www.birdlife.org*

Carey, G.J., M.L. Chalmers, D.A. Diskin, P.R. Kennerley, M.R. Leven, R.W. Lewthwaite, D.S. Melville, M. Turnbull & L. Young. 2001. *The Avifauna of Hong Kong*. Hong Kong Bird Watching Society, Hong Kong.

Cheung, L.K., H. Lui & C. So. 2010. *Rivers Reviving – Sham Pui River*. Green Power, Hong Kong.

Conklin, J.R., Y.I. Verkuil & B.R. Smith. 2014. *Prioritizing Migratory Shorebirds for Conservation Action on the East Asian Australian Flyway*. WWF-Hong Kong, Hong Kong.

Cooper, D.S. 2006. Shorebird use of the lower Los Angeles River Channel: a novel wetland habitat. *Western Birds* 37: 1–7.

Drainage Services Department. 2003. *Environmental Report 2003*. Drainage Services Department, Hong Kong SAR Government.

Drainage Services Department. 2015. *Drainage Services Department Practice Note No. 1/2015 Guidelines on Environmental and Ecological Considerations for River Channel Design*. Drainage Services Department, Hong Kong SAR Government.

Environmental Resources Management. 1999. *Main Drainage Channels and Poldered Village Protection Schemes for San Tin, NWNT EIA Study*. Report to Hong Kong SAR Government.

Fishbase. 2016. *Clarias gariepinus (Burchell, 1822) North African Catfish*. Downloaded 16 Mar 2016 from: *http://www.fishbase.org/summary/1934*

Gilbert, O.L. & P. Anderson. 1998. *Habitat creation and repair*. Oxford University Press.

Gleick, P.H. 2003. Global freshwater resources: soft-path solutions for the 21st century. *Science* 302: 1524–1527.

Green, J.M.H., S. Sripanomyom, X. Giam & D.S. Wilcove. 2015. The ecology and economics of shorebird conservation in a tropical human-modified environment. *Journal of Applied Ecology* 52: 1483–1491.

Hayman, P., J. Marchant & T. Prater. 1986. *Shorebirds: An identification guide to the waders of the world*. Christopher Helm, London.

Hong Kong Bird Watching Society (HKBWS). 2013. *Hong Kong Headline Indicators for Biodiversity and Conservation – 2012 Report*. Hong Kong Bird Watching Society, Hong Kong.

Hong Kong Bird Watching Society (HKBWS). 2015. *Hong Kong Headline Indicators for Biodiversity and Conservation – 2013 & 2014 Report*. Hong Kong Bird Watching Society, Hong Kong.

Kwok, H.-K. & T.D. Dahmer. 2006. Ecological impacts of flood control project on birds. *Acta Ecologica Sinica* 26: 1231–1233.

Lai, P.C.C., W.H. Lee & B.S.F. Wong. 2007. Construction of a drainage channel at Inner Deep Bay, Hong Kong: mitigating ecological and landscape impact through an environmentally friendly design. *Landscape & Ecological Engineering* 3: 179–185.

Leader, P.J. 2009. Inland Wetlands. Pp. 69–86 in: *Ecology of the Birds of Hong Kong* (L.C. Wong, V.M.Y Lam & G.W.J. Ades, Eds.). Kadoorie Farm & Botanic Gardens, Hong Kong.

Leader, P.J. & G.J. Carey. 2003. Identification of Pintail Snipe and Swinhoe's Snipe. *British Birds* 96: 178–198.

Lee V.L.F., S.K.S. Lam, F.K.Y. Ng, T.K.T. Chan & M.L.C. Young. 2004. *Field Guide to the Freshwater Fish in Hong Kong.* Cosmos Books Ltd., Hong Kong.

Ove Arup & Partners. 2013. *Agreement No. CE 53/2008 (CE) Planning and Engineering Study on Development of Lok Ma Chau Loop – Investigation EIA Report.* Report to Hong Kong SAR Government.

Palmer, M.A., E.S. Bernhardt, J.D. Allan, P.S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C.N. Dahm, J. Follstad Shah, D.L. Galat, S.G. Loss, P. Goodwin, D.D. Hart, B. Hassett, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano & E. Sudduth. 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology* 42: 208–217.

Piersma, T., T. Lok, Y. Chen, C.J. Hassell, H.-Y. Yang, A. Boyle, M. Slaymaker, Y.-C. Chan, D.S. Melville, Z.-W. Zhang & Z. Ma. 2016, Simultaneous declines in summer survival of three shorebird species signals a flyway at risk. *Journal of Applied Ecology* 53: 479–490.

Sutherland, W.J., J.A. Alves, T. Amano, C.H. Chang, N.C. Davidson, C. Max Finlayson, J.A. Gill, R.E. Gill, P.M. González, T.G. Gunnarsson, D. Kleijn, C.J. Spray, T. Székely & D.B.A. Thompson. 2012. A horizon scanning assessment of current and potential future threats to migratory shorebirds. *Ibis* 154: 663–679.

Welch, G. 2015. Systematic List. Pp. 24–223 in: *Hong Kong Bird Report 2013* (J. Allcock, G. Chow & G. Welch, Eds.). Hong Kong Bird Watching Society, Hong Kong.