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Diet of the smooth-coated otter *Lutrogale perspicillata* (Geoffroy, 1826) at natural and modified sites in Singapore

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Abstract. After decades of absence, the smooth-coated otter *Lutrogale perspicillata* (Geoffroy, 1826) is now widespread along the northern shores of Singapore. Their diet was examined at four sites along the northern coast, through an analysis of 181 spraint samples, which revealed a diet mostly of fish (92%) and prawns (8%). Dietary composition differed among sites, with a wider diversity of fish consumed at natural sites (mangrove and coastal), while in freshwater reservoirs, exotic cichlids (*Oreochromis* spp., *Etroplus suratensis*, *Mayaheros urophthalmus*) dominated in the diet (91%). An unusually high proportion of prawn was consumed in the mangrove site (35%). Small- to medium-sized fishes (<18 cm) were consumed at reservoirs while larger fish were taken in the mangroves. The differences in diet among study sites suggest opportunistic feeding, where diet reflects prey community present at the site. The study suggest that along the northern Singapore the smooth-coated otter displayed dietary flexibility accommodating a predominantly non-native fish diet in the reservoirs and may exert a degree of predatory pressure on these introduced species.

Key words. Cichlidae, alien fish, mangrove, reservoir, foraging, piscivore

INTRODUCTION

As the top predator in many wetlands, otters are indicators of healthy aquatic habitats. Otter presence is largely dependent on the continuous availability of adequate and uncontaminated food resources (Melquist & Hornocker, 1983; Mason & Macdonald, 1986). Most wetlands and waterways in Asia, however, lack an adequate prey base for sustaining otter populations as a result of pollution by eutrophication and the accumulation of pesticides (de Silva et al., 2015). Thus, the disappearance of otters from apparently suitable sites is often associated with the degradation of their wetland habitats from human causes (Kruuk, 1995).

Of the four Asian otter species, the smooth-coated otter *Lutrogale perspicillata* (Geoffroy, 1826) is the most specialised fish-eater (Tiler et al., 1989; Kruuk et al., 1994). Five studies have indicated that the species is primarily a piscivore, with a diet comprising about 90% of fish with the remaining proportion including crustaceans, frogs and birds (Table 1). They tend to consume larger fish than other Asian species of otters (Wayre, 1974; Kruuk & Moorhouse, 1990; Kruuk et al., 1994), a conclusion supported by a dietary study in India (Anoop & Hussain, 2005).

While the diet of *L. perspicillata* consists of up to 94% fish along major rivers of India (Hussain & Choudhury, 1998) and 75–100% fish in mangroves and rice fields (Foster-Turley, 1992; Melisch et al., 1996), in West Java otters inhabiting mangrove areas consume more crustaceans (represented in 22% of spraints), and in the paddy fields of Malaysia they eat more rice field rats (represented in 43.8% of spraints) (Foster-Turley, 1992). In Singapore, the diet of a resident family of *L. perspicillata* in the Sungei Buloh Wetland Reserve was mostly fish (70%) and an unusually high proportion of prawns (30%), likely due to the relative abundance of prawns in the reserve (Theng, 2011), most of which were former prawn-rearing ponds.

Lutrogale perspicillata is distributed throughout South and South-east Asia, with a range from Indonesia to Malaysia, Thailand, Myanmar, southern China and India, with an isolated population in Iraq (de Silva et al., 2015). There were no records of its presence in Singapore during the 1970s and 1980s (Sivasothi, 1995) until sightings re-emerged in the early to mid-1990s (Lim, 1990; Sivasothi, 1995). Since then, populations have been recorded along the northern shores of Singapore and their numbers appear to be increasing (Theng & Sivasothi, 2016). Their reappearance provides an opportunity to examine how they cope in the highly modified landscapes of Singapore's northern shores. In this study, the diet of *L. perspicillata* was examined at two natural brackish (mangrove and coastal) sites and two freshwater artificial reservoir sites. In this study we addressed two main research questions: (a) is *L. perspicillata* diet in natural habitats (mangroves and coastal areas) more diverse than in human-made habitats (reservoirs); (b) does *L. perspicillata* consume more alien species in reservoirs than in natural habitats.

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Table 1. Literature review on the diet of the smooth-coated otter *Lutrogale perspicillata*.

Source	Location Type	Percentage of Prey in Spraints				Method of Analysis**
		Fish	*Amphibian*	*Crustacean*	*Others**	
Foster-Turley, 1992	Rice fields, bordering mangroves	87.5	–	5.4	25.9	FO
Kruuk et al., 1994	Inland river	89	33	30	26	FO
Haque & Vijayan, 1995	Inland river	96	–	–	25	FO
Sivasothi, 1995	Coastal, beach	100	–	24	–	FO
Melisch et al., 1996	Rice fields, mangroves, freshwater fishponds, brackish ponds	77	0	22	–	SBE
Hussain & Choudhury, 1998	Inland river	97.7	0.03	1.9	1.16	SBE
Anoop & Hussain, 2005	Inland river, reservoir	96.02	1.08	1.07	1.83	SBE
Theng, 2011	Mangroves	70	0	30	–	SBE
Nawab & Hussain, 2012	Inland rivers, reservoir	84	2.9	13	0.2	FO

* Others: frogs, birds, insects, mammals, snake
** FO: Frequency of occurrence; SBE: Score bulk estimate

MATERIAL AND METHODS

Study sites. The Republic of Singapore (1°20'N, 103°50'E) is an island of 710 km^2 located off the southern tip of Peninsular Malaysia (Fig. 1). The Johor Straits is a sea channel about 500–1000 m wide, separating Peninsular Malaysia and Singapore, giving rise to sheltered coastlines. The Johor-Singapore causeway links the two countries. The eastern part of the Johor Straits is severely impacted by coastal development from both countries and by high vessel traffic from the Malaysian port of Pasir Gudang, which began operations in the 1970s (Johor Port, 2012). Singapore's coastline is mostly developed and reclaimed but several relatively intact habitats are still present. Among these are mangrove patches, estuaries and dammed rivers forming reservoirs.

As social carnivores, *L. perspicillata* forage in groups and use communal sites for defecation (Hussain, 1996; Hussain & Choudhury, 1998). Such sites were found during surveys conducted within three days after member of public and naturalist reports of otter sightings to an online submissions page, Mammal Sightings (http://mammal.sivasothi.com/), with weekly follow-up visits thereafter. Actively used spraint sites were found at all four study sites: (1) Sungei Buloh Wetland Reserve (SBWR), (2) Serangoon Reservoir (SR), (3) Punggol Reservoir (PR) and (4) Chek Jawa (CJ), Pulau Ubin (Fig. 1). Sungei Buloh Wetland Reserve is the only wetland reserve in Singapore, a disturbed mangrove site comprising former prawn ponds (Ng & Sivasothi, 1999; Baker, 2000). Serangoon and Punggol reservoirs are large water bodies located near suburban areas, created by damming the estuaries of rivers (Lim & Ng, 1990) in 2007. Chek Jawa is a cape located on the eastern tip of Pulau Ubin, a rural island of 11.31 km^2 off the northeastern coast of mainland Singapore (1°18'N, 103°51'E).

Availability of prey. Information about fish species presence was obtained from literature and past surveys, and information about past prawn catches was obtained from staff of SBWR (see Acknowledgements). Catches from cast nets at SR (four sessions; 83 casts), gill nets at SBWR (one session; approximately 12 hours) and observations of free-swimming fish at the various study sites, were used to draw conclusions as a basis for general statements about the fish fauna.

Permits and certification for fish survey were obtained from National Parks Board (NP/RP10-062-1), Public Utilities Board (PUB/RP11-001), The Institutional Animal Care and Use Committee (IACUC) (B05/11 and SS22/11), Responsible Care and Use of Laboratory Animals (RCULA) (S076/11) and NUS Office of Safety, Health and Environment (OSHE) Occupational Health (OH) Programme (08082011-2491-Fish).

Collection of spraint. Samples were collected by hand, each placed in a separate re-sealable bag and labeled according to date, time and location collected. Multiple spraint batches collected in a single trip in the same spraint location were distinguished by age or colour to differentiate between defecation events. Spraint samples were then taken back to the laboratory and preserved in glass bottles filled with 75% ethanol until analysis. A total of 181 spraint samples were collected from the four study sites (SBWR: 60; SR: 66; PR: 31; CJ: 24) during 43 trips between August 2011 and February 2012.

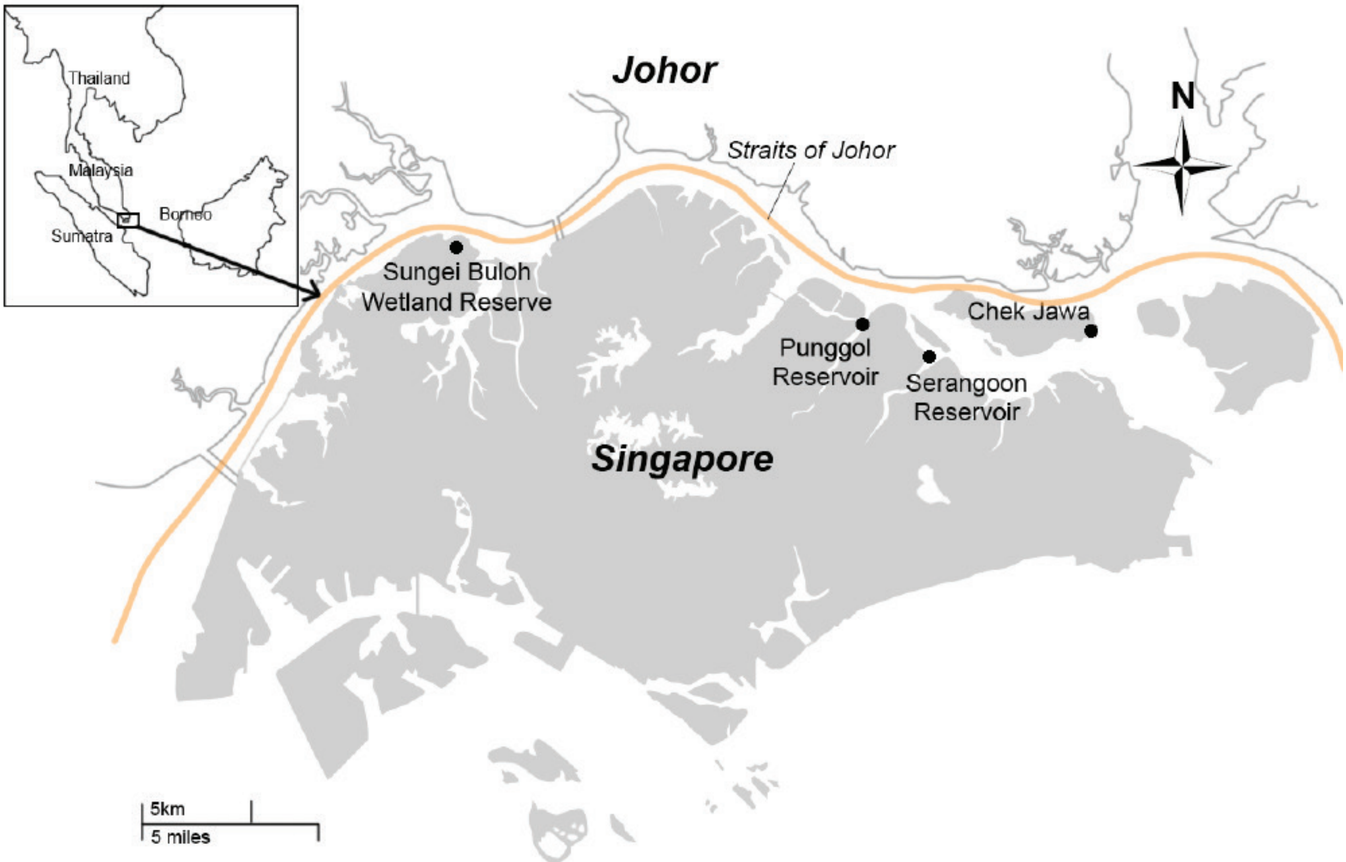

Fig. 1. Location of the four study sites along the northern shore of Singapore.

Reference fish collection. Identification of the fish species from remains in spraints required a reference fish prey collection. This collection was prepared by a previous dietary study from catalogued specimens from the then Raffles Museum of Biodiversity Research now Lee Kong Chian Natural History Museum (LKCNHM), National University of Singapore (NUS) (Theng, 2011). The surface pattern of scales was used to identify fish down to the species level wherever possible. The origin of each species (i.e. native or alien) consumed was referenced from Ng & Tan (2010a) and Lim & Ng (1990).

Analysis of spraint samples. In the laboratory, the entire volume of a stored spraint sample was spread onto a plastic tray and examined in ethanol. Fish scales, prawn rostra and other prey parts were extracted from the sample and examined in a Petri dish using a Nikon SZB2803 microscope with 10× magnification to aid in prey identification. All fish vertebrae were extracted for analysis of prey size. The prey parts were identified and analysed using the score bulk estimate method (Wise et al., 1981) unless otherwise mentioned. Prey proportion in a spraint sample was estimated visually and scored a value from 1 to 10, where the total content of a single sample is 10. Fish scales were used to quantify each fish taxon in this analysis. Dry weight of the sample was not taken because remains are prone to disintegration, while fish scales warp and shrivel. Therefore the volume of the sample contained in ethanol was taken. The score for proportion of each prey category was then multiplied by the volume and the resulting figures were summed and expressed as a proportion of the total score of all prey categories. In some instances, frequency of occurrence values were calculated by dividing the number of times a particular prey taxa occurred in a spraint sample by the total number of samples collected.

Spraints were grouped by the immediate habitat they were collected from, as either natural (mangrove/sea coast: SBWR & CJ) or modified (reservoirs: SR & PR) sites, to make general comparisons of diet between habitat types. Additionally, the Mann–Whitney *U*-test with Bonferroni correction was used for comparisons of diet percentages of native and non-native fish species.

Estimation of fish prey size from spraint. Based on the assumption that there is a positive correlation between length of the individual vertebrae and fish length (Wise, 1980), a linear regression was established for 13 cichlid individuals (*Oreochromis* spp., *Etroplus suratensis*, *Mayaheros urophthalmus*) of various sizes (total length: 108–280 mm) caught in SR. The total length of the fish was then plotted against vertebral length to obtain a coefficient that could be used to estimate total length from the length of vertebrae in spraint (Fig. 2). To do so, all vertebrae were recovered from the spraint sample and measured with a set of calipers. Measured vertebrae were placed in one of nine size classes (<1 mm, 1–1.5 mm, 1.51–2 mm, 2.01–2.5 mm, 2.51–3 mm, 3.01–3.5 mm, 3.51–4 mm, 4.01–4.5 mm, 4.51–5 mm, >5 mm). Since the linear regression only applied to cichlids, only spraint samples that consisted of cichlids (as confirmed by scale analysis) were considered. The occurrence of each size class across all samples was then determined.

Table 2. Comparison of taxa richness and Shannon's diversity (of families) index in the diet of *L. perspicillata* between the four study sites (SBWR: Sungei Buloh Wetland Reserve; SR: Serangoon Reservoir; PR: Punggol Reservoir; CJ: Chek Jawa).

	SBWR	SR	PR	CJ
Taxa richness	12	8	6	10
Shannon index (H') of families	1.483	0.535	0.0472	1.70

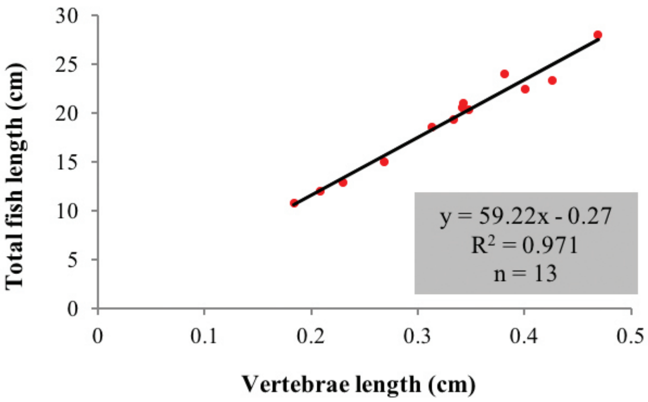

Fig. 2. Linear fit of vertebrae length and total length of cichlids caught in Serangoon Reservoir (SR).

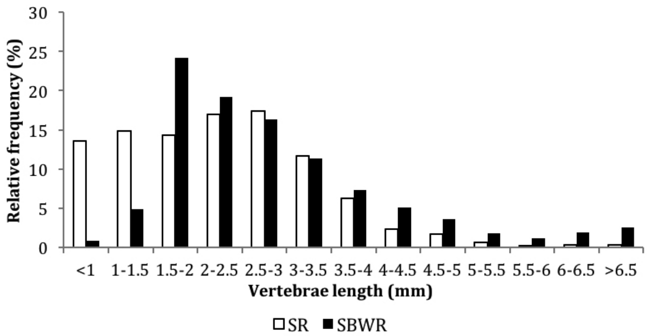

Fig. 3. Frequency distribution of the size classes of fish vertebrae represented in spraints in Serangoon Reservoir (SR) and Sungei Buloh Wetland Reserve (SBWR).

RESULTS

Overall composition of diet. Twenty taxa were detected in the spraint samples collected from the four study sites (Table 3). Fish made up the majority of the diet, being present in 175 spraint samples and constituting 92% of remains by volume. Cichlidae constituted the largest proportion of the diet (70.6%) and occurred in 80.7% of all samples (frequency of occurrence). This was followed by other fish families in much lower proportions: Latidae (6.5%), Mugilidae (6.0%), Gobiidae (2.7%), Channidae (3.7%), and other taxa. The grey mullet (Mugilidae: *Mugil cephalus*), a non-native fish, was eaten in quantity (2.9%). Prawns constituted 8.0% of the diet, all those identified being of the species *Fenneropenaeus indicus* (Penaeidae). Other prey types included small crabs and molluscs whose remains were small and rarely encountered.

Dietary differences between natural and modified sites. There was greater variety in the diet at SBWR and CJ, as seen by the higher taxon richness (SBWR: 12, CJ: 10 vs. SR: 8, PR: 6) and higher Shannon H' indices at these natural sites (SBWR: 1.48, CJ: 1.70 vs. SR: 0.54, PR: 0.047) (Table 2). CJ showed higher taxon richness than the modified sites (SR and PR), and the highest H' of any site, despite having the smallest sample size. Prawns were present in the diet at the natural brackish sites but not at the reservoir sites. They made up a substantial proportion of the diet at Sungei Buloh (34.6%).

There was a 62% difference in the proportion of cichlids (all introduced species combined) in the diet at the natural versus the reservoir sites. Cichlids predominated in the diet at the reservoir sites (90.8%), while the diet at the natural sites had a more even spread and a greater variety of fish families. Of the known origins of fish species consumed, otters in the modified sites consumed significantly higher proportions of alien fish species compared to those in the natural sites (90.9% vs. 37.7% overall volume; Mann–Whitney *U*-test with Bonferroni correction, $U=1554$, $p<0.001$). Conversely, there appeared to be higher consumption of native fish species in the natural sites as compared to the reservoir sites (28.8% vs. 5.9% overall volume), albeit not significant (Mann–Whitney *U*-test with Bonferroni correction, $U=3439$, $p=0.0359$).

Apart from the non-native cichlids, which also constituted a substantial proportion in the diet of otters at the natural sites (29% of diet) another exotic fish species was also consumed in large proportion. In SBWR, the grey mullet (*Mugil cephalus*), a non-native fish farmed in nearby floating cages at Lim Chu Kang, and observed in schools along the coast and inside the brackish ponds at the reserve (pers. obs.), was eaten in considerable quantity (19%).

Size of fish consumed. A total of 13 specimens comprising three cichlid species (*Oreochromis mossambicus*, *Etroplus suratensis*, *Mayaheros urophthalmus*) were caught in SR to establish the linear relationship between total length of the fish and length of individual vertebrae. Application of this correlation (Fig. 2) then showed that most fish consumed (77%) were smaller than 18 cm. 28.4% of total vertebrae from spraint corresponded to a fish length of less than 9 cm, and 48.6% to fish between 9 and 18 cm. Only 23.3% of vertebrae corresponded to fish larger than 18 cm, and fish larger than 30 cm were rare (1.5%). The spraint samples from SBWR contained a higher proportion of larger vertebrae size classes compared to those from SR (Fig. 3). The 1.51–3.5 mm size classes constituted 71% of overall vertebrae occurrence for SBWR.

Table 3. Overall diet composition of *L. perspicillata* based on analysis of spraints from the four study sites (August 2011–February 2012, n=181). Number of occurrences across all spraint samples (n), score bulk estimate (SBE). Origin: N=native and A=alien. (SBWR: Sungei Buloh Wetland Reserve; SR: Serangoon Reservoir; PR: Punggol Reservoir; CJ: Chek Jawa).

Prey type	**Origin**	**Overall**		**SBWR**	**SR**	**PR**	**CJ**
		n	**SBE(%)**	**(n=60)**	**(n=66)**	**(n=31)**	**(n=24)**
FISH		175	92.0	65.4	100	100	91.4
Cichlidae (*Oreochromis* spp., *Etroplus suratensis*, *Mayaheros urophthalmus*)	A	146	70.6	34.6	86.9	99.3	19.3
Mugilidae		29	5.94	14.1	2.88	0	0
Mugil cephalus	A	19	2.91	13.7	0.09	0	0
Ellochelon vaigiensis, *Liza* spp.	N	10	3.03	0.38	2.79	0	0
Other		0	0	0	0	0.47	5.99
Gobiidae		49	2.67	10.1	0.36	0	3.45
Glossogobius aureus	N	0	0	0	0.36	0.055	0
Channidae							
Channa striata	N	21	3.68	0	7.62	0.17	0
Latidae							
Lates calcarifer	N	14	6.54	0	1.89	0	45.6
Apogonidae							
Yarica hyalosoma or *Ostorhinchus pleuron*	N	2	0.20	0.66	0	0	0
Scatophagidae							
Scatophagus argus	N		0	0.90	0	0	0
Clupeidae	N	1	0.15	0.76	0	0	0
Unknown fish 1		3	0.59	2.89	0	0	0
Unknown fish 2		3	0.60	0	0	0	4.89
Unknown fish 3		1	0.55	0	0	0	4.43
Unknown fish 4		1	0.22	0	0	0	1.76
Siluriformes*		10		1.36	0.35	0	5.95
Ariidae							
Hexanematichthys sagor	N						
Plotosidae							
Plotosus lineatus	N						
PRAWN		24	8.0	34.6	0	0	8.58
Penaeidae	N						
Fenneropenaeus indicus		24	8.0	0	0	0	0
CRAB		5	neg	0	0	0	0
MOLLUSC		2	neg	0	0	0	0
Mytilidae							
Brachidontes spp.		2	neg	0	0	0	0

*Figures could not be provided for the catfish that were detected in samples but unable to be identified. The species *Hexanematichthys sagor* and *Plotosus lineatus* are both recorded in SBWR (the former, the dominant catch in gill net surveys), with photographic evidence of otter consumption, thus highly likely the consumed species present in spraints.

DISCUSSION

Spraint analysis is the standard method to study the diet of otters because it is relatively easy to collect spraint samples once the prominent sites have been located (Kruuk, 2006: 99). Within the spraint, parts of the prey skeleton and scales are left undigested and can sometimes be used to identify fish prey down to the species level (Kruuk, 2006: 99). The 'score bulk estimate' has been recommended, and was used as the primary method of analysis in the present study, because it gives better estimates (by considering proportion) compared with the more widely used 'frequency of occurrence' and other methods (Jacobsen & Hansen, 1996).

Through score bulk estimation, fish made up 92% of the overall diet of *L. perspicillata* along the Johor Straits in Singapore. The results support the observation that *L. perspicillata* is primarily a piscivore (Kruuk et al., 1994; Haque &Vijayan, 1995; Hussain & Choudhury, 1998; Anoop & Hussain, 2005; Sivasothi, 1995; Nawab & Hussain, 2012), which is unique amongst the four otter species in Asia but similar to *Pteronura brasiliensis* in South America and *Hydrictis maculicollis* in Africa (Kruuk, 2006).

In Singapore, the diet of *L. perspicillata* differed among the four study sites, noticeably between the natural (SBWR and CJ) and reservoir (SR and PR) sites. This is likely a reflection of the prey community in these sites as the higher diversity of fish consumed at natural sites correlates with the larger number of fish species recorded at these sites (SBWR: 107; CJ: 111) (Tables 4 & 5) as compared to the reservoir sites which see a much lower diversity (SR: 39; PR: 31) since they were dammed (Ng & Tan, 2013). A study in India drew a similar conclusion, where fish species used and their preference by otters varied from river to river depending on their availability in different seasons (Nawab & Hussain, 2012). This apparent opportunistic hunting behaviour is characteristic of otter species like *Lutra lutra*, *Pteronura brasiliensis* and *Lontra canadensis* (Duplaix, 1980; Kruuk & Moorhouse, 1990; Bowyer et al., 1994; Carter et al., 1999).

Cichlid remains were present in every spraint sample from the reservoir sites and constituted 90.8% of *L. perspicillata*'s diet there. This is likely a reflection of the prey community in the reservoirs, as these and other reservoirs in Singapore are known to be almost wholly populated by non-native fish species (Ng & Tan, 2010a). This is reflected by the almost entirely cichlid catch from fish samples taken in SR (95.3%) during the present study. The fish communities of these reservoirs were not always so depauperate nor dominated by exotic species: before the damming of the reservoirs, the estuaries of Sungei Serangoon and Punggol contained a higher diversity of fish (Ng & Tan, 2013). The three species of cichlids recorded and consumed in the reservoir sites (*Oreochromis mossambicus*, *Etroplus suratensis* and *Mayaheros urophthalmus*) have established populations in Singapore, including both freshwater and brackish sites (Tan & Tan, 2003; Ng & Tan, 2010b). The first of these was deliberately introduced by the Japanese in World War II as a source of protein (Tan & Tan, 2003) while the other two species are thought to have been introduced (from South Asia and Central America respectively) through the aquarium trade (Ng & Tan, 2010b). This indicates adaptability to a diet of primarily exotic fish species, and suggests that the reservoir sites can sustain otter populations. The proportion of exotic fish consumed was higher than the 60% of diet recorded in a reservoir in India, of which tilapia constituted 50% of overall diet (Anoop & Hussain, 2005). With non-native fish as a suitable prey base for this native apex predator, otters could possibly help control exotic fish populations in artificial water bodies.

In the SBWR, another fish species, the sagor catfish (*Hexanematichthys sagor*), is suspected to be consumed in higher proportion than detected in spraint because it is from the order Siluriformes, which are scaleless. These benthic fish are abundant in Sungei Buloh Besar, where one gill net yielded more than 20 specimens of *Hexanematichthys sagor* (30–57 cm) within seven hours. Otters were observed to consume this species tail-first, discarding the anterior half that bears large pectoral and dorsal spines and the highly ossified skull.

In CJ, the barramundi (*Lates calcarifer*) was the dominant food item. Though native, the barramundi is commonly imported for intensive aquaculture and is currently farmed in Singapore waters (Leong, 2010). Thus, most of the local population are likely to be escapees (K. K. P. Lim, pers. comm.).

The consumption of prawns at the natural sites and not in the modified sites is attributable to several factors: the existence of former prawn ponds in SBWR (where prawns are still recorded) and Pulau Ubin (where CJ is located), and the consumption of a marine/brackish species (*Fenneropenaeus indicus*) found in the estuarine and coastal natural sites but not in the modified sites that are no longer connected directly to the sea and thus possess no extant pelagic freshwater crustacean of comparable size. The high proportion of prawns in the diet at SBWR (35%) was similar only to one earlier study in the same site (30%) (Theng, 2011) and a diet study in the freshwater habitats of West Java where freshwater prawns were consumed (Melisch et al., 1996), but has otherwise not been recorded for this species. Other dietary studies of *L. perspicillata* have mostly been on inland rivers, reservoirs, mangroves and one in rocky shore habitat (Table 1). The SBWR still has prawns in every brackish water pond (H. P. Ang, pers. comm.). A similar abundance is unlikely at the sites of the other published dietary studies. This suggests that *L. perspicillata* may not be so obligate a piscivore as suggested by the results of the studies (Table 1).

The species of prawn consumed is *Fenneropenaeus indicus* and pond-flushing surveys that have been conducted (in the morning and evening) by SBWR staff members indicate the dominance of this species (42.8% of prawn catch) and *Metapenaeus ensis* (57.0%) (Theng, 2012). The presence of the first and absence of the second in the otters' diet is likely due to the fact that *M. ensis* burrows in the mud substratum during the day and is only active nocturnally (Wassenberg &

Hill, 1994) while *F. indicus* is non-burrowing and is active both by day and by night (FAO, 2007). *L. perspicillata* forages in the day when the accessible prawn species would be *F. indicus*. This again suggests opportunistic feeding.

This study revealed that *L. perspicillata* tends to consume small- and medium-sized fish (less than 18 cm) in SR, similar to the situation in a reservoir in Periyar, India (Anoop & Hussain, 2005). Otter species such as *Aonyx capensis* and *Lutra lutra* have also been found to consume predominantly small- and medium-sized fish (Rowe-Rowe, 1977). A captive experiment with *Lutra lutra* suggested that medium-sized fish (15–17 cm) were easier to catch than small fish (<10 cm) (Erlinge, 1968). Larger fish were taken at SBWR, again suggesting a tendency to take whatever is available. Anoop & Hussain (2005) also found remains of larger fish where local fishermen were active in Periyar, India, which again supports the notion that *L. perspicillata* is opportunistic and will go for large fish when the opportunity arises.

Mainly but not exclusively piscivores, the diet of *L. perspicillata* is dependent on the prey community in their environment. The differences in their diet at four locations suggest that *L. perspicillata*'s opportunistic feeding behaviour allows for dietary adaptation to artificial and modified habitats like reservoirs. Otters could exert predatory pressure on the alien cichlid community and influence the competition between exotic and native fish species. With a suitable prey base available for *L. perspicillata*, the next step could be to improve otter habitats in these waterways that would not only contribute to otter conservation but to the control of the alien fish populations as well.

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APPENDICES

Table A1. Fish species recorded in Sungei Buloh Wetland Reserve (National Parks Board, 2003)

S/No.	Common Name	Scientific Name
	Marine Fish	
1	tropical sand goby	*Acentrogobius caninus*
2		*Acentrogobius janthinopterus*
3	spotted green goby	*Acentrogobius viridipunctatus*
4		*Ambassis dussumieri*
5	kops glass perchlet	*Ambassis kopsii*
6	telkara glass perchlet	*Ambassis vachelli*
7	shrimp goby	*Amblyeleotris gymnocephala*
8	slender amoya	*Amoya gracillis*
9	chacunda gizzard shad	*Anodontostoma chacunda*
10	humpbacked mangrove cardinalfish	*Yarica hyalosoma*
11	four-striped cardinalfish	*Ostorhinchus pleuron*
12	yellow sea catfish	*Arius oetik*
13	tropical silverside	*Atherinomorus duodecimalis*
14	blue-spotted mudskipper	*Boleophthalmus boddarti*
15	Oriental sole	*Brachirus orientalis*
16	bumblebee goby	*Brachygobius kabillensis*
17	crimson-tipped gudgeon	*Butis butis*
18	flathead gudgeon	*Butis humeralis*
19	crested gudgeon	*Butis koilomatodon*
20		*Butis melanostigma*
21		*Calamiana illota*
22		*Calamiana variegata*
23	brownback trevally	*Carangoides praeustus*
24	milkfish	*Chanos chanos*
25	pygmy halfbeak	*Dermogenys collettei*
26		*Drombus globiceps*
27		*Drombus ocyurus*
28	squaretail mullet	*Ellochelon vaigiensis*
29	orange-spotted grouper	*Epinephalus coioides*
30	green chromide	*Etroplus suratensis*
31	western mosquito fish	*Gambusia affinis*
32	silver-biddy	*Gerres kapas*
33	golden flathead goby	*Glossogobius aureus*
34	glass goby	*Gobiopterus birtwistlei*
35	glass goby	*Gobiopterus brachypterus*
36		*Gymnothorax tile*
37		*Hemigobius hoeveni*
38		*Hemigobius mingi*
39		*Herklotsichthys quadrimaculatus*
40	mangrove whipray	*Himantura walga*
41	mangrove pipefish	*Ichthyocampus carce*
42	rough golden toadfish	*Lagocephalus lunaris*
43	sea bass	*Lates calcarifer*
44		*Lutjanus* spp.
45	common ponyfish	*Leiognathus equula*
46	Indo-pacific tarpon	*Megalops cyprinoides*
47		*Mugil cephalus*
48		*Mugilogobius fasciatus*
49	princess mangrove goby	*Mugilogobius rambaiae*
50	priapus fish	*Neostethus bicornis*
51	whitebar oyster-blenny	*Omobranchus ferox*
52	snakehead gudgeon	*Ophiocara porocephela*
53	brown gudgeon	*Oxyeleotris urophthalma*

S/No.	Common Name	Scientific Name
54	Roux's pygmy-goby	*Pandaka rouxi*
55	giant mudskipper	*Periophthalmodon schlosseri*
56	gold-spotted mudskipper	*Peroiphthalmus chrysospilos*
57	dusky-gilled mudskipper	*Periophthalmus novemradiatus*
58		*Periophthalmus walailakae*
59	snake eel	*Pisodonophis boro*
60	bartail flathead	*Platycephalus indicus*
61	striped eeltail catfish	*Plotosus lineatus*
62	mangrove fatnose goby	*Pseudogobius avicennia*
63	Javanese fatnose goby	*Pseudogobius javanicus*
64	serpent mudskipper	*Pseudopocryptes lanceolatus*
65		*Redigobius bikolanus*
66		*Redigobius giurinus*
67	white tamban	*Sardinella* spp.
68	spotted scat	*Scatophagus argus*
69	talang queenfish	*Scomberoides commersonianus*
70	silver sand whiting	*Sillago sihama*
71	pickhandle barracuda	*Sphyraena jello*
72		*Stigmatogobius pleurostigma*
73	pond goby	*Rhinogobius giurinus*
74	prey knight goby	*Stigmatogobius sandanundio*
75	Indian anchovy	*Stolephorus indicus*
76	spot-tail needlefish	*Strongylura strongylura*
77	crescent perch	*Terapon jarbua*
78	spotted green puffer	*Dichotomyctere nigroviridis*
79	Hamilton's thryssa	*Thryssa hamiltonii*
80	spotted archerfish	*Toxotes chatareus*
81	banded archerfish	*Toxotes jaculatrix*
82		*Triacanthus nieuhofi*
83	longtail tripodfish	*Tripodichthys blochi*
84	mangrove waspfish	*Vespicula trachinoides*
85	strip-nosed halfbeak	*Zenarchopterus buffonis*
	Freshwater Fishes (Native)	
86	climbing perch	*Anabas testudineus*
87	common snakehead	*Channa striata*
88	common walking catfish	*Clarias batrachus*
89	swamp eel	*Monopterus javanensis*
90	estuarine catfish	*Mystus gulio*
91	Javanese ricefish	*Oryzias javanicus*
92	marble goby	*Oxyeleotris marmorata*
93	two-spot gouramy	*Trichopodus trichopterus*
94	croaking gouramy	*Trichopsis vittata*
	Freshwater Fishes (Introduced)	
95	Siamese fighting fish	*Betta splendens*
96	giant snakehead	*Channa micropeltes*
97	koi carp	*Cyprinus carpio*
98	armoured sucker catfish	*Pterygoplichthys* spp.
99	red terror	*Mayaheros urophthalmus*
100	common tilapia	*Oreochromis mossambicus*
101	nile tilapia	*Oreochromis niloticus*
102	giant gouramy	*Osphronemus goramy*
103	guppy	*Poecilia reticulata*
104	green molly	*Poecilia sphenops*
105	four-banded tiger barb	*Puntigrus tetrazona*
106	golden dragon fish	*Scleropages formosus*
107	snakehead gouramy	*Trichopodus pectoralis*

Table A2. Fish species recorded in Chek Jawa, Pulau Ubin (Raffles Museum of Biodiversity Research, 2001, Ng et al., 2015).

S/No.	Common Name	Scientific Name
1	blue-spotted stingray	*Neotrygon kuhlii*
2	mangrove whipray	*Himantura walga*
3	chacunda gizzard shad	*Anodontostoma chacunda*
4	white sardine	*Escualosa thoracata*
5	keele shad	*Hilsa keele*
6	threadfin shad	*Nematalosa galatheae*
7	tamban	*Sardinelia* spp.
8	anchovy	*Stolephorus* spp.
9	barred sea catfish	*Hexanematichthys sagor*
10	white-lipped eeltail catfish	*Paraplotosus albilabris*
11	black eeltail catfish	*Plotosus canius*
12	spot-tail needlefish	*Strongylura strongylura*
13	striped-nose halfbeak	*Zenarchopterus buffonis*
14	blue-speckled pipefish	*Hippichthys cyanospilos*
15	spotted pipefish	*Hippichthys penicillus*
16	spotted seahorse	*Hippocampus kuda*
17	tidepool pipefish	*Micrognathus micronotopterus*
18	tropical silverside	*Atherinomorus duodecimalis*
19	slender silverside	*Hypoatherina* spp.
20	priapusfish	*Neostethus* spp.
21	spotted-tail frogfish	*Lophiocharon trisignathus*
22	Singapore toadfish	*Allenbatrachus reticulatus*
23	threespine toadfish	*Batrachomoeus trispinosus*
24	fringe-eyed flathead	*Cymbacephalus nematophthalmus*
25	Japanese flathead	*Inegocia japonica*
26	bartail flathead	*Platycephalus indicus*
27	longspine scorpionfish	*Paracentropogon longispinis*
28	four-lined cardinalfish	*Ostorhinchus compressus*
29	mangrove humpback cardinalfish	*Yarica hyalosoma*
30	mangrove cardinalfish	*Fibramia lateralis*
31	chequered cardinalfish	*Ostorhinchus margaritophorus*
32	four-striped cardinalfish	*Ostorhinchus quadrifasciatus*
33	seagrass cardinalfish	*Archamia bleekeri*
34	golden trevally	*Gnathanodon speciosus*
35	talang queenfish	*Scomberoides commersonianus*
36	false scorpionfish	*Centrogenys vaigiensis*
37	barramundi	*Lates calcarifer*
38	waigeu seaperch	*Psammoperca waigiensis*
39	kite butterflyfish	*Parachaetodon ocellatus*
40	longspine glass perchlet	*Ambassis interrupta*
41	Kops's glass perchlet	*Ambassis kopsii*
42	Nalua glass perchlet	*Ambassis nalua*
43	spotted sicklefish	*Drepane punctata*
44	deepbody mojarra	*Gerres* cf. *abbreviatus*
45	slender mojarra	*Gerres oyena*
46	shoulder-spot goby	*Acentrogobius caninus*
47	blue-spotted goby	*Acentrogobius* spp.
48	blue-spotted mudskipper	*Boleophthalmus boddarti*
49	crested goby	*Butis koilomatodon*
50	shrimp goby	*Cryptocentrus* spp.
51	brown shore goby	*Drombus triangularis*
52	twospot flathead goby	*Glossogobius biocellatus*
53	common mullet goby	*Hemigobius hoevenii*
54	ornate goby	*Istigobius ornatus*
55	sand goby	*Papillogobius reichei*

S/No.	Common Name	Scientific Name
56	giant mudskipper	*Periophthalmodon schlosseri*
57	gold-spotted mudskipper	*Periophthalmus chrysospilos*
58	dusky-gilled mudskipper	*Periophthalmus novemradiatus*
59	Javanese goby	*Pseudogobius javanicus*
60	bearded mudskipper	*Scartelaos histophorus*
61	shadow goby	*Acentrogobius nebulosus*
62	harry hotlips	*Plectrohinchus gibbosus*
63	javelin grunter	*Pomadasys kaakan*
64	seagrass tuskfish	*Choerodon oligacanthus*
65	bicolor wrasse	*Halichoeres bicolor*
66	diamond wrasse	*Halichoeres nigrescens*
67	flagfin wrasse	*Pteragogus flagellifera*
68	ponyfish	*Leiognathus* spp.
69	clouded emperor	*Lethrinus nebulosus*
70	Russell's snapper	*Lutjanus russelli*
71	squaretail mullet	*Ellochelon vaigiensis*
72	grey mullet	*Liza subviridis*
73	carpet eel blenny	*Congrogadus subducens*
74	spotted scat	*Scatophagus argus*
75	orange-spotted grouper	*Epinephelus coioides*
76	seagrass rabbitfish	*Siganus canaliculatus*
77	Javan rabbitfish	*Siganus javus*
78	spotted sand whiting	*Sillago burrus*
79	silver sand whiting	*Sillago sihama*
80	trumpeter perch	*Pelates quadrilineatus*
81	crescent perch	*Terapon jarbua*
82	sharpnose perch	*Terapon puta*
83	banded perch	*Terapon theraps*
84	speckled tongue-sole	*Cynoglossus puncticeps*
85	double-lined tongue	*Paraplagusia bilineata*
86	largetooth flounder	*Pseudorhombeus arsius*
87	Indian halibut	*Psettodes erumei*
88	commerson's sole	*Synaptura commersoniana*
89	seagrass filefish	*Acreichthys tomentosus*
90	feathery filefish	*Chaetoderma penicilligera*
91	fan-bellied filefish	*Monacanthus chinensis*
92	pigface filefish	*Paramonacanthus* spp.
93	longhorn cowfish	*Lactoria cornuta*
94	shortnose boxfish	*Rhynchostracion nasus*
95	milk-spotted pufferfish	*Chelonodon patoca*
96	banded pufferfish	*Takifugu oblongus*
97	rhomboid tripodfish	*Triacanthus biaculeatus*
98	coastal catshark	*Atelomycterus marmoratus*
99	reticulate whipray	*Himantura uarnak*
100	bluespotted ribbontail ray	*Taeniura lymma*
101	Reeve's moray	*Gymnothorax reevesii*
102	striped eeltail catfish	*Plotosus lineatus*
103	rib-bar cardinalfish	*Ostorhinchus pleuron*
104	threadfin blue goby	*Acentrogobius cyanomos*
105	freckled goby	*Amblygobius stethophthalmus*
106	dusky frillgoby	*Bathygobius fuscus*
107	peacock sole	*Dagetichthys commersonnii*
108	variable sabretooth blenny	*Pardachirus pavoninus*
109	copperband butterflyfish	*Petroscirtes variabilis*
110	longtail tripodfish	*Chelmon rostratus*
111		*Tripodichthys blochii*