R E P O R T

POPULATION STRUCTURE, DISTRIBUTION, AND HABITAT USE OF SMOOTH-COATED OTTERS *Lutrogale perspicillata* IN SINGAPORE

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ABSTRACT: The population and distribution of smooth-coated otters (*Lutrogale perspicillata*) in Singapore has increased since their return in 1998, but their population structure, distribution, and habitat use have not been quantified. A nation-wide field study (land surveys, boat surveys and camera trapping) at 15 sites, along with the collection of *L. perspicillata* records from the public, were conducted for six months (August 2016 to January 2017). The current study reveals at least 79 individuals in Singapore from 11 groups. The population in Singapore is growing, and consists of 58.2% adults and 41.8% sub-adults or pups. The average group size is 7.2, with groups ranging from two to 14 individuals. *L. perspicillata* occupy a wide variety of aquatic habitats including mangroves, coasts, reservoirs, rivers, and canals. They have adapted to using urban structures, and have survived and reproduced in urban environments, which shows that they are urban adapters.

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INTRODUCTION

Of the four Asian species of otters, the smooth-coated otter *Lutrogale perspicillata* and the Asian small-clawed otter *Aonyx cinereus* are native to Singapore (Sivasothi and Nor, 1994). Records prior to the 1960s indicated both species' historical presence in Singapore. However, records of either species were absent for three decades in the 1970s to 1990s, a period that coincided with intensive coastal and waterway developments (Theng and Sivasothi, 2016). In 1998, a pair of *L. perspicillata* established in the north-western region of Singapore, in the mangroves of Sungei Buloh Wetland Reserve (Theng and Sivasothi, 2016). Since 1998, the *L.*

perspicillata population has increased, and its distribution has expanded throughout the island, with records in mangroves, coasts, reservoirs and even highly urban areas such as the tourist hotspot of Gardens by the Bay (a 101 hectares nature park adjacent to the Marina Reservoir). The reduced proximity of *L. perspicillata* to humans in many urban environments, coupled with high media attention, has resulted in an increased awareness of its presence in Singapore (Bailey 2016; Lee, 2016; Tan, 2016). This provided an opportunity to incorporate citizen science as a tool to study the local population of this species.

At present, there are limited studies on *L. perspicillata* both in Singapore and throughout its range. The ecology of *L. perspicillata*, especially in an urban context, is also poorly studied. This study attempts to determine the population structure (proportion of adults, subadults, and juveniles), distribution, and habitat use of *L. perspicillata*, to further the knowledge of its ecology, especially in an urban context, and to provide information vital for the conservation of this species.

STUDY AREA

Located one degree north of the equator and at the southern tip of Peninsular Malaysia, Singapore (1.3521° N, 103.8198° E) is an island city state of 719 km^2 in area. Singapore's coastlines are highly modified: large scale developments and reclamations happened between the 1970s and 1990s, and major estuaries are being barraged to form freshwater reservoirs for water supply. Most of Singapore's rivers have also been canalised to form stormwater channels for flood control (Hilton and Manning, 1995; Harris et al., 2013; Public Utilities Board, 2016). However, pockets of natural habitats remain, including primary forests (0.16%), secondary forests (21.01%), freshwater swamp forests (0.39%), mangroves (0.11%), and beaches (Yee et al., 2011).

MATERIALS AND METHODS

Data collection and site selection

Known methods for detailed population studies of otters include employing genetic methods (Park et al., 2011, White et al., 2013) or recruiting large numbers of volunteers in a fixed time period for a population census (Ruiz-Olmo et al., 2001; Garcia et al., 2009). However, genetic markers for *L. perspicillata* are still being developed (Sasaki H., personal communication), and it was not possible to recruit a large number of trained volunteers due to limited resources. Instead, in order to obtain a population estimate, field surveys were conducted and observational records of *L. perspicillata* groups in Singapore were compiled.

For a period of for six months between August 2016 and January 2017, field surveys were conducted and records were compiled. Field surveys involved camera trapping and visual observations on land and by boat at 15 sites around Singapore, selected based on site accessibility. Sixty visual observation land surveys of at least two hours each were carried out at 11 sites (total survey effort of 269 hours) (Fig. 1), and involved searching for *L. perspicillata* by foot, or by scooter or bicycle where terrain permitted. Eleven two-hour-long boat surveys were carried out at six sites (total survey effort of 22 hours), and involved searching for *L. perspicillata* on a boat in reservoirs or along the coast. Twenty-six camera traps were deployed at seven sites around Singapore (Fig. 1), with a total of 2069 potential trap nights (number of active camera traps x sum of active calendar nights). Potential trap nights was used as a metric of data collection effort as any battery depletion or camera glitches were not possible to ascertain (Vickers et al., 2017). Three models of traps (Reconyx™ PC800 Hyperfire™, Bestguarder SG990V, Bushnell NatureView HD) with either photograph

or video capturing functions were used to capture either five photos or a 30-second video per trigger. Traps were fixed and secured to a support structure or tree between 0.3 to 1.5 meters off the ground. Traps were aimed at a spraint site, resting site, holt entrance or a travel path of the otters, and were triggered by an infra-red motion sensor. Camera traps were checked at least once every two months to extract images and renew batteries.

Record collection involved collating *L. perspicillata* records from online platforms, through informal interest groups, and those sent directly to the authors. Online platforms included Facebook pages and groups (OtterWatch and Nature Society (Singapore)), online databases (Mammal sightings in Singapore http://mammal.sivasothi.com and Biodiversity Environment Database System BIOME https://biome.nparks.gov.sg), and social media platforms (YouTube, Instagram and Straits Times Online Mobile Print). These data were collated opportunistically. Informal interest groups included a group of otter photographers and enthusiasts, and a private Facebook group (Birds, Insects & Creatures of Asia). Records sent directly to the authors were records from colleagues and friends. All records collected were verified through a filtering process where only records with a photo or video evidence that matches the number of otters reported were used.

Determining population structure of L. perspicillata in Singapore

Unlike other otter species with unique morphological markings (e.g. *Pteronura brasiliensis* and *Hydrictis maculicollis*) (Procter, 1963; Duplaix, 1980) which allow for identification between individuals, unique morphological markings are absent in *L. perspicillata*. Hence, a combination of methods was used to distinguish groups and obtain a population count. Groups of *L. perspicillata* were first separated based on consistent number of individuals (at least four records) in a group and at a geographically distinct location. To prevent double-counting of a group, other criteria such as the (i) presence of concurrent group sightings (ii) numbers of pups and adults in a group (iii) presence of a female within a suspected pregnancy or gestation period, were used to discern whether groups living in geographically adjacent areas were distinct (Fig. 2).

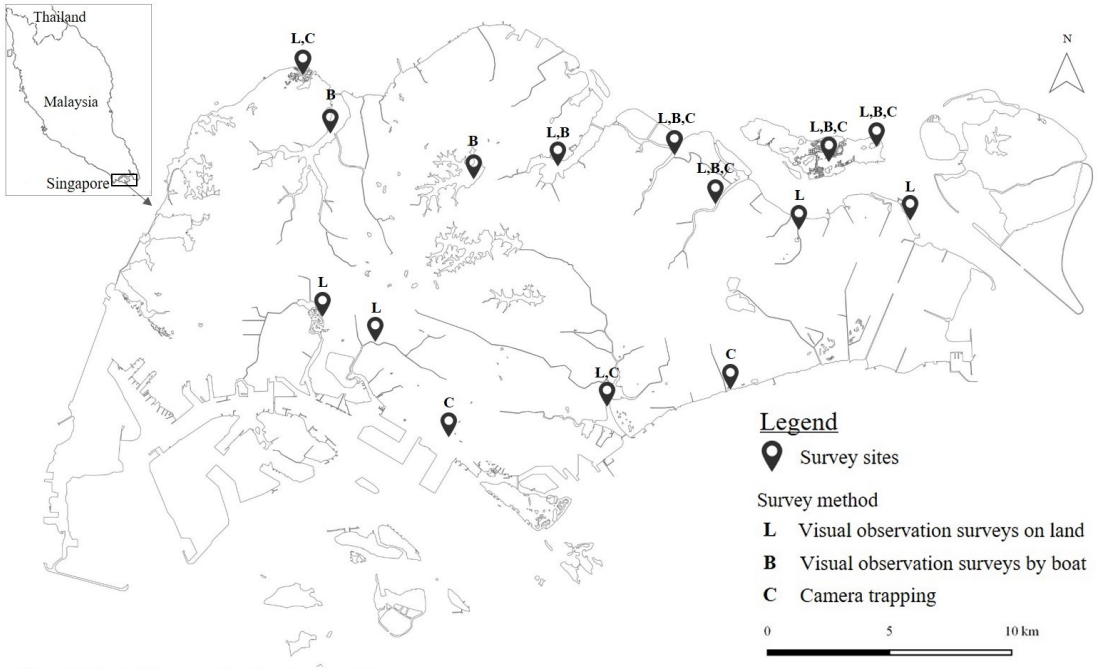

Figure 1. Map of Singapore showing the survey sites.

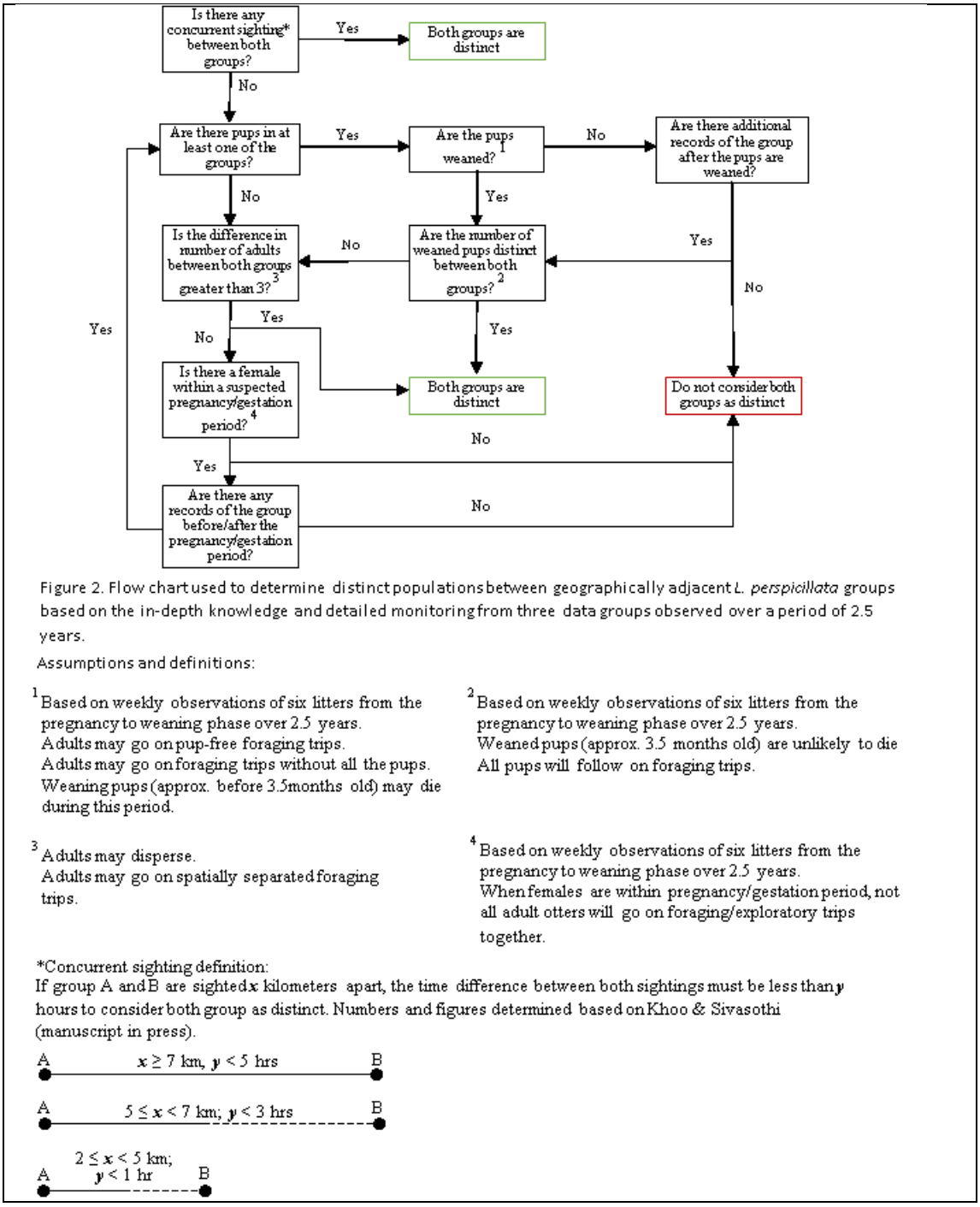

Figure 2. Flow chart used to determine distinct populations between geographically adjacent *L. perspicillata* groups based on the in-depth knowledge and detailed monitoring from three data groups observed over a period of 2.5 years.

Assumptions and definitions:

[1] Based on weekly observations of six litters from the pregnancy to weaning phase over 2.5 years.
Adults may go on pup-free foraging trips.
Adults may go on foraging trips without all the pups.
Weaning pups (approx. before 3.5months old) may die during this period.

[2] Based on weekly observations of six litters from the pregnancy to weaning phase over 2.5 years.
Weaned pups (approx. 3.5 months old) are unlikely to die
All pups will follow on foraging trips.

[3] Adults may disperse.
Adults may go on spatially separated foraging trips.

[4] Based on weekly observations of six litters from the pregnancy to weaning phase over 2.5 years.
When females are within pregnancy/gestation period, not all adult otters will go on foraging/exploratory trips together.

*Concurrent sighting definition:
If group A and B are sighted x kilometers apart, the time difference between both sightings must be less than y hours to consider both group as distinct. Numbers and figures determined based on Khoo & Sivasothi (manuscript in press).

Constructing a distribution map of *L. perspicillata*

To map the distribution of *L. perspicillata* in Singapore, each group's minimum linear home range was calculated in QGIS (version 2.18.2). Minimum linear home range (MLHR) is defined as a subset of the actual home range. MLHR was adopted because the data was pieced together based on records and surveys, which lacks the depth of conventional home range determination methods such as radio telemetry. To determine each group's MLHR, point locations obtained from records of each *L. perspicillata* group were first joined up linearly. The geographically extreme end point locations were then omitted in this MLHR unless the end point consists of more than one record. The omission is to provide a conservative estimate of the MLHR by

omitting one-off areas that a *L. perspicillata* group was recorded in (Hussain and Choudhury, 1995).

Habitat use

The various types of aquatic habitats used by *L. perspicillata* were categorised. In addition, the degree of urbanisation for each habitat was categorised into one of the following: highly urbanised, urban, semi-natural or natural. Spraint sites, holts and resting sites used at least twice by *L. perspicillata* were identified and characterised based on standard methods suggested by the IUCN Otter Specialist Group.

RESULTS

Population structure

Eleven distinct groups of *L. perspicillata* were recorded, with a total estimated population count of 79 (Table 1). Group size ranged from two to 14, with an average of 7.2 ± 0.89 (SE). The maximum number of 14 *L. perspicillata* in a group (Bishan) was only recorded once, as one of the newborn pups disappeared (due to suspected mortality) after the first record. Of the 79 *L. perspicillata*, 46 were adults (58.2%), 21 were sub-adults (26.6%), and 12 were pups (15.2%). The group structures of the 11 groups consisted of a pair, and a pair plus up to three of their litters.

L. perspicillata were also recorded to use a wide range of habitats in an urban-rural gradient. An example of a highly urbanised environment used include rivers that are modified into concrete canals, where the riparian zone consists of very steep or vertical walls, and are near areas with high human traffic. Such urban habitats prevented *L. perspicillata* from directly climbing up to access land. Instead, they were observed to use steps and even vertical ladders to climb up.

Thirty-three spraint sites were recorded. Few of the spraint site characteristics were generally similar to those recorded in previous studies: close to a waterbody or escape cover (median distance: 4.2m), on a gentle slope (median angle: 2°), and above the highest water level mark (median height: 2.17m) (Anoop and Hussain, 2004; Theng and Sivasothi, 2012; Khan et al., 2014). In contrast, characteristics such as highly varied substrate composition, absence of sand within five meters, and high human accessibility (39.4%), are recorded in this study but contrary to what previous studies have found (Anoop and Hussain, 2004; Theng and Sivasothi, 2012; Khan et. al., 2014).

A total of five resting sites and 12 holts were recorded. All resting sites and holts were above the maximum water level (median height: 2.17m) and close to a spraint site (median distance: 1.45m). Distance from the nearest waterbody to each resting site and holt were varied (median distance: 1.45m, range: 1.3–62m). Almost half of all resting sites and holts (41.2%) were easily accessible to humans, especially in urban areas where a few *L. perspicillata* groups would sleep in a site visible to humans and that humans can walk up to. Most of the resting sites and holts were on or in man-made structures (76.5%). Focusing only on holts, all but one were in man-made structures. Examples of holts in man-made structures include gaps below a road, bridge, metal construction beams, or a building structure. There were at least two small entrances or one long entrance for all holts (holt entrance with the lowest height: 0.165m height by 1m length, largest holt entrance: 0.27m height by 0.35m length).

Distribution and habitat use

The distribution of *L. perspicillata* in Singapore and each group's MLHR is shown in Figure 3. Eight groups had distinct MLHR, while three groups had overlapping MLHR at two areas (Marina Bay and East Coast Park Area H). *L.*

perspicillata were recorded in a wide variety of aquatic habitats, including mangroves, coasts, reservoirs, rivers, and canals. However, they were not recorded in freshwater swamp forests and forested inland reservoirs (large waterbodies that are pre-dominantly surrounded by forests).

Table 1. Breakdown of the different *L. perspicillata* groups in Singapore as of 31 January 2017

No.	Group name	Habitat	No. of *L. perspicillata*				Group structure
			T	A	SA	P	
1	Lower Seletar (LS)	Reservoir	7	7	-	-	♂ + 1 litter*
2	Seng Kang (SK)	Canal, reservoir, river	5	2	3	-	♂ + 1 litter
3	Coney Island-Serangoon Reservoir (C)	Coast, reservoir, river	10	3	4	3	♂ + 2 litters
4	Pasir Ris-Changi (PR)	Coast, mangrove, river	7	5	2	-	♂ + 2 litters*
5	Tanah Merah (TM)	Coast, river	9	7	-	2	♂ + 2 litters*
6	Marina (M)	Canal, coast, reservoir	7	4	3	-	♂ + 2 litters
7	Bishan (B)	Canal, coast, reservoir	13	4	5	4	♂ + 3 litters
8	Sentosa (S)	Coast	7	3	4	-	♂ + 1 litter*
9	Ulu Pandan (UP)	Mangrove, reservoir, river	8	5	-	3	♂ + 2 litters
10	Jurong Lake (JL)	Reservoir	2	2	-	-	♂
11	Sungei Buloh (SB)	Mangrove	4	4	-	-	♂ + 1 litter*
	Total:		79	46	21	12	
	Percentage (%):			58.2	26.6	15.2	

Legend: T: Total, A: Adult, SA: Sub-adult (1 to 2 years old, determined based on records), P: Pups (<1 years old).
♂: Adult male and female pair.
*Assumed based on group size and structure

DISCUSSION

The largest group of 14 *L. perspicillata* recorded in Singapore is within the range of known group sizes for this species elsewhere, with the largest known group comprising of 16 individuals in River Palain of the Corbett Tiger Reserve, India (Nawab & Hussain, 2012). Groups with such sizes are also known for two other group-living and social otter species, *A. cinereus* and *Pteronura brasiliensis*, both of which can range up to 16 individuals per group, although not all individuals within a *P. Brasiliensis* group may be related (Wayre, 1978; Duplaix et al.., 2015; Groenendijk et al., 2015). This suggests that group sizes of *L. perspicillata* in Singapore resemble

those of wild groups as opposed to overpopulated groups, where overpopulated groups usually have an increased food supply (through provisioning by humans etc.) and/or reduced mortality rates (Hayward et al., 2007; Mátyás et al., 2015; Riley et al., 2015). In addition, the average group size of 7.2 *L. perspicillata* in Singapore is within the reported range of average group sizes of 2.25 to 10.25 in four rural sites in Malaysia and India (Shariff, 1984; Hussain, 1995; Nawab and Hussain, 2012).

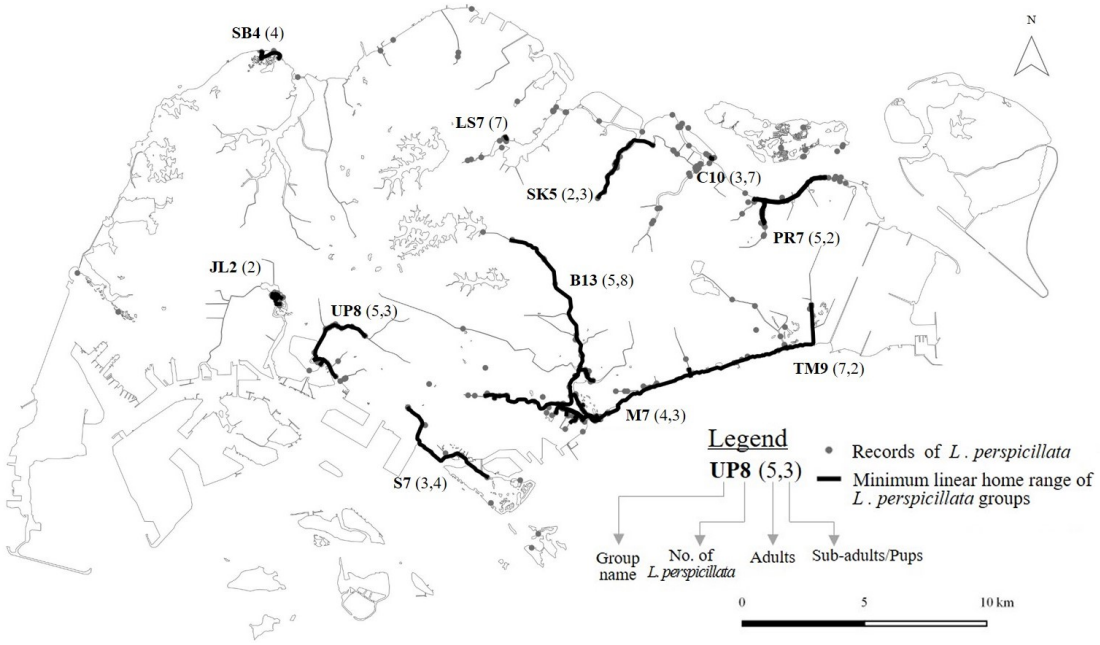

Figure 3. The population structure and distribution of *L. perspicillata* in Singapore (August 2016 to January 2017) based 9h 690 records.

The presence of 11 groups and at least 79 *L. perspicillata* is a positive comeback for the species in Singapore, considering that the species is listed as "Critically endangered" in the Singapore Red Data Book (Lim et al., 2008) and were absent from Singapore 20 years ago. This is also positive for the species, as they are listed as "Vulnerable" in the IUCN Red List of Threatened Species due to threats from habitat loss and persecution in other parts of its range (de Silva et al., 2015).

It is important to note that this six-month study only presents a snapshot of the true population of *L. perspicillata* in Singapore. This species is likely to be present in areas where data collection was not possible, based on past records of their presence (e.g. Western water catchment and western side of Pulau Ubin) (Theng and Sivasothi, 2016). The population count is likely to be an underestimate, as records in certain areas that were few and had inconsistency in group numbers (Woodlands, Sembawang, North-eastern side of Pulau Ubin) were not counted, to prevent overestimation. Also, the methodology used prevented the counting of lone *L. perspicillata* individuals as there was no methodology to differentiate lone otters from other groups.

Based on the current population number and structure, it is likely that the population will continue to increase but at a decreasing rate. The population will possibly increase because most *L. perspicillata* groups can still accommodate additional litters based on the known maximum recorded group size assuming prey is not a limiting factor. Also, increased sampling in restricted sites not covered by this study will likely document additional *L. perspicillata* groups. The rate of population increase will likely decline as most of the reservoirs and major waterways are already occupied, and mortality will likely increase due to intraspecific aggression between

groups and roadkills when *L. perspicillata* explore more areas to find suitable territories in a saturated landscape.

Distribution

L. perspicillata are territorial carnivores that do not tolerate the presence of another *L. perspicillata* group (Estes, 1989; Kruuk, 2006). While multiple groups of *L. perspicillata* have reportedly used the same stretch of river in Malaysia and India (Shariff, 1984; Nawab and Hussain, 2012), it is unclear if these groups did have overlapping territories. During this study, six accounts of intraspecific aggression between two *L. perspicillata* groups were recorded within overlapping territories. One of the aggression accounts resulted in the mortality of a five-month old pup. There have been limited accounts of intraspecific aggression between most species of otters apart from *P. brasiliensis* (Duplaix et al., 2015), and these were the first documented records for *L. perspicillata*.

Habitat use

The range of aquatic habitat types for *L. perspicillata* in Singapore, including mangroves, rivers, coasts, and reservoirs, is coherent with their habitat use in other countries (Hussain and Choudhury, 1995; Anoop and Hussain, 2004; Qamar et al., 2010; Omer et al., 2013; Abdul-Patah, 2014). However, this species was not observed in Singapore's freshwater swamp forests and forested inland reservoirs, although they do occur in similar habitats overseas (Abdul-Patah, 2014). For freshwater swamp forest, the absence of *L. perspicillata* is likely because there is only one remaining patch in Singapore (5km^2), of which the streams are relatively narrow and shallow compared to a typical river *L. perspicillata* uses. As for within forested inland reservoirs, this species was subsequently recorded in one locality after this study. Reasons for their absence initially are unclear, but could include lower prey availability or lower prey catch rate in these areas as compared to other habitats (Nawab and Hussain, 2012).

L. perspicillata are generally not known to be able to persist in urban environments (Kamjing et al., 2017), but this was found to be contrary in this study. In fact, this study have shown that this species have adapted to urban environments. This is evident based on four examples of spraint site characteristics, resting sites and holt characteristics, and habitat use. Firstly, they have adapted to use other substrates such as concrete and grass instead of the preferred choice of sand near spraint sites (Anoop and Hussain, 2004) for grooming, as sand is not common in urban environments. Next, the presence of many spraint sites, resting sites, and holts in areas with high human accessibility indicate urban adaptation, as *L. perspicillata* are generally known to prefer sites that are protected and secluded (Macdonald and Mason; 1983; Melquist and Hornocker, 1983; Anoop and Hussain, 2004; Prakash et al., 2012). Holts were recorded to be mostly in small gaps and crevices that are likely difficult for humans and other predators to enter. This supports the idea that having secure and undisturbed holts for resting is a key factor for *L. perspicillata* to establish in an area (Anoop and Hussain, 2004), and suggests that the location of the holt may not be as crucial to their survival as the protection that the holt provides. The third example of urban adaptation would be types of resting sites and holts recorded. Resting sites were known to be on open clay banks, while holts were known to be in natural rock crevices, among boulders, dug under or between roots of trees, or inside vegetation (Shariff, 1984; Hussain and Chodhury, 1995, Anoop and Hussain, 2004; Theng and Sivasothi, 2012; Sutaria and Balaji, 2013). In contrast, most resting sites and holts in this study were found in man-made structures like the gaps under bridges,

under metal beams and under roads. Such holts have never been recorded for *L. perspicillata*, although other species of otters such *P. brasiliensis*, *Lontra canadensis* and *Lutra lutra* were recorded using similar structures as holts (under bridges, in canals, in buildings, in piers etc.) (Chanin, 2003; Sleeman and Moore, 2005; N. Duplaix, personal communication). The last example of urban adaptation is the use of stairs and ladders to access dry land in concrete canals with steep sloping walls, a habitat that *L. perspicillata* are not usually associated with. While the use of stairs had been documented for *L. lutra* in a similar highly urbanised environment, in the urban centre of Cork, Ireland (K. Loxton and P. Sleeman, personal communication), the use of ladders recorded in this study is likely the first for *L. perspicillata*. As such, the ability of *L. perspicillata* to adapt, survive and reproduce in such highly urban environments means that they can be classified as urban adapters, which are defined as species that can "adapt to urban habitats but also utilize natural resources" (McKinney, 2006).

MANAGEMENT AND CONSERVATION

With the increased *L. perspicillata* population over the years, coupled with the decrease in their proximity to humans due to their presence in urban environments, human-otter interactions are inevitable. Two types of human-otter interactions with the potential to escalate into serious conflicts have already occurred. They include the raiding of private fish ponds by *L. perspicillata* and *L. perspicillata* road kills. Such interactions are major causes of persecution and decline of otter populations in many countries (Coffin, 2007; Jancke and Giere, 2011; Nawab and Hussain, 2012; Bohm et al., 2013; Poledníkov et al., 2013). Hence, there is a need to examine and consider mitigation measures so as to prevent the escalation of interaction to conflict. In response to this, the Otter Working Group, consisting of multiple parties including government agencies, educational institutions, members of public and non-government agencies, was formed in 2016 with the aim of working towards the management and conservation of otters in Singapore using a multi-stakeholder, multi-disciplinary approach. It is also fortunate that *L. perspicillata* is largely well-liked by Singaporeans, evident by the fact that the most famous *L. perspicillata* in Singapore that lives in the city centre was crowned Singapore's fifty-first icon via online polling (Lee, 2016).

Based on this study, it is evident that urbanization and presence of otters in the city is not necessarily a zero-sum game. With the proper conditions, *L. perspicillata* can thrive even in a highly urbanized city like Singapore. With this, Singapore can be used as a model biophilic city to guide otter-friendly urban design in emerging cities around the region that want to plan for otters in their urban areas, and for developed cities currently devoid of otters to see how they can improve current habitats to attract otters back.

CONCLUSION

This study showed that *L. perspicillata* are urban adapters, and the population in Singapore consist of at least 11 groups with 79 individuals. Group sizes of *L. perspicillata* here are within the reported range of group sizes in other countries. Overall, the population of *L. perspicillata* will likely increase but at a decreasing rate. Moving forward, further population studies should be conducted to monitor and better understand the population trends of *L. perspicillata*, ideally covering restricted areas that were not accessed during this study, or using genetic methods.

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RÉSUMÉ

STRUCTURE DE LA POPULATION, DISTRIBUTION ET UTILISATION DE L'HABITAT DE LA LOUTRE À PELAGE LISSE, *Lutrogale perspicillata*, À SINGAPOUR

La population et la distribution de la loutre à pelage lisse (*Lutrogale perspicillata*) à Singapour a augmenté depuis son retour en 1998, mais sa structure de population, sa distribution et l'utilisation de l'habitat n'ont pas été quantifiées. Une vaste étude de terrain au niveau national (relevés sur terre et en bateau, utilisation de pièges photos) comportant 15 sites, couplée à la récolte d'informations auprès du public sur *L. perspicillata*, a été menée durant 6 mois (de août 2016 à janvier 2017). L'étude actuelle révèle la présence d'au moins 79 individus comprenant 11 groupes à Singapour.

La population de loutre à pelage lisse de Singapour a cru depuis que le premier couple a été réintroduit en 1998. Elle comporte actuellement 58,2 % d'adultes et 41,8 % de subadultes ou loutrons. La taille moyenne d'un groupe est de 7,2 individus avec des groupes allant de 2 à 14 individus. *L. perspicillata* occupe une grande variété d'habitats aquatiques incluant des mangroves, des côtes, des réservoirs, des rivières et des canaux. Elles se sont adaptées à des structures urbaines, ont survécu et se sont reproduites dans un environnement urbain, ce qui démontre qu'elles peuvent s'intégrer au milieu urbain.

RESUMEN

ESTRUCTURA POBLACIONAL, DISTRIBUCIÓN Y USO DE HÁBITAT DE NUTRIAS LISAS *Lutrogale perspicillata* EN SINGAPUR

La población y la distribución de las nutrias lisas (*Lutrogale perspicillata*) en Singapur han aumentado desde su retorno en 1998, pero su estructura poblacional, distribución y uso del hábitat no han sido cuantificados. Condujimos un estudio de campo a lo largo de todo el país (relevamientos terrestres, en bote, y con cámaras-trampa) en 15 sitios, además de colectar registros de L. perspicillata a partir del público; dudrante seis meses (Agosto 2016 a Enero 2017). Este estudio revela al menos 76 individuos en Singapur, de 11 grupos. La población en Singapur está creciendo, y consiste en 58.2 % adultos y 41.8 % sub-adutos o crías. El tamaño promedio de grupo es 7.2, con grupos que van desde 2 hasta 14 individuos. L. perspicillata ocupa una amplia variedad de hábitats acuáticos, incluyendo manglares, costas marinas, lagos artificiales, ríos, y canales. Se han adaptado a usar estructuras urbanas, y han sobrevivido y se han reproducido en ambientes urbanos.