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Rapid urbanisation in Singapore causes a shift from local provisioning and regulating to cultural ecosystem services use

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ABSTRACT

Ecosystems support and enhance human life through providing ecosystem services. The use of ecosystem services changes over time, as environmental conditions and people's lifestyles change. Urbanisation is an extreme form of environmental change that can be expected to drastically alter the use of ecosystem services. We analysed people's childhood memories to quantify temporal changes in indicators of 11 ecosystem services in Singapore – a country which has rapidly urbanised over the past 70 years. We performed semi-structured interviews to elicit indicators of ecosystem service use from memories of childhood lifestyles and activities, comparing two groups of respondents; those born before 1960, and those born between 1989 and 1999. The two respondent groups recalled significantly different uses of ecosystem services, with a higher proportion of the pre-1960 respondents benefitting from locally-produced provisioning and regulating services, and a higher proportion of 1989–1999 respondents using most cultural services. This study thus demonstrates that urbanisation can decrease people's reliance on local ecosystems to provide raw materials, while leading to greater appreciation of cultural benefits. Management of ecosystem services in the present must consider the possibility that supply and demand of future ecosystem services may change in potentially unpredictable ways.

1. Introduction

Nature provides many benefits, or "ecosystem services" to people (Daily, 1997; Millenium Ecosystem Assessment, 2003). These ecosystem services include the provision of food, fuel, and building materials, regulation of environmental temperatures and flood risk, and numerous recreational and cultural heritage benefits (Bolund and Hunhammar, 1999; Millenium Ecosystem Assessment, 2003). The use of ecosystem services and their appreciation by people has changed over time, driven by changes in ecosystems, people's livelihoods, lifestyles, and priorities (Friess, 2016; Jiang et al., 2013; Thiagarajah et al., 2015; Tomscha et al., 2016). Some ecosystem services that were important in the past may be considered to be less important today, and vice versa (Renard et al., 2015). Temporal changes in ecosystem services may be particularly notable in cases of extreme environmental and social change, such as during the process of urbanisation (Friess, 2016). However, our understanding of urbanisation-driven changes in ecosystem service use and appreciation is limited, as historical data on ecosystem services can be sparse or complex to reconstruct (Tomscha et al., 2016).

Urbanisation incurs major environmental changes, such as biodiversity losses (Aronson et al., 2014; Seto et al., 2012a), elevated temperatures caused by the urban heat island effect (Manoli et al., 2019), and increased flood risk (Gupta, 2002; Ziegler et al., 2012). Many of these changes occur due to losses of natural and semi-natural habitats, and the ecosystem services that they provide. For example, the loss of vegetation cover may cause services such as water flow regulation to be substantially reduced, which can increase urban flood risk (Gupta, 2002). Conversely, new ecosystem services may be provided by urban ecosystems; urban parks and gardens can create novel recreational experiences that differ from those provided by pristine ecosystems (Donahue et al., 2018). In addition to causing major environmental changes, urbanisation also causes drastic changes in the way that people live (Delisle et al., 2012). New urban residents typically alter their diets and consume less home-grown food, although they may maintain some dietary linkages to rural lifestyles (Maruapula et al., 2011; Padoch et al., 2008). Hence, while urban residents are still ultimately dependent on ecosystem services to provide the food and raw materials that support society, these services are generally provided in rural areas rather than within cities (Tan et al., 2020). Finally, urbanisation impacts cultural ecosystem services such as recreation and spiritual relationships with

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nature (Thiagarajah et al., 2015). The period of rapid global urbanisation over the past 70 years has seen a simultaneous decrease in many types of outdoor activity (Pergams and Zaradic, 2008), resulting in an "extinction of experience" of nature and biodiversity (Miller, 2005). This loss of contact with nature has been shown to have had negative impacts on health and well-being (Soga and Gaston, 2016). Urbanisation therefore impacts both the supply and demand of individual ecosystem services. At the aggregate level, this may be observed as a temporal change in the "bundles" of ecosystem services that co-occur (Renard et al., 2015).

Quantification of historical ecosystem services often necessitates the use of unconventional data types to reconstruct some understanding of past supply and demand (Tomscha et al., 2016; Vellend et al., 2013). Previous work on historical changes in ecosystem services has inferred past service values from archived map data (Jiang et al., 2013; Renard et al., 2015), fisheries and agricultural records (Renard et al., 2015; Selim et al., 2014), and biodiversity data (Jiang et al., 2013). Additionally, paleoenvironmental approaches have been used to reconstruct historical landscapes and infer their ecosystem service provision (Dearing et al., 2012; Jeffers et al., 2015). The use of these historical datasets can provide a high-level perspective of temporal changes in ecosystem services, but is constrained in providing insights into changes in the use and appreciation of ecosystem services at a more personal level. Furthermore, paleoenvironmental reconstructions, historical maps and quantitative records tell us mainly about provisioning services that were recorded for their economic importance in the past (Renard et al., 2015; Selim et al., 2014), or regulating services that can be inferred from land cover changes (Dearing et al., 2012; Jeffers et al., 2015; Stevens and van Wesemael, 2008). Archive data are less informative about the less tangible benefits that nature provides, such as recreational values and cultural heritage (Thiagarajah et al., 2015).

People's memories of past conditions can be an unconventional yet powerful tool for investigating environmental changes over periods of 30–50 years (Bunce et al., 2008; Turvey et al., 2010). Previous work has surveyed people from different age groups about their memories of the past, to understand changes in indicators of biodiversity (Papworth et al., 2009), provisioning ecosystem services (Bunce et al., 2008; Mouri et al., 2013; Turvey et al., 2010), and regulating services (Mouri et al., 2013). There is also a literature using retrospective surveys to quantify memories of childhood lifestyles and activities, including outdoor play (Havari and Mazzonna, 2015; Hosaka et al., 2017; Skår and Krogh, 2009). Memories of the past are commonly elicited from the public in oral history research (Seng, 2009a; Xiong and Brownlee, 2018), for example to analyse historical health indicators and living conditions (Havari and Mazzonna, 2015; Kendig et al., 2014).

In this study we investigated changes in the use of 11 ecosystem services following 30–50 years of rapid urbanisation that has occurred in Singapore. We compared people's childhood memories of ecosystem services between two respondent groups; those born before 1960 (referred to as the "pre-1960 respondents"), and those born between 1989 and 1999 (referred to as the "1989–1990 respondents"). We used semi-structured interviews to elicit memories of ecosystem service use by the respondents and their families by asking them about their lifestyles when they were 10 years old. The specific objectives of the study were to (1) quantify differences in the use of individual ecosystem services over time, and (2) identify bundles of ecosystem services used by respondents' and their families during their childhoods.

2. Methods

2.1. Study area and overview of modern Singapore (1965–2019)

Singapore is a tropical city-state located in Southeast Asia, and has one of the most highly-developed economies and standards of living in the world (Lim, 2015). The nation has urbanised rapidly since the 1950s, with 100% of the population now defined as "urban" (United Nations, 2018). The population has also grown rapidly, with an increase from around 1 million people in 1950 to well over 5 million by 2010 (Fig. 1). This period of urban development has witnessed substantial economic changes, with a shift from plantation-based agriculture to manufacturing around 1965, and a focus on financial services in the late twentieth century (Wee, 2001). Throughout the process of urbanisation, the residents of rural villages were gradually evicted and re-housed in high-rise government apartments (Seng, 2009b). The urbanisation of Singapore has led to substantial changes in diet and lifestyle (Wei, 2000), and significant environmental impacts such as habitat and biodiversity loss (Lai et al., 2015; Sodhi et al., 2004). The rapid rate and magnitude of the changes in Singapore's environment and population make it an exemplary case study for urbanisation-driven temporal change in ecosystem services (Friess, 2016; Thiagarajah et al., 2015).

2.2. Singapore in the 1940s–1960s

Singapore in the 1940s, 1950s, and 1960s was less urbanised than it is today, but was nonetheless a major trading hub and one of the most economically advanced cities in Asia (Huff, 1995). Around 70% of the population in 1951 lived in or around the urban region (Fraser, 1952); typically in terraced shophouses, public housing apartments built by the government (Seng, 2009a; Teo and Savage, 1985), or informal "kampong" settlements built mainly from corrugated tin and natural materials (Teo and Savage, 1985). While built adjacent to the urban area, many informal settlements were peri-urban in character, with their residents living a partially rural lifestyle (Seng, 2009a; Teo and Savage, 1985; Xiong and Brownlee, 2018). Robust data on the number of people living in these peri-urban informal settlements does not exist, but it was estimated in 1962 to be 250,000 people, or about 15% of the total population (Teo and Savage, 1985). The remaining 30% of the total population lived in rural "kampong" settlements, dispersed across Singapore's islands (Fraser, 1952; Thiagarajah et al., 2015). About 35% of the land area was under agricultural use in 1950, with a further 30% forested (Corlett, 1992). The comparison between memories from pre-1960, and 1989–1990 Singapore respondents is therefore not a comparison between a purely rural and purely urban case, but between two samples of a society at different stages along the gradient of urbanisation.

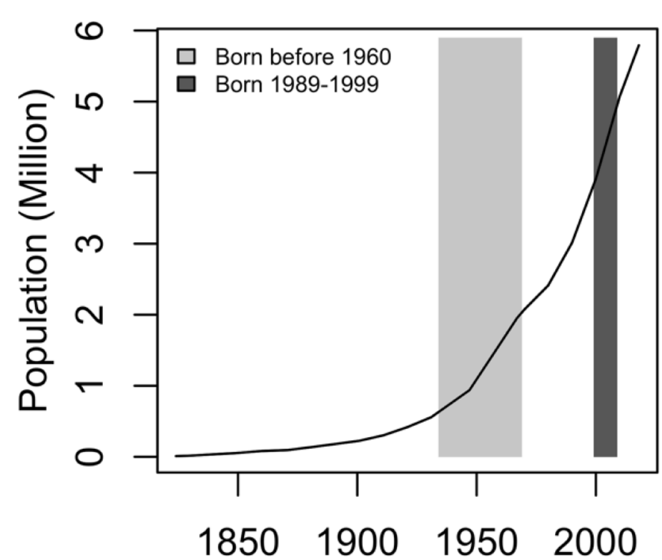

Fig. 1. Historical population growth in Singapore. Data prior to 1967 are from Saw (1969), while data from 1969 to 2018 are from Singapore's Department of Statistics (2019). Grey sections indicate periods of interest for the study, corresponding to the periods in which the respondents were aged 10 years old. The two shaded areas reflect the time periods at which the respondent groups were aged 10 years old.

2.3. Ecosystem services framework

Ecosystem services can be categorised in multiple ways, pending the choice of published framework (Díaz et al., 2018; Fisher et al., 2009; Haines-Young and Potschin, 2011; Maes et al., 2016; Millenium Ecosystem Assessment, 2003). These frameworks typically classify ecosystem services from the perspective of the decision-maker (Fisher et al., 2009), while individual people may perceive ecosystem services and obtain their benefits differently (Flint et al., 2013; Haines-Young and Potschin, 2009; Olander et al., 2018). In this study, we identified key benefits that people might be expected to receive from nature, such as drinking water or nature recreation (Table 1). The surveys conducted with members of the public related to their use or receival of these benefits provided by ecosystem services. For comparison with other studies, we then linked the individual benefits gained from ecosystem services to their corresponding ecosystem service types, following the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2011). The broad CICES divisions partition ecosystem services between "provisioning", "regulating and maintenance", and "cultural" categories, with subsequent division into a finer-scale typology (Haines-Young and Potschin, 2011). The divisions associated with each of our indicators are given in Table 1, alongside the four-digit CICES codes for some of the most relevant finer-scale categories of ecosystem services (Haines-Young and Potschin, 2011).

When discussing differences in ecosystem services use between the pre-1960 and 1989–1999 respondents, we made comparisons firstly at the level of individual ecosystem service indicators. Secondly, we synthesised how urbanisation has impacted the use of broad groups of ecosystem services, according to the provisioning, cultural, and regulating and maintenance categories outlined by CICES (Haines-Young and Potschin, 2011). The definitions between these different categories are not always clear-cut, as a single activity can be associated with provisioning, regulating, and cultural benefits (Díaz et al., 2018). For example, recreational fishing may be primarily enjoyed for cultural reasons, but will often also result in provisioning contributions, in the form of fish that can be eaten. We defined the service indicators into the broad category that best describes their primary benefit to people in this context. We appreciate that all of the service indicators may however be simultaneously providing components of provisioning, regulating and maintenance, and cultural services, and that the ecosystems providing these services may be valued by the respondents for a range of intrinsic, instrumental, and relational reasons (Pascual et al., 2017).

Table 1
List of ecosystem service benefit indicators, categories according to relevant CICES categories, CICES codes, and definition used in coding. Please refer to Supplementation Information Table S1 for an extended list of guiding questions used during semi-structured interviews, and example responses.

	Benefit received by respondents	Ecosystem service class (CICES codes)	Indicators used in coding
a	Water provision	Provisioning (4.2.1.2)	Lived in accommodation type without piped running water, and used well or natural spring water.
b	Natural materials	Provisioning (1.1.5.2)	Lived in accommodation built partially from natural materials e.g. wood, bamboo, palm thatch.
c	Domestic animals – provisioning	Provisioning (1.1.3.1)	Family kept domestic animals for food consumption, medicinal use, or labour.
d	Domestic plants – provisioning	Provisioning (1.1.1.1)	Family kept plants at home for food consumption, medicinal use, or fuel.
e	Domestic animals – cultural	Cultural (3.1.2.3; 3.1.2.4)	Family kept domestic animals for companionship.
f	Domestic plants – cultural	Cultural (3.1.2.3; 3.1.2.4)	Family kept plants at home for ornamental or spiritual reasons.
g	Hunting/fishing recreation	Cultural (3.1.1.1; 3.1.1.2)	Family or individual captured wild animals for recreational reasons, e.g. fishing or collecting invertebrates.
h	Nature recreation	Cultural (3.1.1.1; 3.1.1.2)	Family or individual engaged in outdoor photography or wildlife watching.
i	Folk stories	Cultural (3.1.2.3)	Individual recalled at least one nature-related myth.
j	Learning from nature	Cultural (3.1.2.2)	Individual recalled at least one experience of learning about nature or the importance of nature.
k	Temperature regulation	Regulation and maintenance (2.2.6.2)	Individual cooled themselves during hot weather by visiting windy locations or tree shade, swimming in a river or the sea, or using a hand fan made from natural materials.

2.4. Sampling approach

A total of 249 surveys were conducted between May 2019 and August 2019. This sample comprised 150 pre-1960 respondents, and 99 respondents from 1989 to 1999. We conducted household surveys in public housing estates because approximately 80% of Singaporeans live in high-rise public housing apartment blocks (Singapore Department of Statistics, 2019). We stratified our sampling across two types of estates to increase the probability of sampling the target respondent age groups. For the pre-1960 age group, seven estates were selected randomly from a list of planning areas where at least 15% of the resident population were 60 years old and above (Singapore Department of Statistics, 2019). These seven estates were Outram, Bukit Merah, Queenstown, Bedok, Rochor, Marine Parade, and Serangoon. For the 1989–1999 age group, seven estates were chosen randomly from a list of estates constructed after 2000, as these were more likely to have been bought by people from the target age group (Housing Development Board, 2015). These seven estates were Bukit Merah, Queenstown, Dawson Road, Punggol, Tampines, Buangkok, and Woodlands. Within each estate, we randomly selected five apartment blocks to deliver the survey. If the chosen building was multi-storied, then one storey was randomly selected as the starting point to deliver the door-to-door survey. The surveyors approached all households present on that storey, and continued this strategy for all subsequent storeys until the entire building was completed. Surveys were administered between approximately 9 am to 5 pm on weekdays, and each survey was delivered in either English, Mandarin Chinese, or Chinese dialects, depending on the preference of the respondent. The survey was administered to only one resident per household, with each respondent being at least 20 years of age. Respondents from both age groups were surveyed as encountered, regardless of target age group of the estate. Where door-to-door surveys were not successful in finding suitable respondents, the surveyors approached residents in public spaces surrounding the apartment block. To prevent biased sampling from some estates, we ensured that no more than 25 responses were collected from each estate. Due to difficulties finding sufficient respondents in the 1989–1999 sample group, some respondents in this group were approached at public transport stations ($n = 28$).

2.5. Survey design and implementation

Respondents in retrospective lifestyle surveys can recall their health and living conditions reasonably well (Havari and Mazzonna, 2015; Kendig et al., 2014). However, the use of memories as a source of data on historical ecosystems is not without limitations, as respondents may suffer from recall bias when trying to remember their thoughts and feelings from several decades ago (Hyman et al., 1995). Carefully selecting the type of information collected, the format of the survey, and the phrasing of the questions can help to limit the effects of recall bias (Bowling, 2005; Connor Desai and Reimers, 2019).

To reduce the potential effects of recall bias, we used face-to-face semi-structured interviews to ask respondents about their childhood lifestyles (Bowling, 2005; Connor Desai and Reimers, 2019; Havari and Mazzonna, 2015). We asked open-ended questions rather than closed-response questions as it allowed us to capture a wide array of outcomes. We asked questions about the use of a suite of ecosystem services, either directly by the respondents or by their immediate families (defined as people living in the same home). We specifically instructed respondents to anchor their responses to their childhood, from the time when they were approximately 10 years old (Kendig et al., 2014; Loftus and Marburger, 1983).

A list of guide questions was used to elicit indicators of use or appreciation of four provisioning ecosystem services, one regulating ecosystem service, and six cultural ecosystem services (Table 1). Some indicators, such as the use of natural building materials or local natural drinking water sources, could be quantified objectively (Table 1). Other indicators required some explanation and may be influenced by the opinion of the participants – for example, to determine whether they remembered learning "about nature or about the importance of nature" (Table 1). In coding the responses to this part of the interview, we included experiences related to both formal scientific knowledge (such as learning the names of plants and animals, or about climate change), and informal knowledge (such as learning gardening or fishing skills). We did not include learning experiences that took place in nature but were not directly connected to it – for example learning experiences related to social structures and how to form relationships, or life skills such as learning to take smaller risks when gambling. While these additional learnt experiences are valuable to the respondents and highlight the importance of nature as a backdrop for many of people's important life moments (Chang et al., 2020), we considered only educational experiences directly generated environmental knowledge, in order to link more closely to existing ecosystem service frameworks. The responses to all parts of the survey were coded to generate binary indicators for the use of each ecosystem service by each respondent (Table 1). In addition to the indicator questions, the age group and gender of each respondent was asked and recorded. Participants gave informed consent to take part in the survey and the methodology received approval from the ETH Zurich Ethics Commission (EK 2019-N-56).

2.6. Data analyses

To investigate whether there were temporal and socio-demographic differences in ecosystem service use at the individual level, we extracted binary indicators of the 11 ecosystem services from the responses to the semi-structured interview questions (Table 1; Table S1). As binary responses, these indicators were coded as whether the respondent recalled using the particular ecosystem service (coded as 1) or not (coded as 0). These quantitative ecosystem service indicators were modelled using generalised linear models with a binomial error structure in cases where the proportion of respondents using the ecosystem service was not zero in either age group. For indicators where the proportion of respondents using the ecosystem service was zero in one or both age groups, we used Firth's Bias-Reduced Logistic Regression generalised linear models. These models avoid non-convergence due to perfect separation (Heinze et al., 2018; R Core Team, 2017). Due to the multiple comparisons made here, p values were adjusted prior to assessing significance following Benjamini and Hochberg (1995). We fitted a separate generalised linear model for each ecosystem service indicator separately, and included the respondent's age group and gender as candidate explanatory variables. Gender was included alongside age group to assess possible confoundment due to unequal gender representation in the two samples. The models were then simplified using AIC as the simplification criterion.

To investigate whether there were temporal differences in "bundles" of ecosystem service use, we used ordination to cluster the suite of 11 ecosystem service use indicators reported by respondents (Raudsepp-Hearne et al., 2010; Renard et al., 2015). Due to the binary nature of the data, multiple correspondence analysis (MCA) was used as the form of ordination, implemented through the FactoMiner package for R (Lê et al., 2008; R Core Team, 2017). First, the individual respondents' MCA scores were plotted to visually compare the distribution of the pre-1960 and 1989–1999 respondents along the first two MCA component axes. Second, the factor loadings of the ecosystem service indicators were plotted to indicate the trade-offs and synergies between services.

3. Results

3.1. Sample demographics

The pre-1960 respondents had a mean year of birth of 1949, and the oldest respondent was born in 1924 (Table 2). Contrastingly, the mean year of birth among the younger age group was 1995 (Table 2). Both respondent groups were similar in gender ratio, but differed in ethnic representativeness; the 1989–1999 age group had a similar proportion of Chinese respondents to the modern census; currently 76% (Table 2). In contrast, the pre-1960 group had a higher Chinese proportion (Table 2). As expected given previous knowledge of the housing environment and human development in Singapore in the 1950s and 1960s, a higher proportion of pre-1960 respondents lived in informal settlement houses during their childhoods, and did not have Secondary school-level or higher educational qualifications (Table 2).

3.2. Temporal differences in use of individual ecosystem services

When reporting their childhood lifestyle experiences, the pre-1960 respondents were significantly more likely than the 1989–1999 respondents to report the use of naturally-supplied drinking water by their families, use of natural materials in home construction, keeping of animals for provisioning purposes, engagement in hunting, fishing, or animal capture for recreation, and the use of nature for temperature regulation (Fig. 2; Table S2). Conversely, the 1989–1999 respondents were significantly more likely than the pre-1960 respondents to report keeping animals or plants at home for cultural service benefits, learning nature-related folk stories, and learning either facts about nature or the value of nature (Fig. 2; Table S2). There was no significant difference between age groups in the proportion of respondents whose families kept plants at home for provisioning service benefits, and who engaged in nature recreation (Fig. 2; Table S2). The control variable of gender was retained as a significant predictor for four models, indicating that males were significantly more likely to report use of natural materials in home construction, engagement in hunting, fishing, or animal capture for recreation, use of nature for temperature regulation, and learning either facts about nature or the value of nature (Table S2).

Table 2
Summary statistics of demographics from the two age groups. Number of respondents was 150 for the born before 1960 group, and 99 for the born between 1989 and 1999, unless indicated in parentheses.

Demographic indicator	Born before 1960	Born 1989–1999
Proportion female	0.49	0.51
Proportion Chinese ethnicity	0.90	0.73
Proportion interviews conducted in Mandarin Chinese or Chinese dialects	0.63	0.01
Proportion living in informal settlements at age 10	0.56	0.00
Proportion living in apartments	0.28	0.96
Proportion with Secondary school level education or higher	0.35	0.99
Mean year of birth	1949 (n = 150)	1995 (n = 99)
Oldest year of birth	1924	1989
Most recent year of birth	1959	1999

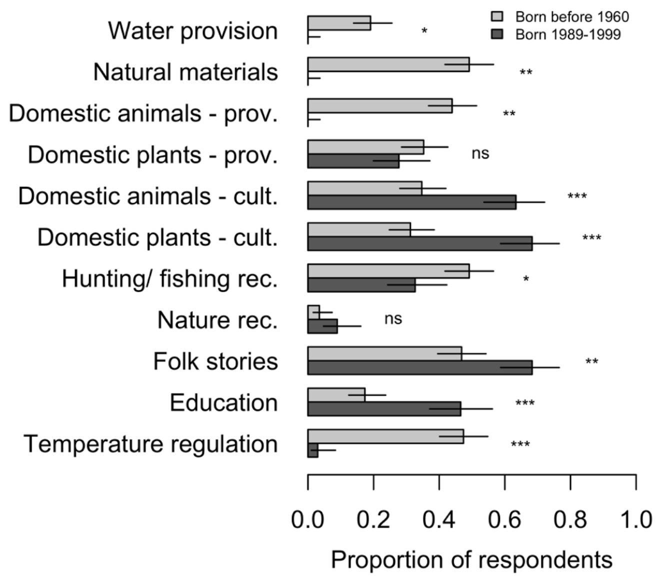

Fig. 2. Proportion of respondents indicating the use of 11 ecosystem service indicators, either personally or by their immediate families, during their childhoods. Error bars indicate binomial 95% confidence intervals. Comparison between the age groups was made by generalised linear models with binomial errors, with model coefficients shown in Table S2. One, two, and three asterisks (*) indicate statistical significance of the difference between the two age groups at the $p < 0.05$, $p < 0.01$, and $p < 0.001$ levels respectively; "ns" Indicates no significant difference. Abbreviations: "prov." = "provisioning", "cult." = "cultural", "rec." = "recreation". Table 1 provides a description of these indicators, which is elaborated in Table S1.

3.3. *Temporal bundles of ecosystem services*

The MCA analysis revealed two main clusters of ecosystem services across the time period, corresponding to bundles of ecosystem services (Fig. 3). The study respondents were strongly partitioned across dimension 1 of the MCA, with the pre-1960 respondents showing a positive association with this dimension and 1989–1999 respondents showing a negative association (Fig. 3a). The ecosystem services were partitioned across dimensions 1 and 2, with the regulating service and most provisioning services positively associated with Dimension 1, and most cultural services negatively associated with Dimension 2 (Fig. 3b). Provisioning and regulating services were more typically used by the pre-1960 respondents, while the cultural services were more typically used by the 1989–1999 respondents (Fig. 3).

4. Discussion

4.1. *Decline in use of locally-provided provisioning and regulating ecosystem services following rapid urbanisation*

The shift in use from provisioning and regulating, to cultural ecosystem services among the 1989–1999 respondents is consistent with the theory that urbanisation reduces the direct reliance of people on local ecosystems to provide basic human needs (Ferreira et al., 2019). Through the process of urbanisation, teleconnections supply basic provisioning needs to urban residents, thus decoupling the extraction of natural resources from the locations where they are consumed (Haberman and Bennett, 2019; Seto et al., 2012b). A substantial proportion of pre-1960 respondents made use of local natural building materials in their homes, such as bamboo, wood, and attap – a product of mangrove palm (*Nipa fruticans*) that was commonly used for thatch (Cheng, 1990). Similarly, many pre-1960 respondents kept chickens, ducks, or fish for food provision, and one respondent recalled the family keeping a water buffalo as a source of labour (Table S1). The use of natural water sources such as wells was also significantly more common among the pre-1960 respondents (Fig. 2; Table S2).

As Singapore's economy has become focused on manufacturing and service industries, fewer people have been directly employed in primary industries (Wee, 2001), and rising incomes have reduced the need for people to supplement their diets with home-grown food (Waller, 1997; Xiong and Brownlee, 2018). Simultaneously, the sustained government effort to replace informal settlements with concrete apartments has reduced the prevalence of natural materials in home construction (Seng, 2009c). While there was no significant difference in the proportion of respondents keeping plants at home for provisioning purposes, there was a qualitative difference in both the type of plants kept, and the quantity grown. Some pre-1960 respondents recalled having gardens with fruit trees and vegetables, while the scale of urban agriculture recalled by the 1989–1999 respondents was much smaller; typically edible herb plants grown on balconies or inside apartments (Table S1). It is therefore likely that 1989–1999 respondents did not rely heavily on home-grown plants for nutrition, but grew plants as additional luxury

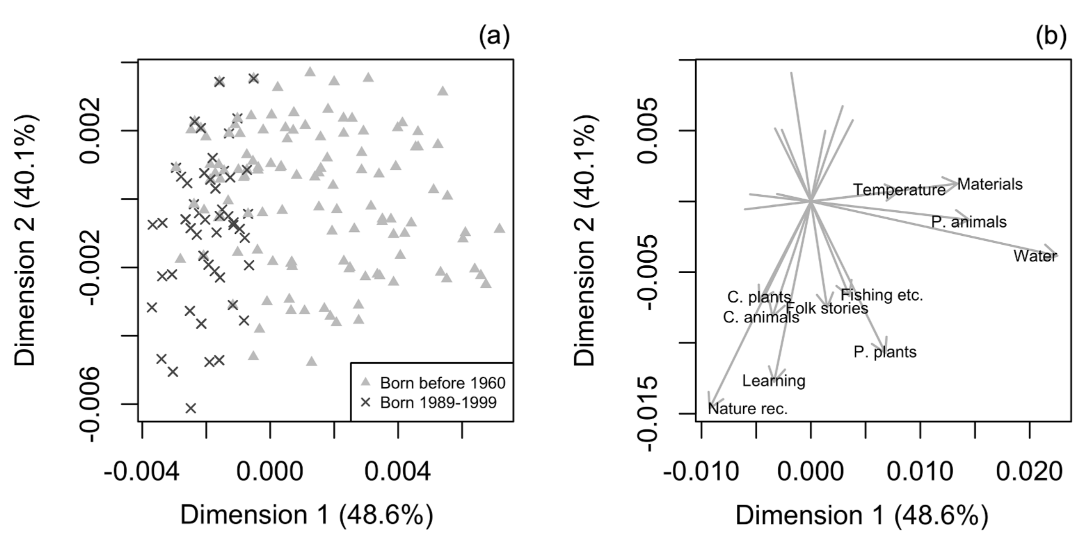

Fig. 3. Multiple correspondence analysis (MCA) of reported ecosystem service use during childhood. (a) Plot of respondents in MCA space, highlighting a division of the two sample groups along Dimension 1. (b) The factor loadings for the MCA indicate two bundles of ecosystem services - mainly provisioning and regulating services with high Dimension 1 scores, and mainly cultural services with low Dimension 2 scores. Abbreviations: "P." = "provisioning", "C." = "cultural", "rec." = "recreation", "Fishing etc." indicates "Hunting/ Fishing recreation" in Table 1. Description of indicators given in Table 1 and elaborated in Table S1.

complements to their diets. The results of our social study are supported by ecological research in Singapore; the historical social norm of growing fruit trees for provisioning purposes has been documented through vegetation surveys of secondary forests that have grown up in abandoned low-density settlements (Neo et al., 2012). In many of these secondary forests, fruit trees such as longan (*Dimocarpus longan* Lour), rambutans (*Nephelium lappaceum* L.) and durian (*Durio zibethinus* L) remain common (Neo et al., 2012). In contrast, plant surveys of high-density residential buildings in 2018 in Singapore reported a dominance of shrubs over trees plant forms (e.g. Pomegranate (*Punica granatum* L.); Curry plant (*Bergera koenigii* L.) (Oh et al., 2018).

The pre-1960 respondents made use of a range of natural products and ecosystems for temperature regulation, including swimming in rivers or the sea during hot weather, sitting under shade trees, and making fans from leaves, wood, or paper (Table S1). In contrast, modern Singapore has a greater reliance on technology and built infrastructure for temperature regulation (Salvo, 2018), with 1989–1999 respondents using air conditioning at home, or moving to public air-conditioned spaces such as malls, during hot periods (Table S1).

4.2. Increasing trends in use of most cultural ecosystem services

Previous work has highlighted that people's use and appreciation of cultural ecosystem services can change following urbanisation (Jaligot et al., 2018; Thiagarajah et al., 2015). The only cultural service that was recalled more commonly by the pre-1960 respondents was the capture of animals for recreational purposes (Fig. 2; Table S2). In some cases, this referred to recreational fishing activities, but more commonly residents described play-hunting and capture of invertebrates for fun, to keep as pets, or for gambling activities (Table S1). The change in use of this ecosystem service therefore reflects a changing pattern in children's play, from outdoor and unstructured play to more indoor play and structured games. This is consistent with non-tropical studies of childhood play, which have shown that children's use of nature areas near their homes has changed substantially from being spontaneous and self-initiated to being part of planned, organised and adult-controlled activities (Skår and Krogh, 2009) or to activities which are more technology-centred (Larson et al., 2011).

The higher use and appreciation of cultural ecosystem services amongst the 1989–1999 respondents reflects a perception of nature as something separate from the city that must be visited and enjoyed, rather than something that is a part of people's day-to-day lives (Thiagarajah et al., 2015). The pre-1960 respondents may have been unaware of many of the facts that they know about nature, as this knowledge is such an integral part of their experience. Given the greater importance of natural materials and food sources among the pre-1960 respondents, and their greater likelihood of engaging in recreational hunting and fishing, it is possible that the pre-1960 respondents actually held more informal ecological knowledge than they reported. However, the higher reported frequency of nature-related learned experiences among the 1989–1999 respondents also reflects higher overall education levels in the population (Table 1) as well as the curricular priority that Singapore schools now place on scientific and environmental education (Kwan and Stimpson, 2010). Even if the 1989–1999 respondents spend less time outdoors, even short field visits to nature can provide substantial learning benefits, particularly when formally led by educational staff (Friess et al., 2016). Although not a statistically significant difference, nature recreation was more commonly associated with the 1989–1999 respondents (Fig. 2; Fig. 3). Bird watching and nature photography have become popular hobbies since the 1980s in Singapore, with small but active communities (Wee and Tsang, 2008).

The 1989–1999 respondents were more likely to keep plants and animals at home for ornamentation and companionship respectively (Fig. 2; Table S2), despite the fact that modern apartments have less available space, and some restrictions on pet ownership (Chan, 2016; Cheng, 1990; Oh et al., 2018). Singapore before 1960 was generally less wealthy than in 1989–1999 (Huff, 1995), and Singaporeans typically had larger families before 1960 (Singapore Department of Statistics, 2010). An increase in free time and disposable income may facilitate pet ownership (Martins et al., 2013), and people living alone or with one other person are significantly more likely to keep companion animals in Hong Kong (Wong et al., 2019). Alternately, it may be that people feel an innate "biophilia", or need for contact with other species (Gullone, 2002). As 1989–1999 respondents have less contact with nature in the urban environment outside their homes, they may feel a need to bring other species inside, in the form of domestic animals and plants. The 1989–1999 respondents had greater recollection of nature-related folk stories, in contrast with previous studies that have shown that declining appreciation of nature-related cultural heritage following urbanisation (Jaligot et al., 2018; Kesebir and Kesebir, 2017; Thiagarajah et al., 2015). Common folk story topics included stories about the moon, black cats, and superstitions about urinating under trees (Table S1). Such stories may have become popular as nostalgia for Singapore's kampong past, and interest in history and national identity has increased in recent decades (Pan, 2016). Furthermore, formal education may have contributed to increased knowledge of folk stories, as these stories are likely to have been taught in schools or provided as reading material to students (Peng and Ishak, 2009).

4.3. Application of historical ecosystem service data for managing future ecosystem services

Historical ecosystem service analysis provides an understanding of the rate at which the use of locally-provided ecosystem services changes over time. In Singapore we observed a rapid change in use of local ecosystem services, with a substantial shift in the types of services that were used within a span of three decades. These rapid changes in ecosystem service use suggest that ecosystem service management must be highly adaptive and responsive, and constantly engaged with ongoing changes in ecosystem service demand and supply. In Singapore, ever-evolving policy and public initiatives continue to change the types of ecosystem services that are valued, and the way that ecosystems are managed. For example, increasing prioritisation of food security is driving government programmes to increase the quantity of certain foods grown in Singapore, with an ambitious target of achieving 30% self-sufficiency by 2030 (Kosorić et al., 2019). Concurrently, bottom-up initiatives to develop urban agriculture are growing, driven by broader societal trends of heightened interest in sustainable living (Rut and Davies, 2018). In addition to land-based fruit and vegetable production, offshore aquaculture has also been prioritised for future expansion (Chou et al., 2019). Future management of Singapore's ecosystems may therefore need to be creative and adapt to the increased demand for agricultural space; either in the sea, on top of buildings or at ground level (Lin et al., 2017).

Another potential application of historical ecosystem service data is in recognising past use of ecosystem services which could be restored or adapted to fill future needs. Similar to the way that vernacular architecture is increasingly being used as a source of inspiration for sustainable design (Ali, 2013), records of past ecosystem service use may provide evidence for potential solutions to existing and future challenges. The use of nature for temperature regulation is an ecosystem service which has been lost in recent years but may experience a resurgence in the near future. Singapore's urban heat island has significant negative impacts on outdoor thermal comfort, and increases energy use (Chow and Roth, 2006; Salvo, 2018). The urban heat island has received substantial research and media attention during the past few years (Mughal et al., 2019), with nature-based cooling strategies proposed as one method to mitigate its impacts (Richards and Edwards, 2018, 2017). Future strategies to cope with the urban heat island could include designs that encourage people to take up behavioural strategies that make use of nature, such as the use of tree shade, water courses, and windy regions reported by the pre-1960 respondents (Table S1).

At the societal level, understanding historical ecosystem service use may provide insights into present ecosystem service demand. Drawing from the vast literature on childhood experiences and environmental behaviour, we can posit that historical ecosystem service use may influence existing environmental behaviour and the expectations on ecosystem service management. Tracking historical ecosystem service use data over longer time periods will allow an understanding of the generational differences in environmental behaviour and present ecosystem service use which in turn can provide some guidance for ecosystem management – be it behavioural changes or modifying the landscape to cater to the diverse generational needs. In Singapore, there have been some attempts to provide multifunctional ecosystems that cater to the needs of different segments of society. For example, the Active, Beautiful and Clean (ABC) waterways programme has implemented several development projects which provide opportunities for both recreational fishing – which may be preferred by the pre-1960s generation – as well as opportunities for education/learning – an activity more associated with the 1989–1999 generation (Lim and Lu, 2016; Quek et al., 2015). While it is uncertain whether generational differences in ecosystem service use are explicitly accounted for in environmental-landscape planning, such planning can benefit from understanding past ecosystem use to manage and design multifunctional ecosystems.

4.4. Parallels to other rapidly urbanising regions

The patterns observed in Singapore are likely to be representative of changes that have occurred over the past decades in other rapidly-developing cities, and may occur in neighbouring Southeast Asian cities in the future. As such, studies from Singapore may be helpful in understanding how urbanisation may impact human relationships with nature in other cities (Friess, 2016). For example, a reduction in the supply of locally-provided provisioning services is likely an inevitable consequence of urbanisation, as agricultural land is developed for urban purposes, and people increasingly import food from rural regions (Ferreira et al., 2019; García-Nieto et al., 2018). However, the extent to which urban areas can produce food is highly variable, depending on the socio-economic circumstances of the city (Lerner and Eakin, 2011; Satterthwaite et al., 2010). As a highly-developed city with a high population density, Singapore is an extreme example of reduced food provision due to urbanisation. In some developing cities in Africa and Asia, urban food production remains an important source of nutrition and income for a substantial number of people (Moustier, 2007; Orsini et al., 2013). Similarly, the observed increase in cultural service use in Singapore may transfer to other cities, but this trend is likely mediated by the way that people's lifestyles react to urbanisation. In cities that have urbanised rapidly but seen smaller increases in average individual wealth and education, a lack of recreational time, disposable income, or scientific interest may reduce the use of nature recreation, learning, and cultural heritage services. When transferring knowledge of ecosystem services and their changes between cities, it is important to be aware of the cultural, environmental, and ecological differences between them (Richards et al., 2019; Song et al., 2018, 2017). These findings from Singapore may thus be more appropriately transferred to cities that have urbanised over a similar period of time, and in a similar tropical and Asian context.

5. Sensitivity to survey limitations

Singapore is a multi-ethnic society, with three major races and four official national languages; Mandarin Chinese, Malay, Tamil, and English (Singapore Department of Statistics, 2010). The majority ethnic group is Chinese, accounting for 74% of the resident population in 2010 (Singapore Department of Statistics, 2010). The primary surveyors for the study spoke fluent English, Mandarin Chinese, and Chinese dialects, but were not able to converse with potential respondents who spoke other languages. This surveyor bias may bias the respondent demographics, particularly for the pre-1960 age group who are less likely to speak English (Singapore Department of Statistics, 2010). To investigate whether the different ethnic makeup of the two respondent groups impacted the results of the data analysis, we conducted a secondary analysis including only the respondents reporting Chinese ethnicity – the most populous group (Fig. S1; Table S3; Fig. S2). The conclusions were similar to the whole-sample analysis; only the result for engagement in hunting, fishing, or animal capture for recreation was slightly different, as the two groups were not significantly different. This lack of significance is apparently due to the resulting drop in sample size, as a higher proportion of the pre-1960 respondents still engaged in this activity (Fig. S1; Table S3). The conclusions of the study are therefore not impacted by the higher proportion of Chinese respondents among the pre-1960 age group.

6. Conclusions

The rapid urbanisation of Singapore has fundamentally changed people's interactions with nature; from a direct reliance on local provisioning and regulating services, to a greater appreciation of recreational, educational, and cultural heritage benefits. This rapid change in ecosystem service use is likely to be observed in other rapidly urbanising contexts, and may be the trajectory that other cities in Asia and worldwide follow as they continue to grow in future. The rapid rate of change in ecosystem service use also has implications for ecosystem service management, because we cannot assume that management for services that are important today will also support important services in the future. Planning and management of ecosystem services in the present must therefore learn from the past while, at the same time, consider the potential for future changes in supply, demand, and use of services.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2020.101193.

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