Possibilities for the Emergence of Civic Ecology Practices in Response to Social-Ecological Disturbance: The Case of Nuisance Chironomids in Singapore

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Abstract

My research aims to investigate the possibilities for the emergence of civic ecology practices in Singaporean reservoir communities in response to chironomid disturbances, using the framework of civic ecology practices. In recent years, unprecedented mass emergence of chironomids have occurred around two of Singapore's reservoirs, disrupting the lives of surrounding communities. Civic ecology practices would have been a valuable source of resilience toward this disturbance for these communities, because the practices would integrate individual, community, and environmental outcomes, through grassroots stewardship initiatives. However, civic ecology practices seemed to be absent among the communities. I observed public behavior around the reservoirs, as well as analyzed news articles, social media content, and government documents, to uncover social-ecological mechanisms underlying the nuisance issue. This allowed me to explain the lack of civic ecology practices, understand the potential of the reservoir social-ecological systems for adapting to the disturbance through civic ecology practices, and detect barriers to the emergence of those practices. I found that the initial conditions were not present for the emergence of civic ecology practices in those reservoir social-ecological systems, because the chironomid disturbance was not sufficiently disruptive. Nevertheless, the systems' potentials lied in various resources related to government, technology, and cultural values. Barriers include negative assumptions about the chironomids and politicization of the nuisance issue. My research will not only further understanding of how Singapore can build social-ecological resilience as it transforms in the 21st Century, but also how other complex urban ecosystems can do so too.

1. Introduction

Recently, chironomids (aka midges) have been emerging from Singapore's Bedok and Pandan reservoirs in mass numbers annually to cause nuisance to the reservoir communities. Although similar events have occurred in both reservoirs in the past, the recent events were unprecedented in the sheer number of chironomids that emerged from the reservoirs. These nuisance chironomids have not only caused extreme discomfort to residents by entering their eyes, ears, and mouths (Lin and Quek, 2011), but also entered food and drinks, stuck to wet laundry, stained walls and ceilings, and covered fluorescent lights (Cai, 2011). In addition, the chironomids have disrupted businesses by up to 50%, and soured the festive mood of Chinese New Year (Tai, 2012). Although the chironomids reportedly had no public health implications, numerous residents were so bothered about the chironomids that they complained to the Town Council, which then worked with the Public Utilities Board (PUB), National Environment Agency (NEA), National Parks Board (NParks), and pest control companies, to fight the chironomids with daily fogging (Toh, 2012). The authorities have also carried out other control measures such as the application of BTI larvicide to the reservoirs, and the removal of chironomid eggs from reservoir structures using scrub brushes (The, 2012). Other measures include installing netting around the reservoirs, planting wetland vegetation to create habitats for predators, and using light to divert the chironomids from homes. At the same time, the authorities maintained a program to regularly monitor the abundance of chironomid eggs, larvae, and adults in and around the reservoirs; and conducted a three-year R&D study in partnership with the National University of Singapore (NUS) to investigate the cause of the chironomid mass emergence and identify potential solutions (Teh 2012). Educational booklets were also distributed to the residents to provide information on the chironomids and preventive measures (NEA and PUB, 2012). So far scientists in the

study have identified the nuisance chironomid species to be *Tanytarsus oscillans* for Bedok Reservoir, and *Polypedilum nubifer* for Pandan Reservoir (Chua, 2012).

Chironomids are a type of non-biting aquatic fly, which spend their egg, larval, and pupal stages in the water before emerging in mass swarms as adults to reproduce. Belonging to the order Diptera, the insects are true flies, and are the most widespread and abundant freshwater insects (Cranston, 1995). The Chironomidae family is divided into 11 subfamilies and 22 nominal tribes (Ferrington Jr., 2008). Chironomids have high species richness, with an estimated 15000 species, as well as high ecological diversity, as their larvae occupy waters of extreme water quality, temperature, depth, and current velocity (Cranston, 1995). The insects spend a disproportionately large part of their life cycle in the egg and larvae stages, in order to store energy for adult reproduction. Upon emergence, the chironomid adults swarm as a strategy to increase mating success (Tokeshi and Reinhardt, 1996). Different species emerge at different seasons of the year and with different annual frequencies (Tokeshi, 1995). The chironomids' swarming behavior, along with mass emergence events, makes the chironomids a potential nuisance to people living close to chironomid habitats (Lin and Quek 2011). Specifically, nearly 100 species from the subfamilies Orthocladiinae, Tanypodinae, and Chironominae, have been known to cause nuisance problems (Ali 1996). Nuisance incidences have been recorded all over the world, such as the United States, Italy, and Japan. The negative effects of the nuisance chironomids include risky driving conditions, allergies, as well as business and agricultural damage (Ali 199).

Bedok and Pandan reservoirs have been created by the Singapore Government as part of a nation-wide reservoir system, which has become one of Singapore's four main water sources. Drains, canals, and stormwater collection ponds collect rainwater before channeling it to Singapore's 17 reservoirs. This water catchment area currently covers two-thirds of Singapore's land area (PUB, 2012 August 2). Today the reservoirs are used for recreation, as

part of the Government's efforts to integrate Singapore's reservoirs with their surrounding communities through the Active, Beautiful, Clean (ABC) Waters Program (PUB, 2013). Under the program, Pandan Reservoir has been transformed into a water sports hub, boasting amenities for rowing, canoeing, sailing, radio-controlled sailing, and fishing (PUB, 2012 January 12). Bedok Reservoir not only offers the above activities, but also challenge courses and spaces for nature watching. Since Bedok and Pandan reservoirs are man-made, immature ecosystems, they contain many alien fish species. A recent survey by Ng and Tan (2010) indicates that Singapore's reservoirs are almost fully populated by alien fish species. With only nine alien fish species in Singapore in the mid-1960s, this number has increased dramatically to 45 in the mid-1990s, and at least 54 at the time of the survey. These alien fish might have been introduced through release of aquarium fish, transfer of raw water from Malaysia, or discarding of baits by anglers. Out of the 54 alien fish species found in the survey, 31 have established and breeding populations in Singapore's reservoirs, out of which eight are from Bedok and Pandan reservoirs (see appendix; table 1). The widespread presence of alien fish in Singapore's reservoirs could account for the unprecedented midge emergence from Bedok Reservoir, as the native chironomid-feeding fishes might have been out-competed by or fallen prey to predatory alien fishes, such as the toman or the Asian arowana (Lin and Quek, 2011).

Various environmental factors were suspected to have caused the chironomid outbreaks too, like water quality, wind direction, temperature, and rainfall. For example, warmer temperatures might have promoted algal growth for chironomid consumption (Lim, 2012). The washing of nutrients into the reservoirs during the rainy season might have also contributed to such algal growth (Lim, 2012). However, this was insufficient to explain why the chironomid outbreak only occurred in recent years despite the existence of the reservoirs for many more years beyond that. Another speculation was that since the reservoir

ecosystems were immature, they might be insufficiently balanced to support predators of the chironomids (Lim, 2012). Despite their nuisance effects, chironomids play an important ecological role in Bedok and Pandan reservoirs, by being an important food source for many fish, birds, invertebrates, and amphibians. During a mass emergence event, Lin and Quek (2011) observed spider webs entirely lined with adult chironomids at the Bedok Reservoir's floating pontoons. They also observed large flocks of swifts circling above the blocks of flats next to Bedok Reservoir to feed on the chironomids. Chironomids also support freshwater fisheries and the production of fish food. Being highly tolerant of extreme environmental conditions, chironomids are good indicators of pollution too (Lin and Quek, 2011).

Immediate adaptive responses to the chironomid outbreaks had so far been top-down ones that focused on fighting the chironomids. As discussed earlier, while the long-term study was underway, the authorities depended on constant fogging to temporarily control the chironomid population, and allay the residents' concerns. The lack of self-organized stewardship practices among the reservoir communities is a point in question. In many cities around the world, communities have innovated civic ecology practices to adapt to social-ecological disturbances that have brought their social-ecological systems to "tipping point" (Krasny and Tidball, 2012, p. 268). As I will discuss later, these communities use their natural, socio-economic, and cultural resources, to steward nature in various spontaneous, creative ways. Moreover, these civic ecology practices help the communities build resilience to the disturbances by generating individual, community, and environmental outcomes (Krasny and Tidball, 2012). Similarly, Singapore has abundant resources for civic ecology practices to emerge too, such as its well-developed physical and IT infrastructures, multiculturalism, and effective government. Significant potential for civic ecology practices thus exist in Singapore.

According to Folke et al. (2002), social-ecological systems can no longer be regarded as linear and predictable, but nonlinear and dynamic instead. This points to the numerous possibilities for achieving multiple desirable equilibrium states. Gunderson and Holling (2002, p. 34) also describes how "creative destruction" occurs when social-ecological systems reach tipping points, because the released potential opens up possibilities for rebuilding through adaptive responses like civic ecology practices. These possibilities have implications for Singapore's social-ecological resilience, as tight coupling exists between the social and ecological systems in the dense city-state, thus making it vulnerable to disturbance. As the nation grapples with further environmental limitations in the future, it will increasingly have to make tough choices about adaptive strategies and desired equilibrium states. Investigating underlying causes to the apparent absence of civic ecology practices in the reservoir social-ecological systems is essential to helping Singapore maneuver such tough choices better in the future. Firstly, the absence of those possibilities might be explained by the lack of the necessary initial conditions. My case study presents a yardstick for assessing the relevance of civic ecology practices amid future disturbances. Secondly, supposing those initial conditions are present, possibilities for the emergence of civic ecology practices might also be limited by the level of potential for those practices, or barriers to those practices. Another study has similarly looked into how these two factors might limit climate change stewardship in Australia (Myers, Carter, and Smith, 2011). Identifying these limiting factors is crucial to understanding the possibilities for civic ecology practices to emerge in Singapore in the future. Using the nuisance chironomid issue as a case study, my research seeks to investigate the following:

1) Why were civic ecology practices absent in the reservoir social-ecological systems despite the nuisance events?

2) What is the potential of the reservoir social-ecological systems for adapting to social-ecological disturbance through civic ecology practices?
3) What are the barriers to the emergence of civic ecology practices in the reservoir social-ecological systems?

2. Research Background

I first became aware of the nuisance chironomid issue while serving an internship with PUB in Singapore from May to August 2012. As a Natural Resources major, minoring in both Urban & Regional Studies and Education, I wanted to gain working and research experience in the management of social-ecological systems, and I chose to do an internship in urban water policy and management in my hometown Singapore. Since my internship was aligned with the interests of Cornell University's Civic Ecology Lab[1], I sought the guidance of Dr. Keith Tidball from the Lab in my honors research thesis. During my stint with the Singapore Government, I participated in their efforts to monitor the chironomid population at Bedok and Pandan reservoirs. This involved identifying and counting chironomid eggs and larvae in reservoir water samples, and I attended workshops and sought the guidance of reservoir staff to learn the ropes. I also managed the databases for both the chironomid monitoring program and the R&D study with NUS, and I conducted research to interpret monitoring results. In addition, I assisted PUB in optimizing the monitoring protocol for the adult chironomid population through a pilot test of yellow sticky traps, and this involved research into chironomids' swarming behavior in relation to these traps. Being immersed in this chironomid management issue, I saw how chironomid biology and ecology were highly interconnected with social systems. I saw a valuable opportunity to research into the social-ecological system of the chironomid issue, and proposed to help PUB survey the residents' perception of the chironomids and their potential for stewarding their water resources. Under

[1] www.civicecology.org

the guidance of my internship supervisors and my thesis advisor Dr. Keith Tidball, I designed a survey questionnaire that investigated the residents' attitudes toward the chironomids, their relationship to Bedok and Pandan reservoirs, as well as their general social and environmental values. However, my supervisors and I later decided that the survey would be inappropriate because the residents were still heated up over the issue. My supervisors then guided me in developing other data collection methodologies, such as the analysis of literature and observation of public behavior. I began collecting social media content and news articles related to the nuisance chironomid issue in Singapore, and recorded my observations of public behavior around Bedok and Pandan reservoirs.

My internship not only provided fodder for the conceptual development of my thesis, it also gave me a firsthand experience of Singapore's environmental governance dynamics and environmental values. Being part of PUB's chironomid management effort has helped me understand how central the Singapore Government was to solving the nuisance chironomid issue. The residents relied heavily on the Government for solutions, and little grassroots initiative was involved. Chironomid management policies were largely driven by the residents' demand for immediate solutions. Residents expressed helplessness and frustration over the nuisance issue through social media, and many even blamed the Government for failing to help them effectively. Even a simple survey had the potential to agitate the residents further. On top of that, I observed that both the Government and residents were more concerned about controlling the chironomids for immediate comfort than applying sound ecological principles. While reviewing social media, I noticed that many residents expressed extreme disgust and annoyance toward the chironomids, and urgently demanded pest control. Given the residents' low tolerance toward the chironomids' nuisance effect, I was relieved to have chosen not to survey their attitudes toward the chironomids. In the short term, the Government responded to residents' demands by intensively fogging the

chironomids, and applying larvicide to the reservoirs. Although the Government made efforts to maintain long-term ecological integrity, such as introducing wetlands to create predator habitat and commissioning the R&D study, they nevertheless placed more emphasis on short-term control to allay residents' concerns. While on-site to participate in chironomid monitoring, I also noticed how the Singapore Government effectively created a park-like setting in the reservoirs through planning. Different recreational activities were meticulously allocated to specific areas of the reservoirs, and their greenery was highly manicured to maintain orderliness. This gave me a sense of the Government's perception of nature as a *constructed* source of comfort and aesthetic value. As I walked the ground to record my observations, I discovered that the reservoir users had limited hands-on contact with nature, other than during angling and water sports. Most of these users were taking advantage of the beautiful park-like setting to jog, stroll, cycle, and socialize. The aesthetic quality of the reservoirs made the area attractive to live in too. For example, I noticed the high concentration of condominiums around Bedok Reservoir, which apparently catered to those with upward mobility and relatively high living aspirations. Hence, I realized that the reservoir communities largely shared the Government's perception of nature as an amenity resource for personal, economic, and social well-beings. This might have explained the residents' immediate reaction toward the chironomids and their preoccupation with pest control.

On the other hand, my observations also showed me how tight the relationship was between residents and the reservoir ecosystems. These reservoirs were an important factor in the residents' quality of life, as the nearby dense residential estates entailed heavy use of the reservoirs. At times joggers were so numerous that I had difficulty coping with the recording of observations. This tight connectivity between the social and ecological systems of the reservoirs alerted me to the implications of chironomid ecology for the residents' lives. To

maintain quality of life, residents and policymakers need to understand various levels of chironomid ecology thoroughly, specifically population, behavioral, and ecosystem ecologies. Firstly, for population ecology, understanding the chironomids' life history is crucial to effective monitoring. By having precise knowledge of the chironomids' emergence timing, the authorities can time their control efforts effectively based on the monitoring data. Determining the growth rate, reproduction rate, and carrying capacity of the chironomids is also important for constructing models to predict population change over time, based on monitoring data. Secondly, behavioral ecology helps policymakers monitor and control the chironomids effectively with respect to target species and life history stage. For example, in my internship, I learnt that reservoir staff sampled the larvae of *Polypedilum nubifer* at Pandan Reservoir using bottom grab samplers since they were mainly benthic, and sampled those of *Tanytarsus oscillans* using plankton nets since they were mainly found near the water surface. Another example is the use of traps to monitor adult chironomids, as explained earlier. Through my research on the traps, I have learnt that positioning these traps effectively depended on the characteristic heights at which the chironomids usually swarm. Consequently, the timing and location of fogging and application of larvicide had to match specific chironomid behavior . Thirdly, knowledge of ecosystem ecology is important for assessing wider environmental implications of control methods. Fogging and application of larvicide might also affect non-chironomid species , and this needs to be taken into serious consideration to maintain ecological integrity. Information on other ecosystem variables like reservoir nutrient levels and chironomid predators are also needed for making decisions about whether to adopt top-down or bottom-up methods to control the chironomid population.

Seeing the critical mass of residents around the reservoirs, I thought about the residents' potential for contributing to the Government's management efforts through citizen science and stewardship activities. Moreover, as I researched civic ecology practices, I learnt

about the positive feedbacks between community and ecosystem outcomes as a result of those activities. Through reflection on my role in the management efforts, I realized that I learnt chironomid identification from scratch within a few weeks only. In addition, many of the reservoir staff were able to acquire the necessary skills after attending a few workshops, even though they had less ecological training than I. Many lay residents could similarly assist in monitoring the chironomid eggs and larvae too. The residents' critical mass also gave them huge potential to be the Government's 'eyes' for monitoring the adult chironomid population at the reservoirs and housing estates. Next, while the Government was planning to introduce wetlands to create predator habitat around the reservoirs, residents could instead help with these efforts through community-based stewardship initiatives. Like community gardening, community-based wetland planting could be a source of enjoyment, social capital, and environmental education. I noticed little voices in the community calling for ecological sensitivity toward the chironomids, and I discovered that those initiatives might be possible after all.

At the end of my internship, I recommended PUB to encourage these community-based stewardship and citizen science initiatives. More importantly, I became curious about the lack of these initiatives in the communities. I started questioning the role of civic ecology practices in the nuisance event. As I did further research on civic ecology practices, I eventually framed my research questions using the civic ecology framework. If the communities had such a tight relationship with the chironomids that they complained about incessantly, and if stewardship potential existed, why did they not initiate civic ecology practices to adapt to the nuisance? Was it because they lacked the necessary resources, did barriers to the practices exist, or were civic ecology practices redundant altogether? I then decided to identify underlying mechanisms that explain the observed phenomenon and predict future possibilities.

3. Literature Review

3.1 Theoretical Review of Urban Ecology and Psychology

Due to the interdisciplinary nature of my research, I used an overall human ecological approach toward it. I developed my research using the conceptual framework of civic ecology, which combines the three fields of ecology, urban planning, and psychology. These fields not only correspond to my academic interests, but also encompass the spatial and temporal processes appropriate to my research topic. Specifically, my research approach was rooted in the 10 civic ecology hypotheses proposed by Krasny and Tidball (2012). Krasny and Tidball's main hypothesis is that civic ecology practices emerge when social-ecological disturbance brings a system to "tipping point", which is the initial condition needed for triggering the emergence of civic ecology practices. These practices are "self-organized stewardship initiatives" in cities and other peopled landscapes that "reflect local cultures and environments" and "integrate environmental, community, and individual" outcomes (Krasny and Tidball, 2012, p. 268). The remaining nine hypotheses explain the social-ecological outcomes of the civic ecology practices, which will be explained later. These hypotheses were apt for framing my research topic of nuisance chironomids, which centered on social-ecological disturbance and resilience. Following, the other nine hypotheses describe how civic ecology practices lead to multiple spatial and temporal scales nested within one another. These hypotheses are in turn grounded in the panarchy theory by Gunderson and Holling (2002), which explains how social-ecological systems evolve (or collapse) through human creativity across multiple spatial and temporal scales, despite environmental limits and drivers of change operating on these scales.

A key model for demonstrating this evolution is the "adaptive cycle" (Gunderson and Holling, 2002, p. 32-33), which is also a useful basis for demonstrating the emergence of civic ecology practices (Krasny and Tidball, 2012). The model represents how the three properties of potential, connectedness, and resilience, shape social-ecological systems. After

reaching tipping points, social-ecological systems release their accumulated potential and lose internal connectedness, thereby moving from a conservation phase to a release phase. As these systems retrieve the released potential and reorganize themselves through innovation, they move from the release phase to the reorganization phase. Opportunists then exploit this newly available potential, which accumulates and becomes more tightly bound within the social-ecological systems, until they become highly connected internally. This characterizes the move from the reorganization phase to the conservation phase through the exploitation phase (Gunderson and Holling, 2002). As social-ecological systems progress through the conservation phase, their potential and connectedness increase, but resilience decreases as they eventually become over-reliant on self regulatory processes and thus vulnerable to disturbance (Gunderson and Holling, 2002). Consequently, potential determines the limits to the possibilities of social-ecological states; connectedness determines the degree to which social-ecological systems can self-regulate and control its destiny amid external vagaries; and resilience determines how vulnerable these systems are to disturbances (Gunderson and Holling, 2002). Civic ecology practices, hence, occur in the reorganization phase, in which they retrieve the released potentials of local cultures, knowledge and natural resources, and innovate to integrate the retrieved potentials into environmental, community, and individual outcomes. Resilience increases with plurality of ideas and more experimentation. As a result, civic ecology practices increase the potential, connectedness, and resilience of social-ecological systems. These practices are only limited by level of potential and barriers to the integration of various potentials to achieve the above outcomes.

Not only does the adaptive cycle involve different spatial configurations of social-ecological systems, it operates on various temporal scales too, as the transition from release to reorganization usually takes place quicker than that from exploitation to conservation (Gunderson and Holling, 2002). Gunderson and Holling (2002) further nest these adaptive

cycles within a hierarchy of spatial and temporal scales, and explore their cross-scale processes. Specifically, the scholars perceive each level of the hierarchy to represent a specific temporal and spatial scale, which is in turn connected to successive higher or lower levels through the processes of "revolt" and "remember" (p. 75). Lower scales represent smaller and faster variables, while higher scales represent larger and slower ones. A continuity of these scales forms, as release occurring in adaptive cycles on lower scales cascade to successively higher scales in the revolt process, and the higher scales in turn govern the reorganization occurring at successively lower levels of adaptive cycles in the remember process (Gunderson and Holling, 2002).

Another theory that the hypotheses are grounded in is that of nested ecologies by Wimberley (2009), which is in turn influenced by Bronfenbrenner's concept of "nested hierarchy" (p. 7). Wimberley's theory complements the panarchy theory as it adopts a holistic approach toward social-ecological systems as well, and characterize these systems as multidimensional, dynamic entities. Furthermore, Wimberley's theory of nested ecologies complements the panarchy theory by attempting to uncover the components of social-ecological systems. Wimberley conceptualizes social-ecological systems as comprising of personal, social, environmental, cosmic, and spiritual ecologies nested within one another. Similarly, Gunderson and Holling (2002) refer to these components in their discussion of ecological, social, cultural, and economic potentials of social-ecological systems (Gunderson and Holling, 2002). Hence, Wimberley (2009) effectively describes the specific types of potentials and internal connections that are lost and built up during the revolt and remember processes respectively. Bronfenbrenner, on the other hand, approaches ecological systems from a developmental psychology viewpoint, and imagines these systems to comprise of individuals nested within multiple social systems of increasing spatial scales. He also specifically discusses how these social systems are nested within history, leading to unique

trends of events (Santrock, 2011; Bronfenbrenner, 1986). I appended Bronfenbrenner's (1986) dimension of time to Wimberley's concept of nested ecologies to more accurately reflect the multidimensional nature of social-ecological systems.

Before Wimberley (2009), and Gunderson and Holling (2002), many scholars have laid the foundations for the field of human ecology. Other than the ecological sciences, the field has its roots in sociology and anthropology, which were investigated through the lens of ecological principles. The Chicago school drew analogies between cities and nature by examining their webs of relationships in the 1920's and 1930's. Later in the mid-20th Century, scholars expanded human ecology to consider the main social variables of population, technology, and organization, on top of the environment. Then in the 1980's and early 1990's, ecologists, sociologists, and anthropologists applied the human ecology framework to various fields (Machlis, Force, and Burch JR, 1997). Building upon this foundation, Machlis et al. (1997) attempt to grasp the complexity of social-ecological systems by describing them as coherent systems that could adapt by operating through a hierarchy of spatial and temporal scales. They make specific reference to how changes on each scale have effects on other scales.

More revealingly, Machlis et al. (1997) argue that the key elements of social-ecological systems are their critical resources and human systems for organizing these resources. Flows characterize the interactions within and between those resources and the human systems, leading to continually dynamic patterns of change and adaptation. Machlis et al. (1997) conceptualize the human systems to consist of social institutions, along with the social order that governs cultural patterns. These social institutions in turn govern the use of natural, socioeconomic, and cultural resources, which are effective indicators of the various potentials that Gunderson and Holling (2002) refer to in their panarchy theory. Machlis et al. (1997) thus add another dimension to Wimberley's theory of nested ecologies by revealing

the interactive processes by which the potential and internal connections within social-ecological systems change during the revolt and remember processes of the adaptive cycle. Machlis et al. (1997) also illuminate how self-regulatory flows within social-ecological systems govern their connectedness, as mentioned earlier.

As the social sciences contributed much to the understanding of human-dominated ecosystems in the first half of the 20th Century, human ecology was developed within the traditions of the various social sciences, instead of the science of urban ecology (Niemela, 2011). Human systems were only recognized as ecosystems components in the 1960's when the increase in atmospheric carbon dioxide levels was published. During the last 30 years, the "equilibrium paradigm", which viewed nature as balanced entity independent of humans; shifted to the "non-equilibrium paradigm", which accepts that multiple equilibria can exist in nature due to human action (Niemela, 2011, p. 7). Gunderson and Holling (2002) also reflect this shift in their discussion of the panarchy framework to investigating the "Nature Evolving" (p. 14) view, which they argue encapsulates the evolutionary nature of social-ecological systems. Consequently, they describe the "Nature Balanced" view as inadequate due to its static view of these systems (p. 12). In the 1970's, scientists began to realize the impact of human action on the rest of the environment (Niemela, 2011), and at the same time, upheavals also provided the moral and intellectual impetus for re-connecting to the environment (Crewe and Forsyth, 2011). Even then, many ecologists still avoided studying human systems in the 1970's and 1980's due to entrenched prejudice against this endeavor, and urban ecology was only revived in the late 1990's when two landmark urban long-term ecological research (LTER) in Baltimore and Phoenix in USA inspired other research (Niemela, 2011).

Two schools of thought have emerged from the discipline of urban ecology, namely the ecology in cities and the ecology of cities. The former, referred to as the pioneer

approach, examines ecosystem structure and function within cities (Pickett et al., 2001), and investigates how cities affect ecosystems (Grimm, 2000). The latter, called the emerging approach, examines the social-ecological linkages within cities using a systems-based approach (Pickett et al., 2001), and investigates the aggregated outcomes of the social and ecological parts of cities (Grimm, 2000). The emergence of the ecology of cities approach probably reflects the continuing shift to the non-equilibrium approach, and the urban LTER in the late 1990's also represent attempts at adopting the ecology of cities approach (Grimm, 2000).

Wu (2008), on the other hand, sees three main traditions in the field of urban ecology; namely the "Ecology in Cities without Socioeconomics" (EIC), the "Ecology of Cities as Ecosystems" (EOC-E), and the "Ecology of Cities as Socioeconomic Structures" (EOC-S) (p. 43). He organizes these traditions along a spectrum, with the EIC end being more biocentric and the EOC-S being more anthropocentric. Specifically, the EOC-E tradition views cities as ecosystems with both socioeconomic and ecological components, whereas the EOC-S tradition views cities as socioeconomic structures through an ecological lens. Wu describes the Chicago school of human ecological thought as part of the EOC-S tradition. The EIC tradition, on the other hand, views cities as structures layered upon nature to affect ecosystem structure and function, and this refers to the ecology of cities approach mentioned earlier (Wu, 2008). Within the EOC-E tradition are the urban systems, integrative urban ecosystem and urban landscape ecology perspectives; which represent increasing degrees of integration between social and ecological systems, on increasing scales of consideration (Wu, 2008). Wu argues that the urban landscape ecology perspective is the most relevant to developing urban sustainability, because it is uses an appropriate scale for examining social-ecological processes, and examines the interactions between these processes and landscape patterns (45).

Pickett (2001) and Grimm (2000) represent the urban landscape ecology perspectives by conceptualizing urban ecosystems as integrated, spatially heterogeneous systems. Pickett (2001) builds upon Machlis et al.'s (1997) work by focusing on how social and ecological processes are linked through their mutual effects. He recognizes the importance of ecological and social drivers, allocation mechanisms, and critical resources, which Machlis et al. (1997) detailed in their human ecosystem model (p. 351). Pickett (2001) demonstrates how social differentiation and spatial heterogeneity in cities interact with ecological functions through different allocation mechanisms at different scales. Therefore, social and ecological allocation mechanisms integrate both systems via distribution of resources in social and ecological processes. Grimm (2000) emphasizes the role of the social sciences in developing an integrative approach to social-ecological systems. She argues that social drivers, such as information flows, culture, and social institutions, are as important as biophysical drivers in influencing patterns and processes, because human decision-making is a huge factor in the dynamics of urban ecosystems. Therefore, urban ecologists should study cities as ecosystems, and not see human factors as disturbances, but as drivers of and limitations to urban ecosystems. Grimm (2000) illuminates the dynamic nature of social ecological systems across multiple scales, by discussing the driver of change in urban ecosystems. Moreover, she advocates approaching land use with patch dynamics, as it facilitates analysis of how changing spatial patterns affect social and ecological processes at various spatial and temporal scales. Overall, Pickett (2001) and Grimm's (2000) work represent the latest development in urban ecology that focuses on the intersection between landscape patterns and processes across human and ecological systems. Their works also complement the perspective of nested ecologies by conceptualizing social and environmental systems to be nested within each other.

Alberti (1999) also continues the urban landscape ecology perspective by attempting to create a conceptual framework for assessing how urban patterns influence ecological functions. She develops the four urban environmental performance measures of “sources”, “sinks”, “ecological support systems”, and “human well-being” (p. 154). These measures evaluate how spatial patterns of cities affect the distribution of natural resources to sustain human well-being, the ability of the environment to absorb wastes, and ecological processes that support the production of natural resources (Alberti, 1999). Alberti (2008) later goes beyond the landscape scale to argue that urban ecosystems are complex, hybrid systems that emerge from the interactions of social and ecological processes, and lead to observable emergent behaviors. Consequently, she makes no distinction between the social and ecological in conceptualizing the drivers, patterns, processes, and effects within urban ecosystems. Alberti’s (2008) conceptualization of emergent properties supports Wimberley’s (2009) ideas about spiritual ecology as a transcendent system focused on meaning and purpose of life. Environmental psychologists and researchers in public health, are also increasingly focusing on the physical and emotional healing effects of greening activities in diasaster contexts (Tidball, 2012). Several authors seek to explain the emergent quality of social-ecological interactions by proposing a biological explanation for these interactions. Wilson (1984) attempts to explain this affinity between humans and nature by arguing for its biological roots in man’s evolutionary history. Man thus has a subconscious, innate attraction toward nature. Louv (2005) builds upon Wilson’s (1984) ideas by arguing that the lack of expression of this innate need to connect with nature leads to behavioral problems in children. Yet later cell biologists continue this line of research by investigating how the inherent attraction among living organisms lead to active alteration of one another’s environment. Sensitivity to such biological effects is consequently sharpened during stressful situations (Tidball, 2012). Building upon these ideas, Tidball (2012) argues that man’s need

to connect with nature is urgently manifested in the conscious realm during disasters, and therefore greening activities are valuable for healing and generating resilience.

The urban ecological traditions have since been adopted in urban planning to design ecosystem services for urban dwellers, and to reduce environmental impacts of cities (Pickett et al. 2001). For example, using the EOC-E tradition, urban planners have attempted to design dense ecocities, which reduce environmental impact through the comprehensive integration of housing, green spaces, transit routes, and other land uses (Crewe and Forsyth, 2011). Based on Alberti's (1999) four urban environmental performance criteria described above; the compact, efficient approach of ecocities can be said to focus on nature as a source of human well-being and a sink for wastes. Nevertheless, alternative approaches to ecologically sensitive designs have arisen from the EOC-E perspective too, like the connective approach. For example, ecoburbs are usually low-density developments that have a naturalistic look, in order to immerse residents in ecological processes and encourage stewardship of natural resources, based on the "ecology of the heart" approach (Crewe and Forsyth, 2011, p. 273). This approach emphasize individual psychology in relation to nature over physical design, and can be said to focus on the deeper notion of nature as ecological support systems instead of mere sources of human well-being. The connective approach also invokes Wimberley's (2009) concept of spiritual ecology. In conceptualizing ecology of the heart, Schroeder (1996) argues that our relationship with nature is defined as much by experience as by science. The "values" that we place on nature drive our "emotions" and "motivations" for action toward nature (p. 18-19). Forsyth and Crewe (2009) also understand these elements to constitute sense of place. Further, Schroeder (1996) concludes that experiencing the environment is a creative process that involves exploring different environmental values and appreciating the diversity of ways in which people experience nature. Developing a sense of place is consequently creative in nature.

These ideas support the constructivist school of thought in educational theory, which argues that individuals learn best by discovering and constructing their knowledge (Santrock, 2011). Two leading authors on this subject are Piaget (1952), who approaches knowledge construction from the perspective of developmental psychology, and Vygotsky (1962), who approaches the subject from the perspective of social context. Piaget (1952) theorizes that children create cognitive frameworks called schemas to mentally represent the world while growing up, and emphasizes that children are motivated to construct knowledge by the need to equilibrate their experiences and schemas when they encounter a "cognitive conflict" (Santrock 2011, p. 40). This supports the importance of previous knowledge in knowledge construction. On the other hand, Vygotsky (1962) takes on a social constructivist approach by emphasizing that the social interaction and cultural context are major factors in motivating children to construct knowledge (Santrock 2011). In his discussion of nested ecologies, Wimberley (2009) also argues that humans only perceives nature through the prism of senses, experience, and culture. The above discussion of education and nature psychology reveals the role of one's personal ecology in drawing from the memories of slower, larger variables in his social-ecological, during the remember process in adaptive reorganization. Motivation for reorganizing one's emotions and understanding toward nature is derived from broader processes like culture and religion. It shows the psychological processes behind the alternative connective approach in urban planning, which also represents reorganization of urban ecosystems after efficient ecocities have reached tipping points. More importantly, the theories illuminate how individuals innovate to self-organize stewardship initiatives during the emergence of civic ecological practices.

Regarding the role of personal ecology in social-ecological adaptation, Kassam (2009) explains that Sorokin and Geertz have already laid groundwork for thinking about the interrelationships between cultural systems, social structures, and individuals. They theorize

cultural systems as the matrices of meanings and symbols from which individuals derive understanding of the world to guide their actions. The cumulation of individual actions then form social structures that represent the patterns of social interaction. Both scholars argue that social change leads to conflict when synthesis between cultural systems and social structures fails to occur through human action. Kassam (2009) also supports these lines of thought through the human ecological lens he proposes for looking at social-ecological relationships. Building upon Geertz and Sorokins's ideas, Kassam (2009) argues for the complex connectivity between nature and culture, and hence the role of human agency in reflection upon and action toward nature. In his human ecological lens, he explains how practical wisdom about nature is generated through cycles of experience and reflection. This complements Piaget's (1952) theory that learning takes place when one continually fits his experiences and schemas with each other.

Moreover, Kassam (2009) situates motivation for learning in nature, as his human ecological lens describes the ecological context as the foundation for society. Knowledge construction then takes place as individuals perceive relationships among other humans, animals and plants, and non-living things, in this context; thereby supporting Vygotsky's (1962) social constructivist approach too. Hence, by involving different local perceptions, civic ecology practices lead to more diverse forms of knowledge and hence more potential. This discussion about Kassam's (2009) ideas sums up how culture and social interactions can be aligned with each other via individual action, whenever social-ecological change occurs. Individual agency also reflects the remember process in which smaller, faster variables adapt through memories embedded at higher scales. Referring back to Machlis et al.'s (1997) framework of human ecosystems and Gunderson and Holling's (2002) panarchy model, these ideas about individual agency and the remember process fit into how resource flows among social order, social structures, and ecology, lead to continual change and adaptation in social-

ecological systems. During adaptation, individuals draw upon socio-economic and cultural resources on a broader scale. My review of ecology and psychology has deepened my understanding of how the connective approach in urban planning promotes human well-being by supporting nature as meaningful ecological support systems. Although less efficient, this alternative approach might represent the reorganization phase that is conducive to the emergence of civic ecology practices. In trying to optimize environmental performance, though, environmental planners have to consider hard to combine both approaches (Crewe and Forsyth, 2011). My review of the literature so far has shaped my conceptual framework for analyzing Singapore's nuisance chironomid case study.

3.2 Review of Singapore's Environmental History

Singapore has always adopted the compact, efficient approach toward urban planning in the EOC-E perspective. Since Singapore has limited land and natural resources, its early leaders believed that meticulous planning was essential and no room for failure existed (Neo, 2007). As such, the Singapore Government made bread-and-butter issues its priority and adopted a top-down approach to ensure the effective implementation of crucial nation-building policies (Geh and Sharp, 2008). Kong and Yeoh (1996) describe how Singapore's historical construction of nature as a resource for health, aesthetic appreciation and recreation, scientific advancement, and economic profit, has been translated into post-independence policies. National developmental imperatives dominated Singapore's urban planning agenda, leading to strict governmental control over land use with little room for politics (Soh and Yuen, 2006). With the emphasis on physical and economic development in Singapore's land use planning, values of nature conservation took a step back (Neo, 2007). In the late 1960s, Singapore's first prime minister, Lee Kuan Yew, adopted a policy to transform Singapore into a garden city by landscaping its streets with manicured greenery. Through this policy, Mr. Lee aimed to distinguish Singapore from other Asian countries with

a clean and green environment, thereby attracting tourists and investors. As a result of the Garden City policy, however, many Singaporeans were unable to appreciate Singapore's indigenous biota (Geh and Sharp, 2008).

Singapore's compact, efficient approach catalyzed Singapore's economic success, but at the expense of Singaporeans' connection to nature. By the late 1980's, Singaporeans started feeling anxiety over their lack of national identity. Conservationists began rediscovering their natural heritage in which to permanently root their identity and develop a transformed set of place meanings and attachments toward Singapore (Geh and Sharp, 2008). At the same time, Singapore's environmental planning was transitioning to a more consultative mode, and a commitment to this approach was made publicly when Singapore's second prime minister, Goh Chok Tong, was inducted in 1990 (Francesch-Huidobro, 2008). Following this in 1992, Singapore ratified the Convention on Biodiversity at the Earth Summit at Rio de Janeiro, and forged its first environmental blueprint – the Singapore Green Plan. The Plan contained recommendations for nature conservation and was eventually revised into the Singapore Green Plan 2012 a decade later (Francesch-Huidobro, 2008). Then in the 21st Century, Singapore emphasized the connective approach more in order to reflect the evolving needs of Singaporeans to develop a sense of place toward Singapore. As mentioned earlier, the Singapore Government implemented the ABC Waters Programme in 2007 to integrate water bodies with their surrounding communities, including those of Bedok and Pandan reservoirs. In 2009, the National Biodiversity Strategy and Action Plan (NBSAP) also replaced the Singapore Green Plan 2012 as Singapore's biodiversity conservation model (NParks 2010). The Singapore Government even assumed leadership in proposing an index to help cities measure biodiversity (NParks 2010). The Government also implemented a sustainable development blueprint in 2009, and while it was built upon a pragmatic approach toward development, the blueprint also emphasized community involvement as a key to

environmentally responsible decisions in Singapore (Ministry of Environment and Water Resources, 2013). As values of nature conservation emerged among Singaporeans during this period, civil society began to play a stronger role in environmental governance.

From my literature review of environmental governance in Singapore, I recognize three landmark events that characterize how Singaporeans have resisted social-ecological change through bottom-up efforts. The first event involved the Singapore Government's plan to develop Sungei Buloh wetlands into an agro-technology park in the 1980's. After the Nature Society (Singapore) (NSS) discovered its ecological value, it proposed against its development through non-confrontational lobbying. The NSS leadership started holding informal talks with key government officials through insider connections. NSS birders even documented the birdlife at Sungei Buloh and produced a brochure on it. The Government finally declared Sungei Buloh a nature park in 1989 (Wee and Hale, 2008). Next, in the second event, conflict over conservation arose over another development plan in the early 1990's. The Government's had planned to build a golf course at Lower Peirce Reservoir, which was surrounded by a nature reserve of mature trees. Again the NSS spearheaded conservation by conducting an environmental impact assessment and launching a campaign. Thousands of Singaporeans petitioned against the golf course development, fueled in part by media confrontations. The Singapore Government eventually shelved the golf course plans (Wee and Hale, 2008). As Singapore continues to mature into the 21st Century, another conflict arose yet again in the third event, this time involving lay Singaporean individuals and the Internet. Chek Jawa, an intertidal zone on an offshore island of Singapore, was slated for reclamation into a military training ground in 2001. This ecosystem contained many rare marine creatures and many Singaporeans saw it as part of their unique natural heritage (Hobson, 2006). A huge public uproar followed and news about the issue flooded the media and the Internet. Members of the public started conducting tours of Chek Jawa to minimize

damage to it, as well as collected and catalogued organisms there. Nature lovers, teachers, and students alike appealed against the reclamation plans profusely, and many wrote in to the press and the Government (Wee and Hale, 2008). Finally the Government took heed of the public opinions and deferred the reclamation plans indefinitely (Ng and Sovacool, 2013).

The environmental history of Singapore not only shows how the nation transitioned through the four phases of the adaptive cycle as a result of development, but also the role of Singaporeans' agency in shaping social-ecological outcomes amid this transition. On a national scale, Singapore reached a tipping point when it gained independence in 1965 and faced the sudden need to survive on its own. This released leadership potential and the Singapore's first prime minister Mr. Lee Kuan Yew then retrieved this potential to help Singapore move into the reorganization phase, through efficient planning. Singapore then moved into the exploitative phase as foreign investment poured into the nation, and as Singapore continued to develop using the compact approach, it moved into the conservation phase. With evidence of value conflict in Singapore's cultural system in the 1980's, Singapore might have started to experience decreasing resilience while moving into the conservation phase back then. The unfolding of the three landmark events from the late 1980's to the early 2000's could represent Singapore's further transition toward the late conservation phase of the adaptive cycle, as the nation's model of efficiency became more fragile. By desiring to reconnect with their natural heritage through environmental activism in the landmark events, Singaporeans were in fact demonstrating their potential for civic ecology practices on a national scale, as the disturbance of conflicting values cascaded upward to the national level through the revolt process. During the revolt process, the smaller and faster variables of passionate lay Singaporeans, communities, and the NSS, communities, might have reached tipping point to have engaged in activism on an unprecedented level.

They eventually reorganized by drawing upon ecological values and negotiation of policy in the remember process.

Today a diversity of values continue to emerge in Singaporean society as public discourse about social resilience, national identity, and public participation has increased in recent years. In fact, Singapore's recent General Election of 2011 was a watershed political event as opposition parties won an unprecedented number of parliamentary seats, reflecting an increasing diversity of political values among Singaporeans (Gopalakrishnan and Lim, 2011). In 2013, the release of the population white paper also sparked many protests by Singaporeans, who were against the Government's plan to raise the population by a third through immigration. Not only were they concerned about the dilution of the Singaporean identity, they were also distrustful of the Government's commitment toward its people instead of economy (Hodal, 2013). Such value conflict will also have implications for Singaporeans' perception of nature and ability to engage in civic ecology practices.

At the same time, Singapore also continues to adapt and remake itself by moving toward the EIC part of the spectrum, and hence the connective approach. In light of Singapore's increased recognition of the need for pluralism amid shifting values, the nation could already have reached a tipping point where adaptation to social-ecological change is gradually taking place. Another possibility is that Singapore's evolving environmental policies could be cushioning Singapore's shift from the late conservation phase to the reorganization phase by bypassing the tipping point. In recent years Singapore no longer envisions itself as a Garden City, but a City in a Garden (NParks, 2011), and this title reflects the recognition of Singapore as an ecosystem disturbed by human action. Furthermore, the Government aspires to harness Singaporeans' potential for realizing this vision by establishing community-based gardens as part of the Community in Bloom (CIB) program (NParks, 2011). These programs aim to foster community spirit and a gardening culture in

Singapore, predicated on the psychological and social benefits of nature (NParks, n.d.). In fact, the community-based gardening program aims to revive the 'kampong spirit', which was the strong sense of community held by Singaporeans who lived in Malay-style villages in the past (Mohamad Azmi, 2009). The ABC Waters Programme mentioned earlier is another example of Singapore's move toward the EIC part of the spectrum, along with commitment to biodiversity through the NBSAP and the proposed biodiversity index. Nevertheless, despite Singaporeans' shifting social and ecological values as reflected by the three landmark events and other recent ones, civic ecology practices still failed to emerge in the nuisance chironomid events. In fact, the numerous complaints by the residents in response to the nuisance chironomids already show that many residents have reached tipping point on a personal level. Broza, Halpern, Gahanma, and Inbar (2003) discuss that an important threshold exists between the chironomid outbreak levels and the number of complaints by the affected public, because this has management implications for predicting the nuisance effects of the nuisance chironomids from the monitoring data of chironomid population dynamics. Investigating the effects of changes in the individual scale on higher scales is needed for a better understanding of the response of the reservoir social-ecological systems to the chironomid disturbance. My overall understanding of Singapore's environmental history will help me analyze my case study better.

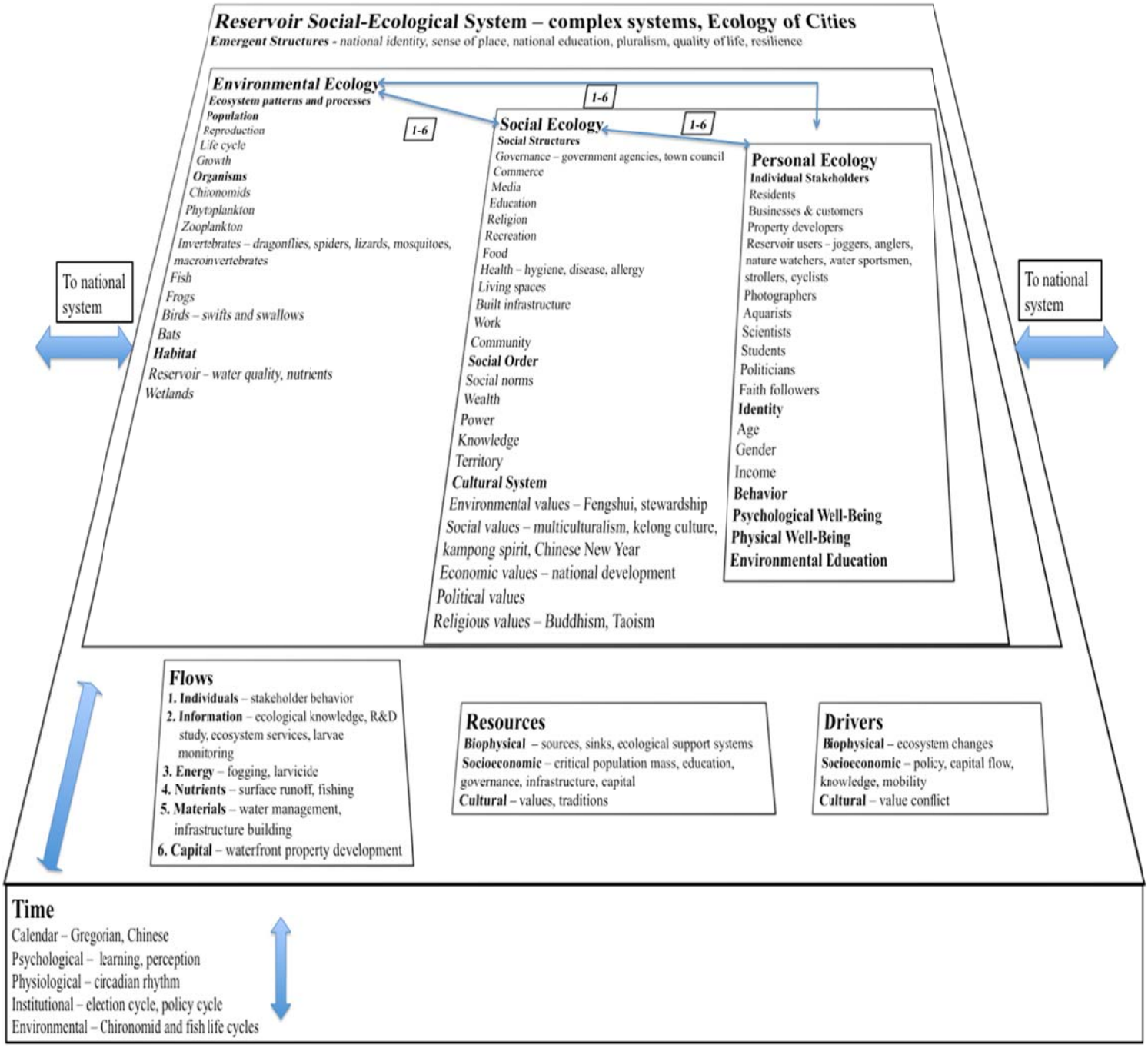
Besides researching into Singapore's environmental history, I have also researched into the local natural history of chironomids in Singapore and the wider region. As chironomids are the most widely distributed and abundant freshwater insects in the world, they have long been an intergral part of Singapore's freshwater ecosystem. However, information is lacking on the natural history of chironomids in the region. With fewer than 100 species in 32 genera documented, these likely represent only a small fraction of the chironomid diversity in the region (Lin and Quek, 2011). In Singapore, the subfamilies

Tanypodinae, Orthocladiinae, and Chironominae have been recorded (Karunakaran, 1969). In Southeast Asia, only an additional species of the subfamily Diamesinae have been recorded in Sabah, Malaysia (Lin and Quek 2011). Chironomids form the ecological support systems that sustain the various ecosystem services that Bedok Reservoir provides its communities directly, such as water supply and recreation as explained earlier. By being an important food source for many organisms, chironomids play a large role in supporting biodiversity in the reservoirs. Chironomids also promote nutrient cycling and energy flow, and play an important role in ecosystem functioning. Chironomid larvae break down detritus at the bottom of reservoirs and release nutrients for macrophytes and phytoplankton to enhance primary productivity, thus supporting food webs. Sediment mixing by chironomid larvae also increases the rate of recycling of nutrients in the reservoir (Covich, Palmer, and Crowl, 1999). Similarly, the benthic nature of the species *Polypedilum nubifer* will enable it to perform the above functions. Chironomids can also be effective at removing excess nutrients from freshwater systems due to their abundant feeding on detritus and eventual emergence as adults (Tokeshi, 1995). Therefore, the chironomids might help to remove excess nutrients washed into Bedok and Pandan reservoirs by rain through feeding on phytoplankton, benefiting water quality.

Chironomids are also important indicators of the biological health of Singapore's rivers, since they are able to inhabit extreme habitat conditions, and Singapore's scientists have used them to assess the impacts of urbanization on Singapore's waterways (Blakely et al., 2008). Chironomids have also been reared in Singapore as fish food by the fish farm industry for the past few decades, and by pet fish keepers (Rajabipour et al., 2011). Chironomids are an integral part of Singapore's natural heritage, and little voices have urged the public and the Government to respect them. However, many other members of the public see these organisms more as a pest than as an ecological gem, and demanded immediate

action from the Government to eliminate them. Little effort was made to connect to the chironomids, despite Singapore's move toward the connective approach. Underlying barriers to the emergence of civic ecology practices might thus exist to block the flow of critical resources. Based on my review of the above social-ecological concepts, Singapore's environmental history, and the case study of Singapore's nuisance chironomid issue, I have formulated a comprehensive conceptual framework (Diagram 1) which formed the basis of my analysis. This framework includes the abovementioned general resilience concepts and local-level elements, and depicts the reservoir social-ecological systems as tightly bound matrices in the late conservation phase of the adaptive cycle.

Diagram 1. Comprehensive conceptual framework for analysis.
Adapted from Alberti (2008), Bronfenbrenner (1986); Grimm (2000), Kassam (2009), Pickett (2001), Santrock (2011), Wimberley (2008), and Wu (2008).



4. Methods

I used a mixture of primary and secondary, as well as cross-sectional and longitudinal methods in my research. My primary method involved personal observation of public behavior around the reservoirs, while my secondary method involved the unsupervised textual analysis of the triad of news articles, government documents, and social media content that I collected. Triangulation in my secondary method gave my research a more diverse set of perspectives and helped me evaluate the consistency of my data (Wee, Harbor, and Shepardson, 2006). Moreover, according to the social amplification of risk framework, the reservoir residents developed their perception of the nuisance chironomids by receiving feedback signals from the media, government agencies, and social networks. These signals get amplified by the above conduits, leading to behavioral responses in the residents that then inform perception in a self-reinforcing manner (Brasier et al., 2013). These conduits of information themselves might also reflect the attitudes of the residents. As noted by Wolch et al., 1997 in a newspaper analysis of changing public attitudes toward California's cougars, the media both influence and reflect those attitudes. The interconnectedness among these information sources is apt for comparison and analysis. After all Vygotsky's (1962) social constructivist approach supports the social amplification theory, in his discussion of the role of social contexts in knowledge construction. My use of both primary and secondary methods also keep subject-centric and researcher-centric biases in check respectively. Next, my personal observation constitutes my cross-sectional method, whereas my unsupervised method constitutes my longitudinal method. Conducted over approximately a month, my observations only represent a snapshot of the reservoir social-ecological systems. Conversely, my textual analysis involved the collection of relevant texts as far back in time as possible.

4.1 Primary Method

For my observational data, I made four sets of observation at Pandan and Bedok reservoirs each over four weeks between 23 July 2012 and 16 August 2012. For Bedok Reservoir, all sets of observation occurred weekly; whereas for Pandan Reservoir, two sets of observation occurred weekly for the first two weeks, while the last two occurred on the same day in the last week. For each set of observation, I chose three evenly spaced sub-locations at each reservoir location, and made thirty-minute observations at each sub-location during the evening. During each thirty-minute observation, I stationed myself at a fixed point at the sub-location and recorded my observations of activities engaged by the public, using tally marks on an observation log sheet. These sheets came in the form of matrices that contain various activity categories, each of which contained age group and gender categories (Table 2 in appendix). Within each thirty-minute period, I constantly made 360-degree visual scans as far as my vision extended within the reservoirs. I made a tally at the respective category each time I made an observation, and used separate codes for observations of individuals, pairs, and groups, which characterized level of social interaction. During my observations, I also used codes to record identification of foreigners. This method constituted a combination of "focal" (Altmann, 1975, p. 242) and "scan sampling" methods (Hino, Reis, Ribeiro, Parra, Brownson, and Fermino, 2010, p. S157). Whenever I observed activities that did not fall into my pre-determined categories, I recorded them as additional notes on my log sheet. I also rotated the order of the sub-locations at which I made my observations every week, to limit any bias that the timing of day might have on my observations.

For the last set of observation at Bedok Reservoir, I collected my observation by roving around each sub-location, in order to diversify my mode of observation. On the other hand, I roved each sub-location for the last two sets of observation at Pandan Reservoir, in order to make up for the lower user density present during my observation time that occurred earlier in the day then. For these two sets of observation, I also did not rotate the order of the

sub-locations between both of them, due to time limitation. However, for one of the sub-locations in the first observation set on that day, I limited my observation to that sub-location only. I also roved for longer distances around another sub-location at Pandan Reservoir for both observation sets in the last week, in order to expand my observation scope for each sub-location as much as possible and make up for the missed rotation of order among sub-locations. After completing my observations, I calculated the percentages of my observation counts according to categories of activity, age, gender, level of social interaction, and native vs. foreign. Then I averaged these percentages over the four sets of observation for each reservoir location. These counts only reflect the number of observed incidences, as I recorded separate incidences of observed activities done by the same person at each sub-location.

4.2 Secondary Method

As for my secondary data, from June 2012 to February 2013, I searched for all news articles, social media content, and government documents, which were related to midges in Singapore, on a rolling basis. On top of that, in November 2012, I also searched for all previous data through systematic procedures. This involved combing the Internet for all relevant news, social media, and government content, using a fixed set of search terms on the Google search engine. I used the search terms in English and Chinese, since these were the two most widely spoken languages in Singapore, and capturing data in both languages would ensure comprehensiveness. Not only did I use Google's main service to search the general web, I used its other services of Google Video, Google News, Google Blogs, Google Discussion, and Google Scholar. Then I delved into specific databases and websites to capture further content. The search terms that I used for these sources were similar to those I used in Google, but differed where I tailored them to specific sources.

My initial Google searches yielded many news articles on interactive media websites, but to obtain print newspaper articles, I searched the databases of Factiva, Access World

News, LexisNexis Academic, and ProQuest via Cornell University Library's website[2]. I also searched for the news articles on NewspaperSG, National Library Singapore's online resource for its digital newspaper archives[3]. When the databases included Singapore news sources in both English and Chinese, I used search terms in both languages. Besides using Google, which yielded the bulk of my social media data, I searched for online social media content on the YouTube website and Singapore's citizen journalism website STOMP[4] (Straits Times Online Mobile Print). I also used a social media search engine to search for relevant Facebook and Twitter posts[5]. I only used English search terms for these non-Google sources as English was their medium of communication. Regarding government documents, I obtained much of my data from Google. In addition, I searched the Singapore Government's official portal website[6] first, before searching the individual websites of key Singaporean government agencies and political parties – the Ministry of Environment and Water Resources (MEWR), Public Utilities Board (PUB), National Enviroment Agency (NEA), Housing Development Board (HDB), Urban Redevelopment Authority (URA), National Parks Board (NParks), the People's Association (PA), the Town Councils, the People's Action Party (PAP), and the Workers' Party (WP). Among these websites, the PAP and the town councils' websites had no search function, and I did not search these websites as a result. I also only used English search terms for these sources as English is the working language of Singapore. Lastly, I also obtained government documents from the databases Factiva and ProQuest, while searching for news articles.

Next, I classified my data into three main sets, namely news articles; social media content; and government documents. I considered reports made by any mainstream media organization as news articles, online material that engaged communities as social media

[2] http://www.library.cornell.edu
[3] http://newspapers.nl.sg
[4] www.stomp.com.sg
[5] http://www.social-searcher.com
[6] http://www.gov.sg/government/web/content/govsg/classic/home

content, and statements made by any member of the Singapore Government as government documents. Some of the data were both news articles and social media content, or both social media content and government documents, at the same time. In these cases, I classified them into both sets of data. For each set of data, I separated the data into 'immediate' and 'peripheral' categories. The former category consists of data from local sources that are relevant to the nuisance chironomid context in Singapore, whereas the latter one consists of data from local and foreign sources that are relevant to all midges in Singapore, including non-chironomid midges. The 'immediate' categories of each set of data was then further divided into 'with quotes' and 'without quotes' subcategories, in order to compare data that included content repeated by one or more sources within the same set of data, with those that did not. After classifying the data, I translated all Chinese content into English myself as I am bilingual. I translated the content according to my best ability, and I used print and online dictionaries[7] when I encountered difficulty in translation. Any bias or error in translation was entirely mine. I included photo captions whenever relevant, and transcribed all relevant video content. I also removed extraneous information, such as usernames, emoticons, and advertisements, which cluttered my data.

For news data, the 'with quotes' subcategory included news reports reproduced by sources other than the original one, whereas the 'without quotes' subcategory excluded these reproduced reports. However, the 'without quotes' subcategory still included reports repeated by the same source at more than one location. For social media data, the 'with quotes' subcategory included all user posts that had been quoted by other users in their reply posts, and all quoted content from other sources that resulted in repeat of content within the social media data, such as online news reports and posts from other social media websites. Social media users quoted posts multiple times in a conversation sometimes, and I included the

[7] Xiandai Hanyu Cidian, 2005, 5th ed., The Commercial Press; A New English-Chinese Chinese-English Dictionary, 1994, Intellectual Publishing Co.; http://www.mdbg.net/chindict/chindict.php

quotes in the data in all of the instances. When social media users posted hyperlinks to cite news reports or social media posts outside of the websites that they are using, I included the linked content as part of the users' original posts. However, I only included the primary texts without their accompanying comments by other social media users of the linked websites. I did not include linked content if they were embedded within totally irrelevant information; or if the linked website was on a general topic, in which case the user had already summarized the relevant information from the linked website in addition to including the hyperlink. I also did not include the content from these links again, when these links appeared in quotes of the posts in which the links originally appeared.

On the other hand, the 'without quotes' subcategory excluded all quotes in reply posts, and all reproduced content that resulted in repeat of content within the social media data. For example, if users cited social media content from a source within my social media data, I only retained the original set of the content. Yet, I included content quoted from a source outside of my social media data; unless this content was reproduced by two or more social media users, in which case only a single set of content was retained. Lastly, for government documents, several statements issued by the Singapore Government were embedded within citizen comments and replies. I included the citizens' voices in the 'with quotes' category and excluded them in the 'without quotes' category. After compiling all relevant information, I compiled them into documents according to the respective sets of data, and fed them into a text analysis software Leximancer for analysis.

Before I divided my data into their respective subcategories, I demarcated the boundaries of each unit of my data according to my judgment of their relevance to my analysis. As my raw data varied in their focus on and relevance toward the nuisance chironomid issue, I used various methods to extract relevant content from their parent content where necessary. If relevant content was continuously embedded within a larger, focused

topic of an article, document, or thread; I included the entire data unit in my analysis. For example, when discussion about the nuisance midges was embedded within a blog entry that recounted the author's experience of Bedok Reservoir's tranquility, I analyzed the whole entry as it was consistently focused on its main topic of Bedok Reservoir throughout. Using such a criterion also ensured that the parent topic of the data unit included in my analysis was strongly related to the nuisance chironomid issue, and hence relevant to my analysis.

However, if relevant content about the chironomids was embedded within a hotchpotch of topics, or was itself a miscellaneous topic within a focused parent topic, I only extracted the relevant content so as not to corrupt my data with unnecessary data. This came in a few types of situations. The relevant content sometimes appeared within the parent content at only a single location, such as a sentence in a forum thread. In this case, I only extracted the content at that specific location. At other times, other social media users replied to that content later on, albeit interspersed with discussions of other topics. I thus extracted the relevant content from where the relevant content started to where it stopped. Yet, even after relevant content about the nuisance chironomids had ceased in a social media discussion, it might have been revived at a distant location afterward, such as tens of pages away. In such a situation, I extracted the content a second time from where it started to where it stopped. In other cases, the relevant content might not have been embedded within a parent content, but had been brought up as part of a parallel topic. For example, in a forum thread about nuisance bees in a Singaporean housing estate, forum users' discussion of the bees led to the discussion of the nuisance chironomids. In this case, I did not consider the entire content to be relevant and only extracted the relevant content as a unit of data.

4.3 Operationalization of Research

I specified socio-ecological variables that I could measure using nominal, ordinal, and ratio methods (Babbie, 2010), based on Krasny and Tidball's (2012) 10 civic ecology hypotheses and my conceptual framework. These variables helped me answer my three research questions by characterizing the state of the reservoir social-ecological systems in relation to the chironomid disturbance, resources available within the systems for adapting to the disturbance through civic ecology practices, and barriers to the emergence of civic ecology practices.

4.3.1 Research Question 1

For my first research question, I distilled various aspects of social-ecological systems from the hypothesized outcomes of civic ecology practices, and concretized them into the specific variables of 'ecosystem', 'governance', 'personal well-being', 'community', 'culture', 'self-regulation', and 'emergent properties' (Table 3 in appendix). According to the 9th hypothesis, these variables generally corresponded to personal, social, and environmental ecologies (Krasny and Tidball, 2012). Personal ecology consisted of personal well-being; social ecology consisted of governance, community, and culture; while environmental ecology consisted of biophysical interrelations and processes. Self-regulation encapsulated the interaction across all three ecologies; and emergent properties transcended all three ecologies to form holistic phenomena, which Alberti (2008) argued were inherent in cities as ecosystems, as discussed in my literature review. Since these variables were derived from the desired outcomes of civic ecology practices, they represented different aspects of a possible equilibrium state that could be generalized to the states of the reservoir social-ecological systems in their current conservation phases of the adaptive cycle. Measuring those variables would then help me assess how different aspects of the equilibrium states of those systems had changed, or were issues of concern, in relation to the chironomid disturbance.

Personal well-being was derived from the 3rd hypothesis, which described "psychological and physical well-being" as an outcome (Krasny and Tidball, 2012, p. 269), and the 2nd hypothesis, which described "individual" resilience as an outcome, which encompassed emotional connection to cultural traditions (Krasny and Tidball, 2012, p. 268). Governance was derived from the 5th hypothesis, which described the growth of "small-scale, self-organized efforts" to "multiple partnerships" as an outcome (Krasny and Tidball, 2012, p. 269). Community is derived from the 8th hypothesis, which describes "community well-being" as an outcome, including economic vitality and healthy social behaviors (Krasny and Tidball, 2012, p. 270); as well as the 2nd hypothesis, which described cultural sustainability to be part of the outcome of "community resilience" (Krasny and Tidball, 2012, p. 268). Culture was derived from the 7th hypothesis, which described "culturally embedded learning about social-ecological systems" as an outcome of civic ecology practices (Krasny and Tidball, 2012, p. 270). Ecosystem was derived from the 8th hypothesis, which described "greening" as an outcome (Krasny and Tidball, 2012, p. 270). This referred to green infrastructure capable of providing ecosystem services that led to healthy behaviors (Krasny and Tidball, 2012), and hence reflected healthy ecosystem structure and function.

Self-regulation was derived from the 6th hypothesis, which described the "ongoing adaptation based on information about outcomes" as an outcome of civic ecology practices (Krasny and Tidball, 2012, p. 270). This represented the transition from the reorganization phase to the exploitation phase, after civic ecology practices had been well-established, and the rebuilt social-ecological system had just developed the ability to self-regulate. Self-regulation also reflected the flows within the reservoir social-ecological systems, which characterized the increasing connectivity of the systems' critical resources during the exploitation phase. Emergent properties was derived from the 4th and 10th hypotheses. The former described "sense of place" as an outcome (Krasny and Tidball, 2012, p. 269), and as

explained in my literature review, this property involved emotions and experiences that I regarded to be more than the sum of the three nested ecologies. Similarly, the 10th hypothesis described "social-ecological resilience" to be an outcome, which was a complex result of all the interactions among the three nested ecologies (Krasny and Tidball, 2012, p. 271).

4.3.2 Research Question 2

For my second research question, I borrowed Machlis's (1997) concept of critical resources in human ecosystems as an organizing principle to assess the potential of the reservoir social-ecological systems for adaptation through civic ecology practices. Therefore, I developed the variables of biophysical, cultural, and socioeconomic resources, in order to measure them. These resources are also referred to in Krasny and Tidball's (2012) hypotheses about civic ecology practices. In the 2nd and 4th hypotheses, they refer to culture as a resource when they discussed "social-ecological memories" (p. 268) and "local history, cultures, and aspects of the built and natural environment" respectively (p. 269). The former represents practical knowledge and ecological resources from one's historic traditions, while the latter represents civic traditions of local places. The latter hypotheses also refers to biophysical resources since it encompasses local natural history. On top of that, the 3rd hypothesis also refers to these biophysical resources in its proposition that "engaging people in working with nature" is needed for civic ecology practices (p. 269). In the 6th hypothesis, Krasny and Tidball (2012) refer to socio-economic resources in their discussion about "citizen engagement in monitoring" (p. 270), which represents grassroots "knowledge", "labor" and "capital" (Machlis et al., 1997, p. 352). I also complemented Machlis's perspective with that of Stokols, Lejano, and Hipp (2013), who conceptualized potential in the form of multiple human and material capitals, like "technological capital", "economic capital", and "human-made environmental capital" (p. 6). I then used this additional perspective to measure my variables.

4.3.3 Research Question 3

As for my third research question, I used the same corresponding variables for resources to measure barriers to civic ecology practices, for better comparison between both properties in my analysis.

4.3.4 Measurement and Analysis

After specifying my variables, I measured them using the results from my primary and secondary methods. I used my observational results to measure the variables by classifying my various activity categories under the variables, and then analyzing the ratios of my calculated percentages among those categories. Likewise, I used my textual analysis results to measure the variables by classifying concepts and themes derived from Leximancer under the variables, and measuring them nominally and ordinally. Leximancer is a text analysis software that decomposes text content into manageable units of analysis like concepts and themes, and displays the extracted ideas visually using those units (Leximancer, 2011). The software generates concepts by clustering highly connected words, starting with seed words that appear the most frequently in the text, and then looking for other words most relevant to the seed words. In the process, Leximancer also learns the definition of the concepts iteratively and constantly updates its thesaurus of words for every concept (Leximancer, 2011). By calculating the concepts' frequency of occurrence in the text, Leximancer produces a relevance score for each concept that measures its frequency of occurrence in the text (Leximancer, 2011). Besides ranking the concepts according to their relevance scores, Leximancer also ranks the concepts according to the percentile of their scores, and allows users to select concepts based on cutoff percentile values using a slide bar (Leximancer, 2011).

Leximancer also calculates the frequencies at which concepts co-occur in the text, and uses the calculated scores to generate the concept map. Not only does Leximancer demonstrate the strength of co-occurrence by displaying these scores, it also visually displays

this information through connecting rays on the map, and the scores of connectivity between each concept to all others (Leximancer, 2011) (Diagram 2). Leximancer generates its maps in a stochastic manner and thus multiple patterns of concept arrangement on a map can result for each data set. Each time a map is generated, the concepts are initially scattered throughout the map space in a random manner, and then clustered according to their co-occurrences to result in a final arrangement. Using the 'recluster' function in Leximancer generates a new map for a data set with this stochastic method each time, and a different pattern of arrangement might result for each map (Leximancer, 2013).

On a broader level of analysis, Leximancer groups closely related concepts into themes. Levels of this analysis lies on a continuous scale of theme size 0% to 100%, reflecting broader, fewer themes with increasing scale value (Leximancer, 2011) (Diagrams 3 & 4). In classifying the concepts and themes under my specified variables, I used whole sets of themes and concepts for each data source, as well as the concepts in the top 50 percentiles, and themes at values of 33% (Diagram 5), as these were the default specifications upon accessing the conceptual maps. In addition, I used themes at values of 100% too (Diagram 4), since they represented the broadest level of analysis and hence the texts in their most raw forms. In my analysis, I compared the variable measurements between whole sets of concepts and the ones in the top 50 percentile for each data source, in order to tease out the priorities of the source.

Leximancer users have manually supervised the analysis of broader-level analyses by looking for triple overlaps among themes manually (Tidball, Svendsen, Campbell, Falxa-Raymond, and Wolf, 2012). Sets of triple themes that overlap on the map might represent a broader-level theme that Leximancer might not be able to capture through its intelligence, and users can detect such themes based on their research needs. Moreover, by detecting the concept nodes of the triple overlaps, users can investigate those broad-level themes in greater

detail (Tidball, Svendsen, Campbell, Falxa-Raymond, and Wolf, 2012). I used this method to perform my analysis on a level that was between theme sizes 33% and 100%, by identifying triple overlaps among themes at 33% (Diagram 6). Not only could I complement Leximancer's analysis with my supervision, I could also compare the variable measurements along a gradated spectrum of increasing levels of thematic analysis, and hence increasing levels of size and speed of operation of the variables that were nested within one another in the panarchy model. Furthermore, this spectrum existed across the three data sources, with social media data representing a smaller, faster scale, and government data representing a larger, slower scale. Comparison among these data sources also allowed me to employ such analysis of scale. Although Leximancer used a stochastic approach to textual analysis, and did not predict quantitative outcomes precisely, it nevertheless provided indicative results for the purposes of my exploratory research.

For each data source, I used the 'immediate' category and 'with quotes' subcategory as my default yardstick for comparison in my research, as these categories reflected the desired scale and accuracy of representation of the study system. The immediate category suited the scale of the reservoir social-ecological system best, as represented by Diagram 1. Although data from this category might have also included Singaporeans outside of the reservoir social-ecological system who made direct references to the nuisance chironomid issue, these data were still a good representation of the reservoir social-ecological systems, as the other Singaporeans were still linked to those systems through common social ecologies in a city-state setting. The 'with quotes' subcategory also accounted for the effects of social amplification, and hence the information flows occurring between personal ecology with the other nested ecologies during the data collection period. This helps me assess the self-regulatory ability and connectedness of the reservoir social-ecological systems too. Results from the abovementioned category and subcategory of the data were compared with their

counterparts for a richer analysis. The peripheral category reflected the national and international scale in which the nuisance issue was embedded in, and reflected the effect of larger, slower variables on smaller, faster ones through the remember process in the panarchy framework. The 'without quotes' category excluded a portion of the information flows occurring among the nested ecologies, but it could still be used as a yardstick for comparison with the 'with quotes' subcategory.

In order to analyze the data at scales smaller than that of the reservoir social-ecological system, I used the 'query' tool in Leximancer, which had many specialized functions for investigating where concepts of interest appeared in the input texts (Leximancer, 2011). I also used Leximancer to analyze the combined text of the three data sources, which consisted of the peripheral categories of all three data sources, in order to extract properties of the reservoir social-ecological systems that are embedded on higher levels of the panarchy. Therefore, I not only analyzed data across thematic and conceptual hierarchies, as well as across subcategories, within each data source; I also analyzed the data across the three data sources and the combined one.

Diagram 2. Display of connecting rays between the concept 'midges' and other concepts, and their scores of likelihood of co-occurrence (Taken from my social media data).

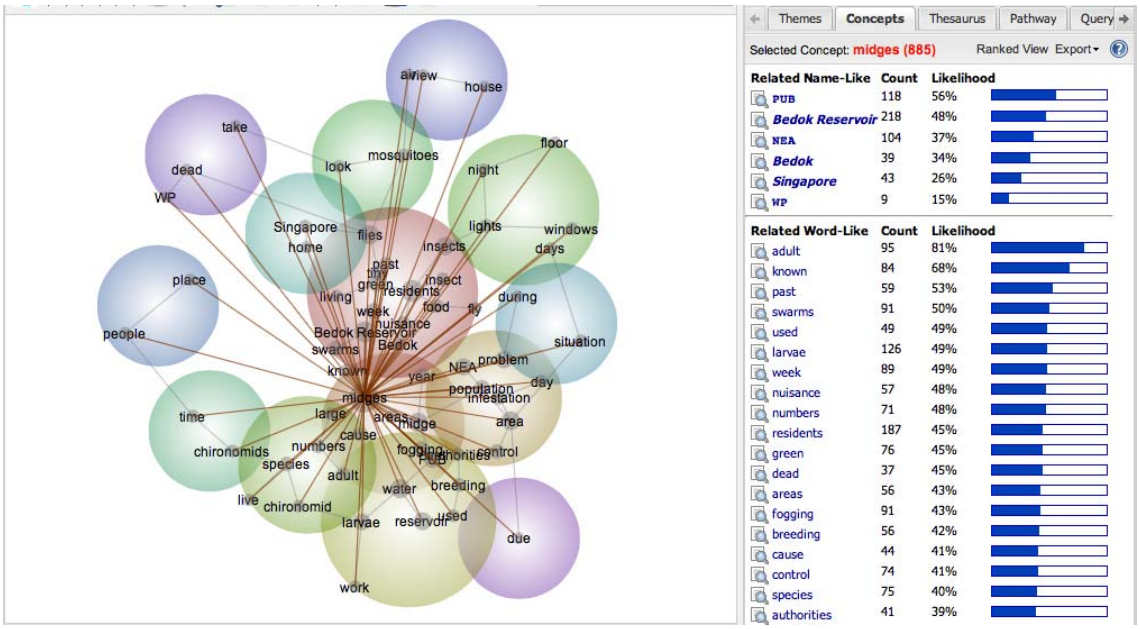


Diagram 3. Example of multiple, narrower themes at 33% (Taken from my social media data).

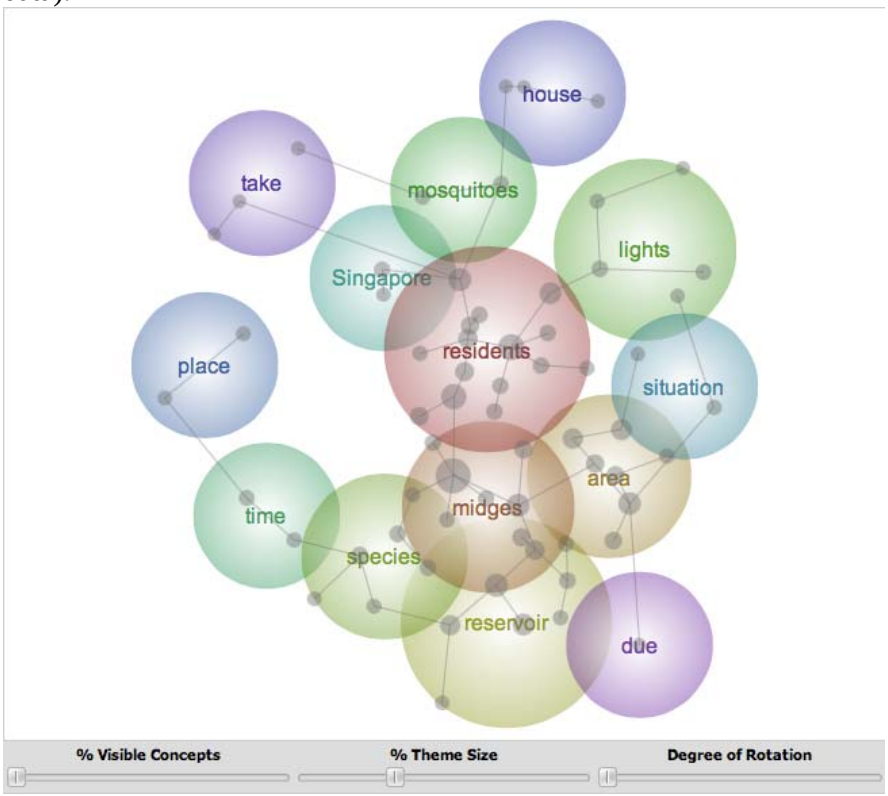


Diagram 4. Example of a single broad theme at 100% (Taken from my social media data).

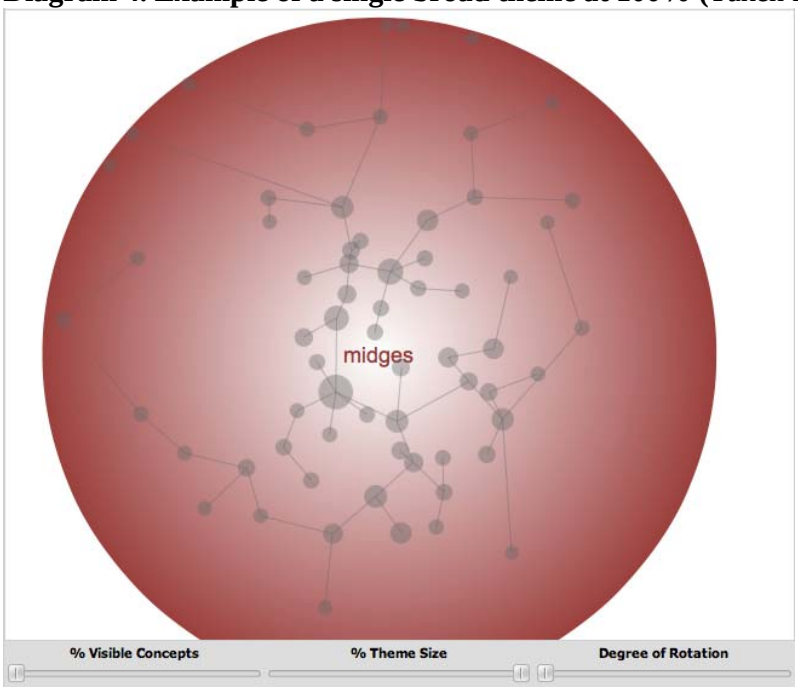


Diagram 5. Example of the top 50% of concepts and their themes at 33% used in my analysis (Taken from my social media data).

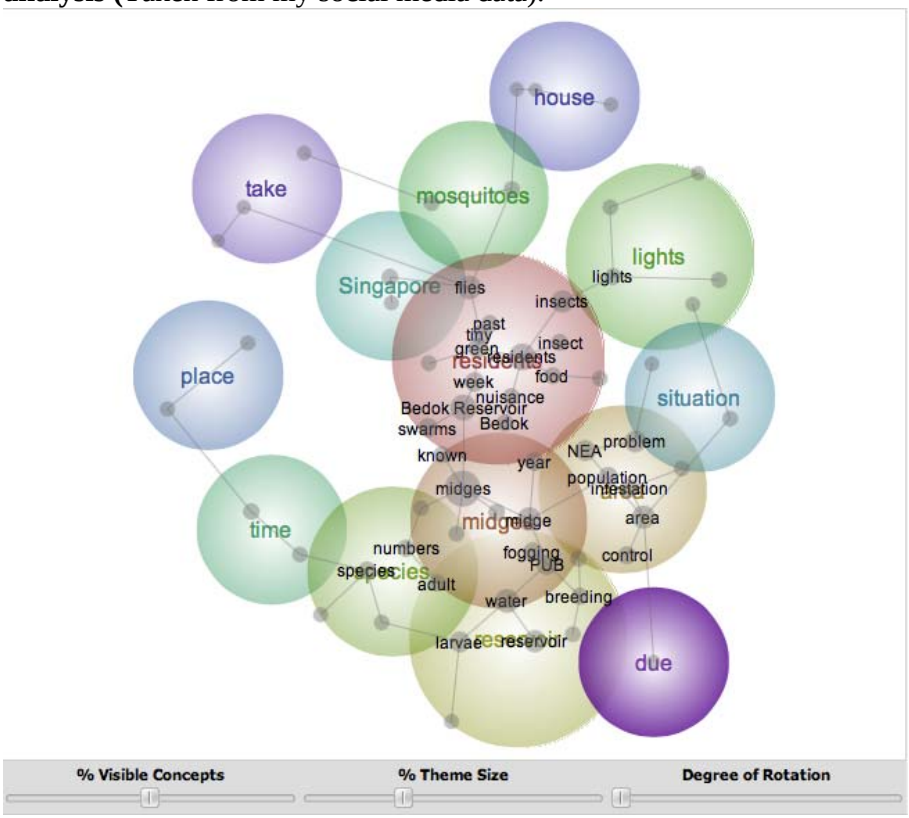
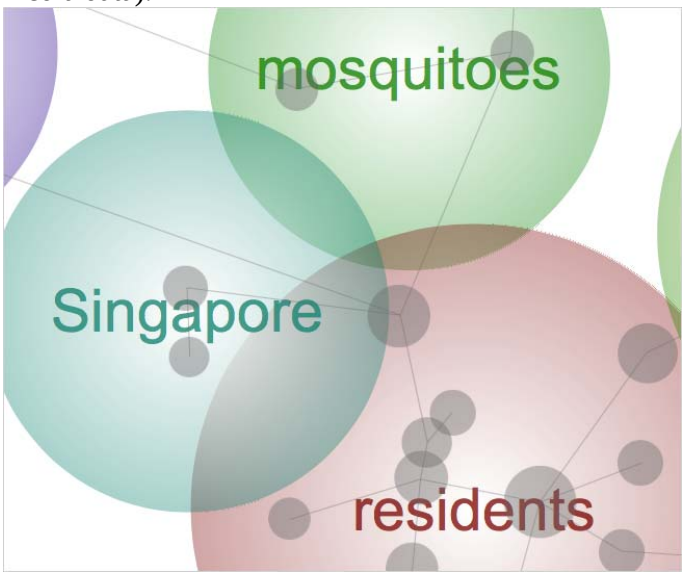


Diagram 6. Example of a triple overlap and its concept nodes (Taken from my social media data).



5. Results and Discussion

My observations of public behavior around the reservoirs have given me a firsthand understanding of the affected communities' relationship with the chironomids and reservoirs, which is valuable to my assessment of their potential for engaging in civic ecology practices. Although my observations were made after the chironomid disturbance had come under control, they occurred in the same year as the disturbance and were useful for showing the states of the reservoir social-ecological systems in the aftermath of the chironomid disturbance. My observations therefore indicate whether the systems had crossed tipping points into the release phase of the adaptive cycle. At the same time, by showing the everyday lives of the affected communities, my observations are also useful for revealing the resources and barriers inherent in the reservoirs' social-ecological systems. On the other hand, my secondary data spanned both the disturbance occurrence and its aftermath, and is therefore more useful for assessing the disturbance effects and the flows within the social-ecological systems; but they only informed my understanding on a secondhand basis.

My observational results are summarized in Figures 1 and 2. Figure 1 shows distinct trends across both reservoir locations. Jogging and walking were the most frequent activities at both locations, while nature watching was the least. Next came resting and observing surroundings, socializing, as well as fishing, in this order for both reservoirs; followed by water sports and photography. The main differences between both reservoirs lied in the frequency of cycling and walking the dog. Cycling was the second most frequent activity for Bedok Reservoir, but the fifth for Pandan Reservoir. Walking the dog was also the sixth most frequent activity for Bedok Reservoir, but the eighth for Pandan Reservoir, on par with nature watching. On the other hand, water sports was the sixth most frequent activity for Pandan Reservoir but the eighth for Bedok Reservoir. Due to the large difference in frequency ranking, the frequency of cycling at Bedok Reservoir was almost 15 times that at Pandan

Figure 1. Frequency of each activity observed at each location.

Activity	**Mean Percentage (%)**[#]	
	Bedok Reservoir	**Pandan Reservoir**
Jogging/Walking*****	79.32	58.40
Cycling	7.83	2.12
Walking the dog	1.37	0
Water sports	0.45	1.82
Resting/Observing surroundings	3.12	25.31
Fishing	1.88	2.21
Socializing	2.29	8.51
Photography	0.69	0.24
Nature watching	0	0

***** I included other forms of sports in minority situations.
[#] Percentages were calculated out of a total number of observations that also included miscellaneous activities not included in the figure.

Figure 2. Frequency of observation according to gender, age group, level of interaction, and citizenship status at each location.

Gender, Age, Social Interaction, Foreigners*	Mean Percentage (%)	
	Bedok Reservoir	**Pandan Reservoir**
Male	67.31	88.13
Female	29.24	11.14
<18	9.98	14.29
18-30	26.87	16.77
31-40	30.46	50.03
41-50	20.67	14.24
>50	8.52	4.12
Pairs	22.72	22.32
Groups	17.25	16.21
Foreigners	0.29	49.65

***** Estimates were made wherever possible. Where data lacked, I used group size of four and did not account for gender. I assumed equal number of males and females if group size was even, and one more male than female if odd. If observed pair spanned two age groups, I assumed one in each age group. If age undetermined, I made best guess according to available information, otherwise I did not account for it. If odd number of people spanned two age groups, I distributed according to likelihood of each age group.

Reservoir. Nevertheless, for several activities, their frequencies differed between both reservoirs by large amounts despite having similar frequency rankings. The frequency of jogging and walking at Bedok Reservoir was almost 1.5 times that at Pandan Reservoir; though this could be accounted for by the relatively high frequency of resting and observing surroundings at Pandan Reservoir, which was about eight times that at Bedok Reservoir. Socializing also occurred almost four times as frequent at Pandan Reservoir than at Bedok Reservoir, even though this activity had similar ranking for both locations. Water sports, despite occurring at consistently low frequencies between both locations, was about four times more frequent at Pandan Reservoir than at Bedok Reservoir.

Next, for the other observation categories shown in Figure 2, more males than females were observed at both locations. The age groups between 18 years and 40 years were also observed the most frequently for both reservoirs, though that for Pandan Reservoir is more skewed toward the age group of 31 to 40 years than Bedok Reservoir. The age groups < 18

years and > 50 years occurred the least frequently on the other hand. The frequencies of users in pairs and groups were surprisingly consistent between both reservoirs too. A glaring difference between both reservoirs was the significantly higher percentage of foreigners observed at Pandan Reservoir than at Bedok Reservoir.

The results of my textual analysis are summarized in Figures 3 to 10. Figure 3 categorizes the issues of concern represented in each data source, according to the social-ecological variables that I distilled from the 10 civic ecology hypotheses. Figure 4 also categorizes the biophysical, cultural, and socioeconomic resources of the reservoirs' social-ecological systems for civic ecology practices, according to data source. Figure 5 shows the barriers to the emergence of civic ecology practices from the perspective of each data source. For these three figures, I measured the variables nominally by extracting relevant issues, resources, and barriers from the total set of concepts, as well as ordinally by comparing the measurements derived from the set of top 50% concepts with those from the total set of concepts. As for figure 6, it shows the issues, resources, and barriers derived nominally from the themes, and categorizes them according to scale of thematic analysis. I compared the measurements across all scales ordinally. Figures 7 and 8 are Venn diagrams displaying the total sets of concepts and themes respectively, according to data source. Figure 9 shows the themes and concepts that emerged from the peripheral categories of each data source, but not from their counterparts. This helps me detect issues, resources, or barriers at higher scales than the immediate category, as the peripheral category encompasses the immediate category. Similarly, Figure 10 shows the themes and concepts that emerged from the 'with quotes' subcategories of each data source, but not from their counterparts. Since the 'with quotes' subcategory encompasses the 'without quotes' one, Figure 10 helps me detect issues, resources, or barriers derived from information flows across the nested ecologies.

5.1 Research Question 1

My results do not reveal evidence of the tipping point being reached by the reservoir social-ecological systems. Overall my observational findings show that the communities were going about their everyday lives smoothly, and resources were still tightly bound within the reservoir social-ecological systems in an equilibrium state, despite the chironomid disturbance. Moreover, the frequencies of activities observed were fairly consistent with the baseline data that I obtained from a past survey of Singaporeans' use of Ulu Pandan Park Connector near Pandan Reservoir (Yuen, Kong, and Briffett, 1999). This indicates maintenance of lifestyle even after the chironomid disturbance. Similarly, while my analysis of the textual data combined reflects issues of concern in each nested component of the reservoirs' social-ecological systems, they did not indicate the loss of ability to self-regulate in the face of the disturbance, or presence of significant shocks to the emergent properties of the systems. None of the concepts or themes derived from my textual analysis specifically indicated loss of sense of place, social-ecological resilience, or the ability to self-regulate in response to the chironomid disturbance.

On the other hand, sense of place was difficult to detect through observations as they represent the "satisfaction", "attachment", and "meanings" toward one's community, and is thus very subjective (Beckley, Parkins, and Stedman, 2002, p. 632). Similarly, self-regulation or social-ecological resilience was difficult to observe as my primary method was a cross-sectional method and could not show self-regulatory processes. Nonetheless, no evidence shows any loss of self-regulatory ability, and hence connectedness across the nested ecologies; or loss of emergent properties; and this supports the other data in indicating that resources remained tightly bound within the reservoir social-ecological systems. In fact, concepts that uniquely emerge from the 'with quotes' subcategory show flows of information and hence self-regulation. The lack of evidence for the loss of social-ecological resilience

itself also does not convince me that any perception of the tipping point being reached existed.

All three data sources share similar concepts related to the overall nuisance effects on residents and the perceived need for the authorities to control the chironomids (Figure 7). Moreover, according to Figures 3 and 6, my combined textual data reflect that personal comfort and material living spaces were the main issues. Maintaining Chinese New Year traditions was also another issue, but it was derived from the concept ‘year’, which also incorporated other aspects of time related to the disturbance. In addition, Chinese New Year was only an annual tradition and did not likely represent ongoing cultural dimensions. Nevertheless, concerns about Chinese New Year were still intertwined with the temporal patterns of the chironomid disturbance in relation to the calendar year, as the chironomid outbreaks occurred annually for Bedok Reservoir (Diagram 1; see time). Hence, Chinese New Year tradition was a variable that was in sync with the chironomid emergence cycles, and the latter cascaded upward to the former through the revolt process. In fact, the triple overlapping themes and their concept node for the social media data show the centrality of the annual calendar year to the chironomid issue (Figure 6). Chironomid and fish ecologies were also issues, but these were natural concerns given that these organisms were related to the disturbance source. Personal issues also seem to be more materialistic than emotional, and this might indicate Singaporeans’ priority of comfort over place attachment, which is consistent with my observational findings of Singaporeans’ attitude toward nature as a resource. Consequently, the combined textual data indicated little perception of transformation of the reservoir social-ecological system across scales as a result of the chironomid disturbance.

One revealing result though is that the temporal scales of ‘day’ and ‘year’ are common to all textual data sources (Figure 7), thus showing that the chironomid issue mainly

operated on these scales. This result shows how the chironomids' daily and annual behavioral cycles intersected with those of the residents. My query of these concepts showed that they stemmed from the chironomids' daily evening swarms and annual outbreak, daily fogging, Chinese New Year, the long-term R&D study, and the annual nuisance event. Hence, the chironomids' disturbance to everyday lives had the potential to cascade upward to much larger variables on annual scales like national politics and ecosystem health, but at the same time, these larger variables provided a wealth of memories for individuals to adapt on an everyday basis.

5.1.1 Environmental Ecology

5.1.1.1 Primary Data

According to my observations, no significant change in ecosystem structure or function was detected. The environmental ecology of the reservoirs' social-ecological systems was thus not disrupted by the chironomid disturbance. I observed that the reservoirs provided the surrounding communities with various ecosystem services besides water supply, and these included recreation, exercise, and social spaces. Community members still used the reservoirs for these services even after the chironomid disturbance, and hence biophysical resources were still locked up in a stable ecosystem at the time of observation. Both Pandan and Bedok reservoirs had designated amenities for fishing and water sports, as well as jogging and cycling paths. Pandan Reservoir had wetlands planted along its dyke, and floating wetlands on its nearshore waters, which provided habitat for birds and other invertebrates. On top of that, Bedok Reservoir had floating decks for relaxation and enjoyment of the reservoir scenery. The reservoir users did all of these activities during the observation period, though jogging and walking made up the highest proportion of all activities.

In addition, fishing, water sports, and nature watching could be indicator activities that reflected the state of the reservoir ecosystems, since they depended directly on ecological processes within the reservoirs. Population levels of desired fish and wildlife species, and water quality levels had to be suitable for these activities to take place, and these factors in turn depended on wider ecosystem processes like nutrient cycling. In a friendly conversation that I struck up with an angler at Pandan Reservoir, I learnt that he was trying for the Peacock Bass and "Zebrafish" (sic) after he had heard that these species were present there. The presence of fishing and water sports indicated that the reservoir ecosystems could still support them. Nature watching was not observed in my study, nevertheless. However, I had observed a lady who seemed to look for something among the wetlands of Pandan Reservoir's dyke occasionally while walking along its perimeter. I also observed other reservoir users taking pictures of the sunset view of the reservoir, or simply admiring the reservoir view on Bedok Reservoir's floating decks. Then I realized that nature watching could be part of the other observed activities, such as walking, photography, fishing, observing surroundings, as opposed to being a distinct activity in its own. After all, many social media users expressed aesthetic appreciation for the reservoirs. Another noteworthy observation was that of two Chinese foreign workers being fascinated by a pair of turtles in Pandan Reservoir outside of my observation window. This showed the presence of wildlife at the reservoirs for users to engage, even after the disturbance event.

According to the abovementioned survey by Yuen et al. (1999), 72.4% of the survey responses indicated use of Ulu Pandan Park Connector for jogging and walking (326). This is fairly consistent with the frequencies of 58.40% and 79.32% that I recorded at Pandan and Bedok reservoirs respectively. Moreover, 0.7%, 0.4%, and 1.3% of the survey responses indicated use of the park connector for fishing, photography, and birdwatching respectively. These figures are similarly quite consistent with the generally low frequencies that I observed

for these activities, and my observed absolute frequencies are only minimally higher for fishing and photography. 67.7% of the survey responses also indicated exercise as a reason for visiting the park connector, while only 0.7% indicated wildlife watching as a reason. This disparity reveals Singaporeans' dominant view toward nature as a resource for maintaining quality of life instead of ecological well-being, and might explain my skewed observational results toward jogging and walking for both reservoirs. My observational findings reflected the lifestyle of the reservoir communities quite accurately overall.

5.1.1.2 Secondary Data

My textual data support my observational findings about the lack of disruption of environmental ecology (Figure 3). Analysis of the concepts of each data source shows that public discourse focused on the species diversity, population ecology, and behavioral ecology of chironomids, on top of their reservoir habitats. Discussion about community ecology was mainly limited to chironomid-fish interactions. On a broader scale of analysis, the themes of the data sources were limited to chironomid habitat and diversity, on top of chironomid-fish interactions (Figure 6). No ecosystem-wide implications was thus indicated. Specifically, both news and social media analyses showed further attention toward chironomid species diversity and larval ecology in the nuisance issue (Figure 7), with social media displaying even higher awareness of chironomid life cycle and reproduction. This might be due to communities' and reporters' higher experience of the chironomid nuisance on the ground than policymakers. When considering only the top 50% of concepts throughout all the data sources, the issues of population and behavioral ecologies could be further narrowed down to chironomid breeding and larvae, excluding chironomid-fish interaction altogether. Chironomid diversity also became less salient in the top 50% concepts of news and social media data. The peripheral category of the government data conversely showed awareness of species diversity of chironomids and dragonflies in other parks (Figure 9), which showed the

embeddedness of the chironomid issue in wider biodiversity commitments. The lack of implications about wider ecosystem issues support my observations of reservoir users being able to carry on 'business as usual'.

Nevertheless, my secondary data findings might also represent the detachment of Singaporeans from wider ecosystem processes, and hence their strong preference for personal exercise observed at the reservoirs. Such environmental attitudes might have delayed their perception of disruption to ecosystem patterns and processes, if it had already occurred. Only government data showed the concept and theme of 'fish' (Figures 7 & 8), though, which showed policymakers' awareness of the role of reservoir ecology in nuisance chironomid management, and their use of this topic in public relations. The concept of fish was not reflected in the 'without quotes' subcategory of the government data however, probably due to the lack of focus on fish as an important part of the ecosystem on the national scale of policymaking. This confirms the role of fish only as an instrument for public (Figure 9) instead of an important part of the reservoirs' ecological support systems.

An unexpected concept and theme that emerged uniquely from the social media data was 'mosquitoes' (Figures 7 & 8). Upon further examination of the concept through the query function, I realized that it partially stemmed from misidentification or misconception of the chironomids as mosquitoes when the disturbance first occurred, though this decreased with time through the Government and the media's educational efforts. My query reflects these efforts by the media to clarify the chironomids' distinction from mosquitoes, and the significance of these efforts is further supported by my query of the same concept in the combined data. The concept also stemmed from discussion of these insects in the parallel contexts of fogging and living spaces. As such, the concept of mosquito does not reflect any related change in ecosystem structure or function, but a mere distraction that might reveal no serious attitude toward the chironomids. Nevertheless, the concept also

reflects the residents' ability to reorganize after the chironomid disturbance by drawing upon scientific knowledge from a higher scale (Diagram 1; see social order), because their learning processes from educational efforts took place at a faster rate than the annual cycle of chironomid outbreak (Diagram 1; see time). This might demonstrate the residents' sensitivity toward their ecosystems, and their detachment from nature might not delay their perception of any ecological disruption very significantly.

Figure 3. Issues of concern related to each variable of the reservoir social-ecological systems as reflected by concepts from each data source.

Issues		Ecosystem	Governance	Personal	Community	Culture	Self-regulation	Emergent
Government	**Concepts**	- Chironomid population ecology - Fish-chironomid interactions - Chironomid habitat	None	None	- Public cleanliness - Public health - Living spaces	None	None	None
	Top 50% concepts	- Chironomid habitat	None	None	- Public cleanliness - Living spaces	None	None	None
News	**Concepts**	- Chironomid diversity - Chironomid larvae - Chironomid population ecology - Chironomid habitat	- Elections	- George Yeo - Home	- Housing infrastructure - Lights - Living spaces - Food	- Chinese New Year - Political values	None	None
	Top 50% concepts	- Chironomid habitat - Chironomid population ecology - Chironomid larvae	None	None	- Housing infrastructure	- Chinese New Year	None	None
Social Media	**Concepts**	- Chironomid diversity - Chironomid population ecology - Chironomid life cycle - Chironomid behavioral ecology - Chironomid habitat - Mosquitoes - Reservoir ecosystem	- Elections - Trust in government	- Home - Health	- Lights - Living spaces - Food	- Chinese New Year - Political values - Economic values toward waterfront property - Values of ecological preservation	None	None
	Top 50% concepts	- Chironomid habitat - Chironomid population ecology - Chironomid breeding - Chironomid diversity - Chironomid life cycle - Reservoir ecosystem	- Trust in government	- Health	- Lights - Food - Area	- Chinese New Year Values of ecological preservation	None	None
Combined	**Concepts**	- Chironomid population ecology - Chironomid life cycle - Chironomid behavioral ecology - Fish-chironomid interactions - Chironomid diversity - Chironomid habitat - Chironomid as fish food - Predator-prey interaction - Mosquitoes	- Elections - Trust in government	- George Yeo - Home - Business - Comfort	- Living spaces - Lights - Businesses - Food	- Chinese New Year - Political values	None	None
	Top 50% concepts	- Chironomid population ecology - Chironomid life cycle - Chironomid behavioral ecology - Chironomid diversity - Chironomid habitat	None	- Windows - Comfort	- Lights - Food	- Chinese New Year	None	None

5.1.2 Personal Ecology

5.1.2.1 Primary Data

My observations show that individuals living around the reservoirs still had the ability to engage in personal recreation, and maintained their physical well-being even after the chironomid disturbance. Moreover, as discussed earlier, a disproportionate number of joggers were males, with the highest percentage of them falling under the 31-40 age group (Figure 2), and many of them were solitary joggers wearing Singapore Army running shirts. After serving mandatory military service, Singaporean males become part of the reserve forces of the Singapore Armed Forces up to at least the age of 40, and many have to take Individual Physical Proficiency Tests (IPPT) regularly for assessment of their fitness. Hence, I can infer that many of those male joggers were reservists who were training for their IPPT. If individual structured exercise could even form a major agenda of the reservoir users, this not only reveals that the structure and function of the reservoir ecosystems were good enough for supporting such physically demanding pursuits, but also that the reservoir communities were in good physical and psychological states overall. The observed frequency of walking and jogging at Pandan Reservoir was nevertheless notably lower than that for Bedok Reservoir and the baseline figures of 72.4% for walking and jogging combined (Yuen at al., 1999). This could be due to the lower population density around the reservoir, as it was on the edge of an industrial area. Pandan Reservoir also seemed less attractive for personal recreation than Bedok Reservoir as a result. Thus, the lower frequency of walking and jogging at Pandan Reservoir might not indicate disruption to personal well-being after all.

Walking the dog, resting, and observing surroundings are yet indicator activities of psychological well-being too, as they reflect mental relaxation. Not only were these activities observed at Bedok and Pandan reservoirs, their frequencies were about equal to or higher than the baseline figures of 1.3% for both activities (Figure 1) (Yuen et al., 1999). The only exception was the absence of reservoir users walking the dog at Pandan Reservoir. This

might be explained by its coarse gravel path that did not seem dog-friendly. Otherwise, the relatively high frequencies of resting and observing surrounding at Pandan Reservoir might compensate for that exception (Figure 1). However, my observation notes show that a large proportion of users resting and observing surroundings were foreigners, thus reducing the effectiveness of this activity for indicating personal well-being of native residents. As Figure 2 shows, Pandan Reservoir had a disproportionately high number of foreign users, and they were likely workers at the nearby industrial estates, according to my observations. This reflects the increasing number of foreigners in Singapore as discussed earlier. I observed that these foreigners had a lower tolerance threshold toward the chironomids than the local reservoir users, as they remained at the reservoirs long after the chironomids started swarming, whereas many locals left once the swarms appeared. This shows that the foreigners had not reached individual tipping points after the chironomid disturbance. This also reflects how the chironomids' effect on use of public space differ between Singaporean residents and foreigners, and this could be a source of value conflict between the two groups in the chironomid nuisance context. Furthermore, observing surroundings might have been more of a pastime for the foreigners than the locals, as the latter had more work and family obligations than the former. Thus, my observed frequencies for resting and observing surroundings might not be comparable to the baseline figures.

5.1.2.2 Secondary Data

Similarly, the textual analysis does not reveal significant implications of the chironomid disturbance for personal well-being, other than those related to physical living spaces and anxiety over potential health concerns. These are represented by the concept of 'home' from the news and social media data, and the concept of 'fogging' from the social media data, respectively (Figures 3 & 7). This shows that the residents only reached tipping point on the sub-personal scale of physical comfort and health, which lacked focus on

emotional well-being. Such a scale might not be sufficient to cascade upward to higher scales. Analysis on a broader scale shows that only homes were a concern, and this was only reflected at a theme size of 33% (Figure 6). The lack of personal issues at even higher broader levels of analysis confirms that disturbance to personal well-being had not been sufficiently significant to cascade upward to the largest variables within the reservoir social-ecological systems. Even the government data did not reveal specific issues of personal well-being, thus showing that those issues might have only cascaded upward to the level of the media (Figure 3).

The social media data reveal the specific concepts of ‘lights’, ‘windows’ and ‘floor’ (Figure 7), indicating the chironomids’ nuisance use of these structures as part of their habitats. My query of the social media data also specifically reveals health concerns of fogging by policymakers as part of its top half concepts (Figure 1), as many reservoir users were worried about inhaling the fumes. This shows an indirect concern related to the disturbance, however. The overlap of the concept of fogging between government and social media further shows that the health concern had political roots (Figure 7). All data sources clearly show that residents were the main individual stakeholders of the nuisance issue, but the news data alone reveal the personal stake of politician George Yeo in the issue (Figure 3). Although this does not have implications for the residents’ personal well-being, it points to wider political implications that will be discussed later. Overall, the salience of materialistic concerns over physical and psychological well-beings is hardly enough to convince that personal ecology was disrupted by the chironomid disturbance.

5.1.3 Social Ecology

5.1.3.1 Primary Data

For social ecology, no observations indicated that community, cultural, or political norms had been disrupted (Diagram 1; see social order). Socializing, water sports, resting, and observing surroundings are indicator activities for culture and community, as these reflect social capital and sense of security. The absolute frequencies of these activities observed (Figure 1) are again overall consistent with my baseline figures, indicating a state of 'business as usual'. In fact, my observed frequencies for these activities are higher than the baseline ones by multiple factors, especially for Pandan Reservoir. Only 1.6%, 0.4%, and 1.3% of survey responses by Yuen et al. (1999) indicated engagement in socializing; sports other than jogging, walking, or cycling; and observing surroundings respectively. My higher frequencies could be explained by the more well-developed recreational infrastructure at the reservoirs than at the park connector in Yuen et al.'s (1999) study. This could be a result of the larger land area of the reservoir parks to support recreation, or the ABC Waters Program that had only unfolded after Yuen et al.'s (1999) study. For example, the development of Pandan Reservoir into a water sports hub as part of the ABC Waters Program might have accounted for the higher frequency of engagement in sports other than jogging and cycling in my study. Being a landmark in itself, Pandan Reservoir might also have been a more likely destination for resting and observing surroundings than Ulu Pandan park connector, which might have served as a transportation corridor more. As discussed above, the higher frequency of observing surroundings might have been accounted for the high proportion of foreigners. I have also observed those foreigners made up a large proportion of Pandan Reservoir users who were socializing, thus accounting for the activity's higher frequency.

Nevertheless, more than a third of the observed activities occurred in pairs and groups (Figure 2), indicating that community bonds and values were still strong in the reservoir communities. School mates and families jogging, cycling, and fishing together were a

common sight. As fish has cultural significance for many Singaporeans, fishing activities might also indicate the expression of cultural traditions around the reservoirs, and thus cultural sustainability. For example, some Malay Singaporeans believe that several fish species have supernatural powers to heal or ward off evil spirits, like the Common Walking Catfish or the Climbing Perch. For many Chinese Singaporeans, fish is also a symbol of abundance, and giving fish is believed to bring blessings. Fish also represents prosperity in Chinese fengshui, especially the species Common Carp, Goldfish, and Golden Dragon Fish. Pet fish-keeping is also a popular pastime in Singapore and popular pet fish species include the above three (Lim and Ng, n.d.). Although those three species are not found to be established and breeding in Bedok and Pandan reservoirs (see appendix; Table 1), their presence in those reservoirs nevertheless show cultural connection between reservoir users and reservoir fish because they are likely abandoned aquarium fish (Ng and Tan, 2010). Fishing activity in those locations might thus support this connection.

5.1.3.2 Secondary Data

While my textual analysis supports my observational findings, it also reveals many underlying issues not captured by my observations. All textual data sources show that implications for community lied mainly in material concerns related to public spaces, housing, and cleanliness (Figures 3 & 7), which is consistent with my earlier findings that individual residents might have only reached tipping point on a sub-personal level of physical comfort and health. Besides, my news and social media data also reveal the salience of chironomids' effect on food, especially social media data in which food is among the top half concepts (Figure 3). My findings of community issues thus show that this individual tipping point only cascaded to another sub-community level of communal comfort, hygiene, and health. My government data reveals that the chironomids were discussed alongside environmental health issues like smoking, dengue, and hygiene of hawker centers (Figure 7).

This indicates that the chironomid issue might have cascaded upward to a national level of public health policy, though no significant health threats have surfaced in Singapore. The above community issues are reflected in the top 50% of concepts (Figure 3), and the themes of all data sources at 33%, as well (Figure 6). Nonetheless, they fade with increasing scale of analysis, with only critical issues of health and food remaining in the level of triple overlap (Figure 6), and this confirms that the tipping points on the sub-personal and sub-community level did not have sufficiently strong impact on the overall community well-being of the reservoir social-ecological systems.

As for governance, my news and social media data detected lack of trust in the government that had been induced by the chironomid disturbance. This even remained salient in the top half concepts of the social media data (Figure 3). Figure 7 also shows that the news data contained unique governance-related concepts like 'election', 'Aljunied GRC (Group Representation Constituency)', and politician 'George Yeo'. This is consistent with the government-directed blames and accusations I had come across in my initial review of the social media data. An even more telling revelation is the implications for Singapore's General Elections and national political landscape (Figure 3). This indicates how civil-state relations are strained by the chironomid disturbance, and the aforementioned management threshold between complaints and level of chironomid outbreak appropriately captures the link between public well-being and expectations of government. This might show that crossing the tipping point on the scale of personal comfort had cascaded upward to the scale of national politics, when the chironomid outbreak coincided with Singapore's five-year general election cycle (Diagram 1; see time), even though the Government had managed to meet public expectations eventually.

In spite of this, the strong governmental efforts in solving the nuisance issue through fogging, application of larvicide, and chironomid monitoring, show that the government has

met public expectations and no real political transformation had taken place. The government data also remains silent on the issue of governance, as reflected by its lack of related concepts and themes (Figures 3, 6, 7), and this confirms the lack of real political implications on a national level. Nevertheless, the reality of the cascade effect of the level of personal comfort on higher levels is still supported by broader levels of analysis. At the thematic level of triple overlap and 100%, the ability of the Government to protect living spaces and solve the chironomid issue remains an issue (Figure 6).

The chironomid disturbance also penetrated the cultural system of the reservoir communities through the revolt process, as political values and interests were shaken up as well. This intersects with the lack of trust in government and concern over the Government's ability to protect their well-being, which were discussed above. The Workers' Party (WP) appeared as a concept for both the news and social media data (Figure 7), and represents the crux of the recent political transformation that Singapore has been undergoing. This transformation is represented by the watershed General Elections of 2011 mentioned earlier. As one of Singapore's leading opposition political parties, the WP has increasingly challenged the dominant ruling party of the People's Action Party (PAP), which also appeared as a concept for the combined textual data (Figure 3). Not surprisingly, George Yeo, a member of the PAP, appeared alongside 'midges' as the second broadest theme in the news data (Figure 6). The politician was also a concept unique to the news data (Figure 7). These findings further support the factional nature of the chironomid disturbance.

My textual analysis uncovers implications for economic, social, and ecological values too, which are not obvious from my observational or textual findings. Economic values are saliently represented by the concept of 'view', which upon further examination, shows the value of the reservoirs' view for property investment around the reservoirs. The unique position of this concept in the social media data also shows that those economic interests

might not have reached tipping point to cascade upward to higher levels of the media or government (Figure 7). Those economic values might also have been disguised as the concern over the chironomids' intrusion into one's house discussed earlier, as 'condominium' is after all one of the traditional '5 Cs' of Singapore's materialistic pursuits, and is an important symbol of status (Diagram 1; see social order and identity). However, economic and political values became less salient when considering the top half concepts of the news and social media data (Figure 3).

Social and ecological values, on the other hand, remain salient. The chironomids' social effect on traditional visitations among friends and relatives during Chinese New Year is embodied in the concept 'year', which is also a concept node that represents the preservation of living spaces (Figure 6). Upon further examination, I discovered that this concept also embodies residents and the media's temporal perspective of the chironomid disturbance in relation to the pre-disturbance period, and the evolution of the disturbance period itself. Hence, Chinese New Year traditions might be a subtle part of the wider issue of preservation, and might not be a salient social issue per se. Moreover, being an annual event, the practice of Chinese New Year traditions might not represent the cultural thread of the community. Values of ecological preservation are also reflected in the concept 'fogging' that emerged from the social media data (Figure 7). The concept shows that other than health issues and the effectiveness of fogging in solving the nuisance issue, the reservoir communities were also concerned about the effects of fogging on the environment. Several social media users were concerned that the chemicals would enter wildlife and be leached into the reservoir water. The intertwinement of these issues makes implications for ecological values less salient. Since only the implications for political values are salient in my analysis, disruption to the communities' cultural system is unlikely.

Figure 4. Resources for civic ecology practices as reflected by concepts from each data source.

Resources	Biophysical		Cultural		Socio-economic	
Data Source	**Concepts**	**Top 50% Concepts**	**Concepts**	**Top 50% Concepts**	**Concepts**	**Top 50% Concepts**
Government	-Reservoir - Fish	- Reservoir	-Religious environmentalism - Values of ecological preservation Values of public cleanliness and health	None	- Support for grassroots initiatives - Ecological knowledge about fish - Technological capital	- Support for grassroots initiatives - Technological capital
News	- Reservoir	- Reservoir	- Political consciousness - Chinese traditions		- Strong governmental involvement - Critical population mass - Built infrastructure - Scientific expertise - Technological capital	- Strong governmental involvement - Critical population mass - Technological capital
Social Media	- Reservoir	- Reservoir	- Political consciousness - Chinese traditions - Aesthetic appreciation of reservoir		- Ecological knowledge - Strong government - Technological capital	- Technological capital - Knowledge of chironomid diversity - Strong governmental involvement
Combined	- Reservoir - Fish - Bloodworms	- Reservoir	- Aesthetic appreciation of fish - Chinese traditions - Values of ecological preservation - Economic values toward bloodworms as fish food - Political consciousness	- Political consciousness	- Strong governmental involvement - Economic capital - Ecological knowledge - Technological capital	- Ecological knowledge - Technological capital - Strong governmental involvement

5.2 Research Question 2

My findings have been useful in uncovering latent resources in the reservoir social-ecological systems that are not immediately obvious. All my data sources indicate that the reservoirs, critical population mass, and governmental involvement are major resources of the reservoir social-ecological systems, through their common concepts of ‘PUB’, ‘NEA’, and ‘residents’ (Figure 7). After all, the broadest-level themes of all my textual data combined are ‘midges’ and ‘people’, reminding me of the tight connectivity of social and ecological systems, and their central role in the generation of biophysical, socio-economic, and cultural resources. Nevertheless, my observations have given me additional insights into the various dimensions of the reservoirs and their users. By walking the ground, I was able to comprehend the user density, aesthetic potential, and well-developed infrastructure of the reservoir parks. Furthermore, I was able to witness the high discipline and healthy lifestyles

of the reservoir users through their activities, which was essential to the self-initiative for the emergence of civic ecology pactices. My textual data also reveal the underlying potential of the reservoir communities that defy many stereotypes. Despite being immersed in a culture of materialism, the communities were able to appreciate and learn about nature. Cultural traditions were still alive in them too. Another important finding was the communities' strong awareness of politics, along with the Government's efforts to support them.

5.2.1 Biophysical Resources

5.2.1.1 Primary Data

My observations have given me a glimpse into the potential of the reservoir social-ecological systems for engaging in civic ecology practices, through my analysis of biophysical, socioeconomic, and cultural resources. These findings are useful for imagining possibilities for the emergence of civic ecology practices in scenarios where the chironomid disturbance brings the reservoirs' social-ecological systems to tipping point. The biophysical resources of Pandan and Bedok reservoir social-ecological systems lied in the park-like setting and beautiful waters of the reservoir parks. While walking around the reservoir parks, I noticed that they were highly planned and manicured. They were landscaped with aesthetically pleasing greenery and trails, and specific areas were designated for each activity. Beautiful wetlands also flanked the banks of Pandan Reservoir, along with floating wetlands near its banks. On the other hand, few forested areas existed around the reservoirs, with the exception of a bird sanctuary and a small piece of wooded area with mature vegetation flanking Bedok Reservoir park. Consequently, few reservoir users wandered into these areas, and no nature watching was thus observed in these areas during the study period. This has implications for the tendency of the reservoir residents to explore the reservoir ecosystems as ecological support systems, and hence develop a sense of place toward the reservoirs.

The aesthetic potential of the reservoir parks might mean that the reservoir communities only valued them for engaging nature on a superficial level. The high frequencies of jogging and walking observed could be mainly due to the clean air and therapeutic atmosphere for these activities. These activities mainly reflected desirable ecosystem patterns instead of the underlying ecological processes, and did not indicate whether the reservoir ecosystems could function sustainably. Nevertheless, the aesthetic value of the reservoir ecosystems also provided opportunities for reservoir users to engage with ecological processes. As discussed earlier, several of the photographers were observed capturing the sunset view of the reservoirs, and this could demonstrate their observation of ecological interactions among organisms and their reservoir habitat. Fishing and water sports were also examples of active engagement between communities and aquatic ecosystem processes like fish behavior and distribution. The presence of fishing and water sports also meant that fish species composition and water quality were desirable. Consequently, these forms of engagement with ecological processes indicated proper ecosystem functioning. My observational findings, however, show that such engagement occurred much less frequently than jogging, walking, or cycling; and mainly indicate that the biophysical resources of the reservoirs' social-ecological systems lied mainly in aesthetic quality. On the other hand, Bedok Reservoir seemed to be more attractive than Pandan Reservoir because it supported more facilities and varied landscapes. On top of fishing, water sports, and jogging, Bedok Reservoir had viewing platforms, seating galleries, a treetop challenge course, playgrounds, wooded areas, and artworks. Not only did Pandan Reservoir lack these other activities, it was in the heart of an industrial area and naturally lacked an atmosphere conducive to those activities. The reservoir nonetheless effectively functioned as a green space for enjoyment.

5.2.1.2 Secondary Data

My textual analysis played a bigger role in revealing ecological processes as biophysical resources. Although the concepts centered on environmental ecology are mainly related to the general ideas of chironomids and reservoirs, they also reveal the specific role of fish and chironomid larvae (aka bloodworms) in the reservoir social-ecological systems, specifically in my combined data (Figure 4). Upon further examination of these concepts, I realized that they stemmed from the communities' attachment to fish as pets, general discussion about the ecological role of fish in the nuisance issue, and the economic value of bloodworms as fish food. This not only confirms the idea that the reservoir anglers were indeed engaging in ecological processes, but also the availability of fish and bloodworms for civic ecology practices. Thus, both taxa are heritage species on a national scale, which could govern the reorganization of the reservoir social-ecological systems through the remember process.

Another interesting comparison is that the concept of fish appears in the peripheral social media data but not in its counterpart data. My query of the concept shows that it stemmed from discussion about the supply of fish as pets in Singapore. This supports my understanding of fish as a culturally significant organism among Singaporeans, as explained earlier. Moreover, the concept of animal also appeared in the government peripheral data (Figure 9), and upon querying it, I realized that it stemmed from biomedical research on animals by the Agri-Food & Veterinary Authority of Singapore (AVA), which was responsible for safeguarding the welfare of domestic and wild animals in Singapore (AVA, 2012). This shows further management practices on the national scale as another form of memory that could be drawn upon for civic ecology practices in the reservoir social-ecological systems.

The concept of 'fish', however, only emerged in my analysis of the government data. This might demonstrate that fish were not general concerns and were thus drowned out by the

flurry of media reports and social media discussions about the nuisance issue. In fact, fish appeared as a concept for the government data due to distinct efforts in building public relations following the nuisance issue. As discussed earlier, the presence of fish as a concept in the government 'with quotes' category but not in its counterpart supports this (Figure 9). Furthermore, my query of the concept shows that the Singapore Government adopted the stance that stocking the reservoirs with fish was beneficial to controlling the chironomid population. This shows that fish could be a biophysical resource for civil-state partnerships in civic ecology practices. Fish also emerged as a theme for the government data at 33%, but faded away as the broader-level themes are considered (Figure 6). Fish is after all only a dormant biophysical resource as compared to the reservoir as a whole.

5.2.2 Cultural Resources

5.2.2.1 Primary Data

My observational findings not only reflect aesthetic appreciation of the reservoirs, but also a culture of independence among the reservoir communities. My frequent observations of jogging and walking reflect self-discipline and commitment to personal health, especially with the numerous citizen-soldiers observed training for their IPPT. Such values are a resource for building individual resilience through self-initiated civic ecology practices. This also reminds me of the wider "disciplined governance" relations between the Government and NGOs in Singapore (Francesch, 2005). Next, while enjoyment of the reservoirs' ecosystem services reflect aesthetic values toward nature, fishing also reflect values of cultural and ecological preservation, as it not only involved sustaining cultural values toward fish, but also the appreciation of fish. In minority situations, I also observed reservoir users doing tai'chi, a popular form of Chinese martial art in Singapore, and this also indicated religious and cultural sustainability. Other than the above activities, few others revealed any

obvious human connection to the civic and natural character of the reservoirs, or culturally embedded activities.

5.2.2.2 Secondary Data

My analysis of the concepts from the combined textual data reveals that the political consciousness of the reservoir communities is the most salient cultural resource, though social, ecological, religious, and economic values are uncovered too (Figure 4). This shows that political consciousness is the most embedded memory within the national psyche, from which rules can be drawn for reorganization in the remember process, among all the values. Both the news and social media data reveal political consciousness, and as mentioned earlier, this is due to the factional nature of the chironomid disturbance. In fact, political consciousness is the only value reflected at the thematic level for both data sources, confirming its significance in the national psyche. Upon querying WP as a concept in my social media data, I discovered that many community members were comparing the performance of the WP and PAP in handling the nuisance chironomid issue. Moreover, some members even expressed annoyance at the politicization of the issue. The news data also contain the concept 'election', which further points to the embeddedness of the nuisance issue within wider politics. A notable point is that the concepts of 'election' and 'council' – the latter referring to the Town Council – emerged from the news 'with quotes' subcategory but not from its counterpart (Figure 10). This reveals how political consciousness in the media's psyche was strengthened through an iterative process, when repeated content was considered. Political consciousness reflects underlying activism and understanding of political workings, and may be a great cultural resource for civic ecology practices.

Both news and social media data reflect Chinese traditions, by demonstrating concern for the preservation of Chinese New Year traditions, amid the chironomid disturbance. As discussed earlier, Chinese traditions govern Singaporeans' perception of fish and these values

are thus useful for community stewardship of reservoir fish in adapting to the chironomid disturbance. Furthermore, when I queried the concept ‘fish’ in my combined textual data, I learnt that the nuisance chironomid issue was embedded within communities’ attachment to their pet fish, and their perception of the ecological role of the reservoir fish. Community members also expressed concern over the health of the reservoir fish amid fogging.

This might reveal social-ecological memories of Singapore’s fishing roots in the reservoir communities. Singapore has its origins as a fishing settlement, and Singaporean fishermen practiced fishing traditions on offshore fishing traps called ‘kelongs’. These traditions were informed by various religious beliefs and rules of social network, which formed the ‘kelong’ culture (Chou, 1992). However, as Singapore’s fishing industry became mechanized, it shifted to focus to hi-tech fish-farms instead, as well as freshwater aquaculture for the ornamental fish industry (Chou, 1992; Lim and Ng, 2013). Chironomid larvae started becoming cultured for fish food commercially as Singaporeans’ demand for ornamental fish grew as well. Today ornamental fish remain a part of Singaporean culture through Malay and Chinese beliefs as discussed earlier. As many popular ornamental fish species are present in both Bedok and Pandan reservoirs, cultural values toward fish could be revived in stewarding the fish in response to the chironomid disturbance. The kelong culture might also be revived to guide those practices.

Next, the social media data support my observational findings by revealing the communities’ aesthetic appreciation of the reservoir, health consciousness, and values of nature stewardship (Figure 3). As discussed earlier, the concept ‘view’ reflects the communities’ appreciation of the reservoir view, and this validates my observation of their enjoyment of the reservoirs’ ecosystem services. The communities’ concern about the health and environmental effects of fogging also reflects health consciousness and stewardship values, and these complement my observational findings of self-discipline and appreciation

of fish. Once again these resources are essential to producing personal and environmental resilience through civic ecology practices. Even though these cultural resources are packed into a single concept, they might demonstrate how they reinforce each other by revolving around a central issue. For example, several residents demanded further understanding of chironomid ecology, and hence nature stewardship, as a long-term solution, after realizing the negative health effects of fogging. The concepts 'natural' and 'fish' are also found in the social media peripheral data but not in its counterpart, and this confirms the wider values of ecological preservation among Singaporeans, even outside of the nuisance chironomid context (Figure 9).

The government data display religious and ecological values in the reservoir social-ecological systems too. After querying the concept of 'fish', I discovered residents discussing the scientific validity of *fang sheng*, a Buddhist practice of releasing captive animals into the wild, after politician George Yeo announced his release of fish into Bedok Reservoir on Facebook. This conflict between religious and ecological values shows their interconnectivity and hence their potential for adding diverse perspectives to civic ecology practices. These values on both data sources also show how they might connect across the scales of government and residents during reorganization in the remember process. Concepts and themes that emerged from the peripheral government data but not from its counterpart include those of species and animal (Figures 9 & 10), which reflect national commitment to biodiversity conservation and animal welfare, as discussed earlier. This further demonstrates the national cultural resources that the reservoir communities can tap upon through the remember process, in their engagement in civic ecology practices. Another cultural resource demonstrated by the government data is national values toward public cleanliness and health (Figure 3 & 6), because the chironomid issue is presented alongside other environmental issues in governmental discourse. When civic ecology practices grow into civil-state

partnerships, those values can be infused into them through the remember process, in order to set standards for best management practices.

5.2.3 Socioeconomic Resources

5.2.3.1 Primary Data

I observed that the socio-economic resources of the reservoir social-ecological systems mainly lied in their critical population mass and well-developed infrastructure. The high user density at both parks could be attributed to the high population density of the residential estates surrounding both reservoirs. This reflects the wealth of community manpower and capital available for civic ecology practices. The resulting high contact between the communities and the reservoir ecosystems would be conducive to citizen monitoring of civic ecology practices. The well-developed park infrastructure in the form of well-maintained trails, public lighting, and clear signs, would also facilitate movement of human and material during civic ecology practices. This is a clear example of the human-made environmental capital that Stokols et al. (2013) discussed, as mentioned in my literature review. I also observed many businesses, like supermarkets and hawker centers, in the residential estates, since they were planned as self-contained new towns. This points to economic capital in the reservoir social-ecological systems. Social capital, however, was less salient from my observations. Socializing and observing people were relatively infrequent activities, though more than a third of my observed activities occurred in pairs or groups (Figure 2). Hence, social capital might be have been manifested through the various activities, instead of socializing and observing people per se. Social-ecological knowledge was also not notably displayed, but the presence of fishing was evidence of such knowledge in the community.

5.2.3.2 Secondary Data

My textual findings, on the other hand, not only point to population and infrastructure, but also government as a socioeconomic resource. According to Figure 6, the broadest-level themes of the news and government data, reveal governmental involvement and community agency as major socioeconomic resources. Figure 4 further unpacks these resources by revealing knowledge, technology, and commerce, as further socio-economic resources in the combined textual data. Ecological knowledge is especially salient as it is the sole resource represented in the thematic analysis of the combined data. In fact, ecological knowledge is also reflected in all data sources, indicating the good scientific training of Singaporeans. Specifically, the peripheral subcategories of the government and news data reveal knowledge of chironomid diversity and life cycle, as reflected by the themes and concepts of 'larvae', 'species', 'adult', 'eggs', and 'cause' (Figure 9). This scientific perspective toward the chironomids is further uncovered in the concept 'study' in the peripheral category of the social media data, which refers to the three-year R&D study or discussion related to the general need to study the chironomid issue. Government, technology, and commerce eventually emerged in the conceptual analysis of the combined data.

The high contact between chironomids and residents leads to direct ecological knowledge of and scientific curiosity about the chironomids, through direct experience with the chironomids as discussed in my literature review. The broadest-level themes from the social media data reveal the prominence of the residents' high experiential knowledge of the chironomids and their whole ecosystems (Figure 6). Housing-related concepts, like 'flats' and 'blocks' in the news data, show the interconnectivity between the chironomids and high-density residential estates, and hence critical population mass for engaging in civic ecology practices and learning about the chironomids. The communities were not only aware of chironomid population and behavioral processes, and chironomid diversity, as discussed

earlier, but also eager to find out the root cause of the chironomid nuisance events, as reflected by the concepts ‘known’ and ‘cause’.

Abundant knowledge resources among the reservoir residents might have been a result of information flows from news reports that had been reproduced in social media websites. My query of the concept ‘known’ shows that it stemmed from news reports explaining that midges were ‘known’ scientifically as chironomids, or ‘known’ causes of the chironomid outbreak. As shown in Figure 10, the concept was also one that appeared in the ‘with quotes’ subcategory of the social media data, but not in its counterpart. Other concepts in this sub-category that point to information flow from the media, are ‘tiny’ and ‘green’, which I found to have been adjectives used by news reporters to describe the chironomids. The residents’ ecological knowledge of fish is another socioeconomic resource displayed by my data, as discussed earlier. Fish as a theme for the combined data, further points to this knowledge in the wider Singaporean society (Figure 6). Figure 6 shows that the reservoir residents’ ecological knowledge appeared at all levels of thematic analysis of the social media data. Ecological knowledge as a resource reflects the human agency of the reservoir communities in adapting to the chironomid disturbance.

All three textual data sources reflect the prominent role of public agencies in the chironomid issue, which is consistent with Singapore’s traditional approach toward effective environmental governance. Figure 7 shows that the concepts of ‘PUB’ and ‘NEA’ are common to all data sources, demonstrating the heavy involvement of these government agencies in the chironomid issue. Moreover, not only is governmental involvement revealed in the top 50% of concepts of the combined data and each data source, it also emerges in the thematic analysis of all data sources (Figures 3 & 6). Governmental scientific expertise is reflected in the news data through the concept ‘study’ that refers to the three-year R&D study. Incidentally, this concept also emerged from the peripheral social media data but not

from its counterpart (Figure 9), thus indicating the memories of scientific curiosity in the communities' psyche. Governmental support for grassroots initiatives also emerged not as a direct outcome of the chironomid nuisance issue, but as an indirect connection to public cleanliness and health issues discussed in parallel to the nuisance issue. This complements the triple overlapping themes and their concept node for the news data, which reveal that partnerships among town councils, PUB, and NEA, were central to control of the chironomids (Figure 6). The intertwinement between government and the chironomid issue is also unmistakable in the broadest-level theme of the news data.

An interesting concept from the news peripheral data that also indicates the government's ability to respond to the residents' needs is that of 'weeks'. My query reveals that it stemmed from reporters' temporal perspective of the chironomid outbreak. This shows that governmental policies and measures implemented to deal with the chironomid issue operated on an intermediate temporal scale between the daily and annual cycles of the chironomid swarms, as discussed earlier. The concept could thus point to the Government's ability to prevent short-term effects of the chironomid issue from cascading upward to long-term variables. Strong governmental involvement indicate memories of policies, institutional rules, and knowledge, at the higher national scale that can govern reorganization of the reservoir social-ecological systems through the remember process.

Technological capital, though a less prominent in the findings, is also reflected by the concepts 'light' and 'fogging', which represent flows of energy between the environmental and social ecologies (Diagram 1; see flows). While fogging is a concept from all three data sources, that of light is only from the news and social media data, which indicates the technology's widespread availability on the ground. Further query demonstrates the huge underlying apprehension about the swarming of chironomids to domestic and public light sources. The availability of light energy indicates its potential for solving the nuisance issue.

In fact, the Singapore Government has already installed bright lights around the reservoirs to divert the chironomids from homes. With its potential, this method of light ecology can be further developed into civic ecology practices. Lights also confirm my observational findings of well-developed infrastructure as a socioeconomic resource. Technological capital also relates to the economic capital of the reservoir social-ecological systems. As mentioned earlier, many businesses surrounded the reservoirs, indicating the economic sustainability of the reservoir communities. This is further supported by the theme and concept of shop in the peripheral category of the social media data (Figure 9), which further points to economic and technological resources on a wider national level. Overall, technology represents the intersection between communities and government as socioeconomic resources.

Figure 5. Barriers to civic ecology practices as reflected by concepts from each data source.

Barriers	**Biophysical**		**Cultural**		**Socio-economic**	
Data Source	**Concepts**	**Top 50% Concepts**	**Concepts**	**Top 50% Concepts**	**Concepts**	**Top 50% Concepts**
Government	None	None	- Values of domination over nature - Association of chironomids with dengue	- Values of domination over nature	None	None
News	None	None	- Values of domination over nature	- Values of domination over nature	- Politicization of issue	None
Social Media	None	None	- Values of domination over nature - Association of chironomids with mosquitoes - Economic values toward waterfront property	- Values of domination over nature	- Lack of trust in government - Dependence on government	None
Combined	None	None	- Values of domination over nature - Association of chironomids with mosquitoes	- Values of domination over nature - Negative attitude toward chironomids as pests	- Lack of trust in government - Dependence on government	- Lack of trust in government - Dependence on government

5.3 Research Question 3

Despite the potential of the reservoirs' social-ecological systems for engaging in civic ecology practices, several barriers exist to block the flow of their resources to establish connectedness among ecologies. In the first place, negative assumptions about the chironomid as a 'pest' and 'problem' underlie public discourse about the nuisance chironomid issue, as reflected by the triple overlapping themes and concept node of the combined textual data (Figure 6). By being embedded in the memories of the reservoir social-ecological systems, negative assumptions might have negated the other resources that residents could draw upon for adaptation. My discussion about constructivist approaches in the field of education also illuminates how previous knowledge of the chironomids can lead communities to construct stigmas around these organisms. Although those negative qualities were inherent to the chironomids as a disturbance, the negative assumptions about them would have been less salient had society recognized the ecological value of the chironomids and opportunity for reorganization to a larger extent.

Analysis of the textual data on a more detailed level reveals the offshoot value of domination over nature. Not only does this barrier emerge in the conceptual analysis of the combined data, it also pervades the concepts and themes of all data sources (Figures 5 & 6). This is also reflected in the concept 'control' that is common to all three textual data sources (Figure 7). Such a value might have stemmed from the high conflict between the chironomids and the residents due to the high connectivity between the two. DeStefano and DeGraaf (2003) supports this by discussing the high level of human-wildlife conflict in suburbs as a result of the abundant resources available for wildlife to exploit, in which my case, could be the increased nutrient levels for chironomid growth by surface runoff. This conflict is also saliently revealed by the broadest-level themes of my government and social media data (Figure 6). On the other hand, domination over nature might have also stemmed from

perception of nature as a resource for maintaining quality of life instead of a valuable ecological support system. This is supported by the emergence of economic values toward waterfront property as a barrier in the conceptual analysis of the social media data. As discussed earlier, since the communities were mainly concerned about material attachments and personal comfort, they might have perceived the reservoir ecosystems as sources for these pursuits. My observations of the highly planned, park-like setting of the reservoir parks, support this too, and tight land use regulations might be additional barriers too. Thus, domination over nature might have blocked the flow of the communities' cultural resources for appreciating the chironomids.

A worldview of domination over nature might also have had implications for how the reservoir communities perceived the nuisance chironomids, through their association of the insects with mosquitoes and disease. The significance of this association is reflected by the themes of the combined data at 33% (Figure 6). It also specifically emerged from the concepts of the government data, and the themes and concepts of the social media data (Figures 5 & 6). As discussed earlier, the Singapore Government and the reservoir communities discussed the nuisance chironomids alongside mosquitoes and dengue because of their similar biology and 'pest' statuses (Figure 5). Although this association was made to clarify the distinction between both organisms in several cases, it might have transferred residents' existing values of domination over mosquitoes to the chironomids.

For example, several social media users had associated fog control of mosquitoes with that of the chironomids, and this might have stemmed from their observation of the Government's similar reaction toward both organisms using fog control, which in turn had been influenced by overall attitude toward them. This reflects the transfer of values across scales in the panarchy model. In fact, the peripheral category of the social media data reveals

this association through the concept of mosquito (Figure 9), and this further shows that the association of both organisms had stemmed from the wider social mindset of Singaporeans.

Nevertheless, the residents' association of the chironomids with mosquitoes had most likely stemmed from their natural tendency to do so as well. Figure 10, however, shows that 'mosquitoes' is a concept that emerged from the 'with quotes' subcategory of the social media data, indicating an iterative reinforcement of the association between the two organisms through circulation of repeated content. This shows that the association of both organisms had been acquired from other social media users or news reports as well, on top of being part of human nature. The association between chironomids and mosquitoes might have also reinforced existing perception of the chironomids as 'pests' to be controlled, and hence dilution of stewardship values. Next, national developmental values of public cleanliness might reflect domination over nature, and block the flow of stewardship values toward the nuisance chironomids. By discussing the nuisance chironomid issue alongside issues of public cleanliness, the Government might have been unintentionally relating both issues with each other.

Next, another major barrier to civic ecology practices lies in the politicization of the nuisance chironomid issue. According to Figure 5, dependence on and lack of trust in government are socio-economic barriers to the emergence of civic ecology practices present among social media users, while the politicization of the issue was indicated by news reports. This barrier emerges most prominently from the news data on two levels of thematic analysis, and this shows the significant role of the news media as a middleman for reporting political interactions between the government and community levels of the reservoir social-ecological systems. The news and social media data not only show conflict of interest between communities and government, but also how this conflict can be exacerbated when the communities develop expectations of government after relinquishing their power to it. This

tension between the communities' need for more political accountability and the need to depend on the government demonstrates the systems' position in the late conservation of the adaptive cycle. As the reservoir communities approached tipping point and increasingly desire to challenge the political status quo, they also found themselves bound to their old ways of relying on the Government for stewarding their natural resources. The communities might be released from the abovementioned barriers when they reach tipping point and enter release phase, but these might remain as barriers to the emergence of civic ecology practices, as long as they are entrenched in the national political landscape and hinder reorganization through the remember process.

Those barriers might hence hinder the emergence of civic ecology practices by limiting civil-state partnerships, even if significant resources lie in strong political awareness and strong governmental involvement in civic issues. Tan and Neo (2009) illuminate how such meaningful partnerships could be impeded through lack of trust of government. They argue that the CIB program mentioned in my literature review, failed to develop to their fullest potential in Singapore, due to the communities' suspicion toward the community garden spaces as an instrument to protect governmental interests. As those spaces were governed by government-led grassroots bodies, residents associated them with government and shunned them (Tan and Neo, 2009). Dependence on government, on the other hand, might also compromise civic creativity for exploring environmental values needed to support civic ecology practices. Lim (2005), argues that creativity involves challenging the existing order; and therefore risks, chaos, and controversy have to be tolerated for innovative development in any field. For example, in order to create a culture of creativity in the arts, society has to embrace the full spectrum of values in the art circle. If this culture of creativity in the arts is reduced to commercialism, the energy of creativity will be dissipated and the meaning of art creation lost. This is parallel to the art of re-connecting to the environment,

which similarly needs an all-embracing creative culture, and nature should not be reduced to a source for human well-being.

Figure 6. Themes of different scales by data source.

		Theme Size at 33%	**Triple overlaps at 33%***	**Theme Size at 100%**
Government	**Themes**	Midges, reservoir, fish, public, areas, people, hawker, year, sure, Singapore	No triple overlaps	Midges, public
	Issues	Ecosystem – chironomid-fish interactions, chironomid habitat Community – public cleanliness, living spaces		Chironomids' nuisance effect on public welfare
	Resources	Reservoir, fish, values of ecological preservation, values of public cleanliness, ecological knowledge about fish, support for community initiatives, religious environmentalism		Human agency to adapt
	Barriers	None		Conflict between midges and the public
News	**Themes**	Midges, reservoir, PUB, George Yeo, flats, housing, residents, home, situation, work, night, Singapore	Midges, PUB, reservoir - Council, National Environment Agency, control	Midges, George Yeo
	Issues	Ecosystem – chironomid habitat Governance – election, trust in govt Personal - home Community – housing infrastructure Culture – political values	Chironomid habitat and population management	Ability of government to solve nuisance issue
	Resources	Strong governmental involvement, reservoir, critical population mass, political consciousness	Partnership between government and communities	Governmental involvement
	Barriers	Politicization of issue	Values of domination over nature	Politicization of issue
Social Media	**Themes**	Midges, species, mosquitoes, area, reservoir, lights, residents, house, situation, take, due, time, Singapore, place	Residents, midges, area – Year Species, midges, reservoir - Adult Midges, area, reservoir – Authorities Mosquitoes, Singapore, residents – flies	Midges
	Issues	Ecosystem – chironomid habitat, diversity Community – lights, living spaces Personal - house	Preservation of residents' living spaces over time Learning about chironomid diversity in management of nuisance adult chironomids Ability of government to protect living spaces of reservoir communities Nuisance effects of mosquitoes	Nuisance effects of chironomids on all aspects of life

	Resources	Reservoir, lights, ecological knowledge	Governmental involvement, ecological knowledge	High experiential knowledge of chironomids and their entire ecosystems
	Barriers	Association of chironomids with mosquitoes	Association of chironomids with mosquitoes	Very high conflict between the chironomids and society
Combined	**Themes**	Midges, residents, water, food, species, mosquitoes, time, fish, windows, people, pest, house, floor	Mosquitoes, food, residents – living, days Residents, food, midges – swarms, midges Residents, midges, pest – called, problem	Midges, people
	Issues	Ecosystem – chironomid habitat, chironomid-fish interaction Community – food, lights Personal – house	Residents' everyday lives, though no clear association with mosquitoes Nuisance effect of adult swarms on residents' food and health Problem of a new pest called midges	
	Resources	Ecological knowledge, aesthetic appreciation of fish, religious environmentalism, values of ecological preservation	None	
	Barriers	Association of chironomids with mosquitoes, negative attitude toward chironomids as pests	Negative attitude toward chironomids as pests	

*****Concept nodes are listed after dashes

Figure 7. Venn diagram of concepts by data source.

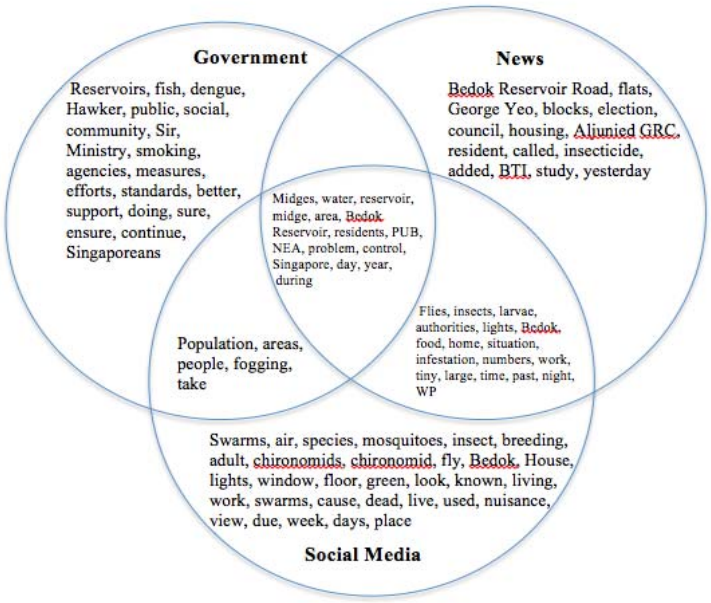


Figure 8. Venn diagram of themes by data source.

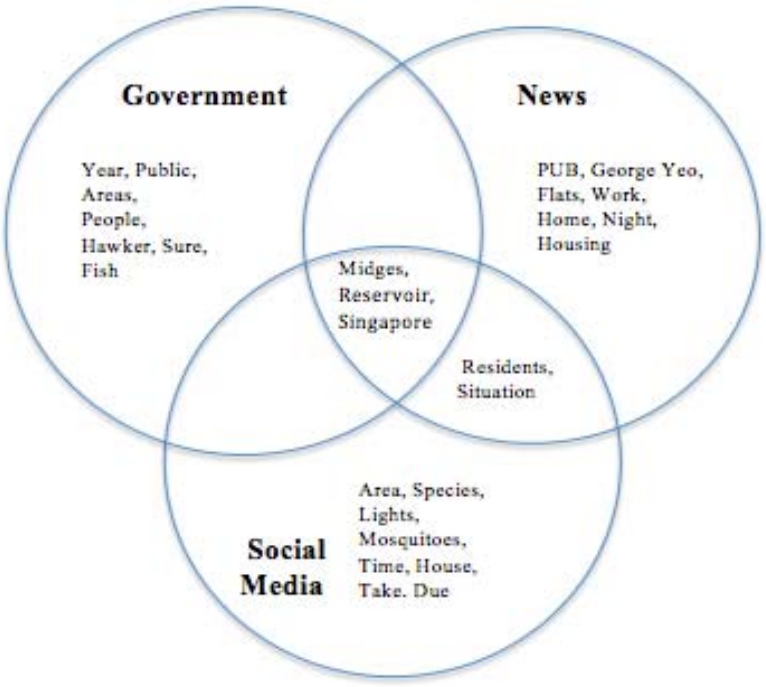


Figure 9. Summary of themes and concepts in the peripheral category of each data source that are absent in their counterparts.

Immediate vs. peripheral	Themes	Concepts
Government	Control, water, continue, species, system, animal	Larvae, used, species, solution, taken, adult, animal, work, system, able
News	Flies, year, lights, time, during, resident	Bedok, windows, weeks, days, nuisance, week, general, eggs, pest, cause
Social media	Water, problem, food, windows, chironomid, night, people, work, shop, life, bugs	Fish, bite, pest, bugs, shop, flying, called, use, study, mosquito, natural, life

Figure 10. Summary of themes and concepts in the 'with quotes' subcategory of each data source that are absent in their counterparts.

With quotes vs. without quotes	Themes	Concepts
Government	Year, people, fish, Singapore	Reservoirs, fish, Ministry, population, area
News	Reservoir, Singapore, PUB, flats, work, night, housing	Blocks, election, council, species
Social media	Reservoir, Singapore, residents, situation, area, species, mosquitoes, house, take, due	Population, authorities, numbers, tiny, past, green, known, nuisance

6. Future Directions

The above findings are valuable to envisaging the futures of the reservoir social-ecological systems. Suppose the chironomid disturbance is large enough to move the systems to tipping point, the reservoir communities will have the impetus to adapt by engaging with the reservoir ecosystems, as hypothesized by Krasny and Tidball (2012). Piaget's (1952) theory also describes how cognitive conflict stimulates learning. As this happens, the reservoir communities will be motivated to retrieve their released potential through the remember process in order to reorganize. However, further research is needed to investigate the exact role of the resources of social-ecological systems in their reorganization, and the exact processes through which barriers might hinder their reorganization. Quantitative analysis of the strength of co-occurrence and connectivity among Leximancer concepts also need to be explored to weigh the results using a more statistically rigorous approach. How barriers can be removed is also another question for future research, and I will try to explore how Singaporeans can be released from their barriers in several scenarios below.

Education could be a possible solution. After all, Piaget (1952) describes how learners fit their schemas to their experiences. In the context of my case study, positive educational

experiences with the chironomids and their ecosystems could have powerful effects on the communities' perception toward the chironomids. As discussed in my literature review, Kassam discusses how knowledge and practical wisdom is generated through cycles of experience and reflection as one perceives ecological relationships. Direct experience of the chironomids is thus nested within one's perception of the organisms. In order to remove the values of domination over nature as a barrier, more educational efforts are needed to reconnect the residents with the chironomid ecosystem, and rebuild disrupted social-ecological systems with new wisdom about the chironomids.

Education as an area of research is particularly pertinent to youth. My observational findings show that youth below the age of 18 were observed less frequently than the other user groups. However, a survey of a community nature project in Singapore shows that users were mainly children and older adults due to the career commitment and economic mobility of young working adults (Foo, 2000). Kong (2000) also discusses how Singaporean children have the ability to play in, learn from, and care for nature, which supports the literature on man's biological need to connect with nature that was discussed earlier (Wilson, 1984; Louv, 2005; Tidball, 2012). They nevertheless face the tension between their parents' fear of danger in nature and their inherent need to find enjoyment in nature (Kong, Yuen, Sodhi, and Briffett, 1999; Kellert and Wilson, 1993; Kellert, 1997). A dense urban setting not only provides little opportunity for connecting with nature, but also conditions Singaporean children to adopt Singapore's pragmatic approach toward nature (Kong, Yuen, Sodhi, and Briffett, 1999). The above factors could thus explain the low frequency of youth observed in my study. Due to Singaporean children limited affinity for nature, Kong, Yuen, Sodhi, and Briffett (1999) recommend immersing children in culturally embedded and enjoyable activities in Singapore's parks and natural areas, in order to help them develop healthily. This relates to Louv's (2005) argument about the need for children to connect with nature to

develop healthy behaviors. Kong (2000) is nevertheless hopeful that Singapore's next generation of environmental leaders has to come from youth who learn to love and explore nature before becoming conditioned by the state's efficient approach toward nature.

Consequently, if the reservoir youth engage with the chironomid ecosystem through civic ecology practices, they will be less likely to adopt adults' preconceived apprehension of mosquitoes and dengue in association with the chironomids, even if a real health threat emerges from the chironomid issue. By playing in nature, the youth might also have more freedom to explore environmental values without the shackles of government. Civic ecology practices in the reservoir social-ecological systems will thus more likely emerge from youth than adults as they face relatively low barriers. Since youth learn on a smaller, faster scale than adults, they can draw upon a greater wealth of memories in the community during reorganization through civic ecology practices. They are also more likely to self-organize civic ecology practices as such. In turn, the development of youths through environmental activities have potential for social-ecological outcomes too as they learn how to become responsible citizens (Schusler, Krasny, Peters, and Decker, 2009). This learning process reflects how reorganization at the smaller scale of youths have greater potential to cascade upward to larger scales that encompass social-ecological resilience. Grassroots initiatives develop more effectively from youth as such.

In fact, youth engagement with the chironomid ecosystems already exist in the reservoir social-ecological systems. Although the following case studies do not represent spontaneous civic ecology practices, they are still useful for exploring what the processes and outcomes of future civic ecology practices in the systems might be like. One example program is the outdoor classroom at Bedok Reservoir that Springfield Secondary School developed out of the nuisance chironomid events. Not only did the program give students the opportunity to learn about the chironomids' reproductive cycle, it also helped them learn

about the biodiversity of the reservoir too. In addition, the program allowed the students to engage in interdisciplinary learning, and thus understand the ecological role of the chironomids' better. For example, students learnt about aquatic ecology by testing water quality, and national education through the history of Bedok Reservoir's contribution to water supply in Singapore (Yang, 2012). In addition, PUB also organizes free guided tours of Singapore's water channels called learning journeys, and works with the Ministry of Education to ensure that these learning journeys are in line with school curricula. PUB also offers water channels for adoption by schools, as part of the ABC Water program mentioned earlier. These adoption programs have a stewardship component too, as the youth clean up the water channels and develop educational notice boards around them (Yang, 2012). These hands-on educational experiences will help the reservoir communities appreciate the chironomids. Such culturally embedded learning applies Vygotsky's (1962) social constructivist approach to helping children actively construct knowledge through social interactions.

The above programs show how youth stewarded their ecosystems and built social-ecological resilience through their unique potentials. The variables derived from Krasny and Tidball's 10 hypotheses would be good yardsticks for evaluating the evident outcomes of those programs. The programs reflected improvement in ecosystem structure and function through stewardship of the water channels, as Bedok Reservoir served as an important biophysical resource. Governance outcomes included multiple partnerships across the schools, PUB, and the Ministry of Education, due to the strong governmental involvement inherent in the reservoir social-ecological systems. By connecting youth with the Government directly, these programs tap upon the Singapore Government's scientific and managerial expertise while avoiding the problem of low community trust in the Government at the same time. As discussed earlier, potential also lies in the Singapore Government's

support for grassroots environmental initiatives, and the above case studies show how this plays out in adoption programs that encourage youth stewardship. This also represents the underlying activism in the reservoir communities, except without the barrier of low trust in government. The programs also capitalized on the students' values of stewardship and aesthetic appreciation of the reservoir to instill a sense of place in them through the history of Bedok Reservoir and its national significance. Ongoing adaptation was achieved too, as the systems' technological and scientific expertise were developed for helping students test the reservoir water quality, and maintain their adopted water channel. The systems' unique values of public hygiene and health were upheld too in the maintenance of water channel cleanliness by the schools. Besides, experienced learning journey guides provide a culturally embedded learning environment for the students, by drawing upon their values of nature stewardship inherent in the reservoir social-ecological systems.

Similarly, civic ecology practices in response to chironomid disturbances will achieve those outcomes using the same set of potential. As explained earlier, youth operate on a smaller, faster scale than adults because they are naturally more energetic, passionate, nimble, inquisitive, open-minded, and have more leisure time. This makes youth more flexible agents for reorganizing after a chironomid disturbance. Thus, youth will be the first to adapt to the chironomid disturbance and will be conduits for the transmission of values for engaging in civic ecology practices in the reservoir social-ecological systems. The critical population mass around the reservoirs also allows the youth to collaborate more efficiently, and engage in civic ecology practices from the comfort of their homes.

The role of women in civic ecology practices also needs further research. My observational findings also show that females were observed less frequently than males in the reservoirs. Kong, Yuen, Briffett, and Sodhi (1997) argue that Singaporean women's enjoy nature through nurturing qualities, though they also face the fears of insecurity and wildlife.

Since the park-like setting of the reservoirs, coupled with the high user density, provided a relatively high sense of security, my observations could be explained by the higher tendency of men to engage in exercise at the reservoirs.

The above discussion is useful to helping me explore the futures of the reservoir social-ecological systems. Various drivers of change could bring the systems to tipping point, and imagining possibilities from different angles is important (Diagram 1; see Drivers). Climate change could bring about ecosystem changes in the future, leading to chironomid outbreaks on scales large enough to bring the reservoir social-ecological systems to tipping point. As postulated by the authorities, increased temperature and rainfall might promote algal blooms and thus chironomid outbreaks. Another driver of ecosystem changes is the continued release of non-native species of fish into the reservoirs by anglers and aquarists. Besides ecological ones, social drivers of change could also bring the reservoir social-ecological systems to tipping point. The increase in foreigners in the reservoir communities might lead to conflicting values toward the chironomids, due to difference in tolerance threshold. Strained political relations also has implications for chironomid nuisance management. Next, as information about the chironomids is still lacking, undiscovered health threats from the insects might remain, especially with climate change. This might have severe consequences for the quality of life of the reservoir communities. I will imagine the possibilities for the emergence of civic ecology practices in those systems, through four different scenarios next.

6.1 Teach a Man to Fish

The first scenario follows the current baseline conditions of the reservoir social-ecological systems, but imagines the chironomid outbreaks to occur on much larger scales, due to the multiplied effects of climate change and continued release of non-native fish into the reservoirs. The chironomids are so numerous that outdoor activity is severely limited.

Although no health implications are involved, residents find it difficult to breathe or see outdoors, when swarmed by the chironomids. Walls, ceilings, and furniture are so filled with chironomids that residents are fearful even in their own homes. Most businesses have shut except for large retail stores. The reservoirs are deserted except for security personnel dispatched by the authorities to keep order. Thousands of helpless residents complain to the authorities every week, and even they cannot solve the situation as fogging or larvicide has little effect. Residents no longer dare to visit their friends and neighbors during Chinese New Year, and remain in great distress at home every day.

The outbreaks last for months at a time and worsen every year with climate change. The residents grow more distressed with every outbreak. When the authorities remain unable to offer any immediate solution, the residents start protesting against the Government and the chironomids online. Many others decide to take matters in their own hands by sealing their doors and windows, setting up electrocutor traps, and putting up sticky traps. While many yearned for the cleanliness that they enjoyed previously and grow vindictive toward nature, a handful look to their pet fish for solace during the outbreaks.

One day after the outbreak has died down, a few residents remember that they used to feed their pet fish with bloodworms. They feel so helpless that they start buying fish of the same species to release into the reservoirs as chironomid predators. Their values of self-discipline and health consciousness finally pricked their conscience to spur them into action. They then think that if they release a few fish into the reservoirs every day, the reservoirs will be well-stocked by the time the next outbreak cycle comes around. As they start doing this, more neighbors join them and they eventually form a watch group to carry out stocking in a more organized manner. Duty rosters are drawn to allocate tasks according to shifts. When the authorities hear of this, they realize that the neighbors are stocking fish without legal permits and issued them warnings.

However, due to the residents' disciplined stance toward governance, they try their best to comply with regulations while engaging in civic ecology practices. They stop their practices but also petition the authorities to allow them to stock fish, based on their ecological understanding of the reservoir ecosystems. The authorities quickly realize the resourcefulness of the neighbors and soon partner with them in their long-term stewardship efforts too. Not only do the authorities give them official permission to stock the reservoirs, they also seek the neighbors' scientific expertise on the fish. The neighbors eventually help the authorities to monitor the chironomid eggs and larvae too, as they are familiar with bloodworm identification due to their economic values toward bloodworms as fish food . The neighbors even get to keep the sampled bloodworms to feed their pet fish. These efforts grow as more like-minded neighbors are recruited. They then set up a webpage for official coordination and communication, and public education about the chironomids and fish. Their stewardship efforts quickly expand to focus on other organisms of the chironomid ecosystem, such as birds, dragonflies, and other invertebrates. Plant lovers who are recruited into the watch group start helping the authorities with planting and maintenance of wetlands to create habitat for predators. As the watch group grows, neighbors start to act as 'eyes' for the authorities by monitoring and reporting the count of adult chironomids at various locations, via smartphone apps or online databases. Eventually, the reservoirs reach a new equilibrium state dominated by the predatory fish species favored by the neighbors.

6.2 Friends of the Reservoir

In the second scenario, civil-state relations have become so strained that a power vacuum exists in the reservoir social-ecological systems. Efficiency no longer presides over natural resource management, as environmental governance practices and land use regulations become relaxed. The chironomid monitoring programs are no longer maintained and control efforts are slow to respond to annual chironomid outbreaks. As a result, the

chironomid outbreaks last uncontrolled for months at a time. The reservoirs also become stocked with all kinds of fish species, as residents release unwanted pet fish and live baits haphazardly, and this leads to further decline of chironomid-feeding fish. Algae start growing on poorly maintained reservoir structures, supporting chironomid growth further. The reservoir parks degrade as water quality is no longer maintained, and greenery no longer pruned. Trash pile up at every corner and user density of the reservoirs reduces significantly. The environment becomes so unhealthy that health issues start emerging rapidly and property prices drop drastically. With the loss of ecosystem services from the reservoirs, residents start feeling depressed and isolated.

A variety of civil society groups start sprouting up across the communities, aiming to control the chironomids through stewardship of the reservoirs. They start stocking the reservoirs with fish, planting wetlands for creation of predator habitats, and monitoring the abundance of chironomid eggs and larvae. However, little coordination exists among them, as each desires to follow its protocol. The lack of economic, technological, or human-made environmental capital hinders them greatly. Management efforts are thus ineffective. Moreover, they lack support and resources from a strong government, and substandard practices are common. Nevertheless, these independent civil society groups are not hindered by the need to rely on governmental help. They start accumulating scientific expertise through trial and error and self-learning tools. Eventually, a few civil society groups become self-sustaining and successful over time, as they draw upon memories of stewardship values, ecological knowledge, aesthetic appreciation of the reservoirs, and cultural traditions to reorganize. These groups start taking the lead on stewardship efforts, and a leadership hierarchy slowly establishes to organize stewardship effort across the groups. Eventually, an efficient system of coordination forms across the civil society groups, and chironomid nuisance management improves gradually. Governmental agencies then seek to partner with

these civil society groups in their management efforts, and the reservoir social-ecological systems reach a new equilibrium state around this rebuilt governance structure.

6.3 Generation Z

In the third scenario, the reservoir communities suddenly experience a huge influx of immigrants, leading to huge value conflict between the local residents and the foreigners. As the foreigners have higher tolerance thresholds toward the chironomids, many do not complain to the authorities about the outbreaks. On the other hand, the local residents continue to complain to the authorities profusely about the chironomids. However, as the authorities are not receiving as many complaints as previously, they do not treat the issue as urgently as before. Surveys conducted by the authorities about residents' attitudes toward the chironomids also show a decrease in negative effects of the outbreak. Control measures are therefore slow to respond to the chironomid outbreaks, leading to prolonged chironomid disturbances every year. Annoyed by the indifference of the foreigners toward the chironomids, local residents confront the foreigners and urge them to take action. The foreigners remain unconvinced about the urgency of the chironomid issue however. Many foreigners also do not celebrate Chinese New Year and are thus unable to empathize with the locals. Conflict between both groups of residents escalates. Many economically mobile local young adults start leaving the community, leaving behind local youth and the elderly. With changing demography, the communities lose their character and cultural values, leaving those who remain behind feeling insecure. Economic capital decreases as businesses fold up.

At the same time, many youth suddenly delight in having the communities to themselves. They feel released from the baggage of the adult world, such as the negative attitude toward the chironomids as pests, values of domination over nature, and preconceived apprehension of mosquitoes and dengue in association with the chironomids. Many of them start reconnecting with the chironomid ecosystems as they regain their freedom to explore

nature. As the youth develop scientific curiosity about the chironomids, they start collecting chironomid specimens, experimenting with the chironomids' attraction to different forms of light, and testing the water quality of the reservoirs. Many start posting their discoveries about the chironomids on Facebook, forming chironomid-related Facebook pages and online communities over time. To help solve the chironomid issue, youth start to share their data with the authorities, and engage in citizen science by monitoring the abundance of adult chironomid using their smartphones. As they are energetic and lack family commitment of adults, they are able to monitor the chironomids extensively at various times of the day. The youth also attempt to link their observations to what they learn in school, and turn their monitoring efforts into school projects. The youth and schools eventually partner with the authorities to share their scientific expertise, leading to more effective management of the nuisance chironomids. As they do not face the barrier of mistrust of government, such a partnership develops more easily too.

In addition, the remaining elderly people in the communities experience freedom to revive their cultural traditions too, in the absence of their adult children. Many revive values of ecological preservation from their kampong days by engaging in planting of wetlands as a community, to create habitats for chironomid predators. Other traditions start thriving among the elderly too, such as using fengshui to position their wetlands, and stocking the reservoirs with culturally significant fish as part of *fangsheng*. The elderly can now also spend more time with the youth, and guide them in their civic ecology practices with cultural traditions. The youth build a sense of belonging toward the communities as they connect with their local natural history and cultural traditions. The reservoir social-ecological systems then reach a new equilibrium state around a new demographic composition of foreigners and community-proud local youth.

6.4 Kelong Revolution

The fourth scenario is the most drastic and involves the extreme upheaval of the reservoir social-ecological systems. In this case, scientists discover that the chironomids have become vectors of a new disease, as climate change occurs. This disease has already caused severe health issues in other countries, and is rumored to have reached the chironomids in the reservoirs. Upon hearing this news, the reservoir communities are in great panic, and everyone is rushing to leave the community before the next outbreak in about a month's time. The authorities have also issued an evacuation order, and no one is allowed to remain within a 5-km radius of the reservoirs by the end of the week. This panic has even reached beyond the stipulated area, and residents in neighboring communities are also evacuating their neighborhoods for fear of the disease. Many residents have found temporary accommodation at hotels and relatives' homes, while others have left the country altogether. Most do not intend to return to their original homes in the reservoir neighborhoods. Complete chaos reigns in the reservoir social-ecological systems.

After the health scare has died down years later, the reservoir neighborhoods have turned into ghost towns. All infrastructure has been degraded, and the reservoirs have turned murky with silt and algae. Most of the organisms in the reservoirs have died due to water quality degradation, except for the chironomids that are tolerant of extreme environmental conditions. With the lack of predators, the chironomids are now emerging on much more massive scales. Several old residents have moved back in, out of attachment to the neighborhoods. The authorities are also just beginning to rebuild homes and other infrastructure. Meanwhile, the residents live in temporary shelter and are looking for fresh opportunities to make their livelihoods. They still feel nostalgia over the old days that they spent fishing in the reservoirs, and long to restore them. Upon seeing the dominance of the chironomids in the reservoirs, they decide to stock the reservoirs with fish to balance their

ecosystems. At the same time, they planted wetlands to filter pollutants and improve the water quality of the reservoirs. As the chironomid population is controlled by the fish and water quality improves, biodiversity returns to the reservoirs. The chironomid larvae provided the fish with an abundant food source, while the wetlands created habitats for other invertebrates and amphibians.

Encouraged by the success of their efforts, the residents start stocking more fish and eventually decide they can make a living by cultivating fish in the reservoirs for subsistence. They eventually built kelongs along the reservoir banks to trap the fish, and revived the kelong culture with traditional religious beliefs and social rules. As they gain success, they built their permanent homes upon the kelongs, and more kelong operators move in to exploit new opportunities. Entrepreneurship emerges as several kelong operators start selling their fish to markets and distribution centers. At the same time, reservoir users return as ecosystem services are restored with improvement in ecosystem structure and function of the reservoirs. A local market for the kelong fish soon develops with increasing use of the reservoirs. Hawker centers and markets also move into the neighborhood to serve the increasing number of new residents, and demand fresh fish from the kelongs at the same time. To exploit this new demand, the kelong operators introduce modern fish-farm techniques for higher efficiency, forging a new kelong culture. The kelong operators also work with reservoir anglers to stock desired fish species, and many start selling their fish as pets. Pet fish stores and aquariums move in afterward, due to the ready supply of fish from the kelongs and increasing demand for the pet fish from the residents. As demand for fish feed grows, the kelong operators harvest bloodworms from the reservoirs to sell to the pet fish stores, controlling the chironomid population at the same time. Tourism soon grows as the reservoir neighborhoods become popular sites for angling and visiting aquariums, and the kelongs become sanctioned as heritage sites. The kelong operators eventually partner with the

authorities to manage the reservoirs and monitor the chironomid larvae. At the end the reservoir social-ecological systems move into a new equilibrium state around fish as a source of livelihood.

7. Research Implications

As Singapore seeks to remake itself as a more resilient social-ecological system, it needs to build upon its existing potential to guide its transformation. Although nobody can tell if and when Singapore will reach a tipping point as its model of efficiency becomes more fragile, we know that transformation is inevitable in the city-state. The nuisance chironomid events have already shown the fragility of Singapore's environmental governance model as sole reliance on government over the years led to the oversight of long-term monitoring of water quality and possible pre-emption of the chironomid outbreaks (Tai and Wong, 2012). Similarly, other social and political changes are arising as a result of Singapore's position in the late conservation phase of the adaptive cycle. Singapore is a relatively young nation that is constantly remaking itself through cycles of conflict, reflection and rebirth (Tan, 2003). Thus, Singaporeans increasingly desire public participation and civil society involvement in environmental decision-making. My case study is important for imagining Singapore's social-ecological futures, and the possibilities for the emergence of civic ecology practices as an important pathway for adaptation to social-ecological change. Understanding the underlying resources and barriers is the first step to exploring this topic, because only then can Singaporeans know how to build on their strengths and overcome their weaknesses. In the context of Singapore's disciplined governance (Francesch, 2005), my case study also has the potential to offer an alternative to the Western notion of pluralism demonstrated by civic ecology practices.

In addition, my research has implications for cities all around the world because it is interdisciplinary and captures the complexity of urban social-ecological systems. As the

number of people living in cities increases around the world, social-ecological systems will become tighter and more vulnerable to disturbance. My research spans issues of human-wildlife conflict, water management, community-based natural resource management, and urban planning. These issues will become more prevalent in urban settings with increasing urbanization. My case study is thus also a good test bed for the framework of civic ecology practices, which is important for conceptualizing the adaptation of cities to social-ecological disturbance. Moreover, values, principles of governance, and institutional paradigms have become increasingly emphasized in environmental governance all over the world, along with the role of local communities and civil society in building social-ecological resilience (Francesch-Huidobro, 2008). Ostrom (2010) reflects this in her argument for "polycentric" approaches toward dealing with global environmental change, which encompasses multiple scales of governance (p. 552).

8. Conclusion

My case study is useful for investigating the possibilities for the emergence of civic ecology practices in Singapore, as it involves a complex human-wildlife conflict issue in a dense residential setting. Using Krasny and Tidball's hypotheses of civic ecology practices as a framework, my findings are not only a yardstick for analyzing the necessary conditions needed for social-ecological systems in Singapore to reach tipping point, but also reveal mechanisms underlying Singaporean society that govern adaptation in response to social-ecological disturbance. This is useful for guiding Singapore in building social-ecological resilience as it matures into the 21st Century. Overall, my case study shows that future emergence of civic ecology practices in Singapore is possible, as my findings reflect the social and political changes already occurring on a national level. Moreover, my findings reveal that Singaporeans have many resources that defy their stereotypes of being

materialistic and detached from nature. My scenarios also show how Singaporeans can overcome barriers to restore the flow of their resources for civic ecology practices.

My research aimed to address the questions of why civic ecology practices were absent in reservoir social-ecological systems despite chironomid outbreaks as social-ecological disturbance, what potential these systems have for adapting to the disturbance through civic ecology practices, and what barriers exist that hinder the emergence of those practices in the reservoir social-ecological systems. My findings suggest that the chironomid disturbance was not sufficiently great to bring the reservoir social-ecological systems to tipping point, and resources were still tightly bound within the systems. Hence, the initial conditions for the emergence of civic ecology practices were absent.

Next, although Singapore's potential of strong government, values of public cleanliness, technological and scientific expertise, and well-developed infrastructure, has long been well regarded in the national discourse; emerging stewardship values, political consciousness, and active cultural traditions are also equally important from my results. Fish is also shown to be a noteworthy biophysical resource in Singapore, and this concept unpacks further ecological values toward the organism. Only by paying attention to these resources can Singaporeans fully develop their potential for civic ecology practices and stewardship. Nevertheless, I have found several barriers that exist to hinder the flow of Singaporeans' potential for civic ecology practices. Due to the high conflict between a materialistic society and nature in a dense setting, a worldview of domination over nature still remain a barrier to nature stewardship in Singapore. This is shown by the reservoir residents' negative attitude toward the chironomids as pests. Another major barrier is the politicization of environmental issues in Singapore, due to Singaporeans' high dependence on and mistrust of government, which also interestingly point to Singapore's imminent transformation. Even though the need for civic ecology practices as a response to social-ecological disturbance is not likely at

present, possibilities for the need for those practices in the future exist nonetheless, due to imminent climate change, and shifting social and political landscapes. More importantly, Singaporeans have shown to possess potential for engaging in civic ecology practices, and I am optimistic about future possibilities for the emergence of those practices when needed. By imagining future possibilities for the emergence of civic ecology practices, this case study perhaps serves as a reminder to Singaporeans' need for continued vigilance to social-ecological changes.

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Appendix

Table 1. List of alien fish species found in Bedok and Pandan reservoirs by Ng and Tan (2010).

Scientific Name	Common Name	Reservoir Location	Established and Breeding[#]
Atractosteus spatula (Lacepède, 1803)	Alligator gar	Bedok, Pandan*	No
Scleropages formosus (Müller & Schlegel, 1844)	Asian arowana, dragon fish	Bedok, Pandan	No
Carassius auratus (Linnaeus, 1758)	Goldfish	Bedok	No
Cyprinus carpio (Linnaeus, 1758)	Common carp, koi	Bedok, Pandan	No
Clarias gariepinus (Burchell, 1822)	African walking catfish	Bedok, Pandan	Not enough information
Pterygoplichthys disjunctivus (Weber, 1991)	Vermiculated sailfin catfish	Bedok	Yes
Gambusia affinis (Baird & Girard, 1853)	Western mosquitofish	Bedok	Not enough information
Poecilia sphenops (Valenciennes, 1846)	Mexican molly	Bedok	Not enough information
Channa micropeltes (Cuvier, 1831)	Giant snakehead/toman	Bedok, Pandan	Yes
Cichla orinocensis (Humboldt, 1821)	Peacock bass	Bedok, Pandan	Yes
Cichlasoma urophthalmum (Günther, 1862)	Mayan cichlid	Bedok	Not enough information
Geophagus altifrons (Heckel, 1840)	Eartheater	Bedok	Not enough information
Heros severus (Heckel, 1840)	Severum	Bedok	No
Oreochromis mossambicus (Peters, 1852)	Mozambique tilapia	Bedok	Not enough information
Tilapia buttikoferi (Hubrecht, 1881)	Zebra tilapia	Bedok, Pandan	Yes

Osphronemus goramy (Lacepède, 1801)	Giant gouramy	Bedok	Yes
Chitala ornata (Gray, 1831)	Clown knifefish	Pandan	Yes
Hypophthalmichthys nobilis (Richardson, 1845)	Bighead carp	Pandan*	Not enough information
Tor tambra (Valenciennes, 1842)	Kelah	Pandan	No
Pterygoplichthys joselimaianus (Weber, 1991)	Spotted sailfin catfish	Pandan	Yes
Pterygoplichthys pardalis (Castelnau, 1855)	Amazon sailfin catfish	Pandan	Not enough information
Synodontis euptera (Boulenger, 1901)	Featherfin catfish	Pandan	No
Phractocephalus hemioliopterus (Bloch & Schneider, 1801)	Redtail catfish	Pandan	Not enough information
Amphilophus citrinellus (Günther, 1864)	Midas cichlid	Pandan	Yes
Datnioides microlepis (Bleeker, 1853)	Finescale tigerfish	Pandan	No

*unconfirmed by authors
'yes' or 'no' indicate highest likelihood according to authors' remarks

Table 2. Observation log sheet used for recording public behavior around Bedok and Pandan reservoirs.

Location: Date:
Start time: End time: Weather:
Notes:

Activity	**#People**	**Age Group**	**Gender**	
			M	**F**
Jogging/Walking		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Cycling		**<18**		

		18-30		
		31-40		
		41-50		
		>50		
Walking the dog		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Water sports		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Sitting/resting/observing people		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Fishing		**<18**		
		18-30		
		31-40		

		41-50		
		>50		
Socializing		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Photography		**<18**		
		18-30		
		31-40		
		41-50		
		>50		
Birdwatching/ Nature watching		**<18**		
		18-30		
		31-40		
		41-50		
		>50		

S = solitary
P = pair
G = group
If not specified, G estimated to be 4

Table 3. Summary of variables derived from civic ecology hypotheses for research question 1.

Variable	Hypotheses*
Personal well-being	"psychological and physical well-being" "individual resilience"
Governance	"small-scale, self-organized efforts" to "multiple partnerships"
Community	"community well-being" "community resilience"
Culture	"culturally embedded learning about social-ecological systems"
Ecosystem	"greening"
Self-regulation	"ongoing adaptation based on information about outcomes"
Emergent	"sense of place" "social-ecological resilience"

* All quotes are from Krasny and Tidball (2012).