Improving Water Quality in Tropical Urban Ponds: A Case Study in East Coast Park

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Objective

This RTN aims to guide landscape managers on how parks and green spaces can be managed to improve the water quality of ponds in their catchments. It estimates the contributions of major pollutant pathways observed in the catchment of a pond in East Coast Park, and discusses appropriate management strategies to restore and maintain good water quality.

Introduction

Ponds are commonly used to provide aesthetic interest in landscapes such as parks and golf courses in Singapore. However, it is often a challenge to maintain large ponds in a state of pristine water quality. Typically, nutrients which accumulate over time fuel algal blooms, which can impact both aesthetic and ecological values of ponds. It is important for pond managers to be aware of the various pathways through which nutrients can accumulate in a pond, so that appropriate management actions can be taken to restore and maintain good pond water quality. This study reports estimates of nutrient loads from various sources specific to the study site (East Coast Park Area D1, Singapore), and describes possible mitigation measures appropriate to control nutrient accumulation at this site.

The study site was a pond located at East Coast Park Area D1, Singapore. The pond is at least 30 years old, with a concrete base and sides, and a rubble wall embankment. Its depth varies from 0.5m in a perimeter ledge, to 2.3m in the central regions. The pond drains a catchment of 0.4 hectares with five inlets along its northern perimeter, and outlets which drain the pond at a fixed height of 0.3m below the top of the embankment. It is divided into four sections which taper towards their extremities, yielding the shape of an exaggerated hourglass (Fig 1).

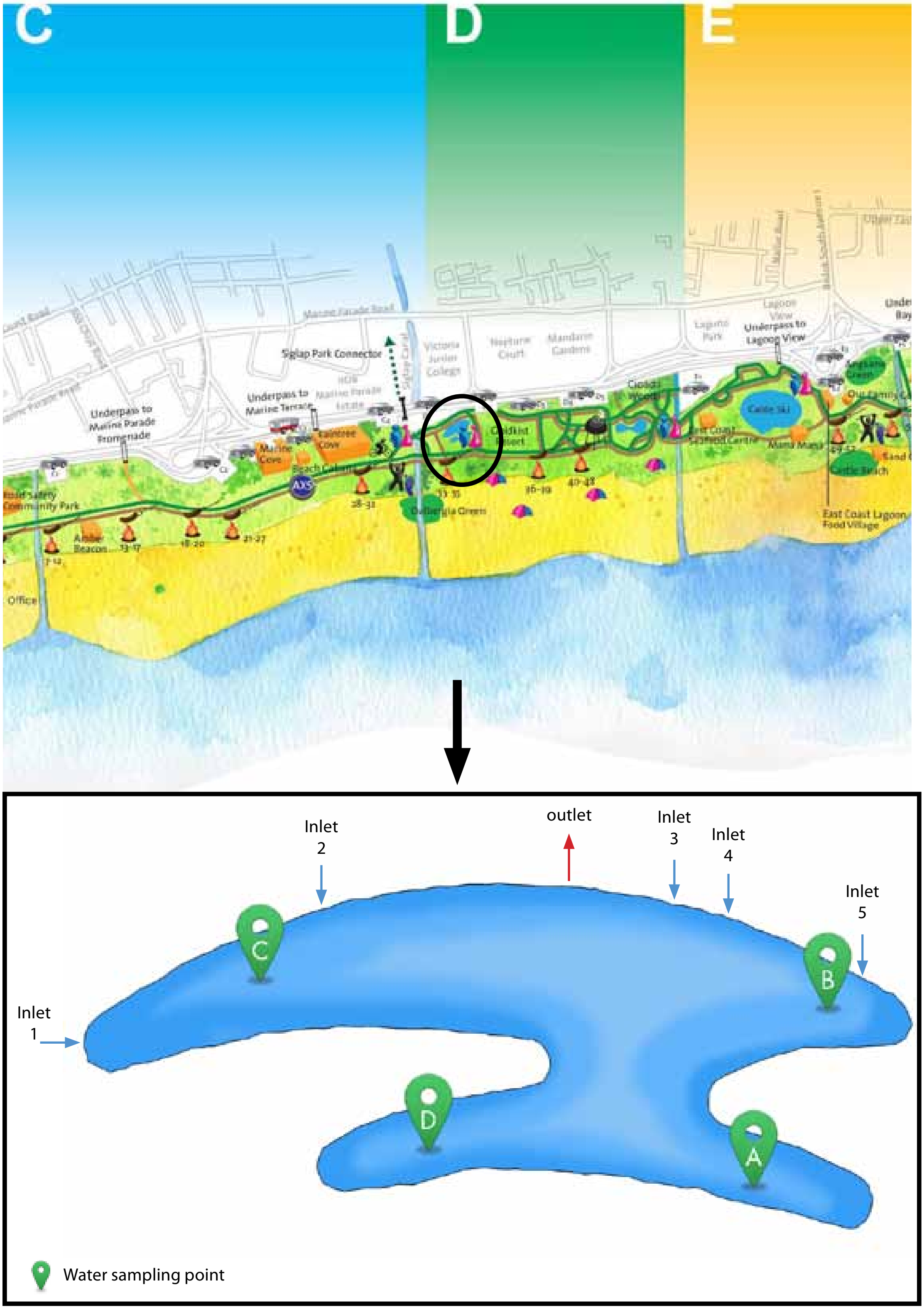

Fig 1. Schematic map of Pond D1, showing locations of inlets, outlets and water sampling points.

Methods

Inlet water quality was measured from water samples taken from inlets 2 and 3 during five separate rain events from April – July 2011. Analyses were conducted for Total Nitrogen (TN) and Total Phosphorus (TP). Annual rates of nutrient inflow attributable to inlet runoff were calculated by multiplying the average TN and TP concentrations measured in the two inlets by the total volume of water entering the pond, as estimated using rainfall records from Changi Airport Climate Station. Annual nutrient loads attributed to grass cutting were estimated based on the following assumptions: 1) 125 kg of grass is cut on a fortnightly basis in the immediate vicinity of the pond, 2) Nitrogen (N) and Phosphorus (P) content in grass are 0.85% and 0.18% respectively, 3) 50% of cut grass enters the pond either by being blown in by wind or carried into the pond via surface runoff. Annual nutrient loads attributed to fish feeding were based on the following assumptions: 1) 5kg of fish food was added to the pond on a weekly basis, 2) N and P content in fish food is 8% and 1.6% respectively.

Table 1. Estimates of total nutrient loads in ECP Pond D1

Source	Flow	Concentration		Load	%	Load	%
	(m^3/day)	TP (mg/L)	TN (mg/L)	TP (kg/yr)		TN (kg/yr)	
Catchment runoff	22	0.37	2.6	2.99	38	20.89	39.5
Rainfall	23.3	0.01	1.04	0.08	1	8.83	16.7
Grass Clippings				2.7	34.4	12.75	24.1
Fish Food				2.09	26.6	10.4	19.7
Total (kg/ year)	45.3			9.15		59.15	

Based on the nutrient concentrations measured in inflows, total external loads into the pond were estimated for the main nutrient sources identified, namely, runoff, rainfall, grass cutting and fish food. It is suggested that catchment runoff accounts for up to 38% of total phosphorous (TP) loads annually, followed by grass clippings blown into the pond after fortnightly grass cutting events (34.4%), and fish food (26.6%). For total nitrogen (TN) loads, three main sources were identified to be catchment runoff (39.5%), grass clippings (24.1%) and fish food (19.7%). The release of aquatic animals such as bullfrogs, terrapins and fish are also expected to have contributed to nutrient loads in the pond, but lack of information on their rates of release precludes meaningful estimates of their role in pond eutrophication.

Discussion

The estimates of external nutrient loads (Table 1) suggest that a combination of strategies is necessary to manage the rate of eutrophication. Firstly, to reduce the entry of dissolved nutrients into the pond via the inlets, the inlets can be diverted to filter beds containing plants selected for rapid nutrient uptake, such as Water Hyacinth (*Eichhornia crassipes*), Dwarf Papyrus (*Cyperus haspan*) and Water Lettuce (*Pistia stratiotes*) (Fig 2). Further, in order to reduce the incidence of grass clippings and leaves blowing into the pond, a vegetated filter strip can be established around the pond perimeter (Fig 3). This could trap excess plant material from entering the pond.

Fig 2. Vegetated filter bed, Bay South, Gardens By the Bay. Note that runoff is detained in the filter bed to allow nutrient uptake by plants. (Credit: Benjamin Loh)

Fig 3. Vegetated filter strip, Bay South, Gardens By the Bay. Note that taller, denser, shrub cover would be necessary to trap excess leaves or grass from blowing into the water body. (Credit: Benjamin Loh)

The control of activities such as release of aquatic animals and fish feeding at the pond will also be necessary, given that these contribute a significant proportion of the total nutrient load. Besides up-scaling public education efforts (Fig 4), one other solution could be to partition one side of the pond apart with a physical embankment, to be dedicated as a fish feeding area. This would divert the nutrient loads associated with these activities into a smaller, more manageable area, whilst continuing to meet the recreational needs of the public.

Fig 4. Signage at Dairy Farm Quarry. Public education about the negative ecological impacts of fish-feeding in ponds should be clearly articulated.

Besides the initiatives to reduce external nutrient loads contributed through runoff, grass clippings and fish feeding described above, it will also be necessary to remove nutrients directly from the pond (internal loads). This is because no external nutrient management strategy can be expected to be 100% successful, and eventually, nutrients can be expected to accumulate in the pond given sufficient duration.

In the case of East Coast Park Pond D1, the nutrient accumulation has been found to be so severe as to warrant a complete reset of the system through dredging. Whilst dredging can be costly, if nutrients already inside the pond are not removed first, any measures to improve long term water quality by reducing external loads are unlikely to be successful. To reduce the frequency of subsequent dredging required, macrophytes should be established in the pond after the dredging operation has taken place, for example inside the shallower pond perimeter zones, or in floating wetlands (Fig 5) or as floating water plants in contained areas (Fig 6). This would allow nutrients to be removed from the pond by the plants when they are pruned periodically to remove biomass.

Fig 5. Floating Wetlands, West Coast Park Pond. To avoid trapping surface debris and contributing to water stagnancy, floating wetlands should be anchored securely some distance from the pond edge. For floating wetlands to improve water quality, it is important to remove plant biomass periodically.
(Credit: Tracy Wyman)

Fig 6. Floating water plants (Water Hyacinth) planted in a contained area, Istana Swan Pond. As for floating wetlands, it is important to remove plants periodically in order to remove nutrients from the pond.

In conclusion, nutrients have accumulated in East Coast Park Pond D1 from a variety of sources, including grass clippings, rainfall, and fish feeding. Moreover, there is a substantial existing internal nutrient build-up from the past thirty years of external nutrient inputs. In order to bring about a sustained improvement in water quality, management strategies are needed to control the various external and internal nutrient sources specific to this pond. CUGE Research is currently working with East Coast Park management to adapt the above recommendations to the specific site context. Landscape managers interested in a more complete overview of pond management options are referred to the upcoming CUGE Guidelines on Water Quality Assessment and Management for Tropical Ponds.

Key learning points from this study are summarised below:

- To manage external nutrient loads- establish riparian zones and filter beds, and set aside a dedicated section of the pond for fish feeding.
- To manage internal nutrient loads- dredge the pond, plant emergent and floating water plants inside the pond and harvest them routinely.

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