Preliminary investigation on anthropogenic impacts on the water quality and biota of "Madola" stream, Hiyare, Galle

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Abstract

Sri Lanka's rich water resources are endowed with a high diversity of aquatic fauna. Water pollution is becoming a major problem in many urban and even rural areas. The present study was carried out to determine the influence of anthropogenic activities on physico-chemiacl and biological characteristics of the "Madola" stream at Hiyare, which drains into the Gin River. Four sites (i.e. A, B, C and D) each of about 20 m in length were selected using criteria such as nature of the substrate, water level and water flow. Data on some physico-chemical and biological parameters were collected monthly for a period of six months during 1998. To assess the influence of anthropogenic activities, data on same physico-chemical and biological characteristics were collected for a period of nine months after five years in 2003. Diversity of fish and macroinvertebrates in each of the sites were determined using Shannon Wiener diversity index. SPSS (version 10) statistical package was used to analyze the data on physico-chemical parameters. Anthropogenic impact on each site was surveyed using a questionnaire to gather information on the livelihood of neighboring community, current and past nature of the stream, different uses of the stream, and views on the impact of the stream. During the period of five years from 1998 to 2003, in each site, physico-chemical parameters such as the biochemical oxygen demand, phosphate concentration, and alkalinity had significantly decreased, while the Secchi disk depth, conductivity and nitrate concentration had significantly increased. In 1998, thirty four fish species were recorded and this number had reduced to 30 in the year 2003. Conductivity in site D significantly decreased, while dissolved oxygen concentration increased in all sites except in site D. Shannon Wiener diversity index calculated for fish fauna decreased in all sites. Total number of fish caught in each site significantly decreased from year 1998 to 2003. Majority of people use the stream for washing, bathing and agricultural purposes, while a few households use the stream for drinking and fishing. Only site A, which is the closest to the origin of the stream, is being used for consumption of water. However, the decrease in diversity and abundance of both fish and macroinvertebrates in all study sites of the Madola stream, is comparatively low and these changes may be due to the change in the above physico-chemical parameters resulting from anthropogenic activities.

Key Words: anthropogenic activities, biodiversity, fish, macroinvertebrates, water quality.

Introduction

Sri Lanka is rich in water resources that include 103 rivers comprising 9 major rivers. These running water habitats differ in size, depth, rate of water flow and substrate types (Fernando, 1990), and are endowed with high diversity of aquatic fauna mainly fishes. Sri Lanka's fresh water fish fauna consists of 108 species, including 62 freshwater dispersants, 26 salt water dispersants and 20 exotic species (Pethiyagoda, 1991). They are at risk mainly due to habitat degradation, ornamental fish trade and pollution of aquatic habitats. According to custom reports, about 65 species of freshwater fishes are being exported including at least 24 endemic species. The exploitation of the natural population for export as part of the aquarium fish trade has been identified as a major threat to endemic fish fauna (Amarasinghe, 1995).

The water quality greatly affects the distribution pattern and survival of organisms in a particular habitat. The quality of water in which many freshwater fishes of Sri Lanka occur, are listed and discussed by Costa and Starmuhlner (1972), Weinger (1972), Radda (1973), and Costa (1980). Generally stream water is slightly acidic (pH: 5.8 - 6.4), cool (20^0 C – 25^0 C in day time) and very clear.

It is a common public debate that all ecosystems especially aquatic ecosystems are being rapidly degraded due to anthropogenic activities. Water pollution has become a major problem in many urban, metropolitan and even rural areas. The streams flow through densely populated and intensively urbanized areas that are modified mainly for infrastructure development and flood control. Irrigation related watershed management, deforestation, cultivation of cash crops and various types of human waste, have affected the quality of Sri Lankan surface water. Eutrophication, salination, faecal contamination, siltation and contamination with organic residues and trace metals have been identified as major water related problem in the country. Unfortunately, the magnitude of deterioration of water quality and the subsequent effects on biotic and abiotic components of aquatic ecosystems and its direct or indirect effects on human health are not well documented (Silva, 1996).

The present study was carried out in Madola stream, which originates as a result of the excess water discharged from the Hiyare reservoir at Galle, which was constructed for the purpose of supplying potable water to Galle town area. Madola stream is blessed with a rich fish fauna. De Silva (1997) recorded a total number of 31 fish species including 8 endemics and one exotic. Amarasinghe, *et al.* (2002) reported a total number of 34 fish species belonging to 14 families comprising 29% endemics, 65% indigenous and 6% exotics. Liyanarachchi (1999) has pointed out some water related problems of Madola catchments in Ginganga basin. He revealed that there was a gradual drying of several streams in the area due to deforestation, low rainfall and unsustainable farming practices and indicated that the natural environment in the Madola catchment has degraded substantially.

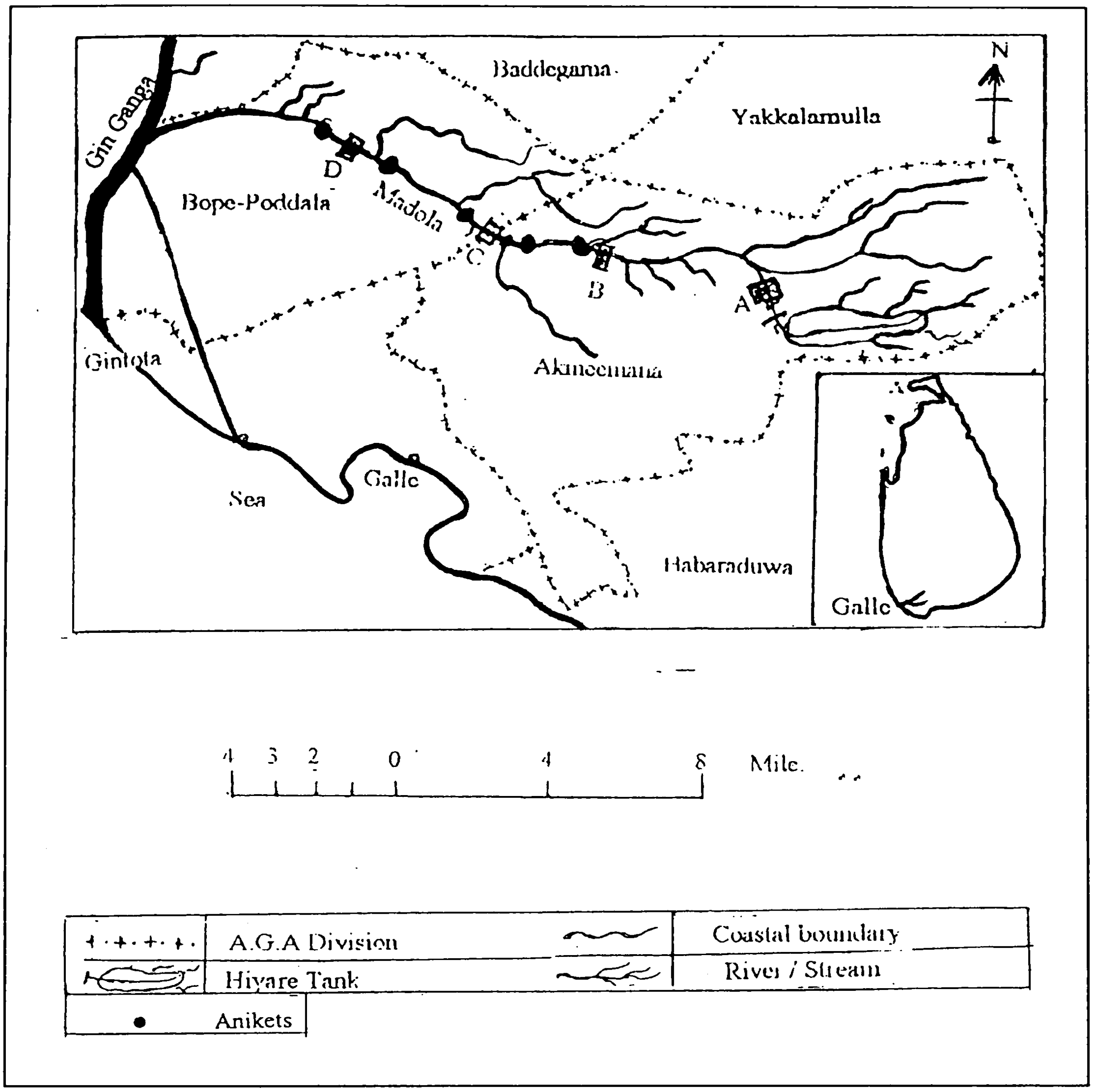
The main objectives of the present study were i) to compare the current status of the fish fauna with previous data and ii) to evaluate the present water quality in comparison to the previous condition.

Materials and methods

Sampling sites were selected along the Madola stream that lies between latitude 6^0 $4^/$ N - 6^0 $6^/$ and longitude 80^0 $13^/$ E to 80^0 $19^/$ E in the Galle district. Madola stream originates from excess water of the Hiyare reservoir and drains to the Gin River after a journey of 12 miles. Four sites (i.e. A, B, C and D) located between Hiyare and Holuwagoda, each of about 20 m length were selected based on criteria such as nature of the substrate, water level and rate of water flow. The distance between each station was more than one and half kilometers (Figure 1).

Some physico-chemical parameters and biological parameters were determined monthly. Initially the data were collected in the year 1998 for a period of six months and subsequently data on same parameters were collected after a period of five years in 2003 to coincide with the same period of the year. Width and depth of the sampling site, air and water temperature, Secchi disk visibility, conductivity, and velocity of water were measured as physical parameters while dissolved oxygen content, biochemical oxygen demand (BOD), pH, salinity, alkalinity, suspended solids, nitrate and phosphate concentrations were determined as chemical parameters. As biological parameters, the fish fauna, plankton and benthos communities were taken into consideration.

To collect the fish fauna, hand nets, gill nets, cast nets, scoop nets and electro fisher were used. Fishes were identified using Munro, (1955); Pethiyagoda, (1991) and other literature. Diversity of fishes in each site was determined using Shanon Wiener diversity index (H^1).



Study sites
Site A – Hiyare
Site B – Ihalagoda
Site C – Totagoda
Site D – Holowagoda

Anicuts
1. Ihalagoda
2. Thunhaula
3. Kanuketiya
4. Kurunda Pahala
5. Bogahaduwa
6. Opata

Figure 1. Location of the study sites.

During each visit benthos were collected from different substrate types such as stone, sand, mud and leaf litter. Collected benthos samples were washed; sieved and benthic animals were collected and sorted. To calculate the benthos diversity Shanon Wiener diversity index (H^1) was used.

To assess the anthropogenic impact on the stream, a survey was carried out and a questionnaire was distributed among households. Sixty households were randomly selected from the areas of Hiyare, Ihalagoda, Totagoda and Holuwagoda. The questionnaire examined the livelihood, current and past nature of the stream, uses of the stream and views of the public on the impact on the stream. Information from the field officers was collected and field observations were also carried out by the authors.

Results

Physico-chemical parameters

Secchi disk visibility had improved in all sampling sites during the 5-year period. Highest Secchi disk visibility was recorded in site D in both years. Conductivity values had increased from year 1998 to 2003. Highest conductivity value was recorded in site D in year 2003. An increase in dissolved oxygen values was observed in each site after 5 years except in site D. Highest dissolved oxygen value was recorded in site A, located in the head water stretch of the stream. The physico-chemical parameters recorded during the study period are given in the Table 1.

Table 1. Mean values (± SD) of some physico-chemical parameters recorded at the four sampling sites of Madola stream.

Parameter	A		B		C		D	
	1998	2003	1998	2003	1998	2003	1998	2003
Mean width (m)	5.46 (1.28)	7.38 (1.21)	7.40 (1.38)	8.18 (2.19)	8.23 (1.38)	4.89 (2.42)	16.72 (1.28)	16.50 (1.41)
Mean depth (m)	0.62 (0.21)	0.61 (0.35)	0.81 (0.22)	0.56 (0.30)	0.88 (0.38)	0.54 (0.29)	1.23 (0.41)	0.84 (0.45)
Secchi disk visibility (m)	0.24 (0.08)	0.43 (0.06)	0.40 (0.12)	0.47 (0.06)	0.42 (0.14)	0.48 (0.07)	0.42 (0.08)	0.72 (0.11)
Flow rate (m/s)	0.117 (0.28)	0.193 (0.28)	0.076 (0.28)	0.14 (0.28)	0.052 (0.28)	0.13 (0.28)	0.018 (0.28)	0.075 (0.28)
Conductivity (μs)	53.3 (1.11)	56 (2.18)	45.7 (1.08)	72.1 (2.11)	62 (2.09)	72.9 (2.06)	52 (2.12)	93.1 (1.14)
Suspended matters (mg/l)		7.2 (2.21)		7.6 (1.12)		10 (1.26)		13.6 (2.19)
Dissolved oxygen (mg/l)	8.81 (1.19)	9.11 (2.12)	6.31 (1.11)	7.84 (2.85)	4.72 (1.78)	5.88 (2.19)	7.38 (1.89)	5.24 (2.11)
BOD (mg/l)	2.94 (0.89)	1.05 (0.78)	3.53 (0.98)	1.28 (0.68)	2.364 (0.91)	1.62 (0.83)	2.73 (0.98)	2.06 (1.11)
pH	6.94 (2.11)	7.52 (2.81)	6.62 (1.98)	7.56 (2.01)	6.38 (2.19)	7.76 (2.31)	7.02 (2.12)	7.84 (2.51)
Salinity %o	0.322 (0.11)	0.42 (0.19)	0.737 (0.21)	0.58 (0.14)	0.573 (0.21)	0.57 (0.16)	0.593 (0.23)	0.89 (0.24)
Nitrate (mg/l)	0.012 (0.09)	0.24 (0.06)	0.039 (0.07)	0.41 (0.11)	0.012 (0.17)	0.61 (0.12)	0.017 (0.16)	0.87 (0.15)
Phosphate (mg/l)	28.125 (4.21)	0.043 (0.21)	27.27 (6.16)	0.06 (0.19)	26.85 (4.11)	0.64 (0.23)	29.75 (5.41)	0.87 (0.16)
Alkalinity (Meq/l)	0.27 (0.17)	0.099 (0.09)	0.379 (0.19)	0.102 (0.14)	0.488 (0.21)	0.132 (0.12)	0.424 (1.16)	0.162 (0.24)
Ammonia (mg/l)	0	0	0.003 (0.09)	0.004 (0.08)	0.003 (0.06)	0.006 (0.09)	0.006 (0.10)	0.01 (0.07)

Biological parameters

Table 2 indicates the total number of fish caught during the study period, the total number of fish species, and the total number of endemics per site of the Madola stream in the year 1998 and 2003.

Table 2. Total number of fish, fish species, endemics, indigenous and exotics per each site in Madola stream in year 1998 and 2003.

Parameter	A		B		C		D	
	1998	2003	1998	2003	1998	2003	1998	2003
Total number of fish	266	174	326	242	167	146	209	117
Total number of fish species	10	10	10	8	21	16	14	13
Total number of endemics	7	5	4	4	3	1	1	0
Total number of indigenous	3	5	6	4	16	12	13	12
Total number of exotics	0	0	0	0	2	3	0	1

Highest total number of fish was recorded in site B while the lowest total number of fish was recorded in site D. Total number of fish species was highest in site C. No exotics were recorded in sites A and B, while exotics abundance was highest in site C. Data revealed that abundance of fish and total number of fish species declined after 5 years period in each site.

Fish species and benthos diversity in year 1998 and 2003 in each site

Fish and benthos diversity were assessed using Shannon Wiener diversity index (H^1). Resulting H^1 values for each site, for 1998 and 2003 are shown in Table 3.

Table 3. Shannon Wiener diversity index (H^1) values based on fish and benthos in each site for 1998 and 2003.

Parameter	A		B		C		D	
	1998	2003	1998	2003	1998	2003	1998	2003
Fish fauna	1.866	1.361	1.618	1.262	2.523	2.180	2.663	2.074
Benthos		1.286		1.802		1.524		0.904

The checklist of fish fauna and the abundance and species richness of fish in Madola stream in 1998 and 2003

Abundance of fish in Madola in the year 1998 was 988 and this was reduced to 679 in the year 2003. Thirty four fish species belonging to 16 families were recorded in 1998 and this was reduced to 30 in 2003. *Danio malabaricus, Puntius sinhala, Puntius nigrofasciatus* and *Rasbora daniconius* are the most dominant fish species in the "Madola" stream. *Oreochromis mossambica, Puntius cumingii* and *Osphronemus goramy* were not recorded in 1998 but they were present in 2003.

Fish species namely, *Channa punctata, Puntius amphibius, Puntius bimaculatus, Puntius sarana, Awaous melanocephalus, Mastacembelus armatus* and *Tricogaster pectoralis* had not been recorded in 2003.

Table 4. Fish fauna recorded, abundance and species richness of fish in Madola stream in years 1998 and 2003.

Family	Fish species	Status	Total number of fish caught	
			In 1998	In 2003
Ambassidae	*Ambassis commersoni*	Indi	12	11
Anabantidae	*Anabas testudineus*	Indi	22	2
Angullidae	*Anguilla nebulosa*	End	1	1
Apolocheilidae	*Aplocheilus werneri*	End	1	1
Bagridae	*Mystus vittatus*	Indi	4	3
Balitoridae	*Schistura notistigma*	End	13	1
Belonidae	*Xenentodon cancila*	Indi	5	9
Cichilidae	*Etroplus suratensis*	End	56	22
	Oreochromis mossambica	Exo	NR	5
	Oreochromis niloticus	Exo	6	2
Chanidae	*Channa punctata*	Indi	3	NR
	Channa striata		3	10
Clariidae	*Clarias brachysoma*	End	2	1
Cyprinidae	*Danio malabaricus*	Indi	123	76
	Esomus thermoicos	End	3	2
	Puntius amphibius	Indi	1	NR
	Puntius bimaculatus	End	1	NR
	Puntius chola	End	51	17
	Puntius cumingii	Indi	NR	1
	Puntius dorsalis	Exo	47	8
	Puntius filamentosus	Indi	172	180
	Puntius nigrofasciatus	End	132	68
	Puntius sarana	Indi	3	NR
	Puntius tittegya	End	3	3
	Puntius vittatus	Indi	33	5
	Rasbora daniconius	Indi	198	161
	Rasbora vaterifloris	End	7	2
Eleotridae	*Butis butis*	Indi	2	1
	Eleotris fusca	Exo	3	45
Gobidae	*Awaous grammeponus*	Indi	7	10
	Awaous melanocephalus	Indi	5	NR
	Glossogobius giuris	Indi	14	2
Heteropneustidae	*Heteropneustes fossilis*	Indi	39	25
Mastacembelidae	*Mastacembelus armatus*	Indi	1	NR
Osphronemidae	*Belontia signata*	End	10	1
	Osphronemus goramy	Indi	NR	4
	Tricogaster pectoralis	Exo	5	NR
		Abundance of fish	988	679
		Species richness	34	30
		Total number of endemics	11	10

Note: End-Endemic, Exo-Exotics, Indi-Indigenous, NR- Not recorded

Anthropogenic impacts

Out of the sixty households that were interviewed, 55 used Madola stream for different purposes. Majority of people used the stream for washing, bathing and agriculture purposes, while only 6% and 11 % of households used the stream for drinking and fishery (Figure 2).

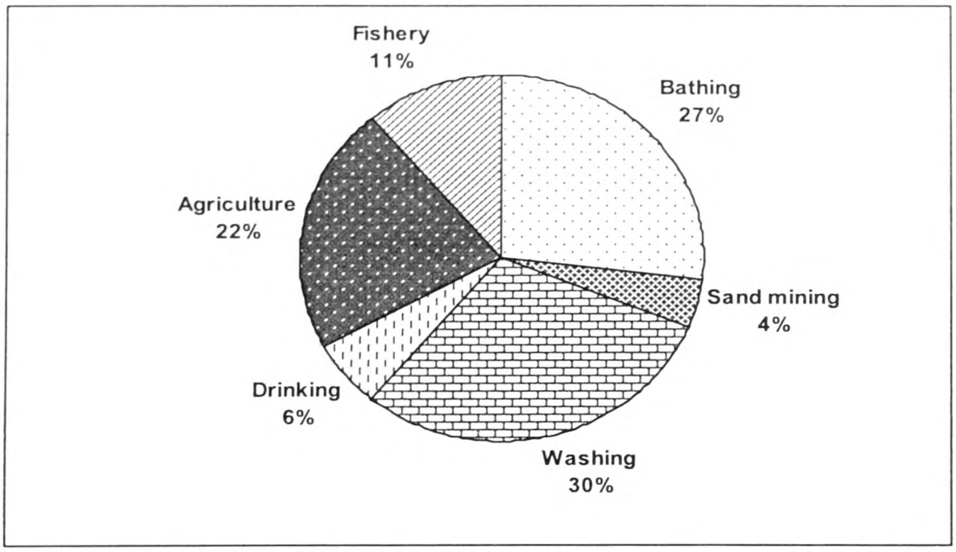


Figure 2. Uses of water in "Madola" stream for livelihood

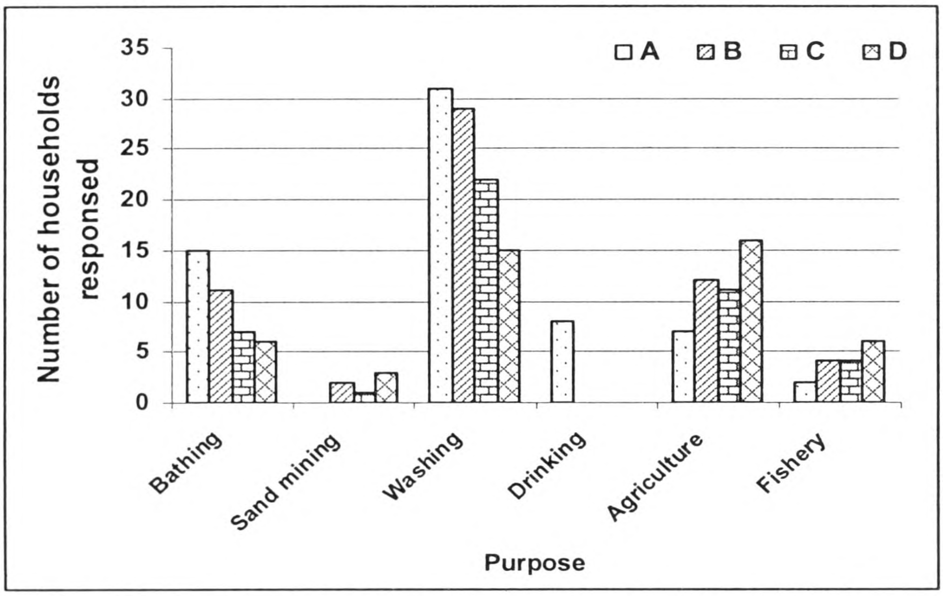


Figure 3. Uses of water in "Madola" stream for different purposes per site.

For drinking purposes people used only site A, which happened to be the site closest to the origin of the stream. Sites A, B and C were highly used for washing purpose. Fisheries, and sand mining activities were comparatively low in all the sampling sites. Compared to other sampling sites, site D was mainly used to draw water for agriculture (Figure 3).

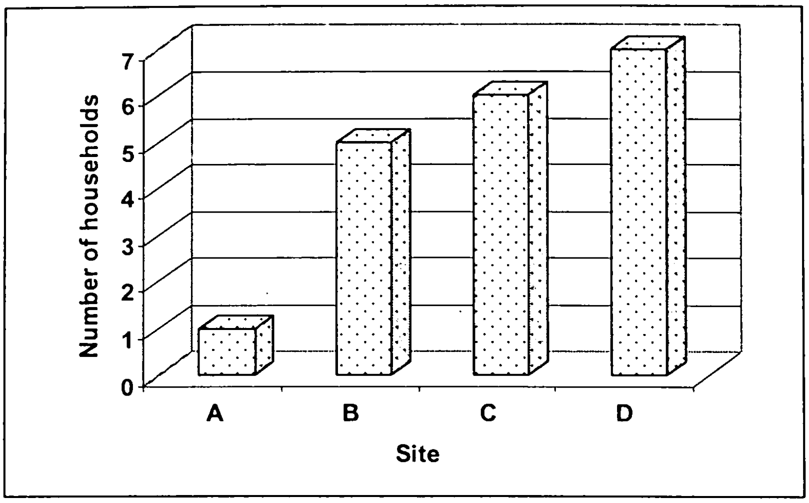


Figure 4. Addition of pesticides, weedicides and fertilizers by households in different sites.

Addition of pesticides, weedicides and fertilizers increased towards downstream. Results of the questionnaire revealed that 7 households added pesticides, weedicides and fertilizers to site "D" while only one household added pesticides, weedicides and fertilizers to site "A" (Figure 4).

Discussion

Mean width of the sites in the upper reaches (sites A and B) of the stream have increased while mean depth had decreased in each site after the five year period. Sites A and B were located at higher altitudes and possibly, high bank erosion occurring in these sites may have contributed to the increase in the stream width. Since low water flow rates were observed in each site, eroded soil particles from the bank and riparian area may have settled down, consequently reducing the depth of the stream. Moyle and Senanayake (1984) have reported that *Puntius filamentotus* is mainly found in deeper parts of the streams indicating that the depth might be an important factor for the occurrence of this fish species. Kortmulder *et al.* (1990) suggested that the number of fish species and their habitat specialization increased rapidly with the increasing size of the stream. Amount of dissolved oxygen in sites A and B, located at higher altitudes, was comparatively higher than in sites C and D located in the lower reach of the stream. This can be attributed to the fact that the strength of turbulence is the main factor that causes the dissolving of oxygen in stream water rather than absorption from the atmosphere.

Nitrate concentration recorded in each site in the year 2003 was higher than that in the year 1998. The adjacent land and most of the riparian vegetation areas associated with all the sites are cultivated with cash crops like tea, spices and paddy. Fertilizers added to the crop lands are washed into the stream as point and non point source polluting agents and eventually increasing the amount of nitrate. Compared to 1998, year 2003 showed higher Secchi disk visibility in all sites. The reason could be the high water flow rate recorded in the year 2003. High water flow rate may not allow the suspended particles to remain within the water column for a long period. Flow rate of water and amount of suspended matter in the water column clearly show an inverse relationship. Lower the flow rate higher the suspended matter. A large amount of suspended matter in the water is detrimental to animals that use gills as respiratory apparatus. Suspended particles accumulate on the gill filaments, eventually block them up and reduce the surface area available for gas exchange and ultimately the animals die (Slingsby and Cook, 1996).

Abundance of fish in Madola stream was reduced by 309 individuals after a five year period. This reduction in number is comparatively significant when considering loss of biodiversity. Individual species abundance of *Anabas testudineus, Schistura notistigma, Danio malabaricus, Puntius chola, Puntius dorsalis, Puntius nigrofasciatus, Puntius vittatus, Glossogobius giuris and Belontia signata* have seriously decreased. The most disappointing fact is that some fish species such as *Schistura notistigma, Puntius nigrofasciatus* etc. which are endemic to Sri Lanka and designated under the category of endangered or threatened species in the Red Data list, have been exploited as ornamental fish which may be the key reason for the reduction in abundance of the above fish species. Species richness was reduced to 30 from 34 after five years. The fish species that were not recorded in the year 2003 were also caught in very low numbers in the year 1998. The sampling gears used for fish sampling may not have been effective to catch these low abundant fish species and this would be a reason for not recording them in the year 2003.

Biological components of natural complexes undergo drastic changes under anthropogenic impact when compared to natural forces and processes. Madola is subjected to a wide variety of anthropogenic activities such as drinking, washing, bathing, waste disposal, transport, sand mining, agriculture, fishery and clay based industries. Sites such as C and D, located in the lower reaches, are affected mainly by the large amount of fertilizer and pesticide runoff from agricultural lands. Fairly high concentrations of nitrate in these sites may confirm the above fact.

Anthropogenic inputs from the urban landscape due to runoff, sedimentation or storm water discharges can lead to altered stream hydrology, greater discharge volume and poor water quality (Trimble, 1997; Davis *et al.*, 2003) which in turn results in decreased in-stream biotic integrity, homogenization of stream communities, change of stream geomorphology and loss of biodiversity. Stream fishes have evolved to inhabit the mosaic of patches created by this geomorphology and where there is greater structural diversity, there also tends to be increased niche habitats (Brierley *et al.*, 1999).). Widespread human activities alter these habitats and compromise the structural diversity and resiliency of natural streams (Gorman & Karr, 1978).

Conclusions

Decline of fish abundance and species richness as well as the quality degradation of some physico-chemical factors in the "Madola" stream suggest the urgent need for conservation of both water and biological resources in "Madola" stream. Since decline of water quality and loss of biodiversity i.e. fish abundance and species richness in "Madola" stream is partly due to anthropogenic activities, it is of prime importance to launch awareness programs about the importance of water resources and biodiversity to the well being of human communities. Moreover, stream restoration efforts, including bank stabilization, and replanting of riparian buffers also will help to conserve water and biological resources in "Madola" stream.

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