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Indian carps reproducing naturally in Udawalawe reservoir, Sri Lanka

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Abstract. The present study indicates that for the first time in Sri Lanka Indian major carps, *viz*, Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*) breed and spawn naturally in Udawalawe reservoir, a man-made perennial reservoir in Sri Lanka with the advent of the North-east monsoon rainy season. Shallow inundated banks of the Walawe River which brings water to the reservoir and those of the northernmost areas of the reservoir act as spawning grounds for the species. Udawalawe reservoir will be the unique manmade heritage of the country, by being the only natural breeding and spawning ground for Indian major carps in Sri Lanka.
Key Words: Catla, Rohu, Mrigal, spawn, perennial reservoir.

Introduction. Aquaculture is the world's largest growing food industry in recent years with an annual growth of 10% compared to 2–3% of other major food sectors. "Aquaculture production has been increasing at an average rate of 3.9% within developed countries while at an average of 8.2% in developing countries" (Osman et al 2012). Sri Lanka is blessed with vast inland freshwater and brackish water resources, amounting to 261,941 ha and 150,000 ha, respectively. Tapping of these vast inland aquatic resources has become imperative to augment the country's food production. In the early 1960s and 1970s, a freshwater fish capture fishery was in operation at the subsistence level with the introduction of *Tilapia mossambica* (Peters, 1852) in the early 1950s into perennial man-made reservoirs in Sri Lanka. Albeit, Sri Lanka did not have a practical tradition for aquaculture and there was virtually no aquaculture carried out until the beginning of 1980. After the mid 1980s, inland fish production was further increased by gearing up the culture based fisheries. This was as a result of the first policy decision taken by the government of Sri Lanka and its concerted efforts in the mid 1970s, to increase freshwater fish production from inland water resources. Significant measure taken by the government to increase freshwater fish production in the mid to late 1970s was stock enhancement of inland water bodies by stocking fingerlings of Chinese and Indian carps produced through induced spawning, using brood stock of Chinese and Indian major carps imported from the People's Republic of China and India, respectively (Weerakoon 2013). As a result, there are 18 exotic species in Sri Lanka, including one estuarine transplant, the sea trout (*Salmo trutta* Berg, 1908) (Weerakoon 2013). Among the introduced species, three major Chinese carps, *viz*., grass carp (*Ctenophayngodon idellus* Valenciennes, 1844), silver carp (*Hypophthalmicthys molitrix* Valenciennes, 1844) and bighead carp (*Hypophthalmichthys nobilis* Richardson, 1845), and Indian major carps, *viz*, catla (*Catla catla* Hamilton, 1822), rohu (*Labeo rohita* Hamilton, 1822) and mrigal (*Cirrhinus mrigala* Hamilton, 1822) are of particular importance in aquaculture. Even though, the common carp (*Cyprinus carpio* Linnaeus, 1758) and Chinese carps are more adaptable and tolerant than the Indian major carps, they are never the most important in the aquaculture sector of Sri Lanka as in India, Pakistan, Burma and

Bangladesh, because of the rapid growth, relatively better taste and higher price of the Indian major carps (Osman et al 2012). Therefore, Indian major carps: catla, rohu and mrigal introduced to Sri Lanka major reservoirs in the early 1980s have gained widespread in aquaculture.

The rivers and backwater of Northern India, Pakistan and Burma are the original habitats of the three Indian major carps. In addition, Rohu inhabits the rivers of Central India and the south of Nepal (Terrai). Indian major carps naturally breed in rivers which play a vital role in their breeding functions. Natural spawning usually coincides with the South-west monsoon in North-Eastern India and Bangladesh and lasts from May to August. In northern India and Pakistan, it last from June to September, and spawning season appears to be variable in the southern parts of India (Jhingran 1968; Khan & Jhingran 1975; Jhingran & Khan 1979). According to Natarajan & Jhingran (1963), catla breeds only once in a year, as do other Indian major carps under natural conditions. Acquiring technique for induced breeding through hypophysation, the brood stocks of these three species were bred artificially at the Aquaculture Development Centers at Udawalawe, Dambulla and Inginiyagala to produce the fish seed for stock enhancement of the Sri Lankan reservoirs. However, transporting larvae, fry or fingerlings from breeding centers to all over the country present many problems of exceptional difficulty. During our tours in Udawlawe, there was evidence which lead us to postulate that Indian major carps are breeding naturally in Udawalawe reservoir. If this hypothesis is true, it may not be necessary for further induced breeding of these species to produce fish seed for artificial recruitment of this reservoir and other similar reservoirs of the country, thus reducing the annual cost of production of fish seed. The present study was carried out to ascertain the natural breeding and spawning success of Indian major carps in Udawalawe reservoir, Sri Lanka.

Material and Method. Udawalawe reservoir (80^0 48.756'–80^0 52.542' E; 6^0 25.456'–6^0 31.745' N), perennial reservoir of Sri Lanka (area, 3362 ha), built in 1962 for irrigation cum hydropower generation by damming the trunk stream of the Walawe River in the southern dry zone at 80 m above mean sea level (Silva & Gamlath 2000) were selected for the present study. Mean annual temperature of the area is 29^0C at day time and 24^0C at night, while annual rainfall is 1520 mm. North-east monsoon rain occur in November to mid January and due to conventional activity rainfall can occur during April to May. Sometimes, it last till September.

Rainfall data of the Udawalawe area from January 2011 to January 2012 was obtained from the Mahaweli Development Authority at Embilipitiya. In order to represent the whole reservoir, eight sampling sites (A to H) were selected to measure the water quality parameters of the reservoir (Figure 1). Water samples were collected from pre-selected sites at monthly intervals in the morning hours from August 2011 to January 2012. Water quality parameters like temperature, pH and conductivity were analyzed *in situ* with a portable digital meter, while Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD_5), chlorophyll-a, phosphate and nitrate were analyzed in the research laboratory, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna. Preservation and analysis of water samples were done as per standard methods of APHA (2005).

The egg survey was carried out from subsurface layers above and around the sites G and H of the reservoir with hapa net (mesh size 0.5 mm) on 26^{th} November 2011. Factors for deciding the day to carry out the egg survey were three fold. Firstly, following the precipitation pattern carefully since the commencement of the North-east monsoon period, that is, the first day with heavy precipitation (25^{th} November), after the reservoir was filled with the advent of North-east monsoon was noticed, egg collection was carried out on the following day morning. Secondly, direct observation of courtship behavior of fish by authors and presence of the mass egg clusters accumulated near the reservoir banks over the surface water around the sites G and H. Thirdly, information from the fishers and observation of their unusual high catch at the fish landing sites of the reservoir.

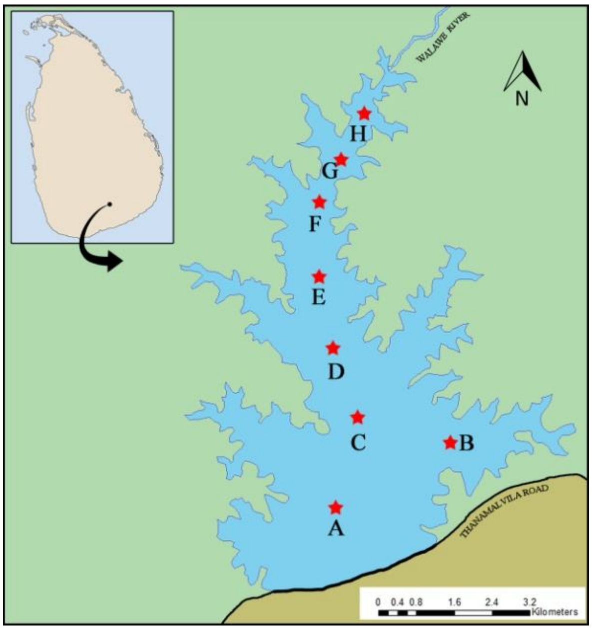

Figure 1. Udawalawe reservoir showing sampling sites (A-H). Inset: map of Sri Lanka showing the location of enlarged area.

Collected eggs were placed in polythene bags filled with source water of the same area and transported to the Aquaculture Development Center (AQDC) of National Aquaculture Development Authority (NAQDA) at Udawalawa and transferred immediately to the hatchery jar for hatching. During egg transportation from the reservoir to hatchery jar at AQDC, eggs were properly aerated. Hatched larvae were allowed to remain in same hatchery jar for 5 days (Figure 2). On the 5^{th} day after hatching, post larvae were transferred to well aerated aquaria at the Faculty of Fisheries and Marine Sciences & Technology of University of Ruhuna, Matara. Post larvae were fed with commercially available Prima pellets (Prima Ceylon Limited) *ad libitum*, and reared up to fingerling stage.

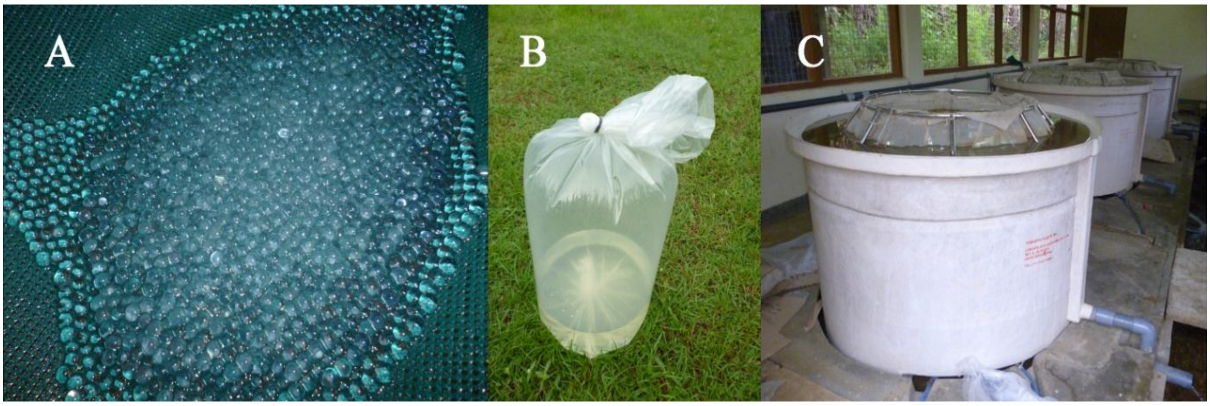

Figure 2. Collected eggs (A), their transportation in aerated polythene bags (B) and hatchery jars used to incubate eggs (C) at Aquaculture Development Center, Udawalawe, Sri Lanka.

After five days from egg collection, larval survey was carried out at the northern most sites of the Udawalawe reservoir (sites F, G & H) using a hapa net. Collected fish post larvae were transported to the well aerated aquaria at the Faculty of Fisheries and Marine Sciences & Technology, and reared up to fingerling size. Animals were fed with commercially available larval diets *ad libitum* throughout the experiment. Post larvae were reared up to fingerling size and fingerlings were analyzed to species composition. Data analyses were undertaken using SPSS statistical software (version 21). Arithmetic means and Standard Deviations (SD) were calculated for most parameters.

Results. Annual rainfall of the Udawalawe area in year 2011 was 1,717.9 mm. Non parametric K-independence sample (Kruskal-Wallis) test indicated that monthly variation of precipitation in year 2011 was significantly different ($p<0.001$) and the highest precipitation in the area during the study period from August 2011 to January 2012 occurs in November which lies in North-east monsoon period (Figure 3). 41.02% of the annual precipitation fell during North-east monsoon period in 2011.

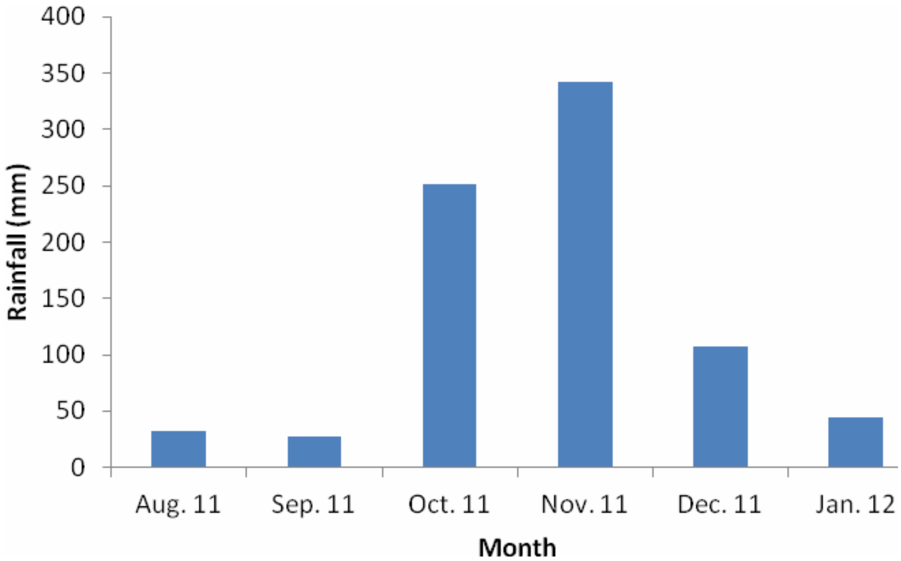

Figure 3. Variation of the monthly precipitation at Udawalawe during the study period from August 2011 to January 2012.

Non parametric Kruskal-Wallis (K-independence sample) test indicated that there was a significant variation ($p<0.05$) in monthly values of temperature, pH, conductivity, BOD_5, Chlorophyll-a, nitrate and phosphate, except DO (Table 1). Mean values (minimum and maximum values in parenthesis) of temperature, pH, conductivity, DO, BOD_5, Chlorophyll-a, nitrate and phosphate in surface water of the Udawalawe reservoir during study period were, 28.7^{0}C (26.6-31.1^{0}C), 8.15 (7.8-8.7), 76.3 μs (57.0-85.0μs), 8.55 mgL^{-1} (4.85-9.26 mgL^{-1}), 3.31 mgL^{-1} (1.60-8.40 mgL^{-1}), 1.68 μgL^{-1} (0.13-13.02μgL^{-1}), 0.27 ppm (0.01-0.29 ppm) and 0.33 ppm (0.01-0.27 ppm) respectively.

Non-parametric Kruskal-Wallis (K-independence sample) test revealed that there was no significant variation ($p>0.05$) in water quality parameters of surface water between sampling sites during the study period (Table 2). However, values of those parameters were slightly different from one site to other.

Courtships behavior of three Indian carps was observed first time *in situ* mainly at night above the site H and around Walawe river mouth of Udawalawe reservoir on the day with highest precipitation in North-east monsoon period, i.e., 25th November 2011 (Figure 4). The area was shallow inundated area consisting of submerged vegetations and boulders.

On the following morning (26th November), milky egg clusters (unfertilized eggs) were observed on the surface water near to reservoir banks mainly around the sites G and H. In the egg samples collected with hapa net from sub surface layers around site G and H, fertilized eggs (shiny transparent) were abundant. Fertilized eggs transferred to hatchery jar at AQDC hatched within 24 hours, resulting in post larvae.

High unusual catch consisting of three Indian major carps were observed at fish landing sites during rainy days, i.e., 25th and 26th November.

Table 1

Monthly variation in water quality parameters (±SD) in Udawalawe reservoir during August 2011 to January 2012

Parameter	*August 2011*	*September 2011*	*October 2011*	*November 2011*	*December 2011*	*January 2012*
Temperature (^{0}C)*	26.9±0.21	27.0±0.19	30.3±0.42	29.8±0.65	30.2±0.72	28.0±0.05
pH*	8.22±0.09	8.14±0.11	8.97±0.11	8.23±0.20	8.12±0.02	8.19±0.04
Conductivity (μs)*	79.75±4.13	79.38±3.93	63.25±6.11	80.75±1.98	79.25±3.50	75.50±3.25
DO (mgL^{-1})	8.64±0.14	8.80±0.27	8.55±0.27	8.69±0.22	8.27±1.40	8.34±1.31
BOD_5 (mgL^{-1})*	2.53±0.63	4.70±0.80	2.78±0.42	3.53±1.39	2.79±0.10	3.55±2.06
Chlorophyll-a (μgL^{-1})*	1.33 ± 0.34	0.19±0.03	6.07±3.55	0.19±0.02	1.26±1.46	1.05±1.46
Nitrate (ppm)*	0.010±0.004	0.010±0.005	0.010±0.005	0.037±0.018	0.018±0.009	0.071±0.093
Phosphate (ppm)*	0.081±0.098	0.023±0.014	0.027±0.018	0.006±0.019	0.028±0.013	0.031±0.013

*The mean difference was significant at the 0.05 level.

Table 2

Mean values of water quality parameters (±SD) between the sampling sites at Udawalawe reservoir during August 2011 to January 2012

Parameter	*Site A*	*Site B*	*Site C*	*Site D*	*Site E*	*Site F*	*Site G*	*Site H*
Temperature (^{0}C)	28.55±1.34	28.77±1.57	28.75±1.90	28.70±1.55	28.57±1.60	28.85±1.87	28.73±1.62	28.75±1.71
pH	8.18±0.07	8.15±0.11	8.13±0.10	8.08±0.12	8.08±0.16	8.13±0.09	8.12±0.13	8.29±0.22
Conductivity (μs)	78.33±5.24	77.50±7.77	76.33±4.93	75.83±9.37	75.17±9.50	77.00±6.51	74.50±8.24	75.83±8.16
DO (mgL^{-1})	7.45±1.92	8.57 ± 0.12	8.85±0.22	8.61±0.29	8.71±0.27	8.75±0.22	8.87±0.26	8.57±0.11
BOD_5 (mgL^{-1})	4.17±0.95	3.80±0.56	2.67±0.46	3.33±0.55	2.55±0.41	2.78±0.21	3.20±0.35	3.98±0.46
Chlorophyll-a (μgL^{-1})	2.69±5.12	2.62±2.68	0.90±1.35	0.95±1.36	2.02±1.62	2.09±3.65	1.24±1.76	0.94±1.34
Nitrate (ppm)	0.030±0.034	0.017±0.082	0.021±0.020	0.023±0.022	0.014±0.011	0.061±0.113	0.027±0.028	0.017±0.010
Phosphate (ppm)	0.070±0.099	0.058±0.071	0.020±0.010	0.019±0.009	0.014±0.008	0.031±0.018	0.017±0.012	0.035±0.024

The post larvae were abundant in subsurface layers of site F, G and H during the larval survey with hapa net, after five days from egg collection (1st December). Total numbers of 468 and 1304 fingerlings were recovered from the post larvae derived from egg survey and larval survey, respectively. The fingerlings reared from post larvae consisted of three Indian major carps with more or less similar proportions and percentages (Table 3).

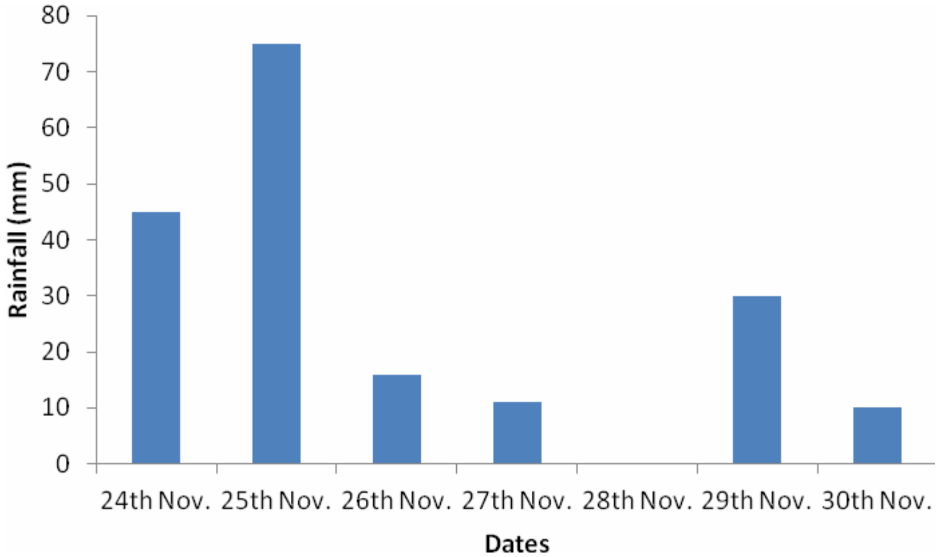

Figure 4. Daily precipitation variations for the week in which natural spawning of Indian major carp took place.

Table 3

Species composition of the fingerlings recovered by egg and larval survey carried out at the Udawalawe reservoir (percentage values are in the parentheses)

Species	*Number of fingerlings from the egg collection*	*Number of fingerlings from the larval collection*
Rohu	325 (69.4)	806 (61.8)
Catla	104 (22.2)	347 (26.6)
Mrigal	39 (08.3)	151 (11.6)
Total	468	1304

Discussion. The present findings revealed for the first time that Indian major carps naturally spawn in Udawalawe reservoir, Sri Lanka with the rise of rainfall amidst the North-East monsoon period from November to January.

Spawning is a complicated physiological process and the internal mechanisms that regulate spawning are similar in most fish. However, these internal mechanisms of breeding in fishes are regulated by environmental factors that trigger internal physiological mechanisms (Rottmann et al 1991). The Indian major carps though attaining gonadal maturity in confined or stagnant waters do not breed there and need inducement for spawning. Major Indian carps spawn naturally in their original riverine habitats, coinciding with the onset of the South-West monsoon period with the rise of water flow and rainfall. It has been documented that interaction of a large number of factors associated with monsoon floods may be responsible for bringing about ovulation and spawning in major carps under natural conditions. The monsoon season is characterized by relatively low water temperatures, torrential rains and consequently a higher relative humidity of the atmosphere and inundation of vast shallow areas along the banks of the rivers (Kapur 1981). In Udawalawe reservoir, natural spawning occurs in November with rise of precipitation during North-East monsoon period by which a higher precipitation is brought to the area during the year. The Walawe River which brings water from its catchment area and releases them to northern most sites of the reservoir plays a vital role for spawning. Low conductivity, tolerable levels of water soluble oxygen, favorable pH, strong currents and muddy water are the features of Walawe River which cause fishes to come to spawn, as observed in Halda River in Bangladesh (Kibria 2012). Also, availability of nutrients with the first showers of the monsoon, huge variety of organic compounds mixed with the water may create a favorable environment for gonadal maturity of fishes in Udawalawe reservoir. On the other hand, Udawalawa national park in which Udawalawe reservoir has been located is an important factor to have high humidity and low temperature in the atmosphere which may be useful for successful natural spawning of the species, as it was shown by Kapur (1981).

Nature of spawning ground as a requirement for spawning is an important factor to be considered, and some scientists are of the view that shallow areas which are inundated by heavy monsoon floods form the breeding grounds of the fishes (Hora 1945; Husain 1945; Khanna 1958). Others viewed that only the availability of shallow spawning grounds is important for spawning (Khan 1947; Ganapati & Alikunhi 1950). Inundated banks of the northernmost sites of the reservoir and those of Walawe river mouth and the increased water flow of both areas play a major role for natural spawning, as the other water quality parameters do not show significant variation in Udawalawe reservoir. This is the most possible reason for the site specific spawning of carps in the reservoir. As per the scientist emphasis (Mookerjee 1945) and direct observations of the authors, breeding does not take place in the Walawe River proper, but in the inundated areas. That is, in Udawalawe reservoir, breeding occurs in inundated areas of riverine habitats and in northern most areas of the reservoir, where high water flow exists due to heavy rainfall that comes through Walawe River from its catchment area. An another important fact is that, breeding occurs only after the reservoir is filled with the advent of the monsoon rain and on the day with heavy precipitation falls in such inundated areas in the reservoir. This provides strong evidence to the argument that fishes spawn in inundated shallow area of the reservoir and the riverine habitats. Although three species used different niches for food and feeding, they used the same spawning grounds for spawning. The submerged vegetation and boulders are more prominent in the breeding area, due to inundation of banks of the river and northernmost narrow area of the reservoir. It is clear that three species require similar environmental conditions and use similar spawning grounds, as observed in Bangladesh (Tsai & Ali 1985). In rivers Godavari, Krishna and Cauvery in South India, sections having large submerged rocks or emergent vegetation form the spawning grounds for catla (Chacko 1946; Chacko & Kuriyan 1948). Breeding occurs two days during a monsoon season in Udawalawe reservoir of Sri Lanka. In addition to the highest precipitation, the judgment of the day of spawning is accurate and fishers' indication by having high catch at the landing centers is a good indication to determine the actual day of spawning. Brooders induced by environmental factors migrate to northern most inundated riverine habitats to spawn and soon after spawning they migrate downstream. In the meantime they are subjected to heavy fishing pressure, resulting in high catch at the landing centers. The direct observation of breeding behavior and other indications on the natural spawning in Indian major carps at Udawalawe reservoir were confirmed by the egg and larval survey. The species composition analyzed at the laboratory provides robust conclusion that the three species spawned naturally in Udawalawe reservoir, and they used the same spawning grounds and season for spawning. With the present findings, it can be noted that Rohu brings the highest number of post larvae to the reservoir, as species proportion is more or less similar in egg and larval survey. It is in contrast to the findings in Halda River where species composition consisted of 81.8% catla, 9.5% rohu and 8.7% mirigal (Rahman 2008). However, it is necessary to study if the recruitment of each species followed a similar trend in the reservoir.

Present findings are important for the Sri Lanka government, as it spent money each year for seed production through hypophysation to strengthen the capture fishery, since the introduction of these species to Sri Lanka. Government's attempts to develop capture fisheries in perennial reservoirs and culture based fisheries in seasonal tanks has been successful, and today, nearly 90% of the inland freshwater fish production is from capture fisheries from perennial reservoirs (FAO 2014). In future, Udawalawe may act as a fry collection area for the country, as the Halda River in Bangladesh where fishermen collect fertilized eggs produced in the river which is of insurmountable economic and nutritional value (Kabir et al 2013). Therefore, Udawalawe reservoir do not only provide habitats for major carps, but also support the very important major carp grow out, spawn and fry fisheries in the near future, as in India and Bangladesh. Present findings contribute to current literature as there is a tendency that Asian carps can attain the ability to spawn in habitats where they have been introduced. Recently, Scientists have confirmed for the first time that a species of Chinese carp hailed as spawning naturally only in their original habitats has reproduced naturally in great lake tributary in North America (National Geographic 2013). Asian carp might adapt now for different environmental conditions which was not seen for several decades, since they were introduced. This study was conducted focusing only on the North-east monsoon due to fund constrains, and it is necessary to investigate whether Indian major carps breed in Udawalawe reservoir during April to March period in which conventional climate condition brings relatively high rain fall. Because under captive artificial conditions Indian carp brood stock can spawn 3-4 times per year, and recently catla and other species of Indian major carps have been bred more than four times in a season/year under controlled conditions (Gupta et al 1995).

Conclusions. In the light of the present research, Indian major carps, catla (*C. catla*), rohu (*L. rohitha*) and mrigal (*C. mrigala*) spawn naturally in Udawalawe reservoir, Sri Lanka on the day with heavy precipitation, after the reservoir is filled, amidst the Northeast monsoon period. Results of the egg and larval survey and its species composition provide strong evidence that the three species used the same spawning ground for spawning. Udawalawe reservoir will be a unique man-made heritage of the country, similar to Halda River in Bangladesh (Kabir et al 2013), by being the only natural breeding and spawning ground for Indian major carps in Sri Lanka. This identity will bring this reservoir into the spotlight of both national and international interests. Present findings warrants further studies to ascertain the recruitment pattern of the species and to investigate the natural breading success of the same species in other reservoirs similar to Udawalawe reservoir.

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