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Status of Rainbow trout (*Oncorhynchus mykiss*- Waldaum 1792) population after the cessation of stocking in waterways of Horton Plains, Sri Lanka.

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Abstract

The rainbow trout *(Oncorhynchus mykiss)* was originally introduced to Sri Lanka as a sport fish in 1882, then it was called *Salmo gairdneri* and reported to be surviving in few numbers only in the Horton Plaints, although, the regular stocking ceased in 1989. This study is concentrated into determine the status of the present population. The study consisted of regular sampling period during April 1998 to March 1999 and occasional investigations in 2000 and 2004. The Rainbow trout, size ranging from 1.0 to 39.0 cm, mature population is just about 1000 in the Horton plaints and they exhibited size dependent distribution over different stream habitats. For breeding they migrate to first order streams where fry and fingering can be found as well. Spawning period is from late December to early March in a year when the temperature was lowest. High egg mortality between 40% and 78% was observed due to poor water quality. Average length of fish caught in each station indicated downstream increase. Surface water temperature and pH had positive relationship while dissolved oxygen content and total dissolved solid showed negative relationship with downstream direction. The slit load in water is high in higher order streams. The populations examined were devoid in headwater streams other than those of Belihul Oya.

1. Introduction

The rainbow trout *(Oncorhynchus mykiss)* has been one of the most extensively studied fish, yet it is not well understood (Gall and Crandall 1992). It is a very popular game fish because of its spectacular leaps from the water and its willingness to fight against the fishermen on the other end of the line. Further, the rainbow trout is probably the one of the older fish in culture (Wales, 1939). It is widely distributed in European cold countries and hence, is very popular in those countries. It is now

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* Died on 26-12-2004 in the Tsunami

being drawn attention as an invasive fish in Asin countries (Day 1989) where they have been introduced during the British regime.

North American trout species were originally placed in the genus Salmo. The genus includes Atlantic salmon and Eurasian species of trout. Smith and Stearley (1989) concluded that North American trout species are more closely related to Pacific salmon *(Oncorhyncus)* than they are to Eurasian trout species (Behnke 1992). The species name *mykiss* was first used to describe the rainbow trout of Kamchatka (formerly called, Salmo *mykiss*) by Walnaum in 1792. Bahnke (1992) described how in 1836, Richardson described a rainbow trout from the Columbia River as a *Salmo gairdneri*. This meant that the oldest species name for rainbow trout was *mykiss*. Therefore, it is called by this name.

Rainbow trout are morphologically, a typical rover-prdator. They have a fusiform, torpedo-like, body and a terminal mouth. The pelvic fins are positioned abdominally and ventrally The pectoral fins are placed low on the body, and are widely separated from the pelvic fins. Rainbow trout have an adipose fin, which is positioned just posterior of the dorsal fin. It is believed this fin might be important in the embryonic stage of development, when the other fins are not fully developed. They have a short dorsal fin, forked tail for speed, and an axillary process by the pelvic fins (Moyle and Cech 1996). The fin, for the most part, are evenly distributed over the body. This helps with stability and maneuverability while foraging in fast water.

Rainbow trout have a physostomous swim bladder, and cycloid scales form the outer covering of the fish. There are between 120-210 scales in the lateral line, depending on the subspecies and form (Behnke 1992). They possess large numbers of pyloric caeca (20-70 depending on subspecies), and have a lower number of chromosomes (58-64) than many other trout species (Behnke 1992). Rainbow trout need water with high oxygen content, because they have a low blood-oxygen affinity (about 17mm Hg) (Moyle and Cech 1996). Because of this physiological fact, rainbows flourish in the rapid moving water of streams and rivers, which tend to have higher oxygen content.

As Willers (1981) describes, trout and their closer relatives are most primitive of the bony fishes. Trout can be linked to lineages tracing back 100 million years. The Wisconsin episode, the most recent of the four Pleistocene glaciation (approx. 40,000 years ago), is thought to have crucial in the current distribution of rainbow trout. When these glaciers melted, huge lakes were left all over the current range of the western US Rainbow trout. As these slowly receded, the subspecies of trout were isolated. Rainbow were restricted south of the Columbia until the late Pleistocene glacial events. It is estimated that rainbows spread into the Columbia

River drainage between 50,000 and 32,000 years ago. The Oregon populations of rainbow trout were separated from the Columbia River populations around 32,000 years ago (Behnke 1992). As the glacial lakes of the Pleistocene receded, the subspecies became more and more isolated, The California golden trout and the Sacramento red band trout are thought to be most primitive *Oncorhyncus mykiss* subspecies (Behnke 1992). The ultimate origin of a rainbow trout-like species was thought to be near the Gulf of Clifornia.

Oncorynchus mykiss was originally introduced to Sri Lanka as a Sport fish in 1882 (Fowke 1938, Pethiyagoda 1994, Welcome 1988), and reported to be surviving in few numbers only in the Horton Plains although, the regular stocking ceased in 1989. (Costa 1974 and Pethiyagoda 1991 and Pethiyagoda 1994). The eyed stages of the embryos were imported from New Zealand and other countries for hatching in the Hatchery in Nuwara-Eliya. (Tissera and Tisseral 1988). Since Rainbow trout was first introduced in 1889 for game fishing, there was a well=developed sport fishery for planters until 1972 dependent on the stocked population rose by Anglers' Assocation of Nuwara-Eliya. The stocking with hatchery reared fingerlings has been continuing until stocking ceased in 1989. Four decades ago (1961-1969) Horton Plaints was used for seed potato cultivation from early seventies to mid seventies and due to protests from scientists and conservationists it was subsequently declared as a national reserve. In 1988 it was elevated to the status of national park and angling was banned. However, a small population sustains in the waterways of Horton Plaints, which is drained by three small mountain streams that are tributaries of three major rives of Sri Lanka. The present study was to understand the size of the existing population with the view reintroduce angling, probable causes as to why the population does not grow and the impacts of rainbow trout on the other species of fish if there is any in Horton Plaints.

2. Materials and Methods

Study area

Rainbow trout is currently distributed only in headwater streams of Belihul Oya in the Horton Plaints national park (HPNP) in Sri Lanka (Fig. 1) The Horton Plaints national park (HPNP) is situated 2200 m above sea level in the central highlands of Sri Lanka. The site is located approximately at 6" 47 to 6" 50N latitudes and 80o 40" to 80" 46' E longitudes. Its area is 3162 ha denoted by the boundaries of HPNP. The main feature of HPNP is the undulating grasslands that are interspered with forest patch and containing meandering streams that flow along the narrow valley streams order was hased on Staler's (1957) method. Streams or reaches of Belihul Oya were classified as small (1^{st} order streams), intermediate (2^{nd} and 3^{rd} order streams) or large (4^{th} order streams) based on above method.

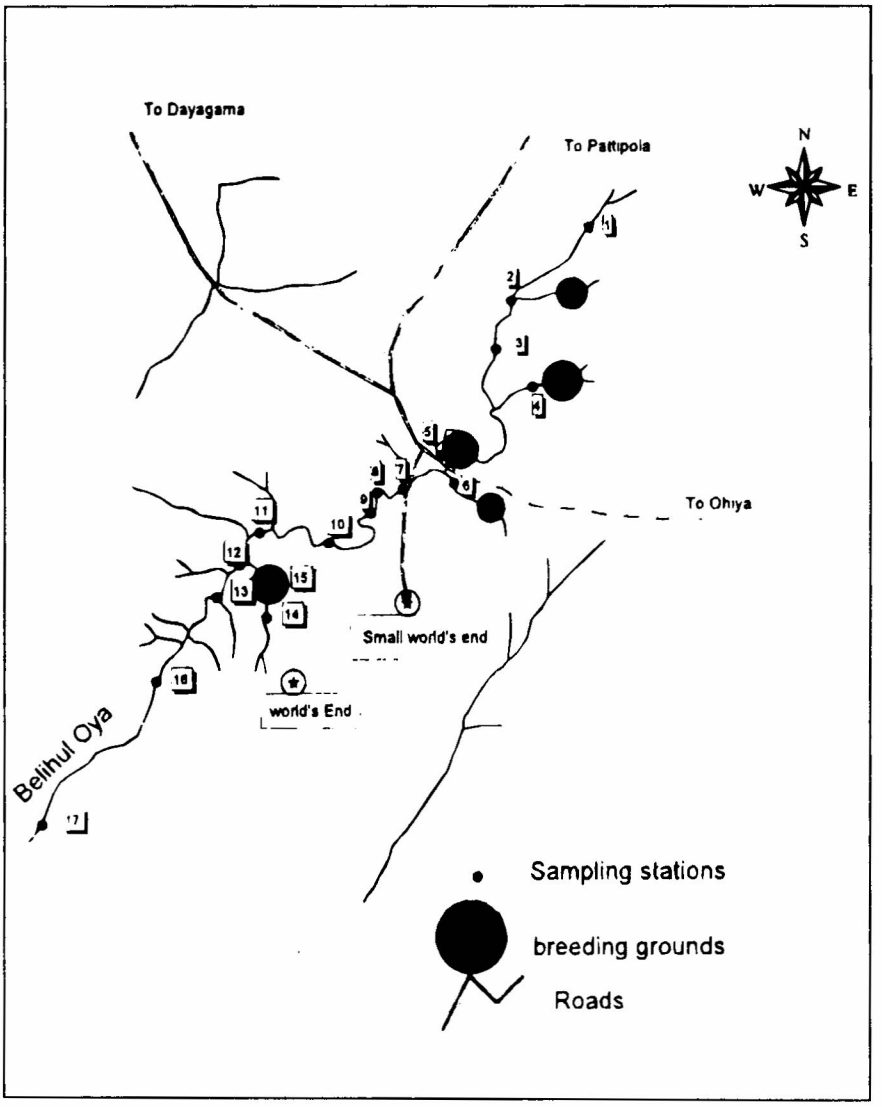

Fig. 1 Study area

Sampling and analytical methods.

Sampling was carried out by monthly basis from April 1998 to March 1999 and once again in 2002 July to September . Number of collection for a Station ranged from 2 (in the case of station 17 due to remoteness) to 12. Some streams section were

sampled continuously from confluence to end, and others were sampled at one to six sites. However, the marked stations were sampled on regular basis. Sample sites selected to ensure representative sampling of all habitats in a stream or a section to obtain a representative sample of all size classes of rainbow trout. To support the above, multi gears were used; gill nets (stretched mesh 2.5), scoop nets (mesh 1.0mm) and hook and line, Fingerlings were sampled using scoop-nets.

All captured individuals were measured (± 1.0mm, length), marked using spaghetti tags fastened to body and returned to the point of capture. Tags with spaghetti tags fastened to body and returned to the point of capture. Tags with different color combination were used for a particular station and they were fixed beneath the dorsal fin of the fish using modified cloth tag gun. The Shnnabel (1938) method modified and described by Baily (1951) was used to estimate the population for recaptured data [$N=\sum m_i f_i^2/\sum R_i F_i$, where, As only few specimens, 16, were allowed to kill, they preserved in 70% alcohol for studies on fecundity and eggs. Since the captured number for a sample and for site was very low all length frequencey data were pooled in to one sample. Size structure of the sample was characterized by grouping individuals in to 20mm classes. Fecundity-Length relationship was determined by regression analysis [$F=aL^b$, where, F=] stogram, was used to classify individuals as juveniles, sub adults or adults. Juveniles were fish in the smallest distinct group in the sample regardless of the time of collection. The next distinctive group, sub adults were specimens between maximum size of juveniles (10.0cm) in the sample and 25.0cm. In the next distinctive group, specimens≥25.0cm were defined as adults. Analysis of variance (ANOVA) was used to compare conditions among grouped sampled 91st, 2nd, 3rd and 4th order streams).

Redds were excavated in order to identify the developed eggs. Development stages, mortality of eggs, fry survival and the frequency of redds in each group of streams were noted. Fecundity was determined accordingly. Eggs coated with sediment were recorded.

Environmental parameters such as, Dissolved Oxygen concentrations (DO). pH Total Dissolved Solids concentrations (TDS), surface water temperature, depth width, flow rate, cover and bottom structure were measured and downward correlation with number of fish associated with each corresponding stations with above feature combination was determined. Silt load in the water was measured. The number of freshwater otter *Lutra lutra* encountered in each of the visit and their feeding behavior was recorded

3.Results

Nature of the streams

The topography of the occupied streams ranges from narrow, low gradient creeks to small, moderately gradient streams. Average flow ranges from <0.2ms^{-1} in the smallest 1st order streams (station: 1,4 and 6), to 0.1-04ms^{-1} in intermediate sized 2nd order streams (stations: 2,3,5 14 and 15), and to 0.12 to 0.66 ms^{-1} in large 3rd and 4th order streams (stations: 7,8,9,10,12,13,16, and 17). The 3rd and 4th order streams contain pools with the diameter ranging from 2m to 12m and depth from 2m to 4m. Within 1st and 2nd order streams, flow often cascades among deep (0.49-1.9m) plunge pools formed around boulders. In between pools and larger streams, channels meander and habitat varied from cobble riffle to pools formed around debris debris piles and boulders. Aquatic vegetation consists of mainly *Aponogeton* sp.

Population Estimation

The estimated population of *O.mykiss* as indicated by mark and recapture was 1010 in waterways of Horton plains. Few fish present down the Galagama Falls off Station 17. (Table 1)

Table I Abundance of trout in stations studied

Month	ST-1	SI-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10	ST-11	ST-12	ST-13	ST-14	ST-15	ST-16	ST-17	ST-18	ST-19	ST-20
April						#									#				0	0
May						#							60		#				0	0
June		16				#									#	18			0	0
July				6	6	#		22	20			12	69		#	19			0	0
August	20	18	18			#			28	55	6	26	50	18	#				0	
September	32	42		10	8	#		32	16	0	24			27	#	68			0	0
October	27	67			16	#	27	54		44	0	60	65	60	#	49	26		0	0
November	21					#						46	96		#			29	0	0
December		82	49	14	40	#		44	48	70	48	72	89		#		22		0	0
January	32		48		54	#			37		48				#		25		0	0
February	40	120			22	#	30	50							#	60			0	0
March	55	82		24		#	19	27	32		25	61	89	47	#		23	28	0	0
Average	32.429	61	38	13.5	24.333		25.333	38.167	30.167	42.25	25.167	46.167	89	38		42.8	23	28		
Total	597																			

ST-1 to ST-17: Belihul Oya
ST-18 & ST-19 Kiriketioya
ST-20: Kuchchadeniya Oya
Not studied for stock assesment

Size of Fish

Decomposed length frequence distribution (Fig.2) of 290 specimens of *O.mykiss* using Bhattacharya's method revealed that their length ranged from 1.0 to 39.0cn with three peaks, which correspond to fingerlings (mean length-4.28 ± 2.02, N=18) juveniles (mean length, 19.92 ± 5.91, N ± 246) and adults (mean length, 34.51 ± 2.265, N=19).

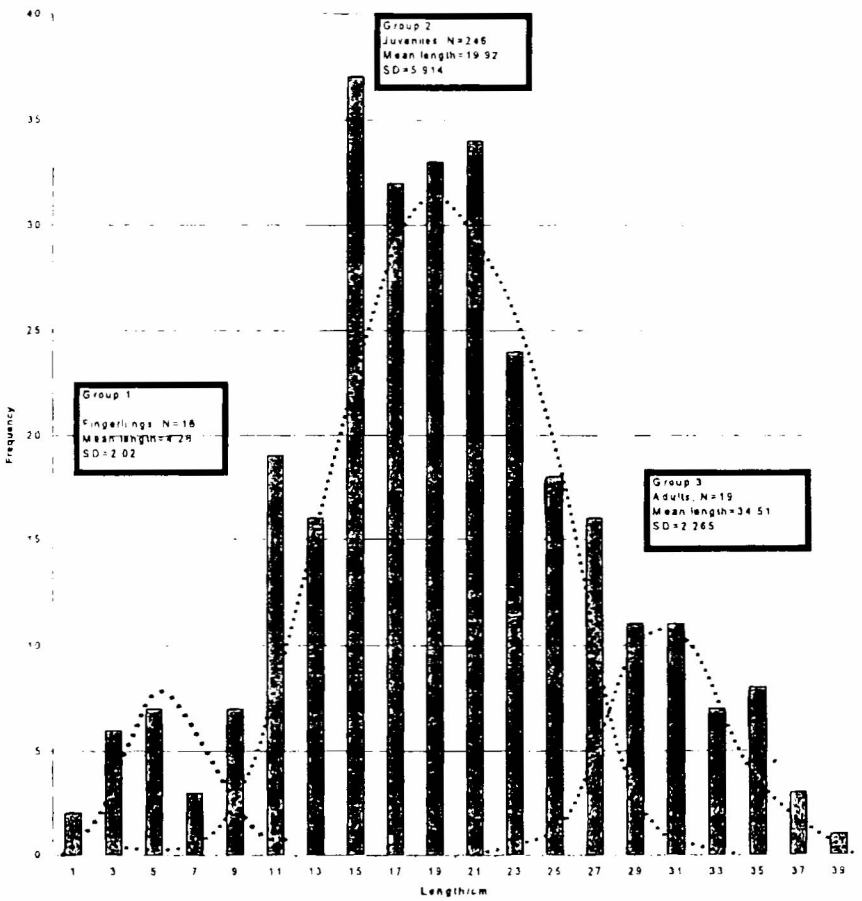

Fig.2 Decomposed length frequency histogram of *O mykiss* using the software, **FiSat** (Bhattacharya Method) in to three groups corresponding to fingerlings, juveniles and adults.

4. Distribution

The present distribution of rainbow trout was confined to Belihul Oya itself from station 1 to Station 17. The other streams which transverse the Plains were devoid of any fish. Within the macro habital of Belihul Oya drainage system itself, it was clearly distinguished the four different group of stream habitats, in which the significantly different environment conditions and physiographpies were associated with. In addition, Rainbow trout was also exhibited the size dependent distribution with those different habitats in their corresponding developmental stages. Among the group (Order, I, II, IV, and V), the size of the fish varied significantly (ANOVA F=80.01, P<0.0001). The fish capture data of each stream groups suggests that there are different sizes associated with the order of the stream. Fish, mean length, 9,9cm (Range 1.0 - 9.0cm), 12.8cm (Range 6.0 - 21.0), 19.1 cm (Range 8.0 - 32.0) and 23.2cm (Range 14.0 - 39.0) were more abundant in first, second, third and forth order streams respectively. The above distribution pattern is featured by increasing the mean length of the fish with the order of the stream. Relating with above distribution pattern with the decomposed length frequency histogram (Fig. 2), it is apparent that the fingerlings were concentrated only first and second order streams where as juveniles were in second and third. The adults were found in both third and fourth order streams. Environmental parameter such as, Dissolved Oxygen (ANOVA-F=3.489, P=0.001), total dissolved Solids (ANOVA-F=31.8, P=0.29) and Surface water temperature (ANOA-F=3.14, P=0.02) differed among stream orders significantly where as pH of the stream water did not show significant difference (ANOVA-F=*1.0*, P=0.39), among stream orders. Further, other physical characteristicsof the streams, such as, depth (ANOVA-F=18-71,P<0.0001), Width (ANOVA-F=183.7, P=<0.0001) cover (ANOVA-F=19.74, P=<0.0001) flow rate (ANOVA-F=4.64, P=<0.006) and altitude (ANOVA-F=10.46, P=<0.0001) also differed among steam order I to IV. Above results apparently indicates that the different life stages of *O.mykiss* are associated with several significantly different habitats event in the same stream.

Fecundity

Total fecundity of *O.mykiss* in Horton plains was estimated as varied from 490 to 962 (Mean, 744.8+159.1). The relationship between total length and fecundity (Fig. 3), derived from regrssion analysis of log transformed data could be expressed as Fecundity=110.93+23.1 TL (r=0.9794).

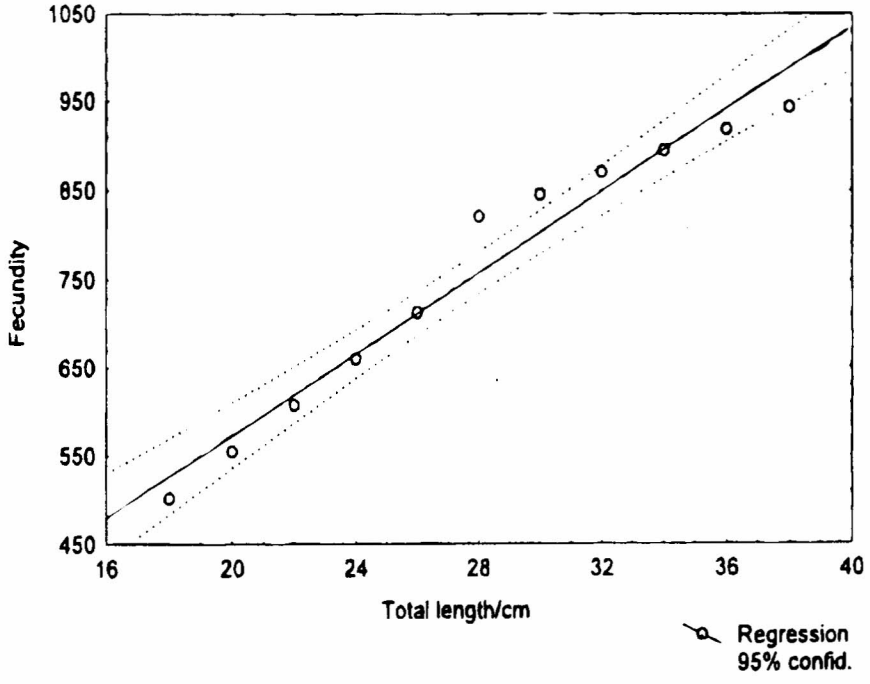

Fig.3 Fecundity of *O.mykiss* (F= 110.93+ 23.1*Total length, Correlation: r= 0.9794)

Eggs

Ovarian eggs of Rainbow trout were mostly spherical and slightly irregular. Colour of eggs changed from while to pink during the maturation within the ovary. They were demersal, deposited in clusters or piles and were non-adhesive but when water hardened they showed very little adhesiveness. Egg diameter distribution of ovarian egg (Fig. 4) and spawned eggs indicated that diameter of eggs in the ovary varied from 0.9mm to 4.1mm where as the diameter as the where as the diameter of spawned eggs varied from 2.9mm to 4.5mm. Modal diameter of ovarian eggs and spawned eggs were 3.3mm and 3.5mmrespectively. Therefore eggs over 2.9mm in diameter are eggs in the redds are larger due to absorption of water and water hardening.

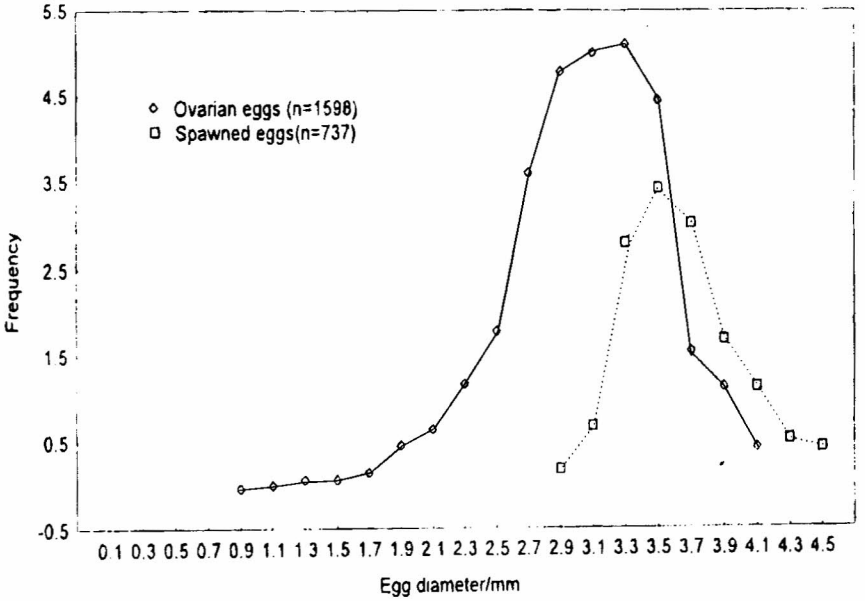

Fig. 4 Egg diameter distribution of *O.mykiss*

Spawning and spawning habitats

The preferred spawning grounds were in 1st and 2nd order streams (station 1.5, 6 and 15), where the bottom consisted of mainly gravel (size range from 1.0-3.0cm) a devoid of plants. Therefore, redds were not observed in vegetated stream segments. Spawning occurred in shallow water (20cm) under direct morning sunlight. Both male and female fish were about 30 cm in total length and they were swimming together with touching each other. While they were swimming the female made a depression on the gravel bed by flapping its pectoral fins and caudal fin. The pair was just above the redds for 1.5 hours and then female swam away but male was around the redd. After fifteen minutes female came again and joined with male and stayed for another 1.5 hours. Pairing ended after 3.5 hours female covered the redd using gravel by flapping the pectoral fin and sometimes the movement of the vent. It was noticed that the aggressive nature of the male during the mating not allwing other approaching males to come near by. This spawning behavior was observed in late December to early April in the year (Fig. 10). The depth of redds varied from 6.

Survival of Eggs

Excavation of 11 redds revealed that majority (66%) of eggs were dead examined by their bad odour and gray colour in the redd. However, in redds in first order streams

(station 1,6 and 16) exhibited low egg mortality, around 52% than that of higher order redds (Station 5). The majority of dead eggs (76%) were coated with black silt.

Downstream variation of parameters,

The average number of fish caught at each station showed that the number increased downstream (*Spearmen R=0.512, P=0.3*) (Fig. 5). The concentration of dissolved oxygen (Fig. 6) (*Spearmen R=0.74*), P=0.0001) and total dissolved concentration (Fig. 7) (*Spearmen R=0.262, P=0.30*) exhibited negative relationship to downwards direction. In addition to that, pH (Fig. 9) (*Spearmen R=0.331, R=0.18*) and surface water temperature (Fig. 8) (Spearmen R=0.262, P=0.3) showed positive relationship to downstream direction. The silt load varied from 0.8mg. to 4.6mg. From the above, it could be concluded that first order streams have better environmental parameters for fry and fingerlings. Lower order streams contained silt load from 2.6mgl-^{1} to 4.6mgl-^{1}, which is not suitable for egg survival.

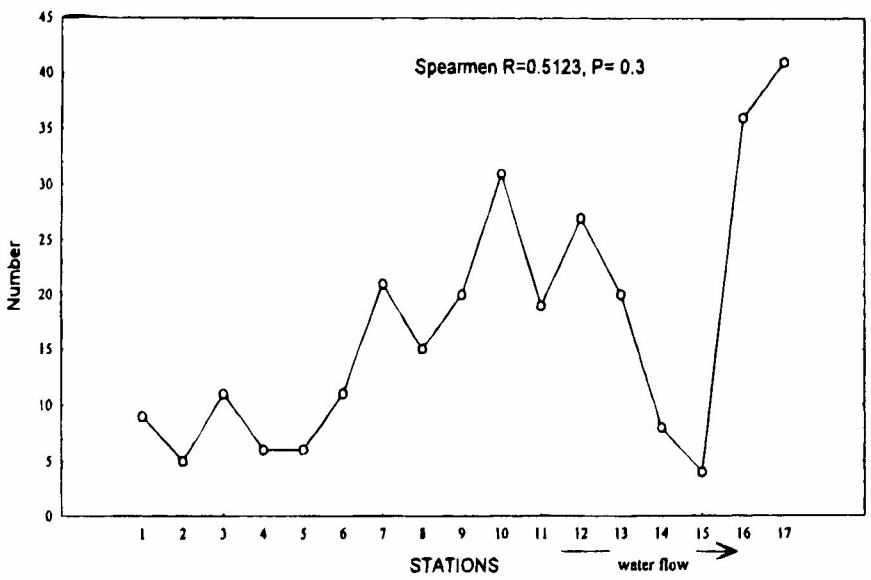

Fig. 5 Variation of mean number of fish captured at sampling stations

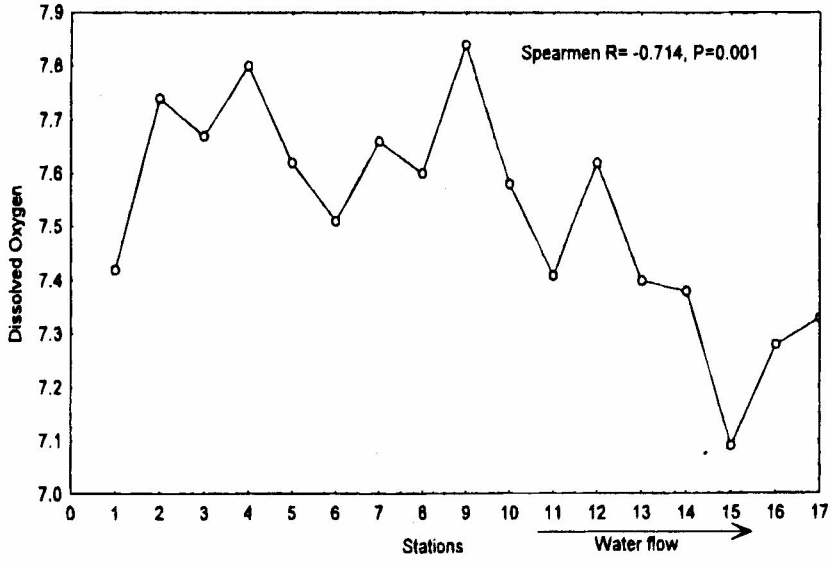

Fig. 6 Variation of Mean Dissolved Oxygen concentration among sampling sites

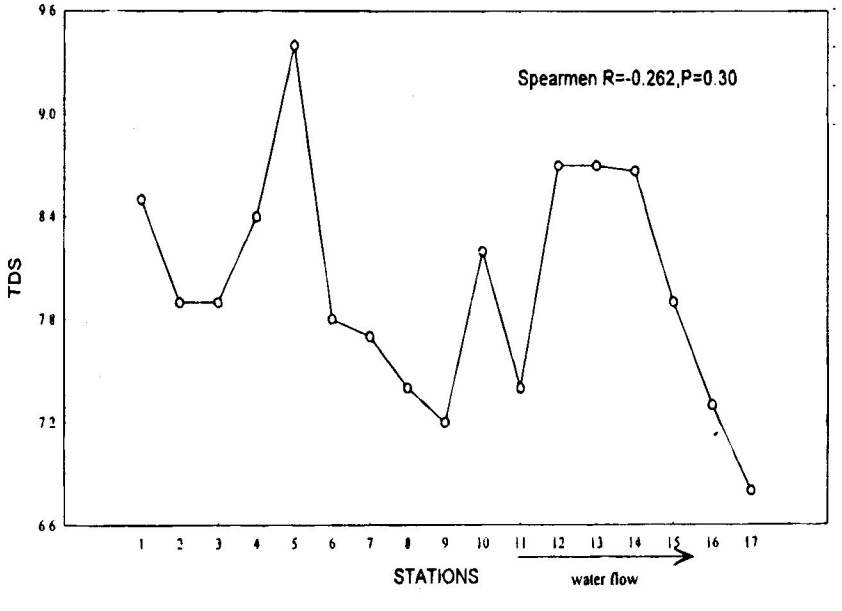

Fig. 7 Variation of mean total dissolved solids among sampling stations

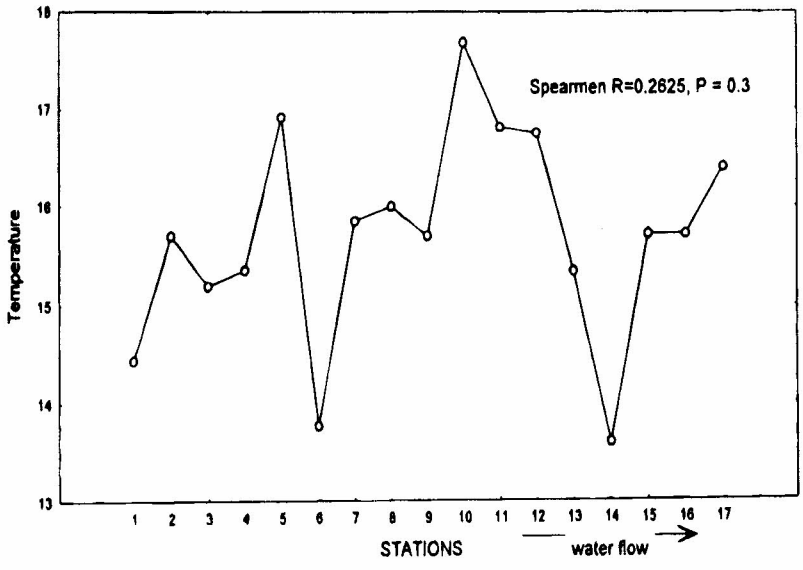

Fig.8 Variation of mean surface water temperature among sampling stations

Predators

There were 4 groups of otters with 20 in numbers (*Lutra lutra*) in station 1,5,7 and 12 specially in rainy gloomy days creeping in side their tunnels feeding on trout. Their feces examined contained skeletal remains of fish create considerable loss to the trout population.

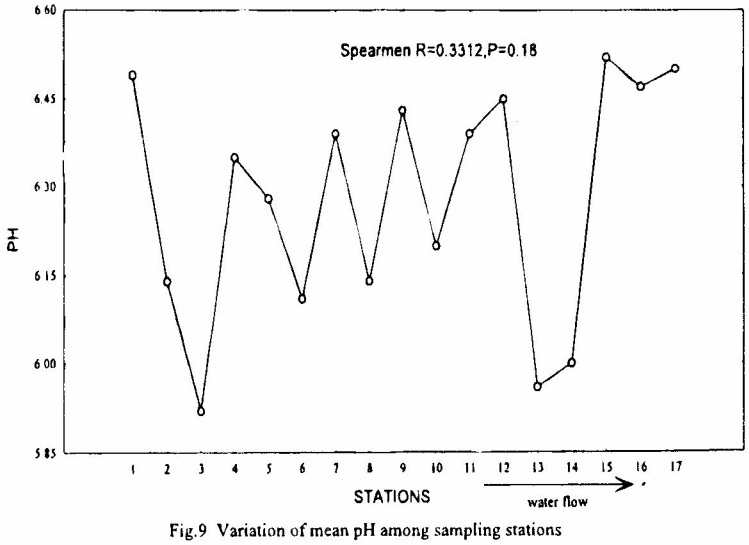

Fig.9 Variation of mean pH among sampling stations

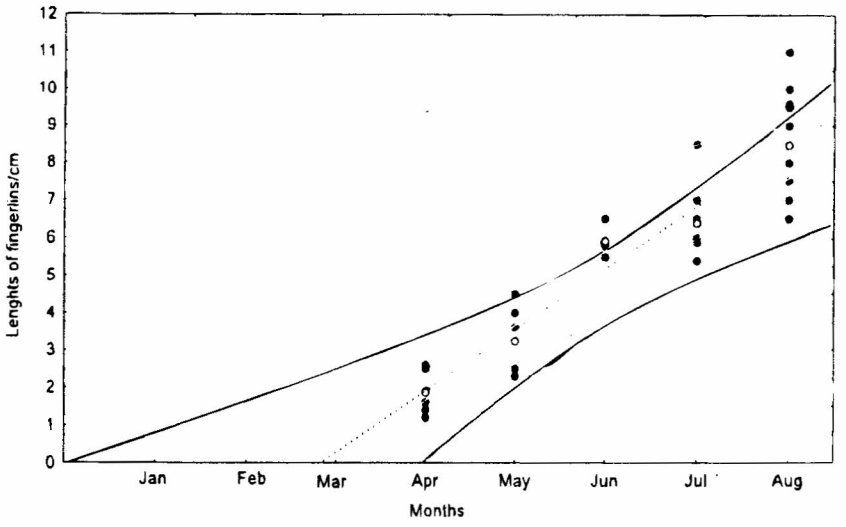

Fig. 10 Lengths of fry and fingerlings of rainbow trout in Horton Plains plotted and extrapolated against their corresponding months of capture to elaborate the spawning season.

Discussion

Prior to this study, very few information on Rainbow trout in Horton Plains were available except Costa (1974) who caught five specimens during his study. Earlier, Fowke (1936) had stated that the stocking of Rainbow trout was done in Horton Plains. Previous studies, however, were short term on one or few locations and did not necessarily reflect the population structure and distribution after stocking ceased in 1989. In 1973 a few fish sampled were of 36cm (TL) (Jinadasa as ACF, personal communication).

The taxonomy of the species inhabiting in the Horton Plains is little ambiguous since, the lack of systematic comparative study on molecular level of *O. mykiss* and what is inhabited up in the Horton Plains now. The doubt of the species was emerging as far back as from Fowke (1936) who stated that after stocking of Rainbow trout fingerlings to Horton Plains, they disappeared forever. This was proved by Ceylon Fishing Club data produced after Costa (1974) that indicated that very low return from what has been stocked. Later Fowke (1936) found that trout have traveled well below the Horton Plains, one occasion to Belihul Oya. This seemed that they exhibited seaward migration, which is inherently done by steelhead trout but Rainbow trout. Apart from that, some, morphometric

characteristics suggested that, at that time, sample from Nuwara-Eliya Hatchery were identified as steelheads, where, the lateral line scales read as 130-140 (Fowke1936). For Rainbow it should be 160-170 (Fowke 1936). However, according to Benhnke 1992, it was between 120 and 210 depending on the sub species and form. The present population breeds up in the plains itself not exhibiting seaward migration before spawning and they show up stream migration instead. Though, Fowke 1936 refereed two species such as Rainbow and Steelhead trout, now both of them in the same taxon, *O.mykiss.* However, it is apparent that there were two species in the Nuwara-Eliya Hatchery, may be not in the same time, and subsequently in the stream of Horton Plains as well. This caused the problem to biologist in the hatchery and led to send samples to USA to further clarification, which revealed that were steelheads. Now it is very difficult to understand what was referred as steelheads at that time. Therefore, the existing population up in the Horton Plains needs molecular level identification in contrast with other known species in the world.

Base flows, channel physiography, previous human activities and time of collection influenced the size structure of captured fish in each station.

Size distribution of *O.mykiss* indicated the presence of weakly built fish in the waterways of Horton Plains in comparison to temperate countries. The maximum size of fish recorded was 39.0cm in the area during this study, while in the USA stable water flow, temperature regimes, and stream banks (Raleigh and Duff 1980). Rainbow trout associates different habited during their development. Therefore, distribution showed the size dependent pattern among tributaries. Adults and juveniles were numerous in the 3rd and 4th order tributaries and pools while fingerlings dominated in 1st and 2nd tributaries and creeks. The similar pattern of distribution exhibited by river Usk brown trout, which belongs to the same genus in South Wales, where the fry and 1 year old fish were numerically dominant in tributaries while oldest were more common in main river and pools (Bembo et.al 1993).

Rainbow trout is a spring spawner; in the Southern Hemisphere it spawns six months later (Gall and Crandall 1992). It usually spawns from 2-4 years after their parent spawned. This age can greatly depend on size and genetics (Benhke 1992). The spawning season determined here is from late December to early April and is rather short with compared to cold-water specimens who spawn from January to July (Raleigh et.al 1984). However, few rainbow trout populations out side of the native range have modified their spawning time to avoid adverse environmental conditions (Van Velson 1974; Kaya 1977). Fecundity of *O.mykiss* in Horton Plains, was very low, 490-962 (mean 744.8), which was earlier estimated by Fowke 1936)

as 900, where as in temperature countries, it varies from 200-12000 (Scott and Crossman 1971, Moyle 1976, Carlander 1969). However, this estimate is very low when compared to cold-water specimens. Fowke 1936 (stated that his estimate were between 600 and 950 of specimens from Nuwara-Eliya. Trout that have a territory that is very productive will usually have a large body size at an early age, and therefore will often breed sooner that a fish that lives in a less productive area (Benhnke 1992). This could be of the reasons to have low fecundity in Horton Plains. Normally, the temperature ranged from 11.8 to 22.0 ^{0}C (mean, 15.8±1.88) in waterways was during the study. Therefore, increased temperature would definitely be a conclusive reason for the low fecundity as the optimum is described as between 7.0-17.0 ^{0}C (Mills 1971).

In natural waterways, without excess good quality food and desirable environmental conditions for adults good quality eggs have not been produced and the egg to fry mortality is high as 100% (Bromage et.al 1992). On the other hand, the high percentage of dead eggs implies that, it also lead to low fecundity and poor quality eggs. High mortally rate of eggs is supported with poor environment conditions, such as, silting and low Oxygen. This is same in other part of the world Rubin (1994). Extensive tilling during the seed potato cultivation in Plain caused heavy accumulations of silt in the streams. In addition to that, the loose nature of the soil increases the silting during the rainy seasons. Here, in Horton Plains redds in higher order tributaries contained high mortality rate. Rubin 1994 studied and revealed that the fine sediments increased egg mortally by decreasing the interstitial water flow as a result egg may die either from lack of oxygen supply or by poisons by waste which cannot be washed away. Since the Optimal temperature and flow velocity above the redd are about 7^{0} to12^{0}C and between 0.3ms-1 and 0.7 ms-1 (Raleigh et al 1984), the high temperature and slow flow rates in the high sihcoad streams of Horton Plains are responsible for high mortally rates. The combine effects of temperature, dissolved oxygen water velocity and gravel permeability are important for successful incubation (Coble 1961).

Fowke (1936) listed enemies such as trout otter, brown fish owl and cormorant. The otter was the only threatening predator found in considerable numbers in Horton Plains during the study, Further, Fowke (1936) stated that harm that otter did for tout frightening the fish for training their cubs was more significant than killing them. However, then in Nuwara-Eliya streams, judging from claw marks when netting the fish revealed that otters appeared to miss more than they seized.

5. Acknowledgment

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