Species richness of fish in relation to environmental factors

The number of fish species in a particular kind of stream is considered to be related to a definite habitat, e.g. pool, run, riffle, rapid or cascade[1,2]. Information is available on the fish communities in different kinds of hillstream habitats[3–6] and there is an agreement that fish biodiversity occurs in the descending order of pool, riffle/run and rapid.

For the present study, twenty-three sites of four river systems, namely the Beas, the Sutlej, the Yamuna and the Ghaggar (each having a stretch of 3–4 km) were sampled at monthly intervals to study the fish diversity during the period August 1998 to September 1999 (see Table 1 for the exact location of the stream).

The abiotic factors like water temperature, total alkalinity, TDS, conductivity, total hardness, dissolved oxygen (DO), chlorides, nitrates, phosphates, turbidity and pH were studied every month for each stream. Out of these, water temperature, conductivity, pH and DO were analysed on the spot using multiline P-4 water analysis kit (E-merck). TDS was determined with the help of TDS scan (E-merck). Rest of the parameters were analysed according to the standard methods as given by American Public Health Association[7]. Longitude, latitude and altitude were determined with the Magellan Trailblazer XLGPS system. Water current was determined by Environmental Measurement and Controls digital current meter. The fishes were caught with the help of a cast net of 1–2 m diameter of mesh size of 1 cm with iron sinkers. In addition, hand net, scoop net and drag net were also used. The sampling was done between mid morning and late afternoon on a fixed day every month during the period August 1998 to September 1999. The representative specimens of different fish species were preserved in 10% formaldehyde solution and then identified in the laboratory using standard references[8–13].

During the period of study a total of 36 species were recorded. Of these, *Barilius* spp., *Puntius* spp., *Crosscheilus latius diplocheilus, Garra gotyla gotyla, Tor putitora, Schizothorax richardsonii, Schistura* spp., *Salmo trutta fario* and *Salmo gairdnerii gairdnerii* are very common. However species richness vs abiotic factors has been calculated on the basis of the number of species available at each site. By using the method of least squares and Karl Pearson, the regression equation, coefficient of correlation and standard deviation values were calculated using SPSS computer program (version 7.5).

Table 1 lists the details of each stream, log of fish species richness and habitat types. Table 2 gives the correlation coefficient and regression equation for species richness and the various

Table 1. Physical characteristics and species richness of the streams

Collection site	River basin	Altitude (m)	Longitude (E)	Latitude (N)	Fish species richness (no./log)	Habitat type
Dehni	Sutlej	390	78°12′	29°30′	11 (1.04)	P,U,R
Seer	Sutlej	580	77°01′	31°25′	9 (0.95)	P,U,R
Gambhar (B)*	Sutlej	600	76°23′	31°12′	14 (1.15)	P,U,R,A
Ali	Sutlej	650	76°48′	31°18′	11 (1.04)	P,U,R,A
Gamrola	Sutlej	710	76°55′	31°35′	12 (1.08)	P,U,R,C
Jarol	Sutlej	750	76°55′	31°43′	8 (0.90)	P,U,R,A,C
Gambhar (S)*	Sutlej	815	76°56′	31°01′	11 (1.04)	P,U,R,A,C
Dehar	Beas	400	75°35′	31°40′	7 (0.84)	P,U,R,A,C
Gaj	Beas	430	76°23′	32°07′	11 (1.04)	P,U,R,A,C
Baner	Beas	500	77°05′	32°25′	15 (1.18)	P,U,R,A,C
Suketi	Beas	754	76°58′	31°43′	7 (0.84)	P,U,R
Jeuni	Beas	850	77°03′	31°40′	7 (0.84)	P,U,R,A,C
Sainj	Beas	957	77°06′	31°58′	2 (0.30)	P,U,R,A,C
Tirthan	Beas	957	77°06′	31°58′	2 (0.30)	P,U,R,A,C
Parvati	Beas	1115	77°11′	31°53′	2 (0.30)	P,A,C
Sarvari	Beas	1245	77°07′	31°08′	1 (0.00)	P,A,C, R
Faujal	Beas	1433	77°08′	31°02′	2 (0.30)	P,A,C, R
Baddi	Ghaggar	400	76°22′	30°57′	13 (1.11)	P,U,R
Markanda	Ghaggar	500	77°21′	30°33′	14 (1.15)	P,U,R
Giri (Y)*	Yamuna	900	77°12′	30°53′	8 (0.90)	P,U,R,A,C
Giri (G)*	Yamuna	900	77°12′	30°53′	7 (0.84)	P,U,R,A,C
Ashni (G)*	Yamuna	900	77°12′	30°53′	8 (0.90)	P,U,R,A,C
Ashni (S)*	Yamuna	1130	77°09′	30°59′	7 (0.84)	P,U,R,A,C

*The streams Gambhar, Giri and Ashni were visited at two points each, namely Gambhar (Bilaspur) or Gambhar (B) and Gambhar (Subathu) or Gambhar (S); Giri (Yashwantnagar) or Giri (Y) and Giri (Gaura) or Giri (G); Ashni (Sadhopul) or Ashni (S) and Ashni (Gaura) or Ashni (G).
P, Pool; U, Run; R, Riffle; A, Rapid, C, Cascade.

Table 2. Species richness vs abiotic factors

Parameter	Correlation coefficient	Regression equation	Mean	Standard deviation	Observed range (range diff.)
Abiotic factors					
Water temp. (°C)	0.880**	$Y = -0.573 + 0.07063\ (X)$	19.73348	4.189778	10.87–24.6 (13.73)
Total alkalinity (mg/l)	0.727**	$Y = 0.298 + 0.003627\ (X)$	144.0435	67.37776	43.75–285.75 (242)
TDS (mg/l)	0.723**	$Y = 0.357 + 0.003118\ (X)$	148.6661	77.92152	34.16–277.27 (243.11)
Conductivity (µS/cm)	0.712**	$Y = 0.363 + 0.001749\ (X)$	261.9378	136.8059	48.16–493.33 (445.17)
Total hardness (mg/l)	0.690**	$Y = 0.290 + 0.004832\ (X)$	109.8152	48.02282	38.08–195.81 (157.73)
pH	0.523*	$Y = -5.450 + 0.749\ (X)$	8.372174	0.234539	7.89–8.7 (0.81)
DO (mg/l)	–0.413	$Y = 3.19 + (-0.290)\ (X)$	8.181304	0.479093	7.31–9.18 (1.87)
Chlorides (mg/l)	–0.024	$Y = 0.839 + (-0.000903)\ (X)$	19.73826	8.809146	8.33–33.55 (25.22)
Nitrates (mg/l)	0.348	$Y = 0.694 + 0.366\ (X)$	0.34565	0.31963	0.04–0.98 (0.94)
Phosphates (mg/l)	0.023	$Y = 0.816 + 0.03107\ (X)$	0.151304	0.25046	0.02–1.01 (0.99)
Turbidity (NTU)	–0.124	$Y = 0.853 + (-0.00404)\ (X)$	8.056957	10.33305	1.3–41.92 (40.62)
Altitude (m)	–0.779**	$Y = 1.531 + (-0.000914)\ (X)$	776.7826	286.4421	390–1433 (1043)
Water current (cm/s)	–0.513*	$Y = 1.373 + (-0.00539)\ (X)$	103.863	31.90353	30.6–163.61 (133.01)

**Significant at 0.01 level.
*Significant at 0.05 level.

Table 3. Fish species found at different altitudes

Altitude	Fish species
Up to 600 m	*Barilius bendelisis, B. vagra, B. barila, B. barna Puntius sarana sarana, P. ticto ticto, P. phutunio, P. stigma, P. carnaticus Crossocheilus latius diplocheilus, Garra gotyla gotyla, Tor putitora*
600 to 1000 m	*T. putitora, B. bendelisis, B. vagra, B. barila, B. barna, Schizothorax richardsonii*
1000 m onwards	*Salmo trutta fario, S. gairdnerii gairdnerii, S. richardsonii*

abiotic factors. The high correlation between species richness and factors like water temperature, total alkalinity, TDS and conductivity became apparent. There is moderate correlation between species richness on one hand and total hardness and pH, on the other. Altitude, water current and DO showed negative correlation with species richness, whereas the factors like turbidity and chlorides showed very poor negative correlation. On the other hand, nitrates and phosphates exhibit very poor positive correlation with species richness.

A decline in the number of fish species occurs with the increase in altitude as shown in Table 3.

It has been observed that those streams which are rich in *T. putitora* have an abundance of various species of *Barilius*, because these constitute the food of the fish. Exceptions to the above classification may occur.

It is, thus, concluded that the level of species richness is dependent on the abiotic factors like temperature, total alkalinity, TDS, conductivity, total hardness, pH, altitude and water current. However, the importance of habitat type, pollution level and human activities cannot be ruled out.

1. Shelford, V. E., *Biol. Bull.*, 1911, **21**, 9–35.
2. Schoener, T. W., *Science*, 1974, **185**, 27–39.
3. Schlosser, I. J., in *Community and Evolutionary Ecology of North American Stream Fishes* (eds Matthews, W. J. and Heins, D. C.), University of Oklahoma Press, Norman, 1987, pp. 111–120.
4. Braaten, P. J. and Berry, C. R. Jr, *J. Freshwater Ecol.*, 1997, **12**, 477–489.
5. Gorman, O. T. and Karr, J. R., *Ecology*, 1978, **59**, 507–515.
6. Arunachalam, M., *Hydrobiologia*, 2000, **430**, 1–31.
7. APHA, *Standard Methods for the Examination of Water and Waste Water*, 1998, 20th edn.
8. Jayaram, K. C., *The Freshwater Fishes of Indian Region*, Narendra Publishing House, Delhi, India, 1999.

9. Day, F., *The Fishes of India: Being a Natural History of the Fishes known to Inhabit the Seas and Freshwaters of India, Burma and Ceylon*, Text and Atlas, (Fourth Indian Reprint 1994), Jagmander Book Agency (Formerly Today and Tomorrow Book Agency), New Delhi, 1878.
10. Johal, M. S. and Tandon, K. K., *Punjab Fish. Bull.*, 1979, **3**, 1–44.
11. Johal, M. S. and Tandon, K. K., *Punjab Fish. Bull.*, 1980, **4**, 39–70.
12. Tilak, R. and Husain, A., *Zool. Jb. Syst. Bd.*, 1977, **104**, 265–301.
13. Talwar, P. K. and Jhingran, A. G., *Inland Fishes of India and Adjacent Countries*, Oxford and IBH Publishing Company Private Ltd, New Delhi, 1991, vols 1 and 2.

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Occurrence of the entomopathogenic nematode in parts of South Andamans

Entomopathogenic nematodes (EPNs) of the families Steinernematidae and Heterorhabditidae have considerable potential for biological control of insect pests[1]. The non feeding infective juvenile (IJ), carrying cells of the symbiotic bacteria, *Xenorhabdus* spp. in gut, migrate through the soil, enter a susceptible host and release the symbiont into the haemocoel. Proliferation of the bacteria lead to death of the insect within days, followed by nematode growth and reproduction.

Surveys for EPNs have been conducted in many parts of the world, including Australia[2], the USA[3,4], Europe[5–8] and India[9,10], both for the purpose of recovering potentially useful isolates and gaining an insight into the ecology of the nematodes. An understanding of the factors governing the natural occurrence and abundance of the nematodes is of importance in formulating a rational approach to their utilization as bio-control organism[11].

A total of 139 soil samples from 10 localities representing cultivated area, forest, scrub land and coastal sandy region were sampled randomly for EPNs during August 1995–August 1998 in South Andamans. One to five samples were taken from each site. Samples collected 1 km away from the sea were considered as inland samples (Table 1).

Samples were baited with rice moth, *Corcyra cephalonica* St., (Galleridae: Lepidoptera) larvae[12]. Baited soils were incubated at room temperature (27–30°C). At intervals, the jars were inspected in the dark for bioluminescence. Insects parasitized by the nematode were recovered from the soils after luminescent cadavers were detected. The cadavers were transferred on whites trap for the emergence of IJs. Emerging nematodes were used to infect fresh *Corcyra* larvae for identification and establishment of cultures.

A representative selection of soil samples from which *Heterorhabditis* was recovered were analysed for pH and determination of organic carbon[13].

The EPNs recovered during the present survey were identified as *Heterorhabditis* sp. (Siva Kumar, pers. commun.) coming close to *H. indicus*; however species level confirmation is awaited. No Steinernematid nematode was encountered.

Heterorhabditis was recovered from North Bay, Mt. Harriet, Mithakhadi, Wandoor, Sippighat, Garacharma and Burmanallah and Chidiyatapu (Table 1). A total of 139 sites were sampled, 86 sites were coastal and 53 sites were inland. Nearly 16.27% of the coastal sites harboured *Heterorhabditis* sp. and only 3.77% of inland sites had *Heterorhabditis* sp. (Table 2). The difference in the frequency of recovery between coastal and inland sites was significant (χ^2-test $P < 0.05$).

Most sites at which *Heterorhabditis* was detected, were within a few hundred metres of the sea. The coastal sites

Table 1. Number of sites sampled in South Andamans and number of sites at which *Heterorhabditis* sp. was recovered

Region	Coastal sites		Inland sites*	
	No. of sites sampled	*Heterorhabditis* positive sites	No. of sites sampled	*Heterorhabditis* positive sites
North Bay	17	5	8	0
Mt. Harriet	6	0	9	1
Bambooflat	6	0	5	0
Mithakhadi	5	2	8	0
Wandoor	12	2	4	0
Sippighat	7	0	4	0
Garacharma	13	0	8	0
Burmanallah	8	1	5	0
Chidiyatapu	12	4	2	1

*Sites are at least 1 km from the sea.