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Full Length Research Paper

Macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi (J&K)

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Benthic macroinvertebrate assemblages at sub-tropical River of Jamu, River Tawi, corresponding to different catchment land uses, were assessed in 2008 to 2009 as indicators of water quality. The relative diversity, species richness, dominance, evenness indices, physico-chemical parameters and percentage of Annelida + Arthropoda + Mollusca (AAM) individuals were determined. Significant spatio-temporal variation was observed in relative diversity, with Diptera dominating the study area instead of Annelida, Odonata, Ephemeroptera, Hemiptera and Gastropoda. Significant relationships were recorded between physico-chemical parameters (air and water temperature, depth, transparency, pH, FCo_2, DO_2, CO_3^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, Cl^-) and the occurrence of specific genera. Significant changes in macroinvertebrate assemblages were primarily due to changes in water quality. As elsewhere, macroinvertebrate communities proved to be good indicators of water quality and should be used as bioindicators in long-term monitoring of this river.

Key words: Macrobenthic invertebrate fauna, correlation, diversity, species richness, Tawi River, water quality.

INTRODUCTION

Invertebrate communities change in response to changes in physicochemical factors and available habitats. The biotic structure and water quality of streams and rivers reflect an integration of the physical, chemical and anthropogenic processes occurring in a catchment area, leading to the concept of ecological integrity. Human induced hydrological changes, physical disturbances (habitat alteration, urban land use) and point and non-point sources of pollution (chemical contamination, surface runoff, intensive agriculture) are examples of processes responsible for a broad-scale deterioration of lotic ecosystems (Chatzinikolaou et al., 2006). The river receives untreated effluents from many urban settlements and industrial discharges in both countries (Chatzinikolaou et al., 2006). The abundance of benthic fauna greatly depends on physical and chemical properties of the substratum. Benthic macro-invertebrates can be used as a barometer of overall biodiversity in aquatic ecosystems (Chatzinikolaou et al., 2006).

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Macrobenthic invertebrates are a ubiquitous and diverse group of long lived species that react strongly and often predictably to human influences in aquatic ecosystem. In addition they are sedentary, therefore body burdens reflects local conditions, allowing detection of a variety of perturbations in a range of aquatic habitats (Rosenberg and Resh, 1993). Macrobenthic invertebrates are an important and integral part of any aquatic ecosystem as they form the basis of the trophic level and any negative effects caused by pollution in the community structure can in turn affect trophic relationships. These can include those that feed on them directly or indirectly such as fish and bird populations, respectively. In addition, aquatic invertebrates have the ability to clean rivers as they utilize the organic and detritus matter. According to Carlisle et al. (2007) macroinvertebrate populations in streams and rivers can assist in the assessment of the overall health of the stream.

Biological assessment and criteria can be used as the basis for management programs, restoring and maintaining the chemical, physical and biological integrity of freshwater. Live organisms offer valuable information regarding their surrounding conditions and can be used

Figure 1. Map of River Tawi (Sawhney, 2008).

to evaluate the physical, chemical and biological impact and their cumulative effects (Karr and Chu, 1999). In addition, surveys of the richness and species composition, the relative abundance of groups or species and the feeding relationships between the inhabiting organisms are the most direct measure to determine if a water body meets the biological standards for aquatic life.

Realising their immence importance, several workers have attempted to study the diversity of macrobenthic invertebrates in aquatic ecosystem in lotic water bodies of Jammu viz: Dutta and Malhotra (1986), Dutta et al. (2000), Sawhney (2004), Mushtaq (2007), Sawhney (2008). River Tawi flows through the vicinity of the City and thus, recieves different pollutants. The pouring of wastes contaminates the river and decreases biodiversity. It is, in view of above facts, a study of polluted river, Tawi river is undertaken to assess its water quality. The study of biodiversity of Macrobenthic invertebrate community also is undertaken as these communities play an important role as link between trophic levels and also serve as indicator species for water pollution assessment. This is a study to aware the people how they are contaminating the source of life. Several workers have studied macrozoobenthic forms of river and have monitored water pollution using them as bioindicators. Corroborating these views, the present study lays emphasis to find the pollution status of River Tawi intriguing macrobenthic invertebrates inhabiting there, so that the results obtained can make an effective contribution to holistic studies in the riverine management.

MATERIALS AND METHODS

Study area

This study which was carried out in September 2008 to August 2009 covered the riverine system of the Tawi River (Figures 1 and 2) in the district of Jammu; J&K. River Tawi drains through the vicinity of Jammu division lies between 74°50' and 33°30'N latitude. The river is also very liable to floods which occur at the time of the periodical rains of summer and in the season of more irregular winter rains. The water of River Tawi is the sole source of drinking water for the inhabitants of Jammu city. Besides, river water is also used for irrigation, recreation, sewage disposal, fishing, etc.

Physico-chemical determinations

The seasonal variations of the physico-chemical factors of water were studied from September 2008 to August 2009. Monthly samples were collected from various sites in the early hours (7.00 a.m. to 9.00 a.m.) of the day during first week of every month. Utmost care was taken to avoid spilling of water and bubbling of air during sampling in iodine treated polyethylene bottles. All the physico-chemical characteristics of water were determined at the sampling sites, while others were analyzed in the laboratory within 4 to 8 h. The water and air temperature was recorded by a mercury bulb thermometer, depth by a meter rod, transparency by secchi disc, dissolved oxygen, free carbon dioxide, pH, carbonates, bicarbonates calcium and magnesium were analyzed according to APHA (1960):

pH: pH of the water was determined by using a portable pH meter (Hanna, model HI 98130).

DO: Dissolved oxygen of the water was determined by sodium azide modification of Winkler's method (A.P.H.A., 1985).

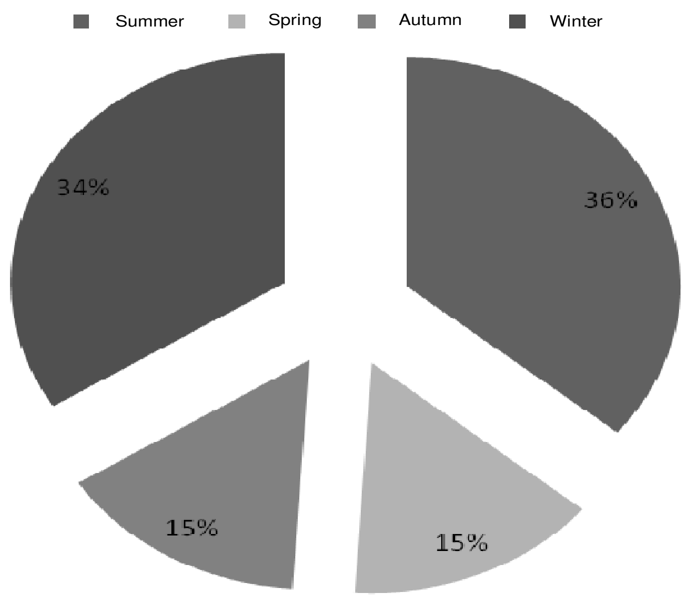

Figure 2. Percentage distribution of macrobenthic invertebrates of Tawi River during September 2008 to August 2009.

Free carbon dioxide: FCO_2 was estimated by titrimetric method recommended by A.P.H.A. (1985).

Carbonates and bicarbonates: Carbonates and bicarbonates were estimated as per Indian Standard Method (1973) and A.P.H.A. (1985).

Chloride: Argentometeric method using potassium chromate as indicator was adopted for the estimation of chloride (A.P.H.A, 1985).

Calcium and magnesium: The estimation of Ca^{++} and Mg^{++} was done by the method suggested by I.S.I (1973) and (A.P.H.A.1985).

The bottom soil samples were collected using an Ekman dredge having an area of 232 cm^2. The soil samples collected were sieved immediately using no. 40 mesh size sieve (256 mesh per cm^2). The organisms retained were segregated and their abundance was calculated as number per square meter according to Jhingran et al. (1969) and Welch (1948) (*). Preserved samples of macrobenthic invertebrates were identified according to Ward and Whipple (1959), Tonapi (1980), Adoni (1985) and Pennak (1978). The abundance of these organisms was calculated as number per square meter by applying the following formula:

N= O/A.S x 10,000   Welch (1948) (*)

Where,
N = no. of macrobenthic organisms/m^2.
O = no. of organisms counted.
A = area of metallic samples in square meter.
S = no. of samples taken at each stations.

Statistical analysis

The correlation coefficients between different physico-chemical factors and Macrobenthic invertebrate diversity were worked out using Sigmastat software. To understand a particular biotic community it is very important to work out certain indices. In this case Shannon- Wiener (H') Shannon- Wiener 1949, Maraglef's index (d) (1958), and Simpson's index (d_{simp}) Simpson (1949). However, evenness is calculated as defined by Pielou index (E) (Pielou's, 1966) using Sigmastat software.

RESULTS

In case of River Tawi, biotic scores and statistical analyses helped to assign distinct catchment and anthropogenic impacts to the benthic macroinvertebrate assemblages along the river gradient during the low flow period, when pollution and hydrological impacts are most evident. Considerable seasonal variations in respect of certain physico-chemical parameters and macrobenthic invertebrate population in the river were observed and are represented in Tables 1 and 2. During the period of present investigations, the air temperature of the river was observed to fluctuate from a minimum of 14°C in January 2009 to a maximum of 42°C in the month of June 2009. The variations in water temperature follow closely the variation in air temperature and vary from a minimum of 14°C in December 2008 to a maximum of 31°C in the month of June. Mean depth of the river ranged from a minimum of 16 cm in the month of January 2009 to a maximum of 51 cm in the month of February 2009. Minimum range of transparency was recorded to be 16 cm in the month of August 2009 and its maximum range was recorded to be 40.75 cm in the month of October 2008.

pH of water showed a wide variation ranging from 6.8 to 9.4. The concentration of DO recorded a seasonal

Table 1. Seasonal fluctuations of macrobenthic invertebrate fauna (org. /m^2) recorded in River Tawi during September 2008 to August 2009.

Group/Genera	Spring	Summer	Autumn	Winter
Annelida				
Tubifex sps.	505	2808	243	491
Branchiura sps.	0	0	0	9
Limnodrillus sps.	0	23	0	0
Insecta :- **Diptera**				
Chironomous sps.	371	131	153	8996
Culcoides sps.	0	31	23	94
Pentanura sps.	0	18	0	14
Tabanus sps.	0	0	18	0
Pshychoda sps.	0	0	0	9
Probezzia sps.	9	0	0	0
Eristalis sps.	24	3560	76	18
Odonata				
Ophiogomphus sps.	0	0	0	9
Perithemis sps.	0	0	0	5
Progomphus sps.	0	0	0	9
Ephemeroptera				
Baetis sps.	0	0	0	14
Caenis sps.	14	0	0	0
Hemiptera				
Corixa sps.	0	36	0	95
Gastropoda				
Lymnaea sps.	0	54	9	0
Physa sps.	0	9	0	50
Gyralus sps.	0	9	0	0
Thiara sps.	0	5	0	0

variation from a minimum of 0.4 mg/l in the month of December 2008 to a maximum of 6.4 mg/l in the month of January 2009. FCo_2 remained absent in the month of April and its maximum range (12 mg/l) was recorded in the month of January 2009. Carbonates were found absent throughout the year except the month of April 2009 in which the recorded value was 18 mg/l. Bicarbonates values ranged from 79.3 mg/l in the month of July 2009 to a maximum 744.2 mg/l in the month of January 2009. The mean value of Ca^{2+} and Mg^{2+} ranges from a minimum of 8 and 19.3 mg/l in the months of July 2009 and August 2009 whereas a maximum of 45.71 to 47.62 mg/l was recorded in the month of November. Cl^- content in the river was observed to vary from minimum of 21.95 mg/l in the month of May 2009 to a maximum of 59.88 mg/l in the month of April 2009.

Altogether 20 taxa of macrobenthic invertebrate fauna were recorded during the period of study belonging to 3 major phyla viz: Annelida, Arthropoda and Mollusca. Among these phyla, Arthropoda (70.54%) dominated and were followed by Annelida (28.11%) and Mollusca (0.95%) (Pie chart as shown in Figure 3). At sites where human pressures were present (anthropogenic stress, Municipal sewage and domestic waste) taxa tolerant to pollution, such as Chironomidae, Oligochaeta and Hirudinea increased in abundance, while non-tolerant ones decreased (eg. some Ephemeroptera families). Sensitive Plecoptera taxa were absent from all sites except from site 1 located on a tributary. Their absence is related to low discharge (abstraction) and high water temperatures. This change in the benthic composition has already been observed in other river systems, where anthropogenic impacts were most evident *Phylum Annelida* was represented by class Oligochaeta only and the peak was observed in the month of June due to the presence of numerically abundant *Tubifex* sps. (1989

Table 2. Range of variation mean and standard deviation of the physico-chemical characteristics of water of River Tawi during September'08 to August 2009.

Parameter	Unit	Range of variation		Mean and standard deviation
		Min.	Max.	
Air temperature	°C	14	42	28.91 ± 8.21
Water temperature	°C	14.5	31	22.79 ± 5.55
Depth	cm	16	51	33.20 ± 10.59
Transparency	cm	12.5	40.75	25.18 ± 10.38
pH	-	6.8	9.4	7.81 ± 0.76
FCo_2	mg/lt	0	12	4.483 ± 3.13
DO	mg/lt	0.4	8	3.9 ± 2.53
Co_3^{2-}	mg/lt	0	18	1.5 ± 5.19
HCo_3^-	mg/lt	79.3	744.2	471.16 ± 221.40
Ca^{2+}	mg/lt	8	45.71	29.94 ± 10.88
Mg^{2+}	mg/lt	19.3	47.62	32.25 ± 9.24
Cl^-	mg/lt	21.95	59.88	36.81 ± 12.78

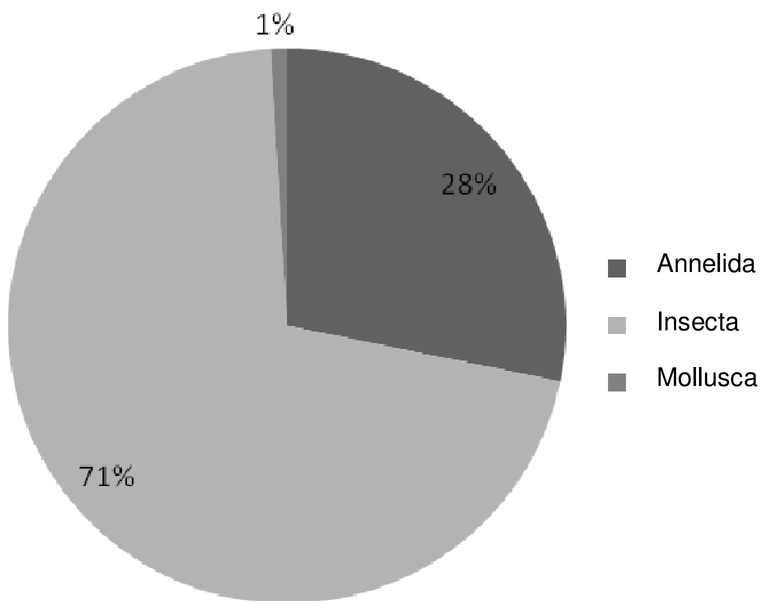

Figure 3. Percentage contribution of macrobenthic fauna inhabiting the river.

org/m^2). Thus, *Tubifex* sps. dominated the total number of Oligochaetes (4019 org/m^2). *Phylum Arthropoda* was represented by class Insecta which was contributed by order Diptera, Odonata, Ephemeroptera and Hemiptera. A peak of Arthropoda was observed in the month of December 2008. This was due to the presence of *Chironomous* sps. (8996 org/m^2). *Phylum Mollusca* was the minor contributor to the overall population density of the macrobenthos and was represented by class Gastropoda which showed its peak in the month of January 2009 which was due to the presence of *Physa sps.* (50 org/m^2).

The relationships found between physic-chemical characteristics and the density of macrobenthic invertebrate fauna were studied and has been summarized in Table 3. Annelida showed a significant positive correlation with air temperature and a negative correlation with bicarbonates and Ca^{2+}. However, Arthropods showed a positive correlation with FCo_2 and bicarbonates and negative correlation with air and water temperature. Mollusca were found negatively correlated with bicarbonates.

The macrobenthic invertebrate fauna was analyzed for species diversity, species richness, dominance and

Table 3. Correlation coefficient (r) between macrobenthic invertebrates with physic-chemical parameters of River Tawi.

Parameter	Annelida	Arthropoda	Mollusca	Total benthos
Air temperature	0.501*	-0.688*	0.258	-0.522*
Water temperature	0.264	-0.613*	0.078	-0.524*
Depth	0.251	-0.219	0.583	-0.132
Transparency	0.075	-0.365	0.020	-0.338
Ph	-0.345	0.352	-0.374	0.238
FCo_2	0.030	0.551*	-0.112	0.555*
DO	-0.067	0.130	0.283	0.111
Co_3^{2-}	0.063	-0.085	-0.185	-0.067
HCo_3^-	-0.676*	0.353	-0.524*	0.131
Ca^{2+}	-0.697*	0.457	-0.439	0.229
Mg^{2+}	-0.270	0.331	-0.241	0.240
Cl^+	0.085	0.336	-0.277	0.357

*Marked correlation were significant ($p < 0.05$).

Table 4. Diversity, species richness, dominance and evenness indices for macrobenthic invertebrate fauna found in River Tawi.

Months	Shannon-weaver (H) index	Marglef index	Simpson's index	Pielou's eveness index
September	0.204	0.194	0.898	0.294
October	1.068	0.534	0.405	0.770
November	1.985	1.326	0.317	0.903
December	0.532	0.460	0.715	0.330
January	0.334	0.246	0.834	0.304
February	0.942	0.444	0.42	1.034
March	0.806	0.448	0.482	0.581
April	0.687	0.221	0.503	0.991
May	1.555	1.013	0.653	0.747
June	0.208	0.771	0.917	0.150
July	-	-	-	-
August	0.656	0.257	0.533	0.946

evenness described in Table 4. The values of species diversity of macrobenthic fauna thus obtained varied considerably during the twelve months of sampling. The index ranged between H' = 0 to H' = 1.985. The minimum species diversity value was obtained in July 2009 which continuously increased in successive 3 months and in November the highest value 1.985 was recorded. The index showed a fluctuating trend in the rest of the months. Maraglef's index varied between minimum value d = 0 to a maximum value d = 1.326. The minimum and maximum values were obtained from the samples of July and November, respectively. The range of variations of Simpson's dominance index ranged from $d_{sim} = 0$ to $d_{sim} = 0.917$ in which the higher values were observed in June. Pielou (1966) suggested the measure to assess the evenness component of diversity. As its calculation is dependent on the Shannon-Wiener, index, evenness values are sample size dependent. The minimum evenness value was observed in July and maximum in February the values being $P_i = 0$ and $P_i = 1.034$, respectively. The ANOVA test performed for Annelida, insecta and Mollusca, indicated the difference in the mean values of the sample is not significant. The values for all the indices used (diversity, species richness, dominance and evenness) was calculated as 0 in the month of July because due to heavy monsoon rains the benthic community was flushed out thus, showing the total absence of macrobenthic invertebrates. Density of macrobenthic invertebrates depends on months over the year as proved by chi square density test.

DISCUSSION

It was observed that Odonata nymphs are inhabitant of fresh waters with rich oxygen concentration and no pollution. Presence of bioindicators, *Chironomus sps.* larvae and *Tubifex* sps. indicate the effect of pollution. *Chironomous* sps. larvae showed its peak during December and January which could be attributed to low water level in the river (16 to 18 cm), less oxygen content (0.4 to 2.8 mg/l) along with sluggish movement of water during these months as suggested by Sunder and Subla (1986), Paoletti et al. (1980) and Dutta and Malhotra (1986). Numerical abundance of Chironomous throughout the year indicates the pollution status of the river as chironomids are the common inhabitants of polluted waters, rich in nutrients and poor in oxygen as also observed by Callisto et al. (2005), Clemente et al. (2005), Olomukoro and Ezemonye (2006), and Manoharan et al. (2006).

Among Oligochaeta, *Tubifex* sps. dominated the total number of Oligochaetes and were found throughout the year showing their peak in the month of June when air temperature was maximum (42°C). Hawkes (1979) has reported that the members of Oligochaeta are usually favored by the organic environment and remain dominant in severally polluted conditions with special emphasis on *Tubifex* sps. which inhabit areas with strong sewage pollution and anoxic waters. However, presence of good organic detritus content contributed the maximum quantity of Oligochaetes as observed by Takeda (1999), Nocentini et al. (2001), Callisto et al. (2005), Chakraborty and Das (2006), Manoharan (2006) and Gasim et al. (2006).

The peak of Molluscan density was observed in the month of January which may be due to soft and organically rich bottom, alkaline nature of water and higher concentrations of Ca2+ (44.11 mg/l) and HCo3- (744.2 mg/l) as has been reported by earlier workers McColl (1972), Malhotra et al. (1990), Manoharan et al. (2006), Aldridge et al. (2007) and Garg et al. (2009).

Low Shannon-Wiener indices were recorded varying between H' = 0 to H' = 1.985. The maximum value of the index was obtained when the number of species was high. Marglef species richness index varied between d = 0 to d = 1.326. The higher index values were recorded when the number of species was high. Hence, the Marglef's index appears to be dependent on number of species in the sample and not on the number of individuals in the sample. Similar observations have been cited by Nkwoji et al. (2010) giving the community diversity and species diversity indexes of macrobenthic invertebrates. The values of Simpson's index obtained ranged between d_{sim} = 0 to d_{sim} = 0.917. At the time of highest value population density was 2075 / m^2 and number of species 4. A decrease in diversity and corresponding increase in dominance of a limited number of species is a common community response to environmental disturbance.

Similar findings have been reported by Olomukoro and Ezemonye (2007). No significant difference was found between sampling periods for evenness. The trend of variations in evenness value was more or less the same as the Shannon-Wiener diversity index. Lower values for evenness during the whole period in river may be accounted to local disturbances. When all species in a sample were equally abundant, it seems reasonable that an evenness index should be maximum and this value decreases toward zero as the relative density of the species diverges away from evenness was observed in the month of July. Similar observations have been given by Yap et al. (2003).

A significant positive correlation of Arthropods with FCO_2 ($r = 0.551$, $p < 0.05$) and HCO^{3-} ($r = 0.353$, $p < 0.05$) was found which has been earlier reported by Zieser (1978). Among Arthropods taxa Chironomous was numerically abundant. This genus is also used as a pollution indicator since it is found abundant in the areas where organic and sewage pollution is very high and these areas also depicits higher FCo_2 values. So, Chironomous can be directly correlated with FCo_2. This has been observed by Verma and Saksena (2010). Temperature is the most apparent factor which affects the seasonal cycle and abundance of macrobenthos (Elliot, 1967; Macan, 1970). It is due to the shallowness of this river that its water gets directly affected by the atmospheric temperatures. It is well known that the shallower the water body, the more quickly it will react to the change in the atmospheric temperature (Welch, 1952). This may be the reason why Annelids showed a positive correlation ($r = 0.501$, $p < 0.05$) with air temperature as it has also been reported by Sunder and Subla (1986) who stated that the role of higher temperature within the optimum range is linked with the greater production of Annelida (Oligochaetes).

Conclusion

The river shows 20 species, out of them insects were well dominant at whole study area because of their potency to tolerate the organic pollution. The present study concludes that the presence of some pollution indicator species such as *Tubifex tubifex*, *Limnodrilus* sp., (among Annelida) *Chironomous* sp., *Culicoides* sp., *Pentaneura* sp., *Tabanus* sp., (among Arhropoda) *Lymnea* sp., and *Physa* sp., (among Mollusca) (Takeda, 1999; Nocentini et al., 2001, Callisto et al., 2005; Clemente et al., 2005; Chakraborty and Das, 2006; Manoharan, 2006; Gasim et al., 2006; Olomukoro and Ezemonye, 2006) directly points to the shifting status of the river from non-polluted to polluted. Municipal sewage and domestic waste showed alarming shift or total elimination of sensitive biotic community form the habitat.

As the human population continues to grow, it will contribute significantly towards the process of river biodegradation. This biosurvey of the macrobenthic invertebrate fauna gives an important insight into the health of the river and appends the knowledge and understanding of the management strategies involving biomonitoring as a significant tool in the river restoration studies.

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