



Establishment of population of introduced brown trout (*Salmo trutta*) co-related to their feeding habits in river Asiganga, district Uttarkashi, Uttarakhand

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Abstract

Uttarakhand is considered as one of the freshwater fish biodiversity zone within India and the aquatic biodiversity here is threatened primarily due to anthropogenic activity and introduction of non-native fishes. Colonization and invasion of new aquatic habitats are common in nature as a result of climatic or geotectonic events but humans provide additional artificial pathways by which introduced non-native fishes can overcome biogeographic barriers. Here, in this paper, we assessed the i) factors assisting establishment of introduced brown trout's (*Salmo-trutta*) population in river Asiganga and other fresh water systems in district Uttarakashi, ii) attributes of brown trout's dietary habits that are helping them establish their population by analyzing the stomach contents of brown trout and, iii) food preferences of brown trout. As evident from our studies it is found that fish fingerlings is the food of choice and based on the morphometric assessment most of these fingerlings being preferred as food are that of an endemic species *Schizothorax*. Brown trout does eat benthos but Selectivity Index data suggest that these benthos are not a preference but lie in the neutral zone as most of the values are between -0.25 to 0.25. Different feeding preferences and reduced water level in pockets of rivers for long distance migration, seems to be major factor in establishment and spread of brown trout which in turn is threatening the endemic fish species of Uttarakhand.

Keywords: endemic species, Asiganga, brown trout, feeding habits

Introduction

Non-native fish introductions and/or their invasions constitute one of the greatest threats to the abundance of endemic piscine fauna of any aquatic system (Richter *et al.*, 1997; Wilcove *et al.*, 1998, Wards and Wipple, 1959). These introductions can result in (or enhance) the rate of species loss and thus affect the structure and function of an ecosystem (Nilsson *et al.*, 2008). For example in Western North America, introduced salmonids have displaced regionally endemic cutthroat trout subspecies, *Oncorhynchus clarkii* subsp., from both riverine and lacustrine habitats (Dunham *et al.*, 2002; Quist and Hubert 2004). Rainbow trout (*Oncorhynchus mykiss*), brooktrout, (*Salvelinus fontinalis*), and lake trout (*Salvelinus namaycush*),

have all contributed to cut throat trout decline through hybridization, competition, and/or predation (Griffith 1988; Ruzycski *et al.*, 2003; Weigel *et al.*, 2003). Various factors play important role in influencing the invasion process and the subsequent success of establishment of populations of introduced species. Niche characteristics are one of the prominent factors (Kolar & Lodge, 2002; Peterson & Vieglais, 2001; Hierro *et al.*, 2005; Kolar, 2004). Besides this, sometimes the food resources and habitat available are used sub-optimally by the native species and thus provide opportunity to the introduced species, if environmental condition is suitable (Heger & Trepl, 2003).

In Garhwal Himalaya, several fish species have been reported (Badola, 1975; Badola and Pant 1973). Besides endemic species, several exotic fish species have been introduced in many rivers and streams in Garhwal region of Uttarakhand. One such prominent introduction site is river Asiganga,

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a tributary of river Ganges, in district Uttarkashi of Uttarakhand, India. *Salmo trutta* was introduced at the origin of river Asiganga at DodiTaal (elevation 4400 m), a high altitude small lake. The exact dates of introduction were never documented but it is said that it was done by British, however no documentation is available. It has been stated by Singh *et al.*, (1983) that introduction of brown trout in the Garhwal Himalaya region of the state Uttarakhand dates back to 1910 when, the then Ruler of Tehri State stocked the eyed ova of brown trout, carried from Kashmir, into Kalyani (Uttarkashi) and Talwari (Chamoli) hatcheries (Mackay, 1945). However credible documentation is still lacking and during all these years no researches were ever carried out to assess the ecological impact of these introduced fishes on endemic fish species in Garhwal Himalaya. With the aim of assessing the impact of these introductions on native fish species and identifying factors assisting the spread and establishment of brown trout's population, we examined, quantified and compared attributes of brown trout's dietary habits in river Asiganga using random sampling. The stomach contents of brown trout, from various section of the river, was analyzed and

compared with the available dietary components (fishes, benthos etc.) in its natural habitat. Here we present data on food preferences of introduced brown trout and its effect on native species and aquatic ecology of river Asiganga and possible ecological/physico-chemical factors aiding the spreading of brown trout.

Material and Methods

Study site

The study site was located in the river Asiganga. River Asiganga originates at an elevation of 4400 meters at Dodital and merges into river Ganges at an elevation of 1158 meters at village Gangori in middle Himalaya (Fig 1, 2).

The river has catchment area of 192 sq. Km. and is predominantly monsoon fed with negligible contribution from snow melt during summer. From the point of origin to the point of its merger with the Ganges, this river flows for about 36 Km. The study area encompassed the last 25 Km region of the stream. In the study area/stretch the river has an average width of 6 to 10 meters, a depth of 80 cm to 4 meters and substratum is mainly composed of cobbles, pebbles and gravel. Fishes were also sampled from other sites (S2 – S5 – Fig 2).

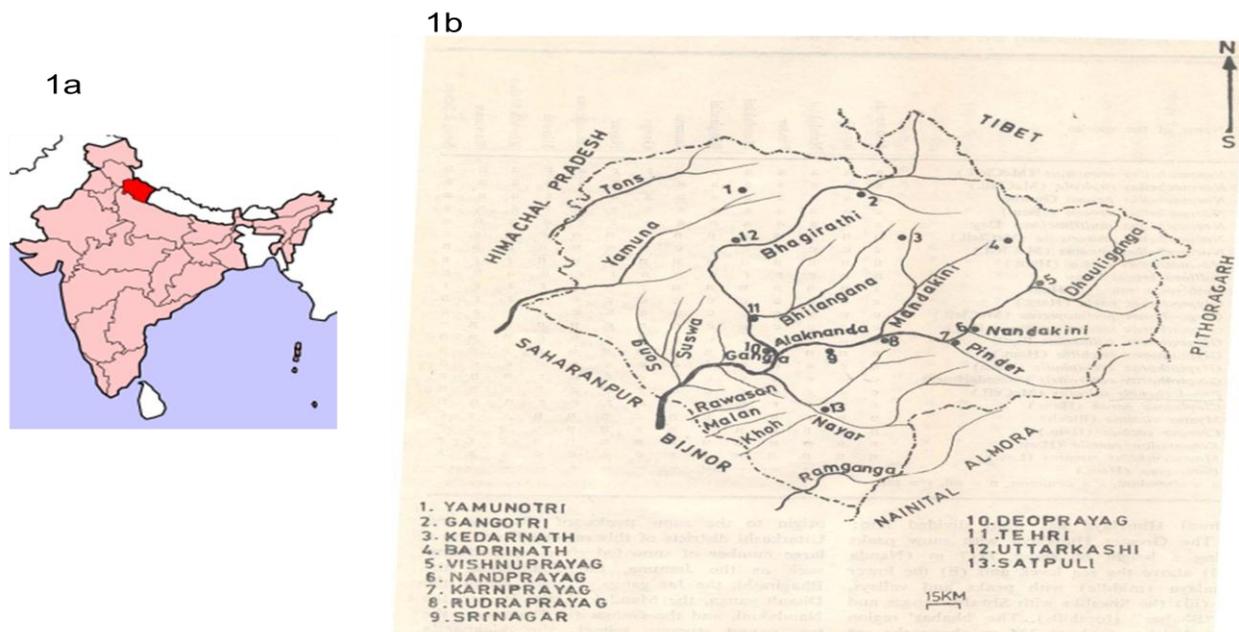


Fig. 1a. Location of Uttarakhand in India. **1b.** Fresh water resources of Uttarakhand. There are over 10 major rivers within a radius of approximately 200 km. Exotic fishes have been introduced in many rivers.

STUDY SITE



Fig. 2 Location of study area in district Uttarkashi. ☆ Represents spread of brown trout in the area. S1 to S5 are the survey sites. Majority of work on feeding behavior is from site S1.

Image from Google Earth

Fish collection

Brown trout were caught by hired fisherman along the same stretch where macro-benthos was collected at all the sites. The fisherman used cast net for capturing the fishes. The captures occurred at dawn and before dusk, from August-2009 to July-2011. Standard length (SL) and total length (TL) of each fish were measured. From each sampling, stomach of one to three fishes was preserved and placed in 10% formalin. Both - qualitative and a quantitative evaluation of stomach content of brown trout was made.

Stomach-content description

The contents of all stomachs collected were examined under a dissecting microscope. We counted and identified all items found within individual trout stomachs. Contents were classified as *Ephemeroptera*, *Trichoptera*, *Plecoptera*, *Diptera*, fish finger ling etc. (native fish).

Prey-selection behavior or feeding preferences study

For prey selection in diet and environment between species, we quantified the abundance and composition of aquatic invertebrates in our study.

We collected benthic invertebrate and the collected sample were preserved in 5% formalin. Quantitative estimation of benthic invertebrates was based on numerical counting i.e. units per meter square (Ind. m²) under a dissecting microscope. Qualitative analysis was made as per the methods/keys of Ward and Whipple (1959), Needham and Needham (1962). Based on sampling data of benthos in aquatic habitat of brown trout and in the stomach, we quantified prey selection for the most common prey items for brown trout using Strauss's linear electivity index, L ($L_i = r_i - p_i$, where r_i and p_i are the proportional abundances of prey item i in the diet and in the environment, respectively (Strauss, 1979). L ranges from -1 to $+1$, with negative values indicating avoidance, positive values indicating preference, and neutral use occurring in the range $0.25 < L < 0.25$.

Physico chemical parameters

Water samples were collected every month during August 2009 to September 2011. Surface water samples were collected with a clean plastic bucket. Preservation and transportation of the water

samples to the laboratory were as per standard methods (APHA, 1998). Water temperature was measured on the site using mercury thermometer.

The samples were analyzed for 7 different parameters. pH was measured by digital pH meter (Model LI-120) using a glass electrode pH, Carbon dioxide and alkalinity was determined by titration. Dissolved oxygen was fixed immediately after collection and then determined by Winkler's method (Trivedy and Goel, 1984). Turbidity was measured by Nephelometer using 0.02 NTU standards indicator but is not include in dataset. Conductivity was measured by water analysis kit. The present study reports the seasonal pattern of the physico-chemical parameters at these three sites (Table 1).

Table 1: Physico-chemical parameters of river Asi- Ganges

Physico-chemical Parameter	Range or Mean \pm SEM
Temperature ($^{\circ}$ C)	8 to 15
pH	7.4 \pm 0.16
CO ₂ (mg/L)	2.13 \pm 0.16
Alkalinity (mg/L)	9.16 \pm 1.6
Dissolved Oxygen (mg/L)	8.86 \pm 0.27
Conductance (mg/L)	84.16 \pm 3.89

Results and Discussion

In total, we collected 60 brown trout during the entire period (over 2 years) of study and examined their stomach contents.

Stomach-content analysis

Stomach content analysis revealed some interesting observations. Almost 98% of brown trout's stomach examined had fish fingerling's and sometimes there were up-to 3 fishes in the stomach (Fig 4, 5). Based on morphometrics these fingerlings were mostly of *Schizothorax* species. Fishes of other endemic species like *Glyptothorax*, *Nimachilus* etc. were also observed. The aquatic insects particularly *Ephemeroptera* and *Diptera* are preferred besides fish fingerlings, while insect order *Hemiptera* and *Trichoptera* were rarely eaten by the trout. In the diet of trout fingerling of native fish present in high percentage (100%) followed by *Trichoptera* (87.6%) and *Ephemeroptera* (22.5%). Rader *et al.* (1997) have also reported that

Trichoptera and *Ephemeroptera* are the most abundant prey in gut contents of Brown trout. In conclusion the diet composition at the whole sample level based on the percentage stomach contents of individuals of prey, fish fingerlings were the most ingested prey along with *Trichopteran*, while non-insect aquatic animals were rarely eaten by the trout. Our linear selectivity index suggests that the aquatic insects are a neutral zone food and not a preference. Our observation on factors assisting the spread and establishment of brown trout's population reveal that brown trout is venturing into new areas from the initial point of introduction. Brown trout is well known as a voracious predator and as there is ample number of endemic fish species in the area, the feeding requirements of this fish are well met. Besides this, there has been a lot of anthropogenic activity in the region, especially construction of hydroelectric power projects. Construction of these dams have a) reduced water level in certain sections of the river and, b) segregated populations of brown trout in specific geographical regions. These populations are now beginning to establish. We examined, quantified and compared attributes of brown trout's dietary habits in river Asiganga using random sampling. Data on stomach contents of brown trout, from various section of the river was analyzed and compared with the available dietary components (fishes, benthos etc) in its natural habitat. Here we present data on food preferences of introduced brown trout, the effect of introduced exotic trout species on aquatic ecology (and endemic fish species) of river Asiganga and possible ecological/ physico-chemical factors aiding the spreading of brown trout. In our study we have analyzed food content from stomach. The main reason for this analysis was the fact that brown trout is well known as a predator and we wanted to assess the impact of this introduced exotic species on endemic species. We could have done the radio-isotope analysis for feeding pattern but it would not give a clear picture on the exact food content. Most of the studies consider only gut content for analysis, but we are of the opinion that stomach content analysis gives the best analytical shot of feeding pattern. As evident from our stomach content analysis, fish fingerlings are the food of choice and based on the morphometric assessment, the endemic species being preferred as food is *Schizothorax* (species being



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preferred as food needs further confirmatory test using molecular biology tools). These results are unique in terms of feeding habit of brown trout. Almost 100% of the diet in stomach of brown trout was fish fingerlings (Fig.5). This is also astonishing from the point of view of native species conservation as our study suggests that there are

well established populations of brown trout in the area and all these populations probably prefer fingerlings of native species of fishes. This feeding habit of brown trout will have a severe impact on endemic fish population. This effect may not be evident as of now due to lack of baseline data on

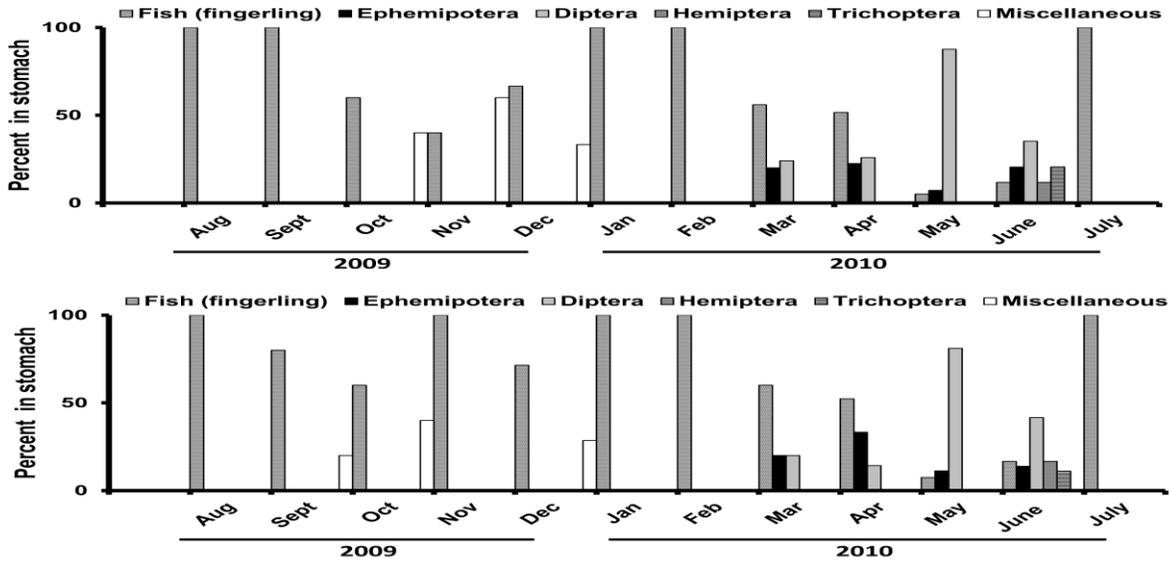


Fig. 3:

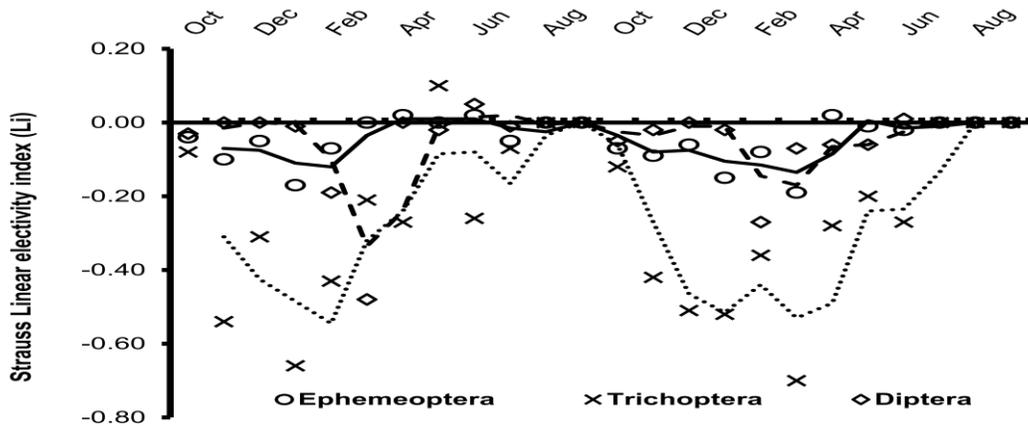


Fig. 4 Feeding preference of brown trout among benthos in river Asi-Ganga. Graph represents monthly data from August 2009 to July 2011 on the feeding preferences based on Strauss Linear electivity index (Li) – Strauss 1979. L ranges from -1 to +1, with negative values indicating avoidance, positive values indicating preference, and neutral use occurring in the range $-0.25 < L < 0.25$. Almost all the fishes examined throughout the lower reaches of river Asi-Ganga had fish or fingerlings of native species (based on morphometrics) in their stomach.

population dynamics of fishes in Uttarakhand but it will surely be the case in near future if immediate remediation steps are not taken. None of the studies so far have documented this fact that brown trout prefers fingerlings as food from this region. They do eat the benthos available but food

preference analysis done using Linear Selectivity Index (Strauss – 1979) reveal that most of the values are between -0.25 to 0.25 which indicate neutral use. It has been reported by many investigators that brown trout prefers *trichoptera*'s, *Ephemeroptera*, *Gammarus* and *Plecoptera*



(Fochettiet. *al.*, 2003; Alp *et. al.*, 2003; Alp *et al.*, 2005) and this seems to be true in our study also. However, the preference lies in the neutral zone. This particular feeding habit preferring native fish fingerlings most of the time and eating benthos

sometimes seems to be one of the main reasons for establishment and spread of brown trout in the region. Besides this habit, reduced water level in specific pockets of rivers (in the area of hydroelectric power projects), seems to be favoring



Fig. 5 Feeding preference of brown trout. Photograph showing fish fingerling in stomach of brown trout. Photograph number DSCN3615 taken during the study.

long distance trout movement/migrations. The movement may possibly also be a result of wash of entire population by fast moving flood waters in this region. The flash flooding does occur in this district at regular intervals. Introduced *Salmo trutta* already constitutes dominant population in the upper reaches of the river Asiganga (a tributary of river Ganges) and can be spotted along the entire length of river. It has even spread in the river Ganges, both up stream and down streams from the point of confluence (at village Gangori). During our survey, we could trace brown trout to almost 30 km downstream from Uttarkashi (till Dharasu and near ChinyaliSaur – a town on the edge of Tehri hydroelectric power project reservoir). Up streams, we could find this fish upto 50 km upstream (till Harsil). But this upstream occurrence/presence could be a result of introductions carried there or may be these brown trout's managed to move upstream before construction of hydroelectric projects at Maneri (Phase-I). In the Himalaya, as in many other parts of the world, several exotic species have been introduced without any consideration of the impact of such introduction on

the endemic fish. All the other countries across the world have taken immediate steps to either same the endemic species or eradicate the invading exotic species. In Uttarkashi district or even in Uttarakhand, the impacts and sensitivity of the situation arising due to this invading exotic species brown trout (*Salmo trutta*), has not been either envisaged or realized at present but this introduced exotic species brown trout (*Salmo trutta*) is going to be a major factor threatening the endemic fish species or Uttarkashi district and even Uttarakhand.

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