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ALTITUDINAL DISTRIBUTION OF ODONATE LARVAE IN NEPAL's GANDAKI RIVER

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The larvae of 19 spp. were collected along an extreme environmental gradient from 50-2560 m altitude in central Nepal's Gandaki River from 1984 to 1986. The number of spp. declined with increasing elevation; 12 spp. were captured in the subtropical lowlands, 10 in the mid-altitude hills, 4 in the Himalaya Mountain zone, and 3 in the high altitude trans-Himalaya ecoregion. The gomphids *Davidius* sp. and *Anisogomphus occipitalis* were most common, comprising 67% of 995 specimens, and had the widest range, occurring from 100-1189 m. The zygopteran *Megalestes major* and 2 anisopterans *Neallogaster hermionae* and *Sympetrum commixtum*, were collected at highest altitude; these spp. occurred in no other samples. Cluster analysis of species composition shows similarity among other high altitude collections, as well as among lowland sites, but low similarity between high and low altitude locations.

INTRODUCTION

Although more than 170 odonate species have been reported from Nepal, limited information is available on their altitudinal distribution (VICK, 1989). Little is known of their ecology, and patterns of odonate zonation in Himalayan lotic systems are poorly understood.

Several authors have hypothesized causal mechanisms for observed patterns of insect species richness with altitude. LAWTON et al. (1987), WOLDA (1987), and FERNANDES & PRICE (1988) suggested that the number of species declines at higher elevations due to reduced habitat, reduced resource diversity, increasingly unfavorable environments, and reduced primary productivity. JAN-

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ZEN (1973) and JANZEN et al. (1976) suggested that species richness peaks at middle elevations because few species have been selected for extreme environmental conditions. McCOY (1990) concluded that a complex interplay of local ecological interactions, latitude, disturbance, and sampling effort determines the elevation of maximum insect species richness. In this paper, we assess altitudinal and longitudinal patterns of odonate larvae species richness and distribution in the Gandaki River of central Nepal, which exhibits extremes of altitude and environmental conditions.

STUDY AREA

The area studied lies between latitudes 27° 20' and 29° 30' N and longitudes 83° 20' and 84° 30' E. The Gandaki River flows from headwaters on the Tibetan Plateau at more than 4000 m altitude to a lowland, subtropical confluence with the Ganges River at less than 50 m altitude (Fig. 1). The drainage crosses several major mountain ranges which divide the basin into at least four ecoregions (ANONYMOUS, 1979): Trans-Himalaya, mountain, hills, and lowlands.

The Gandaki headwaters, known as the Mustang or Muktinath River north of the Himalaya Mountains, flow approximately 50 km southward into the mountains to form the Kali Gandaki. The river then traverses the Himalayas, and pours 100 km south before flowing nearly 200 km east to join the Trisuli River. At this confluence, the river has an average discharge of 1,561 m^3/sec draining 31,100 km^2 (BHATT, 1977), and is known as the Narayani or Sapt Gandaki. It flows approximately 150 km south and then west before cutting through the Churia Hills to move south onto the Gangetic Plain. As the Gandaki flows downstream, dramatic changes in stream hydraulics occur, including decreases in gradient, current speed, and incidence of rocky substratum, and increases in width, depth, and discharge. Chemical and physical characteristics also change, with decreased alkalinity and hardness downstream, and increased temperature and diversity of the substratum and vegetation (EDDS, 1993).

METHODS

Samples were collected by one of us (DE) during an ichtyofaunal survey of the Gandaki River from March 1984 to May 1986 (EDDS, 1993), accessing locations in this rugged terrain by foot. All odonate larvae captured by seine were preserved in 10% formalin solution. Specimens were captured at 42 of 81 sites, and were distributed throughout the range of habitat conditions in the study area, from 50-2560 m altitude (Tab. I). Larvae were identified by using keys in ASAHINA (1961; 1982; 1984), SANGAL & KUMAR (1970a; 1970b), ST. QUENTIN (1970), KUMAR (1973a; 1973b), and KUMAR & KHANNA (1983). Voucher specimens are deposited in the senior author's personal collection.

Presence/absence data were employed to calculate a similarity matrix (NEMEC, 1991), which was used in cluster analysis (Release 1.5) to identify groups of sites with similar odonate assemblages.

RESULTS

Nineteen odonate species were captured (Fig. 2). These included three zygopterans of three families: Euphaeidae (*Bayadera*); Chlorolestidae (*Megalestes*); and Coenagrionidae (*Pseudagrion*); and 16 anisopterans of five families: Gomphidae

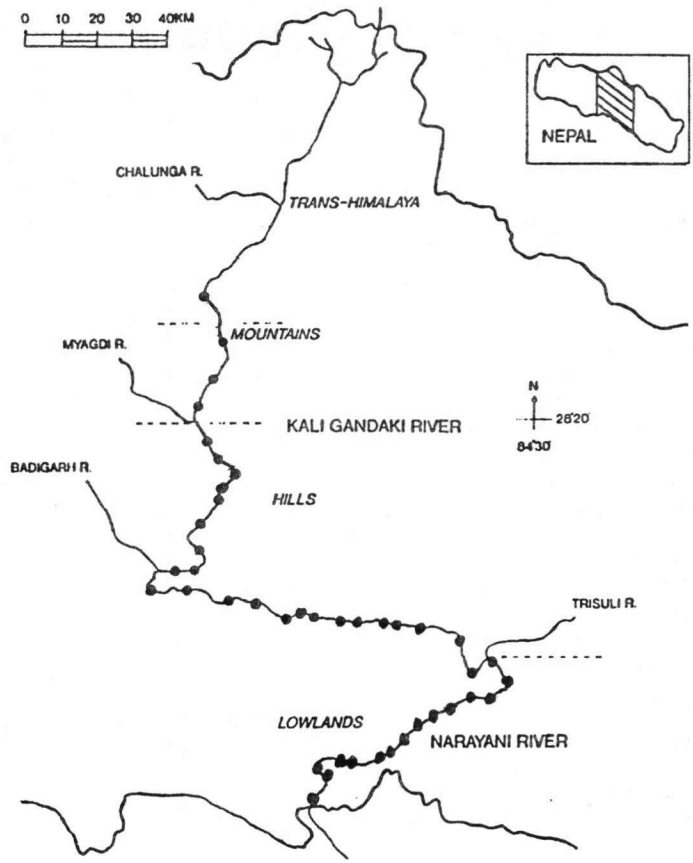

Fig. 1. Collection sites of odonate larvae in the Gandaki River.

(*Anisogomphus*, *Burmagomphus*, *Davidius*, *Paragomphus*); Aeshnidae (*Aeshna*, *Anax*); Cordulegastridae (*Anotogaster*, *Neallogaster*); Corduliidae (*Macromia*); and Libellulidae (*Brachythemis*, *Crocothemis*, *Orthetrum*, *Sympetrum*, *Trithemis*).

The number of odonate species in the Gandaki River declined with increased elevation (Fig. 2). Twelve species were captured in the lowland ecoregion, ten in the hills, four in the mountain zone, and three in the Trans-Himalaya.

Megalestes major, *Neallogaster hermionae*, and *Sympetrum commixtum* were collected in the Trans-Himalaya region at 2560 m. These species occurred exclusively in this high altitude zone. Four species, *Bayadera indica*, *Anisogomphus occipitalis*, *Burmagomphus* sp., and *Davidius* sp., were found in the mountains. *B. indica* was collected only in this region. Of 10 odonate species captured in

Table I

Collection sites (district, altitude) proceeding downstream in the Gandaki River

TRANS-HIMALAYA
(1) Larjung (Mustang, 2560m)

MOUNTAINS
(2) Tatopani (Myagdi, 1189m)
(3) Beg Khola (Myagdi, 920m)
(4) Between Beni and Tiplyang (Myagdi, 900m)

HILLS
(5) Beni (Myagdi, 850m)
(6) Simaa (Myagdi, 835m)
(7) Rite Khola (Parbat, 770m)
(8) Baglung Baleyaa (Baglung, 630m)
(9) Jyamireghat, Thaule Khola (Baglung, 610m)
(10) Binamaare (Baglung, 600m)
(11) Belbagar (Baglung, 550m)
(12) Phulbari (Gulmi, 540m)
(13) Seti Beni (Parbat, 520m)
(14) Pahadi (Syangja, 510m)
(15) Riri Khola (Gulmi, 472m)
(16) Ranighat (Palpa, 400m)
(17) Ramdi (Palpa, 385m)
(18) Nimaa (Syangja, 370m)
(19) Khoriyaghat (Palpa, 363m)
(20) Rampur (Palpa, 360m)
(21) Hardahaa (Nawalparasi, 355m)
(22) Kelaadighat (Palpa, 345m)
(23) Devgaon (Nawalparasi, 340m)
(24) Kalikatar (Tanahun, 325m)
(25) Deuti Khola (Tanahun, 292m)

LOWLANDS
(26) Devghat (Chitwan/Nawalparasi/Tanahun, 290m)
(27) Upper Narayanghat (Chitwan, 285m)
(28) Lower Narayanghat (Chitwan, 280m)
(29) Kharkhareghat (Chitwan, 250m)
(30) Rudragiri Bhusareghat (Chitwan/Nawalparasi, 235m)
(31) Tiger Tops Tented Camp (Chitwan/Nawalparasi, 210m)
(32) Gharial Conservation Project (Chitwan, 200m)
(33) Amaltaarighat (Chitwan/Nawalparasi, 195m)
(34) Laindaghat (Chitwan/Nawalparasi, 180m)
(35) Khanahaa Khola (Chitwan/Nawalparasi, 135m)
(36) Upper Tribeni (Nawalparasi, 126m)
(37) Lower Tribeni (Nawalparasi, 125m)
(38) Below Tribeni Barrage (Nawalparasi, 120m)
(39) Narsai (Nawalparasi, 100m)
(40) Taadighat (Nawalparasi, 50m)

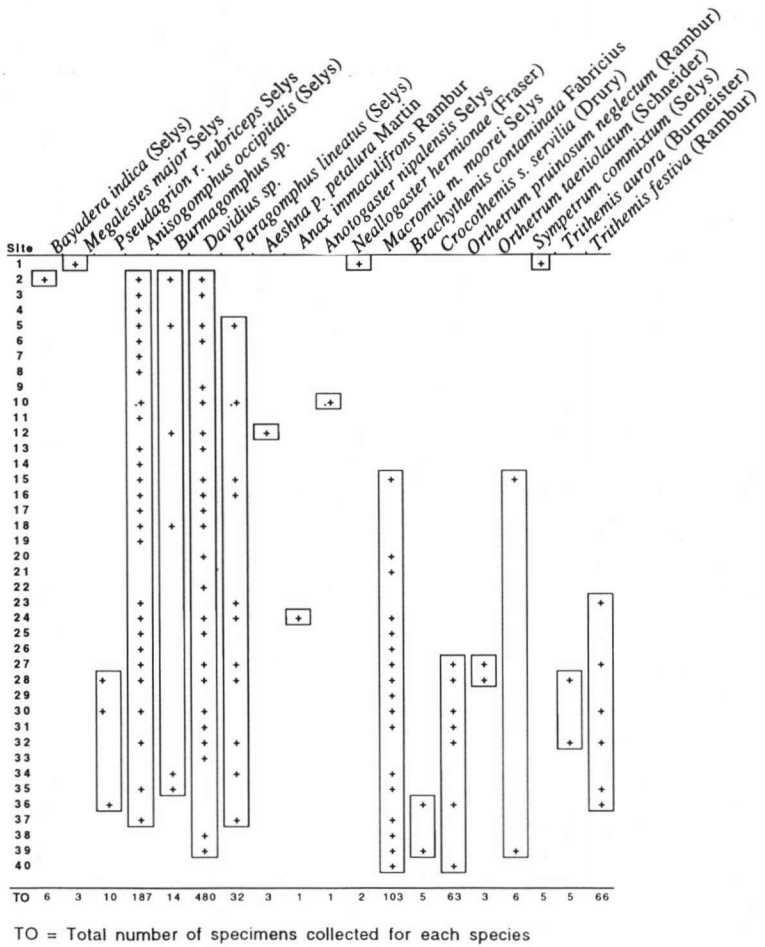

Fig. 2. Odonate species distribution by altitude in the Gandaki River. Sites are as given in Table I.

the hills, *Aeshna p. petalura*, *Anax immaculifrons*, and *Anotogaster nipalensis* were found in this zone and no others. Twelve species were collected in the lowlands, and five of these, *Pseudagrion r. rubriceps*, *Brachythemis contaminata*, *Crocothemis s. servilia*, *Orthetrum pruinosum neglectum*, and *Trithemis aurora* were captured exclusively in this region.

Of 995 odonate larvae in our collections, the gomphids *Davidius* sp. and *Anisogomphus occipitalis* were most common (Fig. 2), comprising 48% and 19% of the total, respectively. These two species also had the greatest altitudinal range (Fig. 2), occurring from 100 to 1189 m. The other most common species

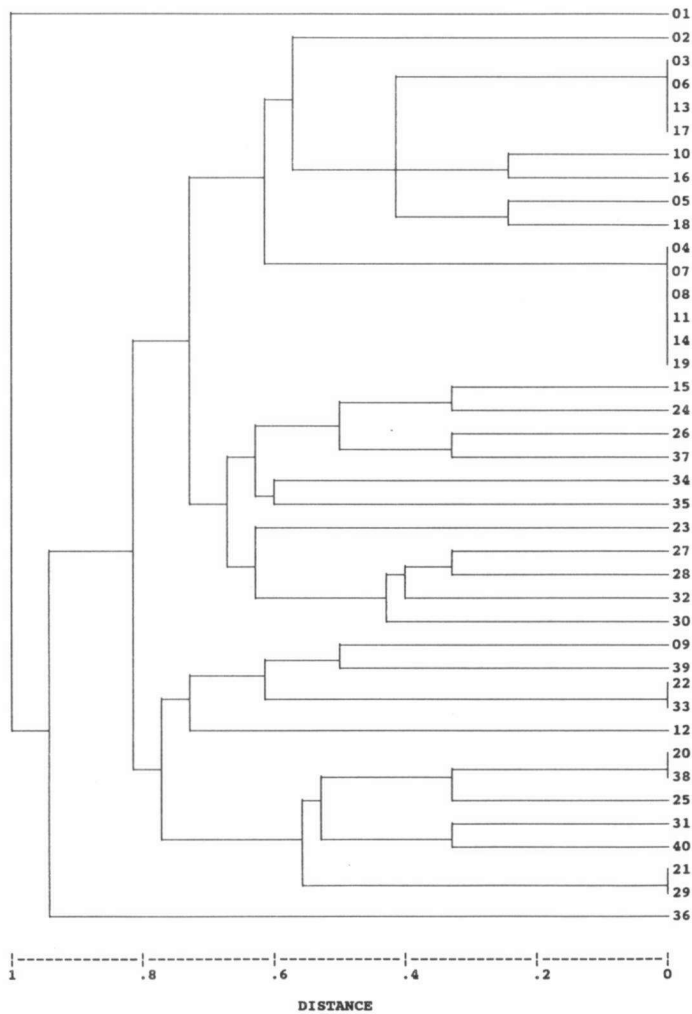

Fig. 3. Cluster analysis indicating levels of similarity of odonate species composition among sites.

and their relative abundance were *Macromia m. moorei*, 10%; *Trithemis festiva*, 7%; *Crocothemis s. servilia*, 6%; and *Paragomphus lineatus*, 3%.

Cluster analysis of similarity in species composition across habitats indicates considerable likeness among lowland collections, as well as among high altitude sites, but low similarity between high and low altitude assemblages (Fig. 3).

DISCUSSION

Many researchers consider gomphids the dominant odonate taxon in lotic habitats, and our results from an extreme environmental gradient in central Nepal's Gandaki River concur. As WRIGHT (1943) and CORBET (1983) described, most riverine odonate larvae have a dorsoventrally compressed abdomen which adapts them for burrowing. This flattening, along with long hooks on short legs, a morphological condition common to gomphids species, as in *Anisogomphus occipitalis* and *Davidius* sp., aids Gandaki River in odonates combatting drift in torrential waters. CORBET (1983) and KUMAR & KHANNA (1983) suggested that *Macromia m. moorei* resists water current with its spider-like long legs and flattened abdomen. These larvae fold their legs tightly against their abdomen, and attach to the bottom of the stream. These characters likely contribute to its high relative abundance in the Gandaki River.

The occurrence of *Megalestes major*, *Neallogaster hermionae*, and *Sympetrum commixtum* only at very high altitude supports observations made by earlier researchers (FRASER, 1933; ASAHINA, 1955; KIAUTA & KIAUTA, 1976). Cluster analysis of similarity among sites indicated no similarity of site 1 with other sites. Extremes of environmental factors such as water chemistry and temperature at high altitude (EDDS, 1993) are obviously suitable habitats for these three Himalayan species.

The number of odonate species declined with increasing elevation along this river system draining the highest mountain range on earth. These results concur with those from other taxa in less striking habitats. A similar pattern of longitudinal zonation has been observed in fishes of the Gandaki River. EDDS (1993) concluded that geographic, water quality, and stream hydraulic factors were the major physiochemical correlates of fish assemblage structure in the Gandaki River. Similarly, a combination of synergistic and related physiochemical variables appear to influence odonate assemblage structure along this extreme environmental gradient.

Such an interpretation agrees with that of McCOY (1990) who concluded that a complex interplay of factors determines the elevation of maximum insect species richness. Our results also concur with the hypotheses of LAWTON et al. (1987), WOLDA (1987), and FERNANDES & PRICE (1988) regarding patterns of species richness with increasing altitude. However, because our study did not extend into India, we cannot reject the hypotheses of JANZEN (1973) and JANZEN et al. (1976). Thus, further studies, including sampling downstream to the Ganges River, are necessary to test whether insect species richness is truly a function of altitude, or whether richness peaks at middle elevations in the subtropical lowlands of Nepal.

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