

EFFECTS OF SEASON AND SUBSTRATE ON AVAILABILITY OF DRIFT FOR FISH IN A SMALL WARMWATER STREAM

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ABSTRACT

Midday drift samples were collected through summer and autumn from two reaches of Jordan Creek, a second-order stream in east-central Illinois. The two study reaches differed primarily in gradient and substrate characteristics, with silt-sand predominating in the low-gradient reach, and gravel-cobble predominating in the high-gradient reach. Aquatic insect larvae, especially dipterans, were the most abundant invertebrates in samples from the gravel-cobble reach, but were uncommon in drift from the silt-sand reach, which was composed mostly of small copepods and cladocerans. Invertebrate abundance and size declined markedly through the summer in both study reaches, then increased through autumn. Insect larvae were virtually absent from the silt-sand drift in October, but were always present in drift from the gravel-cobble reach. On the basis of invertebrate size and abundance, the gravel-cobble reach provided a more dependable food base for Jordan Creek fishes than did the silt-sand reach. Stream modifications that alter substrate composition may increase the severity of seasonal food shortages for fish, and contribute to declining diversities in stream fish assemblages of the Midwest.

INTRODUCTION

Because aquatic invertebrates represent a major food resource for most temperate stream fishes, spatio-temporal dynamics of invertebrate abundance can have

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important implications for fish trophic ecology and community structure. Seasonal changes in invertebrate abundance are probably regulated by cycles of emergence and reproduction, which typically feature high abundance in spring and low abundance in summer for Illinois streams (Angermeier, 1982; Schlosser and Toth, 1984). Seasonal fluctuations in food availability often affect the foraging success of stream fishes (Mathur, 1977; Angermeier, 1982; 1985; Schlosser and Toth, 1984), and may therefore influence growth and survival. Spatial variation in invertebrate abundance and composition often reflects habitat characteristics such as current velocity and substrate type. For example, invertebrate abundance and production are typically lower in sand than in gravel and cobble substrates (Wene and Wickliff, 1940; Mackay and Kalff, 1969; Minshall and Minshall, 1977). Silt and sand substrates have probably always been common in low-gradient streams of Illinois, but have become increasingly more common due to watershed management practices such as stream channelization (Griswold et al., 1978; Schmal and Sanders, 1978) and row-crop agriculture. Long-term shifts in substrate composition of streams are likely to induce changes in fish community structure and declines in stream productivity.

The abundance of drifting invertebrates is commonly used to measure availability of food for fish (Mendelson, 1975; Mathur, 1977; Angermeier, 1982). Drift rates are regulated by light intensity (Holt and Waters, 1967), and are typically greatest shortly after dusk (see Muller, 1974 for a review). This pattern is apparently a behavioral adaptation for avoiding visually-oriented predators such as fish. However because most warmwater stream fishes feed most actively in daylight (White and Wallace, 1973; Mathur, 1977; Baker and Ross, 1981; Surat et al., 1982; Matthews et al., 1982) diurnal drift is a more appropriate measure of the food available to fish than nocturnal drift.

This study was designed to examine summer and autumn patterns of invertebrate abundance and composition in two reaches of a small Illinois stream. We were particularly interested in comparing the dependability of invertebrates as a food resource for fishes inhabiting the two reaches. We restricted our study to summer and autumn because previous studies indicated that food shortages for stream fishes are most severe during these seasons (Mathur, 1977; Angermeier, 1982; Schlosser and Toth, 1984). Patterns of invertebrate dynamics are discussed with respect to their potential impact on fish community structure.

STUDY STREAM

Jordan Creek is a second-order tributary of the Salt Fork of the Vermilion river in east-central Illinois (USA). The stream is 17 km long, and drains a glaciated basin of 30 km² (Larimore, 1961). Riparian and channel characteristics change dramatically from the channelized headwaters to the relatively undisturbed downstream areas (Schlosser and Karr, 1981). Sampling locations were selected to represent conditions in two wooded reaches along the upstream-downstream gradient. The upstream sample site (silt-sand reach) featured a narrow (5-10 m) strip of riparian vegetation comprising mostly multiflora rose (*Rosa multiflora*), osage orange (*Maclura pomifera*), and hackberry (*Celtis occidentalis*). Land use beyond the riparian zone was intensive corn and soybean agriculture. Gradient of the 4 m wide channel was slight (0.7 m/km) and pool-riffle structure was poorly developed. Bottom substrates were 85% silt and sand, and mean depth was 19 cm (Angermeier, 1983). In contrast, the downstream sample site (gravel-cobble reach) was bordered by 10-50 m of ripar-

ian woodland which included maples (*Acer* spp.), oaks (*Quercus* spp.), and sycamore (*Plantanus occidentalis*). The channel was wider (8 m) and gradient was steeper (4.0 m/km), with well developed pools and riffles. Bottom substrates were only 25% silt and sand with 52% gravel and cobble; mean depth was 27 cm (Angermeier, 1983). This reach, 4 km from the silt-sand reach, has never been channelized. Both reaches of Jordan Creek support a diverse fish fauna (25-30 species) composed largely of cyprinids, catostomids, and centrarchids (Larimore, 1961; Angermeier, 1983).

MATERIALS AND METHODS

Invertebrates were sampled with a 30.5 × 45.5 cm tapered drift net with 363 μ m mesh. One net was staked to the center of the stream bottom at the downstream end of a riffle in both study reaches. Samples were collected from the same location during each sampling period. Samples were collected at midday (10:45-13:45) for 1 hr. during the second week of June, July, September, October, November, and December 1983. For all samples except those collected in June and December from the silt-sand reach, drift net height exceeded water depth (i.e., the entire water-column was sampled). Depth of the water column entering the net was measured to the nearest 1.0 cm. Current velocity at the mouth of the net was estimated by repeatedly timing a float traveling 1 to 3 m in front of the net. Depth and velocity measurements were then used to estimate volume of water sampled. Because surface velocity exceeds average velocity of the water column, this method overestimates the volume of water sampled and underestimates the concentration of invertebrates. However, the method was used consistently for all collections, and depth differences between the two sample sites were slight (<15cm); thus, the inaccuracy of our velocity estimates should not influence our interpretation of comparisons of invertebrate abundance from different months and sites.

Invertebrates were preserved immediately in 15% formalin. Samples were then divided into 8 subsamples using a device similar to that of Waters (1969). Previous work with this device indicated that subsamples were consistently similar (Angermeier, 1983). All invertebrates from one subsample were sorted to order beneath a dissecting microscope and measured to the nearest 0.1 mm total length (excluding caudal processes) with an ocular micrometer. All terrestrial forms were regarded as a single taxon. Invertebrates were assigned to one of three arbitrary size groups on the basis of total length: small (0.1-1.9 mm), medium (2.0-3.9), and large (4.0-12.0 mm). Size frequency distributions from different months and sites were compared using the G-test for independence with Williams' correction (Sokal and Rohlf, 1981).

RESULTS

Surface current was always faster in the gravel-cobble reach (\bar{x} = 0.50 m/s; range = 0.27 to 0.75 m/s) than in the silt-sand reach (\bar{x} = 0.32 m/s; range = 0.11 to 0.55 m/s). Differences in taxonomic composition between the study reaches reflected differences in current velocity and associated substrates. Dipterans (mostly chironomids) were the most abundant taxon in drift samples from the gravel-cobble reach; their relative abundance ranged from 78% in June to 21% in December. Copepods were the most abundant taxon only in December, when they made up 60% of the invertebrates captured. Other taxa, including Trichoptera, Ephemeroptera, and Cladocera, were also occasionally common in the gravel-cobble samples.

In contrast, copepods were the most abundant taxon in the silt-sand reach, making up from 22 to 100% of the invertebrates captured. Cladocerans and water mites (Hydracarina) were also common in June and July. Dipterans never made up more than 20% of the total invertebrates; trichopterans and ephemeropterans were always rare and never contributed more than 2.5% of the invertebrates in a sample.

Abundances of all major invertebrate taxa declined markedly between June and September, then increased in late autumn in both study reaches (Fig. 1). Numbers of drifting invertebrates other than zooplankton (copepods and cladocerans) declined to virtually zero in the October sample from the silt-sand reach, while non-zooplankton drift were consistently observed through autumn in the gravel-cobble reach (Fig. 1). Non-zooplankton invertebrates were more abundant in the gravel-cobble reach than the silt-sand reach for all months except July and November.

Seasonal patterns of invertebrate size paralleled patterns of abundance. Drifting invertebrates in the gravel-cobble study reach were larger in June-July than in September-October or November-December (Fig. 2; G-test; $P < 0.005$). The small size of invertebrates in November-December was largely due to a sharp autumnal increase in zooplankton abundance (Fig. 1): size distributions of non-zooplankton invertebrates from June-July and November-December were not different (G-test; $P > 0.05$). Size distribution of invertebrate drift in the silt-sand reach changed little through the summer and autumn, and was always predominated by small zooplankton (Fig. 2). Invertebrates from November-December were slightly smaller than those from June-July (G-test; $P < 0.05$), but no seasonal shift in size distribution were observed for non-zooplankton invertebrates (G-test; $P > 0.05$). Month-by-month comparisons with the G-test indicated that invertebrates were always larger in the gravel-cobble reach than in the silt-sand reach, although sample sizes were too low in September and October to establish significance.

In summary, invertebrate drift in the silt-sand reach of Jordan Creek was predominated by small zooplankton, while drift in the gravel-cobble reach was predominated by larger aquatic insects. Invertebrate abundance declined markedly through the summer in both reaches, but insects become especially scarce in the silt-sand reach.

DISCUSSION

Spatio-temporal patterns of stream invertebrate abundance are extremely complex because they integrate numerous factors, including seasonality, food and habitat quality, and predation pressure. Annual cycles of stream invertebrates typically feature highest abundance in spring and low abundance in summer (Hynes, 1970), largely resulting from patterns of emergence, reproduction, and recruitment. These cycles may have evolved in response to large autumnal inputs of allochthonous organic material (mostly leaves), a primary food resource for stream invertebrates (Cummins and Klug, 1970). Invertebrates in both reaches of Jordan Creek exhibited patterns of seasonal abundance consistent with this typical pattern. Invertebrates are also generally less abundant in substrates predominated by silt and sand than in substrates composed mostly of gravel and cobble (Wene and Wickliff, 1940; Mackay and Kaff, 1969; Minshall and Minshall, 1977). This trend may result from the relative instability of finer substrates (Slack, 1955; Luedtke and Brusven, 1976; Schmall and Sanders, 1978), or their lack of interstitial surfaces available for colonization by invertebrates. Although total invertebrates were not more abundant in the gravel-cobble reach than in the silt-sand reach, aquatic insects (e.g. dipterans)

were generally more abundant in the gravel-cobble reach. Schlosser (1982) observed similar patterns in comparisons of drift samples from the same two study areas of Jordan Creek. In his study, insects were 1.5-3.5 times more abundant in the gravel-cobble reach than in the silt-sand reach from June through November. Our study indicates that small zooplankton, which reside above (rather than on) the stream bottom, were more abundant in the silt-sand reach. Furthermore, aquatic insects virtually disappeared from the silt-sand drift in October, but were always available in the gravel-cobble reach.

Most fish species that inhabit small midwestern streams depend largely on aquatic invertebrates for food (Pflieger, 1975; Smith, 1979; Trautman, 1981). Thus, foraging patterns and growth rates of stream fishes should be sensitive to spatio-temporal dynamics of invertebrate abundance. For example, some species in Jordan Creek, especially cyprinids exhibit sharp declines in foraging success through the summer and fall (Angermeier, 1982; 1985), apparently in response to declines in invertebrate availability. The late-summer scarcity of invertebrates is exacerbated for insectivorous fish because of the pulsed entry of young-of-year fish into the community, as well as high metabolic rates induced by high temperatures. Not only were fewer invertebrates available as food for Jordan Creek fishes through the summer, but invertebrate size (a measure of calorie content) also declined through the summer. Most Jordan Creek fishes preferably consume relatively large invertebrates such as insect larvae (Angermeier, 1982), presumably because of their greater energetic profitability (Werner et al., 1983). Of the ten common species studied by Angermeier (1985), zooplankton made up at least 10% of the prey eaten for only three species. Thus, results from this study suggest that the gravel-cobble reach provided a more dependable food base for fish than the silt-sand reach. This hypothesis has been corroborated for some species (especially cyprinids), which consumed more or larger prey in the gravel-cobble reach than in the silt-sand reach (Angermeier, 1985).

Streams in agricultural watersheds of the Midwest are subjected to numerous disturbances, including clearing, snagging, and channelization. These channel modifications typically cause shifts in substrate composition toward fine, unstable particles such as silt and sand (Griswold et al., 1978; Schmal and Sanders, 1978), and affect all levels of biological production (Marzolf, 1978). In combination with increased temperatures due to removal of shade, food scarcities associated with fine substrates may create extremely stressful conditions for insectivorous fishes during low-flow periods of summer and autumn. Food availability is closely linked to rates of fish growth and production, and may ultimately be a determinant of community structure. Thus, widespread disruptions of food and habitat resource bases due to sediment loads and stream alterations have probably contributed to the declines in diversity and changes in trophic composition observed in Midwest fish faunas throughout this century (Pflieger, 1975; Smith, 1979; Trautman, 1981; Karr et al., 1985). Development of management strategies to halt this trend will require identification of conditions under which growth and survival of fishes are limited, and how anthropogenic impacts increase the severity of those limitations.

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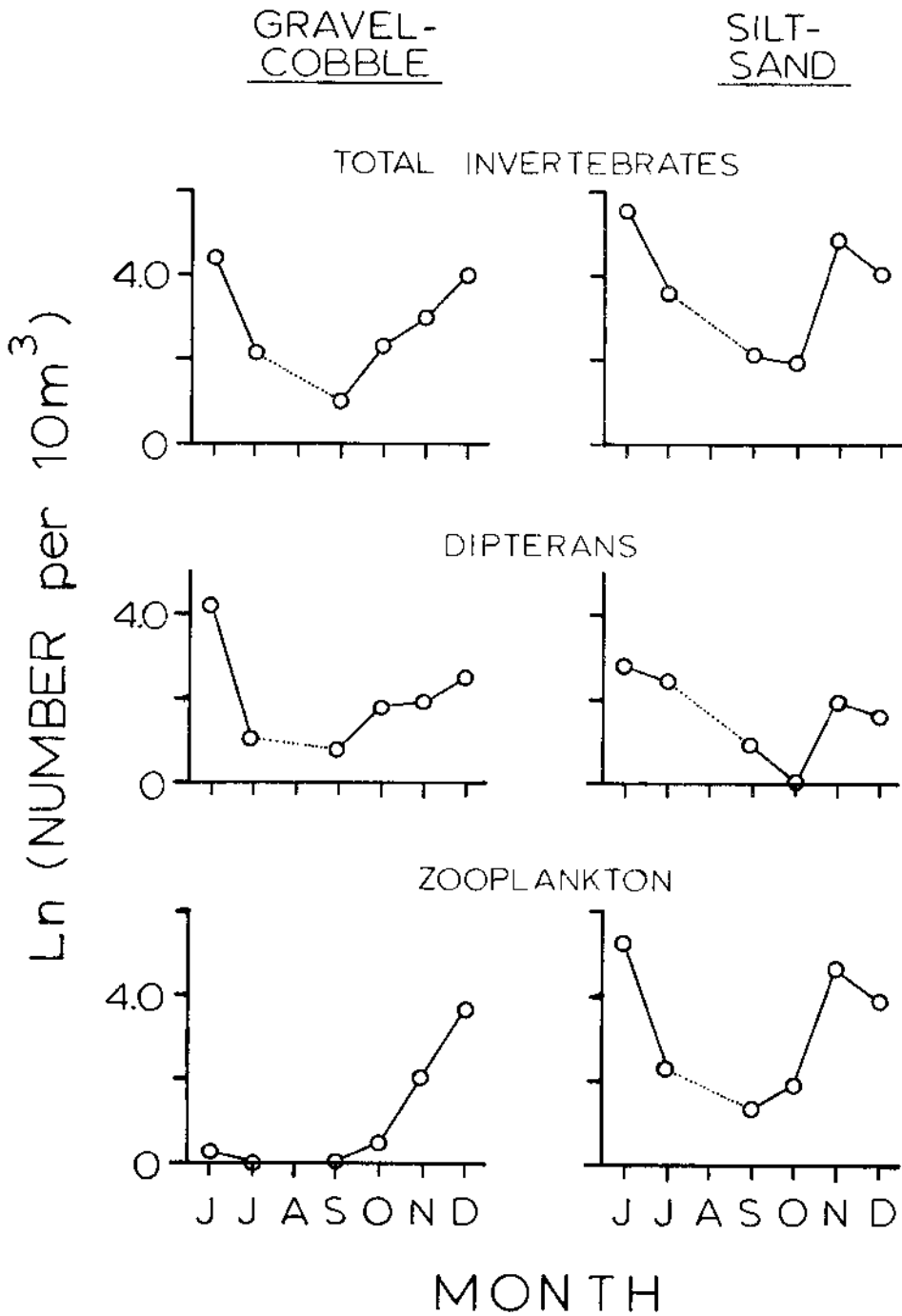


Fig. 1. Numbers of invertebrates captured in midday drift samples from two study reaches of Jordan Creek through the summer and autumn of 1983. Zooplankton comprised copepods and cladocerans. No samples were collected in August.

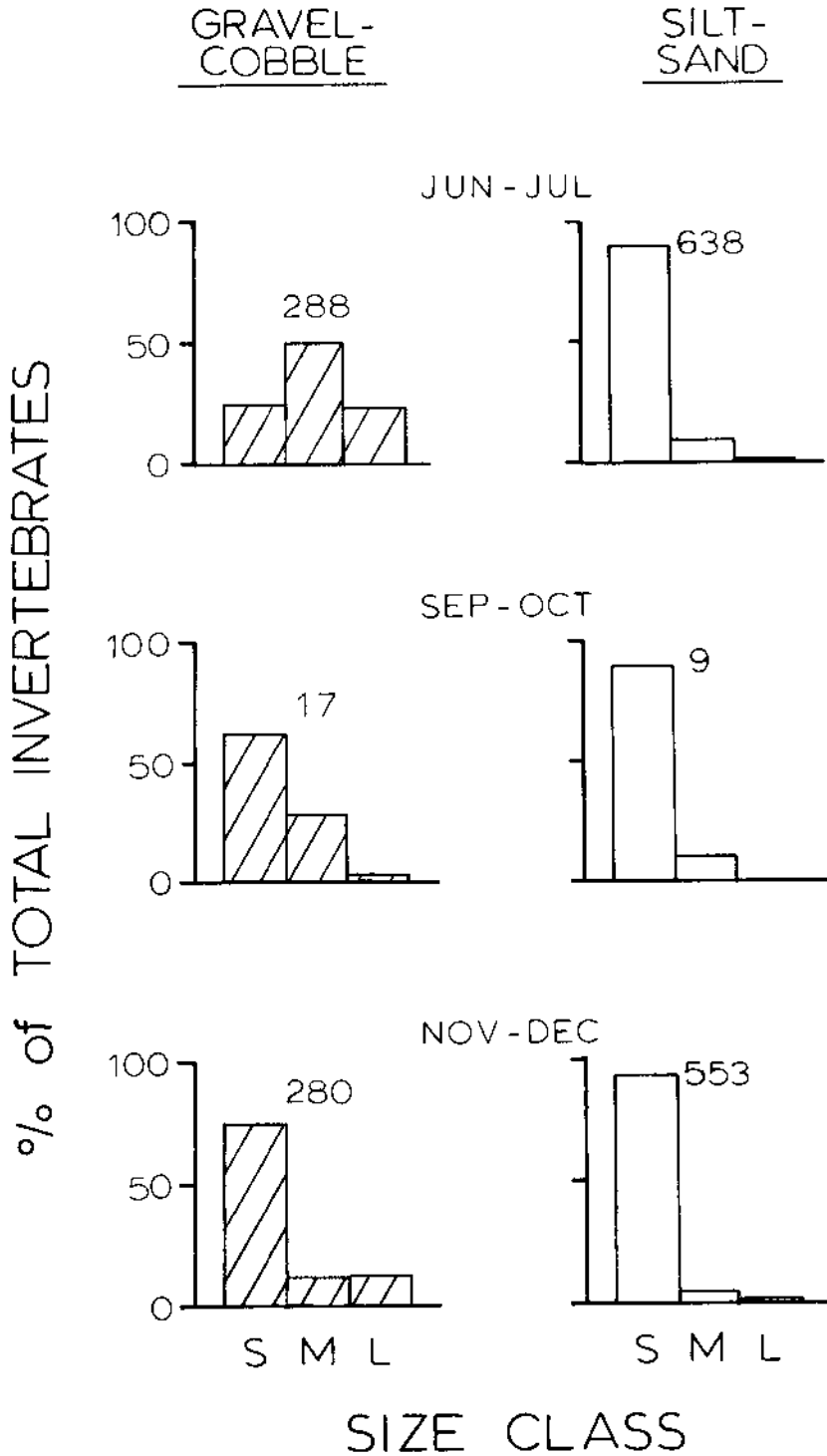


Fig. 2. Size frequency distributions of drifting invertebrates from two study reaches of Jordan Creek. Three size classes were distinguished on the basis of body length: small (<2.0 mm), medium (2.0-3.9 mm), and large (≥ 4.0 mm). Numbers on each graph indicated the total number of invertebrates used to construct the graph.