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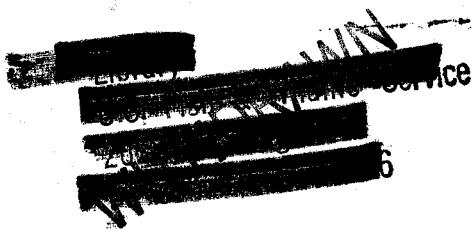
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June 1978

EFFECTS OF STREAM CHANNELIZATION ON AQUATIC MACROINVERTEBRATES, BUENA VISTA MARSH, PORTAGE COUNTY, WISCONSIN

by

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Contract Number 14-16-0008-1147

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EXECUTIVE SUMMARY

Objectives of this study were to assess effects of channelization on density and biomass of benthic and drifting macroinvertebrates, amount of drifting seston, and water temperature and chemistry in the Buena Vista Marsh, Wisconsin. One-hundred meter sections of newly channelized (6-8 year old) and old channelized (52-62 year old) ditches and natural control streams from both upstream and downstream areas of the marsh were sampled between June 1974 and May 1975, and July 1975 and May 1976 at about 6-week intervals during ice-free periods.

Substrate strongly influenced macroinvertebrate populations. Mean benthic density and biomass (excluding molluscs) from upstream and downstream areas were positively curvilinearly related to percentages of productive substrates ($r = 0.89$ and 0.69, respectively). Productive substrates, i.e., vegetation, silt detritus, and gravel, apparently provided interstices for entrapment of drifting seston resulting in negative relationships between seston and substrate ($r = -0.76$ and -0.87 for upstream and downstream sites, repsectively). Productive substrates, discharge, drifting seston, and benthic populations together accounted for as much as 67% of the variation observed in drifting invertebrate density.

Channelization affected macroinvertebrate populations by creating unstable substrate conditions during spring high flows, but created favorable vegetation and silt-detritus substrates as spring flows subsided and substrates stabilized. When vegetation and silt-detritus were predominant, invertebrate populations were high; when substrate was largely shifting sand and unstable silt-detritus, invertebrate populations were low. Newly channelized sites had higher benthic biomass and density than old ditches and natural streams except during unstable substrate conditions. The vegetation and silt-detritus in the ditches were favorable to snails (Gastropoda: Mollusca) and midges (Diptera: Chironomidae). Gastropods accounted for as much as 97% of mean benthic biomass in the upstream new ditch and Chronomidae up to 89% of mean benthic density in the downstream new ditch. More invertebrate taxa were collected from natural streams, but differences were not statistically significant. However, stoneflies (Plecoptera) were only collected from natural streams, and more genera of mayflies (Ephemeroptera) and caddisflies (Trichoptera) were collected from natural streams than ditches.

Channelized areas, with the exception of the downstream new ditch, generally were devoid of depositional areas such as pools and point bars. The resulting reduced diversity of habitats in the ditches, especially during spoil bank instability and high spring flows, may have increased the amount of drifting seston when the more productive substrates were not present or not stable. Changes in amount of drifting seston at all sites seemed to correspond to changes in productive substrates and water level fluctuations.

Channelization appeared to affect invertebrate drift through its influence on drifting seston and benthos. Increases in invertebrate drift upstream, especially Chironomidae, corresponded to increases in amount of seston ($r = 0.71$). Drift density at all sites downstream was significantly related to benthos density ($r = 0.74$). Numbers of drifting taxa were highest at sites with the highest percentages of sand substrate in their respective areas, the upstream old ditch and downstream natural stream. The downstream natural stream, despite low numbers of benthic taxa due to a predominantly shifting sand bottom, had significantly more invertebrate taxa in the drift than the downstream ditches.

Water temperature and chemistry did not differ greatly among the natural streams and ditches, which receive approximately 90% of their flow from ground water. However, water temperature was generally higher in the ditches than in natural streams. Increases in water temperature in the ditches may have resulted from removal of bank shading and slowing of flow. Water temperature exceeded 25°C (the 133-hr upper lethal temperature for brook trout, Salvelinus fontinalis) for five consecutive days in the downstream new ditch in 1975. New and old channelized areas had higher alkalinity and total and calcium hardness than the natural streams.

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Federal Documents Section
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INTRODUCTION

This study was part of a multidisciplinary investigation to determine effects of channel alteration and drainage ditching on fish, aquatic macroinvertebrates, water fowl, and terrestrial and aquatic wildlife resources in the Buena Vista Marsh, Portage County, Wisconsin. Stream channelization is the straightening and enlarging in width or depth, and the shortening in length of a stream or river whereas drainage ditching is the excavation of a narrow hollow in a wetland area where no stream or river existed. Channelization and ditching enhance surface runoff, remove water from wetlands, and lower water tables.

Objectives of this study were to determine the effects of stream channelization and drainage ditching on water quality and temperature, on biomass and composition of benthic macroinvertebrates and drift, and on seston. Field work was undertaken in two sampling periods, June 1974 to May 1975 (Sanders, 1976) and July 1975 to May 1976 (Schmal, 1978).[1]

Schneberger and Funk (1971) and A. D. Little, Inc. (1973) provided comprehensive reviews of stream channelization and its effects on fisheries, wildlife, and recreation. Henegar and Harman (1971) and Blair (1973) listed references on channelization.

Stream alteration projects have been carried out by private drainage districts, the U. S. Soil Conservation Service under the small watershed program of Public Law 566 - Watershed Protection and Flood Prevention Act, and the U. S. Army Corps of Engineers under the Flood Control Acts of 1948 and 1960 (Emerson, 1971). The Soil Conservation Service through 1975 had completed 396 projects affecting 6 million hectares of watershed, and there were another 728 projects on 22 million hectares proposed or under construction. Additional applications for PL-566 projects received as of July 1975, covered approximately 91.5 million hectares (SCS, 1975). The Corps of Engineers through 1973 had been involved in 889 projects and completed work on 9944 km of streams and rivers with 7879 km under construction or planned (A. D. Little, Inc., 1973).

The natural stream - wetland - flood plain ecosystem is composed of interacting subsystems that have evolved over time, and are in dynamic equilibrium with water tables, infiltration rates, and discharge. Disruption of one subsystem, such as bottomland forest or wetland areas, may affect the productive capacity of the entire system. Channelization has involved wetland drainage, clear cutting on the flood plain, elimination of oxbows and meanders with their associated productive areas and diversity of habitat, lowering of water table, and on-site and downstream erosion and sedimentation. These alterations usually result in losses of cover, pools, bank and in-stream vegetation, stable substrates, and stream length, which may adversely affect fish and benthic macroinvertebrates.

---

[1]Invertebrate biomass data from Appendix A-1, A-2, and B, Sanders (1976) were in error. Data were corrected in Schmal (1978) and appear in Table 2 in this report and in Appendixes A-1A, A-2A, and B-1.

Substrate is one of the most important environmental factors affecting the qualitative and quantitative distribution and abundance of benthic macroinvertebrates (Tarzwell, 1937; Smith and Moyle, 1944; Pennak and Van Gerpen, 1947; Cummins, 1966; Eriksen, 1966; Thorup, 1966; Egglishaw, 1969; Barber and Kerven, 1973). Current velocity and water chemistry also significantly influence macroinvertebrate distribution (Cummins, 1975).

A general increase in benthic populations has been found to occur with increasing sediment particle size (Smith and Moyle, 1944; Pennak and Van Gerpen, 1947). Invertebrate abundance and diversity are related to habitable surface area and variety of microhabitats and interstices, which provide shelter (Smith and Moyle, 1944; Sprules, 1947). Substrate particle size, through its effects on turbulence, crevices, and interstitial spaces, affects oxygen renewal and respiration of benthic fauna (Eriksen, 1966).

Drift, a phenomenon in which stream organisms actively leave the substrate, occurs during periods of increased movement before emergence and while foraging for food during periods of reduced light. Invertebrates may also become dislodged from the substrate by mechanical action of the current. Organisms drifting downstream emerge, are eaten by fish, or reattach to the substrate. Waters (1969) divided total observed drift into three classes: 1)"catostrohpic" drift due to an unusually severe physical disturbance of the environment, such as flooding, 2) "density" or "constant" drift due to normal characteristics of streams, and 3) "behavioral" drift of diel periodicity due to an active response to some stimuli by the individual organism. Drifting increases visibility and accessibility of invertebrates to fish and may transport organisms from productive to less productive areas (Waters, 1972).

Some physical factors affecting quantity of drift and downstream displacement include current velocity, discharge, light intensity, water temperature, suspended sediment, and substrate type. Waters (1966) and Dimond (1967) suggested that drift may be a function of the extent to which the carrying capacity of the stream is exceeded. Substrate, in addition to providing suitable surface for attachment, affects drift through effects on benthos production rate, species composition, and population density (Waters, 1961). Drift, at a given lcoation, is not a function of the benthic population at that location, but a function of upstream conditions (Waters. 1965).

Invertebrate stream drift may be important in the recovery of areas of reduced benthos, such as channelized sections, provided suitable substrates are available. Denuded areas can quickly recover (Moffet, 1936; Kennedy, 1955; and Williams and Hynes, 1976). Waters (1964) reported rapid recolonization of a denuded gravel riffle by a drifting mayfly, Baetis, and the scud, Gammarus. Investigations showing rapid recovery of benthos following channelization (Rees, 1959; Warner and Porter, 1960; Burkhard, 1967; and Winger, 1972) occurred in streams with stable gravel, rubble, and vegetation-silt substrates for reattachment of drifting organisms.

Drifting seston (suspended particulate detritus) is composed of two fractions -- inorganic and organic material. Inorganic drift, or sediments, can damage and reduce benthic fauna (Cordone and Kelly, 1961; Gammon, 1970). Luedtke and Brusven (1976) reported sand sedimentation impeded upstream movement of aquatic insects thereby disrupting their colonization. Experimental sedimentation additions (Rosenberg and Snow, 1975 and Bjornn et. al, 1977) filled interstitial spaces and covered invertebrate attachment surfaces on the substrate. The organic portion, or plant detritus, has been found to be one of the chief sources of food for invertebrates (Egglishaw, 1969). Buscemi (1966) listed current velocity, thickness of the "dead water layer" adjacent to the stream bottom, bottom irregularities, feeder stream flow above typical low water values, and channel morphometry as factors affecting seston disposition.

HYDROLOGIC CHARACTERISTICS OF UNALTERED AND ALTERED CHANNELS

UNALTERED

Unaltered or natural stream systems involve a complex of relationships between water flow, sediment movement, and mobile channel boundaries in alluvial and in non-alluvial soil deposits (Leopold et al., 1964). These basic hydrologic factors affect a stream's physical characteristics including width, depth, slope, current velocity, channel resistance, sediment, substrate. A natural channel carries sediment, derived from its drainage basin, and migrates laterally by erosion of one bank and deposition at the opposite bank. The channel tends to maintain a constant or stable cross section while the position of the channel itself is not constant.

The characteristic channel pattern of natural streams in alluvium is meandering, which may be mathematically described as a series of sine-generated curves occurring at intervals of 5 to 7 channel widths (Leopold and Langbein, 1966; Leopold et al., 1964). A stream channel tends to assume a condition with least energy expenditure within the system. The most probable distribution of energy, one in which the rate of energy loss per unit of distance along the stream is equal, is most closely approximated by a meandering channel pattern (Leopold et al., 1964). A meander pattern tends to eliminate concentrations of energy loss and localized areas of heavy bank erosion.

Stream flow through a meander pattern is helical with the surface water deflected toward the concave bank causing bed water and eroded material to move toward the convex bank where eroded material is deposited in a point bar (Leopold and Langbein, 1966). An erosional-depositional continuum exists in which all but coarse substrate units are washed away in areas of rapid flowing water, erosional areas, whereas finer sediments are deposited in reduced current, depositional areas (Cummins, 1966).

Streambank erosion is a function of soil cohesiveness. Streambank and in-stream vegetational binding of soils exert constant pressure to reduce channel size and enhance erosional resistance of the streambank (Maddock, 1972). Vegetated channels tend to be narrower and steeper than strictly alluvial channels with similar discharge and sediment load.

The natural stream and its associated flood plain and swamp areas with their respective groundwater tables, infiltration rates, and discharge properties, supplement the water requirements of each other. The combined surface and groundwater storage capacity tends to even out peak flows and augment base flows (A. D. Little, Inc., 1973). The flood plain allows for the deposition of sediment and absorption of nutrients outside the stream channel during periods of high water. White (1973: 64-65) discussed conditions present in natural cold water streams:

> What we have in the natural stream channel, considered from headwater to mouth, bank to bank, top to bottom, hour to hour, season to season, and in the longer term, is a diversity of habitats: main waters, side waters, bank waters, eddies; turbulent versus more even-flowing, cooler versus warmer, lighter versus darker; mudbanks, sandbars, gravel riffles, rock rapids, clay flats, "weed" beds, large pools and small nooks and crannies.
>
> Diversity in ecosystems promotes productive efficiency and stability in the sense that incoming energy is thoroughly used and the community is buffered against severe environmental damage.

ALTERED

The major purpose of stream channelization, which has usually been accomplished by channel straightening and removal of streambank vegetation, is rapid drainage of agricultural land. Channeling floodwaters fails to dissipate the energy of high water and eliminates the resistances of a naturally meandering channel (White and Brynildson, 1967). The slope of a meandering channel increases when straightened. The increase in slope results in redistribution of bottom materials which alters the streambed. Removal of bankside vegetation reduces vegetational binding of streambanks and results in accelerated erosion and a wider channel. When streambanks erode, sediment transport increases, and equilibrium of bottom materials is reestablished in a wider channel with steeper slopes. Reestablishment and encroachment of streambank vegetation which is dependent on bank characteristics, stabilizes channel banks, reduces erosion, and is important in the establishment of natural stream characteristics (Maddock, 1972).

Floodwaters entering channelized streams may not transport adequate sediment to compensate for increased flows, and additional sediment may be eroded from bed and banks with resultant channel widening (Apmann and

Otis, 1965; Maddock, 1972). The new channel, too wide for normal flow and sediment load, may become unstable and fill at some discharge levels.

Channelization projects have resulted in a wide variety of adverse effects including: destruction of game, waterfowl, and fish habitat; deposition of nutrients, chemicals, silt, and other pollutants in slower downstream waters; drainage of swamps and destruction of their ability to remove silt, organic wastes, and toxic chemicals; increased erosion upstream and flooding downstream; and accelerated release of water which may have augmented flows during dry seasons (Reuss, 1971). Eroded sediments may have detrimental effects on stream bottom, aquatic vegetation, bottom fauna, and fish populations (Cordone and Kelley, 1961; Apmann and Otis, 1965). The effects of channelization, including reduction in diversity of habitats, increased seasonal variations in discharge, width, depth, and water temperature, shifting substrate, siltation, and the absence or reduction of aquatic vegetation are similar to the factors associated with low productivity (Berner, 1951). Uniformity of channelized streams fosters inefficiency and instability of physical and biological systems (White, 1973).

STUDY AREA

HISTORY

Buena Vista Marsh, originally covered by tamarack (Larix laricina) swamps and open marsh, was drained by four streams; Buena Vista Creek, Duck Creek, Four Mile Creek, and Ten Mile Creek with its north and south branches, all of which flowed west toward the Wisconsin River.

The tamarack was logged or burned off before 1900, and most of the marsh land was under private ownership by 1903. The Portage County Drainage District was organized in 1903 and bonds were sold to purchase a floating dredge to drain the area for agriculture. Six ditches, dredged 1.5 to 3.0 m deep and in an east-west direction, were completed by 1907. Drainage, provided by the six ditches, was inadequate and three more main ditches and several lateral ditches were completed by 1913. As a result of the lowered water table, large fires burned in the dried peat and bog soils until only sand remained. Ditch siltation and reed canary grass (Phalaris arundinaceae) encroachment on the channels had a damming effect, and periodic redredging was necessary to keep the channels clear and the water table low. However, dredging and channel maintenance were discontinued in 1923 because of costs and agricultural problems which included acid soil and the frequency of crop killing frosts throughout the growing season. Aldo Leopold (1949: 100) described the series of events:

> They envisaged farms not only around but in the marsh. An epidemic of ditch digging and land booming set in. The

marsh was gridironed with drainage canals, speckled with new fields and farmsteads.

But crops were poor and beset by frosts, to which the expensive ditches added an aftermath of debt. Farmers moved out. Peat beds dried, shrank, caught fire.

The drainage district became inoperative after 1934, and production of bluegrass (Poa pratensis) for seed and raising of horses and cattle became the dominant land uses on the marsh. After dredging and channel maintenance were discontinued, the channels began to develop a meandering course within the old, vegetation-stabilized spoil banks, the water table rose, sheet water collected on fields in spring and after periods of heavy rainfall, and the area was reverting back to a wetland habitat.

Recently, above ground irrigation became practical, and lands adjacent to and in the marsh became valuable for vegetable farming. Several ditches have been dredged or redredged since 1967.

DESCRIPTION

Buena Vista Marsh is a 226 km^2 drained wetland in the central Wisconsin sand plain (Figure 1). The plain, which covers an area of 728 km^2, is bordered on the east by a series of glacial moraines. Elevation in the upstream area, near the moraines, is 329 m and slopes from east to west at 8.6 to 1.1 m/km to an elevation of 311 m in the downstream areas. Geology, hydrology, and climate of the central Wisconsin sand plain have been described in detail by Holt (1965), Weeks et al. (1965), and Weeks and Strangland (1971). Soils in the marsh consist of unconsolidated sediments including glacial till, outwash sand and gravel, and postglacial deposits of peat, alluvium, and dune sand (Holt, 1965). The glacial deposits, which average 30.5 m in thickness, are highly permeable and form the main aquifer in the area (Weeks and Strangland, 1971). Groundwater velocity in the sand and gravel aquifer is approximately 0.3 m/day and the mean water table gradient is 0.95 m/km (Holt, 1965). Groundwater accounts for more than 90% of total streamflow and maintains relatively stable flow and water temperature.

A U.S. Weather Bureau recording station, located on the east side of the marsh at Coddington, reported an average growing season of 104 days, with a range of 47 to 119 days (Vandre, 1975). Average annual precipitation is 78.7 cm, of which 53.3 cm is lost to evapotranspiration, 22.9 cm to groundwater recharge, and 2.5 cm to short duration runoff (Holt, 1965). Sixty-five percent of the annual precipitation occurs during the growing season.

STUDY SITES

Three general stream types are present on the marsh: natural streams which have never been dredged; old ditches which have not been dredged for at least 50 years; and new ditches, which have been dredged since 1967. Two study areas chosen were an upstream area located in the zone of good brook trout (Salvelinus fontinalis) habitat and a downstream area located

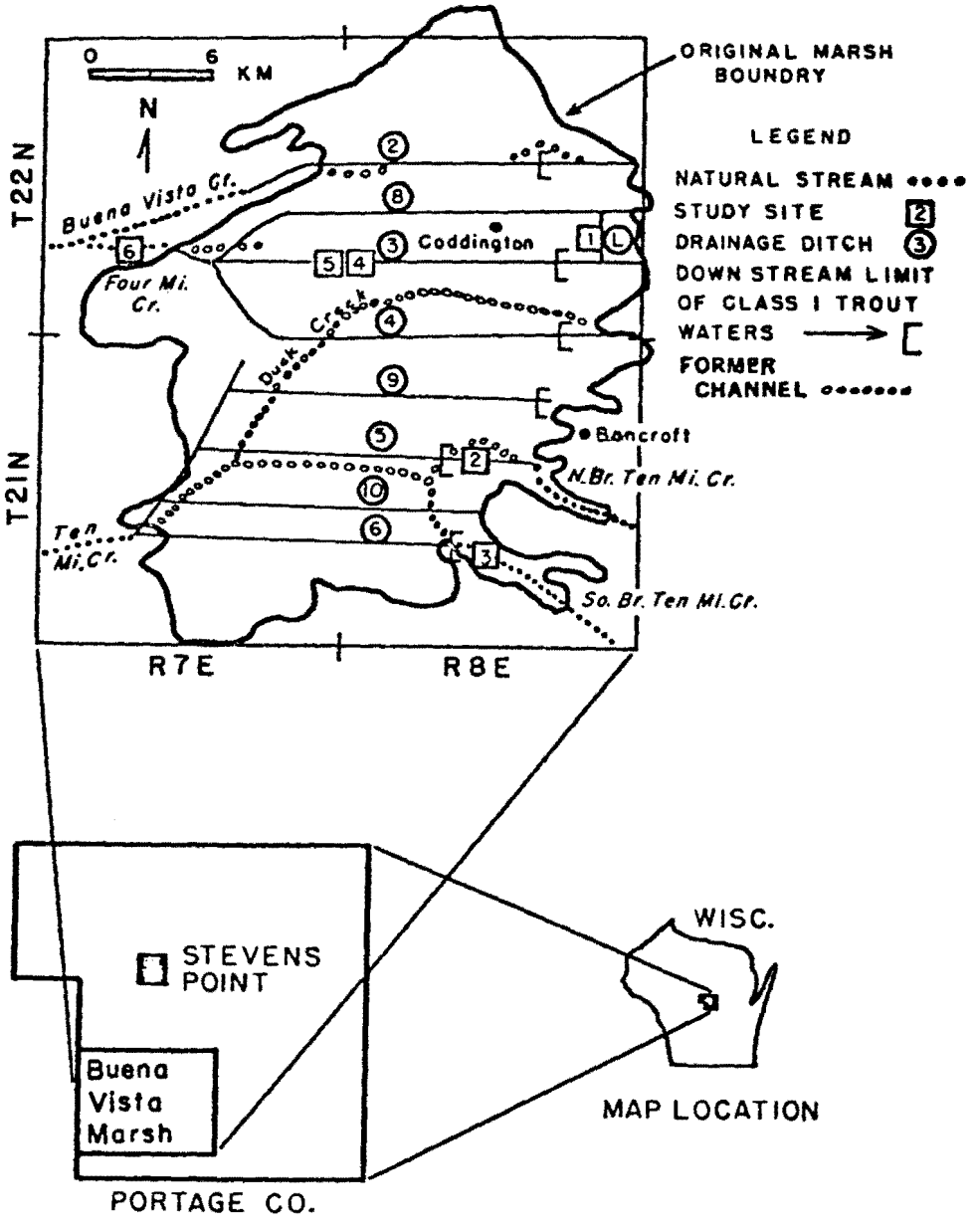


Figure 1. Map of Buena Vista Marsh Showing Location of Study Sites. 1 = upstream new ditch, 2 = upstream old ditch, 3 = upstream natural stream, 4 = downstream new ditch, 5 = downstream old ditch, 6 = downstream natural stream.

in the zone of marginal brook trout habitat. To avoid bias, a 100 m section of a new ditch, old ditch, and natural stream site was chosen in each study area, before sample collection. Sites were selected on the basis of similar stream discharge, distance from headwater areas, and accessibility (Figure 1).

Sinuosity indices (channel length/linear length) were highest in the natural streams and lowest in the new ditches. The more sinuous sections generally had greater surface area except for the downstream new ditch which was originally dredged wide (Table 1). Stream and ditch gradients were all less than 1%.

Upstream

The upstream new ditch (NE ¼, Sec. 26, T 22N, R 8E) was a lateral drainage ditch that diverted water flow from Ditch 8 to Ditch 3. The spoil banks were steep, unstable and sometimes slumped into the channel, particularly during spring runoff in April and May, 1974 and 1975, and to a lesser degree in April, May, 1976. Bank slumping and erosion resulted in a predominantly shifting sand and silt-detritus substrate in the spring and early summer of 1974 and 1975. Reed canary grass grew along the banks. Aquatic vegetation, including white water butter cup (Ranunculus aquatilus), common waterweed (Elodea canadensis), watercress (Nasturtium officinale), and speedwell (Veronica sp.) increased in abundance throughout the growing seasons, June to September, and remained stable in the streambed until dieoff in November 1974 and December 1975. The channel was of uniform depth during spring and early summer of 1974 and 1975, but depth became more varied in late summer and fall when the current cut channels between dense beds of vegetation, Ranunculus, and consequently exposed patches of gravel.

Aquatic vegetation was more abundant in the study section during the summer, fall, and early winter of 1975 than in 1974. In-stream vegetation continued to stabilize the stream bottom over winter, and it reestablished itself as early as March 1976, because of a mild winter and spring. Erosion was less severe, spoil banks were more stable, and aquatic vegetation was not flushed out of the study section in the spring of 1976. Land use adjacent to the ditch was grazed pasture and mint and potato farming.

The upstream old ditch (NE ¼, Sec. 16, T 21N, R 8E) was the channelizd part of the north branch of Ten Mile Creek, or Ditch 5. The old spoil banks were stabilized with reed canary grass, shrubs, and deciduous and coniferous trees. Small holes and undercut banks were present at the cutting edges of the weakly meandering channel. In open areas the channel meandered through reed canary grass. Bank slumping was minimal, and the stream bottom was primarily sand. Narrow areas of silt-detritus, which had become stabilized with scattered Elodea and Nasturtium, occurred near the water's edge in 1974-1975. The vegetation and silt-detritus comprised a greater percentage of the stream bottom in the 1975-1976 sampling program than in the previous year. Gravel was not present in the study site. Corn and hay were grown in the fields adjacent to the channelized ditch, and a cattle crossing was present approximately 100 m upstream from the study site. Manure spreading was a common practice on upstream fields.

Table 1. Description of Study Sites, June, 1974 to May, 1976, Buena Vista Marsh, Portage County, Wisconsin. A--the Sample Period June, 1974 to May, 1975; B--the Sample Period July, 1975 to May, 1976.

Parameters	Upstream Area						Downstream Area					
	new ditch		old ditch		natural		new ditch		old ditch		natural	
	A	B	A	B	A	B	A	B	A	B	A	B
Dredged (year)	1968		1913		----		1967		1922		----	
Sinuosity index[a]	1.00		1.02		1.15		1.00		1.03		1.58	
Area (ha/km)	.42	.48	.48	.45	.92	.76	.96	.91	.65	.54	.98	.94
Mean discharge for study period (m^3/sec)	.262[b]	.240[c]	.246[b]	.261[c]	.236[b]	.224[c]	.726[b]	.700[c]	.726[b]	.569[c]	1.162[b]	1.410[c]
Temperature (°C)												
annual mean[d]	8.0	8.0	7.9	8.6	7.9	8.3	8.9	9.2	9.0	9.0	7.9	8.6
mean daily fluctuation	4.6	3.0	2.5	2.6	3.4	3.3	3.0	3.0	3.4	2.9	2.4	3.1
Substrate (m^2/100 m). Percent in parentheses.												
sand	315 (75.1)	233 (48.8)	353 (73.4)	266 (59.3)	431 (47.1)	390 (51.2)	97 (10.1)	167 (18.3)	547 (80.4)	362 (67.1)	853 (87.0)	898 (95.0)
gravel	14 (3.4)	16 (3.4)	0 (0)	0 (0)	93 (10.2)	69 (9.0)	0 (0)	0 (0)	0 (0)	0 (0)	31 (3.2)	38 (4.0)[e]
vegetation	43 (10.2)	166 (39.4)	13 (2.7)	48 (10.8)	232 (25.3)	67 (8.8)	257 (26.7)	30 (3.3)	64 (9.4)	87 (16.2)	25 (2.5)	0 (0)
vegetation-silt	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	381 (41.7)[f]	0 (0)	0 (0)	0 (0)	0 (0)
silt-detritus	47 (11.3)	61 (12.8)	115 (24.0)	134 (29.8)	159 (17.4)	229 (30.0)	607 (63.2)	335 (36.7)	69 (10.2)	90 (16.7)	71 (7.2)	9 (1.0)
total	419	476	481	448	915	755	961	913	680	539	980	945

[a] Channel length/linear length, July 1975.
[b] Discharge measured in August, September, November 1974; April, May 1975.
[c] Discharge measured in July, September, October, December 1975; April, May 1976.
[d] Temperatures measured September 1974 to May 1976 for Period A; May 1975 to May 1976 for Period B.
[e] Gravel substrate was not estimated monthly July 1975 to May 1976 because of turbidity (see Figure 12).
[f] Vegetation and silt-detritus were classified as vegetation-silt, July, September and October 1975 (see Figure 12).

The upstream natural site (NW ¼, Sec. 27, T 21N, R 8E) was in the south branch of Ten Mile Creek. The channel had a meander pattern without a riffle-pool sequence, which is a condition typical of natural channels carrying uniform sand and silt (Leopold et al., 1964). Sand, gravel, silt-detritus, and vegetation (Ranunculus) substrates were present in the study section from June 1974 to July 1975, but a flood in August 1975 washed Ranunculus out of the site. Scattered vegetation became reestablished in April 1976. Adjacent wetland was grazed by dairy cattle.

Downstream

The new ditch site (W ½, Sec. 30, T 22N, R 8E) was a recently dredged part of Ditch 3, which was similar to an elongated pond. Decreased current velocity in the wide and deep channel resulted in the deposition of approximately 1 m of silt and organic material in mid-channel. No gravel was present. Sand substrate was present only along the stream banks, and the remainder of the stream bottom was silt-detritus, covered with a dense growth of pondweed (Potamogeton sp.) in the summers. Floating mats of algae (Spirogyra spp.) were also common during summer. Wild celery (Vallisneria americana), arrowhead (Sagittaria sp.) and sedges (Carex spp.) were present within the channel. Adjacent land was grazed by cattle and managed for prairie chickens (Tymphanunchus cupido pinnatus).

The downstream old ditch site (E ½, Sec. 25, T 22N, R 7E) was approximately 150 m downstream from the new ditch section of Ditch 3. The channel was narrower and had greater current velocity than the new ditch section. The bottom was primarily sand with small areas of silt-detritus and sparce Potamogeton, Vallisneria and Nasturtium. Aquatic vegetation was abundant in the study section in the second year of the study. Adjacent land was grazed by cattle, planted with corn, and managed for prairie chickens.

The natural site (SE ¼, Sec. 20, T 22N, R 7E), the unchannelized part of Four Mile Creek, received the flow from Ditches 3, 4 and 8. Occasionally, cattle crossed upstream. Dredging approximately 12 km upstream from the study site occurred during the 1974-1975 sampling. Indicators of rapid erosion -- islands, sand bars, and fallen trees -- were present. Portions of the stream had steep eroding sand banks that resulted in a predominantly shifting sand bottom, but silt-detritus and gravel substrates were present in sparce amounts. The current, deflected by fallen and submerged trees, cut holes in the streambed. Vallisneria was sparce and scattered from June to September 1974, but was not present for the remainder of the study. Shifting sand has been shown to inhibit establishment of aquatic vegetation (Fassbender and Nelson, 1971). Land adjacent to the study site was wooded pasture grazed by horses and cattle.

Five replicate quantitative benthos samples were collected from each available substrate (vegetation, silt-detritus, gravel and sand) in each 100-m study site at approximately 6-week intervals during ice-free periods between June 1974 and May 1976. Substrate-stratified sampling suggested by Pennak and Van Gerpen (1947), Bourdeau (1953), Cummins (1962), and Barber and Kevern (1973) was used to reduce sampling variation. A circular, 0.05 m^2, bottom sampler, with a net with a mesh opening of 750 μm was used in the three upstream study sites where it was not too deep for efficient sampler use (Jacobi, 1978). A standard Ekman grab, 0.025 m^2, was used in place of the circular sampler in the three deeper downstream study sites.

Substrate composition (vegetation, silt-detritus, gravel, or sand) was estimated subjectively for each 100-m study site on each sample date, and sample biomass and density were weighted into total benthic biomass (g/m^2) and density ($organisms/m^2$) according to the estimated percent each substrate was of the total. Transect samples were collected in the downstream old ditch in April 1975 and in the downstream natural stream from April 1975 to May 1976 because at these times the sites were too turbid for estimation of substrate composition. Dense growths of Potamogeton over the silt bottom made it difficult to collect individual replicates from vegetation and silt-detritus in the downstream new ditch, July 1975 to October 1975. Replicate samples were collected and classified as vegetation-silt in that time period.

Benthic variability within each study site on each sample date was determined by calculation of standard deviations for samples collected within each substrate. Total variation for biomass and density of each taxa was calculated by weighting standard deviations according to substrate composition. Data were pooled from the June 1974 to May 1975 and July 1975 to May 1976 sampling programs to reduce the large variance associated with invertebrate sampling.

Qualitative benthic samples were collected with nets and screens periodically throughout the 1974-1975 sample program to record the presence of organisms not normally collected with quantitative samples.

Drifting organisms and seston (suspended particulate matter) were collected on the day and night before benthic sampling. Twenty-minute samples were collected in nets with an aperature opening of 750 μm on a 0.1 m^2 frame at midday and one-half hour before and after sunrise and sunset to correspond with major periods of drift (Waters, 1972; Braatz, 1974). Drift net frames had welded-on split rings that slid over 1.27-cm diameter steel rods that were driven into the stream bottom. One set of rods was positioned in the thalweg and another in the side current. Drift nets and frames were stacked on the rods to cover the entire column of water from bottom to water surface. Stream discharge and discharge through the drift columns were measured with a manufacturer's calibrated water current meter. Drift samples and discharge measurements were taken 5 times between August 1974 and May 1975, and 6 times between July 1975 and May 1976. Sample biomass and density were weighted into total drift biomass ($g/100\ m^3$) and

drift density (organisms/100 m^3) according to the percent of the total discharge that flowed through the drift columns. Drift rates (number per unit time) are not presented because of differences in discharge, water depth, and water velocity among the 6 study sites.

Benthos and drift samples were labeled and preserved in the field in a 9:1 mixture of 70% isopropyl alcohol and 10% formalin. In the laboratory, samples were washed on a No. 35 soil screen. Invertebrates were sorted from detritus, identified to genus, if possible, and counted. Invertebrates were not wet-weighed because of weight change in preservative (Leonard, 1939; Howmiller, 1972). Invertebrate biomass, excluding Decapoda, Oligochaeta, and large insects such as Nepidae and Zygoptera, were calculated from organism length with the method described by Hynes and Coleman (1968), which assumes that insect shape is that of a cylinder, that its volume increases by the cube of the length, and its specific gravity is 1.05. Weights of 1-mm length units were 3.3×10^{-5} grams for insects excluding Chironomidae and Ceratopogonidae, 1.4×10^{-5} grams for Chironomidae and Ceratopogonidae, and 5.0×10^{-4} grams for Mollusca, which were considered spheres. Nepidae, Zygoptera, and Decapoda were soaked in water for 30 minutes, blotted dry, and weighed to the nearest 0.01 g. Oligochaeta were soaked in water for 30 minutes, centrifuged at 650 rpm for 3 minutes including acceleration and deceleration, and weighed to the nearest 0.01 g (Stanford, 1973).

Drifting seston was dried at 65°C for approximately 24 hours to a constant weight and expressed as dry weight of drifting seston, or weight of seston per volume of water (g/100 m^3). The dried seston was ignited at 600°C for 1 hour in a muffle furnace, cooled in a descicator and weighed.

Water samples, collected at each site at the same time as invertebrates, and at approximately 6-week intervals outside periods of ice cover, were analyzed by the Environmental Task Force Laboratory, University of Wisconsin-Stevens Point. Methods of analysis were those described in Standard Methods (A.P.H.A., 1971). Water temperature was recorded hourly with thermographs from September 1974 through May 1976. Thermographs were calibrated weekly.

RESULTS AND DISCUSSION

SUBSTRATE EFFECTS

Substrate composition was the most important factor affecting biomass and density of benthos and weight of drifting seston (suspended particulate matter), but not invertebrate drift density. Benthic biomass and density were generally higher in aquatic vegetation and decreased in silt-detritus, gravel, and sand substrates, respectively (Table 2). Therefore, any alteration of a stream or drainage ditch that would increase sand substrate would tend to adversely affect aquatic macroinvertebrates in the Buena Vista Marsh.

Table 2. Total Adjusted Monthly Mean Benthic Density and Biomass For Each Substrate (%) in Upstream and Downstream Sites, June 1974 to May 1976, Buena Vista Marsh, Portage County, Wisconsin

UPSTREAM AREA

		New Ditch					Old Ditch				Natural Stream				
		Vegetation	Silt Detritus	Gravel	Sand	Total	Vegetation	Silt Detritus	Sand	Total	Vegetation	Silt Detritus	Gravel	Sand	Total
		SUBSTRATE COMPOSITION (%)													
June	1974	2.5	5.0	2.5	90.0	100	TR[a]	25.0	75.0	100	9.5	21.2	10.6	58.7	100
Aug.	1974	16.4	12.7	3.6	67.3	100	TR	38.1	61.9	100	20.9	13.2	12.2	53.7	100
Sept.	1974	17.0	13.1	3.4	66.5	100	16.0	12.5	71.5	100	24.7	9.4	28.9	37.0	100
Nov.	1974	9.1	11.5	0.0	79.4	100	TR	29.1	70.9	100	33.0	29.3	TR	37.7	100
Apr.	1975	6.1	12.2	6.6	75.1	100	TR	13.2	86.8	100	26.7	22.7	3.7	46.8	99.9
May	1975	10.0	13.2	4.5	72.3	100	TR	25.9	74.1	100	37.2	8.8	5.5	48.4	99.9
		BENTHOS													
ADJUSTED TOTALS	$\#/m^2$	9,060.0	4,408.0	2,276.0	48.0	550.6		9,488.0	280.0	2,582.0	3,216.0	4,900.0	932.0	460.0	1,712.8
June	1974 g/m^2	44.3	17.0	18.3	1.9	4.0		51.8	3.9	15.8	63.9	25.9	11.2	5.6	15.4
	$\#/m^2$	14,596.0	1,992.0	4,972.0	5,584.0	6,583.7		5,016.0	1,664.0	2,928.6	13,688.0	5,884.0	4,644.0	756.0	4,610.0
Aug.	1974 g/m^2	63.6	12.5	14.5	12.9	20.7		64.4	7.0	30.4	96.1	48.0	27.6	9.0	33.2
	$\#/m^2$	19,600.0			10,616.0	10,391.7	2,267.0	807.0	724.0	981.4	6,420.0	3,065.0	2,752.0	972.0	3,036.2
Sept.	1974 g/m^2	985.6			26.7	97.3	41.9	13.7	11.1	15.6	80.8	28.2	27.0	5.9	28.5
	$\#/m^2$	12,072.0	2,348.0		620.0	1,860.9		5,952.0	1,876.0	3,062.1	3,096.0	2,948.0		592.0	2,108.6
Nov.	1974 g/m^2	139.2	77.2		16.4	31.9		86.4	46.3	52.2	59.6	14.3		17.4	29.2
	$\#/m^2$	5,876.0	8,632.0	1,120.0	255.0	1,676.9		13,684.0	544.0	2,278.5	16,685.0	5,212.0	2,212.0	884.0	6,114.9
Apr.	1974 g/m^2	20.2	39.3	7.8	42.1	34.5		102.6	6.8	14.7	149.7	42.3	17.5	5.7	46.5
	$\#/m^2$	11,128.0	8,120.0	6,280.0	2,088.0	3,976.8		20,528.0	660.0	5,805.8	8,468.0	5,110.0	3,472.0	4,660.0	6,046.1
May	1975 g/m^2	24.5	21.8	7.8	6.8	10.2		114.5	42.4	61.1	94.1	29.7	11.3	4.2	32.8

Table 2. Continued

UPSTREAM AREA

		New Ditch					Old Ditch				Natural Stream				
		Vegetation	Silt Detritus	Gravel	Sand	Total	Vegetation	Silt Detritus	Sand	Total	Vegetation	Silt Detritus	Gravel	Sand	Total
		SUBSTRATE COMPOSITION (%)													
July	1975	23.0	13.5	5.0	58.5	100	0.0	45.0	55.0	100	52.0	9.0	3.5	35.5	100
Sept.	1975	28.0	17.0	4.6	50.4	100	4.0	24.0	72.0	100	0.0	27.2	6.8	66.0	100
Oct.	1975	47.0	11.0	0.0	42.0	100	24.0	18.0	58.0	100	0.0	27.0	20.0	53.0	100
Dec.	1975	46.0	9.6	8.4	36.0	100	22.0	26.0	52.0	100	0.0	39.8	7.2	53.0	100
Apr.	1976	20.6	18.0	0.4	61.0	100	6.0	36.0	58.0	100	0.0	37.0	9.0	54.0	100
May	1976	45.0	7.6	2.4	45.0	100	9.0	30.0	61.0	100	0.4	39.6	14.0	46.0	100
		BENTHOS													
ADJUSTED TOTALS															
	#/m^2	35,462.0	7,292.0	3,276.0	7,308.0	13,571.5		7,464.0	1,452.0	4,900.0	30,161.0	5,494.0	5,240.0	4,989.0	18,208.6
July	1975 g/m^2	363.8	67.6	27.8	52.7	109.4		105.8	7.9	54.8	498.2	38.1	43.1	20.5	240.9
	#/m^2	14,776.0	4,416.0	1,112.0	388.0	5,213.5	17,724.0	2,443.0	5,416.0	5,197.0		3,493.0		994.0	1,606.2
Sept.	1975 g/m^2	4,932.3	32.2	11.4	473.5	1,175.3	255.7	54.5	33.8	40.4		76.5		26.2	36.0
	#/m^2	17,047.0	4,036.0		1,182.0	8,940.9	3,392.0	1,360.0	8,976.0	6,282.9		2,224.0	4,964.0	776.0	1,838.2
Oct.	1975 g/m^2	2,489.6	452.9		34.3	916.8	262.6	19.4	103.4	100.3		39.6	40.7	10.0	27.4
	#/m^2	6,803.0	5,084.0	1,532.0	16,512.0	9,690.8	11,542.0	1,968.0	2,976.0	4,598.5		5,536.0	1,548.0	280.0	2,463.2
Dec.	1975 g/m^2	1,778.3	242.8	270.0	117.6	704.0	267.9	50.9	110.6	112.4		82.7	7.8	2.4	29.3
	#/m^2	11,792.0	2,512.0		1,059.0	3,528.3	14,864.0	4,104.0	216.0	2,494.6		4,400.0	4,056.0	1,784.0	2,960.2
Apr.	1976 g/m^2	1,126.0	65.2		978.6	699.8	311.8	60.7	3.7	34.4		41.4	9.5	11.2	19.7
	#/m^2	17,476.0	2,796.0		5,556.0	10,376.9	9,908.0	426.0	3,380.0	4231.5		11,280.0	3,508.0	10,924.0	10,038.0
May	1976 g/m^2	4,994.9	1,235.6		109.6	1,795.0	120.3	434.2	7.4	92.4		32.0	10.1	49.8	35.7

Table 2. Continued

DOWNSTREAM AREA

		New Ditch					Old Ditch				Natural Stream				
		Vegetation	Silt Detritus	Vegetation/ Silt[b]	Sand	Total	Vegetation	Silt Detritus	Sand	Total	Vegetation	Silt Detritus	Gravel	Sand	Total
		SUBSTRATE COMPOSITION (%)													
June	1974	35.0	50.0	0.0	15.0	100	6.0	4.4	89.6	100	5.0	5.0	5.0	85.0	100
Aug.	1974	55.0	35.0	0.0	10.0	100	26.5	9.2	64.3	100	5.0	7.0	3.0	85.0	100
Sept.	1974	70.0	20.0	0.0	10.0	100	14.5	13.5	72.0	100	0.0	15.0	5.0	80.0	100
Nov.	1974	0.0	90.0	0.0	10.0	100	0.0	15.0	85.0	100	0.0	2.0	0.0	98.0	100
Apr.	1975	0.0	100.0	0.0	0.0	100	c	c	c	0.0	c	c	c	c	
May	1975	0.0	84.5	0.0	15.5	100	0.0	9.1	90.9	100	c	c	c	c	
		BENTHOS													
ADJUSTED TOTALS															
	#/m^2	9,704.0	1,928.0			4,360.4	8,869.0	2,888.0	376.0	996.1	35,730	3,327	2,076	244.0	2,264.0
June	1974 g/m^2	30.0	11.0			15.5	24.6	36.4	0.8	3.8	85.2	48.3	8.5	3.6	10.1
	#/m^2	10,080.0	904.0		472.0	5,907.6	8,084.0	2,624.0	1,072.0	3,073.0	7,796.0	1,216.0	3,000.0	312.0	830.1
Aug.	1974 g/m^2	90.9	12.4		6.6	45.8	103.1	23.4	4.1	23.7	46.2	24.2	10.4	0.1	3.9
	#/m^2	28,544.0	3,904.0		1,436.0	20,808.8	31,696.0	4,240.0	1,830.0	6,521.9		1,250.0	952.0	640.0	747.1
Sept.	1974 g/m^2	2,903.4	17.2		7.0	1,706.5	269.7	20.9	4.6	23.3		147.6	10.9	4.3	25.7
	#/m^2		4,864.0			4,521.2		3,256.0	2,756.0	2,831.0		7,482.0		360.0	502.4
Nov.	1974 g/m^2		51.1			46.7		42.6	13.7	17.6		106.8		0.3	1.8
	#/m^2		468.0			468.0				336.0					999.0
Apr.	1975 g/m^2		4.4			4.4				0.6					2.8
	#/m^2		1,076.0		504.0	978.3		740.0	292.0	332.8					538.0
May	1975 g/m^2		4.9		1.6	4.4		29.4	1.7	4.2					2.5

Table 2. Continued

DOWNSTREAM AREA

	New Ditch					Old Ditch				Natural Stream				
	Vegetation	Silt Detritus	Vegetation/ Silt[b]	Sand	Total	Vegetation	Silt Detritus	Sand	Total	Vegetation	Silt Detritus	Gravel	Sand	Total
	SUBSTRATE COMPOSITION (%)													
July 1975	0.0	0.0	86.0	14.0	100	19.0	11.0	70.0	100		[c]	[c]	[c]	
Sept. 1975	0.0	0.0	85.0	15.0	100	14.6	12.0	73.4	100		[c]	[c]	[c]	
Oct. 1975	0.0	0.0	79.0	21.0	100	28.0	5.0	67.0	100		[c]	[c]	[c]	
Dec. 1975	20.0	70.0	0.0	10.0	100	29.0	12.0	59.0	100		[c]	[c]	[c]	
Apr. 1976	TR	80.0	0.0	20.0	100	TR	33.0	67.0	100		[c]	[c]	[c]	
May 1976	TR	70.0	0.0	30.0	100	7.0	27.0	66.0	100		[c]	[c]	[c]	
	BENTHOS													
ADJUSTED TOTALS														
#/m^2			4,492.0	216.0	3,947.3	4,984.0	2,784.0	40.0	1,278.4					153.8
July 1975 g/m^2			49.6	1.3	40.3	8.3	49.6	0.5	4.6					0.9
#/m^2			3,032.0	1,316.0	2,788.0	4,024.0	704.0	1,352.0	1,664.4					977.1
Sept. 1975 g/m^2			174.0	4.2	137.6	15.8	25.3	4.8	21.3					21.3
#/m^2			5,992.0	196.0	4,775.0	6,384.0	4,304.0	766.0	2,560.2					428.6
Oct. 1975 g/m^2			691.5	3.2	488.9	874.6	146.8	1.7	69.8					16.5
#/m^2	24,380.0	4,792.0		128.0	12,162.0	64,192.0	6,036.0	4,128.0	21,775.5					350.6
Dec. 1975 g/m^2	258.7	106.9		1.1	148.8	179.6	138.2	13.5	70.3					8.1
#/m^2		19,840.0		504.0	16,013.0		9,576.0	1,864.0	4,408.9					1,262.8
Apr. 1976 g/m^2		220.7		0.8	166.8		97.6	47.3	59.6					15.7
#/m^2		6,521.0		608.0	4,747.0	9,128.0	6,444.0	448.0	2,674.5					1,336.9
May 1976 g/m^2		264.7		1.4	202.4	17.8	130.9	2.3	28.6					10.3

a TR = trace amount.
b Vegetation/Silt used as classification only in July, September, and October 1975.
c Water extremely turbid; substrate composition could not be subjectively estimated.

Benthos

Mean benthic density from upstream and downstream sites was positively, curvilinearly, related to the mean percent composition of the more productive substrates, i.e., vegetation, silt-detritus, and gravel (Figure 2). The correlation coefficient between ln mean benthic density (y) and ln mean percent composition of productive substrates (x) was $r = 0.90$ ($p < 0.05$) (Figure 3), and the regression equation was

$$\ln y - 0.949(\ln x) - 4.32$$

Mean benthic biomass was generally higher in higher percentages of productive substrates, but a curvilinear trend was not evident (Figure 2). Gastopods contributed substantially to the high biomass in vegetation and silt-detritus at upstream and downstream new ditches (Schmal, 1978). Exclusion of mollusc data from all sites resulted in the correlation coefficient between ln mean benthic biomass excluding molluscs (y) and ln mean percent productive substrates (x) was $r = 0.69$ ($p < 0.05$) (Figure 5), and the regression equation was,

$$\ln y = 0.5615(\ln x) + 1.126$$

Removal of mollusc data did not significantly change the positive curvilinear relationship of density to productive substrates (Figure 4). The correlation coefficient between ln mean benthic density excluding molluscs (y) and ln mean percent productive substrates (x) was $r = 0.89$ ($p < 0.05$) (Figure 3) with the regression equation,

$$\ln y = 0.999(\ln x) - 4.64$$

Drifting Seston

Mean dry weights of drifting seston from upstream and downstream sites were generally negatively related to mean percentages of productive substrates (Figure 6). Correlation coefficients between ln mean seston dry weights (y) and ln mean percent composition of productive substrates (x) were $r = -0.76$ ($p < 0.05$) and -0.87 ($p < 0.05$), and the regression equations were,

$$\ln y = -2.294(\ln x) + 10.349, \text{ and}$$

$$\ln y = -0.0753(\ln x) + 4.22$$

for upstream and downstream sites, respectively. Apparently, the reason for the negative relationship was that productive substrates provided interstices for entrapment of drifting seston.

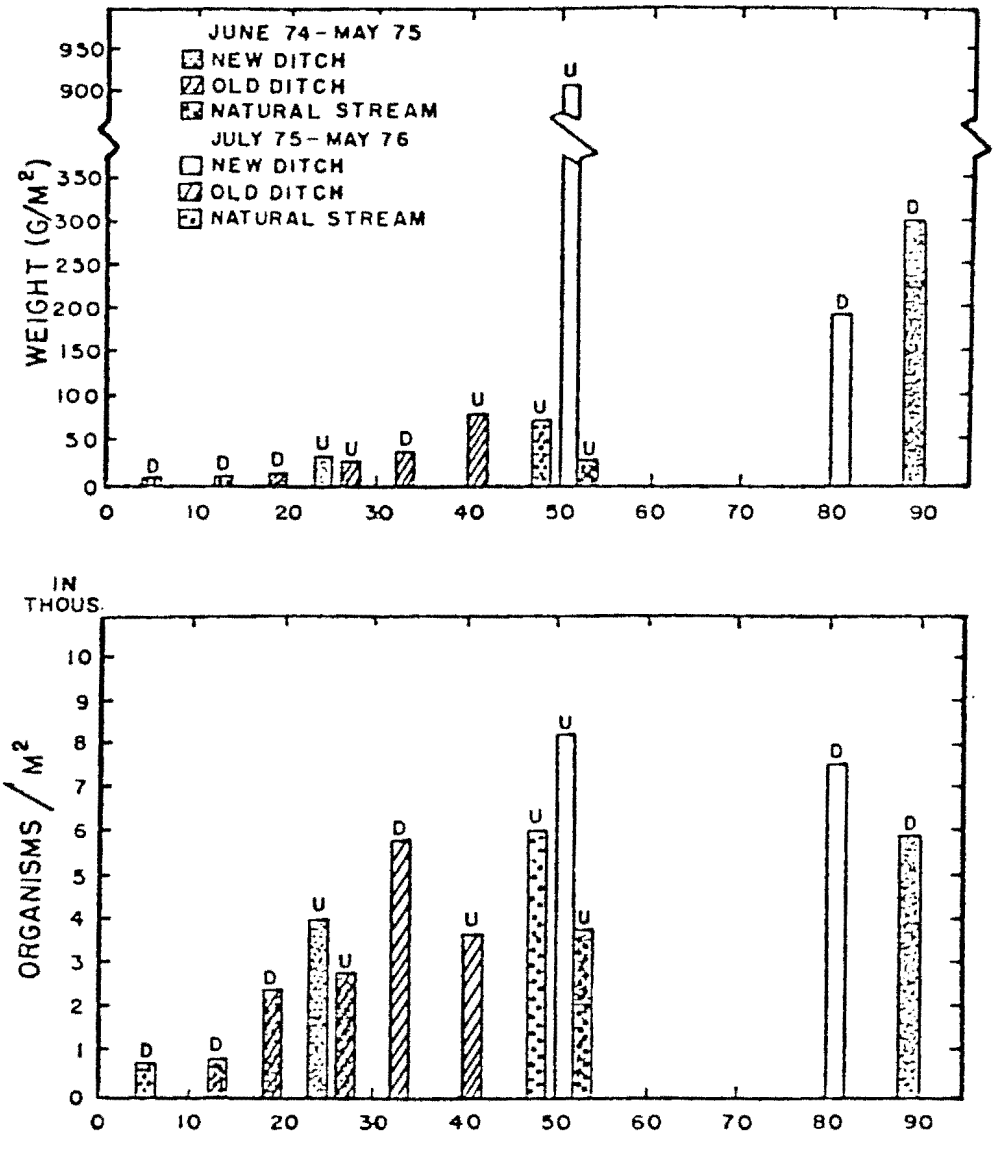


Figure 2 Mean Benthic Biomass and Density of Upstream (U) and Downstream (D) Sites in Relation to Mean Percent Composition of Productive Substrates, i.e., Vegetation, Silt-Detritus, and Gravel, Buena Vista Marsh.

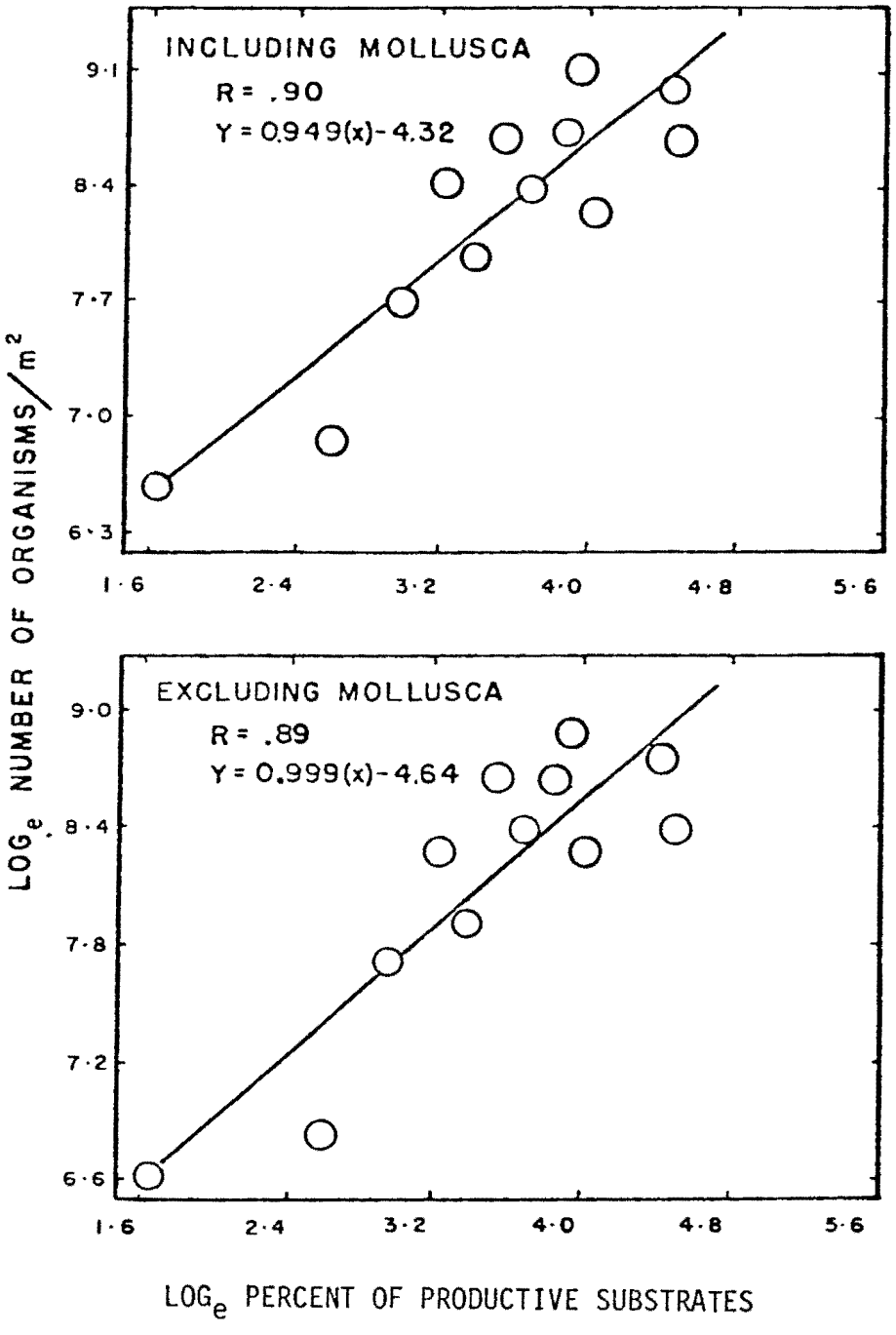


Figure 3 Regression of ln Numbers of Benthic Organisms (With and Without Molluscs) Per Square Meter on ln Percent Composition of Productive Substrates Combined for Upstream and Downstream Sites, June, 1974 to May, 1976, Buena Vista Marsh.

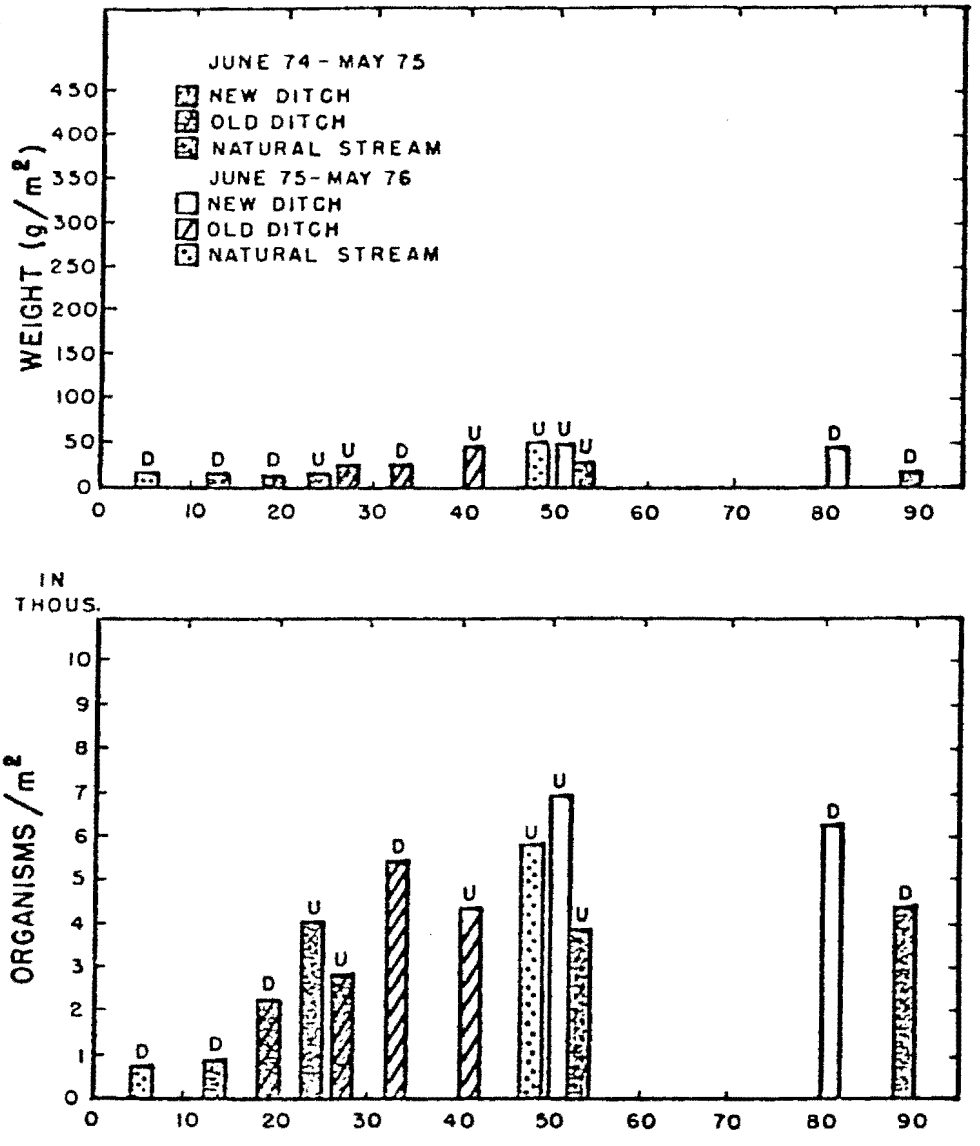


Figure 4 Mean Benthic Biomass and Density Excluding Molluscs in Upstream (U) and Downstream (D) Sites in Relation to Mean Percent Composition of Productive Substrates, I.e., Vegetation, Silt-Detritus, and Gravel, Buena Vista Marsh.

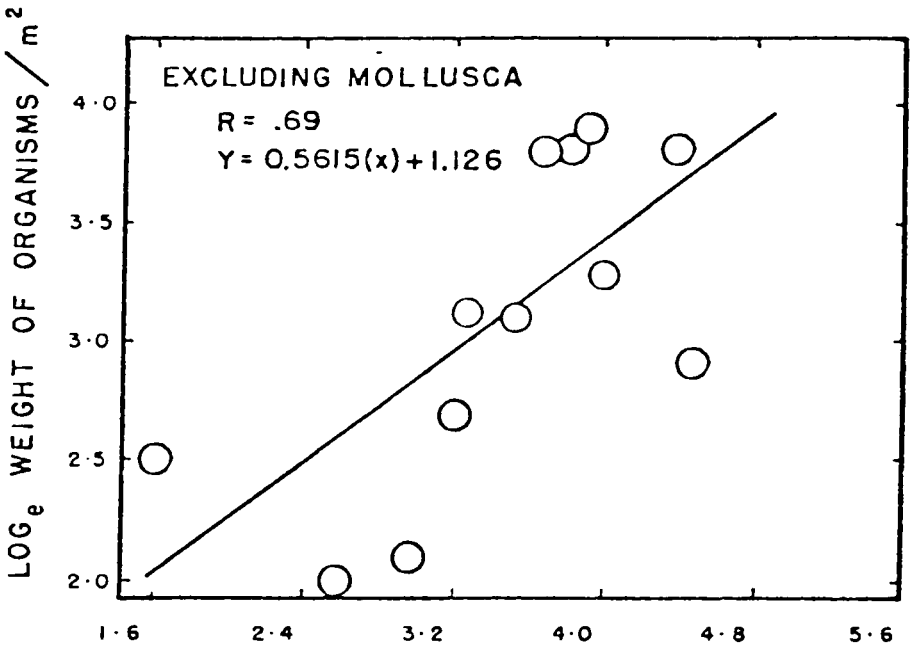


Figure 5 Regression of ln Weight (Grams) of Benthic Organisms (Without Molluscs) Per Square Meter on ln Percent Composition of Productive Substrates Combined for Upstream and Downstream Sites, June, 1974 to May, 1976, Buena Vista Marsh.

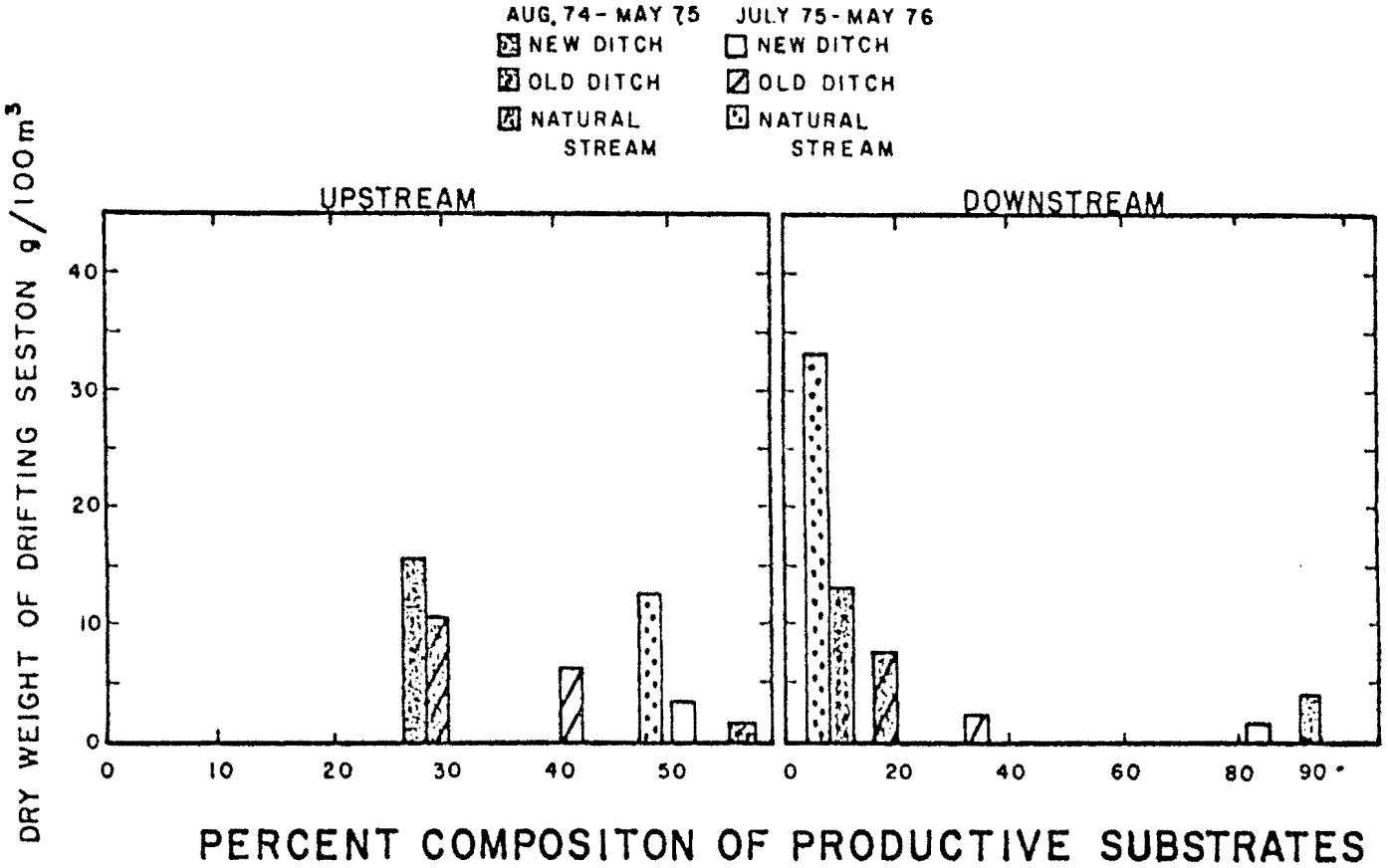


Figure 6 Mean Dry Weight of Drifting Seston (Suspended Particulate Matter) in Upstream and Downstream Sites in Relation to Mean Percent Composition of Productive Substrates, i.e., Vegetation, Silt-detritus, and Gravel, Buena Vista Marsh.

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Drifting Invertebrates

Mean biomass and density of invertebrate drift, with (Figure 7) and without (Figure 8) molluscs did not appear to be related to productive substrates. Invertebrate drift was controlled by at least four factors: 1) percent composition of productive substrates, 2) stream discharge, 3) drifting seston, and 4) benthic populations. The four factors were tested with multiple regression procedures to determine their contribution to drift density and relationship to channelization. The dependent variables were:

Y_1 = invertebrate drift density (numbers/100 m^3) including emerging aquatic adult insects

Y_2 = invertebrate drift density (numbers/100 m^3) excluding emerging aquatic adult insects

Y_3 = invertebrate drift density (numbers/100 m^3) including emerging aquatic adult insects but excluding molluscs

Y_4 = invertebrate drift density (numbers/100 m^3) excluding emerging aquatic adult insects and molluscs

The independent variables were:

X_1 = percent composition of the more productive substrates (vegetation, silt-detritus, and gravel)

X_2 = $\log_e$ discharge

X_3 = dry weight of drifting seston (grams/100 m^3)

X_4 = monthly mean benthos density (numbers/m^2) including molluscs for Y_1 and Y_2

X_5 = monthly mean benthos density (numbers/m^2) excluding molluscs for Y_3 and Y_4

Stream discharge was converted to natural logarithms because drift density was apparently a function of high spring flows (flushing) and low base flows (concentrating) (Figures 17 and 18). Correlation coefficients between all pairs of X and Y variables were calculated to determine interaction among drift density, productive substrates, discharge, seston, and benthos populations (Appendix F).

The four factors accounted for as much as 59.8% (Y_2) and 67.3% (Y_3) of the variability observed in invertebrate drift density from upstream and downstream areas, respectively (Table 3). A hatch of aquatic adult insects substantially decreased coefficients of (R) multiple correlation in the upstream area (Y_1 and Y_3) by creating large sample variances. Adult Chironomidae, which comprised nearly 100% of the aerial aquatic

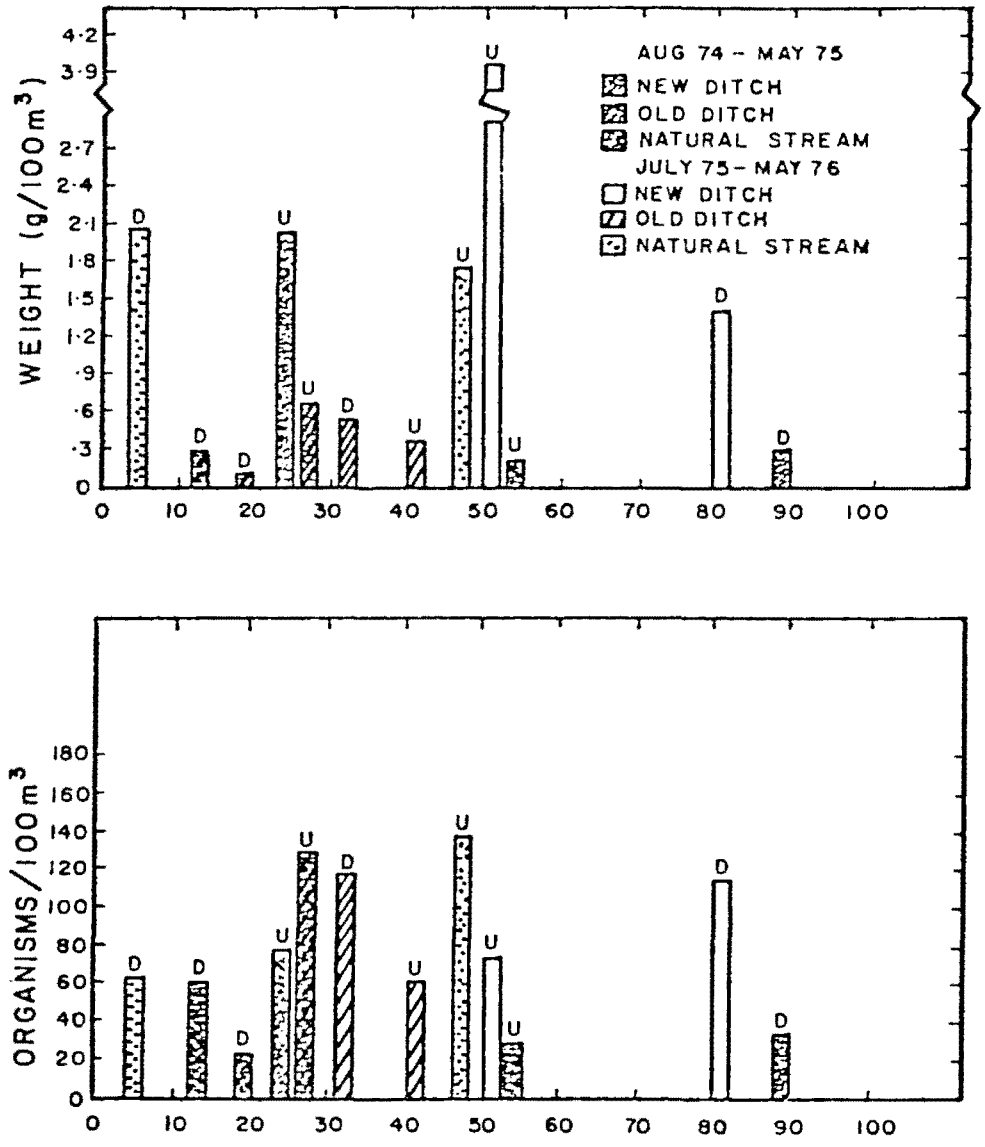


Figure 7 Mean Drifting Invertebrate Biomass and Density of Upstream (U) and Downstream (D) Sites in Relation to Mean Percent Composition of Productive Substrates, Buena Vista Marsh. (Mean drift includes molluscs but excludes emerging aquatic adult and terrestrial insects)

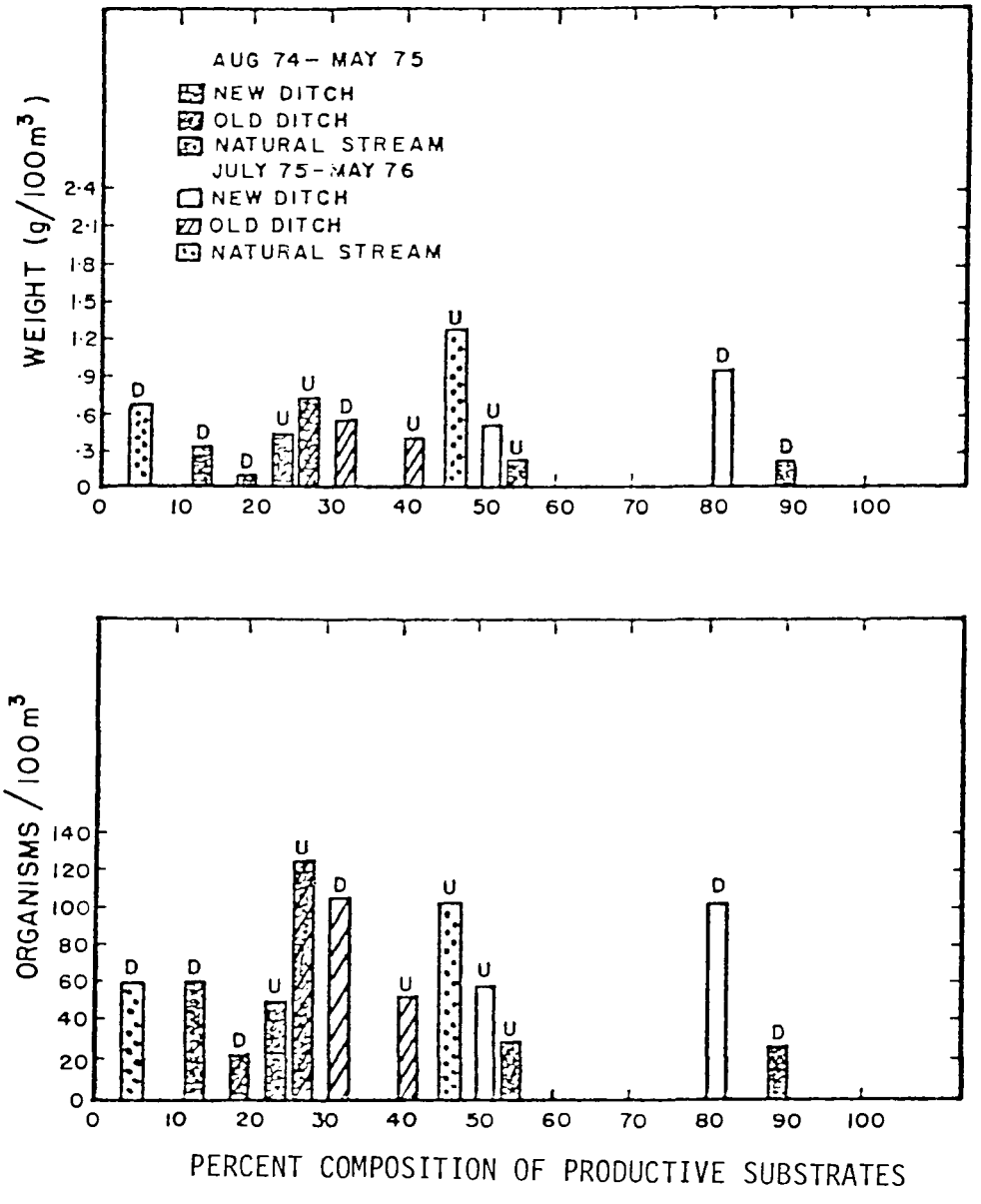


Figure 8 Mean Drifting Invertebrate Biomass and Density of Upstream (U) and Downstream (D) Sites in Relation to Mean Percent Composition of Productive Substrates, Buena Vista Marsh. (Mean drift excludes molluscs, emerging aquatic adult and terrestrial insects)

Table 3. Coefficients of Multiple Correlation (R) from Regression Analysis of Drifting Invertebrate Density and Four Measured Factors in Upstream and Downstream Areas, August 1974 to May 1976, Buena Vista Marsh, Portage County, Wisconsin.

	Drift Density[a]	Factors[b]	Upstream	Downstream
Y_1	molluscs[c] and aquatic adults	$X_{1, 2, 3, 4}$	4.1%	54.9%
Y_2	molluscs but no aquatic adults	$X_{1, 2, 3, 4}$	59.8%	53.4%
Y_3	no molluscs and aquatic adults	$X_{1, 2, 3, 5}$	3.5%	67.3%
Y_4	no molluscs and no aquatic adults	$X_{1, 2, 3, 5}$	52.7%	66.4%

[a]Terrestrial insects not included.

[b]Independent variables used in multiple regression analysis: X_1 = percent composition of productive substrates, X_2 = $\log_e$ discharge, X_3 = dry weight of drifting seston, X_4 = mean benthos density with molluscs, and X_5 = mean benthos density without molluscs.

[c]Snails (Gastropoda) and clams (Pelecypoda)

drift net catches in the upstream old ditch in April 1975 and 1976, accounted for the large variance (Appendix B-1 and B-2). No substantial adult hatches were caught in drift nets in the downstream area and no large sample variances were created as in the upstream area.

Other investigators have found substrate type, especially aquatic vegetation, to be of primary importance in the distribution of aquatic invertebrates. Morris et al. (1964), in a survey of channelized and unchannelized sections of the Missouri River, stated that the percent composition of productive substrates was important in estimating total standing crop of benthic invertebrates. Scullin (1977) found that abundance of benthic macroinvertebrates in a central Wisconsin trout stream was related to presence of suitable and productive substrates and detrital food base. The effects of substrate may be indirect and dependent on the presence of interstices for detrital deposition (Buscemi, 1966). Barber and Kevern (1973) reported extensive use of macrophyte beds, primarily by drifting Trichoptera, Ephemeroptera, and Diptera, and a reduction of current velocity and deposition of detrital materials as plants grew. Egglishaw (1969) found numbers of organisms to be significantly related to the amount of detritus trapped among stones and vegetation. Substrate differences associated with various environmental conditions result in nonuniform distribution of invertebrates (Cummins, 1962).

CHANNELIZATION EFFECTS ON BENTHOS

Effects of channelization on benthos were determined by the invertebrate-substrate relationships shown above. Channelization created unstable spoil banks which eroded during high spring flows covering stream bottoms with silt and sand. Unstable silt and sand substrates, common during the spring months in all ditches, generally became stabilized with aquatic vegetation throughout the summers and falls of the study. When the substrate was primarily unstable silt and sand, benthos abundance was low; when aquatic vegetation was abundant, benthos levels were high. Environmental factors such as spring runoff, length of growing season for in-stream vegetation, and catastrophic flooding affected the impact of channelization on invertebrate-substrate relationships. Some of the changes in benthic biomass and density were also probably caused by seasonal hatch, growth, and emergence patterns of aquatic invertebrates in each site.

Upstream Substrate

Percentages of sand substrate were not significantly different among the upstream sites ($X^2 = 2.68$; 2 d.f., $p < 0.05$). Monthly mean percentages of sand were 62, 66, and 49 for the new ditch, old ditch, and natural stream, respectively (Figure 9). However, seasonal changes in new and old ditch substrate conditions were influenced by channelization. In the ditches, banks slumped and erosion occurred during high flows associated with spring runoff in 1974 and 1975. The new ditch and old ditch had

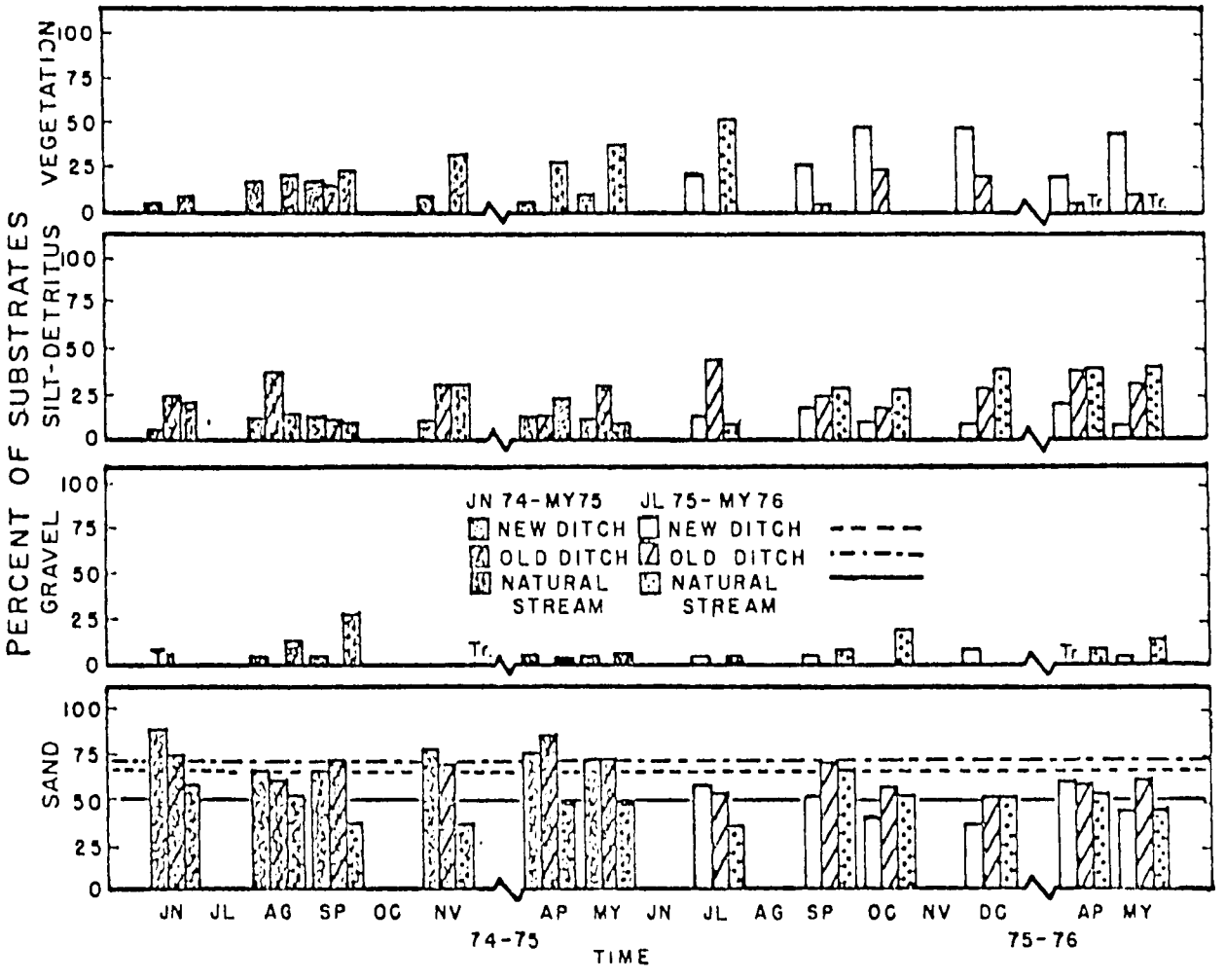


Figure 9 Estimated Monthly Substrate Composition from Upstream Sites, June, 1974 to May, 1976, Buena Vista Marsh. (Tr. = trace amount; horizontal lines represent mean percent composition for entire study)

significantly higher percentages of sand than the natural stream between June 1974 and May 1975 ($X^2 = 7.51$; 2 d.f., $p < 0.05$); mean percentages were 75, 73, and 47 for upstream new ditch, old ditch, and natural stream respectively (Table 1). The following year, July 1975 to May 1976, bank slumping and erosion were less severe in the ditches and mean percentages of sand were 49 and 59 in new and old ditches (Table 1). A flood in August 1975 washed all Ranunculus out of the natural stream which resulted in increases in percentages of sand and silt-detritus substrates (Figure 9).

Upstream Benthos

The new ditch had higher biomass and density comprised primarily of molluscs and chironomids, respectively, than the old ditch and natural stream. Monthly mean benthic biomass was 934, 52, and 48 g/m^2 in the new ditch, old ditch, and natural stream, respectively (Figure 10). Molluscs accounted for 97% of new ditch biomass, 37% in the old ditch, and 28% of the mean biomass in the natural stream (Schmal, 1978). Molluscs contributed less to benthic density than to biomass. Mean benthic density was higher in the upstream new ditch than the other sites because of high numbers of dipteran, Chironomidae (Schmal, 1978). Monthly mean benthic density was 6363, 5062, and 3779 organisms/m^2 in the new ditch, natural stream, and old ditch, respectively (Figure 10). Morris (1964) and Etnier (1972) also found high densities of Chironomidae in channelized areas.

Excluding molluscs, the natural stream had the highest monthly mean biomass, 35 followed by the old ditch, 32, and the new ditch, 31 g/m^2 (Figure 11); these differences were not statistically significant. However, the new ditch had substantially lower benthic biomass than the natural stream during spring flooding and substrate adjustment in 1974 and 1975 (Figure 11). With the lack of spring flooding in April and May 1976, benthic biomass was similar in the ditches and the natural stream (Figure 11). The new ditch had significantly higher benthic density without molluscs than the old ditch and natural stream ($X^2 = 410.4$; 2 d.f., $p < 0.01$); 5512, 4865, and 3591 organisms/m^2 in the new ditch, natural stream, and old ditch, respectively (Figure 11). The highest monthly mean benthic biomass and density occurred in the natural stream study site in July 1975 (Figure 11), when aquatic vegetation comprised 52% of the substrate.

Aquatic vegetation grew within the new ditch channel and stabilized the stream bottom until the winter die-off in November 1974 and December 1975. Emergent watercress and reed canary grass, which formed protective overhangs along the banks of the new ditch, also began to die in November 1974 and December 1975. Thereafter, much of the decaying bank vegetation and in-stream vegetation was dislodged by melting snow, ice, and high spring flow (Headrick, 1976). The bank and in-stream vegetation remained relatively stable during decomposition over the winter and early spring of 1975-1976. Visual observations of decaying watercress revealed abundant population of snails, Lymnaea, Physa, and Gyraulus, throughout the winter

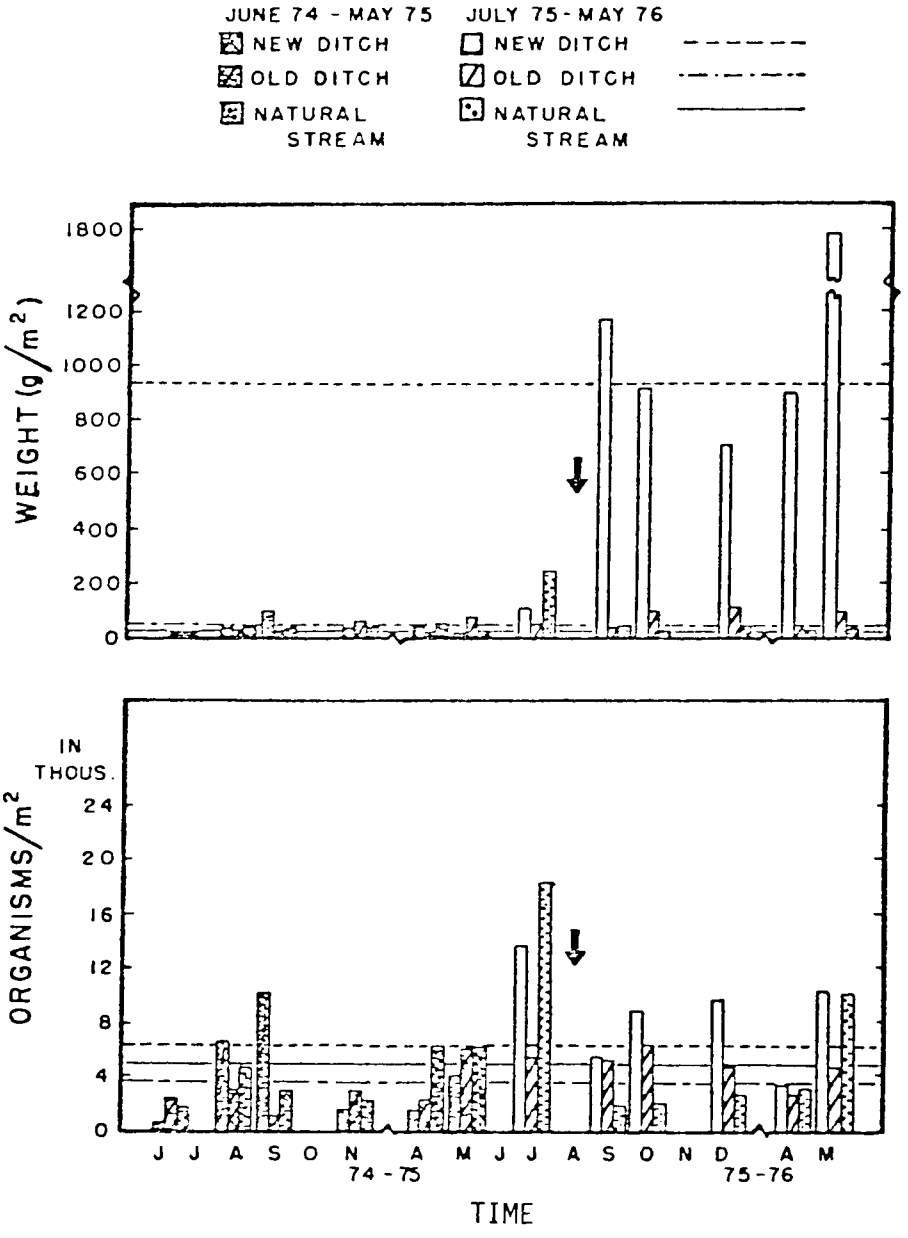


Figure 10 Monthly Mean Benthic Biomass and Density (Including Molluscs) for Upstream Sites, June, 1974 to May, 1976, Buena Vista Marsh. (Horizontal lines represent mean biomass or density for entire study; legend consistent for Figures 11, 13 and 14; arrows indicate August, 1975 flood)

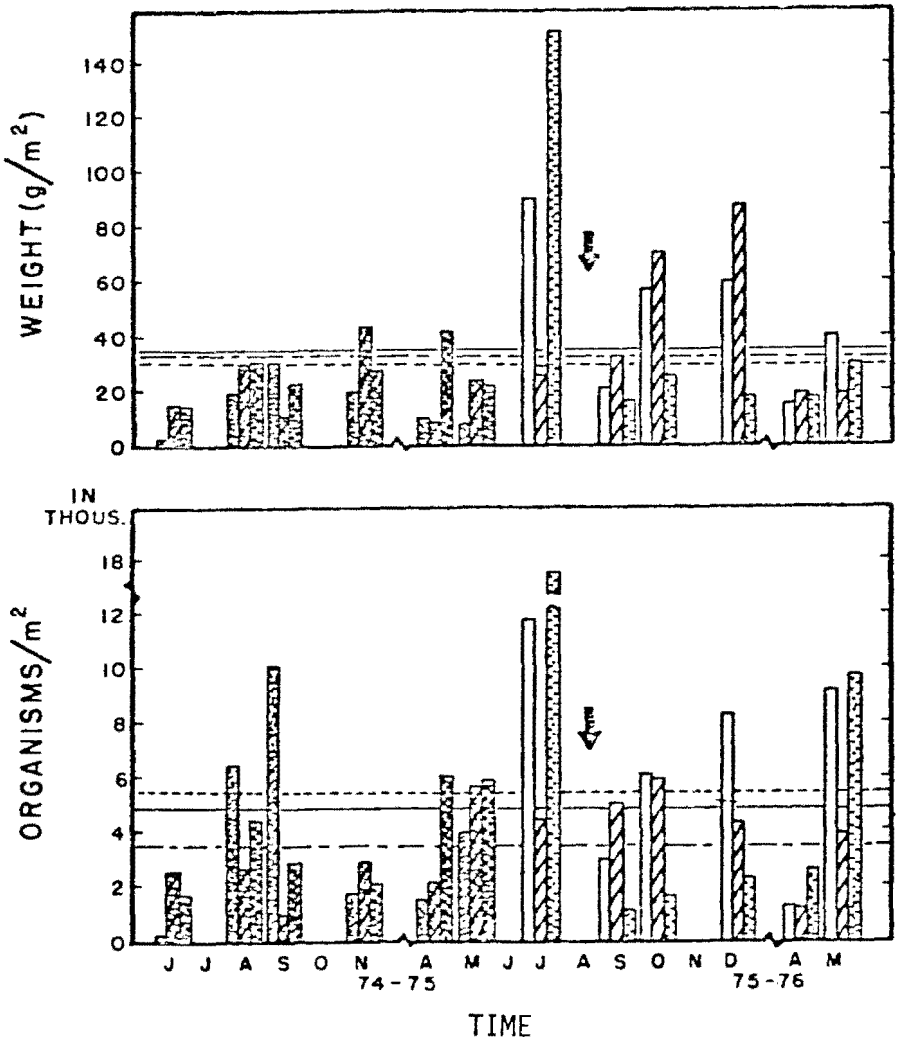


Figure 11 Monthly Mean Benthic Biomass and Density (Excluding Molluscs) for Upstream Sites, June, 1974 to May, 1976, Buena Vista Marsh, (Horizontal lines represent mean biomass or density for entire study; arrows indicate August, 1975 flood)

and spring months. Harmon (1972) stated that non-random distribution of molluscs occurs but that colonies of aquatic vegetation create favorable microhabitats for various species.

The high mollusc populations in the ditches probably resulted from the favorable vegetation substrates. Snails, Physa and Gyraulus in aquatic vegetation, and Physa in silt-detritus, substantially accounted for the high benthic biomass in the new and old ditches during the first year of the study (Schmal, 1978). The following year, the increase in biomass in the ditches was caused by Physa, Lymnaea, and Gyraulus in vegetation and Physa and Lymnaea in silt-detritus (Figure 10) (Schmal, 1978).

Water chemistry may have influenced the mollusc populations in the new and old ditches. The upstream new ditch was in a natural hardwater zone (Holt, 1965) and mean concentrations of alkalinity, total hardness, and calcium hardness were significantly greater in the new ditch than in the old ditch and natural stream (X^2 = 22.1; 2 d.f., $p < 0.01$, 19.9; 2 d.f., $p < 0.01$ and 11.5; 2 d.f., $p < 0.01$) respectively (Appendix D-1 and D-2). Egglishaw (1968) found plant material decomposed more quickly in waters with higher calcium concentrations, and suggested that the quicker turnover of plant material supported larger standing biomass, and presumably higher production of benthic invertebrates. Clarke and Berg (1959), Hunter (1957), and Hynes (1970) stated that molluscs were generally more common in hard water.

Downstream Substrate

Downstream channelization created unstable substrate conditions during spring, but productive substrate conditions in the summer and fall each year in the new and old ditches. The new ditch, primarily depositional and characteristics of a pond environment, contained a 1 m thick layer of silt in mid-channel. Increased discharge in April 1975 stirred and mixed the silt-detritus substrate in the new ditch channel causing turbid water in the old ditch, 150 m downstream. The turbid water may have delayed spring growth of in-stream vegetation in both areas. However, the new ditch contained up to 90% Potamogeton during the growing seasons and up to 90% silt-detritus after vegetation die-off in November 1974 (Figure 12).

Although discharge in the new ditch was higher in the spring of 1976 than in 1975, early reestablishment of Potamogeton on the silt-detritus bottom probably minimized water turbidity that spring.

Channelization also effected substrate composition in the natural stream. The flow from ditches 3, 4 and 8, diverted to the natural stream, brought abnormally high discharge and eroded steep sand banks, which created an unstable shifting sand bottom in the natural stream. Significantly higher percentages of sand were present in the natural stream than in the downstream ditches (X^2 = 54.7; 2 d.f., $p < 0.01$). Monthly mean percentages of sand were 91, 74 and 14 for the natural stream, old ditch, and new ditch, respectively (Figure 12). Benthic.

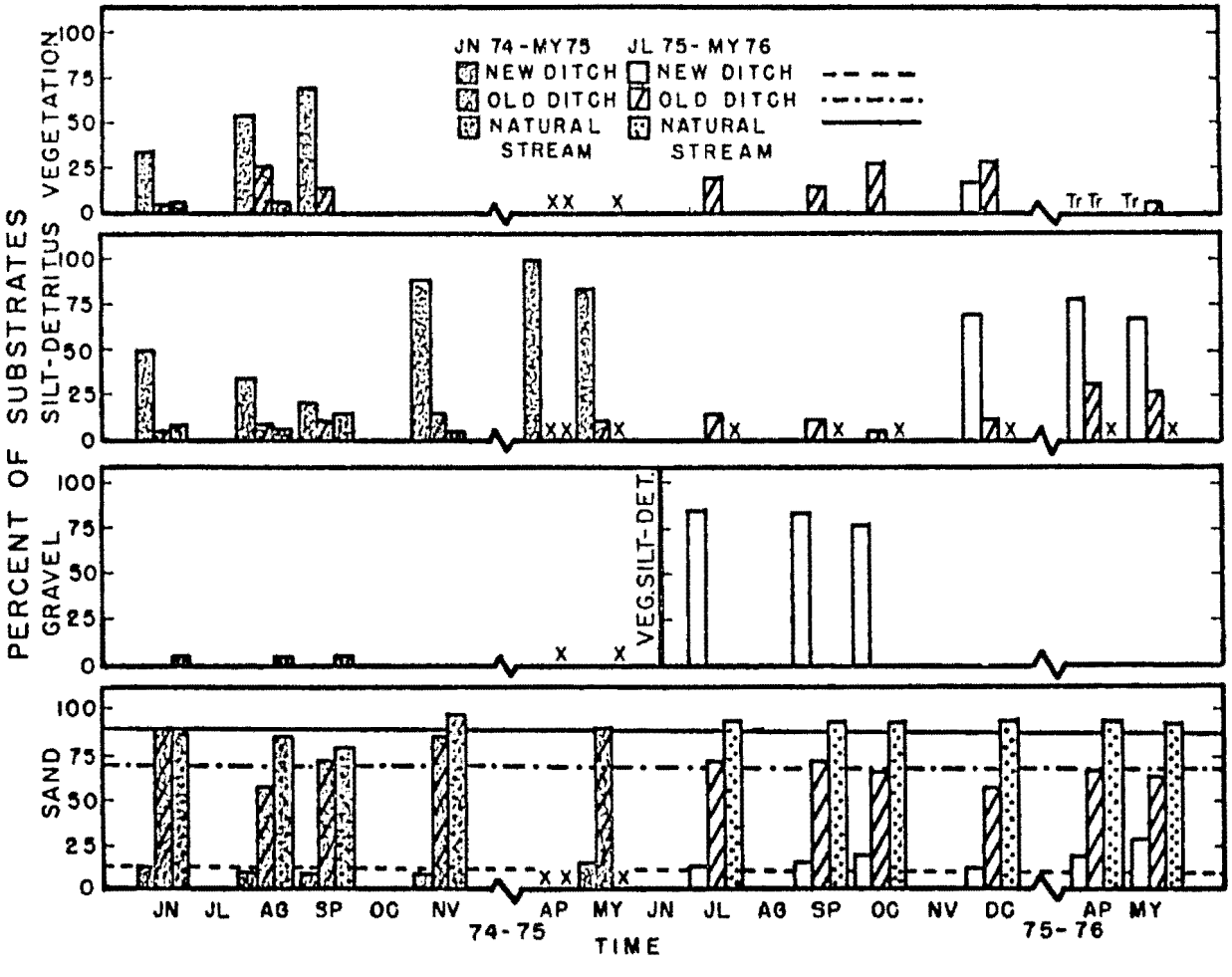


Figure 12 Estimated Monthly Substrate Composition from Downstream Sites, June, 1974 to May, 1976, Buena Vista Marsh. (Tr. = trace amount; x = substrate not estimated because of water turbidity; horizontal lines represent mean percent composition for entire study)

populations were low in the natural stream, a reflection of the large amount of shifting sand.

Downstream Benthos

The new ditch, because of the large amount of vegetation (Potamogeton), had significantly higher benthic biomass (X^2 = 376.9; 2 d.f., $p < 0.01$) and density (X^2 = 4509; 2 d.f., $p < 0.01$) than the old ditch and natural stream. Monthly mean benthic biomass was 251, 27 and 10 g/m^2 whereas monthly mean benthic density was 6790, 4038, and 866 organisms/m^2 for downstream new ditch, old ditch, and natural stream, respectively (Figure 13). Again, molluscs substantially contributed to benthic biomass in the ditches: 88% in the new ditch, 46% in the old ditch, and only 2% in the natural stream. Without molluscs, monthly mean benthic biomass and density were still significantly higher in the new ditch (X^2 = 8.2; 2 d.f., $p < 0.05$) and (X^2 = 3157.2; 2 d.f., $p < 0.01$) respectively (Figure 14). Monthly mean biomass was 26, 14.6, and 9.8 g/m^2 whereas monthly mean density was 5369, 3818, and 847 organisms/m^2 for the new ditch, old ditch, and natural stream, respectively (Figure 14).

Channelization created favorable seasonal substrate conditions for molluscs and chironomids. Snails, Lymnaea and Ferrissia, accounted for the highest monthly mean benthic biomass in the new ditch (Schmal, 1978) when Potamogeton and silt-detritus substrates covered 90% of the bottom. Mollusc biomass in the downstream ditches also may have been influenced by water chemistry as in the upstream ditches. Mean values of alkalinity, total hardness and calcium hardness were consistently higher in the new ditch than mean values in the old ditch and natural stream (Appendix D-1 and D-2), although differences were not statistically significant. Chrionomidae primarily dominated the benthic fauna in the ditches during the second year of the study. The highest recorded mean benthic density, 21,775 organisms/m^2 occurred December 1975 in the old ditch and consisted of 65% Chironomidae and 29% blackfly, Simulium (Schmal, 1978). Chironomidae also contributed 79% to new ditch mean benthic density in December 1975 and 89% in April 1976 (Figure 13). Dodge et al. (1976) reported Chironomidae and Simulium dominated the invertebrate fauna in channelized sections of the Upper Tweed and White Rivers, Vermont.

INFLUENCE OF FLOODING ON UPSTREAM BENTHOS

Heavy rainfall the last week of August 1975 caused flooding in the natural stream and high water levels in the ditches. Flooding completely flushed out aquatic vegetation (Ranunculus) from the natural stream site, but did not appreciably change old or new ditch substrates.

Changes in benthic biomass and density following the flood were probably related to decreases or increases in percentages of productive substrates. Benthic biomass and density were higher in the natural stream before flooding than in the ditches. After the flood, the lowest monthly mean biomass and density estimates occurred in the natural stream

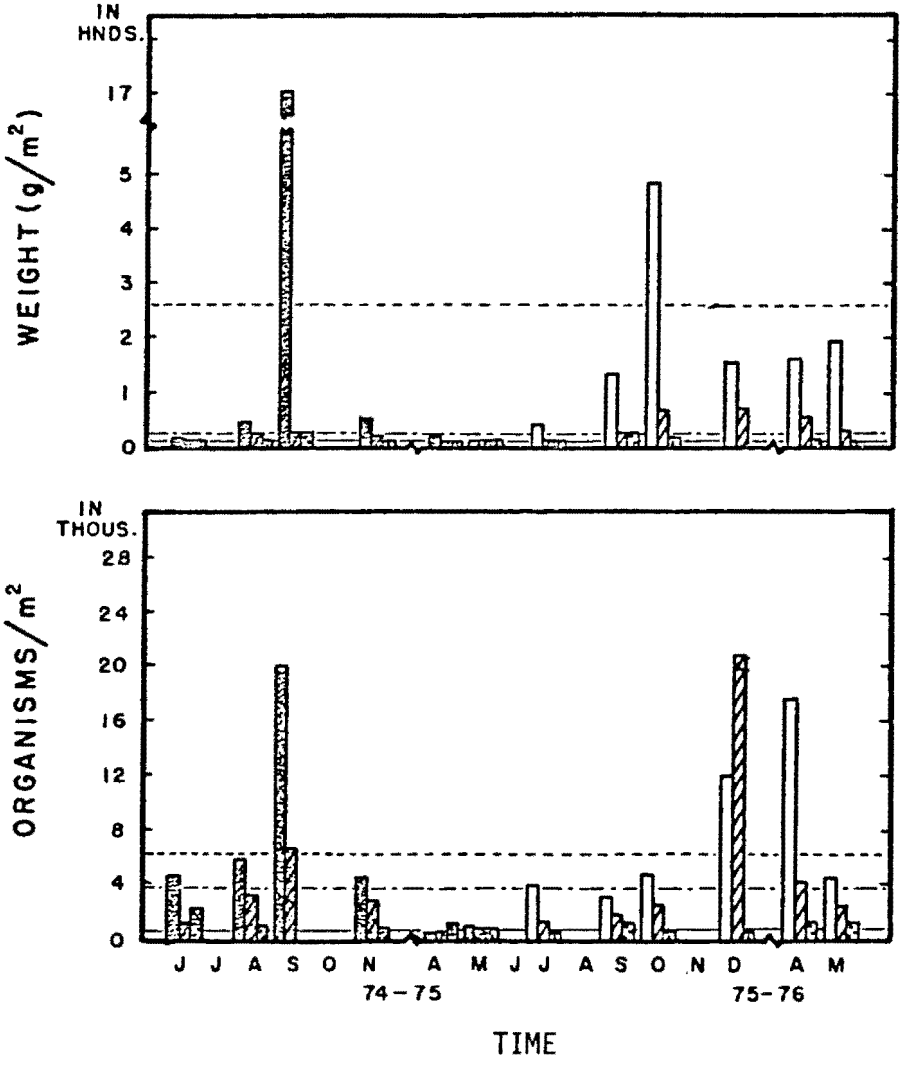


Figure 13 Monthly Mean Benthic Biomass and Density (Including Molluscs) for Downstream Sites, June, 1974 to May, 1976, Buena Vista Marsh. (Horizontal lines represent mean biomass or density for entire study)

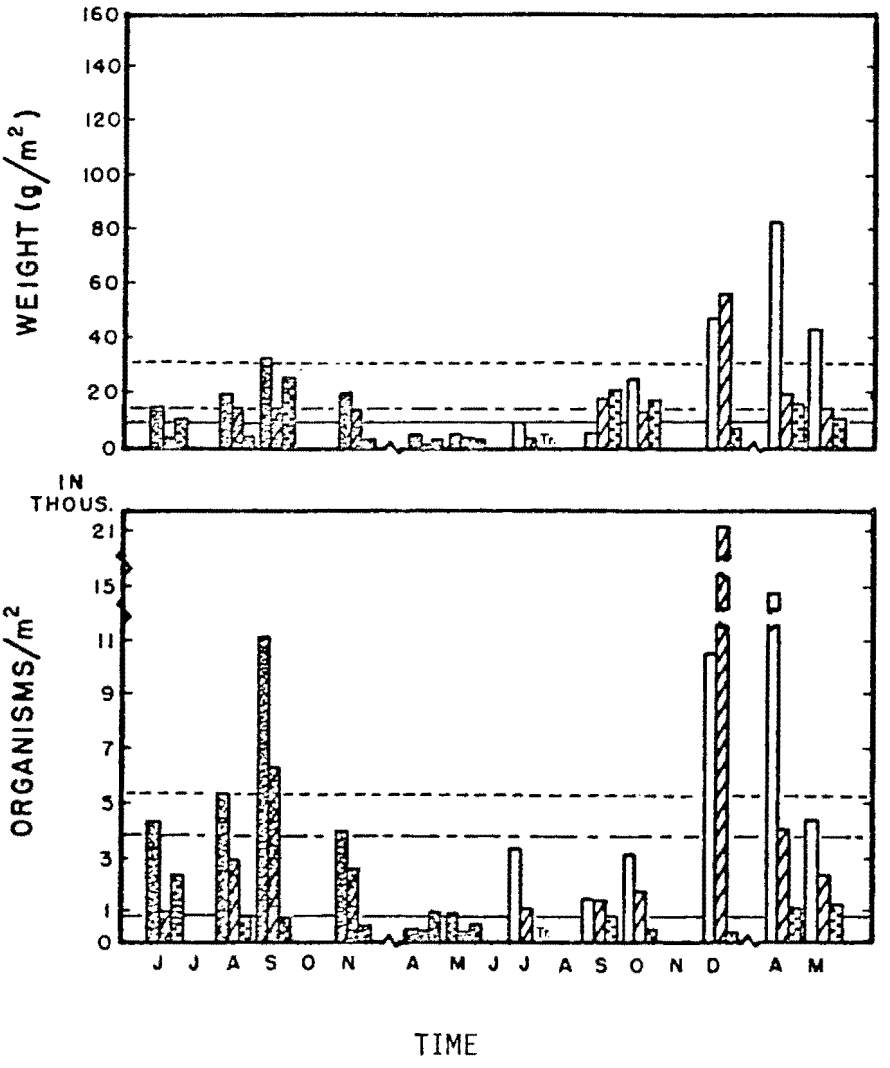


Figure 14 Monthly Mean Benthic Biomass and Density (Excluding Molluscs) for Downstream Sites, June, 1974 to May, 1976, Buena Vista Marsh. (Horizontal lines represent mean biomass or density for entire study)

in September 1975 (Schmal, 1978). Scullin (1977) reported the lowest monthly mean benthic biomass and density in the Little Plover River, Wisconsin after flooding. Although a decrease in benthic biomass and density occurred in the new ditch, they increased slightly in the old ditch (Schmal, 1978). Aquatic vegetation, Elodea, increased in the old ditch site during September 1975 (Figure 9) and our sampling of that substrate accounted for the increases in biomass and density. Elodea was scattered before flooding during the July 1975 sample period in the old ditch.

Faunal changes that occurred in the natural stream after flooding were decreases in scuds, Gammarus, mayflies, Baetis, and caddisflies, Brachycentrus. Densities of Chironomidae and clams, Pelecypoda, increased throughout the remainder of the study in the natural stream (Schmal, 1978). The faunal change that occurred in the new ditch was a decrease in the densities of two mayflies, Caenis, and Baetis, and of Gammarus and Brachycentrus (Schmal, 1978). Moffet (1936) reported Chironomidae dominated the fauna of South Willow Creek, Utah during flood recovery stages. A clam, Pisidium, and Chironomidae, substrate burrowers, survived winter flooding in the River Endrick, Scotland (Maitland, 1964). Invertebrates with short life cycles, such as Chironomidae, may dominate the fauna of a stream after flooding (Hynes, 1970). Increases in stream benthos following a flood could result from recolonization through upstream migration, downstream drift, and aerial sources (William and Hynes, 1976; Williams, 1977). The upstream natural stream gradually recovered from flooding as evidenced by an increase in benthic biomass and density from October 1975 to May 1976 (Figure 11). Scullin (1977) also reported a gradual recovery of benthic biomass and density in the Little Plover River after flooding. The upstream ditches, not appreciably affected by flooding, displayed general increases in benthic biomass and density through December 1975, but had similar biomass and lower density than the natural stream the following spring of 1976 (Figure 11) during periods of substrate instability created by channelization.

CHANNELIZATION EFFECTS ON DRIFTING SESTON

Channelization and climate influenced drifting seston by reducing percentages of productive substrates, especially aquatic vegetation in the spring of 1975 and to a lesser extent in the spring of 1976. Productive substrates apparently provided interstitial spaces for entrapment of drifting seston (Figure 6). Channelized areas, with the exception of the downstream new ditch, generally were devoid of depositional areas of reduced current velocity such as pools and point bars. The reduced diversity of habitats in the ditches, especially during periods of bank instability and high spring flows, may have increased the amount of drifting seston when the more productive substrates were not present or not stable. Low base flows also apparently increased seston.

Upstream Seston

Drifting seston was higher in the ditches than the natural stream from 1974 to 1975, but higher in the natural stream than in the new ditch, with the old ditch intermediate the next year (Figure 15). Increases in drifting seston seemed to be associated with spring flooding in April, May 1975 in the new and old ditches. Low values of drifting seston, in the ditches, appeared to coincide with percentages of productive substrates, especially in-stream vegetation. The vegetation may have reduced the current velocity and trapped and accumulated drifting seston. Increases in drifting seston in the natural stream after the August 1975 flood were most likely due to the absence of Ranunculus in that site (Figure 15).

The absence of depositional areas, generally associated with diverse habitats in meandering channels, and small areas of macrophyte and gravel substrates to trap drifting seston, probably contributed to relatively large amounts of seston in the new ditch in the first year (Figure 15 and Appendix E-1). Early reestablishment of aquatic vegetation and decreased bank erosion, the second year, probably contributed to lower seston values in the new ditch (Figure 15 and Appendix E-2). The weak sinuosity of the old ditch channel, within the vegetation-stabilized spoil banks and abundant reed canary grass, probably accounted for intermediate amounts of drifting seston. Low base flows may have concentrated seston in the drift nets (December 1975) in the old ditch and natural stream (Figure 15).

Downstream Seston

The natural stream had significantly more drifting seston ($X^2 = 23.3$; 2 d.f., $p < 0.05$) than the new and old ditches (Figure 16). The increased discharge in the natural stream from the combined flows from ditches 3, 4, and 8, causing erosion of steep banks, coupled with a paucity of aquatic vegetation, probably accounted for increased seston in that site.

Drifting seston was higher in the ditches during the first year than the second (Figure 16). Increases in drifting seston occurred in the new and old ditches during high spring flows of 1975 before aquatic vegetation reestablished itself. The unstable 1-m layer of silt detritus on the new ditch bottom was subjected to stirring and mixing in the spring and probably accounted for the increases in seston (Figure 16 and Appendix E-1). The following year, vegetation reestablished itself as early as March in the ditches, and decreases in seston values were probably the result of increases in the percentages of productive substrates, primarily Potamogeton (Figure 16 and Appendix E-2).

CHANNELIZATION EFFECTS OF DRIFTING INVERTEBRATES

Effects of channelization on invertebrate drift were determined from the relationships among productive substrates, discharge, drifting seston,

Figure 15 Monthly Dry Weight of Drifting Seston (☐) and Stream Discharge (x——x) in the Upstream Area, August, 1974 to May, 1976, Buena Vista Marsh. (Legend consistent with Figure 16)

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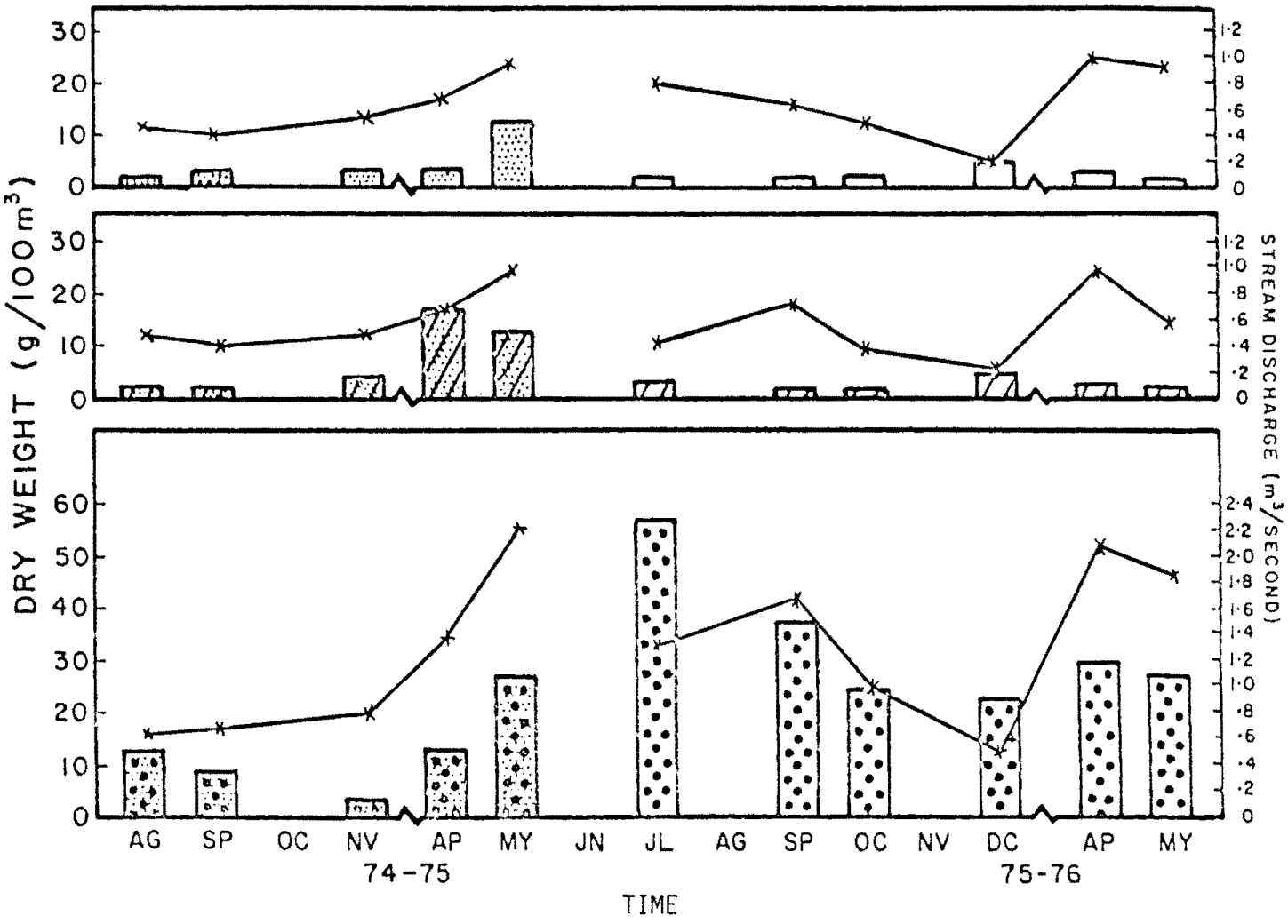


Figure 16 Monthly Dry Weight of Drifting Seston (▭) and Stream Discharge (x——x) in the Downstream Area, August, 1974 to May, 1976, Buena Vista Marsh.

and benthos populations (Table 3 and Appendix F). Increases in drift density generally coincided with substantial increases or decreases in discharge and increases in drifting seston, especially when productive substrates were not present or stable.

Upstream Drift

Channelization apparently affected upstream invertebrate drift through its influence on drifting seston. Increases in invertebrate drift at all sites were related to increases in drifting seston (Figure 15 and 17) and the relationship was significant ($r = 0.71$; $p < 0.01$ for Y_2 and $r = 0.68$; $p < 0.01$ for Y_4) (Appendix F). Drift density was significantly higher in the channelized ditches than in the natural stream the first year ($X^2 = 51.4$; 2 d.f., $p < 0.01$) but significantly higher in the natural stream than in the ditches the next ($X^2 = 26.9$; 2 d.f., $p < 0.01$) (Appendix B-1 and B-2). The increased numbers of drifting invertebrates in the ditches during the first year, especially Chironomidae, generally occurred when productive substrates were not available to trap and accumulate seston. Lower drift densities in the ditches, the following year (Figure 17), were probably due to increased percentages of productive substrates and consequent lower seston values at those sites (Figure 15).

Alteration of substrate composition in the natural stream after August 1975 flooding (Figure 9), which was followed by increases in drifting seston above previous months (Figure 15), may have contributed to increased invertebrate drift density at that site the second year (Figure 17). Substantial numbers of drifting invertebrates were caught in the natural stream and old ditch sites, December 1975 (Figure 17) and seemed to correspond with low base blows (Minshall and Winger, 1972; Zimmer, 1976). Drifting invertebrates and seston (Figure 15) may have been concentrated in the drift nets during the low flow at those sites.

Other investigators have shown drift density increased with increased suspended particulate matter in the water column. In brush removal studies on the Little Plover River, Wisconsin, Braatz (1974) reported invertebrate drift increased linearly with increased drifting seston, and Holey (1978) observed that drift densities of Chironomidae were proportionately higher when seston increased in the drift. Rosenberg and Weins (1975) also showed that number of Chironomidae in the drift increased with experimental sediment additions.

Downstream Drift

Benthic populations accounted for substantial variation in downstream drift density (Appendix F). Drift density at all sites was significantly related to benthos density ($r = 0.64$ for Y_1, 0.64 for Y_2, 0.74 for Y_3, and 0.74 for Y_4; $p < 0.01$) (Appendix F). High statistical correlation between invertebrate drift density and benthos density (without molluscs) occurred in December 1975 and April 1976 (Figures 14 and 18).

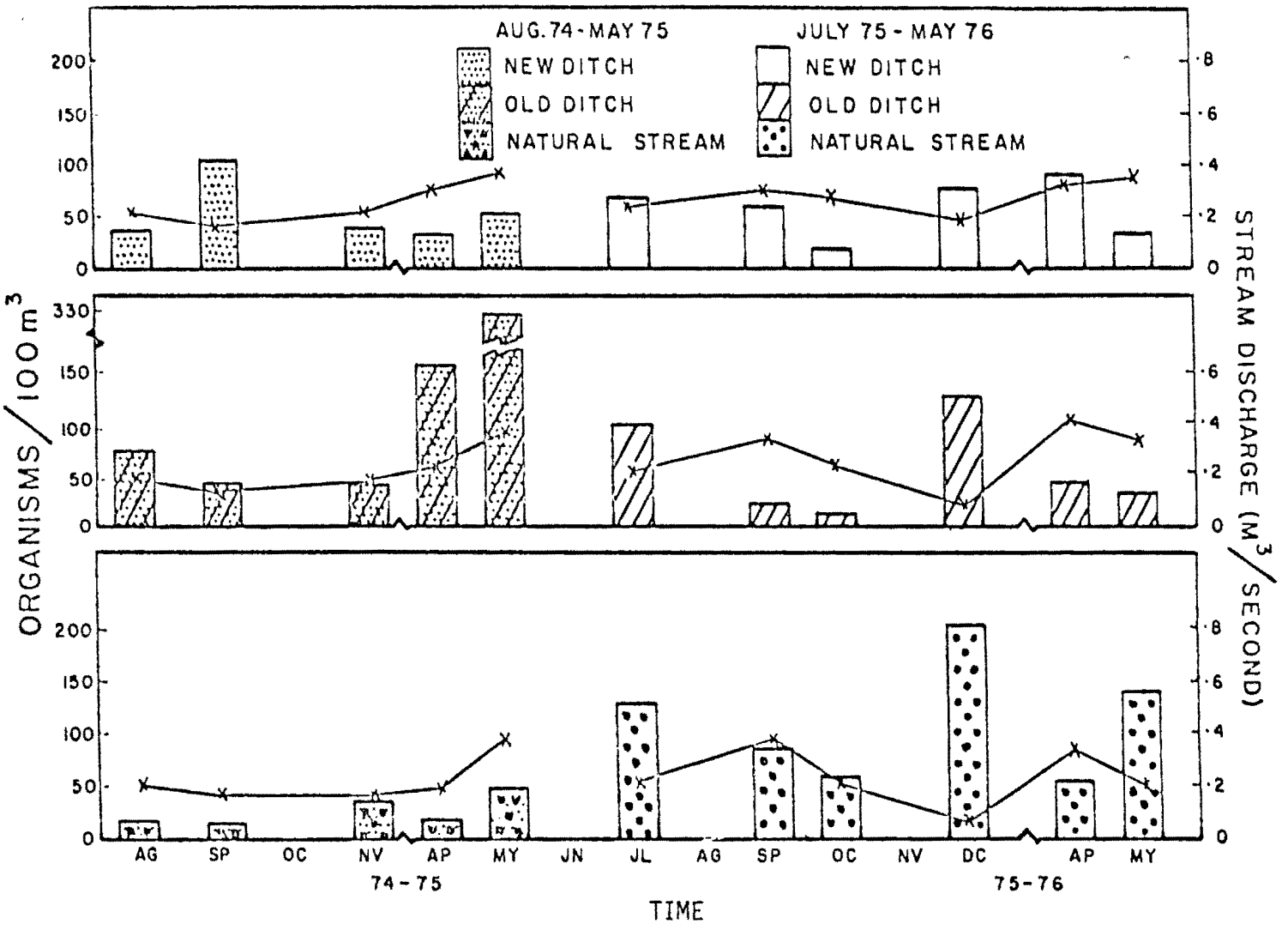


Figure 17 Monthly Mean Drift Density (▭) and Stream Discharge (x—x) in the Upstream Area, August, 1974 to May, 1976, Buena Vista Marsh. (Legend consistent with Figure 18; mean drift excludes molluscs, emerging aquatic adult and terrestrial insects)

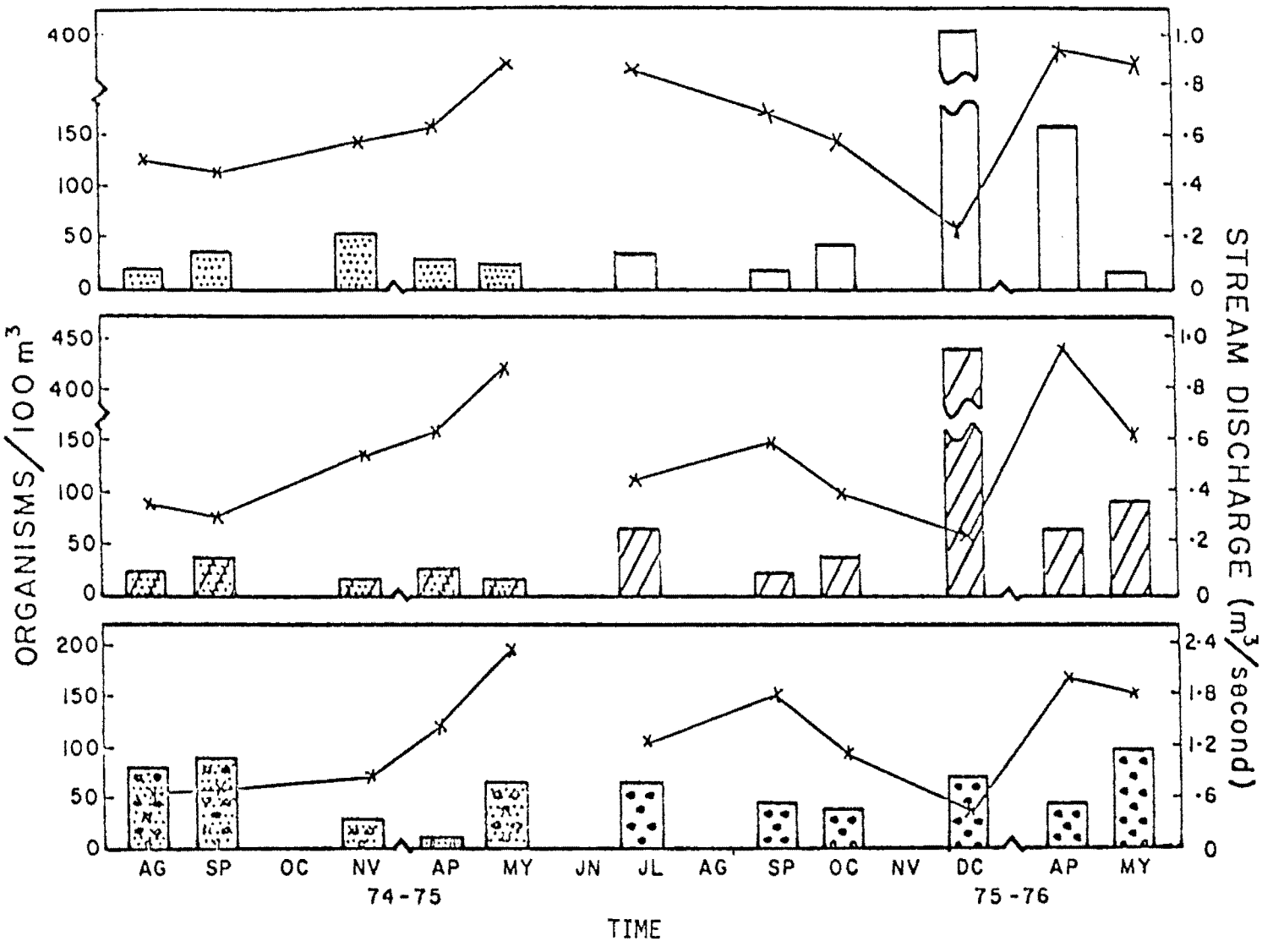


Figure 18 Monthly Mean Drift Density (▭) and Stream Discharge (x—x) in the downstream Area, August, 1974 to May, 1976, Buena Vista Marsh. (Mean drift excludes molluscs, emerging aquatic adult and terrestrial insects)

Low flows also probably influenced invertebrate drift. Invertebrate drift density was significantly higher (X^2 = 15.9; 2 d.f., $p < 0.01$) in the natural stream than in the ditches the first year (Figure 18 and Appendix B-1 whereas the channelized ditches had significantly more drift density (X^2 = 19.6; 2 d.f., $p < 0.05$) the second year (Figure 18 and Appendix B-2). The substantial increase in drift density in the ditches the second year occurred during low flow periods, December 1975 (Figure 18) and probably accounted for the drift density differences among the sites.

TAXONOMIC DIFFERENCES

Although more invertebrate taxa were collected from natural streams than ditches, differences were not significant. Total taxa (benthos, drift, and qualitative) collected were 76, 81, and 84 from upstream and 64, 77, and 81 from downstream new ditches, old ditches, and natural streams, respectively (Table 4).

However, stoneflies (Plecoptera) were only found in natural streams and mayflies (Ephemeroptera) and caddisflies (Trichoptera) were more common in natural streams than in ditches. The upstream and downstream natural streams each contained 6 more genera of Trichoptera than the new ditches in their respective areas, with the old ditches intermediate. Four more genera of Ephmeroptera were collected from the natural stream than in the new ditch in the downstream area. Benthic taxa collected were 55, 57 and 64 from upstream and 48, 59, and 48 from downstream new ditches, old ditches, and natural streams, respectively (Table 4). Lower numbers of benthic taxa collected in the downstream natural stream than in the ditches probably was related to low benthic populations in the predominantly shifting sand bottom in that site. Etnier (1972) reported reduced diversity of invertebrate fauna, especially Ephemeroptera, Trichoptera, and Plecoptera following channelization of a small Tennessee stream.

Numbers of drifting taxa were higher in the upstream old ditch and downstream natural stream, which were sites with the highest percentages of sand substrate in their respective areas (Figures 9 and 12, Table 4). In the upstream area, numbers of drifting taxa were not significantly different among sites; 48, 49, and 47 for new ditch, old ditch, and natural stream, respectively. However, the downstream natural stream, despite low numbers of benthic taxa, had significantly more invertebrate drift taxa (X^2 = 29.9; 2 d.f., $p < 0.01$), 69, than the old ditch, 43, and the new ditch, 33 (Table 4). Zimmer (1972) suggested that aquatic invertebrate production on submerged logs and overhanging brushpiles, associated with areas of shifting sand substrates, add significantly to the diversity of drifting fauna in a stream.

CHANNELIZATION EFFECTS ON WATER TEMPERATURE

Channelization associated with loss of foliage for bank shading and decreases in flow may have contributed to higher water temperatures in

Table 4. Aquatic Macroinvertebrates Collected from Various Stations June, 1974, through May, 1976, Buena Vista Marsh, Portage County, Wisconsin. (Benthos samples - B, June, 1974 - May, 1975; b, July, 1975 - May, 1976; Drift samples - D, June, 1974 - May, 1975; d, July, 1975 - May, 1976; Q - present only in qualitative samples, June, 1974 - May, 1975).

	UPSTREAM			DOWNSTREAM		
Arthropoda	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
C. Insecta						
O. Coleoptera - beetles						
F. Chrysomelidae - leaf beetles						
Donacia	bD		D	b	Bb d	Bb d
F. Curculionidae - weevils	D	B D		D	D	
F. Dytiscidae - predaceous diving beetles						
Agabus	BbD	BbDd	b			d
Copotomus					Q	
Deronectes	B	b	Bb			
Hydaticus		Q	D	Q	Q	
Hydroporus	B	B d	B	B d	Dd	D
Hydrovatus			b			
Hygrotus			b d		b	D
Ilybius		b	b		B	
Laccophilus		Q	D	B D	D	
Liodessus	Dd	D	B Dd		b d	B D
F. Elmidae - riffle beetles						
Dubiraphia	Bb	Bb	b d	BbDd	BbDd	BbDd
Optioservus	Bb d	BbD	BbD		BbDd	B Dd
F. Gyrinidae - whirligig beetles						
Dineutus	Q	b				
Gyrinus	B Dd	Q	bQ	BbDd	BbDd	BbDd
F. Haliplidae - crawling water beetles						
Haliplus	BbDd	D		B D	B D	D
Peltodytes	b	D	D		B	D

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
F. Hydraenidae						
Hydraena		d	D			D
F. Hydrophilidae - water scavenger beetles						
Berosus	b			bQ		
Crenitis			d			
Enochrus	Dd					
Helophorus	B	D	Dd		D	D
Hydrobius			B d			
Hydrochus	D					d
Hydrophilus						d
Tropisternus	D	Q	Dd	B	D	bQd
O. Diptera - flies						
F. Ceratopogonidae - biting midges	BbD	BbD	BbD	Bb	Bb	Bb d
F. Chironomidae - midges	BbDd	BbDd	BbDd	BbDd	BbDd	BbDd
F. Culicidae - mosquitoes						
Anopheles				Q		
F. Empididae						
Clinocera		Q				
Hemerodromia	B D	B D	Bb d	B	Bb	D
F. Ephydridae - shore flies	B		B		B	
Hydrellia	D	b				
F. Muscidae - anthomyiids		D		B	D	D
Limnophora	B D					
F. Psychodidae - moth flies						
Pericoma			B			
F. Ptychopteridae - phantom crane flies						
Liriope		Bb d				
F. Rhagionidae - snipe flies						
Atherix	BbD	BbDd	Bb	BbD	BbDd	BbDd

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
F. Sciomyzidae	D					
Sepedon				Q		
F. Simulidae - black flies						
Simulium	BbDd	BbDd	BbDd	BbDd	BbDd	BbDd
F. Stratiomyidae						
Eulalia		B				
Euparyphus	Dd	d				
Stratiomys			D			
F. Tabanidae - horse flies						
Chrysops	BbDd	BbD	Bb d	Bb	Bb d	BbDd
F. Tipulidae - crane flies						
Antocha	b		Bb	b d	Bb	BbDd
Dicranota	BbDd	BbD	BbDd			d
Erioptera						B
Hexatoma	BbD	Bb	Bb	Bb	Bb	BbD
Limonia		b				
Pilaria	b	Bb	Bb	B	b	Bb
Prionocera						Q
Tipula	b	BbD	Bb d	b	bQ	b d
O. Ephemeroptera - mayflies						
F. Baetidae						
Baetis	Bb d	Bb d	BbDd	B Dd	B Dd	BbDd
Callibaetis				B	D	D
F. Baetiscidae						
Baetisca	d				B d	b d
F. Caenidae						
Caenis	BbDd	d	BbD	BbDd	BbDd	BbDd
F. Ephemerellidae						
Ephemerella			d		b	bDd

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
F. Ephemeridae						
Hexagenia	BbD		BbD	Bb d	BbDd	BbDd
F. Heptageniidae				b		
Heptagenia						B d
Stenonema		d	B		b	BbDd
F. Leptophlebiidae						
Leptophlebia	D	Bb d	Bb		b d	BbDd
Paraleptophlebia		B		D		
F. Siphlonuridae						
Isonychia						B
F. Tricorythodes						
Tricorythodes	Bb		BbD	B		b d
O. Hemiptera - bugs						
F. Belostomatidae - giant water bugs						
Belostoma		B	Q	Qd	Bb	Q
Lethocerus				d		
F. Corixidae						
Hesperocorixa	BbDd	BbDd	BbDd	BbDd	BbDd	BbDd
F. Gerridae - water striders						
Gerris		Q	Qd			
F. Nepidae - water scorpions						
Ranatra		Qd	D		Q	Qd
F. Notonectidae - back swimmers						
Notonecta			Q	Q	Q	Q
F. Pleidae - pygmy back swimmers						
Plea striola	d	d				
F. Saldidae	D	D				
O. Megaloptera						
F. Sialidae						

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Sialis	Bb	Bb	Bb			
O. Odonata						
S.O. Anisoptera - dragonflies			D			
F. Aeshnidae						
Aeshna	b	B		Bb d	Bb	
Anax				Q		
F. Cordulegastridae						
Cordulegaster						B
F. Gomphidae	d					b
S.O. Zygoptera						
F. Calopterygidae						
Agrion	Q		B	B	B	Q
F. Coenagrionidae						
Anomalagrion	B					D
Enallagma					d	d
Ischnura	D			Qd	D	D
O. Plecoptera						
S.O. Filipalpia						
F. Nemouridae						
Taeniopteryx			Bb			Bb d
F. Pteronarcidae						
Pteronarcys						B d
S.O. Setipalpia						B
F. Perlidae						
Perlesta						B d
F. Perlodidae						
Isoperla			Bb			B D
O. Trichoptera - caddis flies						
F. Brachycentridae						

Table 4.(cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Brachycentrus	BbD	BbD	BbDd		Bb	BbDd
F. Glossosomatidae						
Glossosoma			b			
F. Hydropsychidae						
Cheumatopsyche	Bb d	D	Bb	Bb d	BbDd	Dd
Hydropsyche	B D	B D	B D		D	B Dd
F. Hydroptilidae						
Agraylia					d	
Ochrotrichia					B	
F. Lepidostomatidae						
Lepidostoma		D	B			
F. Leptoceridae			d	Bb	B	Dd
Athripsodes			B			B
Mystacides						D
F. Limnephilidae	b					
Glyphopsyche		b				
Hesperophylax		B	Bb			
Hydatophylax	D	b d	d			b d
Limnephilus	BbDd	BbDd	BbDd	Dd	Bb d	Dd
Nemotaulius	d	bQd	B		b	
Platycentropus	Bb	Bb d	b d	Q	b d	bDd
Pseudostenophylax	Bb		b			
Psychoglypha	B		B			
Pycnopsyche	Bb d	BbD	BbDd	b	BbDd	BbDd
Neophylax		b				
Nyctiophylax						d
F. Molannidae						
Molanna		B	B	D		D
F. Phryganeidae						
Ptilostomus		Bb	d			

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
C. Crustacea						
O. Amphipoda - sideswimmers						
F. Gammaridae						
Gammarus	BbDd	BbDd	BbDd	Bb	BbDd	BbDd
O. Isopoda - sowbugs						
F. Asellidae						
Asellus						d
O. Decapoda - crayfish						
F. Cambarinae						
Orconectes	bQd	B		B d	B	B d
Annelida - segmented worms						
C. Hirudinea - leeches						
F. Eropobdellidae						
Erpobdella		Bb	Bb	Bb	b	
F. Glossiphoniidae						
Glossiphonia complanata		B	B			
Glossiphonia sp.	b	b	b d	b	B	
Placobdella montifera				B		
Placobdella sp.				B	b	
F. Hirudidae						
Haemopis	b	Bb d	Bb	B	Bb	d
Macrobdella decora	B					
C. Oligochaeta - aquatic earthworms	BbDd	BbDd	BbDd	BbDd	BbDd	BbDd
Nematoda - roundworms	Bb	Bb d	Bb d	Bb d	Bb d	BbDd
Hydracarina - water mites	Bb	D	BbD	BbD	B	B D
Collembola - spring tails			b d	d	d	d

Table 4. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Mollusca						
C. Gastropoda - snails						
F. Ancylidae - limpets						
Ferrissia	Bb	B		BbDd	BbDd	
F. Lymnaeidae - pond snails						
Lymnaea	BbDd	Bb d	Bb d	BbDd	BbDd	Dd
F. Planorbidae - orb snails						
Gyraulus	BbDd	BbDd	B	Bb d	BbD	b d
Helisoma	BbDd	D		BbD	BbD	
Planorbula	B	d				
F. Physidae - pouch snails						
Physa	BbDd	BbD	BbDd	Bb	BbD	BbD
Aplexa			Bb			
F. Viviparidae						
Viviparus					b	
C. Pelecypoda - clams						
F. Sphaeriidae						
Musculium			b		B	
Pisidium	Bb d	Bb	Bb d	BbD	Bb	Bb
Sphaerium	Bb	Bb	Bb	b	b	Bb
F. Unionidae						
Lasmigona					b	
Nemertea - proboscis worms						
Prostoma				B	B D	D
Nematomorpha - horsehair worms	d	d			d	d
Tubellaria - flatworms						
O. Tricladida						
F. Plannaridae		b	b			
Coelenterata - hydroids						

Table 4 (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
O. Hydroida F. Hydridae Hydra		b d		d	d	
Total Taxa	76	81	84	64	77	81
Benthic Taxa	55	57	64	48	59	48
Drift Taxa	48	49	47	33	43	69

new ditches than in old ditches and natural streams. New ditches had higher mean monthly daily maximum water temperatures than other sites (Table 5); differences were not statistically significant. Daily fluctuations, maxima, and means of water temperature were also generally higher in new and old ditches than natural control streams between September 1974 to May 1976 (Appendix C-1 and C-2). Abundant groundwater flow should have tended to lower water temperatures in all streams and ditches during the study. However, newly channelized sites had significantly higher mean maximum water temperatures ($F = 4.73$; 1, 26 d.f., $p < 0.05$) between the first and second year of the survey (Appendix C-1 and C-2).

Water temperatures in the newly channelized downstream ditch exceeded the requirements of cold water fish and probably resulted from lack of shading from bank foliage, and slower flow than old ditches and natural streams. Headrick (1976) recorded water temperatures of 25°C or higher in the downstream ditches for 10 days in July and August 1975, and 25°C was recorded for 5 consecutive days in the downstream new ditch. The 133-hr upper lethal temperature for brook trout is 25°C (Federal Water Pollution Control Administration, 1967). Hence, the maximum water temperatures recorded in the downstream ditches in 1975, although not statistically different from natural stream temperatures, were biologically important. A small increase in water temperature, which is likely to be caused when flow is slowed or shade is removed, can be important to cold water fish and aquatic macroinvertebrates. Gaufin (1973) suggested that maximum water temperatures should not exceed the requirements of cold water fish, such as trout, if a diversity of cold water insects is desired.

CHANNELIZATION EFFECTS ON WATER CHEMISTY

Channelization appeared to increase alkalinity and total and calcium hardness in new and old ditches. In the upstream area, alkalinity, total and calcium hardness, and specific conductance were significantly higher in the ditches than in the natural stream and the same parameters were generally higher, although not significantly, in the ditches than in the natural stream in the downstream area (Appendix D-1 and D-2). Arner et al. (1976) reported increases in total hardness in a newly channelized segment of the Luxapalila River in Mississippi and Alabama. Since approximately 90% of the stream flow in the Buena Vista Marsh originates as groundwater, surface water hardness would reflect the hard water conditions of groundwater.

Other water quality parameters such as NO_3, PO_4, pH, etc., were similar in the ditches and natural streams or exhibited trends described by Wilson (1977) for land use, fertilizer application, and irrigation.

Table 5. Monthly Mean Water Temperatures (°C) from Upstream and Downstream Sites, September 1974 through May 1976, Buena Vista Marsh, Portage County, Wisconsin.

	Upstream			Downstream		
	New ditch	Old ditch	Natural	New ditch	Old ditch	Natural
September 1974 to May 1975[a]						
Mean of daily maxima	8.8	8.4	7.6	7.1	7.2	6.3
Mean of daily minima	4.1	3.5	3.7	4.4	4.1	3.8
Mean of daily temperature	6.1	5.9	5.7	5.6	5.7	4.9
Mean of daily fluctuation	4.7	3.9	3.8	2.6	3.0	2.5
June 1975 to May 1976[b]						
Mean of daily maxima	9.8	9.8	9.1	11.0	10.3	10.3
Mean of daily minima	6.5	7.4	6.4	7.7	7.6	7.0
Mean of daily temperature	8.0	8.6	8.3	9.2	9.0	8.6
Mean of daily fluctuation	3.0	2.6	3.3	3.0	2.9	3.1

[a] data averaged for 9 months of daily thermograph recordings.

[b] data averaged for 12 months of daily thermograph recordings.

CONCLUSIONS

Both density and biomass of macroinvertebrate benthos are strongly influenced by substrate. The greater the amount of productive substrates, i.e., vegetation, silt-detritus, and gravel, the greater the amount of benthos. Hence, channelization or any other activity that increases the amount of sand substrate will tend to decrease the amount of benthos. Also, channelization or other activities that cause substrates to be unstable will be detrimental to benthos.

The relation of drift to substrates is not so simple. Drifting seston (suspended particulate organic and inorganic matter) was inversely related to proportions of productive substrates, probably because they provided interstices for entrapment of seston. Consistent with this inverse relation for drifting seston, numbers of drifting invertebrate taxa were greater at sites with greater percentages of sand substrate. Invertebrate drift density was positively related to amount of seston in one area (upstream) and to benthos density in another (downstream), and it also appeared to be influenced by proportion of productive substrates and discharge. Hence, the effect of channelization on drift will be difficult to predict, but it will be a function of its effect on substrate, benthos, and discharge.

Channelization or other activities that remove stream-side vegetation or decrease flow or both will probably increase water temperature, which can be detrimental to cool-water biota.

RECOMMENDATIONS

Cost benefit analysis incorporating fish and wildlife losses, adverse effects of possible increased downstream flooding, adverse effects to potential development on the drained flood plain, and an evaluation of the need for more agricultural land of marginal quality, should be determined for each proposed channelization project.

If channelization is to be undertaken, cold water fish and invertebrate losses may be mitigated by:

1) Controlling sediment movement. Spoil banks should be spread on adjacent fields and vegetation should be maintained.

2) Stabilizing the channel to provide a more productive habitat. Bank stabilization and stream improvement structures, such as rock revetments and wing deflectors might be installed to create pools, add cover, maintain stream bed stability, and reduce inflow of sediment.

3) Not diverting flow from two or more ditches to a downstream natural stream. Increased discharge can cause erosion of natural stream banks if the channel cannot compensate for additional flow.

4) Keeping cattle off spoil banks to minimize erosion and siltation.

5) Providing shade along spoil banks. Trees and shrubs could be planted along ditches to reduce summer maximum water temperature.

6) Designing ditches similar to lotic rather than lentic water. Dredging a channel wide and deep slows flow and tends to increase surface area and water temperature.

Channel sinuosity, caused by stream improvement structures, would result in establishment of erosional and depositional habitats with associated diversity of substrate, current velocity, depth, and light intensity. Improvements in a stream or watershed tend to cause new sediment or flow adjustments to the changed current velocity and sediment load and capacity (Apmann and Otis, 1965). Stream improvement structures, especially in channelized areas, must be anchored to avoid undercutting.

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Appendix B-1. Biomass and Density of Drifting Invertebrates, Buena Vista Marsh, Portage County, Wisconsin. (August, 1974 to May, 1975)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³
Insecta												
Coleoptera												
Aug., 1974	2.06	.01	2.40	TR.	5.37	.01	1.21	.04	2.60	.01	.46	TR.
Sept., 1974	1.48	.01	1.26	TR.	.95	.16	.63	TR.	1.27	TR.	1.78	TR.
Nov., 1974	1.31	.01	.46	TR.	1.39	.02	2.90	.01	1.06	.02	8.78	.02
Apr., 1975	1.14	TR.	1.79	TR.	3.01	TR.	5.01	.04	2.63	.01	1.01	TR.
May, 1975	1.44	.01	1.75	.01	--	--	--	--	.29	TR.	.62	TR.
Diptera												
Chironomidae												
Aug., 1974	22.49	.03	22.01	.02	1.31	TR.	6.13	TR	4.25	.01	7.40	.01
Sept., 1974	83.26	.15	8.84	.01	2.60	TR.	14.41	02	9.31	.01	10.24	.01
Nov., 1974	3.93	.01	9.25	.01	1.39	TR.	4.36	TR.	3.34	.01	1.76	.01
Apr., 1975	12.09	.01	94.18	.26	8.69	.02	15.02	.02	18.34	.03	7.09	.02
May, 1975	33.76	.04	250.30	.67	28.63	.03	16.49	.01	9.15	.02	22.50	.06
Simulidae												
Simulium												
Aug., 1974	4.88	.02	10.46	.02	--	--	1.82	TR.	1.77	.01	.93	.01
Sept., 1974	.50	TR.	5.05	.02	.24	TR.	3.13	.01	5.50	.01	20.47	.05
Nov., 1974	.33	TR.	1.39	TR.	.70	TR.	3.63	.01	2.44	.01	2.34	TR.
Apr., 1975	.68	.01	1.18	.01	1.67	.01	1.00	TR.	.38	TR.	--	--
May, 1975	.72	TR.	12.71	.05	16.68	.05	3.09	.01	1.07	TR.	31.73	.11
Ephemeroptera												
Aug., 1974	.38	TR.	5.02	.02	5.87	.01	--	--	.73	.01	26.29	.06
Sept., 1974	--	--	13.89	.08	4.26	.02	4.38	.02	2.54	.02	46.72	.13
Nov., 1974	1.97	.01	--	--	--	--	2.90	TR.	1.41	.01	4.10	.03
Apr., 1975	.23	TR.	.30	TR.	.33	TR.	--	--	.38	TR.	.14	TR.
May, 1975	.36	TR.	.44	.01	.31	.01	2.75	TR.	1.24	TR.	3.42	.03

APPENDIX B-1. (cont.)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³
Insecta (cont.)												
Hemiptera												
Hesperocorixa												
Aug., 1974	3.20	.01	.87	TR.	--	--	12.90	.03	11.31	.03	2.94	.01
Sept., 1974	6.94	.02	1.90	.01	.47	.01	15.04	.03	16.50	.05	2.22	.01
Nov., 1974	8.84	.13	.46	TR.	2.09	.03	35.58	.39	4.96	.08	10.25	.09
Apr., 1975	16.20	.08	3.25	.01	1.34	.02	9.02	.05	3.04	.03	.72	TR.
May, 1975	--	--	--	--	--	--	2.06	.01	.25	TR.	3.32	.02
Trichoptera												
Aug., 1974	.89	.01	5.24	.15	1.94	.01	--	--	2.81	.03	29.61	.27
Sept., 1974	--	--	--	--	2.60	.02	--	--	1.69	TR.	4.45	.04
Nov., 1974	1.31	.39	1.32	.05	16.36	.12	2.18	.01	--	--	1.46	.04
Apr., 1975	.68	TR.	2.09	.04	3.34	.03	1.00	.40	--	--	.43	TR.
May, 1975	--	--	3.07	.26	3.78	.12	.34	TR.	--	--	1.24	.03
Amphipoda												
Gammarus												
Aug., 1974	2.06	.02	31.38	.19	5.37	.01	--	--	--	--	13.51	.12
Sept., 1974	12.39	.17	10.10	.03	5.91	.04	--	--	--	--	4.45	.01
Nov., 1974	19.66	.59	25.90	.33	4.52	.09	--	--	--	--	--	--
Apr., 1975	.91	TR.	36.37	.87	2.67	.07	--	--	--	--	.58	.01
May, 1975	17.24	.31	14.03	.28	--	--	--	--	.25	TR.	1.55	.02
Mollusca												
Aug., 1974	3.99	.22	.87	TR.	--	--	.45	TR.	--	--	.70	.01
Sept., 1974	80.78	8.14	--	--	.24	TR.	--	--	1.69	.02	.44	TR.
Nov., 1974	1.31	.05	--	--	--	--	--	--	--	--	--	--
Apr., 1975	29.67	.60	1.79	TR.	--	--	2.00	.01	.19	.03	.14	TR.
May, 1975	3.23	.02	2.19	.19	--	--	.69	.07	.29	TR.	--	--

APPENDIX B-1. (cont.)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³	#/100m³	g/100m³
Total Aquatic												
Aug., 1974	40.35	.33	79.99	.42	18.06	.05	22.92	.07	25.13	.08	82.74	.48
Sept., 1974	189.31	8.61	41.04	.15	17.98	.52	37.58	.08	39.34	.12	94.34	.29
Nov., 1974	40.29	1.19	41.16	.47	38.28*	.25	53.00	.43	14.08	.13	29.86	.21
Apr., 1975	62.07	.71	156.15	1.32	21.73	.18	34.05	.52	25.32	.11	11.57	.06
May, 1975	57.46	.38	331.40	1.61	50.34	.20	26.12	.11	13.20	.03	67.91	.29
Aerial Aquatic												
Emerging Adults Insects												
Aug., 1974	47.17	.85	12.00	.04	4.06	.01	1.50	TR.	8.08	.36	10.31	.13
Sept., 1974	133.80	.05	53.66	.02	14.90	.01	13.15	.01	27.91	.01	13.35	.01
Nov., 1974	13.76	.01	3.70	TR.	2.44	TR.	.73	TR.	.35	TR.	1.76	TR.
Apr., 1975	--	--	964.15	1.96	7.02	.01	1.00	TR.	.19	TR.	--	--
May, 1975	10.42	.01	5.70	.01	51.60	.03	1.38	TR.	.12	TR.	1.55	TR.
Terrestrial												
Hymenoptera												
Aug., 1974	6.55	.01	2.61	.01	2.11	TR.	--	--	.73	TR.	5.02	.01
Sept., 1974	7.43	.01	1.90	TR.	.71	TR.	--	--	.84	TR.	8.46	.01
Nov., 1974	--	--	--	--	--	--	--	--	--	--	--	--
Apr., 1975	--	--	--	--	--	--	--	--	.19	TR.	.29	TR.
May, 1975	2.16	.03	1.75	.01	.31	TR.	--	--	--	--	3.94	.02
Total Terrestrial												
Aug., 1974	8.36	.04	7.40	.01	3.75	.01	1.95	TR.	3.21	.02	7.27	.02
Sept., 1974	297.34	.07	22.10	.01	5.68	TR.	194.81	.03	189.90	.04	16.46	.02
Nov., 1974	5.24	.01	--	--	--	--	.73	TR.	.35	TR.	3.22	TR.
Apr., 1975	--	--	--	--	--	--	--	--	.19	TR.	.43	TR.
May, 1975	3.23	.07	10.52	.09	1.57	TR.	.34	TR.	.50	TR.	7.57	.04

*27.84 without collembola.

Appendix B-2. Biomass and Density of Drifting Invertebrates, Buena Vista Marsh, Portage County, Wisconsin. (July, 1975 to May, 1976).

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3
Insecta												
Coleoptera												
July, 1975	---	---	64.68	.08	2.76	.01	3.50	.01	4.15	.01	1.61	.01
Sept., 1975	2.35	.02	.48	TR.	---	---	---	---	1.24	.01	1.65	.01
Oct., 1975	.50	TR.	.64	TR.	2.30	.01	---	---	2.81	.01	1.24	.01
Dec., 1975	4.25	.03	2.31	TR.	1.48	.04	---	---	2.99	.02	1.88	TR.
April, 1976	.33	TR.	---	---	1.70	.03	.91	TR.	.62	TR.	.71	TR.
May, 1976	2.11	.01	1.38	.01	.79	TR.	---	---	2.29	.01	.73	.01
Diptera												
Chironomidae												
July, 1975	6.23	.01	20.02	.02	100.85	.12	15.40	.02	32.94	.04	18.51	.03
Sept., 1975	4.20	.01	2.52	.02	23.72	.03	5.00	.01	6.47	.01	9.25	.01
Oct., 1975	6.16	.01	1.38	TR	5.15	.01	11.38	.08	16.06	.02	2.17	.01
Dec., 1975	5.95	.01	71.64	.03	47.68	.11	173.23	.18	85.91	.14	14.08	.04
April, 1976	70.31	.09	36.85	.05	37.49	.04	148.08	.35	44.32	.05	26.20	.04
May, 1976	24.25	.03	13.91	.02	99.57	.09	14.26	.02	68.87	.13	20.36	.04
Simulidae												
Simulium												
July, 1975	3.44	.03	1.29	TR.	5.21	.06	2.93	.02	8.80	.04	.42	TR.
Sept., 1975	14.60	.06	.48	TR.	---	---	---	---	4.81	.03	8.70	.02
Oct., 1975	1.38	.01	---	---	---	---	4.26	.03	6.53	.04	7.55	.03
Dec., 1975	39.83	.19	8.25	.09	4.90	.12	88.14	.31	275.94	1.05	3.70	.01
April, 1976	1.11	TR.	1.42	.02	.86	TR.	4.14	.03	14.11	.09	2.87	.01
May, 1976	2.11	.01	6.10	.03	27.26	.10	1.40	TR.	5.48	.02	53.59	.19

APPENDIX B-2 (cont.)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3
Ephemeroptera												
July, 1975	8.19	.05	2.29	.04	9.94	.04	.88	TR.	5.07	.02	8.96	.04
Sept., 1975	---	---	4.53	.04	1.29	.01	.91	TR.	1.85	.01	5.43	.01
Oct., 1975	---	---	6.35	.04	1.08	.01	---	---	---	---	13.15	.12
Dec., 1975	---	---	6.43	.04	.74	.01	2.68	.03	7.48	.04	10.10	.06
April, 1976	.33	TR.	.91	.01	.86	.02	---	---	.52	.03	3.73	.08
May, 1976	1.05	TR.	6.12	.02	2.19	.01	---	---	3.47	.48	13.41	.11
Hemiptera												
Hesperocorixa												
July, 1975	47.05	.07	---	---	1.22	TR.	10.11	.01	5.00	.02	2.02	TR.
Sept., 1975	39.11	.17	9.23	.02	2.52	.01	7.98	.06	4.89	.03	3.30	.01
Oct., 1975	5.85	.03	.49	TR.	11.67	.12	28.98	.22	7.83	.06	4.24	.04
Dec., 1975	5.60	.03	4.34	.05	.74	TR.	139.94	.87	54.29	.36	7.45	.08
April, 1976	11.38	.04	.91	.10	.42	.01	2.26	.01	1.42	.01	1.41	.01
May, 1976	1.05	TR.	.49	TR	---	---	.47	TR.	6.50	.04	.44	TR.
Trichoptera												
July, 1975	---	---	2.29	TR.	3.67	.02	---	---	1.94	TR.	6.42	.01
Sept., 1975	---	---	.27	.01	8.29	.19	.91	TR.	---	---	1.39	.01
Oct., 1975	---	---	---	---	6.45	.02	---	---	---	---	3.73	.05
Dec., 1975	3.68	.62	4.12	.39	90.47	2.06	---	---	2.00	.30	13.46	.27
April, 1976	1.11	TR.	.30	TR.	8.61	.13	.49	TR.	.09	TR.	4.65	.09
May, 1976	---	---	.89	.10	7.85	.90	.47	TR.	.73	TR.	4.62	.43
Amphipoda												
Gammerus												
July, 1975	4.95	.01	7.16	.19	6.53	.08	---	---	---	---	19.14	.21
Sept., 1975	2.58	.04	3.33	.05	46.59	.76	---	---	---	---	13.63	.11
Oct., 1975	2.41	.10	1.04	TR.	30.37	.18	---	---	---	---	2.85	.03
Dec., 1975	20.99	.87	28.33	.61	51.64	.88	---	---	---	---	16.19	.50
April, 1976	4.63	.10	2.42	.05	3.70	.02	---	---	.21	.02	3.08	.06
May, 1976	3.69	.02	1.61	.01	1.77	TR.	---	---	---	---	3.88	.01

APPENDIX B-2 (cont.)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3
Mollusca												
July, 1975	---	---	1.65	.01	2.44	.09	---	---	---	---	---	---
Sept., 1975	44.90	9.64	1.56	.01	.15	TR.	.67	TR.	---	---	---	---
Oct., 1975	13.27	3.33	---	---	---	---	1.90	.01	2.84	.02	---	---
Dec., 1975	6.85	2.49	---	---	---	---	---	---	---	---	---	---
April, 1976	14.73	1.82	1.12	.17	.42	.01	7.24	2.97	---	---	.72	8.30
May, 1976	3.16	4.04	.89	TR.	---	---	---	---	.57	TR.	---	---
Total Aquatic												
July, 1975	70.69	.17	101.97	.34	133.84	.42	34.61	.06	63.81	.13	66.92	.36
Sept., 1975	109.02	9.94*	23.33	.15	88.48	1.14	17.49	.07	20.49	.08	47.51	.22
Oct., 1975	32.34	3.51	11.67	.11	59.22	.35	47.47	.35	40.73	.19	38.00	.43
Dec., 1975	88.21	4.27	127.24	1.21	207.42	3.67	406.61	1.40	429.61	1.94	72.43	1.74
April, 1976	105.69	2.09	43.93	.27	55.63**	.40	168.35	3.35	62.54	.20	45.64	8.61
May, 1976	37.42	4.11	32.37	.34	146.52	1.45	17.68	.02	90.83	.70	100.34	.86
Aerial Aquatic												
Emerging Adults Insects												
July, 1975	12.34	.01	108.56	.12	35.65	.10	5.31	.01	6.18	.04	3.21	.05
Sept., 1975	26.59	.04	9.42	.01	---	---	4.72	TR.	2.77	TR.	4.34	.01
Oct., 1975	29.72	.03	21.35	.03	13.40	.01	2.85	TR.	41.42	.11	11.05	.05
Dec., 1975	6.85	.02	1.82	.02	3.95	TR.	20.59	.05	16.33	.04	4.92	.01
Apr., 1976	.33	TR.	728.88	.89	102.91	.05	12.86	.01	3.60	.01	2.13	TR.
May, 1976	5.27	TR.	26.70	.05	101.55	.07	4.45	TR.	26.08	.01	12.45	.02
Terrestrial												
Hymenoptera												
July, 1975	4.75	.02	18.54	.04	5.52	.01	3.54	.01	4.24	TR.	2.84	.01
Sept., 1975	14.64	.04	3.14	.01	3.24	.01	1.34	TR.	1.23	.01	3.41	.02
Oct., 1975	5.54	.01	3.36	TR.	3.43	.01	---	---	7.76	.01	1.56	.01
Dec., 1975	---	---	---	---	---	---	2.68	.01	2.00	TR.	---	---
Apr., 1976	---	---	.30	.01	.84	TR.	.49	TR.	---	---	---	---
May, 1976	1.05	TR.	.98	TR.	.79	.01	---	---	4.32	.01	2.86	.02

APPENDIX B-2 (cont.)

	UPSTREAM						DOWNSTREAM					
	New Ditch		Old Ditch		Natural		New Ditch		Old Ditch		Natural	
	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3	#/100m^3	g/100m^3
Total Terrestrial												
July, 1975	13.07	.05	54.55	1.09	12.91	.04	6.21	.01	9.45	.13	8.85	.09
Sept., 1975	181.49	.11	11.56	.04	3.39	.01	21.61	.01	19.95	.02	6.20	.02
Oct., 1975	57.13	.04	13.47	.01	13.29	.02	6.29	TR.	27.00	.03	7.53	.01
Dec., 1975	9.46	TR.	4.34	TR.	9.80	TR.	38.52	.05	8.26	TR.	6.09	.01
Apr., 1976	---	---	.90	.01	1.26	TR.	2.40	TR.	.50	TR.	.95	TR.
May, 1976	1.05	TR.	3.88	.01	3.76	.04	1.41	TR.	4.89	.01	5.66	.10

* 17.12 with one Decapoda.
**690.45 with Collembola.

Appendix C-1. Monthly Water Temperature (°C), Buena Vista Marsh, Portage County, Wisconsin. (Sept., 1974 to May, 1976) (---thermograph data not available).

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
MEAN DAILY MAXIMUM						
SEPT.	15.0	13.3	14.3	16.4	15.3	14.9
OCT.	11.4	12.1	10.9	10.4	10.3	9.9
NOV.	6.8	9.2	6.5	4.8	4.6	4.5
DEC.	4.8	4.7	3.2	1.4	1.2	1.1
JAN.	4.3	3.2	1.3	0.6	0.2	0.7
FEB.	4.9	---	1.7	1.2	0.7	1.4
MAR.	---	4.2	4.5	5.4	4.6	3.0
APR.	7.9	8.1	10.5	9.5	10.9	6.1
MAY	15.6	12.7	15.2	14.3	17.1	15.3
MEAN DAILY MINIMUM						
SEPT.	8.4	8.1	8.8	12.0	10.9	10.6
OCT.	6.1	4.2	5.5	7.1	5.4	6.1
NOV.	3.3	1.4	3.7	2.4	2.2	1.8
DEC.	1.8	-0.4	0.8	0.2	0.0	-0.3
JAN.	1.6	-0.3	0.5	0.3	-0.2	0.1
FEB.	0.5	---	-0.2	0.2	-0.3	-0.6
MAR.	---	1.7	0.4	1.5	1.7	0.4
APR.	2.8	4.4	4.0	6.4	5.4	5.1
MAY	8.4	8.6	9.5	9.8	11.7	11.3
MEAN TEMPERATURE						
SEPT.	12.0	10.8	12.9	14.0	13.0	12.7
OCT.	7.6	8.2	7.8	8.7	8.5	7.9
NOV.	4.9	5.2	5.1	3.6	3.4	3.2
DEC.	3.2	2.2	2.0	0.6	0.5	0.2
JAN.	2.6	1.4	0.8	0.4	0.0	0.3
FEB.	2.2	---	0.6	0.7	0.1	0.1
MAR.	---	2.8	2.4	3.2	3.0	1.5
APR.	5.1	5.8	7.0	7.8	8.0	5.2
MAY	11.1	10.8	12.7	11.9	14.5	13.1
MEAN DAILY FLUCTUATION						
SEPT.	6.5	5.1	5.4	4.4	4.4	4.3
OCT.	5.5	---	4.7	3.5	3.9	3.9
NOV.	3.4	---	2.8	2.4	2.4	2.7
DEC.	3.0	---	2.4	1.2	1.2	1.3
JAN.	2.7	---	0.7	0.3	0.3	0.7
FEB.	4.4	---	2.3	0.6	0.9	2.1
MAR.	---	2.5	4.1	3.8	2.9	2.7
APR.	5.1	3.7	6.3	3.1	5.8	0.9
MAY	7.3	4.2	5.7	4.3	5.4	3.9

Appendix C-2. Monthly Water Temperature (°C), Buena Vista Marsh, Portage County, Wisconsin. (Sept., 1975 to May, 1976)

	UPSTREAM			DOWNSTREAM		
	New Ditch	Old Ditch	Natural	New Ditch	Old Ditch	Natural
MEAN DAILY MAXUMUM						
JUNE	16.7	13.0	13.6	18.3	17.8	18.0
JULY	17.6	18.2	17.1	23.5	22.7	21.2
AUG.	16.2	17.2	19.7	20.6	20.8	19.1
SEPT.	11.8	10.8	12.3	14.3	14.2	13.7
OCT.	9.8	10.4	10.6	10.9	12.9	12.0
NOV.	6.0	7.9	6.9	6.6	6.8	6.4
DEC.	3.0	4.8	4.9	3.1	2.4	3.0
JAN.	2.0	2.1	0.2	-0.2	-0.5	0.3
FEB.	5.3	4.6	3.6	2.6	1.6	2.1
MAR.	4.5	5.5	5.5	5.0	4.7	5.8
APR.	11.2	9.9	10.6	12.0	10.4	9.8
MAY	13.8	12.8	14.7	14.7	9.7	12.2
MEAN DAILY MINIMUM						
JUNE	10.9	11.3	10.4	13.7	14.1	13.1
JULY	13.8	15.2	12.2	19.4	18.0	14.8
AUG.	13.8	15.2	16.2	16.8	17.	14.6
SEPT.	10.0	9.4	8.9	10.9	11.4	10.7
OCT.	6.8	7.8	6.4	8.5	9.0	8.3
NOV.	4.5	6.5	4.0	4.8	4.4	4.1
DEC.	1.5	3.7	2.4	1.4	0.9	1.9
JAN.	1.3	1.0	-1.2	-0.4	-1.1	-0.9
FEB.	1.9	2.9	-0.1	0.8	0.1	0.6
MAR.	2.5	3.3	3.2	1.4	3.2	2.9
APR.	5.7	5.5	6.9	7.2	6.7	6.0
MAY.	5.7	7.2	8.0	7.9	7.9	8.1
MEAN TEMPERATURE						
JUNE	13.6	12.7	12.6	15.9	16.6	15.1
JULY	15.7	16.6	14.7	21.2	20.6	17.9
AUG.	14.9	15.9	17.6	18.9	19.0	16.8
SEPT.	10.4	9.9	10.5	12.1	12.7	12.3
OCT.	7.9	9.1	8.6	9.6	10.5	10.2
NOV.	5.3	7.2	5.5	5.7	4.8	5.3
DEC.	2.2	4.2	3.6	2.2	1.6	2.0
JAN.	1.6	1.7	-0.6	-0.3	-0.3	-0.3
FEB.	3.5	3.8	2.4	1.7	1.0	1.0
MAR.	3.6	4.5	4.4	3.2	4.6	4.0
APR.	8.5	7.8	9.2	9.6	8.4	8.7
MAY	9.2	9.8	11.3	10.6	8.8	10.0
MEAN DAILY FLUCTUATION						
JUNE	6.0	3.2	4.5	4.1	5.1	5.0
JULY	3.4	2.8	4.8	4.1	4.7	6.1
AUG.	2.8	2.3	3.5	3.9	3.6	4.5
SEPT.	1.4	2.8	3.4	2.2	2.7	3.0
OCT.	3.1	1.6	3.9	2.5	2.9	3.7
NOV.	1.6	1.4	3.1	1.8	2.5	2.5
DEC.	1.5	1.1	2.1	1.7	1.5	0.8
JAN.	0.7	1.2	1.4	0.5	0.6	1.3
FEB.	1.8	1.8	1.7	1.4	1.5	2.1
MAR.	2.0	2.3	2.3	3.6	3.1	2.0
APR.	5.5	4.4	2.7	5.0	4.3	2.1
MAY	6.2	5.8	6.6	5.4	1.8	4.1

Appendix D-1. Maximum, Minimum, and Mean Values[1] of Various Chemical Parameters, June, 1974 - May 1975[2], Buena Vista Marsh, Portage County, Wisconsin. (all values are ppm unless otherwise stated)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Dissolved oxygen						
mean	10.5	9.8	11.3	10.3	10.3	9.6
maximum	11.7	12.0	13.9	12.2	12.1	12.5
minimum	9.3	7.3	9.1	7.9	7.8	7.6
Chemical oxygen demand						
mean	12.82	7.68	6.21	20.98	15.83	19.81
maximum	16.90	12.66	18.98	33.22	23.12	30.96
minimum	7.40	4.61	0.77	11.52	2.30	11.52
pH (standard units)						
maximum	8.1	8.3	8.4	8.3	8.4	7.9
minimum	7.8	7.5	7.6	7.7	7.5	7.5
Alkalinity						
mean	183	117	113	184	185	162
maximum	194	124	120	194	198	170
minimum	160	112	106	170	174	154
Conductivity (µmhos/cm)						
mean	429	332	293	440	440	378
maximum	550	390	345	550	540	455
minimum	362	268	239	390	393	325
Total hardness						
mean	237	171	163	244	246	215
maximum	270	182	204	258	279	230
minimum	226	165	144	222	228	200
Calcium hardness						
mean	165	119	113	168	175	156
maximum	200	166	174	226	220	200
minimum	136	92	88	132	128	122

APPENDIX D-1. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Ortho phosphate						
mean	0.022	0.335	0.083	0.258	0.017	0.220
maximum	0.030	1.900	0.370	1.600	0.026	1.400
minimum	0.012	0.005	0.021	0.018	0.007	0.016
Total phosphate						
mean	0.098	0.419	0.082	0.289	0.027	0.233
maximum	0.430	2.240	0.250	1.900	0.037	1.450
minimum	0.018	0.028	0.036	0.014	0.016	0.017
NH_4-N						
mean	0.005	0.14	0.02	0.04	0.02	0.03
maximum	0.04	0.32	0.14	0.14	0.07	0.04
minimum	0.00	0.00	0.00	0.00	0.00	0.00
NO_3+NO_2-N						
mean	3.06	5.32	4.67	2.89	2.90	2.12
maximum	3.82	5.46	5.29	3.64	3.61	2.91
minimum	2.49	4.73	3.96	2.06	2.06	1.47
Total N						
mean	0.64	0.59	0.51	0.64	0.78	0.78
maximum	1.09	0.77	1.09	0.77	1.19	1.26
minimum	0.39	0.28	0.11	0.25	0.56	0.42

[1] All analysis follows Standard Methods (A.P.H.A., 1971).

[2] Samples collected June, August, September, and November, 1974; January, February, April and May, 1975 (n=8).

Appendix D-2. Maximum, Minimum, and Mean Values[1] of Various Chemical Parameters, July, 1975 - May 1976[2], Buena Vista Marsh, Portage County, Wisconsin. (all values in ppm unless otherwise stated)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Dissolved oxygen						
mean	9.5	9.6	10.5	9.0	8.8	9.5[3]
maximum	11.7	11.1	12.2	13.1	12.7	11.3
minimum	7.1	7.2	7.3	6.3	6.3	7.7
Biochemical oxygen demand (5 day)						
mean	0.97	1.19	0.83	1.12	1.15	0.9[3]
maximum	2.35	2.45	1.90	1.75	2.35	2.70
minimum	0.00	0.40	0.15	0.35	0.35	0.15
Chemical oxygen demand						
mean	14.00	9.42	8.76	23.83	32.07	25.69
maximum	25.94	20.92	28.45	31.80	102.68	42.84
minimum	2.50	4.01	1.01	13.75	10.00	15.00
pH (standard units)						
maximum	8.0	8.3	8.4	8.0	8.1	8.0
minimum	7.5	7.7	7.7	7.6	7.5	7.6
Alkalinity						
mean	180	117	111	176	181	162
maximum	190	124	128	200	190	174
minimum	160	112	98	120	166	148
Conductivity (μmhos/cm)						
mean	451	340	303	468	471	409
maximum	550	390	345	550	540	455
minimum	416	288	272	425	425	376
Total hardness						
mean	259	186	172	274	268	236
maximum	292	234	200	322	296	270
minimum	230	156	138	224	240	196

APPENDIX D-2. (cont.)

	UPSTREAM			DOWNSTREAM		
	NEW DITCH	OLD DITCH	NATURAL	NEW DITCH	OLD DITCH	NATURAL
Calcium hardness						
mean	155	112	109	182	175	157
maximum	186	132	208	240	216	210
minimum	128	86	76	138	138	116
Fecal coliform[4] (MFFC-No/100 ml)						
mean[5]	38	390	183	196	122	273
maximum	130	1960	1010	940	580	1280
minimum	<5	<20	<5	<5	3	<5
Ortho phosphate						
mean	0.021	0.027	0.033	0.016	0.015	0.024
maximum	0.032	0.035	0.040	0.024	0.026	0.039
minimum	0.005	0.014	0.019	0.005	0.005	0.014
Total phosphate						
mean	0.040	0.072	0.051	0.068	0.041	0.046
maximum	0.049	0.169	0.081	0.226	0.073	0.085
minimum	0.027	0.029	0.028	0.014	0.011	0.003
NH_4-N						
mean	0.06	0.28	0.20	0.07	0.04	0.05
maximum	0.18	0.60	0.39	0.18	0.21	0.28
minimum	0.00	0.07	0.00	0.00	0.00	0.00
NO_3-NO_2-N						
mean	3.17	5.25	4.50	2.79	2.68	1.98
maximum	3.82	5.67	5.29	3.64	3.61	2.80
minimum	2.45	4.05	3.32	2.35	1.50	1.50
Total N						
mean	0.58	0.72	0.62	0.89	0.85	1.04
maximum	1.30	1.51	1.12	1.89	1.96	1.96
minimum	0.00	0.11	0.07	0.28	0.07	0.04

[1] All analysis follows Standard Methods (A.P.H.A., 1971).
[2] Samples collected July, September, October and December, 1975; January, February, April and May, 1976 (n=8).
[3] (n=7)
[4] (n=6)
[5] When calculating mean values, less than signs were ignored.

Appendix E-1. Drifting Seston From Buena Vista Marsh, Portage County, Wisconsin. (August, 1974 to May, 1975)

	UPSTREAM			DOWNSTREAM		
	New Ditch	Old Ditch	Natural	New Ditch	Old Ditch	Natural
Aug., 1974						
Dry weight ($g/100m^3$)	1.78	6.94	2.90	1.49	2.30	12.94
Organic detritus (%)	69.1	72.3	76.4	65.6	72.6	65.8
Sept., 1974						
Dry weight ($g/100m^3$)	26.50	3.23	1.61	3.03	1.78	9.51
Organic detritus (%)	67.1	81.7	82.9	51.9	76.1	72.4
Nov., 1974						
Dry weight ($g/100m^3$)	12.68	5.70	0.93	2.90	4.01	3.71
Organic detritus (%)	52.2	73.9	78.3	79.1	77.0	79.2
April, 1975						
Dry weight ($g/100m^3$)	13.32	6.11	1.40	3.62	16.54	13.30
Organic detritus (%)	73.4	61.9	77.1	78.1	67.2	70.6
May, 1975						
Dry weight ($g/100m^3$)	23.81	31.83	1.25	12.34	12.39	26.77
Organic detritus (%)	67.4	77.0	82.9	67.3	63.0	56.1
Mean for study period						
Dry weight ($g/100m^3$)	15.62	10.76	1.62	4.68	7.40	13.25
Organic detritus (%)	65.8	73.4	79.5	68.4	71.2	68.8

Appendix E-2. Drifting Seston From Buena Vista Marsh, Portage County, Wisconsin. (July, 1975 to May, 1976)

	UPSTREAM			DOWNSTREAM		
	New Ditch	Old Ditch	Natural	New Ditch	Old Ditch	Natural
July, 1975						
Dry weight ($g/100m^3$)	2.10	5.29	3.45	0.91	3.06	57.24
Organic detritus (%)	76.8	73.9	87.0	81.3	72.9	71.4
Sept., 1975						
Dry weight ($g/100m^3$)	3.46	0.82	16.34	0.36	0.47	37.97
Organic detritus (%)	75.0	83.4	68.5	76.1	71.5	76.4
Oct., 1975						
Dry weight ($g/100m^3$)	2.74	2.41	6.99	1.95	1.93	24.97
Organic detritus (%)	67.1	82.4	79.1	54.4	56.3	77.7
Dec., 1975						
Dry weight ($g/100m^3$)	2.44	26.26	41.85	4.65	5.61	22.70[1]
Organic detritus (%)	58.0	11.5	76.6	71.3	79.1	50.6
April, 1976						
Dry weight ($g/100m^3$)	6.41	1.42	2.58	3.08	2.17	29.64
Organic detritus (%)	64.9	93.4	87.1	72.1	62.7	53.9
May, 1976						
Dry weight ($g/100m^3$)	1.57	1.88	5.11	0.61	1.63	26.59
Organic detritus (%)	72.4	43.5	61.2	78.7	77.7	52.8
Mean for study period						
Dry weight ($g/100m^3$)	3.12	6.35	12.72	1.93	2.48	33.18
Organic detritus (%)	69.0	50.8	76.6	72.3	70.3	63.8

[1]Dry weight based on one sample from drift nets, remaining portion destroyed during processing

Appendix F. Correlation Matrices of r Values For All Variables Used In the Multiple Regression Analysis of Factors Affecting Invertebrate Drift Density From Upstream and Downstream Areas, August, 1974 Through May, 1976, Buena Vista Marsh, Portage County, Wisconsin. Variable Codes Are: Y_1 = Drift Density With Molluscs and Aquatic Adult Insects, Y_2 = Drift Density With Molluscs But No Aquatic Adult Insects, Y_3 = Drift Density With No Molluscs But With Aquatic Adult Insects, and Y_4 = Drift Density With No Molluscs and No Aquatic Adult Insects (Dependent Variables); X_1 = Percent Composition of Productive Substrates, X_2 = Log_e Discharge, X_3 = Dry Weight of Drifting Seston, X_4 = Benthic Population Density With Molluscs, and X_5 = Benthic Population Density Without Molluscs (Independent Variables).

	Upstream Area				Downstream Area			
	Y_1	X_1	X_2	X_3	Y_1	X_1	X_2	X_3
X_1	-.180				.143			
X_2	.103	-.348			-.457**	-.412		
X_3	.114	-.388*	-.376*		-.062	-.582**	.610**	
X_4	-.089	.346*	-.063	-.149	.642**	.480**	-.479**	-.348
	Y_2	X_1	X_2	X_3	Y_2	X_1	X_2	X_3
X_1	-.203				.147			
X_2	-.207	-.348			-.434*	-.412		
X_3	.712**	-.388*	-.376*		-.043	-.582**	.610**	
X_4	.173	.346*	-.063	-.149	.635**	.480**	-.479**	-.348
	Y_3	X_1	X_2	X_3	Y_3	X_1	X_2	X_3
X_1	-.155				.139			
X_2	.100	-.348			-.457*	-.412		
X_3	.097	-.388*	-.376*		-.059	-.582**	.610**	
X_5	-.085	.400*	-.072	-.124	.739**	.421*	-.469**	-.335
	Y_4	X_1	X_2	X_3	Y_4	X_1	X_2	X_3
X_1	-.191				.143			
X_2	-.224	-.348			-.435*	-.412		
X_3	.680**	-.388*	-.376*		-.040	-.582**	.610	
X_5	.158	.400*	-.063	-.124	.735**	.421*	-.469**	-.335

* $p < 0.05 > 0.01$, 31 d.f.

** $p < 0.01 > 0.001$, 31 d.f.

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