SPECIES DIVERSITY AND RELATIVE ABUNDANCE
OF BENTHIC FAUNA, AND RELATED PHYSICOCHEMICAL FEATURES
IN JOHN REDMOND RESERVOIR, KANSAS 1971-72

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by

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INTRODUCTION

At the time of this study the Kansas Gas and Electric Company together with the Kansas City Power and Light Company were considering the feasibility of constructing a nuclear generating station on John Redmond Reservoir and using water from the Reservoir as a coolant. When released back to the Reservoir the heated water could become a source of thermal pollution. Many species of aquatic organisms have narrow ranges of tolerance for temperature and those are generally the bottom dwellers (benthic fauna) which comprise a substantial percentage of the fish food items (Tarzwell, 1965). A baseline study of the benthic species diversity and related physicochemical features was needed to provide data on conditions as they existed before the nuclear station was to go into operation. Those data could then be compared to data collected after the nuclear station became operational.

In May, 1972, Kansas Gas and Electric Co. with Kansas City Power and Light Co. announced they would purchase land east of John Redmond Reservoir and build their own storage and heated-water reservoirs, if preliminary environmental impact research and geological research, as well as other research, indicate it would be feasible to locate there. Therefore, the data of this 1971-72 study will not be useful in terms of determining the effects of heated discharge water. It will be useful as environmental inventory data and as baseline data for future aquatic research in the area.

Investigators have attempted to classify bottom organisms according to pollution tolerances; but Gaufin and Tarzwell (1956) found the presence or absence of a given species is less reliable than population associations in determining water quality in streams. Wilhm and Dorris (1968) drew attention to the use of species diversity indices to characterize water quality of streams. Ransom and Dorris (1972) first demonstrated the application of diversity indices to characterize water quality conditions in a lake (Keystone Reservoir, Oklahoma).

Several water quality surveys using species diversity indices ($\bar{d}$) have been made in the vicinity of John Redmond Reservoir. Edwards (1970) used $\bar{d}$ values to characterize the effects of cattle feedlot runoff into the Cottonwood River above John Redmond Reservoir. Prather (1968) applied $\bar{d}$ values to zooplankton within John Redmond Reservoir and within two other reservoirs above it. The objective of this study was to characterize John Redmond Reservoir using species diversity indices of benthic macroinvertebrates found at various depths along selected transects and to relate those indices to the physicochemical features.

DESCRIPTION OF THE RESERVOIR

John Redmond Reservoir was formed by impounding the Grand(Neosho) River at a point approximately 48 kilometers below the confluence of the Cottonwood and the Neosho rivers east of Emporia, Kansas The dam was built by the United States Army Corps of Engineers and completed in 1965. The Reservoir forms a shallow pool having a surface area of 3,157 hectares and approximately 75 % of the basin is less than 3 m in depth (Prophet, 1966).

Unlike most multipurpose reservoirs in eastern Kansas which have many bays and small tributaries causing an irregular shoreline, John Redmond has a relatively smooth shoreline, few tributaries and a generally round shape at conservation pool, elevation 1036 msl (Fig. 1). Winds blowing across the Reservoir have a long fetch from any direction. This feature, coupled with the extremely shallow depth, causes the Reservoir water to be mixed from top to bottom on most days. Thus, summer thermal stratification rarely occurs.

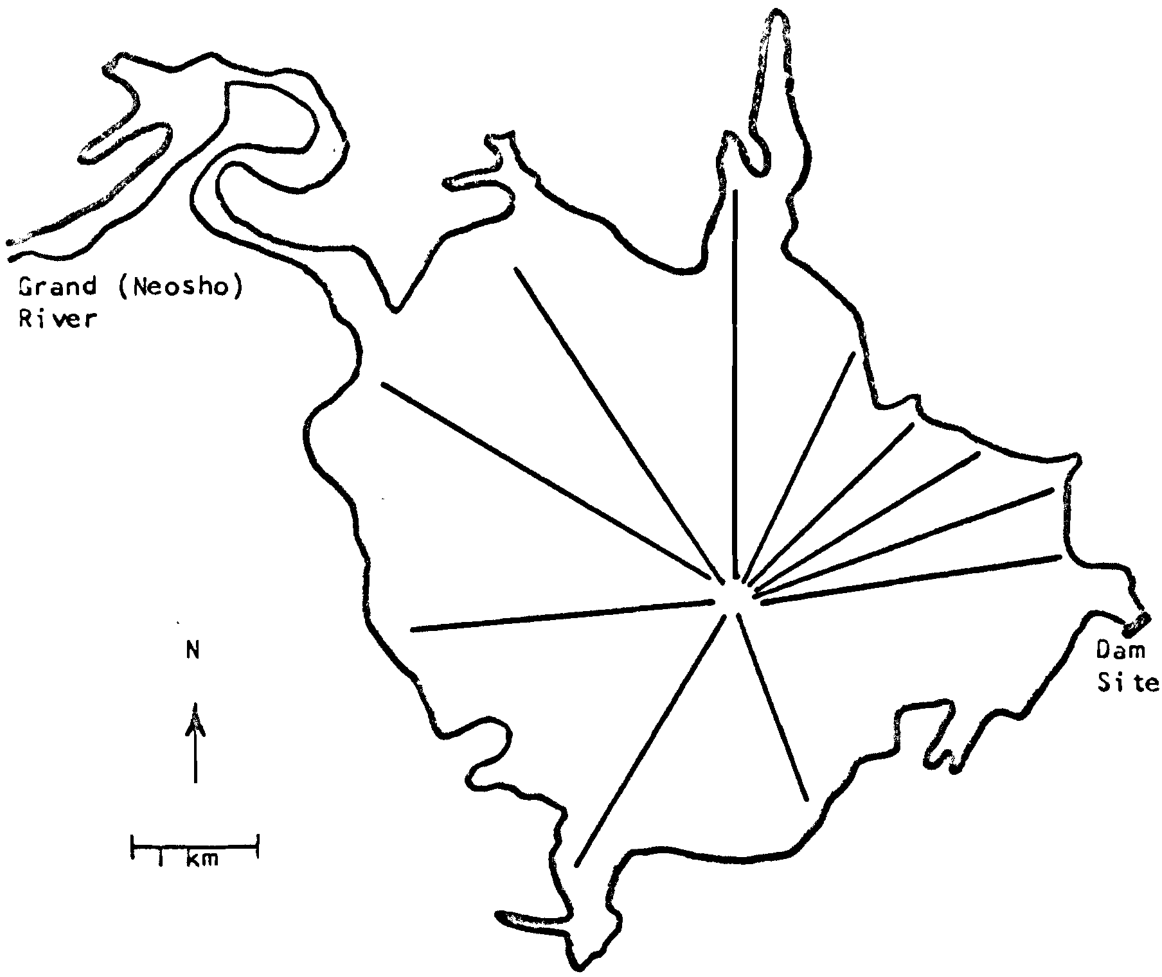

Figure 1. John Redmond Reservoir, Kansas. Enclosed lines indicate approximate locations of monthly transects.

MATERIALS AND METHODS

Bottom fauna samples and water samples were taken once each month, except in January when ice covered the Reservoir, during a twelve month period beginning in September, 1971, and ending in August, 1972, Sampling was started approximately two hours after sunrise on each collecting date. Samples were taken at each meter drop in depth from top and bottom along a transect extending from shore to the deepest area of the Reservoir (Fig. 1). Samples were not taken from depths greater than 4 m because the maximum depth was in the old river channel and represented an atypical portion of the Reservoir. All samples were taken when the water level was at or near conservation pool (1036 msl), except during the month of May when the pool was approximately one meter deeper than conservation pool.

Four benthic samples were taken with a 15 cm Ekman dredge at each sampling depth and combined into a pair of double samples. Samples were washed free of mud and silt in field screens of 60 to 80 mesh. Organisms and remaining debris were preserved in 10 % formalin. Organisms were sorted and picked by hand in the laboratory and preserved in 80 % isopropyl alcohol. Identifications and density determinations were made at later dates in the laboratory.

Estimates of diversity per individual ($\bar{d}$) were determined by equations given in Patten (1962):

$$\bar{d} = -\sum_{i=1}^{s} \left[\frac{n_i}{n} \log_2 \frac{n_i}{n} \right]$$

where n is the total number of individuals and n_i is the number of individuals of species i. Species diversity ($\bar{d}$) values were subjected to a t-test at the p = .95 level of significance. Data were programmed and analyzed by the Kansas State Teachers College Data Processing Center.

Water temperatures were measured at the top and bottom with the aid of a Yellow Springs Tele-Thermometer. Specific conductance was determined by measuring the electrical resistance converted to micromhos/cm at 25 C with a Bechman RB3 Solu-bridge. Transparency was determined with a 20 cm Secchi disc and was correlated and converted to Jackson Turbidity Units on a Bausch and Lomb Spectronic 20.

Chemical analyses of water samples were conducted according to procedures outlined in Standard Methods (A.P.H.A., 1960). Water samples were taken with a Kemmerer water bottle. Except for dissolved oxygen, a composite water sample consisting of 2 liters from the top and 2 liters from the bottom at each sampling site was used for laboratory chemical analyses. Dissolved oxygen was determined on duplicate top and bottom samples by the Alsterberg modification of the Winkler Method titrated with .025 N phenylarsene oxide. The stannous chloride method was used to measure phosphates and the direct Nesslerization was used to measure ammonia nitrogen. A colorimetric method was used to measure pH. All chemical estimates, except dissolved oxygen, were made on a Bausch and Lomb Spectronic 20.

RESULTS AND DISCUSSION

Biological

Species Collected

A total of 6,259 individuals representing 23 species of benthic macroinvertebrates was collected (Table I). Eleven of the 23 species were midges of the Family Chironomidae. The members of this family are an important link in the food chain between algae and micro-invertebrates, and the larger macroinvertebrates and fishes (Mason, 1968). They exhibit a wide range of tolerance to environmental factors, but work by Paine and Gaufin (1956) questioned the use of chironomid larvae as indicator organisms. However, certain genera within the family have adapted well to living in water where concentrations of dissolved oxygen are low and where lake bottoms are composed of fine silt (Pennak, 1953). The distribution of chironomids and other macroinvertebrates collected in this study seemed to bear this out. Specimens taken from the one meter depth where little or no silt occurred were few in number. As depth of water and bottom silt increased, generally greater numbers of chironomids and oligochaetes were found. This condition was somewhat different than that found by Ransom and Dorris (1972) who collected from a much larger and deeper reservoir which stratified throughout the summer. John Redmond Reservoir rarely, if ever, stratifies. *Tanypus* sp., *Procladius* sp., *Coelotanypus* sp., and *Chironomus* (*Chironomus*)sp. were the most abundant and represented 98 % of the total chironomids collected.

Three species of oligochaetes, *Branchiura sowerbyi* Bedd., *Tubifex*

TABLE I

ANNUAL NUMBERS OF BENTHIC MACROINVERTEBRATES

DEPTH (Meters)	1	2	3	4
	Individuals/m^2			
NEMATODA	0	4	0	0
ANNELIDA				
OLIGOCHAETA				
Branchiura sowerbyi Bedd.	0	6	4	11
Tubifex tubifex (O.F.M.)	1	13	55	60
Limnodrilus sp.	52	239	592	742
MOLLUSCA				
PELCYPODA				
Sphaerium sp.	3	1	1	4
ARTHROPODA				
EPHEMEROPTERA				
Caenis sp.	1	0	0	0
Hexagenia sp.	13	53	11	1
TRICOPTERA				
Polycentropus sp.	1	10	0	1
Neothremma sp.	1	1	0	0
COLEOPTERA				
Dubiraphia sp.	1	0	0	0
Narpus sp.	1	0	0	0
DIPTERA				
CULICIDAE				
Chaoborus punctipennis Say	78	34	88	124
CHIRONOMIDAE				
Anatopynia (*Psectrotanypus*) sp.	7	0	0	0
Tanypus sp.	39	392	213	154
Procladius sp.	20	263	527	423
Coelotanypus sp.	106	351	454	598
Pentaneura sp.	1	1	1	0
Chironomus (*Xenochironomus*) sp.	0	10	3	0
Pseudochironomus sp.	14	7	1	0
Chironomus (*Cryptochironomus*) sp.	14	8	2	3
Chironomus (*Chironomus*) sp.	17	138	213	163
Chironomus (*Dicrotendipes*) sp.	7	6	0	2
Polypedilium sp.	8	1	0	2

tubifex (O.F.M.), and Limnodrilus sp. were collected. Limnodrilus sp. was the most abundant and represented 26 % of the total macroinvertebrates collected. One nematode, one pelecypod, two ephemeropterans, two tricopterans, two coleopterans, and one dipteran were collected.

Distribution and Seasonal Changes in Numbers of Benthic Organisms

Six benthic species were collected in sufficient numbers to establish trends in distribution or to identify seasonal changes in numbers of organisms. Generally, density of individuals increased as depth increased (Table I). Limnodrilus sp., Chaoborus punctipennis Say, and Coelotanypus sp. increased in number at each meter increase in depth. Procladius sp. and Chironomus (Chironomus) sp. increased as depth increased, but were less abundant at the 4 m depth than at the 3 m depth. Tanypus sp. was most abundant at the 2 m depth and their number decreased as depth increased. Perhaps this is additional evidence that most bottom species do not distribute themselves evenly over the bottom. They prefer certain depths and bottom types.

Only 317 individuals were collected from the one meter depth. The reason for such a small number at this depth was probably due to the lack of suitable substrate on which benthic organisms could thrive. Hard clay was often encountered near the shore making collections with the Ekman dredge difficult. Coelotanypus sp. was by far the most abundant organism at that depth.

Seasonal changes in some instances were dramatic (Table II). For example, Tanypus sp. was not collected during the winter, then suddenly in the month of June the total for this species was 931 individuals per m^2 and continued high throughout the summer. A possible answer may

TABLE II

SEASONAL CHANGES OF SELECTED BENTHIC MACROINVERTEBRATES

	Individuals Per M^2											
Month	Sept.	Oct.	Nov.	Dec.	Jan.*	Feb.	Mar.	Apr.	May	June	July	Aug.
OLIGOCHAETA												
Limnodrilus sp.	69	39	8	97	—	438	791	666	358	575	706	735
DIPTERA												
CULICIDAE												
Chaoborus punctipennis Say	61	120	17	47	—	116	131	83	19	28	0	19
CHIRONOMIDAE												
Tanypus sp.	58	6	3	17	—	0	0	0	0	931	898	286
Procladius sp.	41	64	22	603	—	917	703	606	225	72	97	75
Coelotanypus sp.	228	272	50	367	—	1,143	512	428	306	203	253	473
Chironomus (*Chironomus*) sp.	3	156	136	559	—	392	100	70	25	6	3	0

*No samples taken due to ice cover.

be that Tanypus sp. have strict temperature requirements necessary to initiate hatching. That is, either hatching or growth of early instars may not occur until a certain temperature range is reached. Assuming this is true, and since no individuals of Tanypus sp. were collected where water temperature was less than 18 C, then hatching and rapid larval growth must occur somewhere between 18 and 25 C. With the exception of Tanypus sp., all species of Chironomidae were most abundant during the winter months. Their numbers built up to a peak in February and declined as air and water temperatures increased throughout the spring and summer. Numbers of the aquatic annelid, Limnodrilus sp., were highest in March and remained high throughout the summer months. Chaoborus punctipennis Say did not exhibit a sharp rise or fall in number but was slightly more abundant in the winter. Generally, benthic macroinvertebrates were least abundant in September, October, and November.

Seasonal fluctuations of insect larvae apparently were due to growth and emergence. Many larvae were probably too small to be noticed or passed through the screens in collections made during the fall. As growth occurred more larvae were collected until they emerged from the water as adults. Aquatic annelids reproduce during the winter months and do not exhibit emergence as do some insects. Therefore, their continued abundance throughout spring and summer was not unexpected.

Species Diversity

The species diversity index ($\bar{d}$) reflects the manner in which individuals are distributed among species in a community. As the probability of collecting a species increases, $\bar{d}$ decreases and as the probability decreases, $\bar{d}$ increases. If an aquatic environment is polluted, some degree of stress will be exerted upon those communities involved and after a period of time only the more pollution tolerant species will remain. This is not to say all individuals of the less tolerant species will be eliminated; but their abundance will remain low while the abundance of individuals of the more tolerant species will remain high. Hence, the probability is high that an individual in a sample will belong to a species already collected, causing $\bar{d}$ to be low. The opposite is true in clean water environments.

Diversity per individual ($\bar{d}$) values generally range from 0 - 4, or more, in aquatic environments. Values of less than one represent grossly polluted streams or lakes, values of 1 - 3 represent areas of moderate pollution, and values greater than 3 are found in clean water environments (Wilhm and Dorris, 1966).

A diversity index ($\bar{d}$) was calculated for each depth each month. The results indicated the Reservoir was moderately polluted and at times it tended to be more severely polluted. Mean annual diversity per individual ($\bar{d}$) by depth was never more than 2 (Fig. 2). A t-test at the p = .95 level of significance revealed no significant differences among mean annual $\bar{d}$'s by depth. Monthly $\bar{d}$ values with all depths combined were slightly higher in the winter than in the summer (Fig. 3). No significant differences were found among monthly diversity indices.

Applying species diversity indices to zooplankton in John Redmond Reservoir, Prather and Prophet (1968) found $\bar{d}$ values ranging from 1.83 to 2.70. Ransom and Dorris (1972) found $\bar{d}$ values generally ranged between 1.5 and 2.5 in Keystone Reservoir, Oklahoma. They also found

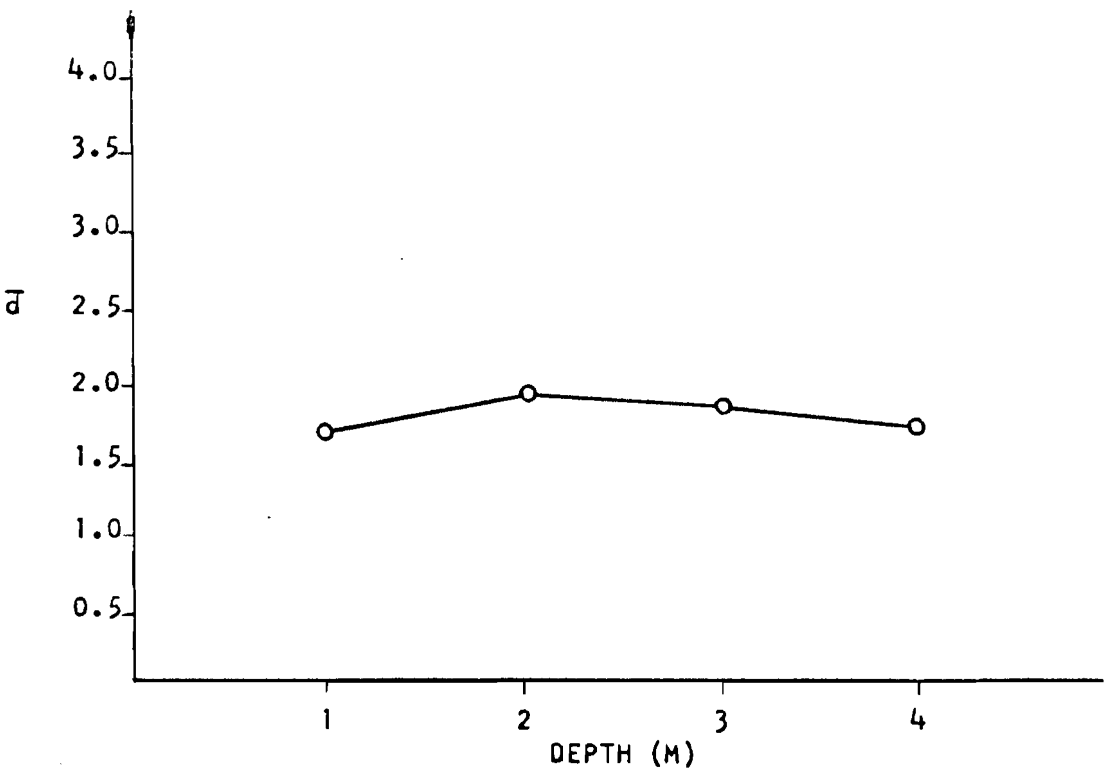

Figure 2. Mean Annual Variation in Diversity per Individual ($\bar{d}$) by Depth.

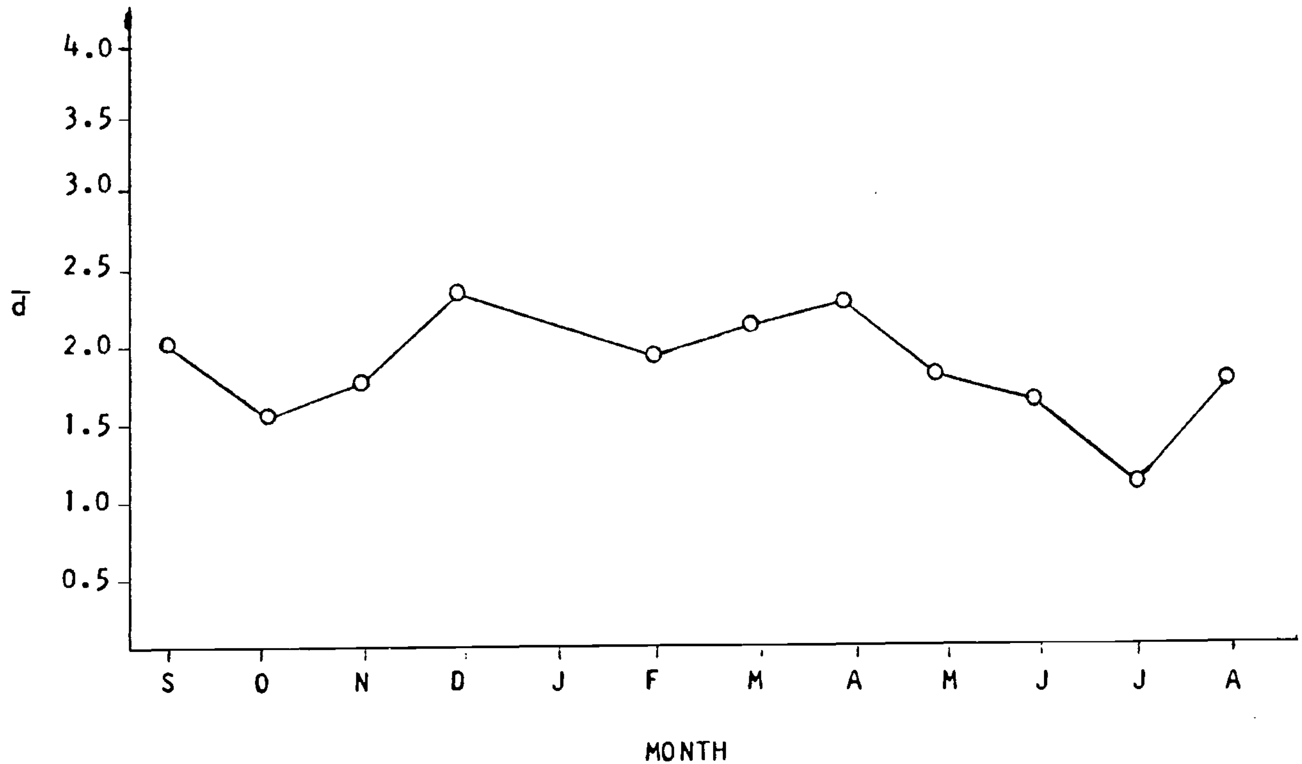

Figure 3. Monthly Variations in Diversity per Individual ($\bar{d}$). All Depths Combined.

that $\bar{d}$ values decreased with depth. This was not the case in the much shallower John Redmond Reservoir and a good comparison was not possible. Edwards (1970) applying species diversity indices to benthic macro-invertebrates in the Cottonwood River above John Redmond Reservoir found $\bar{d}$'s ranged from near 3 at stations above sources of pollution to a value of 1.29 below those sources.

Physicochemical

pH and Temperature

Little difference was observed in pH among depths or months except in August when values ranged from 6.9 at the 1 m depth to 5.1 at the 4 m depth (Table III). This may be evidence that weak stratification occurred during the month of August causing a build up of CO_2 which resulted in lower pH values. Dissolved oxygen at the 4 m depth was low.

Water temperatures were not abnormal and were nearly uniform from top to bottom (Fig. 4).

Transparency

Secchi disc transparency was highest in March and lowest in July (Fig. 5). Transparency was uniform across the lake except in June and August when turbidity was considerably higher near the shore. At no time could the Secchi disc be observed below 0.45 m.

A comparison was made on summer water samples between Secchi disc transparency and transparency determined on the Baush and Lomb Spectronic 20 and converted to Jackson Turbidity Units (Fig. 5). In July when Secchi disc transparency was less than 0.25 m, measurements of 131 to 156 J. T. U.'s were recorded.

TABLE III

MONTHLY pH BY DEPTH

Month	Depth (M) 1	2	3	4
Sept.	8.4	8.4	8.4	8.4
Oct.	8.2	8.4	8.4	8.4
Nov.	8.1	8.1	8.1	8.1
Dec.	6.3	6.3	6.2	6.3
Jan.*	—	—	—	—
Feb.	8.4	8.3	8.4	8.3
Mar.	8.1	8.1	8.2	8.1
Apr.	8.1	8.2	8.2	8.6
May	8.0	7.9	7.9	7.8
June	8.3	8.2	8.2	8.0
July	7.6	7.6	7.6	7.7
Aug.	6.9	6.6	6.2	5.1

*No samples taken due to ice cover.

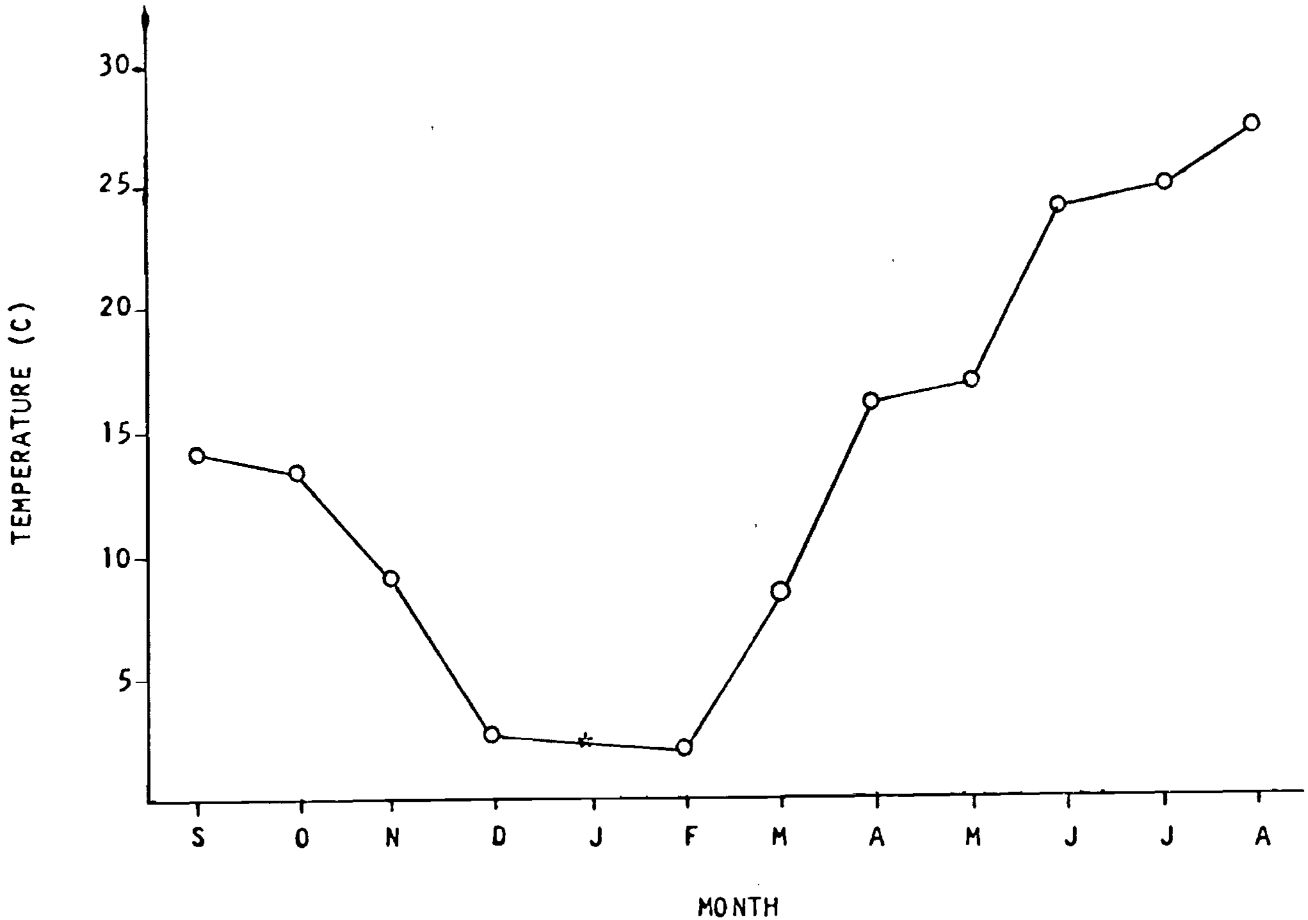

Figure 4. Mean Monthly Variations in Water Temperature.

*No samples taken due to ice cover.

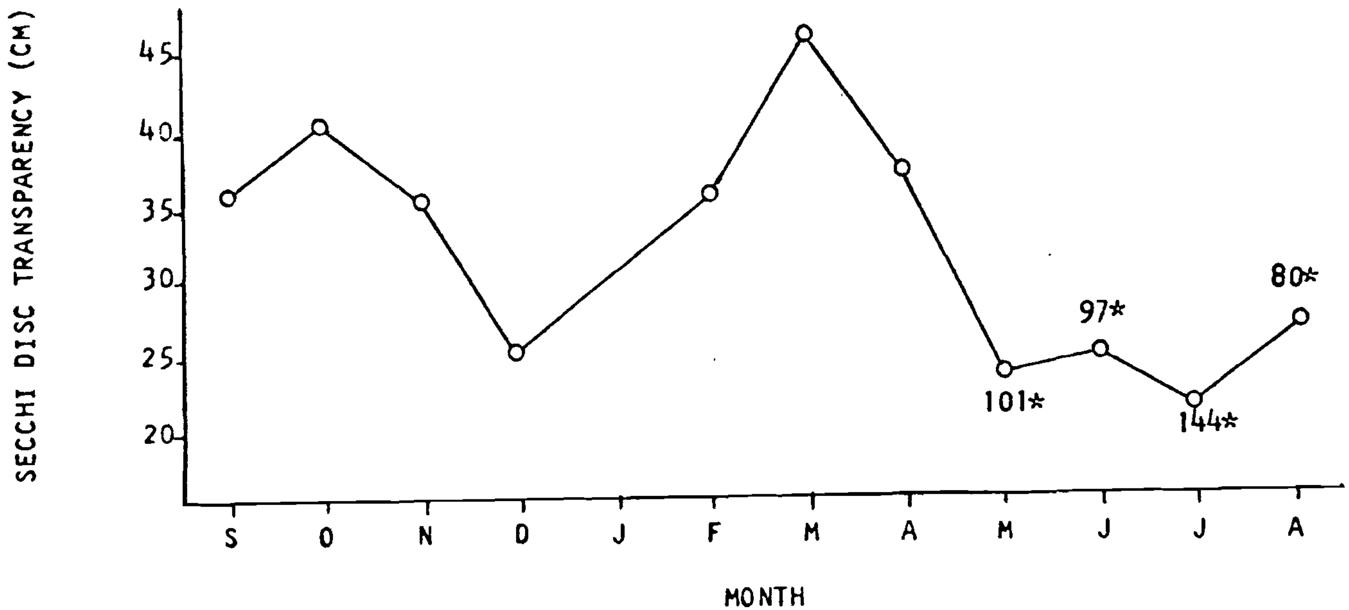

Figure 5. Mean Monthly Secchi Disc Measurements. *Represent Jackson Turbidity Units.

High turbidity in the Reservoir was due to a combination of shallowness, constant mixing by the wind, and inflow of sediment. High turbidity corresponded to periods of high rainfall and inflow. During July 21.6 cm of rainfall was recorded at Emporia and resulted in the highest turbidity readings during the study period.

Dissolved Oxygen and Conductivity

Of all the chemical parameters of waters, oxygen is one of the most significant (Reid, 1961). It is significant because oxygen is a product of photosynthesis; it is taken up by plants and animals during respiratory activities; it enters into oxidation reactions of inorganic material; and its solubility varies inversely with temperature.

The most remarkable feature concerning dissolved oxygen in John Redmond Reservoir was its uniformity from top to bottom which indicates that waters were well mixed throughout the year (Fig. 6). Thermal stratification was not evident on any of the sampling dates. Dissolved oxygen did not appear to be a limiting factor to the benthic macroinvertebrates. Dissolved oxygen values were never below 9 mg/liter until May and the following summer months. This 4 month period coincided with the period of highest rainfall. Therefore, the lower O_2 values, although not limiting, were probably due to the oxygen requirements of bacteria necessary to break down new organic debris brought into the Reservoir and to rises in water temperature. Edwards (1970) found organic debris from feedlots and the resulting decomposition was a limiting factor in the Cottonwood River above John Redmond Reservoir. Probably the dilution by reservoir water prevents complete

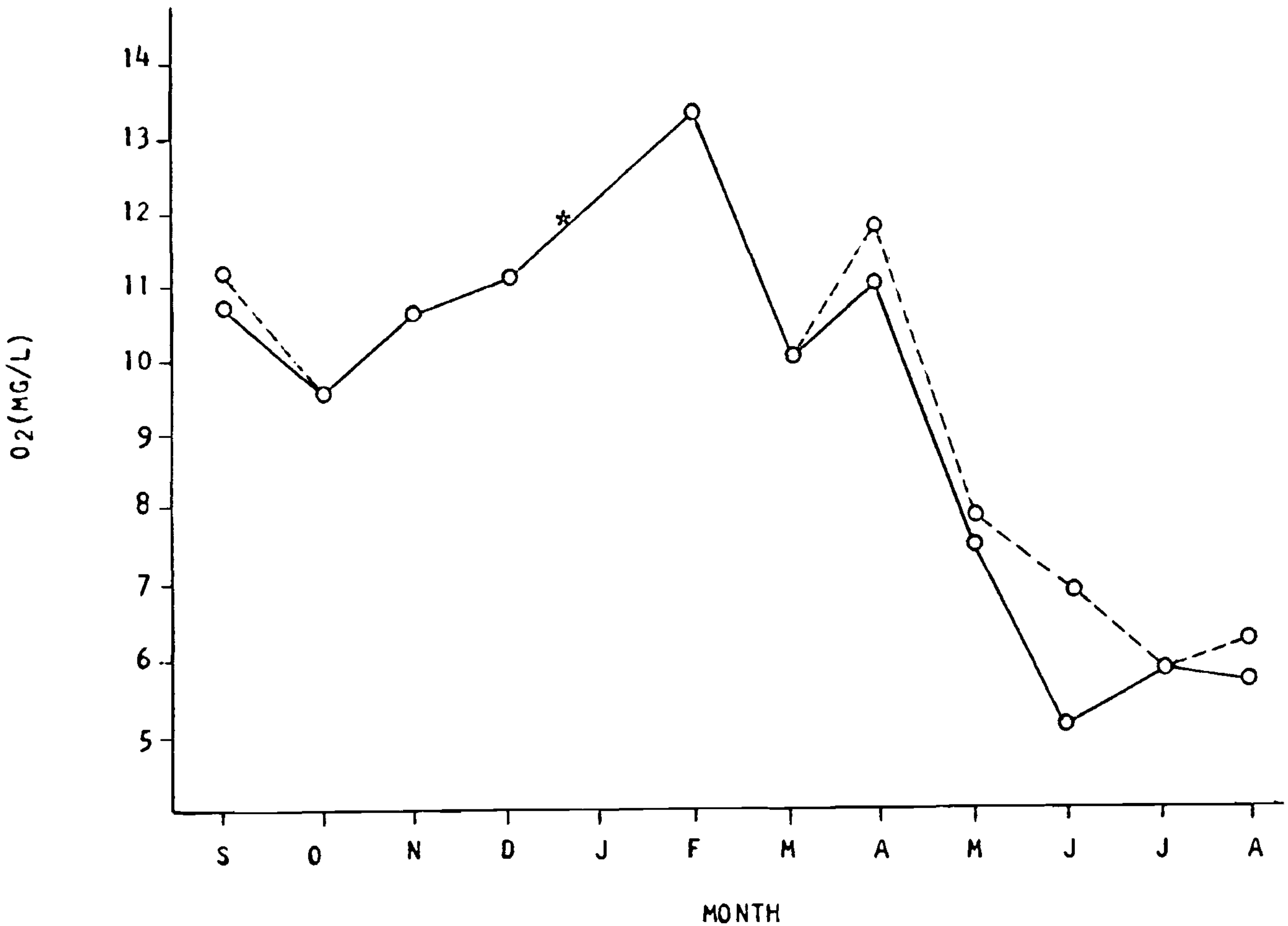

Figure 6. Mean Monthly Top (----) and Bottom (____) Dissolved Oxygen.

*No samples taken due to ice cover.

anoxia during these times.

Specific conductance varied greatly from month to month (Fig. 7), but was uniform from top to bottom. Generally, specific conductance was low in the winter and high in the summer; however, the highest measurement occurred in April when it was nearly 480 micromhos, but that was not unusually high for fresh waters.

Phosphate and Nitrate

Both phosphate and nitrate values were relatively high when compared with other Eastern Kansas reservoirs. Slight differences were noted among sampling dates and among depths, but no trends were established (Tables IV and V). Prophet, et al. (1970) reported phosphate means in Council Grove and Marion reservoirs in the same watershed above John Redmond to be 0.09 mg/liter and 0.18 mg/liter, respectively. Nitrate means in the two reservoirs were 0.95 mg/liter and 0.37 mg/liter, respectively. The yearly phosphate mean in John Redmond was 0.28 mg/liter and the yearly nitrate mean was 1.28 mg/liter. Possible sources of these two nutrients include effluents from treatment plants, effluents from slaughter houses, runoff from fertilized cropland, and runoff from feedlots. Feedlots may constitute the single most important source of nutrients for John Redmond Reservoir. It is important to note that phosphate and nitrate levels during the study period were nearly the same as those recorded by Prophet (1966) during the early years of impoundment.

Ammonia Nitrogen

Little difference was noted among depths in concentrations of ammonia (Table VI). Some differences did occur among sampling dates.

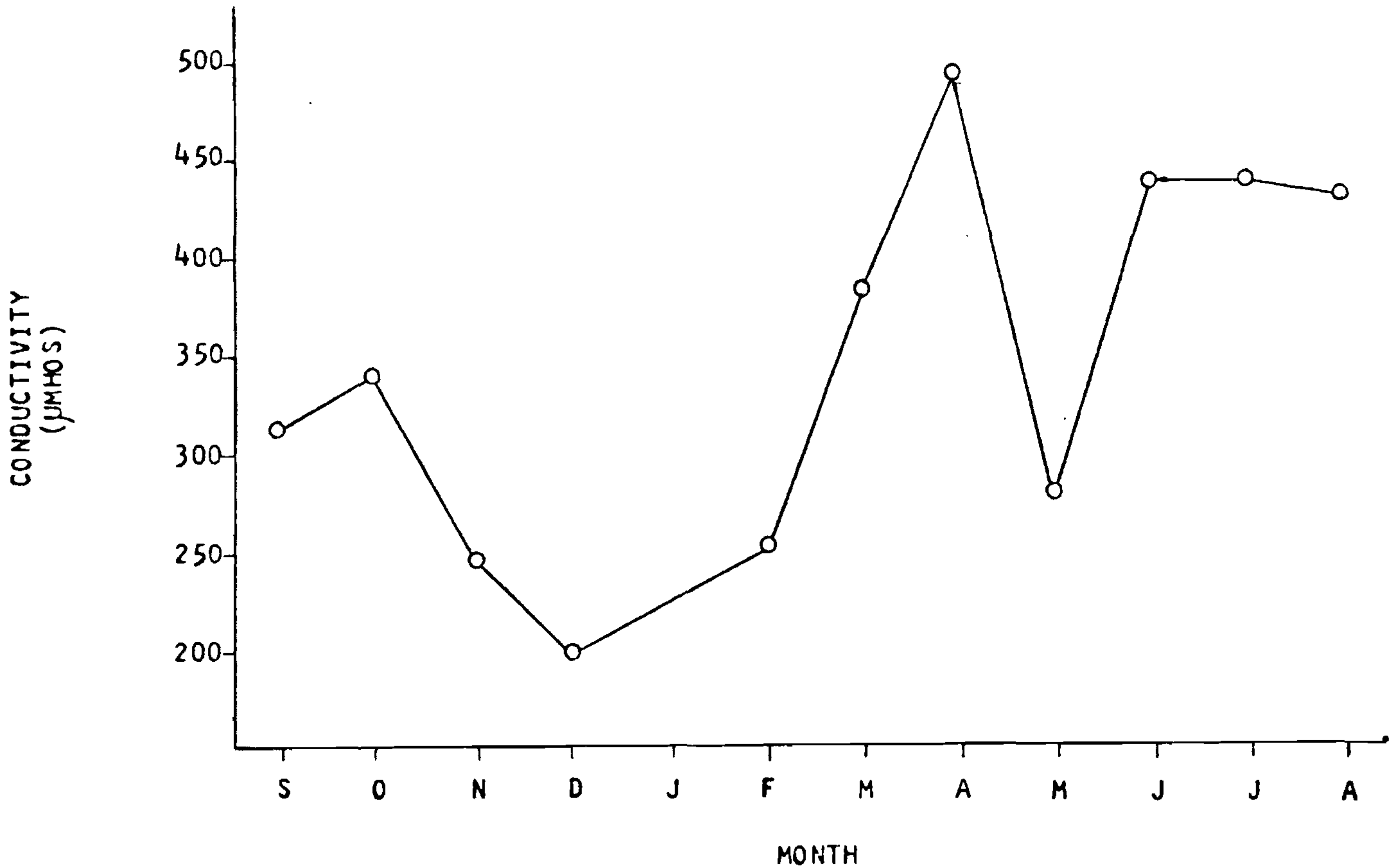

Figure 7. Mean Annual Specific Conductance by Month, All Depths.

TABLE IV

MONTHLY SOLUABLE PHOSPHATES (PO_4) BY DEPTH

Month	Depth (M) 1		2		3		4	
	Total	Ortho	Total	Ortho	Total	Ortho	Total	Ortho
Sept.	0.30	0.23	0.25	0.14	0.44	0.28	0.25	0.16
Oct.	0.17	0.07	0.12	0.09	0.16	0.12	0.12	0.11
Nov.	0.40	0.36	0.40	0.34	0.38	0.36	0.40	0.34
Dec.	0.40	0.30	0.44	0.32	0.68	0.44	0.59	0.40
Jan.*	——	——	——	——	——	——	——	——
Feb.	0.09	0.00	0.12	0.00	0.15	0.01	0.14	0.02
Mar.	0.11	0.09	0.19	0.12	0.16	0.12	0.16	0.16
Apr.	0.04	0.04	0.04	0.04	0.06	0.06	0.07	0.07
May	0.38	0.32	0.44	0.36	0.46	0.36	0.44	0.32
June	0.12	0.06	0.11	0.07	0.06	0.02	0.09	0.06
July	0.57	0.44	0.44	0.42	0.53	0.44	0.53	0.42
Aug.	0.36	0.21	0.36	0.19	0.32	0.25	0.36	0.21

*No samples taken due to ice cover.

TABLE V

MONTHLY NITRATE NITROGEN (NO_3) BY DEPTH

Month	Depth (M) 1	2	3	4
Sept.	2.280	1.782	2.098	4.585
Oct.	0.078	0.080	0.172	0.078
Nov.	1.450	1.451	1.255	1.552
Dec.	1.751	1.851	0.433	1.748
Jan.*	——	——	——	——
Feb.	0.974	0.972	0.767	0.461
Mar.	0.976	0.671	0.571	0.571
Apr.	1.968	1.968	2.072	2.071
May	1.822	1.420	1.228	1.122
June	0.717	0.911	0.163	0.160
July	2.568	1.508	1.805	1.817
Aug.	2.017	2.130	2.551	2.241

*No samples taken due to ice cover.

TABLE VI

MONTHLY AMMONIA NITROGEN (NH_3) BY DEPTH

Month	Depth (M) 1	2	3	4
Sept.	1.04	1.07	1.07	1.15
Oct.	0.66	0.64	0.75	0.66
Nov.	1.46	1.50	1.66	1.58
Dec.	1.50	1.50	2.23	1.70
Jan.*	———	———	———	———
Feb.	0.86	0.98	0.98	1.11
Mar.	0.83	1.07	1.04	1.07
Apr.	1.01	1.15	0.95	1.07
May	2.18	1.97	1.93	1.80
June	1.97	1.93	1.17	1.15
July	2.23	2.07	2.07	2.02
Aug.	1.62	1.28	1.31	1.25

*No samples taken due to ice cover.

During the spring and summer high ammonia concentrations generally followed periods of high rainfall. The highest amount recorded was in July following the period of highest rainfall.

Sulfates

Sulfates were generally lowest in the fall and highest in the spring (Table VII). Sulfates were over 100 mg/liter at all depths in March and April. Apparently sulfates in the Reservoir came from sedimentary geologic formations existing in the watershed. Other reservoirs in the Flint Hills Region have high concentrations of sulfates. Tuttle Creek Reservoir, which is similar to John Redmond in turbidity and which is also located in the Flint Hills, had sulfate concentrations over 120 mg/liter in April, 1969 (Corps of Engineers Data, 1970). Reid (1961) suggested that seasonal pulses in sulfate concentration are due to reductions of sulfide taken up in the bottom mud.

Physicochemical Effects on Species Diversity

Even though other studies have shown that productivity is good, turbidity may be the single most critical factor limiting species diversity in John Redmond Reservoir. Of those physical and chemical parameters estimated in this study, turbidity departed most from the range of average values reported for freshwater lakes (Tarzwell, et al., 1962). Nutrient levels may also have contributed to the low diversity of benthic invertebrates. Nitrate nitrogen and phosphate values were much higher than world averages (Reid, 1961). Ammonia nitrogen was high enough to be limiting to most forms of bottom fauna. Ammonia was

TABLE VII

MONTHLY SULFATES (SO_4) BY DEPTH

Month	Depth (M) 1	2	3	4
Sept.	54.0	54.0	54.0	54.0
Oct.	38.0	36.0	35.0	36.0
Nov.	42.0	42.0	41.0	42.0
Dec.	58.0	52.0	52.0	52.0
Jan.*	———	———	———	———
Feb.	91.0	88.0	88.0	91.0
Mar.	102.0	104.0	103.0	103.0
Apr.	103.0	103.0	100.0	103.0
May	27.0	25.5	29.5	30.5
June	58.0	55.0	61.0	59.0
July	29.5	26.5	31.0	31.0
Aug.	37.0	35.0	34.0	35.0

*No samples taken due to ice cover.

probably derived mostly from organic breakdown. This is further evidenced by the high coliform bacteria counts found in the Reservoir. The Kansas State Health Department at one time closed the Reservoir to contact recreation (Grey, 1973).

SUMMARY

Benthic fauna and water quality along selected transects at John Redmond Reservoir, Kansas, were investigated monthly from September, 1971, through August, 1972. Species diversity analyses were conducted on benthic community structure. Relationships between species diversity and physicochemical estimates were established.

A total of 6,259 individuals representing 23 species of benthic macroinvertebrates was collected during the year. The aquatic oligochaete, Limnodrilus sp., was the most abundant species collected. Members of the family Chironomidae represented 45 % of the total number of macroinvertebrates collected. Generally, numbers of individuals increased with depth and were not abundant during the winter and early spring. Emergence accounted for large seasonal fluctuations in numbers of insect larvae.

Chemical concentrations were generally uniform from top to bottom. Nutrient levels were high at times, but did not appear to be critical. Little evidence of thermal stratification was noted and dissolved oxygen was not a limiting factor.

Turbidity was extremely high throughout the year. Following periods of high rainfall, Secchi disc transparency averaged less than 30 cm. This compared to readings of more than 100 Jackson Turbidity units.

Results of species diversity analyses indicated there was moderate pollution. Monthly variations ranged from 2.39 to 1.18. The t-test at the p = .95 level revealed no significant differences of $\bar{d}$ values by depth or by month. It appeared that turbidity may have been the single

most critical factor limiting diversity of benthic macroinvertebrates in John Redmond Reservoir.

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APPENDIX

TABLE VIII

VARIATION IN $\bar{d}$ BY SAMPLING DATE

Sampling Date	Depth (M)			
	1	2	3	4
24 Sept. 71	1.95	2.58	1.63	2.18
23 Oct. 71	1.16	2.03	1.56	1.48
11 Nov. 71	1.50	1.44	2.30	1.76
20 Dec. 71	2.32	2.66	2.22	2.35
26 Feb. 72	1.41	2.13	2.13	1.95
25 Mar. 72	2.83	1.48	2.03	2.32
15 April 72	2.76	2.17	2.12	1.92
17 May 72	1.00	2.27	1.92	1.99
30 June 72	1.41	1.86	1.95	1.47
22 July 72	0.65	1.21	1.65	1.22
8 Aug. 72	1.90	1.68	1.57	1.86