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Ecological Factors Affecting Turbidity and Productivity in Prairie Ponds in the Southern Great Plains

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by

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Abstract

Ecological Factors Affecting Turbidity and Productivity in Prairie Ponds in the Southern Great Plains

Farm ponds play an important role in the economy of the southwestern plains. Water quality of these ponds, however, is often impaired by high turbidity due to suspension of colloidal clay. The reason for this turbidity in certain ponds but not in others was investigated as well as ecological consequences of turbidity.

Pond morphometry and chemical characteristics of the water of 29 farm ponds was related to turbidity on a seasonal basis. The clarity of pond water was positively correlated with mean depth, pH, dissolved solids and conductivity ($r > 0.7$). Shallow ponds with large surface areas tended to be turbid. Wind action in these cases probably negates any natural clearing effect. In selecting pond sites (or in improvement of existing ones), (1) the pond should be built such that the pond area is small relative to pond volume; the mean depth is great; (2) erosion and siltation should be prevented (possibly by settling basins); (3) roiling of the water by cattle discouraged; (4) gypsum or lime be added to increase the pH, dissolved solids and conductivity. Seasonal pigment diversity of 29 farm ponds was lower in turbid ponds than in clear ones suggesting an ecological consequence of turbidity, that is, phytoplankton populations in turbid ponds are always in the initial stages of algal succession. Production/respiration ratios for two clear and two turbid ponds indicate that energy utilized in turbid ponds is not fixed there ($P/R < .88$) at the rate it is in clear ones ($P/R > .88$). Hence, clear ponds appear to be more suitable for fish production.

Preliminary laboratory studies favor the conclusion that clay particles in suspension do not adsorb NH_4-N and thus do not play an important role in nitrification.

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Keywords --- turbidity/productivity/P/R ratio/ farm ponds/ small impoundments/ Southern Great Plains/ colloidal clay/ clearing of pond water/ ecological consequences/ planning farm ponds/ NH_4 - N adsorption/ nitrification/ fish production/pigment diversity/ physical-chemical limnology.

Preface

This project was initiated by Dr. Troy Dorris who wished to investigate ecological factors affecting turbidity and productivity in prairie ponds. Mr. Wayne Epperson and Mr. Freddie Rainwater worked initially on what was to become Mr. Epperson's thesis problem, "Physical-Chemical Factors affecting Productivity in Prairie Ponds." When I became project leader in January, 1966, it was evident that Mr. Epperson no longer needed assistance. This enabled Mr. Rainwater and myself to choose related problems.

The main objective of the project since its inception, however, is embodied in Mr. Epperson's thesis problem. The results and conclusions presented below substantially satisfy objectives of the original proposal. For this reason, and because I wished to investigate another subject (nitrogen cycling in prairie ponds) we decided to terminate this project. It was anticipated that Mr. Epperson would have his thesis prepared by this August (1967) and that Mr. Rainwater would be writing his thesis at this time and be graduated by June, 1968. Thus, I planned to carry Mr. Rainwater on my new project, because he would be helping me with my new research while he prepared his thesis. Mr. Epperson did not progress as fast as I had anticipated and he has yet to write his thesis. He will be supported by Dr. Troy Dorris after 1 September 1967.

Introduction

Farm ponds play an important role in the economy of the southwest. They are used to water livestock, as a source of potable water where subsurface waters have poor quality, in irrigation, in flood control and as sites for water based recreation.

Many ponds in this region, however, are continuously turbid due to clay particles in suspension which have been eroded from the soil surrounding the pond. The turbid ponds are less suitable as sources of water for farm use and generally less productive of fish and wildlife. The reason why certain ponds are turbid and others are not and the ecological consequences of this turbidity are not well understood.

My graduate students and I have been attacking specific tasks to shed some light upon the above considerations, realizing that our effort would just begin to throw some light on these problems. One student, Mr. Epperson, sought to learn what physical and chemical factors affect turbidity in farm ponds or, in effect, to learn why some are turbid and others are not.

The tasks undertaken by another student, Mr. Rainwater, and myself dealt with the ecological consequences of turbidity. Mr. Rainwater sought to learn the community structure of benthic macroinvertebrates in an effort to catagorize ponds according to their fauna and to learn their capacity to produce fish food. My task was to learn if clay particles in suspension adsorb ammonium ions and thus speed up the process of nitrification. The rate of nitrification will determine how fast nitrogen "turns over," and indicates how quickly nutrients become available for growth of algae and other plants.

Each task is described in detail below in regard to its objectives, the research procedures used, important results and conclusions (especially those which bear on water quality), and the degree of achievement of objectives.

TASK 1

Physical-Chemical Factors Affecting Productivity in Prairie Ponds With Special Emphasis on Turbidity

Wayne Epperson, Graduate Assistant

Objective

The objective of this task was to learn what physical and chemical factors affect turbidity in farm ponds. An effort was made to derive knowledge which will be of predictive value in helping plan sites for the construction of new ponds and to aid in the clearing of established waters.

Research Procedures

Twenty-nine ponds of widely differing turbidities were selected and their morphometry was learned. Between December, 1965, and December, 1966, limnological conditions (water level, turbidity, total solids conductivity, pH, alkalinity) were observed monthly. In addition, the biomass of planktonic algae was determined and pigment diversity values were calculated (Margalef, 1957, 1961). Correlation coefficients between the annual mean of these parameters and mean annual percent light transmission were calculated (Snedecor, 1957).

Results and Conclusions

Precipitation and Water Levels. - Total precipitation during the study (December, 1965 through December, 1966) was 70.23 cm (27.65 in). Approximately 73 percent of the total fell during the period of April through August (Table 1). Less than 0.5 cm of precipitation fell during two of the prior four months.

Heavy rainfall during July caused twenty of the ponds to overflow. Rainfall had a major influence on the water economy of the ponds since considerable evaporation occurred before and after the July rainfalls. Precipitation during April, May, and June, however, did offset some evaporation during this period.

Precipitation during the study was so light in most cases that runoff was just adequate to replace that lost by evaporation and few ponds rose above spillway level (except during July). For this reason, we do not feel we can correlate water renewal with turbidity.

Turbidity and Rainfall. - The heavy rainfall during July had varying effects on turbidity in the ponds. The clear ponds were muddied by inflowing erosion material; however, the highly turbid ponds showed an increase in percent light transmission since the runoff water was clearer than the water in the ponds. The clear ponds were murky only for a short period, since erosion material carried into the ponds appeared to settle out quickly (Table 2).

The greatest increase in light transmission was noted in Pond #9. For the 6-month period prior to July, the light transmission averaged approximately 6 percent and immediately after the rainfall it increased to 27.5 percent. Settling out of the particles continued and at the termination of this study light transmission was 93 percent.

Turbidity and Mean Depth. - The morphometry of each pond at spillway level was observed in order to learn if the surface area to volume ratio of the pond could be correlated with turbidity. Our hypothesis was that ponds with large surface areas relative to volume would clear faster than these with opposite characteristics. We felt that evaporation and concentration of ions would be greater in the former and this would lead to an accelerated precipitation of the clay particles.

The inverse ratio surface area to volume is mean depth. Mean depth and percent light transmission were strongly correlated ($r = 0.7661$). Shallow ponds with large areas are more apt to be turbid than deep ones with small surface areas. This finding is opposite to what we expected. We feel, however, that the conclusion has validity, because ponds with small mean depths are more apt to be stirred by wind than those with greater mean depths. The influence of the wind on pond turbidity, however, is difficult to quantify to prove this point conclusively.

Turbidity appeared to vary in response to several factors during the study which we cannot explain. The mean annual percent light transmission ranged from a low of zero to a high of 94 among the ponds. Pond #16 was quite turbid and never exhibited any measurable light transmission (Table 2).

Turbidity and Solids (Total and Dissolved). - Both total solids and dissolved solids were correlated with percent light transmission, $r = 0.7059$ and $r = 0.7296$ respectively. As these parameters rose, turbidity decreased.

Mean annual total solids in Pond #16 was 1462 mg/l with the highest monthly reading occurring in June just prior to heavy rains in July. Between June and July the total solids decreased sharply from 1922 mg/l to

1170 mg/l in Pond #16 (Table 3). This decrease was noted in all but three of the ponds (Table 4). Although total solids were quite high in Pond #16, only five ponds had a lower mean annual dissolved solids (Table 4). In general turbid ponds seem to have lower dissolved solids; however, this was not so for two clear ponds. These two clear ponds had unusually low total solids and dissolved solids.

Pond #23 had the highest mean annual percent light transmission and mean annual total solids were 107 mg/l with 101 mg/l of this being dissolved solids. Pond #6 had the lowest mean annual total solids, 88 mg/l, with 71 mg/l being dissolved solids.

Turbidity and Conductivity. - Mean annual conductivities ranged from 97 μmhos/l in Pond #6 to 551 μmhos/l in Pond #21. Only two ponds, Pond #28 and Pond #21, had mean annual conductivities over 500 μmhos/l. A direct relationship between conductivity and percent light transmission was shown (r = 0.7835). Clear ponds generally had higher conductivity (Table 5). However, other factors appear to be operative in Pond #6 and Pond #23 which had lower conductivities. Ponds exhibiting high conductivities had correspondingly high dissolved solids.

Increased conductivities during winter and early spring months appeared to be related to less rainfall. A small decrease in conductivity was noted in June and a sharp decrease occurred in July. Each of these was related to the amount of rainfall occurring during each period. After July, conductivity increased steadily indicating an inverse relationship with water levels. Concentration by evaporation and dilution by rainfall seems to greatly affect the conductivity.

Turbidity and Hydrogen Ion Concentration and Alkalinity. - The hydrogen ion concentration was strongly correlated with percent light transmission (r = 0.8337). As pH rose, pond water became clearer (Table 6). The lowest mean annual pH was 7.2 in Pond #8. This pond was extremely turbid. During February, May, and July the pH was 6.8 in Pond #8. Eight other ponds had pH 6.8 following heavy rainfall in July. Pond #26 had the highest mean annual pH, 9.0, with low monthly readings of 8.2 during January and February. This pond had a mean annual light transmission of 92 percent.

Total alkalinity was also correlated with percent light transmission (r = 0.7418) and thus clear ponds generally had higher alkalinities. Carbonate alkalinity occurred in all but two of the winter months with a monthly high of 148 ppm in June. In July carbonate alkalinity dropped to 10 ppm. Pond #28 had carbonate alkalinity every month except January with a mean annual pH of 8.6. Pond #19 was the only pond with carbonate alkalinity in January and it was present every month except July. Each of these are clear ponds.

Eight turbid ponds never produced carbonate alkalinity. Of these eight ponds, only one had a mean annual conductivity greater than 300 μmhos/1 and four of the ponds had a mean annual conductivity less than 200 μmhos/1.

Both pH and alkalinity decreased sharply during July apparently due to dilution of runoff. Carbonate alkalinity was recorded in 21 of 29 ponds in May, 15 of 29 ponds in June and only three ponds in July. Pond #6 showed a decline of 2.6 pH units between June and July. Pond #6 had an unusually low mean annual pH, 7.7, for a clear pond; yet in May bicarbonate alkalinity was depleted and hydroxide alkalinity was produced. Hydroxide alkalinity was also found in Pond #20 during May.

Eight ponds exhibited average pH values of 8.3 or greater. Carbonate alkalinity occurred frequently in these ponds and only sporadically in those with averaged pH values less than 8.3.

Pigment Diversity. - The ratio of the absorbance of an acetone extract of phytoplankton at 430 mμ to the absorbance at 665 mμ (pigment diversity) was correlated with percent light transmission (r = 0.7494). Average pigment diversity was lower in extremely turbid ponds (Table 7).

Plankton in the turbid ponds thus appears to be biochemically less complex than plankton communities in clear ponds. Low pigment diversity usually indicates young, rapidly growing phytoplankton; consequently, this would indicate that turbid ponds contained younger populations of plankton. High pigment diversity indices are associated with mature phytoplankton which was most prevalent in clear ponds.

Temporary ecological succession in plankton is displayed by fluctuating pigment diversities. Changes in pigment diversities show the cyclic trends in phytoplankton which occur in the ponds. Climatic factors seem to play an important role in phytoplankton ecology in that nearly all of the ponds displayed the same ecological trend for a climatic period. Pigment diversity indices were low during the cold months of January and February but with the advent of spring the indices increased sharply (Table 8). Reduction in the indices is again seen during the warmer months except during July. The increased values in July were evidently due to young growing communities of phytoplankton that increased activity after a heavy rainfall altered the environment. In October pigment diversity increased sharply again and generally maintained a high level until the termination of the study. Since the ponds followed the same cyclic trend, lower pigment diversities in turbid ponds seem to indicate that the phytoplankton populations are eliminated by unfavorable conditions before maturing.

Considerations in Selection of Pond Sites. - From the positive relationship between clear ponds and mean depth, it appears that pond sites should be chosen so as to afford small surface area and relatively deep water, at least in this area. This may not be a useful criterion, however, where prevailing winds are not as strong as in the Great Plains or where turbidity is due to plankton or humic matter. It must be added that steep sided ponds are also more suitable as fish ponds, which should be an additional reason to consider potential morphometry of a pond when selecting a site.

In general, turbidity was lower in ponds where pH, alkalinity and dissolved solids and conductivity were relatively high. Runoff water with high pH conductivity and dissolved solids should be suitable for ponds. We would expect the negative charges on the clay particles to be easily satisfied under these conditions and clearing to proceed rapidly. Pond owners may find it advantageous to add gypsum or lime to the pond to accelerate clearing.

The variability encountered from pond to pond however, suggests that other factors may negate any natural clearing (physical or chemical). Livestock and waterfowl usage, concentration by evaporation, and wind action were responsible in some cases for increased turbidity. Random events such as livestock roiling a pond can greatly increase the turbidity of ponds. A decrease of 40 percent transmission in one pond was attributed to extensive use by waterfowl during the month. Moreover, although difficult to quantify, we suspect that ponds occupying well-grassed drainage areas remain clear; conversely, turbid ponds receive drainage from roadways, fields or poorly managed grassed areas.

Careful selection of construction sites is an important aspect in improving water quality in prairie ponds. The central idea is to reduce the silt load before it enters the pond. Modification of existing ponds by building catch basins for erosion silt and restricting cattle access to the pond should greatly increase the water quality of these ponds.

Degree of Achievement of Objectives. - In attempting to draw conclusions of predictive value, it is always important to know the limits wherein these predictions are valid. The substantial achievement of this task was that it showed these limits. For example, most of the turbid ponds had lower dissolved solids except for two ponds. Thus, although this conclusion must be qualified, we do have a clearer idea of the limits of the predictive value of the statement that turbid ponds have lower dissolved solids.

The objectives of this task have been realized. Data has been collected and the results have been analyzed and the more obvious conclusions have been drawn. But as with any large mass of data, one can find many ways to treat it. Hence, Mr. Epperson believes that computer analysis may lead to more conclusions not evident at the outset. The results and conclusions reported above, however, are substantially complete.

I anticipated that Mr. Epperson would have his thesis complete at this time. However, due to the demands of the graduate program he was not in a position to prepare his thesis. He will continue, however, with his doctoral program even though these project funds will be terminated. (Dr. Dorris has agreed to support him). His thesis should be completed by June, 1968.

TABLE 1

TOTAL MONTHLY PRECIPITATION IN CENTIMETERS

AT STILLWATER, OKLAHOMA

FROM DECEMBER, 1965, TO DECEMBER, 1966.

DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
5.74	0.46	3.76	0.43	6.07	8.84	9.53	18.64	8.43	3.40	1.02	0.33	3.58

TOTAL: 70.23

TABLE 2

AVERAGE PERCENT LIGHT TRANSMISSION IN FARM PONDS DURING JANUARY, JUNE, JULY AND DECEMBER, 1966.

POND NUMBER	JAN	JUNE	JULY	DEC
1	70	92	82	66
2	54	34	50	59
3	9	7	14	12
4	51	10	4	76
5	1	1	4	51
6	73	93	61	88
7	14	76	26	87
8	2	44	2	64
9	3	3	28	93
10	0	0	1	0
11	28	41	11	88
12	1	0	0	51
13	22	2	36	17
14	62	0	6	79
15	68	84	53	92
16	0	0	0	0
17	88	43	52	92
18	76	21	5	88
19	88	78	26	89
20	85	84	62	93
21	94	82	71	92
22	96	86	45	88
23	94	96	91	93
24	48	9	23	51
25	22	4	14	12
26	93	94	85	87
27	18	6	52	5
28	80	69	27	71
29	62	55	38	90

TABLE 3

MONTHLY CHANGES IN TOTAL SOLIDS (mg/1)

IN POND 16 DURING 1966.

DEC	JAN	FEB	MAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1482	1298	1242	1374	1678	1922	1170	1228	1300	1522	1632	1694

TABLE 4

MEAN ANNUAL TOTAL SOLIDS, MEAN ANNUAL DISSOLVED SOLIDS AND MEAN ANNUAL PERCENT LIGHT TRANSMISSION IN FARM PONDS DURING 1966.

POND NUMBER	TOTAL SOLIDS (mg/1)	DISSOLVED SOLIDS (mg/1)	LIGHT TRANSMISSION %
1	275	230	82
2	355	301	53
3	368	132	12
4	289	168	40
5	515	165	14
6	88	71	82
7	290	207	53
8	521	168	24
9	291	128	41
10	888	112	1
11	264	180	51
12	511	143	17
13	250	87	27
14	297	148	45
15	253	227	84
16	1462	112	0
17	183	143	77
18	176	118	69
19	258	198	80
20	290	231	84
21	357	335	91
22	220	184	84
23	107	101	94
24	242	154	41
25	304	97	16
26	2174	235	92
27	313	107	19
28	377	359	73
29	262	191	65

TABLE 5

MEAN ANNUAL CONDUCTIVITY AND MEAN ANNUAL PERCENT LIGHT TRANSMISSION IN FARM PONDS DURING 1966.

POND NUMBER	CONDUCTIVITY µmhos/1	LIGHT TRANSMISSION %
1	372	82
2	479	53
3	236	12
4	298	40
5	283	14
6	97	82
7	333	53
8	260	24
9	227	41
10	135	1
11	338	51
12	245	17
13	162	27
14	282	45
15	370	84
16	144	0
17	261	77
18	206	69
19	353	80
20	430	84
21	551	91
22	286	84
23	182	94
24	285	41
25	163	16
26	423	92
27	140	19
28	526	73
29	318	65

TABLE 6

MEAN ANNUAL HYDROGEN ION CONCENTRATION, MEAN ANNUAL TOTAL ALKALINITY AND MEAN ANNUAL PERCENT LIGHT TRANSMISSION IN FARM PONDS DURING 1966

POND NUMBER	pH	TOTAL ALKALINITY (ppm)	LIGHT TRANSMISSION %
1	8.43	136	82
2	8.28	153	53
3	7.78	83	12
4	8.24	125	40
5	8.04	121	14
6	7.74	36	82
7	8.08	85	53
8	7.19	25	24
9	7.91	75	41
10	7.50	37	1
11	8.17	116	51
12	7.49	42	17
13	7.85	66	27
14	8.13	111	45
15	8.51	142	84
16	7.52	28	0
17	8.19	93	77
18	7.85	82	69
19	8.82	113	80
20	8.34	98	84
21	8.54	103	91
22	8.30	82	84
23	7.97	71	94
24	8.25	100	41
25	7.88	110	16
26	9.00	151	92
27	7.70	45	19
28	8.58	197	73
29	7.26	26	65

TABLE 7

MEAN ANNUAL PIGMENT DIVERSITY AND MEAN ANNUAL LIGHT TRANSMISSION IN FARM PONDS DURING 1966.

POND NUMBER	PIGMENT DIVERSITY RATIOS D 430 / D 665	LIGHT TRANSMISSION %
1	1.29	82
2	1.31	53
3	1.41	12
4	1.52	40
5	1.44	14
6	1.43	82
7	1.33	53
8	1.33	24
9	1.11	41
10	1.23	1
11	1.46	51
12	1.41	17
13	1.27	27
14	1.50	45
15	1.53	84
16	1.10	0
17	1.30	77
18	1.22	69
19	1.38	80
20	1.59	84
21	1.30	91
22	1.23	84
23	1.38	94
24	1.39	41
25	1.09	41
26	1.68	92
27	1.20	19
28	1.64	73
29	1.64	65

TABLE 8

MONTHLY CHANGES DURING 1966 IN PIGMENT DIVERSITY
IN A CLEAR POND AND IN A TURBID POND.

	JAN	FEB	MAR	MAY	JUNE	JULY
(Turbid) Pond 25	1.00	0.23	2.02	0.50	0.06	1.12
(Clear) Pond 28	0.63	1.33	3.25	2.75	0.90	1.51

	AUG	SEPT	OCT	NOV	DEC
(Turbid) Pond 25	0.27	2.04	1.09	1.97	1.66
(Clear) Pond 28	0.51	0.56	1.48	3.15	1.96

References Cited

Margalef, R. 1957. La Teoria de la informacion en ecologia. Mem. real. Acad. Ciencias y Artes Barcelonia. 32: 372-449.

Margalef, R. 1961. Correlations entre certains caracteres synthetiques des populations de phytoplanition. Hydrobiologia. 18: 155-164.

Snedecor, G. W. 1957. Statistical methods. 5th Ed, Iowa State College Press, Ames, Iowa, 534p.

TASK 2

Community Structure of Benthic Macroinvertebrates in Prairie Ponds

Freddie Rainwater, Graduate Assistant

Objective

A lengthy background to my objective is presented below to give the reader some idea as to how I set out to learn the ecological effects of turbidity in farm ponds.

Community structure analyzes communities in terms of species frequency, species per unit area, spacial distribution of individuals and numerical abundance of species (Hairston, 1959). A mathematical expression which expresses the ratio between species and individuals in a biotic community is refered to as a diversity index.

In the present study diversity indicies of benthic macrofauna will be related to physicochemical conditions, primary productivity, and bottom sediments of four farm ponds. Diversity indicies derived from information theory by Margalef (1951, 1958) and Patten (1962) make it possible to summarize large amounts of information about numbers, biomass, and kinds of organisms. Several investigators have shown that diversity indicies may be used as valid ecological parameters to describe changes in community structure and to denote successional status. Empirical mathematical expressions regarding the regularity of the distribution of individuals by species was reviewed by Wilhm and Dorris (1966).

Wilhm (personal communications) regards biomass units as a more adequate expression of diversity than units based on numbers for individuals. Variation in weights among bottom macrofauna populations may be considerable. The present investigation will compare numbers and biomass (ash-free weight) of diversity indicies in order to evaluate changes in community structure within and among the four farm ponds.

Limited attention has been given to the effects of environmental factors on the community structure of benthic macroinvertebrates. Most studies relating turbidity effects on bottom fauna have been concerned with distribution and relative abundance.

Turbidity expresses the optical property of the water, permitting it to scatter and absorb light and affects the aquatic environment by rapidly absorbing radiant energy in the upper layers of water and reducing the depth of effective photosynthesis (Bartsch, 1960). Particles in suspension may directly or indirectly have a profound affect on the aquatic biota. Degradation of water quality from eroding watersheds, gravel washing and road building operations, placer mining, deforestation, overgrazing, unwise irrigation and other agricultural practices damage water use as does pollution from municipalities and industries (Wilson, 1960). Despite increased erosion control, quanities of soil leave the land and head toward the sea (Newcombe, 1951). Hynes (1962 reported that macroinvertebrates serve as useful tool in detection of very mild pollution and they retain their sensitivity down to levels at which most other methods of study cease to be useful. Butcher (1955) stated that pollution should be defined as biological conditions instead of chemical standards..

Research Procedures

Four farm ponds were studied between June,1966 and June,1967. Turbidity was the main criterion in selection of the four ponds. Two ponds were relatively clear while two were turbid. Turbidity was measured with a colorimeter at 450 mμ since turbidity expresses the optical property of the water and is not really a measure of the weight of suspended matter.

Sixteen Ekman dredge hauls were taken at eight randomly selected stations from each pond at least monthly, except during December, when the ponds' surfaces were frozen. Physicochemical data (see above) were obtained monthly.

Oxygen relationships of the ponds were investigated for a 24 hour period (at three hour intervals) in August 1966 and June 1967. The dissolved oxygen concentration was determined with a galvanic cell oxygen analyzer calabrated against a control where dissolved oxygen was determined stoichiometrically. Photosynthetic productivity, community respiration, and diffusion were calculated by construction of a 24 hour rate-of-change curve (Odum and Hoskin, 1958; Copeland, 1961). Samples were taken at the surface, one meter, and the bottom (bottom depth was 2 m in all ponds except for Pond D, which was only 1.5m deep).

Results and Conclusions

Turbidity of the ponds, expressed as per cent transmission of light at 450 mμ, ranged from an annual mean of 90.1 in the clear pond (Pond A) to 0.0 in the muddy pond (Pond D). Fluctuation in turbidity was reflected by the amount of precipitation and runoff during any particular month. Alkalinity, conductivity, and hydrogen ion concentration decreased in all ponds as light transmission decreased (Table 1). Although the physicochemical conditions present in all ponds were well within the tolerance limits of most aquatic organism the interaction of these conditions upon the community structure has not yet been analyzed.

Metabolism in an aquatic community may be shown by the relationship of oxygen produced (by photosynthesis and by diffusion from the atmosphere) and by the oxygen consumed (by the respiration of aerobic organisms). The photosynthesis/respiration ratio (P/R) facilitates classification of communities into autotrophic and heterophic types (Odum, 1956). An autotrophic community is one that yields a P/R ratio of greater than one (productivity exceeds respiration). A heterotrophic community yields a P/R ratio of less than one (respiration exceeds photosynthesis). Only the clear pond (Pond A) was an autotrophic type. The P/R ratio of 1.12 and 1.20 were observed during August and June respectively, (Table 1). Ponds B, C, and D were heterotrophic on both dates. In Ponds C and D the percent light transmission was zero in August and both had the lowest P/R ratios (Table 1). The P/R ratio for June was lower in Ponds B, C, and D than during August. These ponds were exceedingly turbid during June following spring rains (Pond B had 2% light transmission; Pond C had 4% light transmission; Pond D had 0% light transmission).

These ratios also indicate that turbid ponds are generally less productive than clear ponds. Fish production is likely to be lower in turbid ponds and more dependant on energy fixed exogenously than in clear ponds. A situation where P/R ratios and light transmission increase simultaneously appears to reflect these conditions.

The effect or interplay of community metabolism (P/R) upon the community structure of benthic macroinvertebrates will be evaluated shortly. Bottom sediments of each pond will be analyzed and evaluation of these sediments with the community structure of the benthic macrofauna relationships will be made.

The importance of bottom fauna as a direct source of food for fishes has been shown by numerous investigators as one of the most influential features in biological productivity. The application of diversity indicies of bottom macrofauna as a result of this study may be important in establishment of water quality criteria in reference to turbidity. Since benthic animals play an important role in the productivity of the pond (Welch, 1936) it is important to discover the limiting effects that turbidity has upon these animals and to the structure of their community.

Degree of achievement of objectives. - Data has been collected and evaluated according to schedule. All that remains is to finish the evaluation of diversity of benthic macroinvertebrates in reference to turbidity as described above. I anticipated in the 1967 continuation proposal that Mr. Rainwater would have his thesis complete by 1968. He will assist me with my work on nitrogen cycling during the next year.

TABLE 1

PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF FOUR FARM PONDS.

POND	AREA COVERED BY WATER(ha.)	TURBIDITY (% trans. at 450 mμ)	CONDUCTIVITY (mhos/cm)	ALKALINITY (ppm)		pH	P/R RATIO
				Bicarbonate	Carbonate		
<u>A</u>							
mean	0.2254	90.1	480.5	64.2	35.2	8.8	1.16
max.	0.2982	98.0	574.0	101.0	58.0	9.4	1.20
min.	0.1951	71.0	407.0	14.0	00.0	7.4	1.12
<u>B</u>							
mean	0.2094	34.2	258.0	90.2	03.0	8.2	0.65
max.	0.3512	56.0	314.0	128.0	20.0	8.4	0.96
min.	0.1524	02.0	173.0	18.0	00.0	8.1	0.25
<u>C</u>							
mean	0.4057	10.5	144.5	58.3	00.0	7.9	0.66
max.	0.7061	18.0	176.0	72.0	00.0	8.2	0.82
min.	0.3084	00.0	104.0	10.0	00.0	7.5	0.40
<u>D</u>							
mean	0.4052	00.0	135.7	30.6	00.0	7.6	0.56
max.	0.6101	00.0	168.0	44.0	00.0	8.0	0.88
min.	0.3029	00.0	91.0	05.0	00.0	6.8	0.23

LITERATURE CITED

Bartsch, A. 1960. Settleable solids, turbidity, and light penetration as factors affecting water quality. Biol. Prob. in Water Pollution. U.S. Public Health Serv. 118-127.

Butcher, R. W. 1955. Relation between the biology and the polluted condition of the Trent. Verhandl. Int. Ver. Limnol., 12: 42-58.

Copeland, B. J. 1961. Primary productivity in oil refinery effluent holding ponds. M.S. Thesis, Okla. State Univ., 46p.

Hairston, N. G. 1959. Species abundance and community organization. Ecology, 40: 404-416.

Hynes, H. B. N. 1965. The significance of macroinvertebrates in the study of mild river pollution. Public Health Service Publication No. 99-WP-25, 235-243.

Margalef, R. 1951. Diversidad de especifica en las communidades de organismos. Pub. Inst. Biol. Apl. (Barcelona), 9: 5-27.

________. 1956. Temporal succession and spatial heterogeneity in phytoplankton. Persp. Mar. Ecol. 1: 323-349.

Newcombe, C. L. 1951. Water wealth lost by silt pollution. Soil Conservation Magazine 16: 4 pages.

Odum, H. T. and C. M. Hoskin, 1958. Comparative studies on metabolism of marine waters. Publ. Inst. Mar. Sci., Univ. Texas., 5: 16-46.

Patten, B. C. 1962. Species diversity in net plankton of Raritan Bay. J. Mar. Res. 20: 57-75.

Welch, P. S. 1936. A limnological study of a small sphagum-leatherleaf-black spruce bog lake with special reference to its plankton. Pap. Mich. Acad. Sci., Arts, Let. 21: 727-751.

Wilhm, J. L. and T. C. Dorris. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. Amer. Midl. Nat. 76: 427-449.

Wilson, J. M. 1960. The effects of erosion, silt, and other inert materials on aquatic life. Biol. Prob. in Water Pollution. U.S. Public Health Serv., 235-239.

TASK 3

Adsorption of Ammonium Ions by Clay Particles in Aqueous Solution.

Introduction

Adsorption is a familiar phenomenon to limnologists and yet details concerning the surfaces involved and the modes of bonding are not clear. Every surface has some capacity for adsorption of ions or complexes of ions but some are more important than others. Mortimer (1941-42) felt that ferrolignoprotein plays an important role in adsorbing many ions. Particulate matter and certain colloidal complexes may also play adsorptive roles in the open water of lakes (Hutchinson, 1957).

Particulate matter has been suggested as a site for the adsorption of NH_4-N in the sea (Cooper, 1937). Hutchinson (1957) feels that adsorption of NH_4-N may be quite important in lakes because lakes contain large quantities of particulate matter and adsorption of NH_4-N to particulate matter may be vital for bacterial nitrification of this compound.

High turbidity, largely due to high concentrations of particulate clay, is a dominant feature of Oklahoma impoundments. It was felt that these clay particles might play an important role in nitrification by adsorbing NH_4-N. The object of this research was to learn if clay particles adsorb this cation.

Mineral clays and soils have been studied for their adsorptive capacities of NH_4-N and other ions for many years and much is known about their behavior (Grim, 1953). An example from the literature on soils will illustrate one fundamental approach in such studies. Kelley and Cummins (1921) saturated 400 g of dry clay loam with 0.01N NH_4Cl (150 mg NH_4-N/1). The extract contained only 72 mg NH_4-N/1 and 80, 19, 34 and

5 mg/1 respectively of Ca, Mg, K and Na. About 78 mg NH_4-N was exchanged for other cations. In the case of mineral clays cations may be held by broken bonds around the edge of the silica-alumina units, by substitution in the lattice and/or by replacement of hydrogens of exposed hydroxyls (Grim, 1953). The quantity of NH_4-N adsorbed by 400 g of dry soil was 170 μg NH_4-N/g dry soil. In this case, the NH_4-N was adsorbed by both clay particles and humus.

Objectives

To learn the affinity of clay particles for NH_4-N, the same approach was used here but with some important differences. First, only clay particles were used as potential adsorptive surfaces to learn the role of inorganic particulate matter in adsorption of NH_4-N. Secondly, the aqueous phase was well water, containing a relatively small quantity of ammonia (about 1 mg NH_4-N/1). An attempt was made to simulate natural conditions, however, dissolved organic matter and particulate organic matter were purposely excluded, because these may also interact with NH_4-N.

No uptake of NH_4-N could be detected with the techniques employed The problem of measuring uptake of NH_4-N is discussed relative to the results of these experiments. The importance of simulating natural conditions is stressed.

Research Procedures

Clay was added quantitatively to an aqueous solution containing a known quantity of ammonia. After two days the clay was separated from the water phase, and the latter was analyzed to learn if the ammonia concentration had decreased.

Montmorillonite clays were selected because of their high cation exchange capacity and because these minerals are commonly found in suspension in Oklahoma waters (Irwin and Stevenson, 1951). A "standard" clay, (Montmorillonite 26, Clay Spur, Wyoming, A.P.I. Research Project 49), and subsoil (mostly clay) from a local roadcut were used in these experiments (Table 1). Each clay was ground in a mortor and then sifted through a soil seive (mesh size 62 μ).

Local well water was chosen to simulate natural surface water. Ammonia was added as $(NH_4)_2CO_3$ or NH_4OH such that concentrations in the flasks were between 1.082 to 1.207 mg/l NH_4-N (Table 1).

In all experiments four flasks were prepared as follows. Flask A contained one liter of well water, flask B contained one liter of well water plus NH_4-N, flask C contained one liter of well water plus a known quantity of clay and flask D contained one liter of well water and known quantities of NH_4-N and clay respectively.

Two days were allowed for the system to equilibriate. The flasks were shaken vigorously several times during this period. The pH was then determined with a Beckman Zeromatic pH meter. The clay phase was separated from the water phase by centrifugating the solution in each flask for one hour in a Sorvall, Model SS-4 centrifuge (RPM = 7000, r = 5.75, g = about 7,970).

Ammonia in 20.0 ml from each flask was recovered in boric acid indicator solution after Kjeldahl distillation. The indicator solution was titrated with 0.00528N H_2SO_4 to the stoichiometric point (1.00 ml acid = 0.047 mg NH_4-N). The same technique was used to determine the ammonia concentration of solutions from each flask after centrifugation. All determinations were made in triplicate.

Glassware used in the experiments was carefully washed and rinsed with glass distilled water. Contamination by atmospheric ammonia was reduced by steaming glassware over a waterbath.

Ionic constituents and total solids were determined by the Oklahoma State University Soil and Water Service Analytical Laboratory.

Conclusions

Statistically significant adsorption of NH_4-N by clay particles cannot be demonstrated. In each experiment a "t" test was used to learn if a significant difference existed between solutions in each flask before and after separation of the clay phase from the water. For example, in the first experiment 0.457 ml 0.00528N H_2SO_4 was used to reach the stoichiometric point before separation while 0.453 ml was used after separation of the clay and water ($t = 0.55$, 4df and $P > 0.50$). Concentrations of ammonia in control flasks before and after centrifugation, respectively, were not statistically different ($P > 0.50$).

In addition, the values of reagent blanks were learned for each set of determinations. In Experiment 1 the standard deviation of the blank was ± 31 µg NH_4-N/l while for both Experiments 2 and 3 the standard deviation was ± 192 µg NH_4-N/l. Such large deviations are due in part to contamination of the glassware by atmospheric NH_4-N.

A number of factors probably mitigated against extensive adsorption of NH_4-N by clay particles in these experiments: particle size, equilibrium time, relative concentration of NH_4-N, pH, and the kinds of ions on exchangeable sites.

In general, cation exchange capacity increases as particle size decreases. The cation exchange capacity of montmorillonites does not vary substantially over a wide range of particle sizes (Grim, 1953). However, it is possible that mean particle size in the experiments above was too large and that consequently the cation exchange capacity was rather low.

The equilibration interval may have been too short, particularly for substitution in the lattice. However, there is no reason to suspect it was too short to measure uptake on broken bonds. The interval for the latter is a matter of hours (Grim, 1953).

The concentration of NH_4-N used is relatively low compared to the other cations (Table 2). Furthermore, the high pH in the experiments (8.22-8.77) also limited availability of the dissociated ammonium ion. For example, at pH 6 the ratio of NH_4-N to undissociated hydroxide is 100 times the ratio at pH 8 (Hutchinson, 1957). It is likely that in these experiments ammonium ions lost out in the competition with other more abundant cations for exchangeable sites on the clay particle. Gedroiz (1922) showed that in a soil the replacement of Ca and Mg by NH_4-N increased as the concentration of NH_4-N increased.

The species of ion on the exchangeable sites will also affect the replaceability of NH_4-N. There is no single replaceability series but in general NH_4-N will replace Na and K easier than it will replace Ca and Mg (Grim, 1953). It is not known what cations were on the exchangeable sites for the particles used here.

The factors discussed above probably work against uptake of NH_4-N by clays in nature as well as in the laboratory. Except for the relatively high total solids, all other conditions in the experiments were of a magnitude expected in small Oklahoma impoundments. While uptake of NH_4-N by clay could be demonstrated easily under very artificial conditions (leaching with 2N NH_4OH), this kind of experiment would not yield data of predictive value for situations in natural water.

Limnologists who investigate adsorptive phenomena should simulate natural conditions as closely as possible in the laboratory, isolate variables and use the most sensitive analytical techniques available. In regard to future experiments on the adsorption of NH_4-N by clays, I plan to use the same approach but to employ an isotope dilution technique. It has been my experience that even colormetric techniques cannot overcome problems of spurious contamination by atmospheric ammonia. Only an isotope dilution technique is apt to demonstrate statistically significant differences between control and experimental vessels under conditions described above.

Application to existing water problems. - The loss of NH_4-N in sewage effluents and into the subsoil around feed lots is responsible in no small measure for eutrophication and contamination of subsurface waters respectively. This research casts doubt upon whether cheap clays can be used to strip NH_4-N from effluents to the point where removal will lessen eutrophication. It also points out why NH_4-N appears to be free to migrate through the subsoil.

Degree of achievement of objectives. - The objectives of this task have been satisfied only in a preliminary fashion. The problems suggested by this research are legion, but rather than proceed with the techniques above, I have decided to terminate the task until isotope dilution techniques are developed in our laboratory.

TABLE 1

TOTAL DISSOLVED SOLIDS, AMMONIA CONTENT, pH OF SOLUTIONS USED TO LEARN RATE OF NH_4-N UPTAKE BY THE TYPE OF CLAY INDICATED.

Experiment	Total Dissolved Solids mg/1	Ammonia Source	NH_4-N/1 mg	pH	Clay	
					Type	g/1
1	450	$(NH_4)_2CO_3$	1.082	8.65	montmorillonite	2.002
2	450	NH_4OH	1.207	8.46	local clay	0.676
3	450	NH_4OH	1.188	8.77	montmorillonite	2.232

TABLE 2

IONIC COMPOSITION OF WELL WATER USED IN EXPERIMENTS ON ADSORPTION OF NH_4-N BY CLAY PARTICLES.

Ion	ppm
calcium	18
magnesium	T
sodium	61
ammonium-N	1
sulfate	26
carbonate	59
bicarbonate	299