A LIMNOLOGICAL STUDY
OF WATER LEAVING LAKE LANAO THROUGH AGUS RIVER

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Introduction

Based on area, depth, age, and economic importance, Lake Lanao is considered one of the major tropical lakes in Southeastern Asia (Frey, 1969). Yet little is known about its limnology. The handful of publications on Lake Lanao dealt mostly with fish — its taxonomy (Herre, 1933), its evolution (Myers, 1960), and fishing methods and fish conservation (Villaluz, 1966). The fragmentary data obtained by the Wallace Expedition in 1932 and the inclusion of the Lake in Woltereck's list of deep tropical lakes (see Frey, 1969) were the first data of limnological nature. In 1967 and 1968, David G. Frey conducted the first real limnological studies on Lake Lanao (Frey, 1969). He continued his studies in 1970-71, with William Lewis, Jr., making the fulltime investigations (Lewis, 1973).

Continuing studies on the limnology of Lake Lanao, its tributaries and outlet are highly important. Knowledge gained from such studies is necessary for understanding how the lake works and changes with time. It can provide the basis for recommendations on its conservation and utilization.

I conducted my own study on water draining from the lake through the Agus River from July 1968 to July 1969. It was an indirect but reliable way of studying part of the Lake Lanao limnology. It included the study of certain physical-chemical conditions of the effluent water which would reflect the lake's own physical-chemical conditions. It also aimed at obtaining quantitative data of the zooplankton organisms leaving the lake. The data would reflect the qualitative and quantitative composition, seasonal fluctuations, and biomass loss of zooplanktonic organisms from the lake during the period of

study. A third objective of the study was to determine the loss of the biomass of water hyacinths, *Eicchornia crassipes*, from the lake through the Agus River. This loss, together with the zooplankton biomass loss, would be considered energy loss from the lake.

Study Area and Methods

The Agus River, the only outlet of Lake Lanao, runs along two courses, one emptying into Iligan Bay through the Maria Cristina Falls, and the other through the Linamon Falls (see Frey, 1969).

The main sampling areas were three equidistant stations seven meters apart, across the approximately 25-meter wide Agus River at the site of the Marawi City bridge (Fig. 1). The fixed stations were marked by posts along the bridge, which is approximately 200 meters from the mouth of the lake.

A sampling station was also established midway between Marawi City and Tamparan (Fig. 2) for gathering comparative data. Two trips were made to this station.

Preliminary surveys, which included physico-chemical analysis of water and qualitative plankton samplings, were made during the period July through September, 1968. Regular early-Sunday-morning trips were made from January 26, 1969 to July 27, 1969. During these trips *in situ* measurements of water temperature and conductivity, water samplings for laboratory physico-chemical analysis, quantitative zooplankton samplings, and counts of the number of water hyacinths that left the lake through the Agus River during a ten-minute period were done. A Whitney thermistor and a conductivity meter were used for measuring temperature and conductivity, respectively. Water samples were collected by throwing with force a 5-liter bucket into the water below the bridge. The water above the 5-liter line was placed in a plastic container for physico-chemical analysis. The rest of the water was poured through a Juday plankton net (No. 25 mesh net) for the quantitative zooplankton samples. For a zooplankton sampling of a station, 10 liters (two buckets) of water were obtained. The samples were immediately preserved in *situ* in 10% formalin. The water analysis included measurements of turbidity as SiO_2 (Hellige turbidimeter), dissolved CO_2 (through methyl-orange alkalinity methods) and chloride
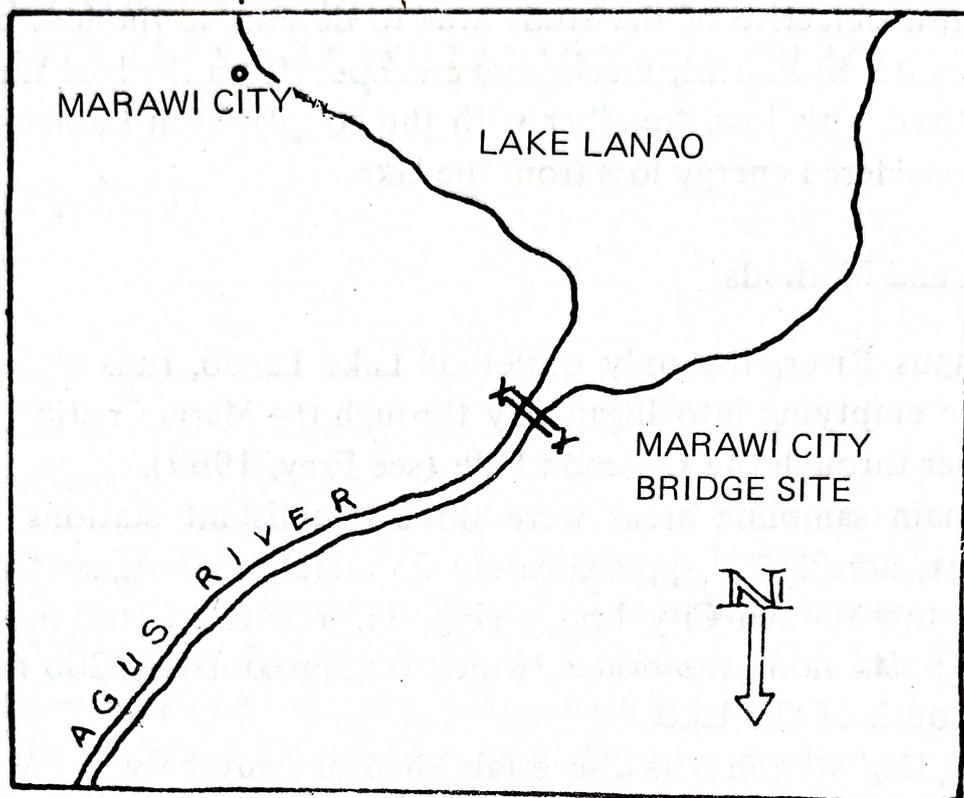
a. AGUS RIVER AT THE MARAWI CITY BRIDGE SITE
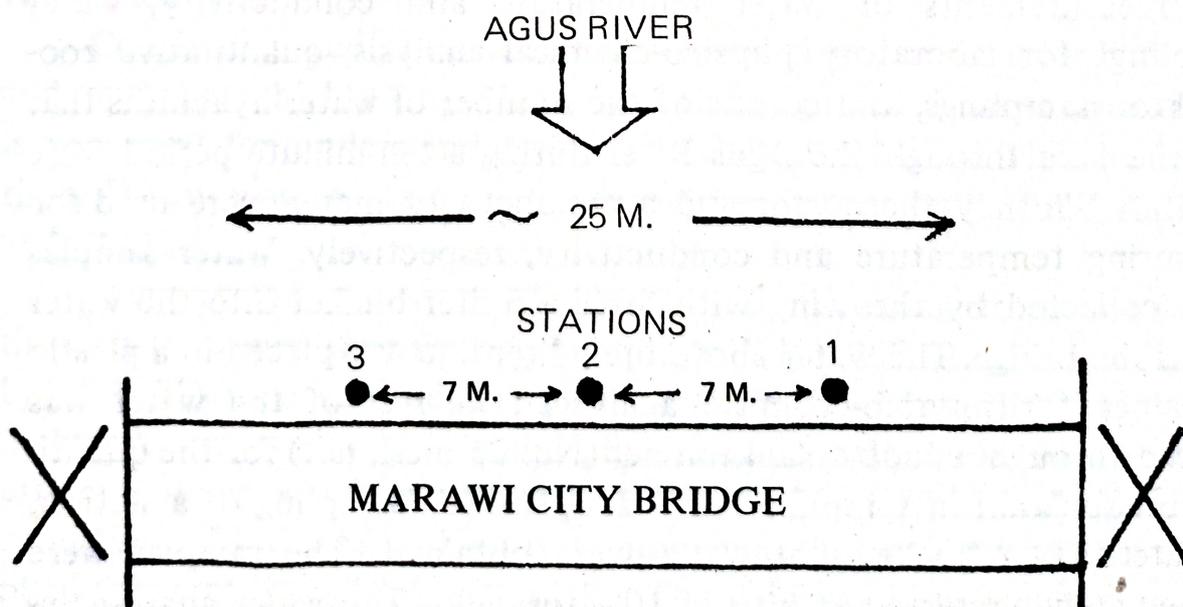
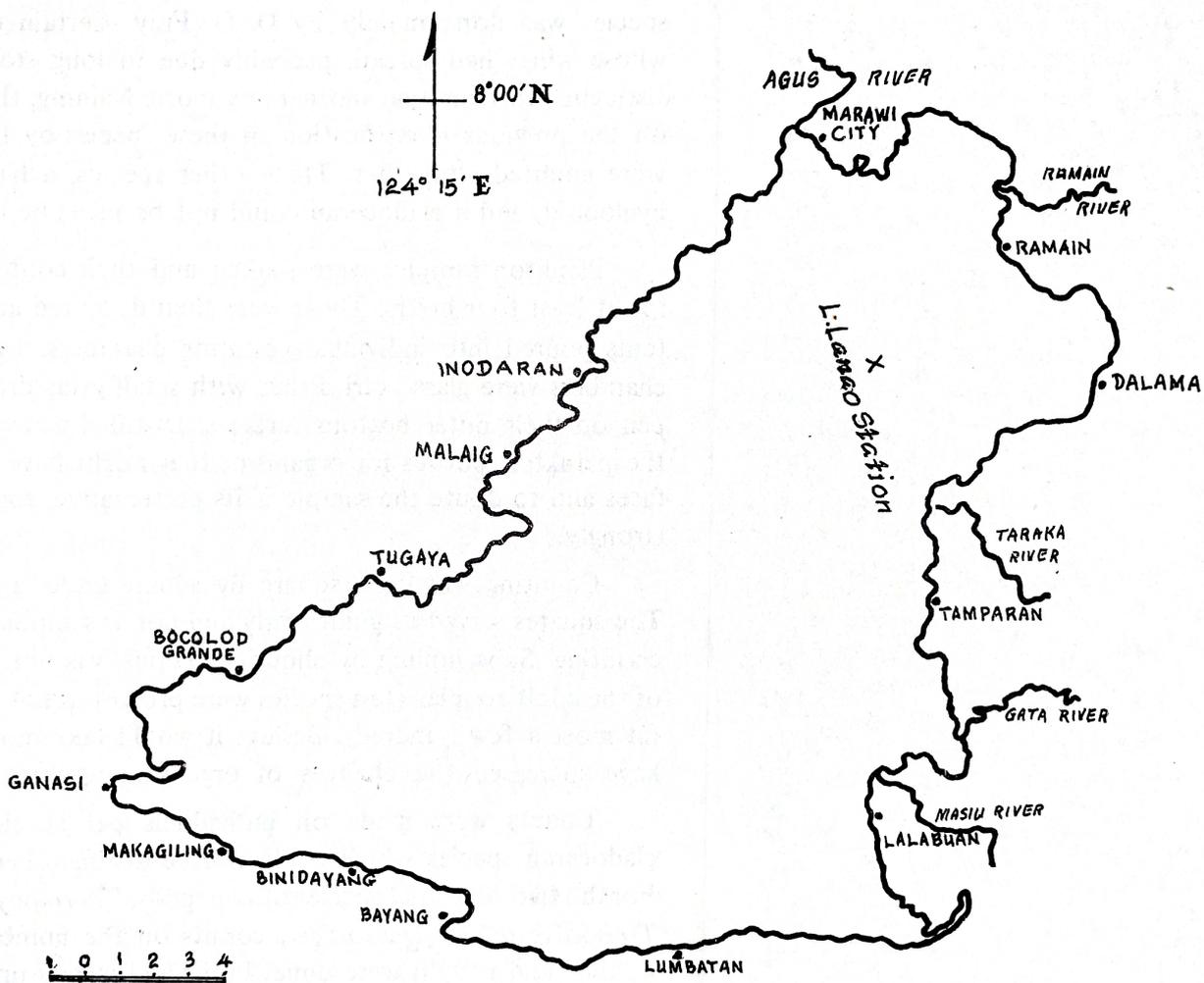## b. STATIONS ACROSS THE AGUS RIVER

FIGURE 2. LAKE LANAO STATION. (MAP MODIFIED FROM D. G. FREY, 1969)

content (through standard argentometric methods — APHA Standard Methods for the Analysis of Water and Wastewater).

The zooplankton samples were analyzed at the Biological Laboratory of Silliman University in 1973. Indication of the zooplankton species was done mainly by D. G. Frey. Certain cladoceran species, whose wings had spread, probably due to long storage, could not be distinguished from one another any more. Naming, therefore, was based on the previous identification of these species by Lewis. Both species were counted altogether. Three other species, a harpacticoid, a giant cyclopoid, and a cladoceran could not be identified yet at this writing.

Plankton samples were shaken and their contents made to settle for at least four hours. These were then decanted and the settled contents poured into individual counting chambers. Improvised counting chambers were glass petri dishes with small grids drawn with a colored pen on their outer bottom surfaces. Distilled water was used to wash the plankton bottles for organisms that might have stuck to their surfaces and to dilute the sample if its preservative, formalin, smelled too strongly.

Counting was done square by square under a stereo microscope. The squares served as guides only and not as sampling areas for random counting. Subsampling by aliquot portions was not done because most of the adult zooplankton species were present in not very large numbers (at most a few hundred). Besides it would take more time and would have increased the chances of organisms sticking to the glassware.

Counts were made on individuals per species, except for the cladoceran species which could not be distinguished from each other. For the two perennial species of copepods, *Thermocyclops hyalinus* and *Tropodiaptomus gigantoniger,* counts on the number of adults, copepodids, and nauplii were done. Individual instars under the copepodid and nauplii stages, however, were not counted separately since differentiating them was difficult without a powerful plankton microscope. Males and females in the adult and late copepodid stages were counted separately when possible.

Detailed sketches of some of the species were done in 1974 using a Swift Series SRL research microscope.

Fig. 3. Temperature curves of 3 stations
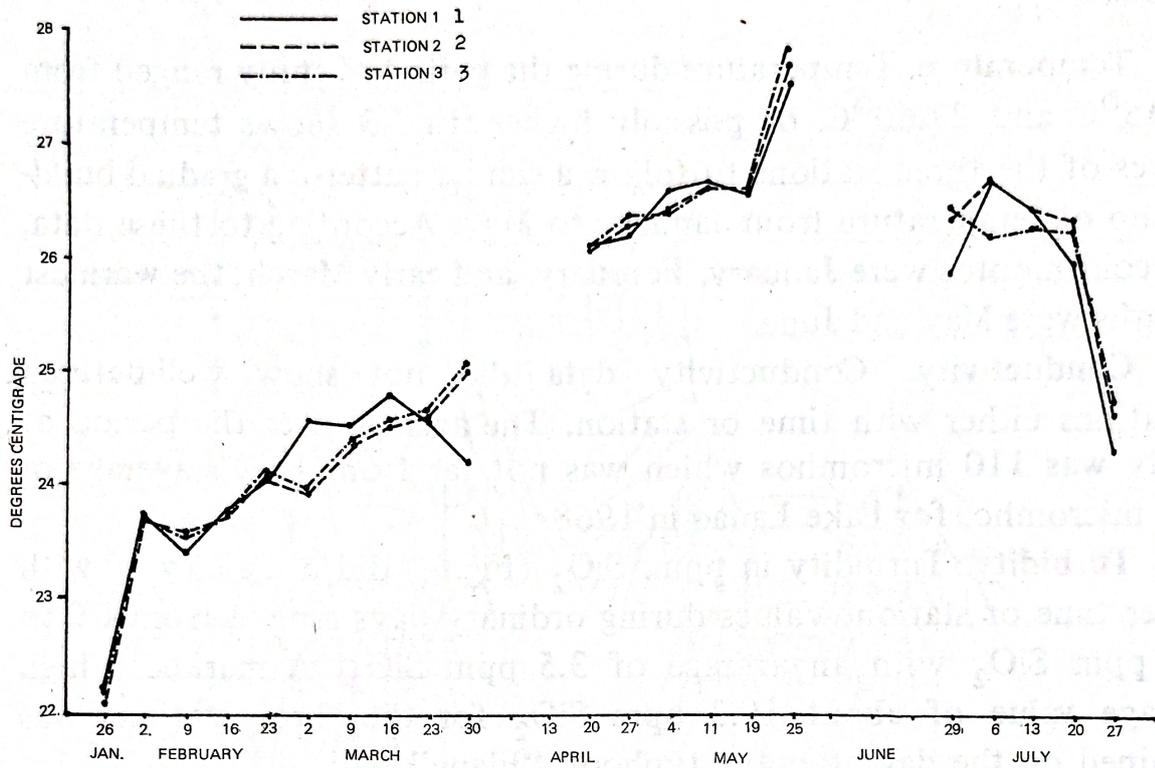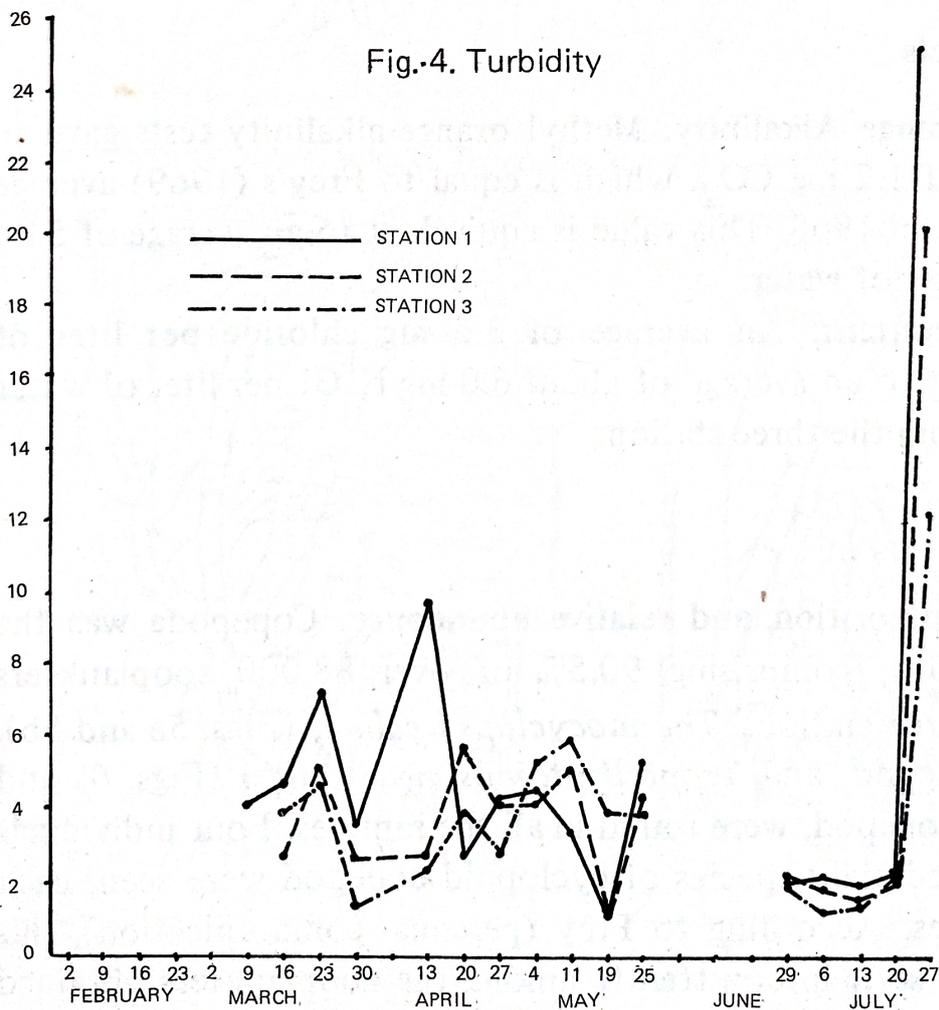

Fig. 3. Temperature curves of 3 stations

Fig. 4. Turbidity

Results

Temperature. Temperature during the period of study ranged from 22.15°C and 27.60°C, or possibly higher. Fig. 3 shows temperature curves of the three stations to follow a similar pattern: a gradual building up of temperature from January to May. According to these data, the cold months were January, February, and early March; the warmest months were May and June.

Conductivity. Conductivity data did not show well-defined variations either with time or station. The average over the period of study was 110 micromhos which was not far from Frey's average of 120 micromhos for Lake Lanao in 1968.

Turbidity. Turbidity in ppm. SiO_2 (Fig. 4) did not also vary with either time or station. Values during ordinary days ranged from 1.0 to 9.7 ppm SiO_2 with an average of 3.5 ppm SiO_2. A markedly high average value of about 19.3 ppm SiO_2 for the three stations was obtained on the day after the typhoon "Elang".

Chemical Aspects

Methyl Orange Alkalinity. Methyl orange alkalinity tests gave an average value of 1.2 mg CO_2, which is equal to Frey's (1969) average for Lake Lanao in 1968. This value is equivalent to an average of 54.4 mg. CO_2, per liter of water.

Chloride content. An average of 3.6 mg chloride per liter of water equivalent to an average of about 6.0 mg NaCl per liter of water was obtained from the three stations

Zooplankton

Species composition and relative abundance. Copepoda was the most predominant, comprising 90.5% of over 88,000 zooplankters caught at the three stations. *Thermocyclops hyalinus* (Figs. 5a and 5b), a cyclopoid copepod, and *Tropodiaptomus gigantoniger* (Figs. 6a and 6b), a calanoid copepod, were found in all the samples. Four individuals of an unidentified giant species of cyclopoid copepod were seen, each at different times. According to Frey (personal communication), this species was also seen intermittently among the zooplankters obtained
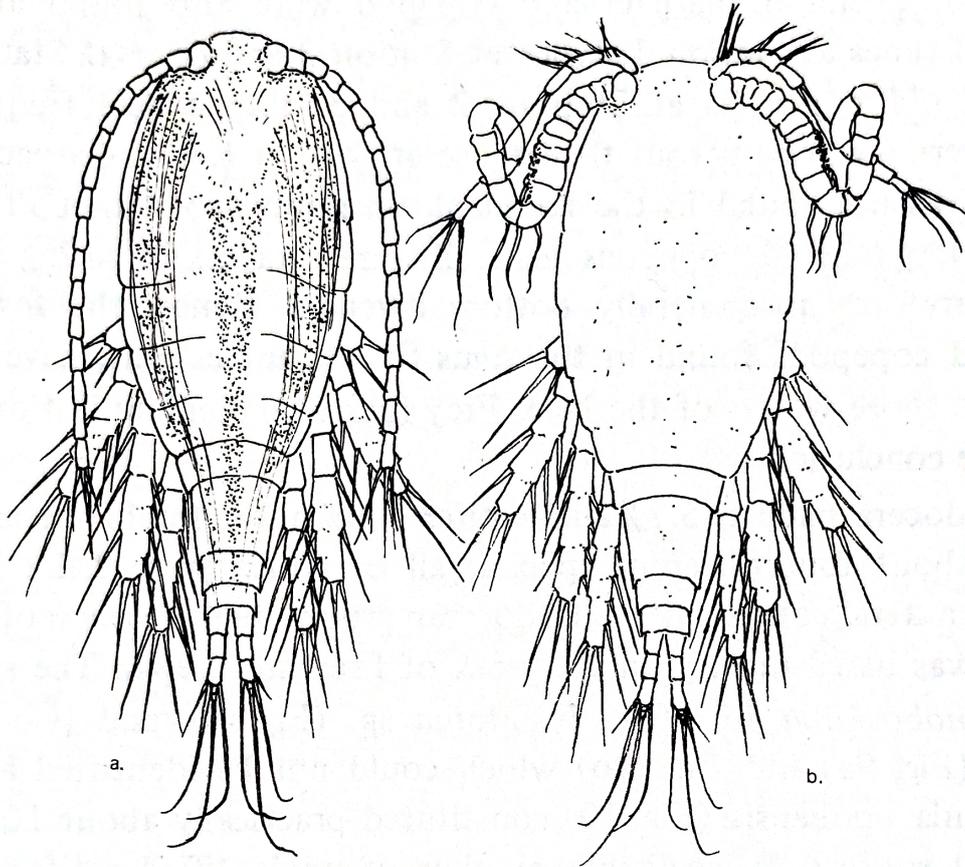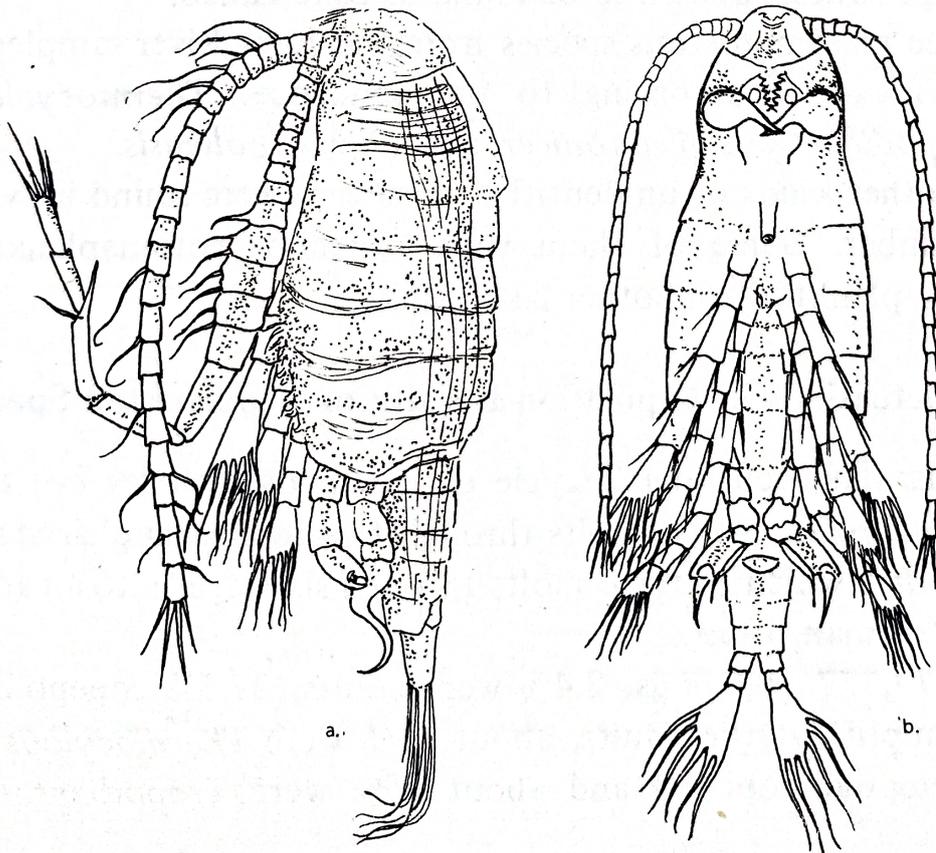
Fig. 5. *Thermocyclops hyalinus*

Fig. 6. *Tropodiaptomus gigantoniger*

by Lewis from Lake Lanao in 1970. Fifteen individuals of an un-identified species of harpacticoid copepod were also found at four different times at Station 1, twice at Station 3 and once at Station 2. Harpacticoid copepods at Stations 2 and 3, though less frequently found were more numerous than those at Station 1. This harpacticoid species was not found in the zooplankton samples of either Frey or Lewis. Harpacticoid copepods generally are scrapers in eating habits and, therefore, are generally bottom dwellers. Hence, the few har-pacticoid copepods found in the Agus River samples must have come from the shore waters of the lake. Frey (personal communication) had the same conclusion.

Cladocera made up 5.7% and Rotifers 3.8% of the total zooplankton catch. About four different species, all of which were Lake Lanao limnoplankters, composed the cladoceran group. Identification of these species was based mainly on the work of Frey and Lewis. The species were *Sinobosmina* sp. (Fig. 7), *Moina* sp. (Fig. 8), and two other species (Fig. 9a) and Fig. 9b) which could not be identified as yet.

Filinia opoliensis (Fig. 10) constituted practically about 100% of the total rotifers. A negligible number of unidentified rotifers were seen from time to time. Frey (personal communication) listed nine other species of rotifers known to be found in Lake Lanao.

The three most numerous species from the Agus River samples in 1969 were, in order according to predominance: *Thermocyclops hyalinus, Tropodiaptomus gigantoniger,* and *Filinia opoliensis.*

Fifteen other kinds of unidentified organisms were found in very negligible number. Some of them were probably potomaplankton ("true" stream plankton) and other lake plankton.

Temporal Fluctuations in Population Density of Zooplankton Species

Copepods. The general life cycle of copepods include: *egg* that hatches into *nauplius,* which molts through five to six naupliar stages into a *copepodid,* which in turn, molts through six stages into an adult (Wilson and Yeatman, 1959)

Out of 79,677 copepods, 8.4% were adults, 27.5% copepodids, and 64.3% nauplii. Of the adults, about 55% were *Thermocylops hy-alinus,* a cyclopoid copepod and about 45% were *Tropodiaptomus*
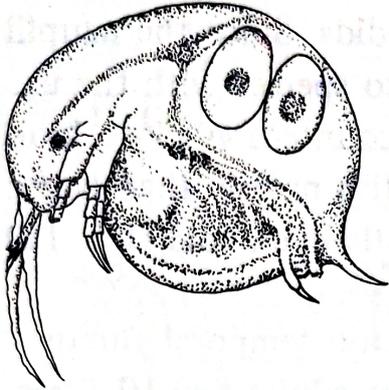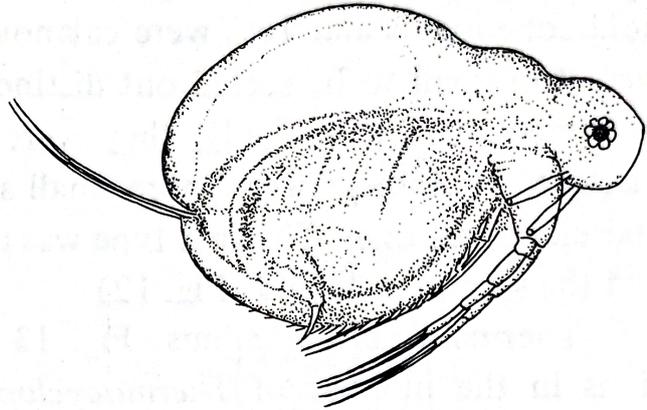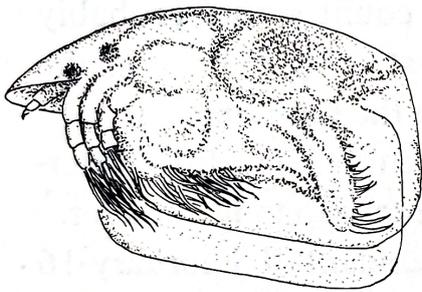
Fig. 7. *Sinobosmina* sp.

Fig. 8 Moina sp.

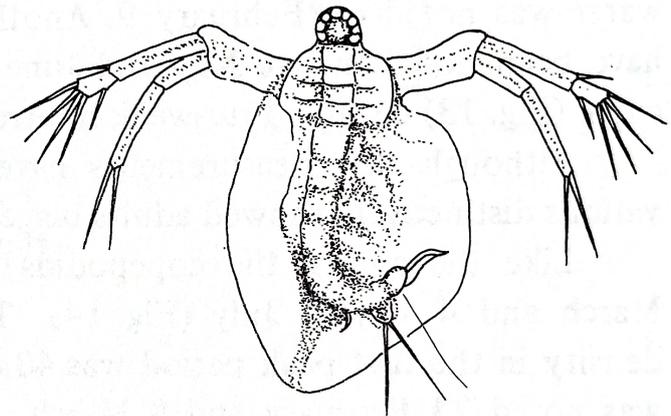Fig. 9. Unidentified cladoceran species

Fig. 9b. Unidentified cladoceran species belonging to Family Daphinidae; carapace spread out
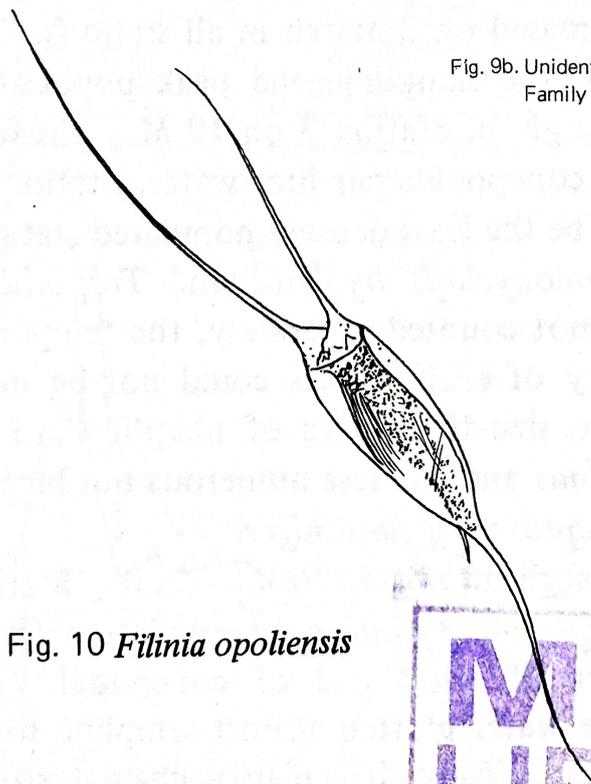
Fig. 10 *Filinia opoliensis*

gigantoniger, a calanoid copepod. Of the copepodids, 82% were cyclopoid copepodids and 18% were calanoid copepodids. Since the nauplii were too small to be sorted out distinctively into species with the use of stereo microscope only, they were merely counted. A close look disclosed that there were more small and roundish nauplii than larger and elongated ones. The first type was undoubtedly cyclopoid (Fig. 11) and the second, calanoid (Fig. 12)

Thermocyclops hyalinus. Fig. 13 presents the temporal fluctuations in the number of *Thermocyclops hyalinus* adults per 10 liters water from the three stations. The lowest count was obtained from Station 1 of the west side and the shallowest part of the river. The highest average count of 20 individual adult *Thermocyclops hyalinus* per liter water was noted on February 9. Another high count would probably have been noted in late May and June as suggested by the rise in the curve (Fig. 13) cut to a four-week interruption in the sampling.

Although size measurements have not been taken, close observations distinctively showed adults bigger in February than in summer.

Like the adults, the copepodids were abundant 9 February-16 March and 4 May-13 July (Fig. 14) The highest average population density in the first peak period was 40 copepodids per liter water. This was noted 23 February and 9 March. For unknown reasons, the population density decreased on 2 March in all stations. Due to the four-week interruption in the sampling, the peak population density for summer could not be given. Station 3 on 19 May already had a population density of 88 copepodids per liter water. Station 1 in almost all samplings showed to be the least densely populated station.

Since the *Thermocyclops hyalinus* and *Tropodiaptomus gigantoniger* nauplii were not counted separately, the temporal fluctuations in population density of each species could not be determined. Observations on relative size-differences of nauplii were the cyclopoid *Thermocyclops hyalinus* and the less numerous but bigger nauplii were the calanoid *Tropodiaptomus gigantoniger*.

Tropodiaptomus gigantoniger. From counts, Station 1 had the least dense *Tropodiaptomus gigantoniger* population (Figs. 15 and 16). The average number of adult and of copepodid *Tropodiaptomus gigantoniger* per liter water plotted against sampling time in shown in Fig. 17a and 17b respectively. Irregularity characterized the manner
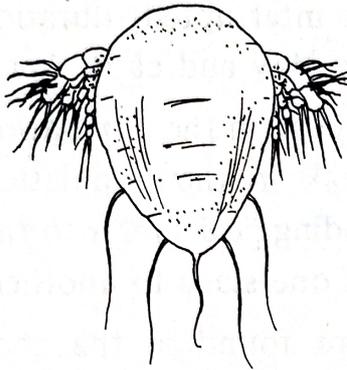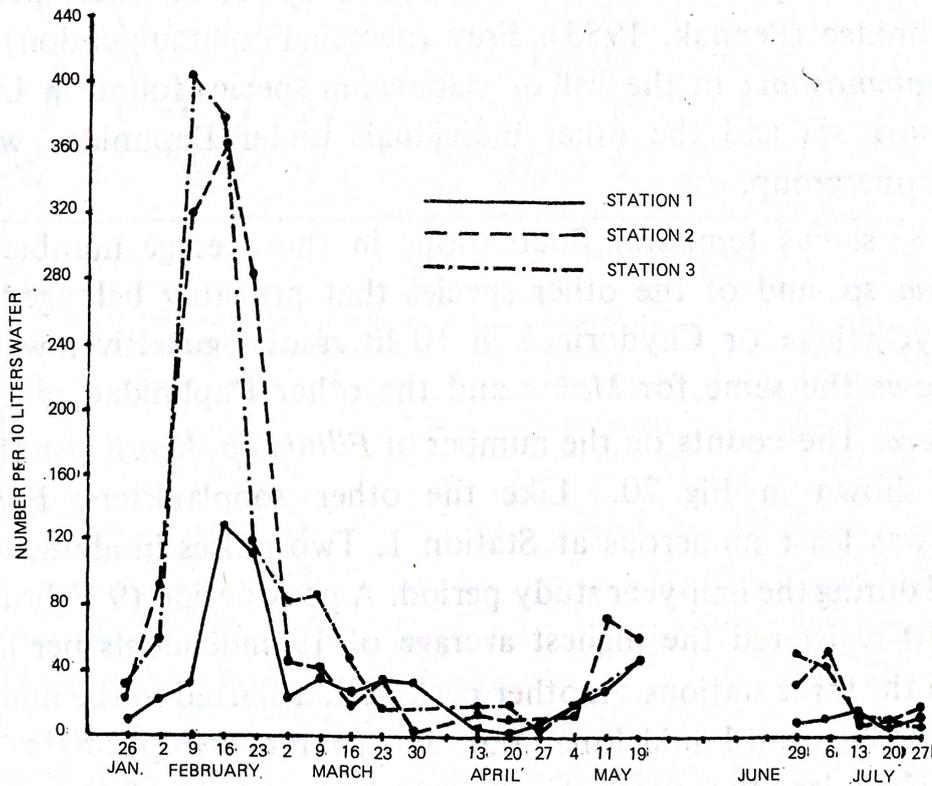
Fig. 11. Cyclopoid

Fig. 12. Calanoid

Fig. 13. Fluctuations in the number on
Thermocyclops hyalinus adults

by which the population density of adult *Tropodiaptomus gigantoniger* and its copepodids fluctuated with time.
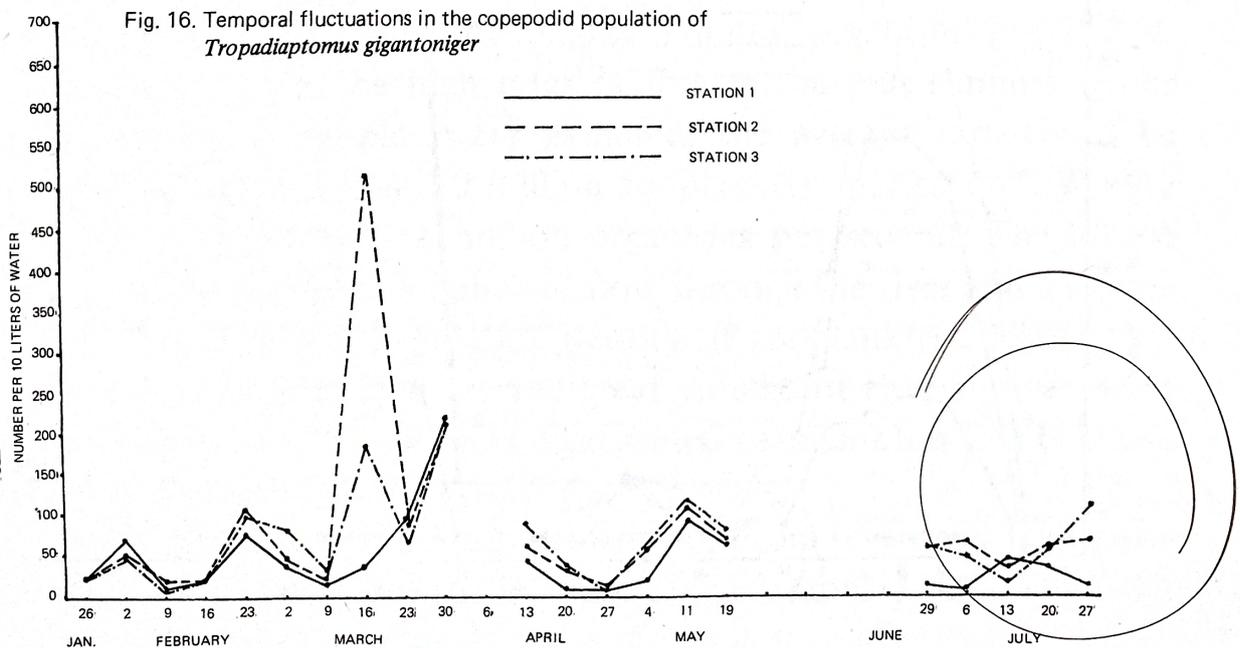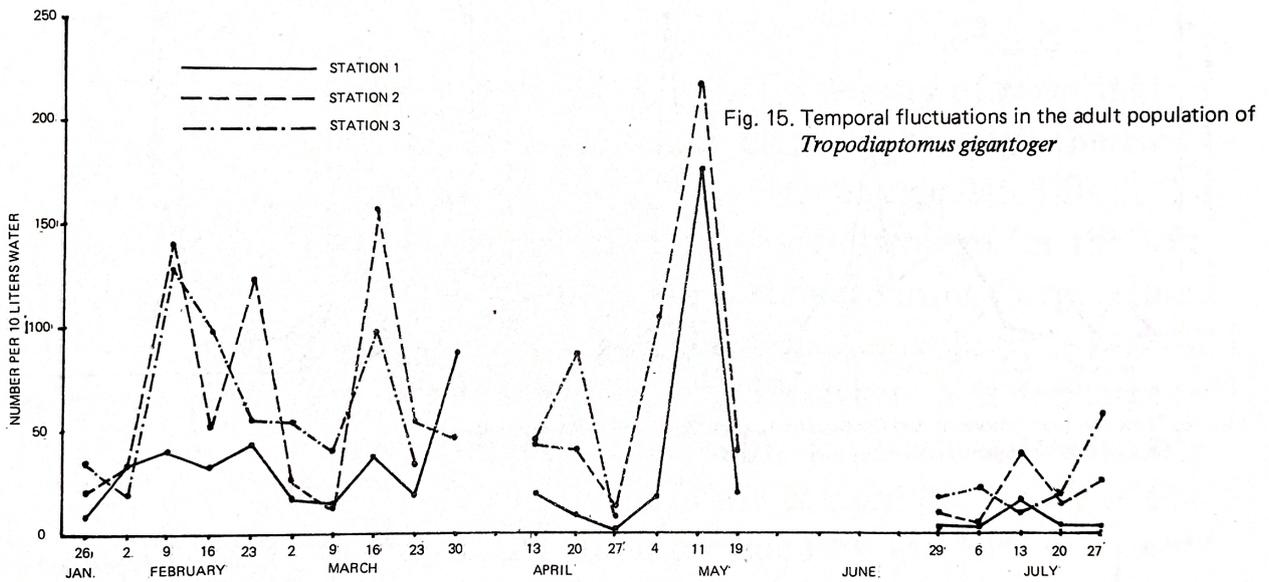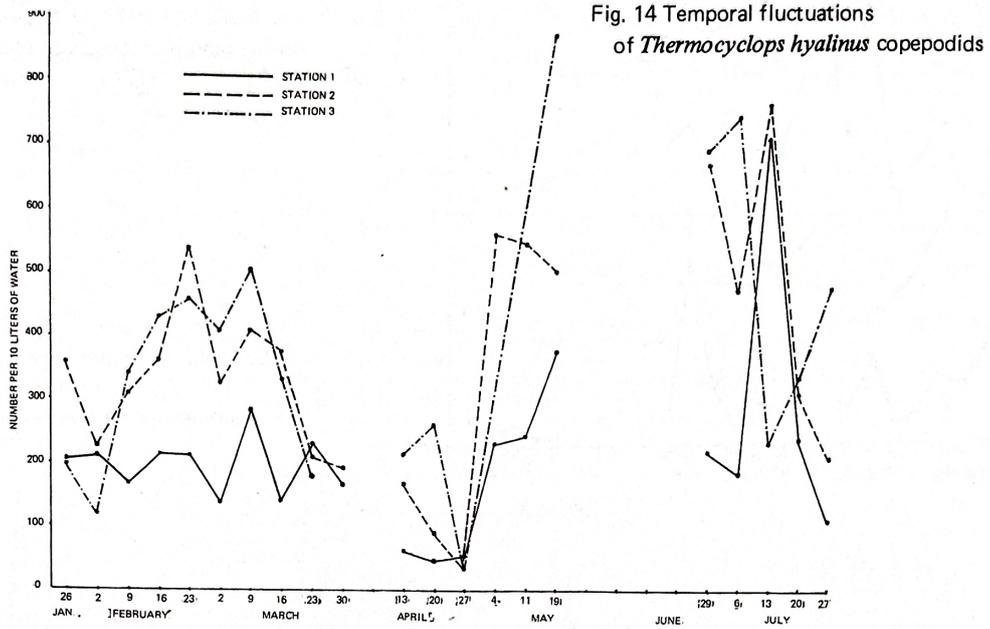
Minor peaks preceded the major peak on 11 May in the population density of adult *T. gigantoniger*. Similarly, minor peaks of short duration preceded the great pulse with a longer, though interrupted, duration in the population density of copepodids in late May and early April.

The data (Figs. 17a and 17b) suggest that a peak in the population density of copepodids had a corresponding peak in the population density of adults at a later time. These corresponding peaks refer to the same brood of *T. gigantoniger* developing from one stage to another.

Cladocera. Four species of cladocera were found in the zooplankton samples from the Agus River. Two were identified as *Sinobosmina* sp. (Fig. 7) and *Moina* sp. (Fig. 8) . An unidentified species (Fig. 9a) may either be Eurycercinae or Chydorinae (Pennak, 1953), as the length and form of its rostrum indicate. The other unidentified species (Fig. 9b) was in morphology similar to *Moina.* But the identification was difficult because the carapace of the individual sample species had been spread. It could be a *Moina* sp. or another species under Daphnidae (Pennak, 1953). Frey (personal communication) included *Diaphanosoma* in the list of cladoceran species found in Lake Lanao. *Moina* sp. and the other individuals under Daphnidae were counted as one group.

Fig. 18 shows temporal fluctuations in the average number of *Sinobosmina* sp. and of the other species that probably belonged to either Eurycercinae or Chydorinae in 10 liters of Agus River water. Fig. 19 shows the same for *Moina* and the other Daphnidae species.

Rotifera. The counts on the number of *Filinia opoliensis* per 10.1. water are shown in Fig. 20. Like the other zooplankters, *Filinia opoliensis* was least numerous at Station 1. Two pulses in abundance were noted during the half-year study period. A peak period (9 February to 9 March) registered the highest average of 19 individuals per liter water from the three stations. Another peak period started in the middle of May, possibly until mid-June. But due to the disruption in the sampling schedules, the exact duration and magnitude of this pulse could not be determined. Judging from the very steep rise in the graph, this pulse could have been greater than the previous one. It is possible

Fig. 14 Temporal fluctuations
of *Thermocyclops hyalinus* copepodids

Fig. 15. Temporal fluctuations in the adult population of
Tropodiaptomus gigantoger

Fig. 16. Temporal fluctuations in the copepodid population of
Tropadiaptomus gigantoniger

Fig. 17. Developmental Stages of *Tropodiaptomus gigantoniger*. Arrows point out succession of particular cohorts from one stage of development to the next.

Fig. 19. Temporal fluctuations of *Moina* sp. and other Daphnidae (Fig. 9b). Counts for both were combined.

Fig. 18. Temporal fluctuations of two Cladoceran Species. Solid line — *Sinobosmina* sp.; broken line — unidentified species (see Fig. 9a, 9b)

Fig. 20 Temporal fluctuations of *Filinia opoliensis*

that the steep rise was followed by a sharp fall. *Filinia opoliensis* disappeared completely from the three stations during the rest of the study period.

Biomass Lost From Lake Lanao Through the Agus River Zooplankton. The rate of loss of zooplankton organisms from the lake was derived from the data on the population density of zooplankters and on the rate of flow of water. In equation form, it would be

$$\text{No. of zooplankton organisms drained from Lake Lanao/second} =$$

$$\frac{\text{volume of flow of } H_2O \text{ in } m^3}{\text{second}} \times \frac{\text{number of zooplankters per liter } H_2O}{} \times \frac{1{,}000 \text{ liter } H_2O}{m^3 H_2O}$$

Table 3 summarizes data on the population density of zooplankton in the Agus River, volume of flow of lake discharge through the river, and the rate of zooplankton loss through the river as calculated from the above equation. The data on volume of flow of discharge for the lake were read from a graph supplied by the National Power Corporation. Such data could also be computed from a regression equation derived by Frey (1969): $Y = 118.375 \, X - 82{,}981.536$ where Y is discharge in m^3/sec. and X is lake level in meters. This equation is linear only within certain limits (Frey, 1969) and in my computations gave at one instance negative Y. Hence, the graph provided by the NPC was used.

The rates of zooplankton loss from Lake Lanao from 21 sampling weeks gave a weekly average of roughly 8 million organisms per second. With allowances for the high rates of loss in the four summer weeks during which no samples were gathered, the average rate could be corrected to not less than 10 million zooplankters per second. Weekly rates ranged between 2-21 million organisms per second. The lowest rate was due to the small amount of flow through the river and a corresponding relatively low population density of zooplankters. High population density of zooplankters and great volume of river flow account for the highest rate. These rates represented zooplankton loss between 7-10 A.M. during which all samplings were made.

Water Hyacinths (Eicchornia crassipes). From seventeen 10-minute countings of *E. crassipes* individuals drained from Lake Lanao, an

average loss of 1.02 plants per second was computed. From a sample population of 271 individual plants, an average of 91.5 x 10^{-3} kg wet weight and 18.2 x 10^{-3} kg dry weight of *E. crassipes* were lost from the lake every second.

Assuming that these samples were representative of the hyacinth population for the whole year, then the lake would have a year's drain of about 2.9 x 10^6 kg wet weight or 5.7 x 10^5 kg dry weight of *E. crassipes* for 1969.

Discussion

Physical-Chemical Aspects. The temperature curves of the Agus River water coincided with the seasonal temperature pattern obtained by Frey (1969) and Lewis (1973). Since all temperature data were obtained in early morning (7-9 a.m.), when insolation could have been minimum, these data could be taken as reasonable reflections of temperature in the upper strata of Lake Lanao. Lake Lanao, being a warm monomictic lake (Frey, 1969) probably underwent mixing during the cold months. Both Frey (1969) and Lewis (1973) obtained physico-chemical evidence of mixing during such cold months and stratification during the rest of the year, especially during the warmest months.

Data on methyl-orange alkalinity exactly agreed with Frey's (1969) average for the lake 1968. Such average would classify the harness of the lake as medium, according to the American system used by Birge and Juday (1911) and by Welch (1952).

In general, these physico-chemical characteristics of the Agus River water at the Marawi City bridge site seemed within the water quality standards of the U.S. Public Health Service (1962) and the World Health Organization (1958; 1961) for drinking, industrial, and irrigation use. In this context, the water of Agus River, in particular, and Lake Lanao, in general, were not polluted in 1969. Compared to the quality of finish water in the 100 largest cities in the U.S. (U.S. Geological Survey, 1962), the Agus River water, had a slightly lower median values for specific conductance, SiO_2 and chloride contents.

There was, however, obvious organic pollution (eq., faecal matter and in certain locations, decaying sawdust) in the littoral portions of the lake and in the riverside. Whether such pollutants affected the

dissolved organic matter content of the lake and the river greatly could not be ascertained by the limited chemistry done during the study. A tremendous increase in the dissolved organic matter content of a body of water could result in an irruption in its bacterial population and an increase in its biological oxygen demand. In a stratified lake, great reduction or even complete depletion of the oxygen content of the bottom waters, due mainly to an increased rate in bacterial respiration, could result from a great organic matter pollution. Lewis (personal communication) observed a marked reduction in the oxygen content of the bottom strata of Lake Lanao in 1970 from that obtained by Frey from the same layer during a stratification period in the summer of 1968. Such increase in the biological oxygen demand of the bottom waters, if continued because of unchecked organic matter pollution and siltation from deforested watersheds, could endanger the various life forms including fishes in the lake.

Biological Aspects

The species obtained from the Agus River during the early morning samplings could not have represented all the zooplanktonic species found in Lake Lanao. This was because the outflow came mainly from the uppermost layer of the lake. Therefore species in the deeper layers could not be represented fairly in the samples. If some samplings were done in the evening, then zooplankton species that inhabited the deeper layers in the day but that would generally surface at night, would have been caught. No such samplings were done for some reasons.

Such species composition, as had been determined, however, relatively agreed with Pennak's (see Ruttner, 1968) characterization of the composition of the limnic zooplankton in his investigations of 27 Colorado lakes. According to this author, the zooplankton would be composed of about 1-3 copepods, 2-4 cladocera, and 3-7 rotifers; seldom could more than one species of a given genus occur at the same time; and even within the three bigger systematic groups namely copepods, cladocerans, and rotifers, one species in each group would be predominant.

The zooplankton collected from the Agus River consisted of four species of copepods, about four species of cladocera and several species

of rotifers. The two perennially occurring copepod species belonged to different suborders: *Thermocyclops hyalinus* (Suborder Cyclopoids) and *Tropodiaptomus gigantoniger* (Suborder Calanoida). The third species was cyclopoid but there were only four individuals of this species in the samples. The fourth copepod species belonged to suborder Harpacticoida; this, too, was found in the samples a number of times only. Two identified cladoceran species belonged to different genera. The remaining species could not be identified, but their morphology suggested they probably belonged to different genera. Only one species of rotifier was commonly found. Considering all three bigger systematic groups, the cyclopoid copepod *T. hyalinus* was the most predominant species and Order Copepoda was the most predominant group.

The number of zooplankton drained from the lake depends to a great extent on the zooplankton population size in the uppermost waters (including shore waters) of the lake, especially the portion proximal to the river. Temporal fluctuations in the population density of individual zooplankton species from the river, therefore, would reflect temporal fluctuations in the population size of such species in the uppermost lake waters. Assuming that the horizontal distribution of these zooplankton species over the entire lake basin was more or less uniform and that the responses of their population sizes to seasonal environmental changes were similar, then such temporal fluctuation patterns in the Agus River would relatively reflect those in the upper layer of the lake. I can, therefore, say that peaks in the population sizes of the individual zooplankton species in Lake Lanao took place about the same time that peaks in the population density of these species sampled from the river were observed.

Population density of any community of organism over a period of time would fluctuate as a result of the interaction between the *rate of multiplication* and the *rate of depletion* (Ruttner, 1968). In a plankton community, depletion would be by death through various causes, both biotic and mechanical. Ruttner (1968) cited as an example of biotic depletion the work of Canter and Lund (1951), that showed the depopulation of *Asterionella formosa* in Lake Windermere through an attack of the fungus *Rhizophidium planktonicum*. Biotic depletion may also be due to death by predation and old age. Mechanical causes of

death would include sinking into the hypolimnion with subsequent sedimentation and draining through the lake's outlet. The rate of multiplication, on the other hand, depends on the rate of the reproductive process, which varies with seasonal variations in environmental factors. The exact influence of any single environmental parameter on the productivity of a community at any given time is difficult to define since in nature no single factor can be isolated for study of its effects. A natural phenomenon, such as seasonal fluctuation of population density cannot be attributed to any single environmental factor but to the interaction of many environmental factors. Among these, temperature, light, and nutrients are of prime importance.

Light affects primary productivity mainly. We know, for example, that too little light limits the rate of photosynthesis. Too much light inhibits photosynthesis by the inactivation of chlorophyll (Ruttner, 1968). The amount of light must be at its optimum to increase the photosynthetic rate to the maximum. Light affects zooplankton productivity indirectly since part of the zooplankton energy source comes from the primary producers.

Temperature doubly affects zooplankton productivity: first, by indirectly affecting the rate of photosynthesis in the phytoplankton and therefore the amount of energy available for the zooplankton; second, by directly affecting metabolic rate in the zooplankton community. According to Van't Hoff's law, the rate of a chemical reaction is about doubled for every $10^\circ C$ rise in temperature.

Although it is difficult in most cases to establish direct correlation between the amount of nutrients available and productivity in a lake due to the nutrients being in constant use, the phenomenal effect of their ready availability during turnovers on the massive development of phytoplankton, especially diatoms, is well established (Ruttner, 1968). The massive bloom of diatoms during a spring circulation in temperate lakes, for example, is explained by the recycling into the upper waters of a lake of silicon, which during the stratification period accumulates without much use in the lake bottom.

As stated in the results, adults of the cyclopoid *Thermocyclops hyalinus*, adults of the calanoid *Tropodiaptomus gigantoniger*, and the rotifier *Filinia opoliensis* each showed two pulses in population density

during the cooler months of February and early March and the other sometime during the warm months of May and June.

Cyclopoid and calanoid adults found during the February pulse were generally bigger than those found during the summer pulse. There should be little doubt that circulation in Lake Lanao occurred at about the same time. Frey (1969) and Lewis (1973) showed that circulation, although variable in duration, annually took place during the coldest part of the year. The availability of nutrients brought about by such circulation could very well be a major factor in the abundance of the three species and relative largeness in the physical size of the copepod species. In temperate lakes, phytoplankton, particularly diatom, blooms normally follow an overturn (Ruttner, 1968), supplying greater sources of food energy for, and, therefore stimulating higher production rates in, their consumers.

The summer pulse in abundance could perhaps be attributed to the prevailing general weather conditions during the period. First, light was abundant. Within certain limits, more light could bring about higher rates of CO_2 assimilation by phytoplankton and, therefore, higher production. More phytoplankton available meant more food for the primary consumers (e.g. calanoids, and most rotifers) whose increase would in turn increase the production rate of their predators (e.g. cyclopoids). Higher production rates would favor greater accumulation of biomass, assuming, of course, that the mortality rate did not increase just as rapidly.

Second, temperature was getting higher. Higher temperature would mean higher metabolic rate. Rates of energy-fixation, as well as of energy-breaking, could therefore be high. The amount of biomass accumulated would be a balance between these two rates — the first expressed in the production of greater number of individuals per unit time, the second expressed in general reduction of physical size and of life span, meaning greater mortality rates. It is therefore possible for high productivity, without a corresponding high biomass, to take place during a very hot summer.

At certain optimum temperature, however, the rate of energy-fixation would be favored more than the rate of breaking down, thus allowing accumulation of plankton biomass. Hence, the occurrence of

peaks in abundance. But as mortality rates exceed production rates, the number of individuals declines.

Temperature beyond the tolerance of individual species could mean great reduction or even complete disappearance of the species. It is believed that this had happened to the population of *Filinia opoliensis* (Fig. 20). On 19 May a peak in abundance was observed. In subsequent samplings, the first of which was about four weeks later. The species totally disappeared. It is possible that *F. opoliensis* is an organism that forms spores or resting stages under an extremely unfavorable condition, probably temperature. Such spores would sink to the bottom to await the coming of more favorable conditions.

The three sampling stations were marked by three equidistant points fixed along the Marawi City Bridge. Station 1 at the western side of the river (towards Mindanao State University) was the shallowest and therefore was most affected by fluctuations in the lake water level (the lower the lake level, the shallower and closer to the shoreline Station would become). Station 2 at the middle of the river was the deepest. Station 3 at the eastern side (towards Marawi City) was not as deep as Station 2, nor as shallow as Station 1.

Curves on the physical-chemical parameters showed Station 1 to be the most variable, hence, different from Station 2 and 3. Stations 2 and 3 had data of different numerical values but had almost parallel changes most of the time.

Station 1 had the lowest population density of zooplankton organisms in almost all cases. An analysis of variance to test differences among the means of the population densities of two copepod species (*Thermocyclops hyalinus* and *Tropodiaptomus gigantoniger*) in the three stations showed significance at the 5% level. For Stations 2 and 3, analysis of variance gave an F ratio of .000086, which was insignificant.

A probable explanation for the similarity between Stations 2 and 3 and the difference between them and Station 1 would be these: 1) fluctuations in depth of water and proximity to the shore line that followed fluctuations in lake water level was greatest at the shallow Station 1; such could affect temperature (shallower water means greater insolation) and chemical data (run-off water, drainage, etc. that join the river at its shores carry chemicals); 2) Both stations 2 and 3 were fixed at relatively deeper waters, bringing about similar fast rates of the

discharge; hence similarly carried away great although variant number of organisms.

At the 5% level of significance, the value of F (critical value: 4.00) for *T. hyalinus* was 44.3 (very high) and that for *T. gigantoniger* was 4.75 (slight). Whether or not this great difference between the species was due to differences in their ability to swim and thus in their ability to avoid being drifted by the current could not be ascertained. Ruttner (1968) mentioned the ability of cladocera *Moina* and *Diaphanosoma* (generally, better swimmers) to escape from the outgoing current, thereby preventing their complete depletion during periods of high mountain waters.

The quantitative zooplankton data from the Agus River represented the number of zooplankters lost from Lake Lanao through the river. The magnitude of such biomass loss from the lake over a period of time would depend not only on the size of the zooplankton population in the upper lake layer that contributes to· the outgoing current. But it would also depend on the volume of flow of water through the river, and, very possibly, also on the strength of the outgoing current.

The zooplankton population size in the upper lake strata would be influenced mainly by seasonal fluctuations and by diurnal migration, aside from such factors as competition and predation. The greater the population, the more zooplankters would carried by the current out of the lake. Likewise, assuming that all the other conditions are similar, a smaller zooplankton population in the lake would reduce the number lost through the river. Since most plankton generally surface in early evening and return downward at dawn (Ruttner, 1968), it should be expected that a plankton biomass loss occurs much more at nighttime than at daytime.

The volume and strength of water flowing out of the lake would depend on the lake water level. The lake water level in turn would vary with the amount of precipitation on the lake and its watersheds. Logically, the biomass drained from the lake would be directly related to both volume of flow and strength of current. Ruttner (1968) mentioned water renewal, which was associated with the amount of inflow-overflow in a lake, as a radical depletion factor in the population of zooplankton in the Alpine lakes. He further cited how a massive

development of plankton right after ice thawed in spring could disappear completely during a high inflow of mountain water coming from melting snow.

The interaction of two factors — volume of flow and strength of current — is shown in Table 4. The highest rate of zooplankton loss from the lake occurred on sampling day 19 May when the highest available population density of 439 zooplankters per liter of Agus River water was obtained. Volume of river flow at this time was about $62 \frac{m^3}{sec.}$ less than half the peak flow on 20 July. The lowest rate of zooplankton loss, however, did not coincide with the lowest population density (about 52 zooplankters per liter) on 26 January; instead it was noted on 27 April when both population density (69 organisms per liter) and the volume of flow (28 m^3/sec) were fairly low.

The average rate of zooplankton loss from Lake Lanao through the Agus River in the first half of 1969 was about 10 million zooplankters per second. It represented the loss at the first half of the morning (between 7:00-10:00 A.M.). Slight changes probably occurred as the day progressed and marked ones, as twilight approached. Greater rates of zooplankton loss would be expected during nighttime.

The loss of zooplankton energy from the lake would consequently affect the energy budget in the next higher trophic level — that of organisms that would feed on the plankton (e.g. shrimps, fishes). If a way to convert the number zooplankters lost from the lake into weight could be devised, then such energy loss could be expressed in terms of energy lost from the next higher trophic level (fishes, shrimps, etc. which are directly useful to man) knowing that the net amount of energy conversion from one trophic level to the next is approximately 10%. This study on zooplankton biomass loss, therefore, is important because it provides us rough ideas on how much potential useful energy is involved in the loss.

The estimated annual drain of 2.9 x 10^6 kg wet weight or 5.7 x 10^5 kg dry weight of *E. crassipes* from Lake Lanao would represent loss through the outflow of energy in macrophytic form. Such energy could have been partly transformed into animal flesh energy since fishes, shrimps, mollusks that live on them, and insects would feed on various parts of this macrophyte, and the greater part recycled into the chemical

energy of the lake through bacterial action after the organisms' death. This plant species would also be valuable organisms, to the mollusks and the many other organisms that live on them. Villaluz (1966) discussed three methods of fishing among the Maranaos — the "tagik", the "oyon", and the "bonsod". These methods use *E. crassipes* as shelters to the fishes.

Summary and Conclusion

A study on the water leaving Lake Lanao through the Agus River was done from January 26 to July 27, 1969. The study included determinations of certain physical-chemical characteristics of the water, qualitative and quantitative characteristics of the zooplankton drained from the lake relative to the volume of water, and the biomass of water hyacinths being drifted out of the lake relative to time. Three sampling stations were established at the Agus River at the Marawi City bridge site, about 200 meters away from the lake mouth. Regular once-a-week samplings were done between 7:00-10:00 A.M.

Water temperature curves showed the same seasonal temperature pattern obtained by Frey in 1968 (Frey, 1969) and by Lewis in 1970-71 (Lewis, 1973). Circulation in Lake Lanao undoubtedly occurred sometime during the cold months which included January, February, and early March, Lake Lanao being a warm monomictic lake (Frey, 1969 and Lewis, 1973). Methyl-orange alkalinity data also agreed with Frey's average for the lake (Frey, 1969) and would describe the lake as medium in hardness. Data on conductivity and on silicon oxide and chloride contents of the river water showed means lower than the median values established by the United States Geological Survey in 1962. These physico-chemical tests on water leaving lake Lanao through the Agus River in 1969 showed that the water was, in those particular aspects, unpolluted. Since, however, organic matter pollution was obvious, as can be gleaned from the constant presence of faecal matter along the riversides and the lake shores and of rotting sawdust where the sawmill is located, studies on the dissolved organic matter content of the water and on its microbiology, would be highly recommended. Continuing studies on the oxygen profile of the lake would also show responses of the lake chemistry to organic matter pollution.

The zooplankton species may represent only those found in the upper lake-water layer that contributed to the lake outflow. Such composition, consisting of 4 species of copepods belonging to 3 Suborders, about 4 species of cladocera belonging to 3 Families, and several species of rotifers of which only one occurred commonly, however, agreed closely with Pennak's (see Ruttner, 1968) characterization of the composition of the limnic zooplankton. According to Pennak, the zooplankton would be composed of about 1-3 copepods, 2-4 cladocera, and 3-7 rotifiers. That seldom could more than one species of a given genus be present at the same time, and, that only one species would be predominant, according to Pennak, were given credence in the zooplankton samples from the river. Of the species identified, no two species belonged to the same genus, and the cyclopoid copepod species, *Thermocyclops hyalinus*, was predominant.

Patterns in the temporal fluctuations of the zooplankton population density in the Agus River samples reflect similar patterns of those in Lake Lanao because: 1. The zooplankton species collected from the river came from the lake. The magnitude of such drain greatly depended on the population size of the respected lake zooplankton species. 2. The zooplankters drained from the river might have come mostly from the upper layer of the lake water, especially from the portion proximal to the river. It could be assumed, however, that the horizontal distribution of these zooplankton species over the entire lake basin was about uniform (Ruttner, 1968) and that the response of their respective populations to seasonal environmental changes was also similar.

Population density, as a function of the interaction between the rate of multiplication and the rate of depletion, would fluctuate according to the magnitude of these two rates. Among the various factors that influence the magnitude of these rates, such environmental factors light, temperature, and nutrients available are of primary importance.

Adults of the cyclopoid copepod *Thermocyclops, hyalinus*, the calanoid copepod *Tropodiaptomus gigantoniger*, and the rotifer *Filinia opoliensis* each exhibited peak population density during the cold months and during the warm summer months. Cyclopoid and calanoid adults found during the February (a cold month) peak were bigger than those found during the summer pulse. The probable main cause for the

peak density in the colder months was the availability of nutrients brought about by the circulation in the lake occurring at about this time. The peak summer pulse could be attributed to the general weather conditions prevailing during the period. Light and temperature, for example, were both high. Greater rates of photosynthesis stimulated under such conditions would bring about greater phytoplankton bio-mass, and therefore, more food sources for the zooplankton. When environmental factors, however, went beyond the upper tolerance limits of individual species, a decline in their respective population could be expected. For instance, the complete disappearance of the rotifer *Filinia opoliensis* during the warm months, could have been due to some environmental factors, probably among them, extreme temperature which was beyond the tolerance limit of the species. This rotifer could possible be an organism that would form spores under extremely unfavorable environmental conditions.

Physico-chemical data showed that Station 1 had the most variable curves while Stations 2 and 3 followed about the same patterns. Quantitative zooplankton data also showed that Station 1 had the lowest population density in almost all cases. Analysis of variance showed significant difference at the 5% level among the means of the three stations for the two copepod species but showed no significant difference between the means of Stations 2 and 3. The probable cause for this was the difference in depth of the stations, Station 1 being shallowest, while Stations 2 and 3 were fairly deep. This difference in depth could bring about:

1. greatest effect on Station 1 when the lake water level fluctuates; that is, its proximity to the shoreline increases with a lowering of the lake water level; and

2. a rush of lake outflow towards the deeper stations, the stronger currents bringing more zooplankton organisms than at Station 1. The degree of significance between the means of the three stations was very high (F = 44.30) for *Thermocyclops hyalinus* and slight (F = 4.75) for *Tropodiaptomus gigantoniger* and seemed to suggest some inherent differences in these organisms' ability to swim and thus in their ability to avoid being carried away by the current. This contention, however, could not be supported further for lack of data.

The magnitude of the zooplankton biomass loss from Lake Lanao

through the Agus River would depend mainly on three factors: 1. the population density of the zooplankton in the upper strata of the lake as affected by seasonal fluctuations and diurnal vertical migration; 2. the volume of flow of the lake discharge; 3. the strength of the outgoing current. The interaction between population density of zooplankton and volume of river flow gave an estimated average rate of loss of about 10 million zooplankters per second. This rate, however, represented early morning loss only since all the samplings were done between 7:00-10:00 a.m. Loss of zooplankton, as well as of water hyacinths (estimated from data to be 5.7×10^5 kg dry weight during the year), was part of the energy drained from Lake Lanao permanently. Such energy could have been partly transformed into useful forms in the next higher trophic level — that of organisms that would feed upon the zooplankton and on various parts of the water hyacinths — and partly recycled as the chemical energy of the lake.

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