4.2 Phytoplankton

4.2.1 Component Species

The phytoplankton in the Ypacarai, generally divided, is made up of cyanophyta, flagellated algae, chlorophyta and others (chrysophyceae, euglenophyta) and, seen from the cell number structure ratio, cyanophyta is principal ; for example, at the middle of the lake, its percentage is 46~96% (a simple average would be 84%).

Cyanophyta dominance is one characteristic of a eutrophic lake such as the Ypacarai, reflecting the water quality, highly dense in nitrogen and phosphorous. Moreover, in a temperate zone lake, cyanophyta dominates only in the summer, however in the Ypacarai, the situation is all year long, which typifies a tropical lake.

Cyanophyta frequently multiplies grossly, resulting in a layer formation on the water surface called water bloom. This was true for the Ypacarai from Feb. - Mar. 1988 when water bloom was observed.

The following species are those recorded which exceed 1000cells/ml.

Cyanophyta

- *Anabaena sphaerica*
- *Anabaena spiroides*
- *Aabaenopsis sp.*
- *Microystis aeruginosa*
- *Microcystis tenuissima*
- *Rhaphidiopsis curvata*
- *Rhaphidiopsis mediterranea*

Flagellated algae

- *Melosira granulata*
- *Melosira granulata v. angustissima f. spiralis*

These species always appear in an eutrophic lake.

4.2.2 Present Amount (cell number density)

(1) Results from this study

According to the cell density index, in general when the present phytoplankton amount exceeds 10^3/ml, this results in the possible development of water bloom and fresh water red tide.

In the example taken from the center of the Ypacarai, there are 2000 cells/ml and 5000cell/ml cases, however in the other seven cases, at 10^4/ml (average at 17,847 cells/ml), the level was high enough.

The cyanophyta ratio was 60% at 2000cells/ml and 46% at 5000cells/ml, and because this is relatively lower than that of the highly dense cases, it was understood that the cyanophyta in a multiplying state sways the density.

(2) Comparison with 1984

According to the ICB study results from 1984, the highest value for phytoplankton density in all of the data never exceeded 250 bodies/l and the lake phytoplankton was determined as very scant. As the expressions in the data differ and it is thought the survey methods do as well, direct comparison cannot be performed with this study's results. However, in indexing the cell number density, the lowest is estimated as exceeding 10^3.

The low density of the 1984 phytoplankton was due to pollutants in the water, a low transparency level at 0.13m because of coloring in the water, and the inability of receiving adequate light for phytoplankton breeding.

In contrast to this, in this study, due to discharge of the lake's pollutants by heavy rains in Jan. 1988, the illumination penetration ratio increased, the average transparency level in 1988 was 0.50m with maximum value at 1.00m. Because there was no restrictive factor of illumination deficiency, abundant nitrogen and phosphorous could be used and phytoplankton greatly increased resulting in the high density of phytoplankton seen in this study.

Even in the results from this study, in Feb. and March in 1989, the transparency level average was back down to 0.24m, which shows a return to the condition preceding the heavy rains. Accordingly, the conditions showing the effect of the rains one year later are specifically shown in this study's data.

4.2.3 Horizontal Distribution

The phytoplankton distribution accompanying the lake's major axis differs depending on the density of the phytoplankton.

(1) Average density exceeding 30000 cells/ml in the lake

When phytoplankton is of a high density, there are 3 cases which increase from the SE corner (the Pirayu inflow area) to the NW shore (example in Fig. S3.4.2) and 1 case which decreases (Fig. S3.4.3), as they run along the major axis of the lake (SE-NW).

The principal component of the Ypacarai's phytoplankton is cyanophyta, especially in highly dense cases. Cyanophyta contains a gas vacuole and, depending on the buoyancy, tends to concentrate on the surface water layer. Consequently, its distribution, due to the wind, is easily influenced by the surface flow.

The direction of the Ypacarai's prevailing winds, according to this study's results, are ENE and SSW and sometimes the winds change direction during the course of one day.

Synthesizing the surface flow by the ENE and SSW winds results in a direction just about equal to that of the lake's major axis (SE-NW) and the increasingly dense phytoplankton distribution from the SE corner to the NW shore can be seen as accumulation due to the influence of the wind. As for the decreasing case from the SE corner to the NW shore, until the day preceding the phytoplankton study, the winds prevailed from W, ENE and NE. Synthesizing the wind results in approximately the NW-SE direction and shows that the distribution is influenced by the wind.

(2) Average density under 10000 cells/ml in the lake

When the phytoplankton is of a low density, distribution tendencies along the major axis cannot be identified (4 cases).

Even in this case, the surface phytoplankton can be thought to accord more with the wind, however, because the overall density is low, it is believed that accumulation does not appear to be remarkable.

The distribution along the short axis (NE-SW), due to few observation points, could not be verified, however in the case of high density, the wind gives rise to moving and accumulation patterns. At the time of water bloom development in Feb. 1988, water bloom was observed as blown by the wind toward the NW shore (Feb. 16) and the S shore (Feb. 24).

4.2.4 Seasonal Changes

In this study, as data was obtained from Feb. 1988 to Mar. 1989, it should be possible to understand phytoplankton seasonal changes.

However, as stated in 4.2.2, this data is also believed to include the transition process from the heavy rains in Jan. 1988.

(1) Species composition changes

The fact that the principal structural component of phytoplankton is cyanophyta doesn't change over the course of the year, however, judging from the seasonal change in the structure ratio at the center of the lake, the ratio of cyanophyta in March 1988 and Feb. 1989 was low (Fig. S3.4.4). This period represents the end of summer, in other words, the period where the continuous warm water temperature of the summer begins to cool down.

When the ratio of cyonophyta decreases, the ratio of chlorophyta relatively increases. However, the overall density decreases and the chlorophyta does not increase. Accordingly, as for the decrease of the cyanophyta structural ratio, the believed condition is that the plankton species principally dominant in the summer decreases and another species increases, representing a dominant species rotation period.

The change in the cell structure density of the principal plankton species (above 10000 cells/ml) at the center of the lake is shown in Fig. S3.4.5. In the summer of 1988, the principal species was *Anabaena spirodes*, however changed to *Microcystis tenuissima* in the winter, and then to *Anabaenopsis* sp. In the summer of 1989, the dominant species was *Microcystics aeruginosa*, and changed to *Anabaenopsis* sp. at the end of the summer season.

This type of dominance rotation represents a phenomenon where some individual groups of species increase quite exclusively until reaching the saturation level under these conditions. Then, as the saturation level continues, depending on the density effects whereby the waste matter concentration increases, individual group recession is prepared for. Later, depending on changes in the water temperature and other environmental conditions, the density decreases. Finally, other species becomes dominant and begin to increase.

The dominant species in the summer of 1988 and that of 1989 differed, however due to the transition process induced by heavy rains in Jan. 1988, it is thought, there is still no establishment of a seasonal cycle.

(2) Existing Amount Fluctuation

Fig. S3.4.6 shows the existing amount (cell density) of the phytoplankton in the lake and the density fluctuation of the primary dominant species (the species with the highest cell density for a given season).

The fluctuation occurs between the 20000 - 45000 cells/ml range, however there are no seasonal tendencies discovered.

When the existing amount is low, the primary dominant species ratio shows a low tendency corresponding to the primary dominant species rotation period, it is believed.

(3) Relationship with Environmental Conditions

The principal environmental conditions related to the multiplication of phytoplankton are water temperature, illumination, nutrient salts and the retention period.

From among these conditions, water temperature and the light (solar energy) change over seasons, and it is believed those changes relate to dominant species alternation of phytoplankton, but not to their existing amounts. Furthermore, these changes provide the phytoplankton with the adequate conditions for growth. (It is believed that the speed of multiplication is influenced by the water temperature and the light conditions.)

Transparency, which reflects the illumination condition in the water, was about 0.50m on the average in 1988. It decreased to 0.24m in 1989. However, this has not influenced the constitution of species nor the existing amount of phytoplankton yet.

As for nutrient salts, although there is a tendency for the T-P and PO_4-P density to decrease in winter and to increase in summer, there is no relationship to the variation of phytoplankton. However, in contrast to that, in 1988, PO_4-P density decreased to 0 frequently and then increased suddenly in 1989, and NH_4-N increased as well. This shows that nutrient salts, which are not used by phytoplankton, increased. Although decrease in transparency from the beginning of 1989 has not shown an influence against the constitution and the existing amount of phytoplankton species, there is a possibility of influencing multiplication speed.

It is enough that the retention time is more than the time needed for the multiplication of algae. During this observation period, the average retention time was 153 days. There is probably no influence on the algae multiplication time because algae reproduction occurs daily regardless of the rainy or dry season.

4.3 Zooplankton

A qualitative investigation on zooplankton was performed in July 1988.

4.3.1 Component of Species

Zooplankton consists of Rotifer (*Keratella*, etc.), Cladocera (*Daphnia*, *Bosmina*, etc.), Copepoda and the component species was the same as that in normal eutrophic lakes (Table S3.4.1).

The main species was *Daphnia* sp. of Cladocera, which appears in every part of the lake. As for Rotifer, *Keratella americana* was found covering a wide area. Also Copepoda was abundant in the form of *Nauplius*.

According to the results from the ICB investigation in 1984, components were roughly the same as those in this study. However, for Cladocera and Copepoda, some different species appeared. As for Rotifer, *Keratella americana* appeared frequently according to ICB reports. Therefore, the basic component species of zooplankton was the same for both, this study and that of ICB.

4.3.2 Existing Amount and Distribution

Although this study does not clarify the existing amount because it is a qualitative analysis, there was quite a large amount viewed in the lake by visual survey, which made the distribution tendencies impossible to decipher.

According to the results of the ICB investigation in 1984, the existing amount of zooplankton was often seen at 0-46 bodies/l, 20 bodies/l, but in this study, the estimate is at least more than 10 times this amount.

The reason the existing amount of zooplankton was estimated larger in this study compared to that of the ICB, was that the amount of phytoplankton, which provides a food source for zooplankton, was larger than that in 1984.

4.4 Benthos

Benthos was investigated on July 15, 1988.

4.4.1 Component Species

Benthos consisted of mainly the larvae of the insect Chironomidae, of which nine species were collected. Besides this, one species of leech, one of Oligochaeta and one of the insect Ephemeridae, are recorded. All of these were tiny species, smaller than several mm in length.

Generally speaking, the larvae of Chironomidae is the main component of Benthos in lakes. In a temperate zone eutrophic lake, *Chironomus* appears often, but is not seen here. Whether the absence of *Chironomus* is due to the distribution of the biological geography or to the nature of the lake is not clear.

Although no conclusion can be reached because the larvae of *Chironomus* is not found in these species, the nine species identified are believed to subsist near the shore. Furthermore, one species of Oligochaeta, a swimmeret, is believed to inhabit places which are influenced by hydrophyte colonies. One species of Ephemeridae inhabits areas where half-decomposed plants accumulate. Thus, it is believed that the components of Benthos collected this time, which originally inhabited areas closer to the shore, possibly widen the distribution area.

According to the ICB investigation results of 1984, there had not yet been an analysis of the species yet, however, the benthos consisted of Nematoda, Oligochaeta and Empidae. Species composition of Benthos according to the ICB survey differs from that of this study's results.

4.4.2 Existing Amount and Horizontal Distribution

The existing amount of Benthos appears the most at the observation points near the NW shore of the lake, and 30 bodies were collected at one time by an Ekman-Berge bottom sampler. At the center of the lake and around the inflowing mouth of the Pirayu, fewer were collected ; only 3 bodies at the former point and 1 body at the latter. An amount falling between these two was found at San Bernardino on the east shore and at Aregua on the west shore (7 bodies and 10 bodies, respectively).

The distribution of Benthos reflects the deposit situation of organic matters which act as its food, it is believed. If the assumption were correct that the organisms originally inhabiting areas closer to the shore expanded the distribution, then this would especially reflect the deposit situation of the halfdecomposed matters of hydrophyte.

According to the ICB study results in 1984, 1/10 of the matter collected once by an Ekman - Berge sampler was used for counting benthos. As the size of that sampler is probably the same as the one used in this study, the ICB data is multiplied 10 times and compared with that of this survey. In San Bernardino, where the existing amount was the largest, an average of 20 bodies were collected, which exceeds that of this survey. In Aregua, the amount collected matched that of this survey at 8 on the average. At the middle of the lake, out of the 7 collection attempts, absolutely none was collected, which is lower than the results of this study. In this way, the existing amount of Benthos in 1984 equals that of 1988, which is less than that of the temperate zone eutrophic lake.

It is believed that the existing small amount of Benthos in the lake Ypacarai is due to its lack of *Chironomus* and of Tubifecidae of Oligochaeta. The reason is not clear whether this is caused by the distribution of biological geography or by characteristics particular to the lake.

4.5 Fish

A fish study was carried out from Feb. 1988 to June 1988, through 11 field observations, including the identification of collected fish and the analysis of the content of the stomach of the fish. All of this was done in order to understand fish stratification and eating habits.

4.5.1 Fishing Yield

Throughout the 11 catches, 3 - 138 bodies (48 bodies as an average) were collected at one time. (Other than this, there were 5 catches which were not recorded in the data, as they consisted mostly of only one type of fish.)

4.5.2 Fish Classification

In this study, 10 more species were caught in the lake, thus, together with the previous data, the total recorded is 22 families, 45 genus and 50 species (Table S3.4.3).

It is believed that there are two different groups ; one of them is breeding in the lake and surrounding rivers, the other is entering from the Paraguay River, through the Salado River, and inhabiting the lake temporarily. However, the life cycles of each of the species are still not clear.

4.5.3 Eating Habits of the Fish

The results of this survey concerning the eating habits of ten species of fish are as follows :

Five species were carnivorous, eating fish or aquatic insects : Dentudo : *Rhaphioidon vulpinus*, Piraña : *Sarrasalmus* sp., Dientudo : *Charax gibbosus*, Cabeza amarga : *Crenicicula lepidota*, Anchoa de rio : *Lycengrauldis olidus.*

Three species were herbivorous : Boga : *Schizodon fasciatum*, Pira mbocaya : *Aequidena paraguayensis*, Colitas rojas : *Moenkhausia oligolepis.*

One species was an algae eater : Morenita : *Hypophtalmus edentatus.*

One species was omnivorous, found with fish, aquatic insects, pieces of plants and branches as stomach content : Carimbatá : *Prochilodus acrofa.*

In this way, fish eating habits take on various different patterns, allowing us to understand the position of each species within the lake aquatic ecosystem.

Relatively, carnivorous species are the most abundant, with herbivorous coming next. It is believed that herbivorous species inhabit the aquatic colonies near the shore or areas near them. The aquatic insects found in the stomachs of the carnivorous fish are believed to be those insects inhabiting the aquatic plant colony or near them because there is little existence of Benthos at the bottom of the Lake. Therefore, carnivorous fish are believed to inhabit the plant colonies or areas near them also, where aquatic insects, all types of fry and herbivorous exist. The same is thought to be true for the omnivorous species. That thought to exist on the open water surface of the lake is the algae-eating Morenita : *Hypophtalmus edentatus.*

4.5.4 Utilizing Fish

According to the local residents, a valuable species is called Corvina, which is Sciaenidae. According to the ICB study in 1984, this fish exists as a fry as well as a mature fish and weighs about 1.5Kg. Recently, it is reported that the number is declining, however these figures are not clear.

There is no species existing which would offer interest for recreational fishing.

About 10 years ago, ICB stocked the lake with a fast-growing, edible African species called Tilapia, on an experimental basis, however, following this, Tilapia was never caught in lake nor did it seem to inhabit the lake at any point. The reason for this is thought to be that the total amount was too low at 1000, and that, as the fish were fries, they mostly became feed for the carnivorous species.

4.6 Aquatic Ecosystem of the Lake

4.6.1 Non-biological Environment

As for the non-biological environment of the lake aquatic ecosystem, the characteristics of the principal factors are as follows.

(1) Water Temperature

Although the average daily water temperature in the lake is between 13 - 30°C, the low temperature periods last only a few days and the lowest monthly average in the winter is still high as 15°C even at the lowest value. Therefore, biological processes such as the primary production and decomposition, are active throughout the year.

(2) Nutrient Salts

The density of nutrient salts in the lake is as high as the level in eutrophic lakes with the T-P average at 124 μg/l and that of T-N at 1901 μg/l. Therefore, if other environmental factors are favorable, there is high possibility for primary production.

(3) Illumination Conditions

Solar energy entering the lake has a monthly average between 240 - 500 cal/cm^2, throughout the year, which is adequate solar energy for primary production. However, in 1984 the transparency was at about 0.1m because the transmissivity in the water was low due to turbidity and water coloration. In 1988, a heavy rain flushed out the pollution, resulting in a transparency average of 0.5m, equivalent to that of general eutrophic lakes. However, the transparency has decreased to 0.24m in early 1989, thus there is a possibility that, if this decrease continues, primary production will be hindered, due to the decreasing amount of illumination in the water, as was the situation in 1984.

(4) Retention time

The rotation ratio of the water in the lake in 1988 was 2.4 times/year. In other words, it takes 152 days to completely replace the water. The retention time is adequate for several repetitions of the circulation of matter in the aquatic ecosystem. The cycle is : production - decomposition - mineralisation - production. This is believed to promote eutrophication.

(5) Morphology of the Lake Basin and Water Depth

The morphology of the lake basin is like the shape of a flat dish, the water depth is shallow at approximately 2m (depending on the lake water level) and flat at most parts. Due to the shallowness of the water, wind-driven currents constantly year-round stir up the upper and lower water strata of the lake, preventing water stratification. Therefore, DO extends to the bottom of the lake, preventing aggravation due to the anarobification of the lake.

(6) Bottom Material Quality

The bottom material quality in the flat areas of the lake floor consists of black clay and the underlayer consists of fine grey clay. Accordingly, it is believed that most of the lake bottom is not adequate to support the existence of benthos.

4.6.2 Primary Production (Phytoplankton)

It is phytoplankton which is the main constituent of primary production in the aquatic ecosystem in the lake. The entire non-boilogical environment is suitable for primary production. Although the primary production itself was not measured, it is believed that the primary production amount is high because of the dominance of Cyanophyta with the existing amount at a level of 10^4 cells/mℓ, throughout the year.

4.6.3 Secondary Production and Decomposition

(1) Zooplankton

The existing amount of zooplankton is high as it is supported by a high primary production. Although the secondary production itself was not measured, it is believed to be high due to a high existing amount and the abundance of larvae of Copepoda.

In the eutrophic lake where Cyanophyta is dominant, the course of decomposition is said to lie between the energy shift from phytoplankton to zooplankton. This course is as follows and illustrated in Fig. S3.4.7.

Most of the Cyanophyta forms colonies and thus, the size increases. As for the species dominant in the lake, *Anabaena* and *Anabaenopsis* become thread-like colonies, *Microcystis* becomes a colony wrapped with agar-like matters. Large-size Cladocera can take in the large-size Cyanophyta directly, however it is well understood that Cyanophyta prevents large-size Cladocera from taking in foods or will decrease its growth and multiplication. Thus, if Cyanophyta is dominant, the existing amount of large-size Cladocera will decrease. Rotifer, Copepoda, and small-size Cladocera can not take in large-size algae directly. Therefore, they must take in algae some other way, or cyanophyta decomposed to a certain degree.

In lakes with high temperatures, like the Ypacarai, the speed of decomposition is high. It is thought that it doesn't take long before produced algae reaches the stage to be used by zooplankton. Moreover, zooplankton, through feeding-excretion activities, renders nutrient salts, in particular, phosphorous, a form which phytoplankton can use.

(2) Benthos

There is not a large existing amount of Benthos in the lake, which is thought to contribute to secondary production in the aquatic ecosystem. One reason for this is that there is not any species present which is suitable for a eutrophic lake. However, the reason for this lack of presence is not clear. Although this is pure supposition, it is thought that half-decomposed algae, which is a food source for Benthos, cannot easily accumulate at the bottom of the lake due to the fact that the upper and lower layer of water are constantly mixed by the high-speed decomposition and the shallow water depth.

(3) Fish

There was found a species of fish among those inhabiting the lake which eats algae. However, it is doubtful that this species is directly taking in principally phytoplankton as algae. It is said that the amount of phytoplankton has been small and that after the heavy rains and flooding in Jan. 1988, the existing amount increased. Therefore, it is not natural to think that the species eating phytoplankton began to inhabit the lake following the increase in the existing amount of phytoplankton. Although this species eats algae, it might be taking in that algae growing on stones and aquatic plants.

4.6.4 Advanced Production (Fish)

The advanced production in the lake concerns principally fish. However, as it was shown above, it is hard to believe that there is a species in the lake which would take in phytoplankton. Moreover, there does not seem to be one which takes in zooplankton. And finally, the existing amount of Benthos is not enough to maintain fish production.

Consequently, fish seem to relate, in the food chain, to groups such as shrimp and aquatic insects which feed on aquatic plants and the attached algae. In other words, there is a partial system within the aquatic ecosystem where aquatic plants are the primary producers, and fish are believed to be a component of that system.

CHAPTER V

FUTURE TOPICS

5.1 Vegetation

As regards the basin vegetation, presently at the mountainous area and at the Yuquyry water source, the vegetation function concerning environmental conservation is not adequate and, in order to restore this function, reforestation is necessary. Consequently, a future concern will be basic and applied survey and research for the promotion of reforestation and for the selection of the appropriate species for reforestation, given the location conditions. The survey and research on the reforestation was begun for wood resource development, however, the environmental aspects need now to be taken into consideration.

As for lakeside vegetation, the water quality purification function by vegetation at the downstream low marsh of the Yuquyry is adequate, however that at the downstream of the Pirayu is not and needs restoration. A conservation measure covering this aspect has yet to be established. Consequently, the relationship between the marsh vegetation and the environmental conditions and the ecological evolution will require, in the future, survey and research.

5.2 Aquatic Life

From 1984 - 1985, the aquatic ecosystem of the lake showed, due to remarkable turbidity, a very scant amount of phytoplankton, a primary producer, and the same for benthos and zooplankton, secondary producers. Fish were produced to a certain degree. This is thought to be due to the existence of a partial ecosystem based on primary producer aquatic vegetation which is not affected by turbidity and to the introduction of fish from the Salado into the lake.

By the way, in this 1988 survey, due to the heavy rains in Jan. 1988, the phytoplankton resulting from the sweeping away of the lake pollutants was seen thriving with Cyanophyta as the dominant species. With this high primary production base, zooplankton also flourished. In the July 1988 survey, benthos was still low, however, if this situation continued, the production in the entire lake would rise, resulting in an estimated rise in the production of benthos, fish, secondary producers and high producers. However, from the start of 1989, an increase in turbidity has been recognized and there is a possibility that the situation will return to what it had been previously.

In this way, there is information showing the opposite characteristics for the lake aquatic ecosystem. Thus, for the inevitable continuation of ecological change, there must be survey and research done. Basic data must be accumulated on the environmental conditions related to this change.

In that case, the most important object for the survey would be the turbidity of the water. The existence of turbidity in the water sways the primary producers, and thus influences the secondary and higher producers in the lake's ecosystem.

With a more detailed study on the mechanisms of the turbidity, a more specific investigation concerning the methods of monitoring the lake aquatic ecosystem could be realized.

The importance of the study subject is the growth of Cyanophyta. When there is a large development, there results a remarkable smell in the water and the drinking water value decreases. In the years preceding the rain in Jan. 1988, there was seen partial development of water bloom. The details on this are unclear. Therefore, in the future it will be necessary to conduct a study on the relationship between the development conditions of water-bloom and the water quality, rain, wind and other environmental conditions.

As regards fish, the species composition and the food habits of many species in the lake became clear, however, the life cycle and relationships among species are unclear issues and require study in the future. Without this knowledge, stocking the lake with fish is thought to be an unsafe measure. As for a way in which to increase the fish species at present, one thought is to conserve the aquatic plant communities at spawning sites, fry development and herbivorous fish feeding places, or to establish an embankment for the easy growth of aquatic plant communities.

Appendix

Phytoplankton Analysis

AGP Tests

In order to study the relationship between N, P and phytoplankton, the AGP test was carried out.

(1) Materials and Methods

1) Test Water

The test water is surface water from the center of the lake (St. No. 25) collected on July 8, 1988. In addition as a reference, tests were carried out on inflowing river water collected on August 9, 1988 at a fixed water collection point.

2) Test Cases

At the time of the commencement of the testing, the concentration of the test water T-P was unknown, however as it was estimated as being fairly high, the following cases were established.

a. object : unhandled lake water (× 1)
b. lake water passed through a GF filter (1 μm) (filt. ×1)
c. b filtered water diluted 10 × (filt. × 10)
d. b filtered water diluted 20 × (filt. × 20)
e. 20 × diluted water, P concentration raised 0.1mg/l (×20 + 0.1P)
f. 20 × diluted water, N concentration raised 0.1mg/l (×20 + 0.1N)
g. water N concentration raised 1.0mg/l, P concentration raised 0.05mg/l (1N +0.5P)
h. water N concentration raised 1.0mg/l, P concentration raised 0.05mg/l (0.5N +0.1P)

i. water N concentration raised 1.0mg/l, P concentration raised 0.05mg/l (1N +0.5P)

<Reference>

j. Yuquyry River water (Yuquyry)
k. Ypucu River water (Ypucu)
l. Yagua-Resa-u River water (Yagua-Resa-u)

3) Accompanying Test Algae

As accompanying test algae, algae collected on July 9, 1988 at the edge of the San Bernardino shore embankment was used. Collection was carried out using NXXX25 Plankton net and the algae carried back was filtered through NXX14 net and the large development of Copepoda zooplankton was removed. (The Copepoda species was not completely removed, leaving micro-rotifera and protozoa to exist.)

The constitution of the species of algae used in this test was principally from the group of *Melosira granulata* of filiform diatoms.

4) Test Methods and Conditions

After placing 200 mℓ of every sample of water described in 2) into 300 mℓ triangular vials, which later were covered with aluminum foil, the vials were subjected to temperatures of 121°C for fifteen minutes in an autoclave in order to disinfect them at high pressure. After the vials had cooled down, approximately 1000 cells/mℓ of test algae were cultivated in each vial. To add P, secondary potassium of phosphate of hydrogen was used; and to add N a potassium of nitrate was used.

The vials were placed on a white heater in order to be subjected to continuous radiation from the upper part by phosphorescent lights. The temperature and the illumination were constantly maintained at 26°C and 2.400 lux, respectively.

During the period of cultivation, the vials were shaken once or twice a day.

After the cultivation period, observation was conducted on the species of multiplied algae, then SS was measured form the newly produced quantity.

5) Testing Period

The cultivation of algae was finished on July 9, 1988, but it was not until July 13 that they were conditioned to the pre-determined temperature and illumination. Cultivation was finally completed on July 27.

(2) Results Obtained through Testing and Observations

The results obtained from the test are the following:

1) Concentration of P and the Quantity Reproduced of Algae

The concentration of T-P was 73μg/ltr when algae reproduction of 28.0mg/ltr was observed.

When the concentration of T-P was reduced by filtration or dilution, the reproduction of algae fell. The rate of reduction was almost proportional to the reduction of the T-P concentration.

When the concentration of T-P was increased by adding P, the reproduction of algae also increased. The concentration of N also affected such an increase. When T-P was 173μg/ltr, the reproduction of algae was greater when the T-N was 2,155μg/ltr than when it was 1,655μg/ltr.

As regards the river waters, in all cases algae reproduction was greater than the algae in the lake water, although it had the same concentration of T-P.

2) Concentraton of N and the Quantity of Algae Reproduced

The concentration of T-N was 1.155μg/ltr as algae reproduced at a level of 28,0mg/ltr.

When the concentration of T-N was reduced through filtration or dilution, the reproduction of algae fell too. When the concentration of T-N was increased by adding N, the reproduction of algae increased accordingly. Such an increase was also affected by the P concentration. When T-P was 57µg/ltr after being diluted twenty times, algae reproduction was minimal (5,0mg/ltr). When the concentration of T-N was 2,155ug/ltr, algae reproduction was greater when the concentration of T-P was 173ug/ltr than when it was 123ug/ltr.

As regards the river waters, in all cases reproduction was greater than in the lake water which had the same concentration of T-N.

3) NxP concentration and the Quantity of Reproduced Algae

Within the pre-determined parameters of the present test, that is, up to 173µg/ltr for the T-P and 2.155µg/ltr for the T-N, synergism was found to exist between the concentration of P and N in algae reproduction. In this case, it is advisable to take the multiplied value of the two concentrations instead of taking the values of N and P separately.

When the concentration of NxP is low, the reproduction of algae is also low, and vice versa. When the concentration of NxP was greater than the maximum value determined in this test, algae reproduction reached the saturation point. Therefore, by applying the formula Y=a-b(c)x, the following results: $\frac{NxP-2000}{2000}$

SS(mg/ltr.)=49,85 - 34,37(0,887)

(When NxP > 2000 g/ltr.)

Thus, under the conditions determined in this test and with the algae that was used, when the concentration of N and P increases, algae reproduction reaches approximately 50mg/ltr. When T-P is 1.77 and T-N is 2.218µg/ltr, which are the maximum values determined in this test, algae reproduction reaches 48mg/ltr, which is the approximate value of the saturation point. In the case of the river waters, in reference to the NxP concentration, algae reproduction was greater than in the lake water of the same concentration. This indicates that the N and P found in the river water are more useable for the algae than that which is found in the lake water, or indicates the presence of other elements promoting algae reproduction.

4) Species of Algae Reproduced

Many species of algae were used in the cultivation experimnents and among them the best adapted to the established conditions and reproduced most prolifically was *Melosira granulata v. angustissima spiralis*. This was the second most important species, in terms of number of cells, among the algae cultivated in this test.

The cases in which the concentration of N and P was high, 1N + 0,1P, other species predominated in the waters of the Yuquyry river, such as the *Nitzchia* sp. and *Nitzchia linearis*.

(3) Conclusion

According to the results obtained in this AGP test, phytoplankton reproduction that occurs in the lake in the winter is controlled by the concentration of N as much as P (within the parameters of 173μg/ltr for T-P, and 2.155μg/ltr for T-N). Therefore, algae reproduction will increase if the N and P increase, and vice versa.

Supposing that the concentration of NxP represents the effect that the two elements exercise over algae reproduction, when increased algae reproduction is seen in contrast to the increase in the concentration of NxP by means of the saturation curve, the current concentration of NxP reaches the halfway point of the gently sloped curve. Therefore, although the concentration of N or P increases or diminishes to some degree, it is supposed that the increase or reduction of algae reproduction will not be so notable in comparison to the variation of the concentration.

Finally, one must take into account that in the AGP tests, especially in the cases in which algae was extracted from the field, (where a great variety of algae is mixed with bacteria and zooplankton), normally the results are scattered and variable.

TABLES

Table S3.2.1 DISTRIBUTION OF DOMINANT SPECIES

Point / Species Name	Riverside				Montane				
	I	A	G	B	E	C	D	F	H
Cathormion polyanthum	⊛	+							
Terminaria triflora	+	⊛							
Sapium haematospermum	*		+						
Croton urucurana	+		⊛						
Celtis pubescens	*	*	+				+		
Cupania vernalis				⊛				+	
Rollinia emarginata	+	*	+		+			+	+
Tabernamontana australis	+	+	*	*				+	+
Chrysophyllum marginata	+	+	+	*				+	+
Inga uruguensis	⊛	+	⊛	+		*		*	+
Enterolobium contortisiliquum	+	+	+	+				⊛	+
Pithecellobium scalare	+	+	+		*			+	
Peltophorum dubium	+	+	+			+	⊛	⊛	+
Parapiptadenia rigida	+	+	+			⊛	+	*	+
Gleditsia amorphoides	+	+							*
Patagonula americana	+						+	+	⊛
Anadenanthera colubrina				+		⊛	⊛	+	
Chorisia speciosa					⊛				
Cedrela odorata								⊛	
Phytolacca dioica							+		⊛
Chrysophyllum gonocarpa							*		*
Cordia trichotoma					⊛	+			+
Holocalyx balansae						⊛		+	+
Diatenopteryx sorbifolia							*	*	+

⊛ : dominant in the tree-layer in each point.

* : dominant in the lower tree-layer in each point.

+ : appeared but not dominant.

Blank :not appeared.

TABLE S3.3.1 LIST OF AQUATIC AND WETLAND PLANTS OF LAKE YPACARAI

Family Name	Genera & Species Name	Life Form
Salviniaceae	Salvinia sp.*	free-floating
Azollacae	Azolla sp.	free-floating
Polygonaceae	Polygonum spp.*	terrestrial
Nymphaceae	Cabomba sp.	submersed
Leguminosae	Aeschinome sp.	terrestrial
	Acacia spp.	terrestrial
Onagraceae	Ludwigia sp.	terrestrial
Haloragaceae	Myriophyllum brasiliense(?)*	emersed
Umbelliferae	Hydrocotyle sp.	floating-leaved or emersed
Menyanthaceae	Nymphoides aquatica(?)	floating-leaved
Convolvulaceae	Ipomoea carnea ssp. fistula	terrestrial
	Ipomoea spp.	terrestrial
Typhaceae	Typha sp.	emersed
Potamogetonaceae	Potamogeton sp. (?)	emersed or terrestrial
Alismataceae	Sagittaria montividensis	emersed
Butomaceae	Hydrocleis nymphoides*	floating-leaved
Hydrocharitaceae	Hydromysteria sp. (?)*	floating-leaved
Graminae	Paspalum repens (?)*	emersed
Cyperaceae	Cyperus grandiflorus (?)*	emersed or terrestrial
	Scirpus sp.*	emersed
	Rhyncospora sp.*	emersed and terrestrial
Araceae	Philodendron undulatum	terrestrial or emersed
	Pistia stratiodes	floating-leaved
Lemnaceae	Lemna sp.	free-floating
Pontederiaceae	Eichhornia azurea*	free-floating
	Eichhornia crassipes	free-floating
	Pontederia cordifolia	emersed
	Pontederia rotundifolia	emersed
Marantaceae	Thalia sp.	emersed
Cannaceae	?	emersed

*-marked ones are preserved as dry specimen in IBN

Table S3.4.1 ZOOPLANCTON IN LAKE YPACARAI

(July.15.1988)

T A X A	№ 4	AREGUA №30	CENTRO №25	S.BERNARDINO №27	SALADO №49
ROTIFERA				X	X
Keratella Valga	X	X	X		
Keratella Americana	X	X		X	X
Keratella Cochlearis	X	X	X		X
Asplanchna Priodonta				X	X
CLADOCERA					
Daphnia SP.	X	X	X	X	X
Bosmina Longirostris	X		X	X	X
Bosmina SP.	X	X			X
COPEPODA					
Nauplius II	X			X	X
Nauplius III	X	X	X		
Diaptomus SP.	X	X	X		
Nauplius de Calanoidea				X	X

Table S3.4.2 The number of organisms of bentos in Lake Ypacarai by species (July. 15. 1988)

species observation point	No.4	No.25	No.27	No.30	No.49
HIRUDINEA					
Hirudineo no ident			44		528
EPHEMEROPTERA					
Hexagenia? sp.			44		
OLIGOCHAETA					
Dero(Dero)cooperi					44
DIPTERA					
Ablabesmyia? sp		44			308
Micropsectra? sp.				88	308
Microtendipes? sp.				44	
Paratendipes sp.			88		
Polypedilum sp.	88			44	132
Procladius sp.		44			
Pseudochironomus			88		
Rheotanytarsus? sp.		44			
Tanypus sp.			44	264	
total cell counts (cells/m²)	88	132	308	440	1320

Table S3.4.3 SPECIES LIST OF FISH RECORDED FROM LAKE YPACARAI

Scientific Name	Common Name	Family	Season
Pellona flavipinis	Lacha	Clupeidae	verano
Astianax bimaculatus p.	Mojarra	Characinidae	ver-otoño
Hoplias malabaricus m.	Pirá ñaró	Erythrinidae	inv-ver
Acestrorhynchus falcatus	Dientudo	Tetragonopteridae	otoñ-inv
Triportheus paranensie	Piráguirá	〃	otoñ-ver
Aphyocharax rubropinnis (1)	Colitas rojas	〃	otoño
Moenkhausia oligolepis (1)		〃	otoñ-inv
Prochilodus scrofa	Carimbatá	〃	otoño
Thoracocharax sp.	Pechito	〃	verano
Gymnocorymbus ternetzi	Monjita	〃	〃
Charax gibbosus	Dientudo	〃	otoño
Holoshesthes pequira		〃	otoño
Odontostilbe paraguayensis (1)		〃	〃
Cichlasoma sp			
Achirus jenynsi	Lenguado	Achiridae	invierno
Corydoras microps	Tachuela	Callichthyidae	otoño
Corydoras aeneus	〃	〃	〃
Hoplosternum littorale	Cascarudo	〃	ver-otoño
Hoplosternum thoracatum	〃	〃	〃
Hypophthalmus edentatus	Sola	Hypophthalmidae	〃
Pyrrhulina brevis australis		Lebiasinidae	otoño
Pimelodella gracilis	Bagre gris	Pimelodidae	〃
Perugia argentina	Pati de aletas ne.	〃	〃
Parapimelodus valencie nnessi	Bagre misionero	〃	otoño-ver
Thachydoras paraguayensis	Armado	Doradidae	otoño
Platydoras costatus	〃	〃	〃
Pimelodus albicans	Moncholo	〃	〃
Curimata (1)		Curimatidae	〃
Pterolebias sp.		Cyprinodontidae	〃
Lebistes recticulatus	Puqui		verano
Hypopomus brevirostris	Morenita	Rhamphichthydae	otoño
Otocinclus vittatus	Limpiavidrios	Loricariidae	verano
Pterygoplichthys anisitsi	Vieja	〃	otoño
Loricaria spp.		〃	ver-otoño
Crenicichla lepidota	Cabeza amarga	Cichlidae	ver-otoño
Aequidens paraguayensis	Pira mbocaya	〃	〃
Potamotrigon brumi	Raya	Potamotrygonidae	otoño
Symbranchus marmoratus	Mbuzú	Symbranchidae	〃
Schizodon sp.	Boga	Anostomidae	〃
Lycengraulis olidus	Anchoa de rio	Engraulidae	ver-otoño
Serrasalmus marginatus	Piraña	Serrasalmidae	otoño
Serrasalmus spilopleura	〃	〃	〃
Gymnotus carapo	Morena	Gymnotidae	verano
Pachyurus sp.(2)	Corvina	Sciaenidae	ver-otoño
Plagioscion sp.(2)	〃	〃	〃
Rhaphiodon vulpinus	Dentudo	Tetragonopteridae	otoño

(1) Classification uncertain
(2) There are 3 species between both

Table S3A-0(1) Initial Species composition of algae

Species	cell/ml
Blue-green algae	
Anabaena spiroides	+
Microcystis sp.	+
Diatoms	
Melosira granulata v.angustissima	56,400
Melosira granulata v.angustissima f.spiralis	38,800
Nitzschia spp.	+
Green algae	
Pediastrum duplex	2,850
Pediastrum simplex	600
Staurastrum spp.	600
Oocystis sp.	400

+ : less than 50 cells/ml

Table S3A-0(2) Results of algal cultures

case	T-P (μg/l)	T-N (μg/l)	algal yield (mg/l as ss)	dominant species
a.×1	73	1,155	28.0	Mel.gr.ang.spir.
b.filt.×1	31	816	14.0	Mel.gr.ang.spir.
c.filt.×10	3.1	82	4.5	Anabaena sp.
d.filt.×20	1.5	41	2.0	Mel.gr.ang.spir.
e.×20+0.1p	103.6	58	0.0	Mel.gr.ang.spir.
f.×20+1N	3.6	1,058	5.0	Staurastrum spp.
g.1N+0.05P	123	2,155	34.0	Mel.gr.ang.spir.
h.1N+0.1P	173	2,155	48.0	Nitzschia sp.
i.0.5N+0.1P	173	1,655	34.0	Mel.gr.ang.spir.
j.Yuquyry	286	2,146	86.0	Nitzshia linealis
k.Y Pucu	103	891	57.5	Mel.gr.ang.spir.
l.Yagua-Resa-u	65	493	31.4	Mel.gr.ang.spir.

Mel.gr.ang.spir.=Melosira granulata v.angustissima f.spiralis

FIGURES

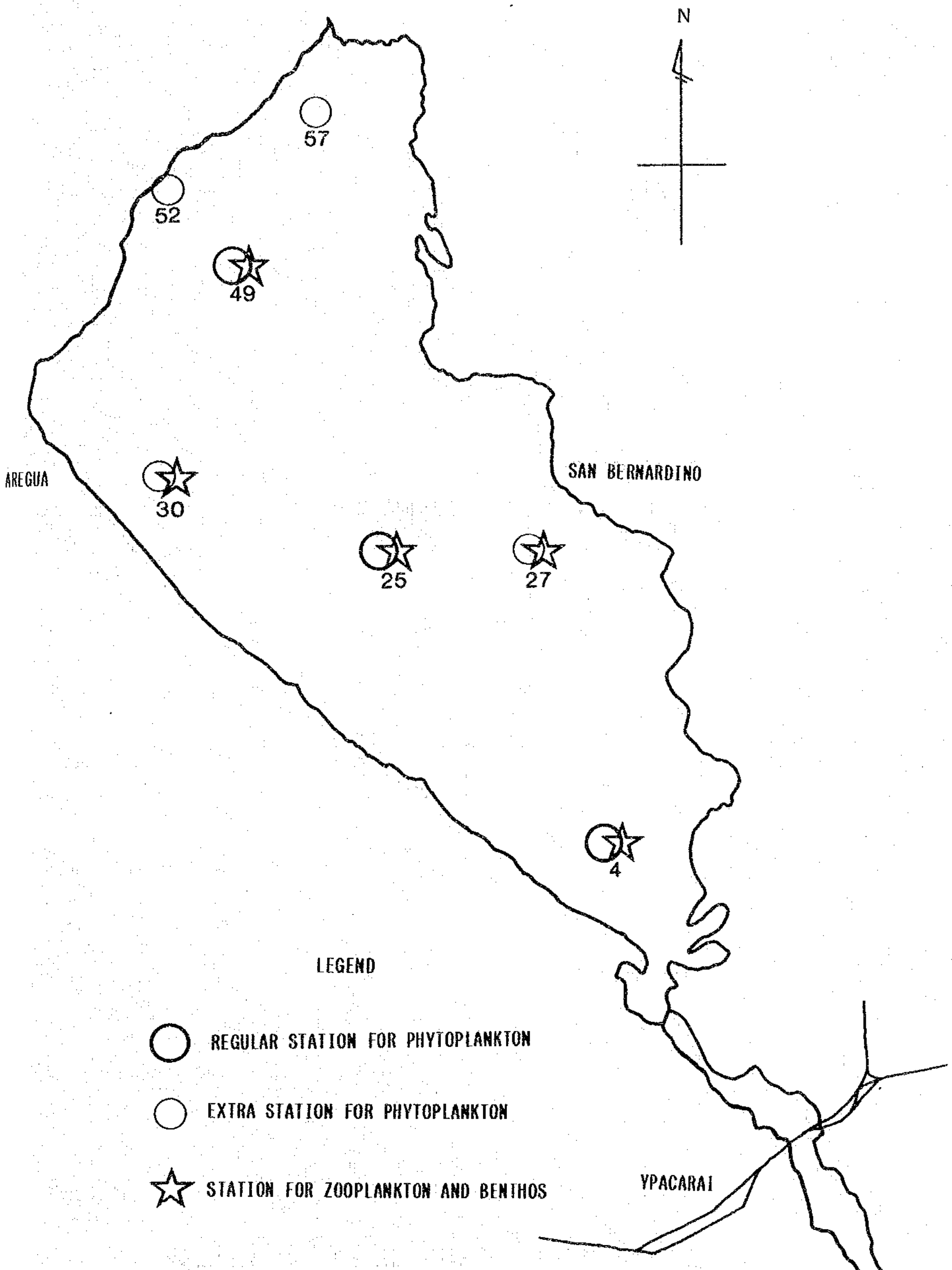


Fig.S3.1.1 LOCATION OF SAMPLING SITE OF PLANKTON AND BENTHOS

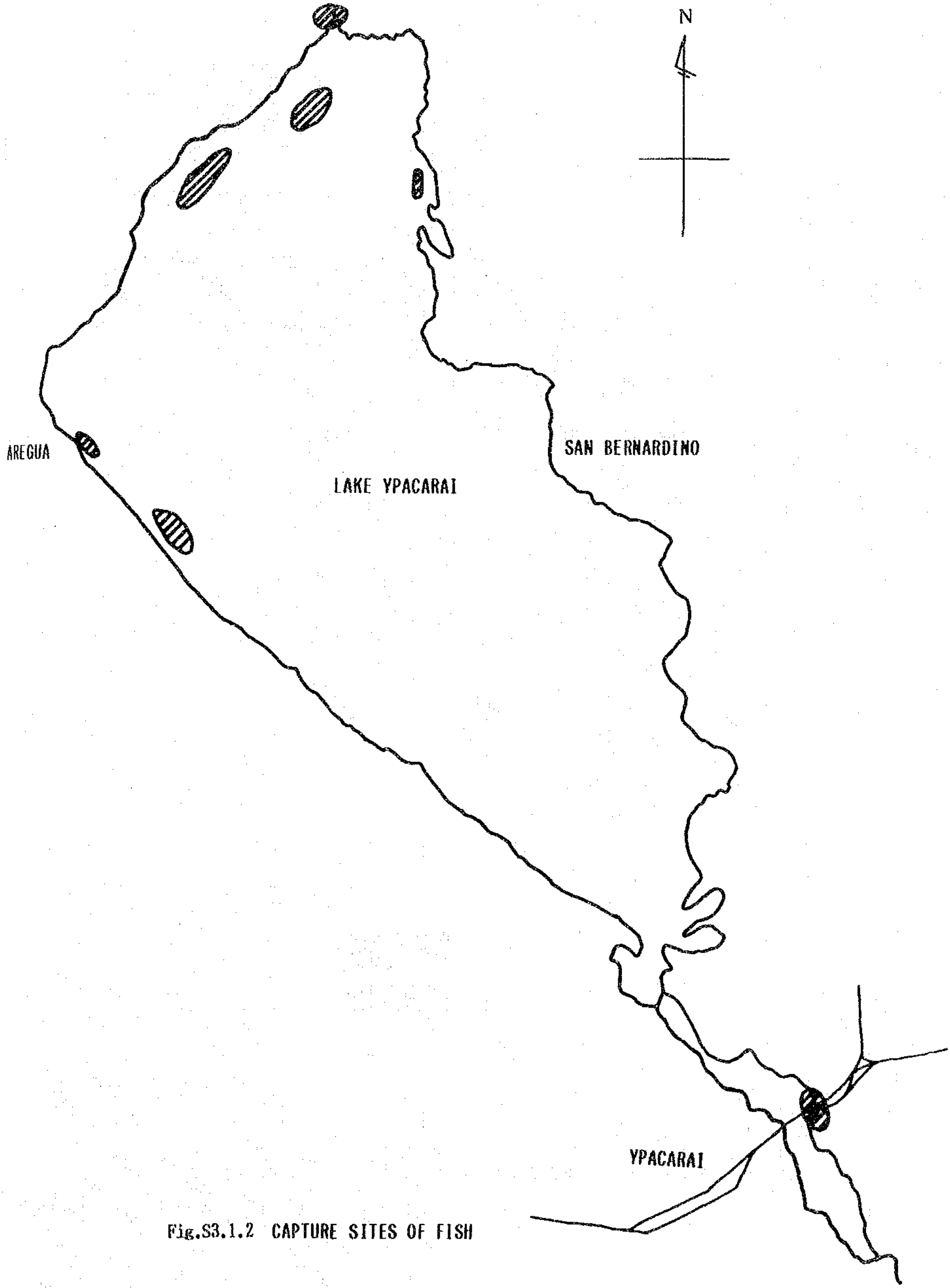


Fig.S3.1.2 CAPTURE SITES OF FISH

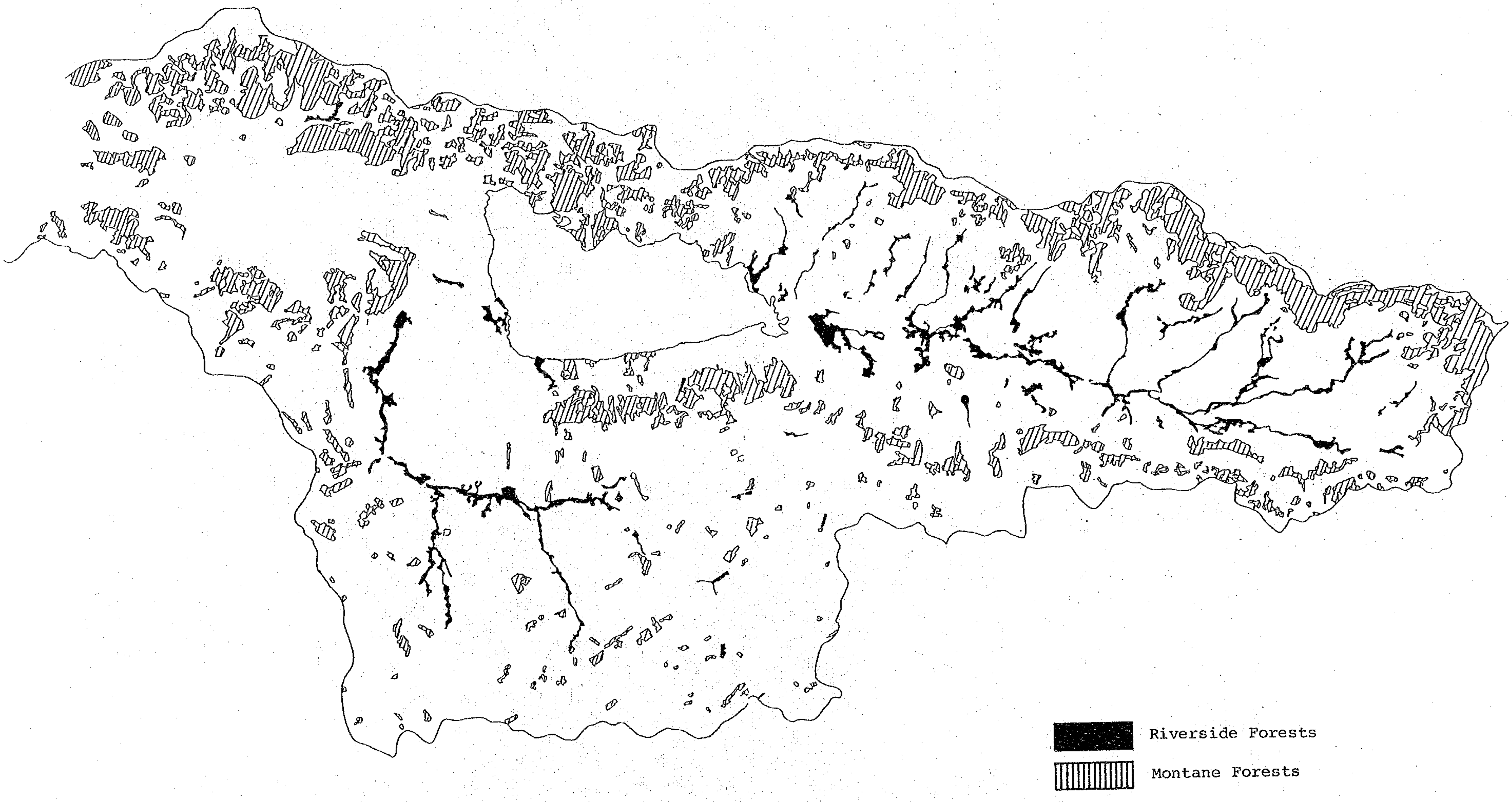


Fig. S3.2.1 **Distribution of Mountain and Riverside Forest**

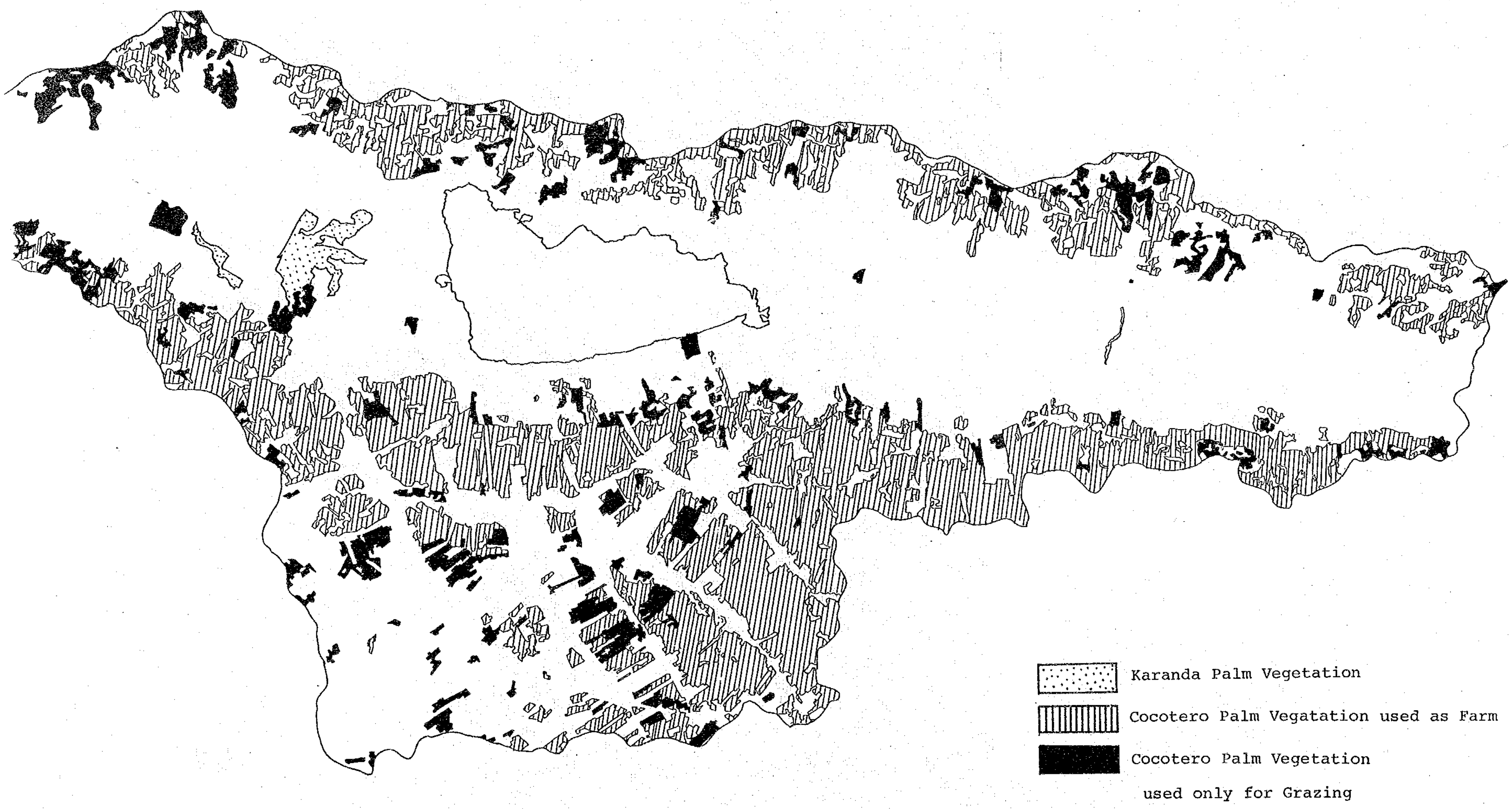


Fig. S3.2.2 Distribution of Karanda Palm and Cocotero Palm Vegetation

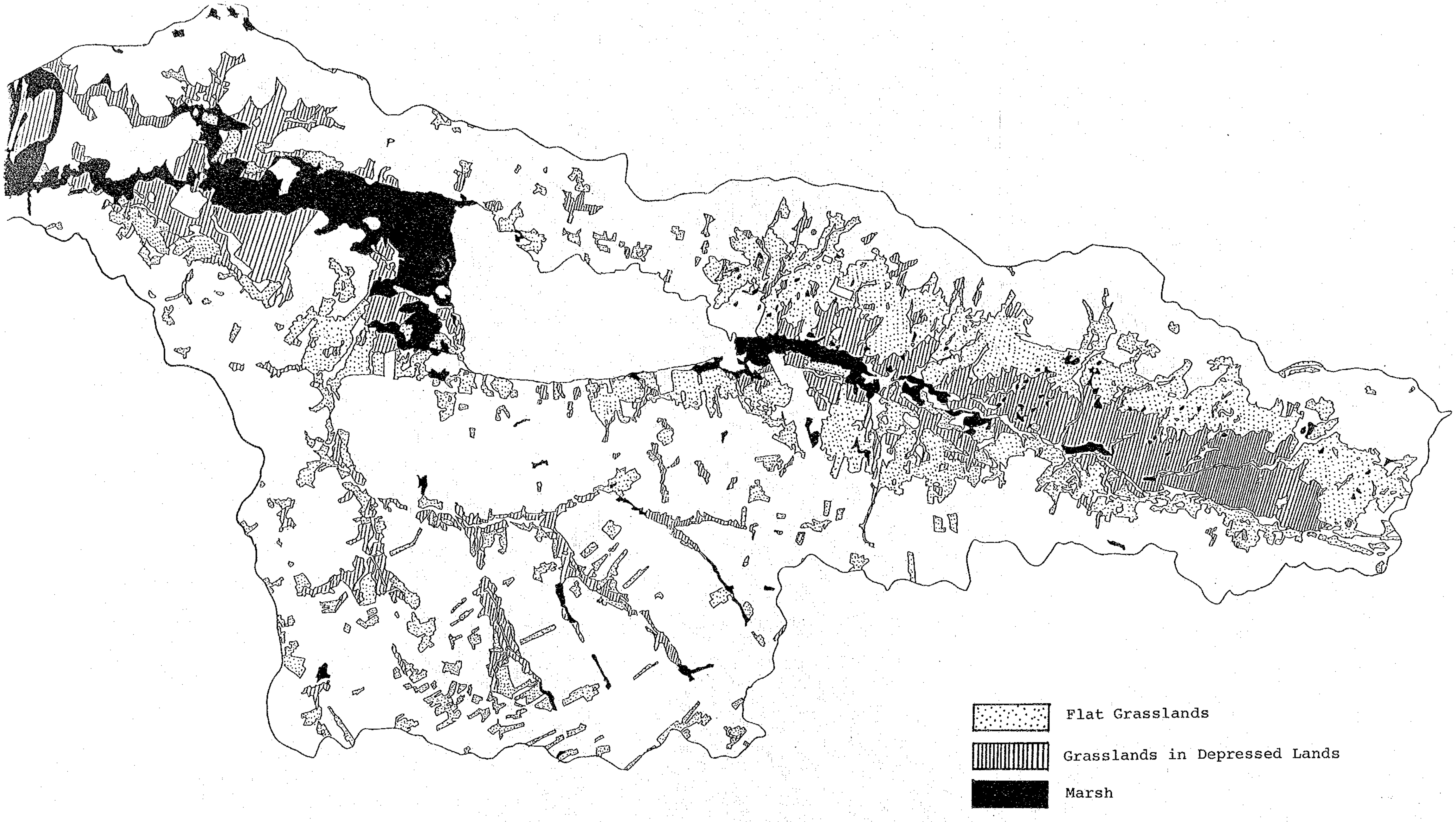


Fig. S3.2.3 **Distribution of Flat Grassland, Grass in Depresed Land and Marsh**

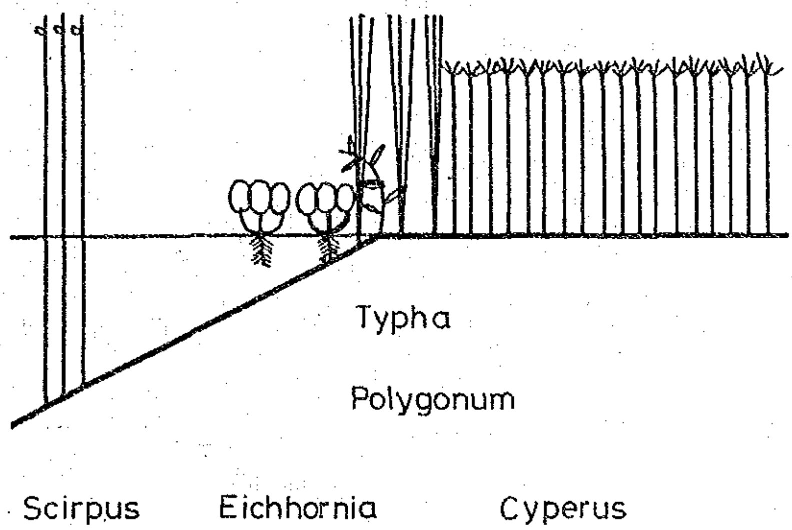


Fig. S3.2.4 **Zonal Arrangement of Lakeside Vegetation**

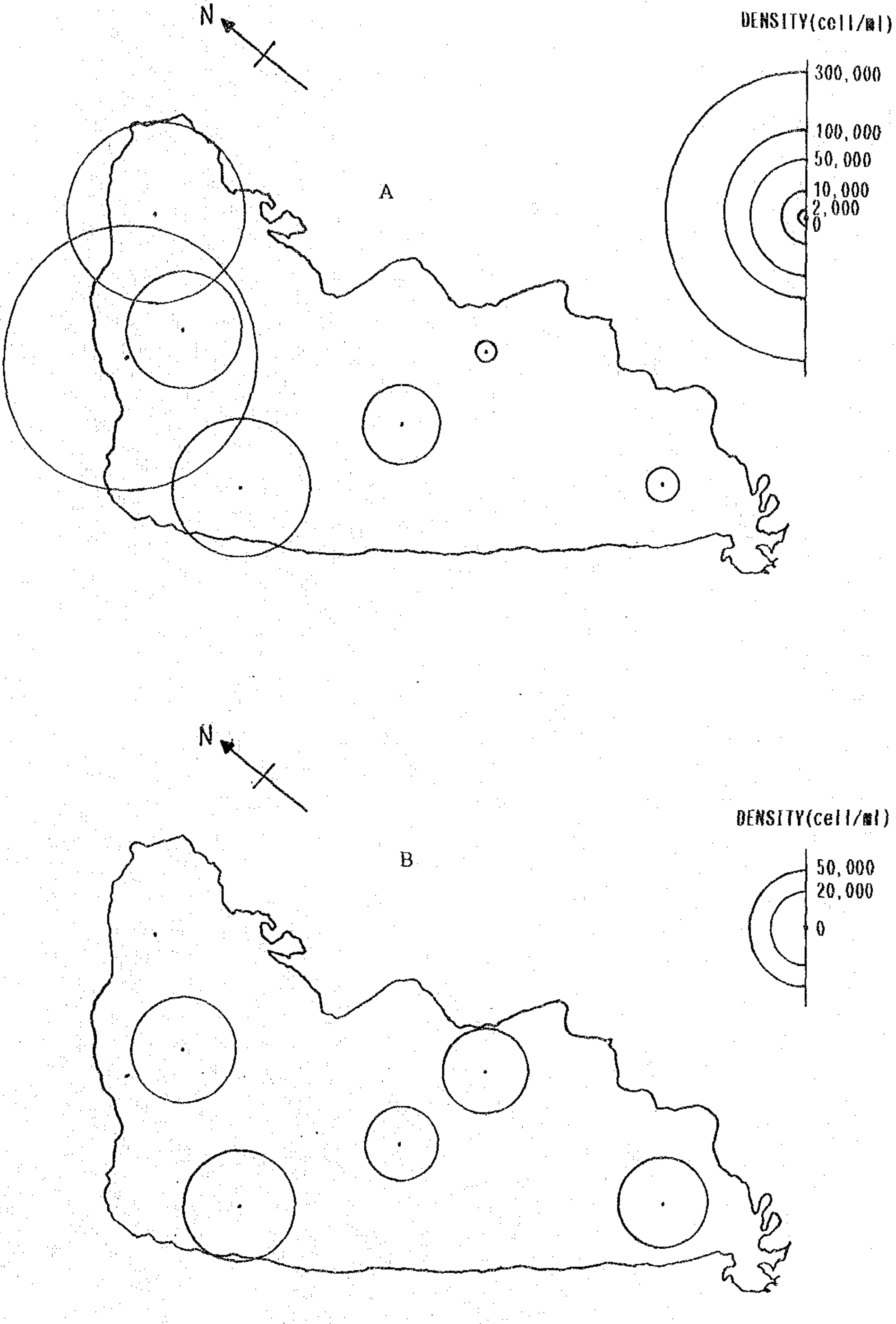


Fig.S3.4.2 HORIZONTAL DISTRIBUTION OF PHYTOPLANKTON
(a:16.FEB.1988, b:15.JUL.1988)

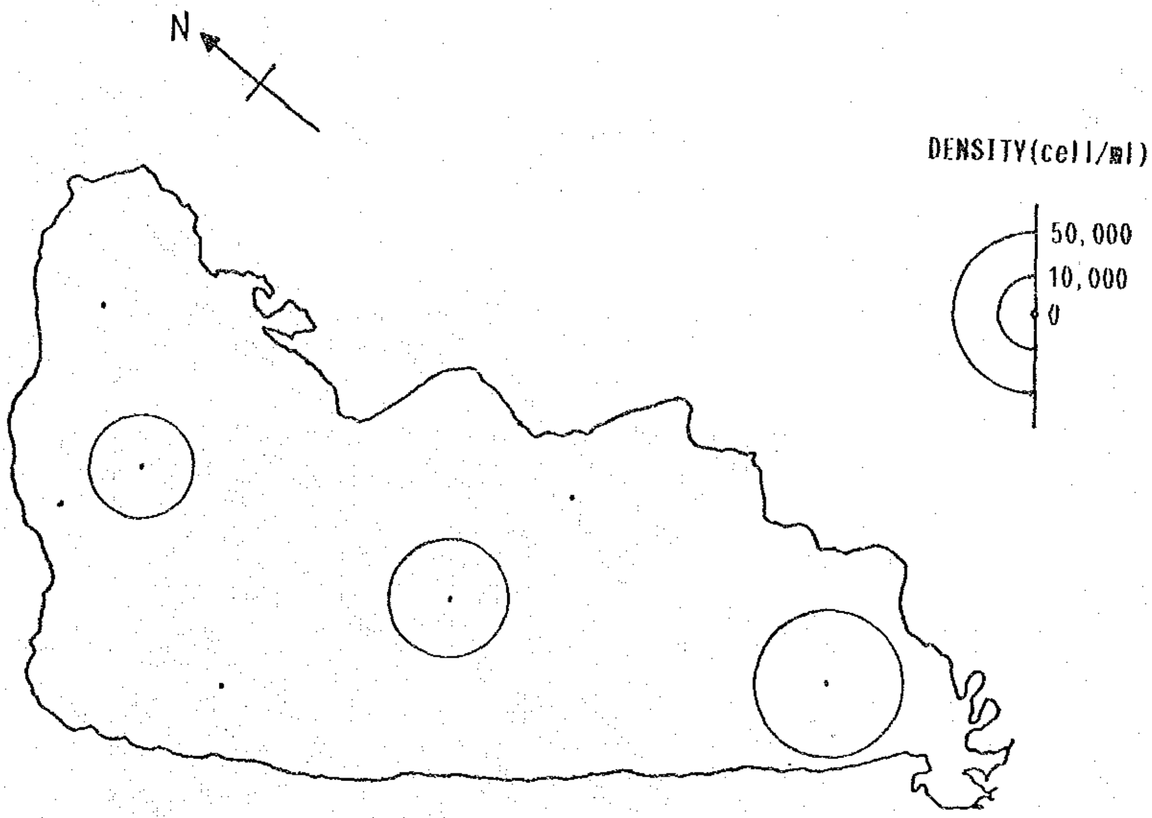


Fig.S3.4.3 HORIZONTAL DISTRIBUTION OF PHYTOPLANKTON (22.NOV.1988)

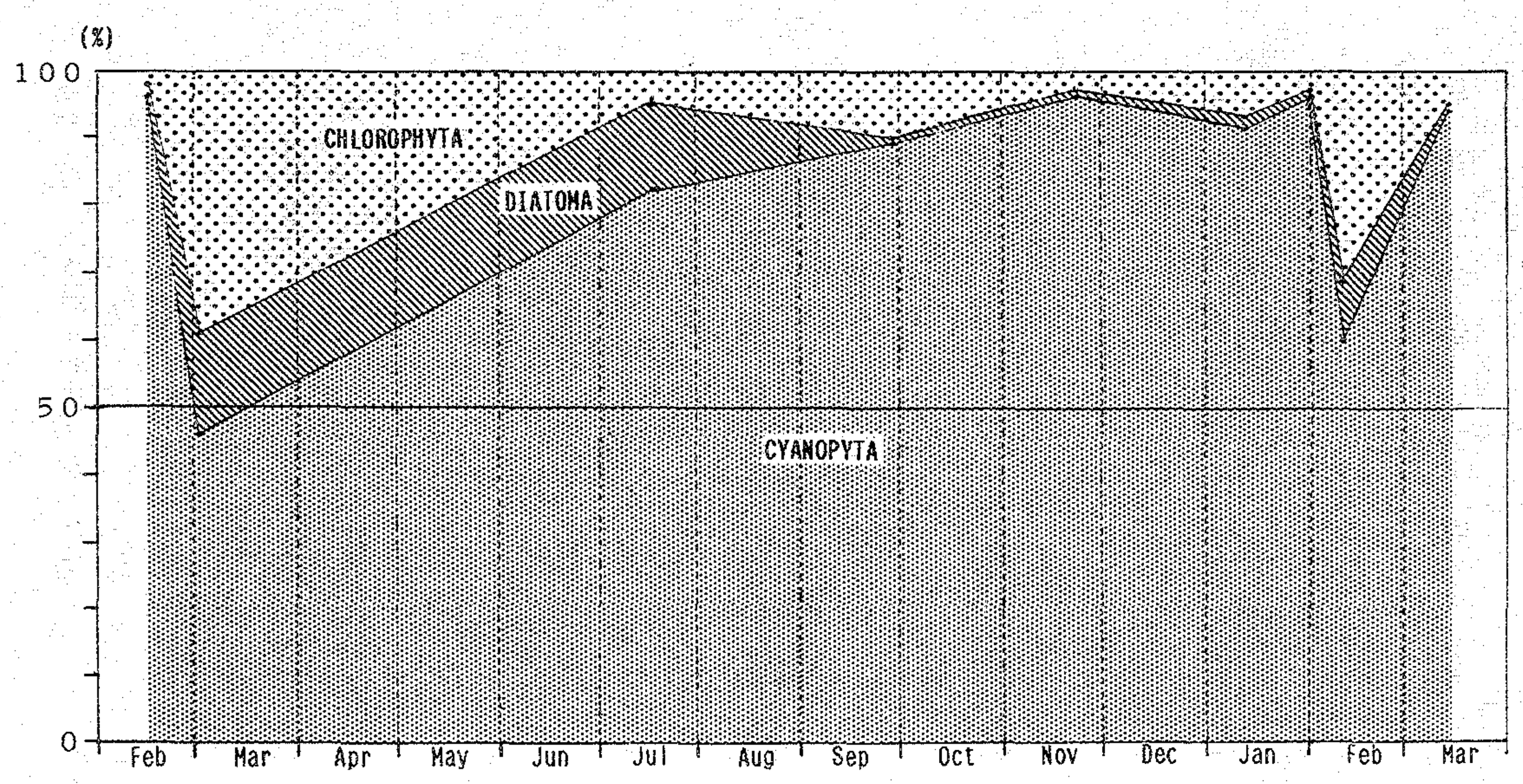


Fig.S3.4.4 CHANGE OF COMPOSITION OF CLASSES IN PHYTOPLANKTON AT THE CENTER

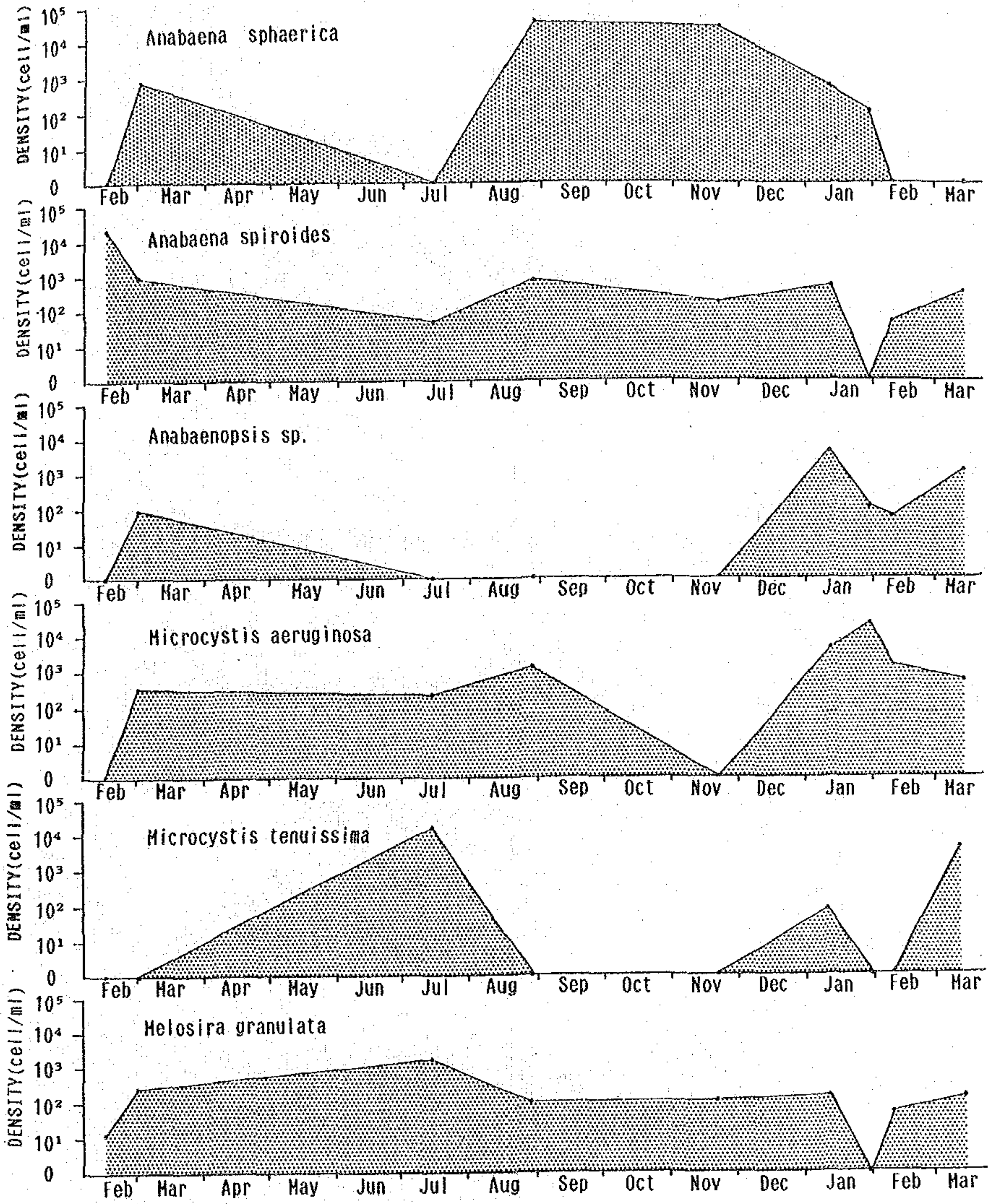


Fig.S3.4.5 CHANGE OF DENSITY OF MAIN SPECIES OF PHYTOPLANKTON AT THE CENTER

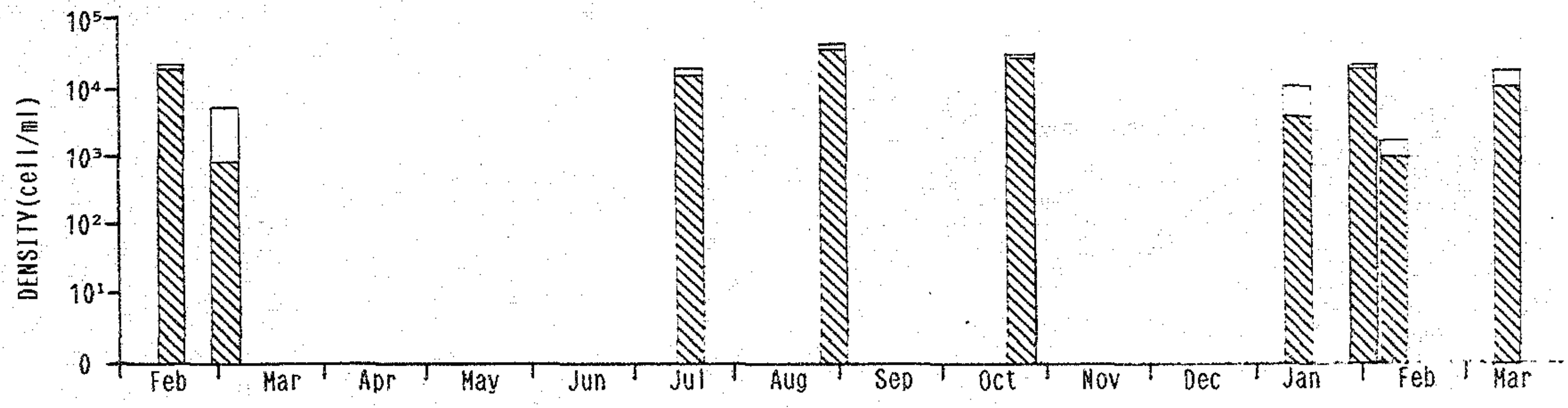


Fig.S3.4.6 CHANGE OF DENSITY OF TOTAL AND MOST ABUNDANT SPECIES OF PHYTOPLANKTON AT THE CENTER

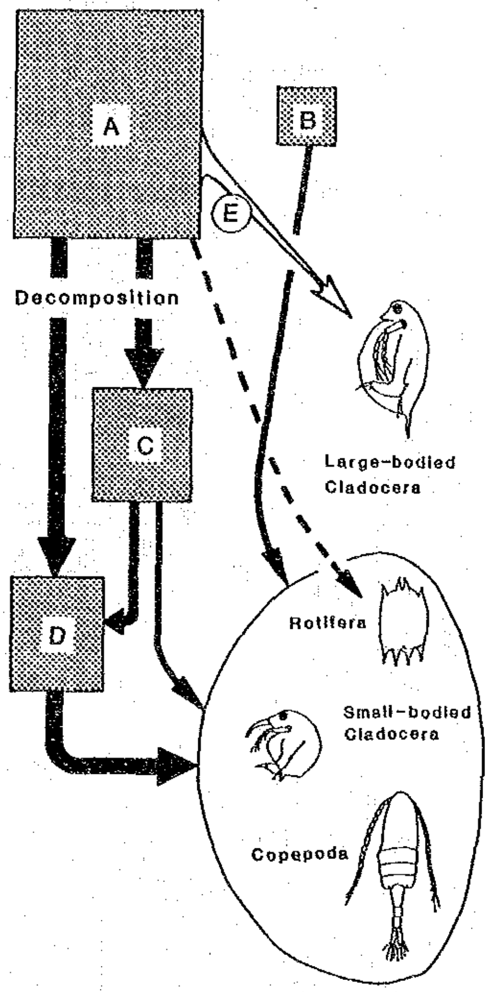
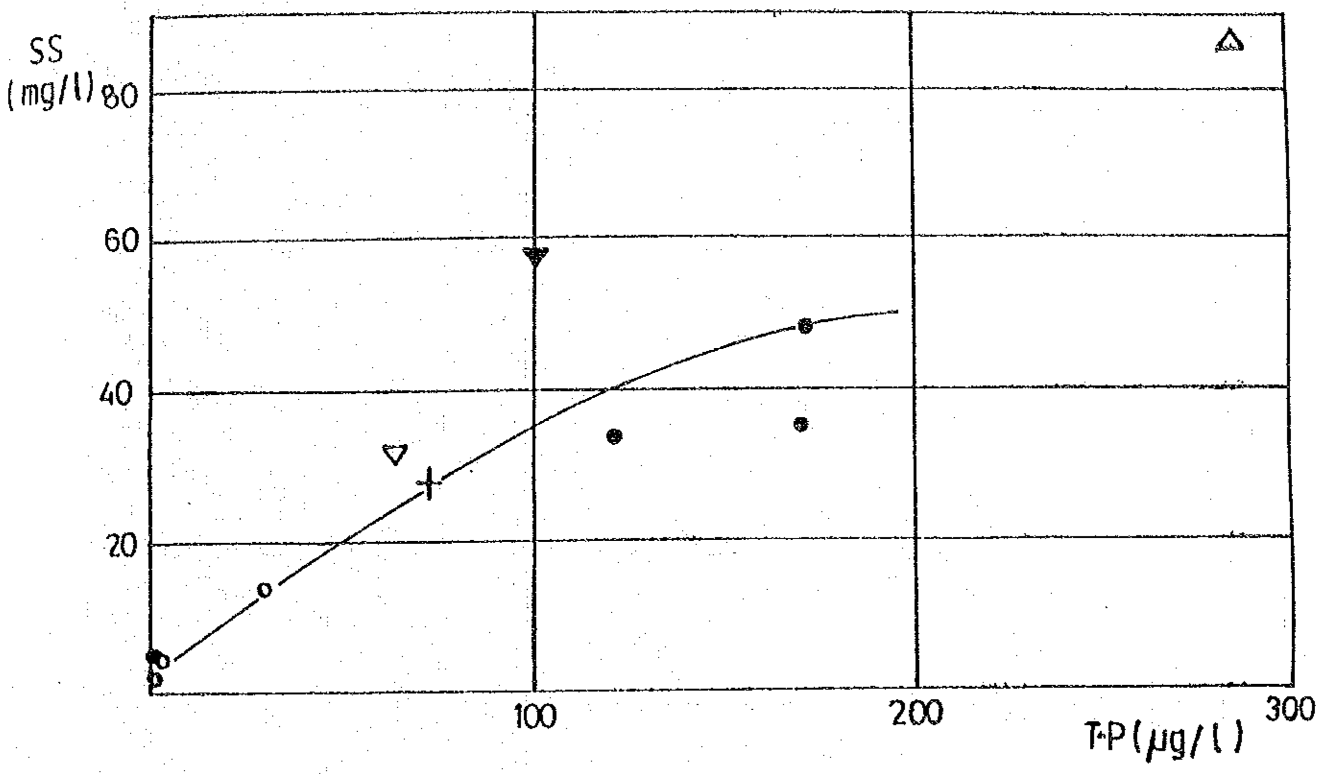


Fig.S3.4.7 Food chains from phytoplankton to zooplankton in eutrophic lakes in the blooming season of blue-green algae. A) Blue-green algae; B) Edible algae (nannoplankton excepting blue-green algae); C) Decomposed blue-green algae; D) Bacteria; E) Direct feeding on blue-green algae by large-bodied cladocerans, of which feeding, growth, reproduction and survivorship are suppressed by the algae.

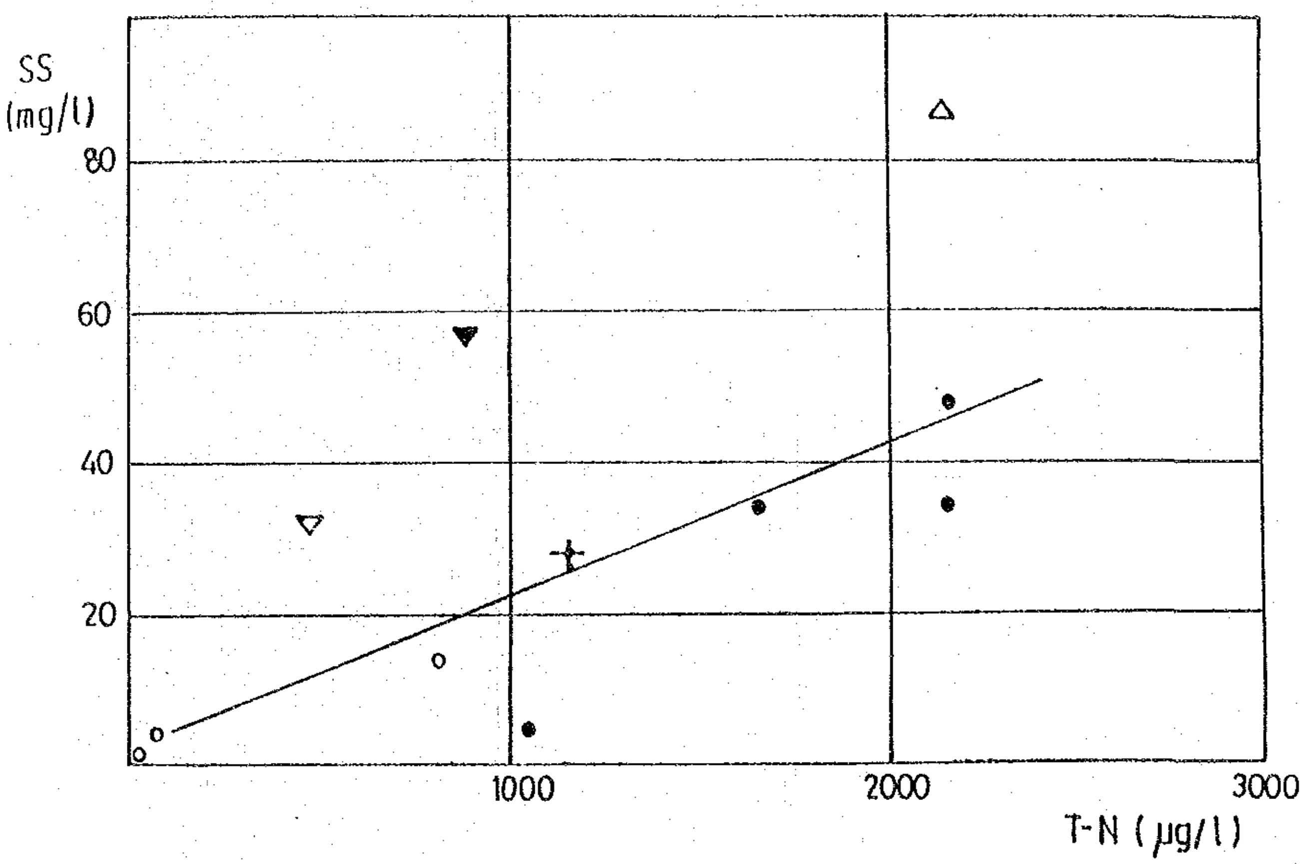
(After HANAZATO T. Interrelations between Blue-green Algae and Zooplankton in Eutrophic Lakes. (in Japanese) Jap. J. Limnol. 50, 1.)



Reference

+	:	Lake Water
●	:	Filtered Water
△	:	Yuquyry River Water
▼	:	Y-Pucu River Water
▽	:	Yagua-Resa-u River Water

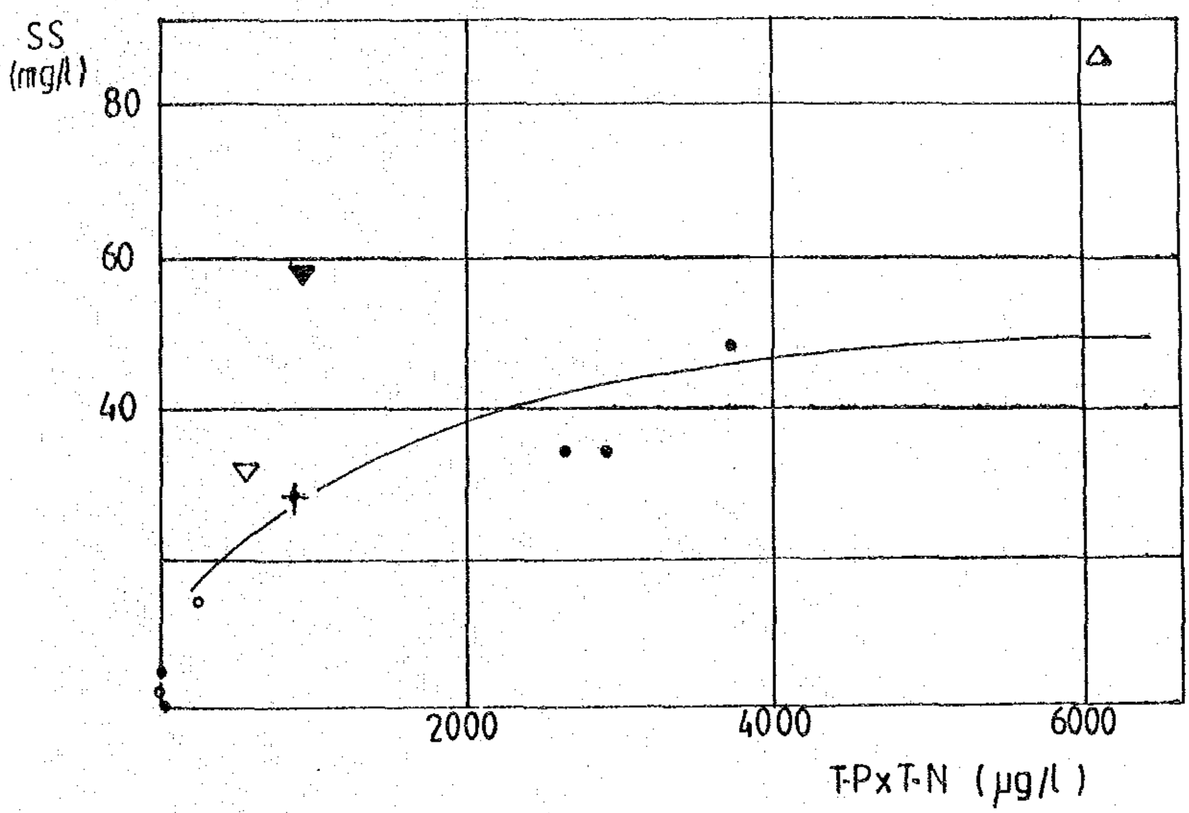
Fig. S3.A.1 T-P Concentration and Alage Increase Quantity



Reference

- ┼ : Lake Water
- ● : Filtered Water
- △ : Yuquyry River Water
- ▼ : Y-Pucu River Water
- ▽ : Yagua-Resa-u River Water

Fig. S3.A.2 T-N Concentration and Alage Increase Quantity



Reference

- ┼ : Lake Water
- ○ : Filtered Water
- △ : Yuquyry River Water
- ▼ : Y-Pucu River Water
- ▽ : Yagua-Resa-u River Water

Fig. S3.A.3 N×P Concentration and Alage Increase Quantity

SUPPORTING REPORT Ⅳ

SOCIOECONOMY AND LAND USE

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1. INTRODUCTION

1.1 Purpose of the study

The purpose of this report is to describe the socio-economic milieu in which the contamination problem has been originated. Due to the close relationship between land use and generation of pollutants, land area by existing type of use is to be estimated.

1.2 Data and study procedure

Primary and secondary data were used in this study. Primary data were obtained from personal interviews with officials of the Paraguayan Government at the national and local levels. Primary data were also obtained from interviewing selected representatives of the private sector, specifically from the manufacturing, real estate, farming and ranching subsectors. In addition, a new set of aerial photographs with full coverage of the Lake Ypacarai basin was taken as part of the Project.

Secondary data consisting of reports, statistical data, aerial photographs and maps were obtained from different Government offices. Reports were reviewed, and statistical data were tabulated appropriately to facilitate the corresponding analyses, emphasizing determination of trends and variations in selected socioeconomic indicators. Aerial photographs were interpreted and the results were transferred onto the topographical map.

Field reconnaissance of the lake basin was conducted by land as a complement and reconfirmation of the interpretation of the aerial photographs.

II. ECONOMIC AND LIVING CONDITIONS IN PARAGUAY

2.1 Economic conditions

2.1.1 Economically active population (EAP)

The economically active population (EAP), defined as the population group "12 years old and up", comprises 34.3% of the country's total population, according to the 1982 PopulationCensus. The EAP is 32.9 years old on the average. Of the total EAP, 80.3% are male and 19.7% are female. Unemployment rate is higher among the male EAP (5.1%) than among the female EAP (2.4%), giving a general unemployment rate of 4.6% for 1982.

According to the Inter-American Development Bank (IDB), the Paraguayan labor force by economic activity in 1982 was distributed as follows : 46.9% agriculture, 0.1% mining, 13.6% manufacturing, 7.5% construction, and 31.9% others. A more detailed breakdown by the 1982 Population Census indicates that agriculture is the most important economic activity, even if a sex differential can be observed. As a matter of fact, slightly over half of the male EAP hold agriculture related jobs in contrast to 10.7% of the female EAP (Table S4.2.1).

At the regional level, Table S4.2.1 shows that agriculture is, by far, the major employer in Paraguari Department and Cordillera Department, but a distant second place employer in Central Department which concentrates six of the nine Districts comprising the Lake Ypacarai basin. Craft and manufacturing concentrates the largest portion of the labor force in Central Department. If this trend continues, environmental pollution by industrial effluents can be expected to worsen in the Lake Ypacarai basin. On the other hand, if industrial activities diminish in the lake basin, a high unemployment or underemployment can be expected to affect the basin population.

2.1.2 Gross domestic product (GDP)

In the Paraguayan GDP, production and services share almost equally. Production is composed of the primary sector accounting for some 25% and the secondary sector for about 23%. With regards to services, basic services comprise some 7%, and other services about 44% (Table S4.2.2). It can be seen that, despite ups and downs, most sectors keep a stable share in the GDP composition. An exception is the electricity sector which increased considerably in the past 10 years, reflecting the importance accorded by the country to hydroelectric generation plants. The small share comprised by the water and sewerage sector should be noted because of its implications on public health and environmental contamination.

The evolution of the GDP reflects domestic economic conditions and international economic events. The Paraguayan GDP showed an impressive growth during the 1970's, especially during the second half of the decade. As a matter of fact, GDP grew at a 10.2% cumulative annual rate between 1976 and 1981, as a result of favorable factors such as the full implementation of the Itaipu hydroelectric project, and rising international prices of export products cotton and soybeans. However, the Paraguayan economy fell into a recession in 1982 and 1983 when growth rates were −1% and −3%, respectively (Table S4.2.3). This recession was reportedly triggered by the debt crisis in Brazil and Argentina, which reduced their imports and, consequently, their demand for Paraguayan exports. Exacerbating factors were unfavorable weather conditions, the drop in international prices of cotton and soybeans, and the declining weight of the construction industry as the Itaipu hydroelectric dam approached final stages of civil works.

Following two recessionary years, GDP grew 3% in 1984 and 4% in 1985, fueled by a strong agricultural production. The GDP growth rates by sector can be seen in Table S4.2.3. The 1986 GDP remained stationary at 5,634 Million US$ (Table S4.2.4).

Agriculture

The GDP structure shows that agriculture is the most important economic activity of the country accounting for about 15% of GDP and around 43% of the EAP. Cropped area was about 1.5 million ha in 1981, representing an estimated one-fifth to one-sixth of total arable land suitable for cropping. There were slightly over one million farms in the country according to the 1981 agricultural census.

In terms of cultivated area, crops exceeding 100,000 ha were soybeans, corn, cotton and cassava. In terms of frequency of crops in relation to the number of farms, crops found on over 100,000 farms were corn, cotton, and cassava. Paraguay used to depend completely on imported wheat, but a national wheat program was initiated 20 years ago seeking self-sufficiency, and achieving it just recently.

Farming practices consisting of shifting cultivation may give rise to soil erosion and ensuing water contamination problems. The agricultural extension service needs to greatly intensify its campaign to promote soil conservation practices if soil erosion problems are to be kept under manageable proportions. Potential environmental problems are also posed by the unregulated use of pesticides and other agricultual chemicals. The problem of agricultural chemicals is expected to worsen as farming practices turn to more intensive systems which are feasible even on small farms prevailing in the Lake Ypacarai basin.

Paraguayan exports are comprised by agricultural products or processed farm products. In 1986, export of cotton lint and fiber accounted for about one-third and soybeans for about one-fifth of total export values amounting to 227 Million US$ (Table S4.2.5). Despite the high proportion comprised by a few products in the total export value, Paraguay produces other unique and promising exportable products such as essential oil from orange leaves, mint essence, jojoba oil, which are all used in cosmetics.

Livestock

The main livestock activity in Paraguay is cattle ranching on the basis of large expanses of land supporting a low density of cattle per unit area. This ranching characteristic is even more pronounced in Chaco (Western Paraguay) where 37.5% of cattle is raised on 2.6% of ranches existing in the country. At the regional level, the three Departments (Central, Cordillera, Paraguari) together account for less than 15% of cattle of the country. The nine Districts comprising the Lake Ypacarai basin account for 1.2% of cattle, 1.7% of pigs and 1.2% of horses of the country.

Cattle excreta, due to their volume, are known to be significant sources of contaminants released into the environment. This contaminant source will get worse as cattle ranching characteristics change towards more intensive systems, increasing the animal load per unit area, or fattening cattle in feedlots.

Livestock activities comprise only around 8% of GDP and about 2% of EAP, but they are important as source of staple food, as well as an export product (14.5% of total export values in1986), even though meat export is in the doldrums due to the stringent requirements imposed by beef importing countries.

Forestry

Forestry activities take place mainly in Eastern Paraguay along the border with Brazil and Argentina. Forestry products comprise only about 2.5% of GDP, but their export values account consistently for at least 10% of total export values.

Valuable indigenous species include hardwood species like lapacho, while exotic species include eucalyptus and pine trees used for reforestation. Deforestation advances quickly, causing environmental problems due to the slow pace of afforestation and reforestation which amount to less than 10,000 ha. Very large land-holding transnationals used to operate in Western Paraguay using quebracho trees as raw material to extract tannin.

Energy

The Paraguayan determination to find a solution to the problem of energy resources led to the undertaking of two gigantic hydroelectric projects, Itaipu and Yacyreta, thus transforming Paraguay into an electricity exporting country. These projects spurred the construction industry which contributed heavily to GDP during the high growth years of the second half of the 1970's. However, such large scale constructions undoubtedly affect the environment adversely by their high demand of construction materials, the construction works per se, and the change in the environment caused by the flooding of large areas submersed under the man-made lake.

In addition, a national program has been launched to promote production of fuel alcohol as replacement for oil to power motor vehicles. It is estimated that the distillation of one liter of alcohol produces 12 to 14 liters of mash which have the same biological oxygen demand as the daily urban wastes of six people. At present, there is little control over the dumping of untreated mash into rivers.