The Plant Debris in Lake Tatsu-numa, the Urabandai District*

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Abstract

It has been noticed by recent studies that allochthonous organic matter plays a great role in biological production in a lake, swamp or river.

Lake Tatsu-numa is surrounded by *Salix-Pinus* vegetation. Transitional processes of the plant debris deposited on the littoral zone are evident in the lake, where the plant debris supply 80% of the primary food source for benthos and stands in considerable trophic relationships.

It was made clear that the plant debris is fed by *Glyphotaelius admorsus* etc., besides being used for nesting by *Neuronia latipennis* and *Anisocentropus immunis*, on the other hand an acceleration of decomposition by fungi or bacteria is also found. It does not take a long time for those micro-organisms, such as bacteria, flagellates, ciliates and nematodes to attach to plant debris after shedding.

The C/N ratios change in parallel with the fragmentation of plant debris, however the C/N ratio of organic suspensions becomes 5 to 10 as a result of the increase of micro-organisms.

The origin of organic suspension in Tatsu-numa comes from the terrestrial plant debris and the algal mat taking a great part in increasing suspended organic seston. Besides it is considered that bacteria or other micro-organisms are involved in the formation of deposited manganese grains obtained from the samples by an EKMAN-BIRGE's bottom sampler.

1. Introduction

Plant debris is observed much frequently not only in the floor of lake, but also in the bottom of swamp or marine waters. It was clarified as a beginning that organic matter including plant debris originated from the land often contributes the greater part of energy of a freshwater ecosystem (TEAL 1957). In the soft muddy bottom of estuary of the bay, a large amount of plant debris is transported by the river and contributes the eutrophication of water as well as direct food supply to the benthic community (YAMAMOTO, *et al.* 1968). A continuing fall out of sea grass distributed

by the gulf stream is transported as a source of organic enrichment for the deep-sea floor (MENZIES, *et al.* 1967).

Recent studies have successively noticed that allochthonous organic matters play a great role in biological production in a small lake, swamp, river and even in a sea area. It should be especially important that the plant debris is derived from terrestrial ecosystem (ODUM and DE LA CRUZ 1967, MACIOLEK and TUNZI 1967, SEKI, *et al.* 1968, KAUSHIK and HYNES 1968, KUBOTA and SHIRAISHI 1971, 1972, YAMAMOTO 1970, 1971, 1972, AIOI and YAMAMOTO 1972, 1973, MANN 1972, YAMAMOTO and AIOI 1973, BICK 1973, UEDA 1975).

Even in our survey in Lake Tatsu-numa, one of the disharmonic acidic type of lakes, the above-mentioned phenomenon is without

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exception. A large amount of plant debris, which consists mainly of broken pieces of partly decomposed terrestrial plants, can be observed (INOUE and IGARASHI 1971, YAMAMOTO 1971).

Lake Tatsu-numa is one of the Urabandai Lake Group. This Group was formed by the eruption of Volcano Bandai in July 1888. In this eruption, one of three peaks of the volcano was carried to 12 km distant from its crater as mud-streams by a landslide on its northern slope. The landslide buried eleven villages, four rivers and valleys, and resulted in the formation of Lakes Hibara, Onogawa and Akimoto, and about 80 additional small lakes and ponds on the uneven surface formed by the landslide.

A great many of those lakes have acid water as a direct result of volcanic activity. Of these, the strongest acid water is Lake Akadoro-numa situated near the crater. Its water contains of sulphuric acid and inorganic salts in high concentrations and has a pH as low as 3.2. Under such environmental conditions, only two species of algae are found in the lake. With decreasing acidity, it increases organisms not only in the number, but also in the species. In weak acid lakes, such as Lake Tatsu-numa, all trophic levels are present, but because of the high concentration of inorganic salts and sulphuric acid, the number of species at each trophic level is very limited in comparison with other types of lakes.

Only two species of cyprinid fish inhabit Lake Tatsu-numa, *Tribolodon hakonensis hakonensis* (GÜNTHER), and the common fat-minnow, *Moroco steindachneri* (SAUVAGE).

The water of Lake Tatsu-numa contains SO_4^{--} 186.0 ~ 386.8 mg/l, Ca^{++} 60.7 ~ 117.2 mg/l, and shows a pH of about 6.7.

The terrestrial woody vegetation is well-developed around the circumference of Lake Tatsu-numa. The most common species are *Pinus densiflora* SIEB. et ZUCC., *Alnus pendula* MATSUMURA, *A. hirsuta* var. *sibirica* C. K. SCHNEID., *Sorbus commixta* HEDL., *Betula Maximowiczii* REGEL, *Wistaria floribunda* WILLD.; near the lake shore *Salix gilgiana* SEEM., *S. integra* THUMBERG, *Phragmites communis* TRIN., *Epilobium angustifolium* L. are dominant, blending into the aquatic vegetation which includes *Potamogeton*, *Myriophyllum spicatum* L., *M. verticillatum* L. The terrestrial woody plants shed their leaves in autumn and supply, in this way, a large amount of organic matter to the lake. The addition of such a large quantity of organic matter must play an important role in the small sized lake with low productivity.

At the end of November, 1969, nearly all woody plants have shed their leaves and a large quantity of fallen leaves was found on the littoral region of the lake. Accumulation of fallen leaves were observed throughout the littoral area, but no accumulation of them was found on the profundal bottom of the lake.

2. Materials and Methods

Observations and sampling were made from September, 1971 to September, 1972. Every 2 meters from both sides of the shore line, 14 sampling stations were set, in addition 4 stations in the central area of the lake at every 10 meters on the line LM (Fig. 1.).

An EKMAN-BIRGE grab (1/44 m²) was used to obtain samples together with mud. The residue after sifting out mud by 1 mm meshed sieves were sorted into leaf, branch, adventitious root and manganese grains.

Fig. 1. Stations sampled in Lake Tatsu-numa. Arrows show inlet and outlet. Dotted line shows the vegetation of reed growing over the water area.

Weighed the plant debris dried for 24 hours at 80°C and obtained the ignition loss burned at 500°C for 30 minutes. The organic carbon and nitrogen were determined by a YANAGIMOTO CHN analyser (STRICKLAND and PARSONS 1968).

The residue after sieving contains much black manganese grains, which were detected by X-ray spectro-photometry.

3. Results

i) The amount of plant debris

Fig. 2 shows the histogram of the plant debris at each station. The amount of the deposited plant debris is larger in the stations of L side than those of M side, and least in the central area of the lake. The seasonal prevalence of the total stand-

ing crop at the three areas is shown in Fig. 3. The falling leaves increase in autumn from September to October and is in steady state until next spring of thawing. There is no fall of leaves from April to June.

The greater amount of the plant debris is shed in autumn and deposited on the bottom of the littoral area shallower than 4 m deep. This prevalence is not so conspicuous in the central area of the lake.

ii) C, N and C/N ratio

The contents of nitrogen, carbon and C/N ratios of plant leaves, branches and adventitious roots are shown in Fig. 4. The contents of carbon are about the same in the plant leaves, branches and adventitious roots, but the nitrogen contents are

greater in the leaves than the other two materials. The C/N ratio ranges from 10 to 50 in the leaves and branches, but 20 to 40 in the adventitious roots.

In Fig. 4 the contents of carbon and nitrogen and the C/N ratios show a discontinuity in the depth of about 4 m, that is, the ranges of these values are smaller in the area shallower than 4 m in depth. In the littoral area shallower than 4 m there is covered with a mass of new plant debris as compared with the more deeper area, where there is a tendency of remaining of old plant debris, especially in the central area.

The C/N ratio indicates decomposition processes, that of leaf from 14.4 to 23.7 in the littoral shallower than 3 m, 17.2 to 54.6 in the deeper area, and that of branch shows 20.4 to 32.5 in the littoral, 21.8 to 58.2 in the deeper area.

The stability of N-contents is the same tendency in *Salix* and *Alnus* after all the progress of decomposition in spite of decreasing C-contents (Fig. 5).

iii) The decomposition process

New plant debris is discriminated in the shape of leaves which is not fragmented, and also in the value of C/N ratio which is smaller in the new ones than in the older ones.

In Lake Tatsu-numa decomposition commences with the fragmentation by the activities of insect larvae. The gradual increase of decomposition of plant debris after shedding goes in parallel with the increase of fragmentation. The leaves are all gone off the trees in the defoliation from October to November. Such autumn-shed leaves of *Salix* have been fragmented into several pieces until next April and developed to the granular stage in September and

Fig. 2. Amount of plant debris at each station along the transect LM in Lake Tatsu-numa.

October. A large amount of fallen leaves of willow trees, about 40% of the production of leaves in willow trees (KASHIMURA 1970), were observed even in June, these fallen leaves were still green and fragmented into small pieces in September. So far as the observation of fragmentation, has been made the decomposition of leaves advanced rapidly in summer. It seems to be a little bit slowly going on in *Alnus*.

Through the decomposition process, the plant debris has to do with the biological

Fig. 3. Seasonal prevalence of the total standing crop (dry weight g/m²) of plant debris depositing in each area of L, O and M.

production. The plant debris soon after shedding is fed by *Glyptotaelius admorsus* etc., besides being used for nesting by caddis-worms like *Neuronia latipennis* and *Anisocentropus immunis*. On the other hand, an acceleration of decomposition by fungi or bacteria is also found in the lake. After some time the old plant debris is exploited by *Neuronia* for feeding, as well as *Glyptotaelius* for nesting. Some insect larvae such as *Tipula* sp., chironomid and culicoides feed on fragmented plant debris. Then fungi and bacteria advance the progress of decomposition to dissolve inorganic nutrient passing through the stage of organic particles (Fig. 6).

iv) Manganese grains

Manganese grains seemed to be at first carbonized plant debris obtained with the other samples of plant debris. The means of ignition loss and C/N ratio are showed in Table 1. The ignition loss indicates the

Table 1. Average measurements of ignition loss, C-content, N-content and C/N ratio in manganese grains in Lake Tatsu-numa (Sept. 1971). Standard deviation is calculated and the ranges are shown in parenthesis from five measurements.

Ignition loss %	C mg/g	N mg/g	C/N
27.3 ± 5.4 (20.4~34.6)	46.9 ± 14.6 (34.5~70.6)	4.0 ± 0.9 (3.6~4.8)	11.3 ± 2.3 (8.8~14.4)

near value as the mud on the bottom surface.

If these granules were the products of decaying of plant debris, the C/N ratio would show higher value. However, the C/N ratio is rather low. It means that there exist some organic as well as inorganic substances which form about 70% of these granules. The result by X-ray spectrophotometry shows that the grains are composed of Mn, Fe, Zn, Ni, Cu and Co as inorganic substances, mainly of Mn.

Fig. 4. The distribution of carbon contents, nitrogen contents (mg/g) and C/N ratios in each plant debris, leaf, branch and adventitious root along the depth of the transection LM (Sept. 1971).
(○ : C-content ● : N-content)

Fig. 5. The prevalences of the contents of C, N and C/N ratio in leaves of *Salix* and *Alnus*, as the deposited plant debris in Lake Tatsu-numa.

4. Discussion and Conclusion

The standing crop of plant debris depends mainly upon the terrestrial vegetation around the lake, in the littoral area shallower than 4m deep in Lake Tatsu-numa. Terrestrial vegetation is composed of *Salix*, *Alnus* and *Pinus* in the area of L side, and of *Pinus* and *Salix* in the area of M Side. Leaves of *Pinus* are shed only in the land shore and little in the water area. Therefore, the standing crop of plant debris deposited in the bottom of water is much more in the area of L side in comparison with the area of M side.

In Lake Tatsu-numa, terrestrial plant debris predominate for all the extremely less productivity of phytoplankton (YAMAMOTO

Fig. 6. Diagram of decomposition processes of plant debris and algal mat in Lake Tatsu-numa. Numerals show the value of C/N ratio.

Fig. 7. The results of transection surveys at the littoral zone of Lake Tatsu-numa. (After INOUE and IGARASHI, 1971)

1975). The amount of leaf production in *Salix* reaches 3.7 tons in dry weight per year. The amount of leaves deposited on the bottom of the lake was estimated to be 1.4 to 1.7 tons dry weight in autumn of the same year. Transitional processes of the plant debris deposited on the littoral zone are evident in the lake.

The distribution of benthos runs parallel with the amount of plant debris from the shore line to the center of the lake (Fig. 7, INOUE and IGARASHI 1971, INOUE, *et al.* 1975). Moreover, it was clarified that the plant debris soon after shedding is fed by some insect larvae, besides used for nesting by some other insect larvae, and accelerated decomposed by fungi or bacteria. Some time after shedding, somewhat decomposed old plant debris is also exploited for feeding, as well as for nesting. The larvae of such as *Tipula* sp. and chironomid feed on fragmented plant debris.

Thus larvae of aquatic insects attack the plant debris in various stages of the decomposition processes and contribute to the

fragmentation and decomposition of plant debris by feeding and nesting (Fig. 6). From this point of view, it can be easily comprehended that the plant debris holds the key to the production of benthos. Furthermore, stored energy is reutilized by bacterial production through heterotrophic and chemosynthetic processes (SEKI, *et al.* 1968). Ooze as a reserver in Cedar Bog Lake is taking a great part in not only supply herbivores with food such as micro-organisms attaching to it, but also transforming into dissolved nutrients for autotrophic organisms (LINDEMAN 1941).

With the development of decomposition in fallen leaves, an increase of micro-organisms was observed, viz., bacteria, diatoms, flagellates, ciliates, rotifers and nematodes attached to the plant debris. It does not take a long time for those micro-organisms to attach to plant debris after shedding except the winter period. The remarkable increase in relative nitrogen content in leaf was not recognized with its development of fragmentation in spite of gradual decrease in carbon content.

Micro-organisms such as bacteria, fungi and protozoa grow on the plant debris in the decomposition processes. Therefore, the nitrogen contents were estimated to be comparatively high value even in old plant debris.

It is possible to clarify the processes of decomposition by C/N ratio. The example of marine sediment deposition indicates 7 in summer and 11 in winter in its C/N ratio (SEKI, *et al.* 1968). It is clear that coastal macrophytes are major producers of organic matter and that little of this production enters the grazing food chains. The dissolved organics may be assimilated by micro-organisms, especially bacteria, or

they may be converted to particle form by physico-chemical processes. Both micro-organisms and particulate organic matter are constituents of detritus (MANN 1972).

In Lake Tatsu-numa plant debris supply 80% of the primary food source for benthos and stands in considerable trophic relationships (YAMAMOTO 1975). The origin of organic suspension in Lake Tatsu-numa comes from the plant debris just mentioned above and algal mat of *Vaucheria hamata*, *Oedogonium* sp. etc. rather than phytoplankton. The thawing snow cause the lake to rise in spring and the more amount of suspension 1.5 to 1.6 mg/l obtained rather than in autumn 0.4 to 0.7 mg/l, but the ignition loss became 30% in spring, 40% in summer and autumn (YAMAMOTO 1970, 1971, 1972). From the standing crop of organic suspension and its seasonal movement, the most part of it cycles once every seven or ten days between April and December (YAMAMOTO and AIOI 1973). It is concluded from the seasonal prevalence at the littoral and profound areas, that the origin of organic suspension in Tatsu-numa comes from the terrestrial plant debris and the algal mat taking a great part in increasing suspended organic seston.

As previously described, manganese grains are much deposited on the lake bottom. It would be thinkable from the value of C/N ratio that bacteria or other micro-organisms work in creation of manganese deposition utilizing the plant debris as concretions of manganese grains under the conditions in which the water contains much in Mn (YOSHIMURA 1937, KUZNETSOV, *et al.* 1963). The water contains 1.64 mg/l of Mn in Lake Tatsu-numa and Mn is not recognized in other types of lake.

Plate 1. A microphotograph of manganese grains in 300 magnifications. A diatom can be seen in the center.

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摘 要

河川、湖沼に流入する外来性有機物は、分解過程を経て無機栄養塩類を供給するばかりでなく、二次生産者の餌としての役割も果している。

裏磐梯、五色沼湖沼群の一つ、竜沼は周囲にヤナギ類などの群落があり、底生生物の食餌の約80%は、陸上植物遺骸に依存している。湖底に堆積する陸上植物遺骸は、主に秋に落葉したものが湖岸の浅い水域に堆積する。

陸上植物遺骸は、水生昆虫幼虫、マルバネトビケラ、エグリトビケラ、コバントビケラ、カワゲラなどにより食餌として利用されたり、巣として利用されていることが明らかにされた。これら水生昆虫幼虫による利用は、陸上植物遺骸の細片化を促進し、並行して分解が進む。C及びNの含量については、C量が徐々に減少するのに比べN量はあまり変化しない。これは植物遺骸にバクテリア、原生動物等の微小生物が存在する

ため、細片化が進み有機懸濁物の段階になると、バクテリア等の増殖に伴ないC/N比率が5~10となる。

竜沼における有機懸濁物の起源は陸上植物遺骸、及び湖底に繁茂している藻類に由来するものと考えられる。

陸上植物遺骸のサンプル中から得られたマンガン粒子は、水中のMn量が他の湖に比べ多いことと、マンガン粒子が形成される時に結核となるものが生物遺骸であることから、陸上植物遺骸が関与しているのではないかと推定できる。

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