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＜論 文＞

Creeping Environment Problem of Rapid Growth of Water Hyacinth in the Shallow Reservoir of Ishiduchi with Influence of Global Warming at Warm Temperate Region in Japan

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Abstract

Under the influence of global warming and climatic change in the south-west warm temperate region in Japan, rapid growth of water hyacinth of sub-tropical origin is a major source of thick muddy sludge sedimentation in the shallow lakes and/or reservoirs, which deteriorates water quality environment and eco-system as well as decreases the capacity of effective storage volume for flood control. This study aims to evaluate the influence of free-floating aquatic plant such as water hyacinth (*Eichhornia crassipes)* on the water quality and eco-system of the shallow semi-artificial flood retention reservoir in Kochi, Japan. A series of laboratory experiments have been carried out to examine the absorption-emission capacities of nitrogen (N:T-N) and phosphorous (P:PO_4-P) in the growing-dying processes of water hyacinth in the aquarium at controlled water temperature in both summer and winter. The rate of absorption-emission of N-P amounts to 40-95% in a week, which is the major factor to control the nutrient (N-P) level of the reservoir. Vulnerability assessment is being carried out to restore the Ishiduchi reservoir taking into account of the application of bio-manipulation technology.

Key words: aquatic plants, water hyacinth, quality, purification, eco-system, bio-manipulation

要旨

温暖な温帯気候に属している西南日本では、地球温暖化と気候変動の影響下で浅い湖沼や貯水池に亜熱帯原産の外来植物であるホテイアオイが大増殖し始めている。その結果水界の生態系や水質が悪化して池底にヘドロの堆積が進む過程で雨水調整池の治水調整容量が減少してきている。本論の目的は浮遊性水生植物（ホテイアオイ：*Eichhornia crassipes*）が高知県の浅い湖沼や貯水池の水質と生態系に与える影響を評価することにある。夏期と冬期を代表する水温にコントロールした室内実験水槽に石土池のホテイアオイと水を移し、成長過程（夏）と枯死過程（冬）における窒素（T-N）と燐（PO_4-P）の濃度変化、すなわちN-Pの吸収量と放出量を測定した結果、ホテイアオイの成長と枯死過程が池の栄養塩濃度を大きく支配していることが判明した。バイオ・マニピュレーション（Bio-manipulation）手法を適用した石土池の自然再生計画における脆弱性評価（Vulnerability assessment）に取り組んでいる。

1. INTRODUCTION

Under the influence of global warming and climatic change in the warm temperate region, rapid growth of water hyacinth in the shallow lake is a major source of thick muddy sludge sedimentation to deteriorate water quality environment and eco-system as well as decreasing the effective storage volume of the flood retention reservoir of Ishiduchi lake. The study area of Kochi is a typical hot spot in Japan to study the influence of global warming to incorporate the change of sea surface water temperature (SST) of the black (Kuroshio) current in the Pacific Ocean[1). Water quality deterioration with excess growing blue-green algae and bottom muddy sludge in the shallow lakes and

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reservoirs is a typical creeping environmental problem in warm temperate climate region in Japan.

This study focuses on the free-floating aquatic plant of water hyacinth (*Eichhornia crassipes*), which is tropical origin and transmigrated from Brazil to Japan in 1880s, to deteriorate water quality and eco-system of many shallow lakes and reservoirs in the south-western part of Japan[2,3].

The purpose of this study is to evaluate the impact of water quality purification on the eco-system, by examining the effects of absorbing-emitting nitrogen and phosphorous in the different two processes of growing and dying of water hyacinth in the Ishiduchi lake.

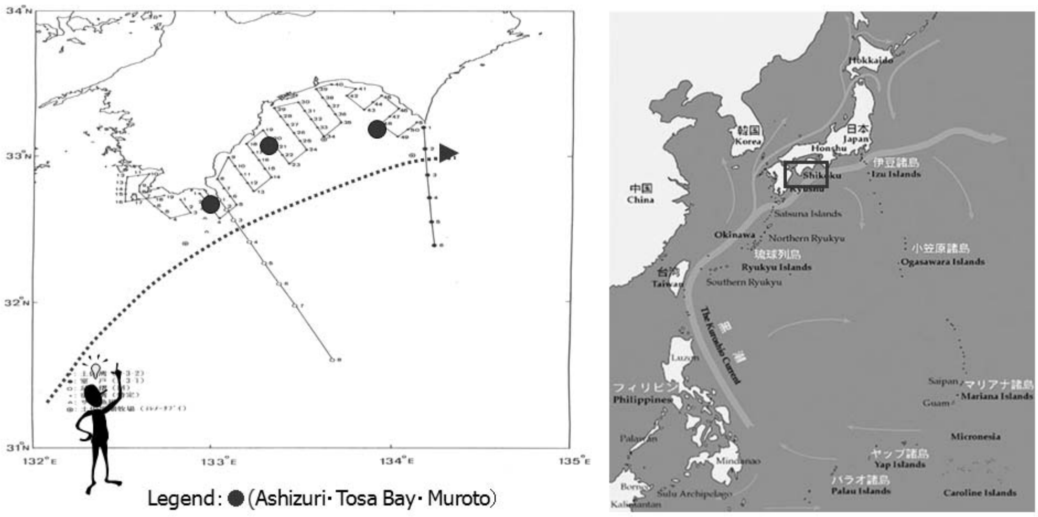
A series of laboratory experiments have been carried out to examine the change of absorption-emission capacities of nitrogen and phosphorous in the processes of growing and dying of water hyacinth in the aquarium at controlled water temperature in summer and winter.

From the experiment of this study in 2010, it is confirmed that the free-floating aquatic plant such as water hyacinth grows rapidly at an average water temperature of 25 ℃ in summer to purify the eutrophic water by absorbing the nutrients such as 40% of nitrogen (T-N) in 4 days and 90% of phosphorous (PO_4-P) in 2 days. In the beginning of winter season of December, the dying process of the leaf of water hyacinth is monitored in the Ishiduchi reservoir water sample. It takes 8 days to emit 100% of T-N and 6 days for 70% of PO_4-P in the Ishiduchi reservoir water sample, and then after muddy sludge sedimentation can be observed at the bottom. This emission is a main reason why the nutrients level of N-P is kept so high in the winter season. As a result, water quality environment and eco-system of Ishiduchi reservoir have been deteriorated since 1990s when the temperature started to increase in Kochi.. This creeping environment problem appears after long periods such as more than 10-20 years without any notice of fear.

Vulnerability assessment is being carried out to restore the Ishiduchi reservoir taking into account of the application of bi-manipulation technology in the shallow lakes[4].

2. INFLUENCE OF GLOBAL WARMING ON THE CLIMATE OF KOCHI

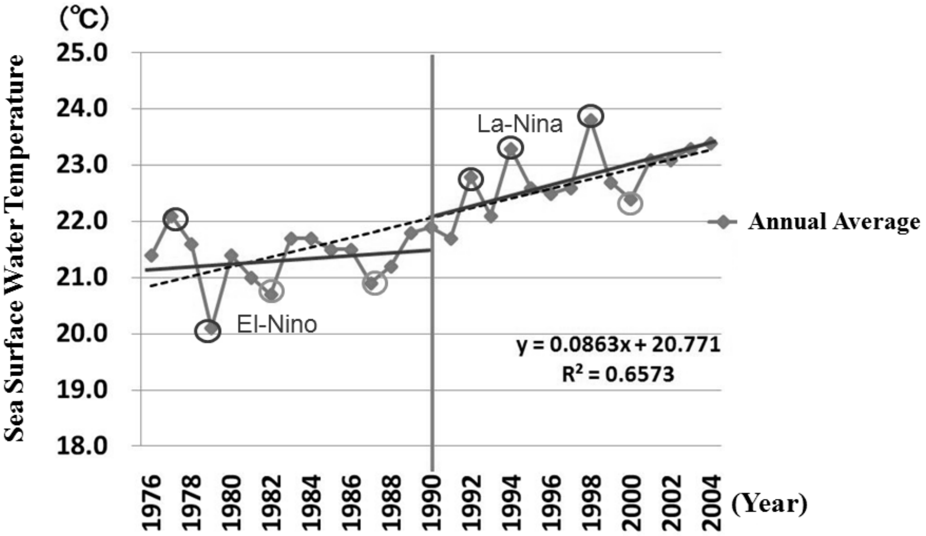
Kochi prefecture is located in the western part of Japan with temperate warm climate. The climate is largely influenced by black (Kuroshio) warm ocean current which is one of the largest warm ocean current in the world (Fig.1). Sea surface water temperature along the Pacific coast of Kochi prefecture has started to increase by steps since 1970s. Kochi is one of the best hot spot in Japan to study the influence of global warming on either SST (Sea Surface Temperature) or land along the off shore of western rim of Pacific ocean. Kochi prefectural government measures the SST monthly at off shore of Kochi since 1970s (Fig.1)



Source: Kochi prefecture government: H.P. , Fishery Promotion Division (2009)

Fig. 1 Map of Sea surface Temperature (SST) Monitoring Point and Black (Kuroshio) Warm Ocean Current

The sea surface water temperature along the coast of Kochi prefecture rises more than 2.47 ℃ in the past 29 years from 1975 to 2004, of which the increasing rate is alarming and among the highest in Japan, owing to the direct influence from the black (Kuroshio) warm ocean current[1]. Frequent changes of sea surface water temperature along the off-shore of Koch are under the influence of global scale climatic change including La-Nina and El-Nino as shown in Fig.2.



Source: Kochi prefectural government, Fishery Promotion Division (2006)

Fig.2 Influence of El-Nino and La-Nina on the sea surface temperature (SST) along the off shore of Kochi in Japan

The long-term change of annual average air temperature is monitored for more than 100 years at the national meteology station at Kochi city and Muroto cape since 1906. It is noted that the annual average air temperature was almost steady or declining trend before the World War-II. The increasing trend started after the World War-II to rise 1.81℃ in the past 50-100 years with significant influence of the urbanization of Kochi city, which is more than two times as high as the world average of 0.7℃ (Fig.3).

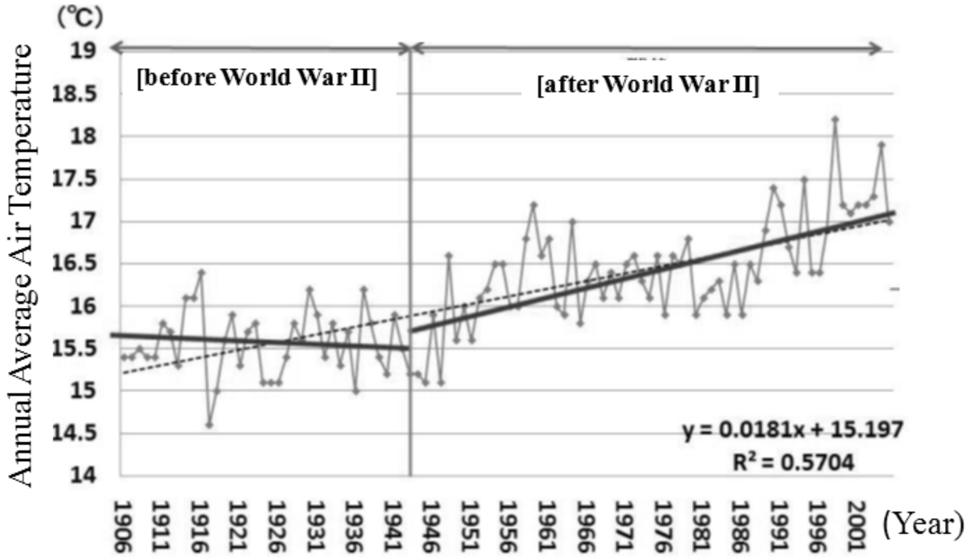


Fig.3 Long-term trend of annual average air temperature change in Kochi city

The long-term air temperature change after the World War-II in Kochi is dependent on not only global warming but also heat island effect. The long-term anomaly of monthly air temperature in January (winter) and August (summer) at Muroto meteorology station, which is conceived one of the best ideal tip of the cape in Japan without any influence from the heat island effect, was analyzed to confirm the more significant increasing trend in the January of winter season than the August. This is due to the direct influence from the nature of sea surface water temperature of Black (Kuroshio) ocean current along the coast of Kochi as shown in Fig.4.

Creeping environment problem such as long-tem increasing air temperature in winter season give a significant impact and influence on a part of water hyacinth group to survive throughout a year. The water hyacinth will not die but over grow in south-western part of Japan island.

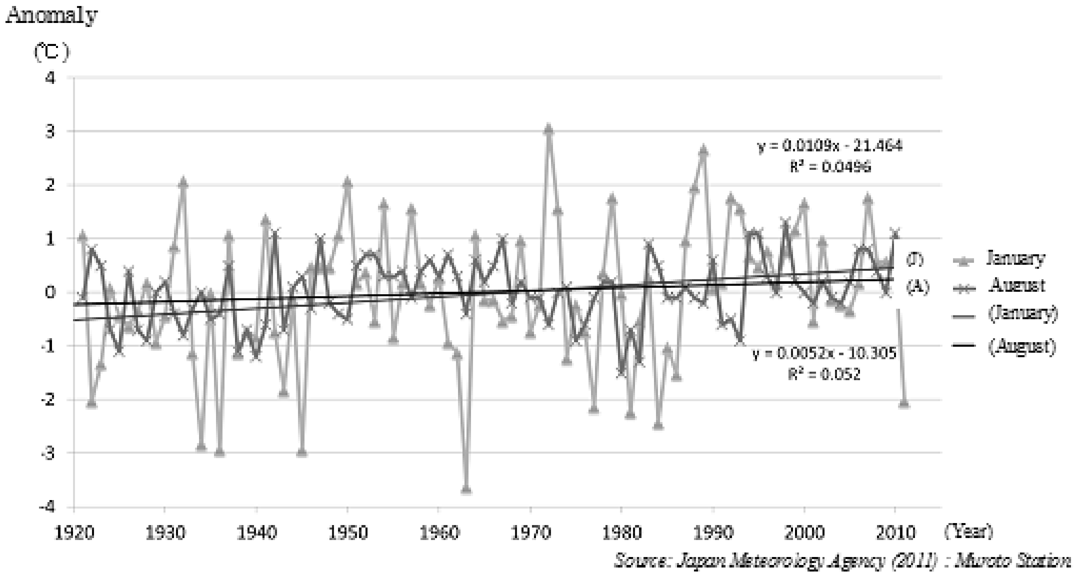


Fig.4 Long-term anomaly of monthly air temperature in January and August at Muroto meteorology station

2. INFLUENCE OF GLOBAL WARMING ON ECO-SYSTEM AND WATER QUALITY

Water quality deterioration with excess growing blue-green algae and bottom muddy sludge in the shallow lakes and/or reservoirs is a typical creeping environmental problem to sustain the good quality of water with relevant eco-system in warm climate region.

This study focuses on the free-floating aquatic plant of water hyacinth (*Eichhornia crassipes*) which is tropical origin and transmigrated from Brazil to Japan in 1880s to deteriorate water quality and eco-system of many shallow lakes and reservoirs in the temperate warm climate zone of south-western part of Japan after 1990s.

The free-floating aquatic plants including water hyacinth started to grow up in summer season since 1980s when the increase trend of annual average air temperature has been observed in many gauging stations in Kochi. The water hyacinth purifies the water quality by absorbing the nutrients of nitrogen and phosphorous in the shallow lakes in summer season. While, the water hyacinth is susceptible to winter killing to emit the nutrients and then be decomposed to the point where the muddy sludge can be observed at the bottom[3] (Figs.5,6). As a result, water quality environment and eco-system have been deteriorated by steps.

Fig.5 Growing and dying water hyacinth in summer and winter season

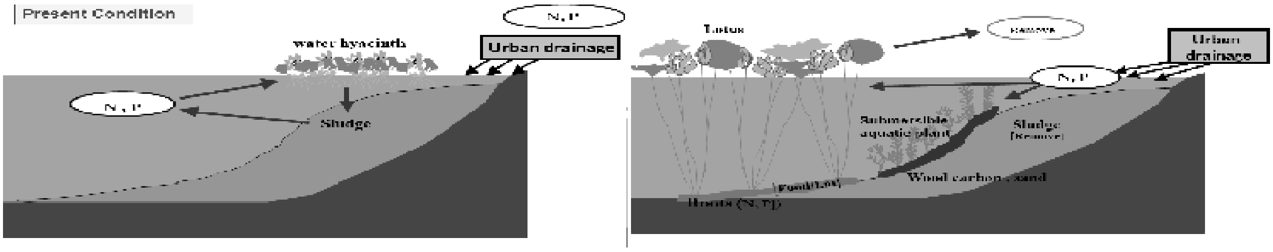


Fig.6 Free-floating aquatic plant of “water hyacinth” and muddy sludge on the bottom of Ishiduchi reservoir

Kochi prefectural government paid 3 million yen per annum to remove the water hyacinth which covers 1/4 of the surface area of Ishiduchi reservoir since beginning of 1990s (Fig.7). It is costly routine work to remove the increasing water hyacinth after 1990s when the air temperature start to rising significantly (Figs.2,3).

Fig.7 Ishiduchi flood retention reservoir and water hyacinth

The creeping environment problem of the quality deterioration appears after some long periods such as more than ten to twenty years. It is still not known the mechanism and process of dying aquatic plant to emit the nitrogen and phosphorous in the water body and the optimum time to either harvest of remover the water hyacinth.

3. LABORATORY EXPERIMENT

A series of laboratory experiments have been carried out to examine the change of absorption-emission capacities of nitrogen and phosphorous in the processes of growing and dying of water hyacinth in the aquarium at controlled average water temperature in summer season of August such as 25℃ (=average water temperature in summer at Kochi). Method and condition of the laboratory mesurement is shown as below:

Photonic synthesis process is kept constant for 24 hours a day in a dark room using artificial green fluorescent light tubes (Toshiba,No.20,LUX:420lx) for specific green vegetable.

The influence of dissolved CO_2 in water sample with water hyacinth on the photo synthesis process in the water hyacinth was examined to apply the Tetra CO_2 Test Kit by adding optimum concentration of CO_2 gas such as 28 mg l^{-1} in a case of average concentration of the Ishiduchi reservoir.

Water Quality Monitoring Sonde (YSI-6600) was used to measure the chlorophyll-a and turbidity at time interval of 1 minute. Sensor array photometer (LASA-1/20 : LCK238/138, LCK349) was adopted to measure the T-N and PO_4-P.

Two different type of water samples were taken from 1) Ishiduchi reservoir and 2) tap water with liquid fertilizer of typical commercial product such as HYPONeX with 5% of N, 5% of P and 5% of K.

(1) Comparative Aquarium Experiment and Treatment Conditions

A series of laboratory experiments using three (No.1,No.2,No.3) small aquarium units (20cmx20cmx30cm) have been carried out to compare the influence on the growth of free-floating aquatic plant at different concentration of nutrients such as T-N and PO_4-P with constant water temperature of 25℃ in August and at natural air temperature in December. Water sample and aquatic plant were taken from Ishiduchi reservoir as shown in Tables 1 and 2.

No.1 aquarium unit measures the absorption capacity of water hyacinth with water sample of Ishiduchi reservoir without adding any artificial nutrients. No.2 aquarium unit monitors the absorption capacity with water sample from tap water to add the artificial liquid fertilizer with 300 mg l^{-1} of T-N. No.3 aquarium adds 28 mg $l^{-1}$of CO_2 as shown in Table

2 and Fig.8. The measurement of nutrients (T-N, PO_4-P) has been carried out at time interval of 2 days.

Table 1 Dimensions of laboratory experiment

Aquarium	Water sample	Aquatic plant
20cmx20cmx30cm (*Volume: 12ℓ*)	Ishiduchi reservoir	Ishiduchi reservoir *Two pieces of water hyacinth for each aquarium*

Table 2 Treatment conditions of laboratory experiment

Aquarium	No.1	No.2	No.3
Water temperature	25℃	25℃	25℃
Water sample	Ishiduchi	Ishiduchi	Ishiduchi
Adding nutrients	non	T-N=300 mg l^{-1}	T-N=300 mg l^{-1}
Adding CO_2	non	non	CO_2=28mg l^{-1}

Remarks:
※T-N=300 mg l^{-1} is equivalent to the concentration of liquid fertilizer
※ (CO_2)=28 mg l^{-1} is equivalent to the concentration of Ishiduchi reservoir water

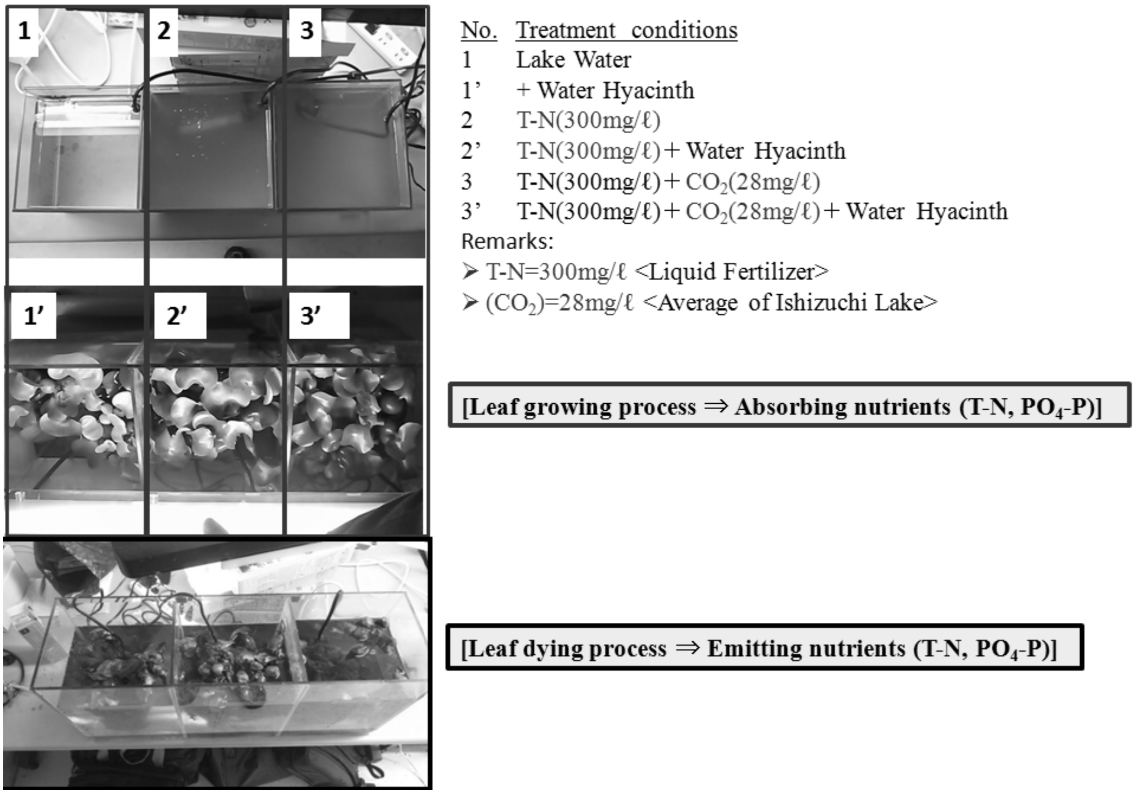


Fig. 8 Treatment conditions of comparative aquarium testing

a) Result in absorption process

Monitoring of absorption capaity of nutrients of T-N and PO_4-P through grwoing water hyacinth in aquarium No.1,2,3 has been carried out in summer season at controlled water temperature of 25℃.

The leaf of water hyacinth grows rapidly to absorb the nutrient in the aquarium with either Ishiduchi reservoir water or artificial liquid fertilizer. It takes 4 days to absorb 40% of T-N and two days for 90% of PO_4-P in the Ishiduchi reservoir water sample (No.1) as shown in Figs.9 and 10 .

Influence of the dissolved CO_2 in water sample with water hyacinth on the photo synthesis process by adding 28 mg l^{-1} of CO_2 gas (treatment condition No.[3] in Fig.8) was estimated to be very small in an error range of the in-situ measurement.

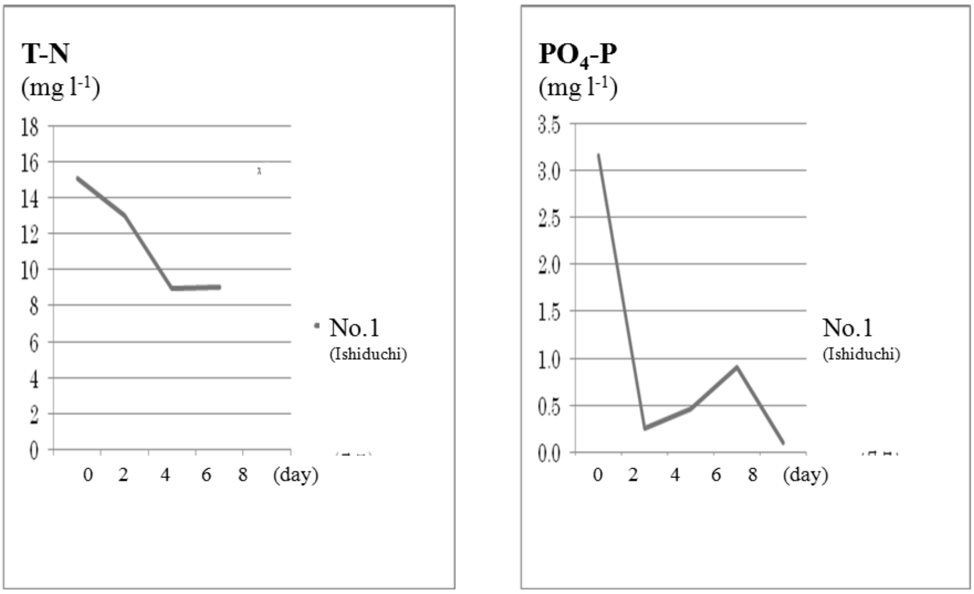


Fig.9 Monitoring of absorption capaity of nutrients of T-N and PO_4-P through grwoing water hyacinth in aquarium No.1 (Ishiduchi)

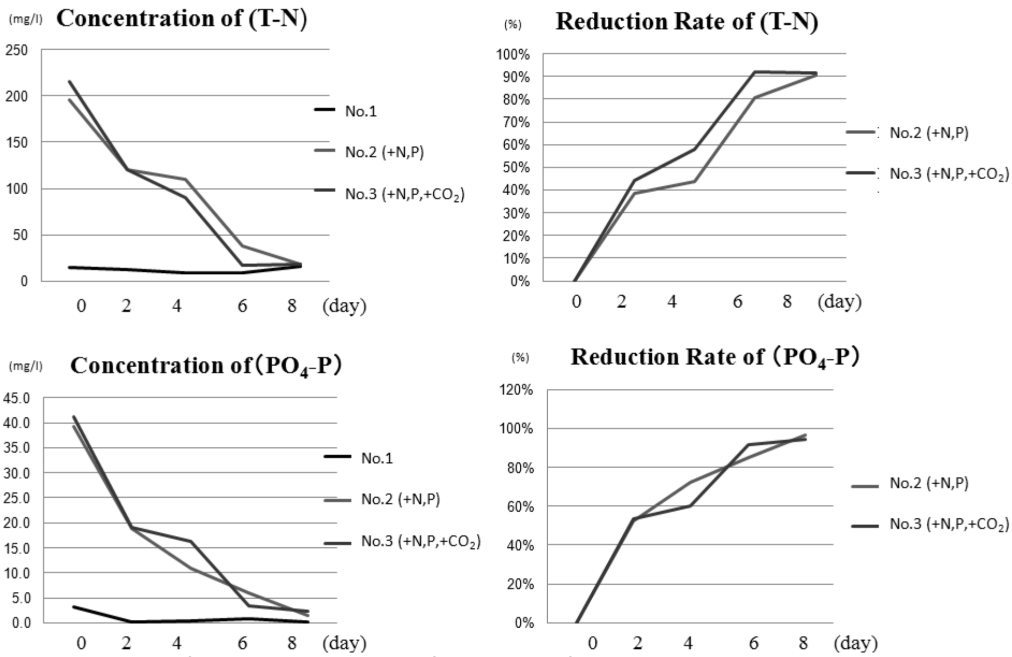


Fig.10 Monitoring of absorption capaity of nutrients of T-N and PO_4-P through grwoing water hyacinth in aquarium No.1,2,3 (Liquid fertilizer)

b) Result in emitting process

Similar type of aquarium experiment has also been performed to evaluate the change of nutrient concentration through the process of leaf dying in winter season. Monitoring of emission capaity of nutrients of T-N and PO_4-P through dying water hyacinth in aquarium No.1,2,3 has been carried out in winter season atnatural room air temperature of the December.

The leaf of water hyacinth is decomposed in winter to emit the nutrient of T-P in the aquarium with either Ishiduchi reservoir water or artificial liquid fertilizer. It takes 8 days to emit 100% of T-N and 6 days for 70% emitting of PO_4-P in the Ishiduchi reservoir water sample (No.1) as shown in Figs.11 and 12 .

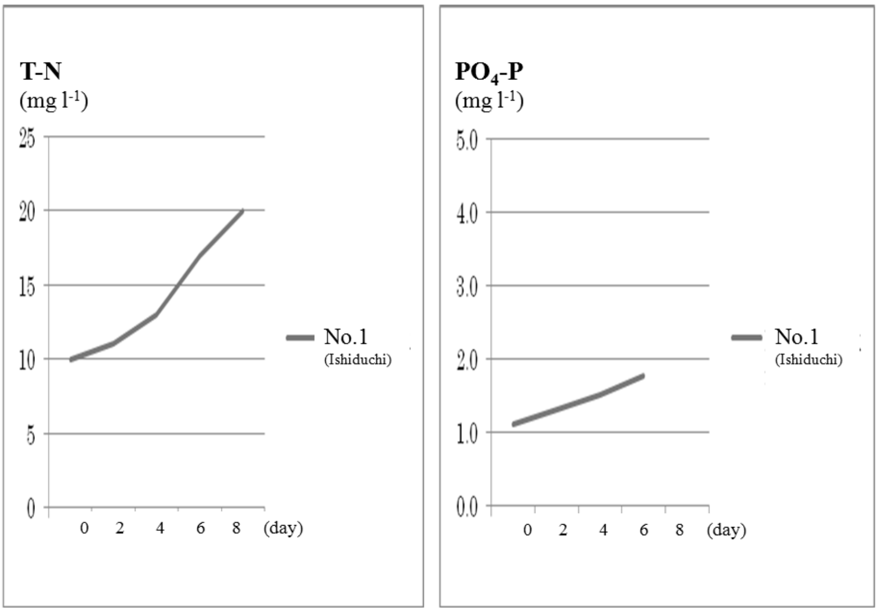


Fig.11 Monitoring of emissiion capaity of nutrients of T-N and PO_4-P through dying water hyacinth in aquarium No.1(Ishiduchi)

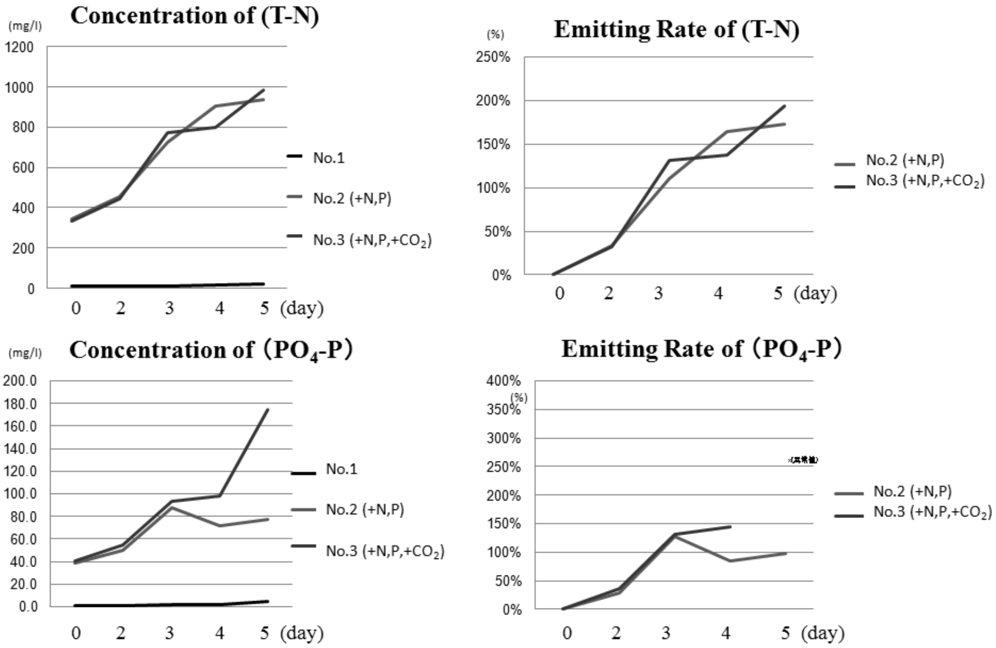


Fig.12 Monitoring of emissiion capaity of nutrients of T-N and PO_4-P through dying water hyacinth in aquarium No.1,2,3 (Liquid fertilizer)

CONCLULDING REMARKS

The free-floating aquatic plant such as water hyacinth grows rapidly at an average water temperature of 25 ℃ in summer to purify the eutrophic water by absorbing the nutrients such as 40% of nitrogen (T-N) in 4 days and 90% of phosphorous (PO_4-P) in 2 days. In the beginning of winter season in December, the dying process of the leaf of water hyacinth is monitored in the Ishiduchi reservoir water sample. It takes 8 days to emit 100% of T-N and 6 days for 70% of PO_4-P in the Ishiduchi reservoir water sample, and then after muddy sludge sedimentation can be observed at the bottom. This emission is a main reason why the nutrients level of N-P is kept so high in the winter season.

As a result, water quality environment and eco-system of Ishiduchi reservoir have been deteriorated since 1990s when the both air and SST temperature started to increase in Kochi. This creeping environment problem appears after long periods such as more than 10-20 years without any fears on disaster.

It is concluded that the water hyacinth significantly absorbs the N-T in the process of growing in summer season and then emits the nutrients (N-T) in the process of dying in winter season.

In order to take preventive measures for overgrowth of free-floating aquatic plants, it is recommended to either harvest or remove the water hyacinth just before the winter season such as in October to November with aim of saving the cost of hard routine work of securing the effetive storage volume of flood retentiion reservoir and the lake eco-system management of Ishiduchi.

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