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# MONITORING AND EVALUATION OF THE WATER QUALITY OF TAAL LAKE, TALISAY, BATANGAS, PHILIPPINES

*Felipe B. Martinez and Imelda C. Galera*

*De La Salle University – Dasmariñas.*

**Key words:** Cool dry season, hot dry season, rainy season, Taal lake, water quality.

## ABSTRACT

**Abstract**

The study is an update on the physico-chemical properties of Taal Lake for local and government officials and non-government organizations. A total of nine (9) water quality parameters were monitored and analyzed. The study shows that Taal Lake's surface temperature, pH, total dissolved solids, total suspended solids, color, and dissolved oxygen content conform to the standards set by the DENR while phosphate, chlorine, and 5-Day 20°C BOD are below the standard. T-test result shows that there is no significant difference in the overall average of the two sites at Taal Lake ($P > 0.05$). Based on the data, the lake is safe for primary contact recreation such as bathing, swimming, and skin diving and can be used for aqua culture purposes.

## 1. INTRODUCTION

The health condition of every human being depends on the environment where they live. With the unabated urbanization of localities due to increasing population, human and industrial activities and more so the extreme climatic condition, the supply of substantially healthy and fresh food in the market is affected. Sources of fish like lakes, seas, and rivers have been abused by man in exchange to industrial and domestic consumption. Non-conformance of businessmen particularly those who rely on the supply of natural food such as fish pen and cage operators from water sources to government imposed regulations make our body of waters more vulnerable to pollution.

The Philippines has a typical humid tropical climate. Average rainfall is approximately 2,026 millimeters per annum, which falls during rainy season, from June to October. Its surface area covers about 234 square kilometers with an average depth of about 63 meters. The normal range of annual water level fluctuation of the lake is 2 meters (Lakenet 2003).

Despite governments' declaration as protected area, illegal fish cages continue to increase rapidly in the lake. Approximately, there are 12,000 fish cages that contribute to its degradation. Some native fishes disappeared and the scenic view of the lake is blocked and its nature reserve put at risk.

Before, the fish cages in Taal Lake were regulated by the Department of Environment and Natural Resources (DENR) under secretary Lito Atienza in coordination with Batangas Governor, Vilma Santos Recto. The two government servants tried to limit the number of fish cages. However, problems arose during the phase one of program implementation. This is because thousands of people benefit from this business and provide aquatic food products for CALABARZON and Metro Manila

## 2. METHOD

*Water Sampling Method*

Water sampling was done in *situ* to determine the quality of water of Taal Lake at Talisay, Batangas. Samples were collected at two sampling sites according to depth namely; Site 1 (with fish cages) and Site 2 (without fish cages) in Talisay, Batangas. Each site was divided into two layers, the surface layer (layer 1) and the layer where the light is no longer visible (layer 2, 10.5 feet). Depth level of layer 2 was measured using Secchi disk. Collection of sample was conducted quarterly for one year. Sampling was done in two sampling intervals namely early morning and late afternoon to determine if there are differences in the results done in different times of the day.

In chemical and physical analysis, approximately 1000 mL of water sample per sampling site were collected. The samples collected were placed in ice cooler and transported promptly to the laboratory for analysis.

*Physico-chemical Analysis*

Water temperature was measured *in situ*, using handheld thermometer. Other factor like chloride and phosphate were tested at JEFCOR laboratory.

In biochemical oxygen demand (BOD) test, a standard 300-mL glass BOD bottles was used. Two DO measurements were involve in the 5-day, 20ºC BOD of the water samples, an initial measurement when the test begins at t = 0 and a second measurement when t = 5. It was done after the sample has been incubated in the dark for five days at 20ºC. The BOD is the difference among the two measurements. To determine the BOD of the water sample Dilution Technique was used.

To determine the dissolved oxygen (DO) concentration a membrane electrode meter was used after careful water sampling. The electrode probe senses small electric currents that are relative to the dissolved oxygen in the water.

Gravimetric method was used to determine the total suspended solids (TSS). A 100mL water sample was evaporated into dryness using pre – weighed 100mL beaker. The beakers were placed in desiccators before weighing after evaporation.

set by DENR-EMB.

Total dissolved solids (TDS) were also determined using Gravimetric method. The water sample was filtered and 100 mL of the filtrate was evaporated in a pre-weighed evaporating dish on a stove. The residue left after evaporation was dried to constant weight in an oven. The increase in mass over that of the empty evaporating dish represents the TDS in mg/L.

*Analysis of Data*

The gathered data were clustered according to layer, site, and into three seasonal variations namely; rainy (June to November), cool dry (December to February), and hot dry season (March to May) after determining the physical and chemical characteristics of water samples. T – test was used to test if there is a significant difference in the characteristics of water of Taal Lake based on the selected sampling sites. The average mean for the whole year were calculated since there is no significant difference in the values per site, layer, and season. It was compared with the standard set by Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB).

## 3. RESULTS

Physical and chemical characteristics of Taal Lake were monitored and analyzed for twelve months. The results were compared with the standard set by DENR-EMB. Table 1 shows the total mean of physical and chemical characteristics of Taal Lake for the whole year as compared to the standards

**Table 1.** Results of physical and chemical characteristics of Taal Lake at Talisay, Batangas for the whole year. Values shown are total mean and standard limits set by DENR-EMB for surface waters

| Parameters | Unit | Total Mean/Observation | Standard Set by DENR-EMB | Interpretation |
|---|---|---|---|---|
| Water temperature | °C rise | 26.14 | 3* | Within the standard |
| Color | | No abnormal discoloration from | No abnormal discoloration | Within the standard |
| pH | | 8.31 | 6.5 – 8.5 | Within the standard |
| Total Dissolved Solids (TDS) | mg/L | 912.96 | 1000 mg/L | Within the standard |
| Total Suspended Solids (TSS) | mg/L | 5.17 | Not more than | Within the standard |
| Chloride as Cl | mg/L | 576.36 | 250 mg/L | Exceed the standard |
| Phosphate as Phosphorus | mg/L | 0.21 | 0.2 | Exceed the standard |
| 5-Day 20°C BOD | mg/L | 3.25 | 5 (minimum) | Below the standard |
| Dissolved Oxygen (DO) | mg/L | 7.79 | 5(minimum) | Within the standard |

* The allowable temperature increase over the ambient temperature is 3°C

## 4. DISCUSSION

Stable water temperature was observed at Taal Lake during the 12-month period of monitoring with an average of 26.2°C. The increase during hot dry season is very minimal and conforms to the standard set by DENR-EMB. Increase of water temperature results to greater natural activity while its decrease results to increase of dissolved oxygen (Johnson, 2000). If the water gets warm, water and nutrients mixed uniformly right through the water and oxygen is restored. This oxygen is being used by microorganisms in Taal Lake that results to the reduction of the amount of dissolved oxygen. In general, the increase of temperature of Taal Lake for the whole year did not affect its situation since no irregularities have been monitored like degrading of environment and decline of photosynthetic movement. The study of Heejun Chang in Han River also shows no considerable increase in temperature for the entire period of the research while Odemis and Evrendilek study of National Watersheds in Turkey shows increasing trend in river water temperature, at a mean annual rate of about 0.2°C.

Average pH level is extremely significant to the health of marine life. Low pH level may cause death to many fishes in rivers and lakes because some aquatic organisms are susceptible to changes in pH and a few of them may not be able to endure the changes. Low pH can also raise the quantity of heavy metals such as aluminum and mercury (Lusch, 1997). For example, a pH of 4 or less of water cannot be tolerated by a fish in the river. In Taal Lake, a negligible change in pH was monitored with an average value of 8.31 pH units. This value conforms to the standard set by DENR-EMB.

The lake has a total mean of 912.96 mg/L and 5.17 mg/L of total dissolved solids (TDS) and total suspended solids respectively for the whole year. The value of TDS is very close to the standard set by DENR-EMB which is 1000mg/L but still conforms to the standard. TSS also conforms to the standard set because more than 30% of this amount was not monitored. The amounts of these parameters are possibly because of the accumulated lava from the volcano or maybe from the feeds given to fishes and other activities such as bathing and fishing. The rising water temperature is directly correlated to total dissolved or suspended solids (TSS and TDS). An increase of amount of TDS and TSS can increase the temperature of water since floating materials absorbs heat from sunlight. These two parameters can also reduce the color of the water and can influence photosynthesis. (IWR-MSU 1997).

An average of 576.36 mg/L Chloride was monitored during the entire period of the study. This value did not conform to the standard set by DENR-EMB which is 250mg/L. High amount of chloride is perhaps because of the thirty-seven (37) tributaries that drain into the lake for years. This is quite alarming because high chlorine content can cause poisoning of aquatic organisms. This could be one of the possible reason why fish kills happened at Taal Lake for many times (ADB 2003). Chloride is also damaging and killing some parts of the body each time one bathes, or swims in the river (Bordin, 2007). This result is the same with the findings of Moskovchenko, Babushkin and Artamonova in their study of Vatinsky Egan River catchment in West Siberia which shows wide and high concentration range of chloride.

Phosphorus has an average value of 0.21 mg/L. Based on the data, the study shows that Taal Lake has a little bit higher phosphate content as compared to the DENR-EMB standard of 0.2 mg/L. This condition is anticipated since heavy rainfall increases the downpour of top soils carrying naturally occurring phosphorus from the neighboring highlands (Helmer and Hespanhal, 1997).

Higher phosphate content in the lake can be dangerous to marine organisms. It can cause tremendous development of plants that may lessen the quantity of light in the water and decrease the amount of dissolved oxygen. It can also cause algae growth, thus fish will be deprived of sufficient oxygen (Bodzin, 2004).

Biochemical oxygen demand (BOD) is a measure of how a huge quantity of oxygen is used by marine life in the aerobic oxidation, or subsides of natural substances in the lake. BOD presence in the lake can be attributed to the increase of discharges into the lakes such as polluted topsoils and other household wastes from the nearby resident transported by heavy precipitation. In the case of Taal Lake, below the minimum standards set by DENR-EMB were monitored with a value of 3.25 mg/L.

Dissolved Oxygen (DO) in Taal Lake has a value of 7.79 mg/L for the whole year. This value conforms to the standard set by DENR-EMB. DO is necessary for the survival of most marine organisms. Low DO readings show high oxygen requirement from microorganisms, and can result to severe pollution.

Color was also monitored but no abnormal discoloration (changes color of water to light brown or more intense light brown) from unnatural causes was observed meaning it conforms to the standard set by DENR-EMB.

T – test was used to test if there is a significant difference in the characteristics of water of Taal Lake based on the selected sampling sites. The result shows that there is no significant difference in the overall average of the two sites at Taal Lake since the t-value of 0.006 has a p-value (0.996) greater than 0.05.

To preserve the quality of water in Taal Lake, safety, security and environmental management plan should be implemented by concerned local government units (LGU), so that the present best beneficial use of the lake is likely to last. Information campaign on the protection and preservation of the lake has to be advocated in nearby residents and mountaineers to atone the quantity of contaminants in the vicinity.

## CONCLUSION

Based on the overall results of the study, Taal Lake water can still be classified as Class B (DENR-EMB 2005), Recreational Water Class I. The classification is the same with Pagsanjan river of Laguna, the Bolbok river of Batangas, and Palicpican and Mamba River at Mts Palaypalay. In general, the lake can be beneficially used for primary contact recreation such as bathing, swimming, and skin diving. Taal Lake is still suitable for aqua culture purposes, for fish propagation and growth.

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# 網走川大曲堰における塩分収支の推定

田崎 冬記[1], 小林 潤[1], 法村 賢一[2], 渡邊 康玄[3], 吉川 泰弘[3], 駒井 克昭[3]

[1](株)北開水工コンサルタント, [2]国土交通省 北海道開発局 網走開発建設部, [3]北見工業大学 工学部

キーワード: 可動堰, ADCP, 塩水楔, 塩分収支, 湖沼・河川モニタリング技術

**抄録**

網走湖は, 下層が塩水層, 上層が淡水層の 2 層構造の汽水湖である。昭和 50 年代後半以降, アオコ・青潮の発生が確認され, これらの原因は湖内塩水層の上昇によるものと結論づけられた。海水流入による湖内塩水層の上昇を抑制するため, 網走湖下流に可動堰(大曲堰)が設置された。大曲堰の適切な運用には, 塩分収支を正確に把握する必要がある。そこで, 自記塩分計を鉛直に複数台設置し, 塩分の遡上・流下特性を調査した。また, ADCP による鉛直層別流量と自記塩分計から層毎に算出した塩分量の総和の収支と, 各層の塩分計を鉛直代表として算出した塩分収支を比較検証した。その結果, 前者では, 塩分は逆流から順流への切り替わり時に塩水楔となる現象を確認し, 後者では, 底層の塩分計で算出した塩分収支ほど流出を過大に評価することを明らかとした。また, 各層の塩分収支の誤差率から今後の塩分収支の正確な把握に向けた塩分計の設置標高について提案した。

## 1. はじめに

北海道オホーツク地方に位置する網走湖は, 面積 32.3km$^2$, 水量約 2 億 3 千万 m$^3$ を有する。網走湖は潮汐によって, オホーツク海の海水が流入する下層が塩水層, 上層が淡水層の 2 層構造の汽水湖であり, ヤマトシジミ, ワカサギ等の水産資源も豊富である。湖の水量の半分近くを占める塩水層は重く, 高濃度の栄養塩を含んでいる。塩水層は淡水層からの酸素供給が少ないこと, 水生生物・プランクトンの死骸の分解時に酸素を消費することから無酸素状態となっている。

網走湖の塩水層は, 昭和 50 年代後半以降, 徐々に上昇し, アオコや青潮の発生が確認されるようになった。これらの対策のため, 国・流域市町村では, 様々な技術的な検討や対策事業が行われてきた。網走湖水環境改善事業では, 平成 16 年度～平成 29 年度にかけて, 青潮・アオコの発生抑制, 流域を含めた汚濁負荷削減等の対策事業が集中的に実施されてきた。

網走湖における青潮発生は, 強風に伴う塩水層の上昇が条件となっている。また, アオコの発生は, 塩水層からの栄養塩供給が主要因の 1 つとされる。したがって, 青潮・アオコの発生抑制には, 湖内塩水層を降下・安定化させる必要があり, その目標として塩水層の上層の淡水層厚を 6～7m に管理することとしている。上記を背景に, 海水流入による湖内塩水層の上昇を抑制するため, 平成 25 年, 網走湖下流に可動堰(以下, 大曲堰)が設置され, 平成 26 年 1 月より運用が開始された。

大曲堰の運用には, 塩分収支を正確に把握する必要があり, 塩分の遡上・流下特性を把握することが重要である。特に大曲堰周辺では, 逆流から順流への切り替わり時に塩水楔のような現象が確認されることから, この現象を踏まえた塩分収支の把握が重要である。

そこで, 本研究では, 大曲堰周辺に自記塩分計を鉛直に設置すると共に河床に ADCP(以下, V-ADCP)を設置し, 層別の流量推定と層別の塩分濃度から塩分収支の精密観測を行った。また, これらの結果を基に今後の自記塩分計の設置標高について考察を行った。

## 2. 大曲堰について

大曲堰は, 網走川河口から約 7.0km 上流の川幅約 45m に設置された幅 20.7m×2 門の鋼製起伏ゲートであり, 逆流時のみ起立する。堰倒伏時は EL-1.5m の河床にあるが, 堰起立時には EL0.0m まで上昇し, 逆流時越流方式の堰としている。大曲堰は冬期間の海水流入を防止する施設であるため, その運用期間は概ね 1～3 月の3ヶ月間である。堰周辺には, 自記水位計, 自記塩分計, 自記 DO 計および自記水温計が設置され, 10 分間隔でモニタリングが行われている。

## 3. 方法

(1) 遡上・流下時の塩分鉛直分布

大曲堰の上下流の KP6.9 および KP7.1 に自記塩分計を設置した(図 1)。自記塩分計は河床から 0.3m 毎に 7 層設置し, 10 分間隔で計測した(図 2)。設置期間は, 2018 年 1 月 10 日～2018 年 2 月 8 日の約 1 ヶ月間とした。堰通過塩分濃度は, KP6.9 とKP7.1 の各層の平均とした。

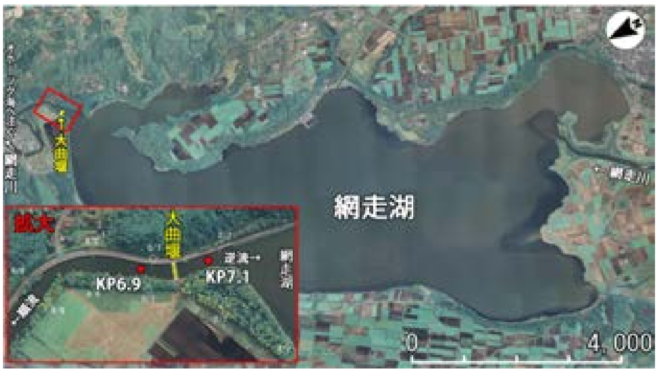


図 1　自記塩分計および **V-ADCP** 設置位置

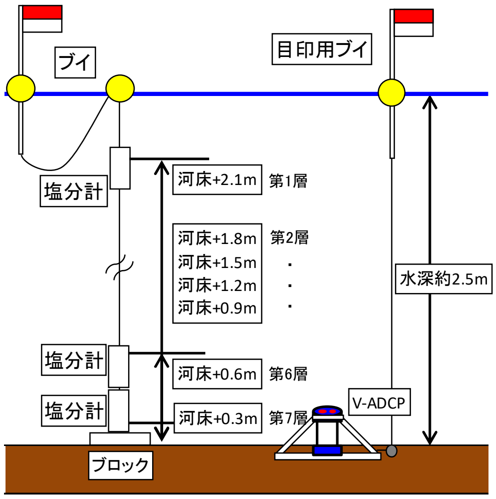


図 2　自記塩分計および **V-ADCP** の設置模式図

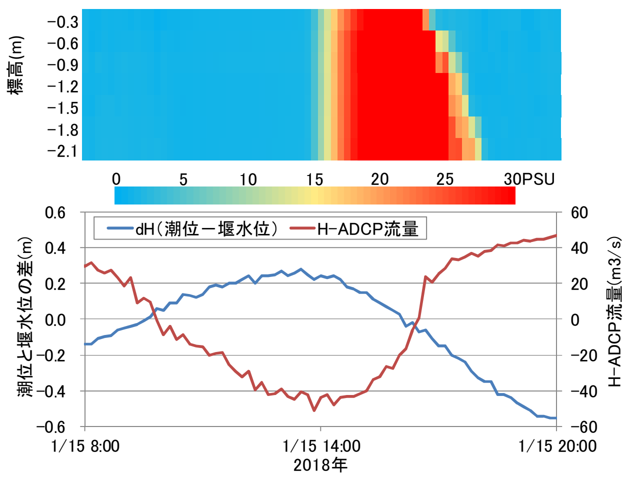


図 3　大曲堰周辺における遡上・流下時の塩分鉛直分布
流量はマイナスが逆流，プラスが順流を示す

(2) 層別流量の推定と大曲堰塩分収支

網走川 KP7.1 の流心部河床に V-ADCP（Teledyne RD Instruments 社製 Workhorse 1200kHz）を設置し，0.05m 間隔の鉛直流速分布を 10 分間隔で計測した。

V-ADCP からは流心の鉛直流速分布のみ得られることから，各層の流量に換算する必要がある。そこで，各層の流量算出にあたっては，アメリカ地質調査所

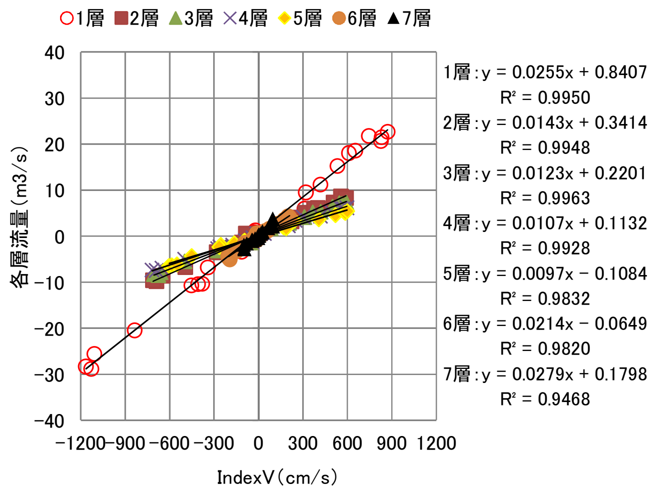


図 4　各層流量と **IndexV** との関係

（USGS）の Index Velocity 法（IndexV）を適用した[1], [2]。

まず，ADCP（Teledyne RD Instruments 社製 Workhorse1200kHz）曳航観測から，各層の流量を算出した。次いで，V-ADCP の各層に該当する流速の総和（IndexV）を算出し，IndexV-Q 相関式により各層流量に換算した。

大曲堰塩分収支は，各層の流量とそれに該当する層の自記塩分計値を乗じた塩分量の総和とした。なお，各層の流量および塩分量は表層から第 1 層～第 7 層と称す。

ADCP 曳航観測は，2018 年 1 月下旬，2 月上旬の大潮時に各 1 回，満潮ピーク付近から干潮ピーク付近までの概ね 12 時間を対象に 1 時間に 1 往復の観測を基本とした。V-ADCP の観測期間は，自記塩分計の設置期間と同様とした。

## 4.　結果および考察

(1) 遡上・流下時の塩分鉛直分布

大曲堰周辺における遡上・流下時の鉛直塩分濃度について図 3 に示した。大曲堰地点においても既往の知見同様，遡上時の鉛直塩分濃度はほぼ一様であり，強混合で逆流してくることが示された[3]。一方，流下時には，上層ほど，塩分濃度が低い傾向が見られる。これは，順流に転じた際には，より潮位との標高差の生じやすい上層から網走湖表層の淡水と入れ替わるためと考えられる。

(2) 層別流量の推定

層別流量の推定ための ADCP 曳航観測による各層流量と V-ADCP 流速の総和（IndexV）との関係を図 4 に示した。いずれの層の流量においても IndexV との相

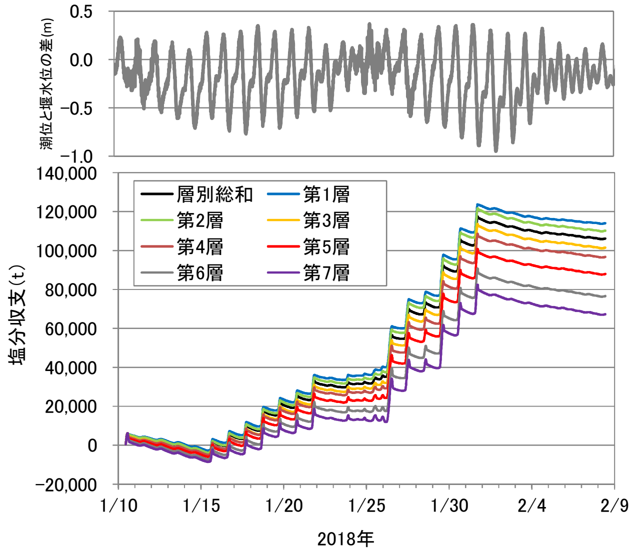


**図 5　各層塩分収支の比較と算出期間の潮位・堰水位差**

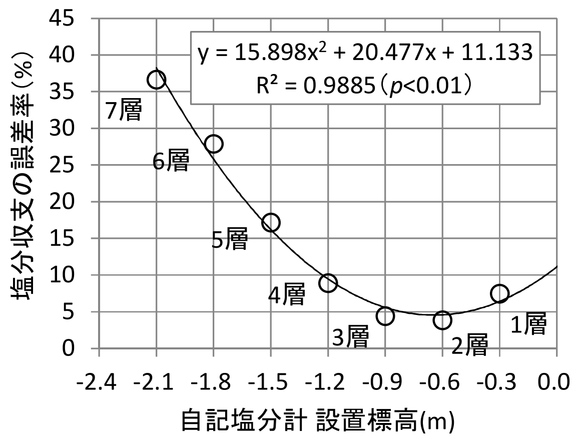


**図 6　各層自記計の塩分収支の誤差率**

関が高く，V-ADCP 流速分布から十分な精度で層別流量およびその総和である断面流量を推定できることが示された。

(3) 大曲堰塩分収支の推定

各層流量と各層自記塩分計から算出した塩分収支の総和を真値とし，断面流量と各層の自記塩分計値から算出した塩分収支との差を図 5，同誤差率を図 6 に示した。2018 年 1 月 10 日〜2018 年 2 月 8 日の約 1 ヶ月間での塩分収支は，約 10 万 6 千 t となった。

一方，各層自記塩分計での塩分収支では，第 2 層（設置標高-0.6m）の塩分計から算出した塩分収支が最も真値と近い値を示し，底層の塩分計で算出した塩分収支ほど，真値より小さい値を示した。これは，強混合で遡上した塩分が順流に切り替わった後も底層部に残存することを反映した結果と考えられる。

誤差率は，2 次曲線式で近似され（$p<0.01$），得られた 2 次曲線式からも実測の誤差率と同様，設置標高-0.6m で最小値を示した。

## 5.　今後の大曲堰塩分収支の把握に向けて

大曲堰に設置された自記塩分計は，当初，EL-2.0m（第 6 層〜第 7 層のほぼ中間に相当）の河床付近に設置されていた。本研究より，逆流から順流への切り替わり時には上層から徐々に淡水に切り替わるため，底層に近い EL-2.0m の自記塩分計で塩分収支を評価した場合，流出を過大に評価していたことが示された。大曲堰には，自記計が左右岸に各 1 台設置されているため，今回観測したように鉛直に複数台の自記塩分計を設置し，塩分収支を把握することが困難と考えられるが，現状の機器を誤差の最も小さい標高へ調整することで大曲堰塩分収支の精度向上が図られると考える。

一方，今回の観測期間（1 月上旬〜2 月上旬）では，第 2 層塩分計による塩分収支と真値との差は 4 千 t 程度であった。網走湖の冬季の塩水層の平均標高に換算すると凡そ 0.01m に相当する。本研究で得られた自記塩分計標高に調整することで適切な大曲堰の運用が可能であると考える。

## 6.　結論

網走湖下流に設置された大曲堰の塩分収支の正確な把握のため，塩分の遡上・流下特性の調査およびそれを踏まえた層別の流量・塩分収支の把握を行った。

その結果，塩分の遡上・流下特性では，遡上時には強混合であるが，流下時には塩水楔のように高濃度の塩分が底層に一定時間残存する現象を確認した。層別自記計による塩分収支では，底層ほど，塩分収支の真値との差異が大きいことを確認し，1 台の塩分計で塩分収支を把握する場合には，EL-0.6m（第 2 層）に設置することで精度の高い塩分収支を把握できることを明らかにした。

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**P6-3**

# 網走川大曲堰におけるH-ADCPによる通過流量の推定

井上 和哉[1], 小林 潤[1], 天野 広之[2], 吉川 泰弘[3], 渡邊 康玄[3], 駒井 克昭[3]
[1](株)北開水工コンサルタント, [2]国土交通省 北海道開発局 網走開発建設部, [3]北見工業大学 工学部

キーワード:H-ADCP, 可動堰, 感潮域, 逆流時越流方式, 湖沼・河川モニタリング技術

**抄録**

網走湖は塩水層と淡水層の 2 層構造を呈し, 塩水層は高濃度の栄養塩を含む無酸素層となっている。網走湖ではアオコ, 青潮の発生がみられ, 塩水層の上昇が要因とされている。海水流入による塩水層の上昇を抑制するため, 逆流時越流方式の可動堰(大曲堰)が網走湖下流に設置された。大曲堰の適切な運用には, 塩分収支を正確に把握するための流量把握が重要であるため, 堰倒伏時・堰起立時の流量推定を H-ADCP で行うと共に H-ADCP 推定流量の経年的な精度管理についても検討した。その結果, 堰起立時も含めて, 同じ定数の春日屋の式から精度の高い H-ADCP 推定流量が得られることを明らかにした。また, 網走湖下流河川のような河床変動が余り大きくない環境での経年的な精度管理には, 実測による定数の変更の検討よりも H-ADCP 設置断面の河床変化によるノイズデータの発生状況を踏まえた有効計測幅の検証が重要であることを示した。

## 1. はじめに

北海道オホーツク地方に位置する網走湖は, 面積 32.3km$^2$, 最大水深約 16m の汽水湖である。網走湖は塩水層と淡水層の 2 層構造を呈し, 塩水層は高濃度の栄養塩を含む無酸素層となっている。昭和 50 年代以降, アオコ, 青潮の発生が確認され, これらを改善するため, 国・流域市町村で様々な技術的な検討や対策事業が行われてきた。網走湖水環境改善事業では, 平成 16 年度～平成 29 年度にかけて, 青潮およびアオコの発生抑制, 流域を含めた汚濁負荷削減等の対策事業が集中的に実施されてきた。

網走湖における青潮発生は, 強風に伴う塩水層の上昇が条件となっている。したがって, 青潮発生抑制には, 湖内塩水層の降下・安定化が必要であり, 海水の流入による湖内塩水層の上昇を抑制するため, 平成 25 年, 網走湖下流に可動堰(以下, 大曲堰)が設置され, 平成 26 年 1 月に運用が開始された。

一方, 網走湖内における塩水層の降下・安定化に資する大曲堰の運用には, 堰の塩分収支を正確に把握する必要があるが, 塩分収支の把握には, 第一に堰通過流量の正確な把握が不可欠である。しかし, 感潮域かつ堰稼働時の流量推定の事例は無く, 流量推定手法の確立が課題であった。そのため, 大曲堰上流 100m に H-ADCP(Teledyne RD Instruments 社製 Workhorse 600kHz)を設置した。H-ADCP による流量推定は, 堰のない感潮域での事例はあるが[1], 堰稼働条件での観測事例はこれまで報告されていない。

そこで, 本研究では, ADCP による経年的な現地観測から感潮域かつ堰稼働時における H-ADCP による流量推定について検証した。さらに, H-ADCP 流量の経年的な精度管理についての知見についても報告する。

## 2. 大曲堰ついて

大曲堰は, 網走川河口から約 7.0km 上流の川幅約 45m に設置された幅 20.7m×2 門の鋼製起伏ゲートであり, 逆流時のみ起立する。堰倒伏時は EL-1.5m の河床と同等の高さにあるが, 堰起立時は EL0.0m まで上昇する逆流時越流方式の堰である（図 1)。

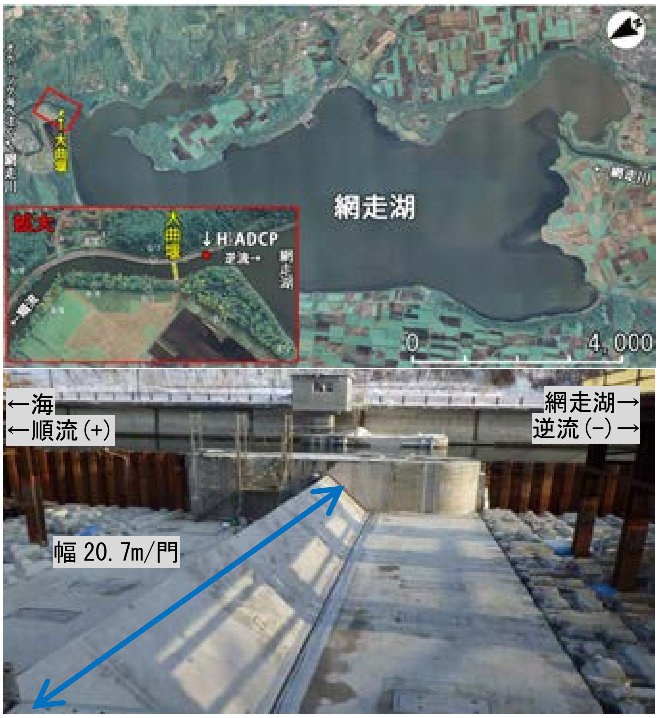


**図 1 網走川大曲堰位置および堰外観**

## 3. 方法

(1)H-ADCP による連続観測

H-ADCP は，大曲堰上流約 100m の EL-0.2m の右岸河岸壁面に設置し，水平層厚 1m 間隔での流向・流速分布を 10 分間隔で測定した。観測は河岸垂直線より上下流 25 度の 2 ビームを使用し，1 秒間隔で 150 サンプル測定した。観測は，同機が設置された平成 26 年 3 月以降，連続観測が継続されている。

(2)H-ADCP を用いた流量推定

①H-ADCP 流量推定の基本式

H-ADCP から得られるデータは，水平方向の流速分布である。流量を算出するためには，断面流速分布を得る必要がある。そこで ADCP（TeledyneRD Instruments 社製 Workhorse 1200kHz)曳航観測による流速鉛直分布と H-ADCP による水平流速分布との関係から断面流速分布を推定した。断面流流速分布の推定には，既往の感潮域での事例[1]から春日屋の二次曲線形流速分布[2]を採用した。

$$v(z) = \frac{V_m}{p}\left\{pk + 2a\left(\frac{z}{h}\right) - \left(\frac{z}{h}\right)^2\right\},$$

$$p = \frac{1-3a}{3(k-1)}, \quad k = \frac{V_s}{V_m},$$

$$V_m = b * V_{H-ADCP}, \quad V_s = c * V_{H-ADCP}$$

ここで，$v(z)$は流下流速の鉛直分布，$z$ は水面からの深さ，$V_m$ は鉛直平均流速，$a$ は流速ピーク位置の相対水深，$h$ は水深，$V_s$ は表面流速を示している。$V_m$, $V_s$ は H-ADCP の測定値 $V_{H\text{-}ADCP}$ に比例すると仮定し，$b$, $c$ は定数である。

②H-ADCP 流量推定の手順

流量推定の手順としては，まず，大曲堰倒伏時に ADCP による曳航観測を行い，ADCP による流速分布と上記の春日屋の式から推定した流速分布との誤差が最小になる $a$, $b$, $c$ を求めた。次に大曲堰起立・逆流時に ADCP による曳航観測を実施し，同様に $a$, $b$, $c$ を求めた。最後に経年的な ADCP による曳航観測によって，春日屋の式の精度検証を行った。精度検証の際には，定数の変更および H-ADCP 流速の有効計測幅等についても合わせて検討した。

大曲堰倒伏時の観測は，平成 26 年 10 月下旬，平成 27 年 12 月中旬，平成 29 年 1 月中旬及び平成 29 年 12 月上旬に実施した。大曲堰起立・逆流時の観測は，平成 27 年 1 月下旬，平成 28 年 1 月中旬，平成 28 年 2 月下旬，平成 29 年 1 月下旬及び平成 30 年 2 月上旬に実施した。いずれの観測も 1 時間に 1 往復の ADCP 曳航観測を行うことを基本としたが，逆流から順流へと流向が変わる時間帯では 10 分間隔で密に観測を実施した。

## 4. 結果

(1)堰倒伏時の H-ADCP 推定流量

堰倒伏時における ADCP 曳航観測データより，H-ADCP 流速全層で，順流時，逆流時ともに $a$ =0.15, $b$ =0.85, $c$ =1.00 で誤差が最小となった。この定数を用いて推定した H-ADCP 流量と ADCP 曳航観測流量の比較結果を図 2 に示した。大曲堰倒伏時においては，逆流から順流全ての観測において，H-ADCP 推定流量は ADCP 曳航観測流量とほぼ一致した。

(2)堰起立時の H-ADCP 推定流量

次いで，堰起立時における ADCP 曳航観測データより定数を求めた結果，堰倒伏時と同じ定数で誤差が最小となることを確認した。H-ADCP 推定流量と ADCP 曳航観測流量の比較結果を図 3 に示した。堰起立時においても H-ADCP 推定流量は堰倒伏時と同じ定数で ADCP 曳航観測流量とほぼ一致した。

(3)H-ADCP 流速の有効計測幅

H-ADCP 流速計測の超音波が河床と干渉した場合や，2 ビームの流速の差が大きい場合にノイズデータが現れる。H-ADCP による流速観測データを図 4 に示した。図中の黒または白くかすれたものがノイズデータである。平成 27 年以降は全観測を通じ H-ADCP より 12～29m の範囲でノイズデータの発生が少なく，安定した観測ができていることを確認した。よって，これを経年的に共通する H-ADCP 流速の有効計測幅と判断した。以降，H-ADCP 流量算出にはこの有効計測幅の流速を使用することとした。

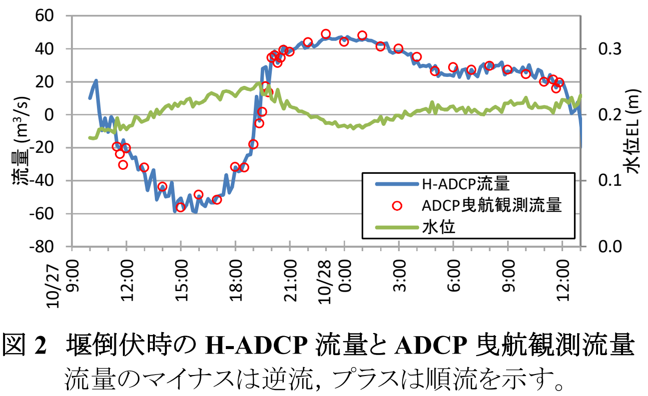


**図 2 堰倒伏時の H-ADCP 流量と ADCP 曳航観測流量**
流量のマイナスは逆流，プラスは順流を示す。

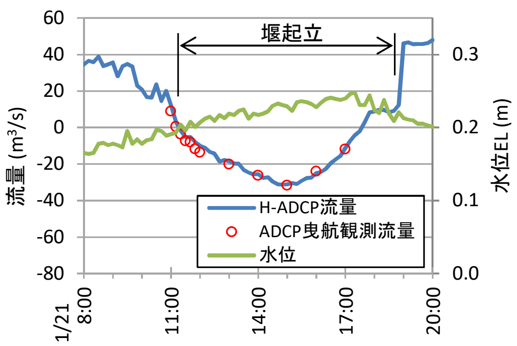

図 3　堰起立時の H-ADCP 流量と ADCP 曳航観測流量

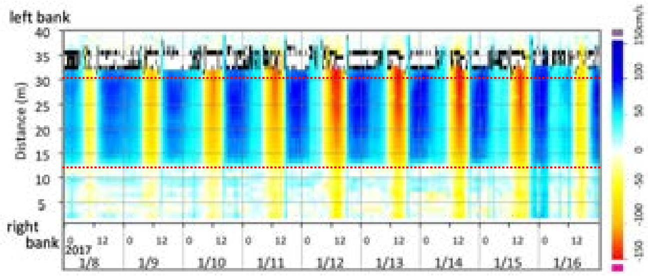

図 4　H-ADCP 流速のノイズデータの発生状況

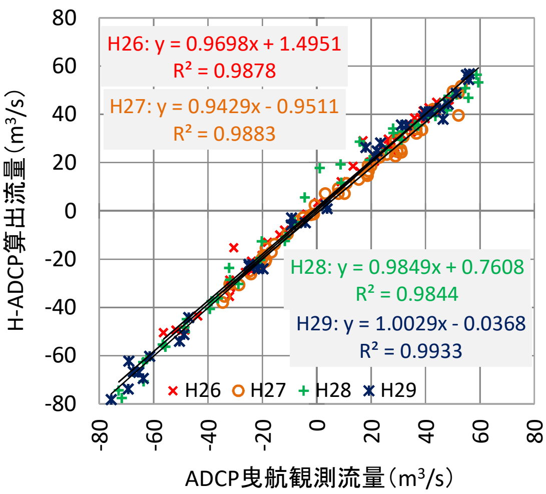

図 5　H-ADCP 推定流量精度の経年変化

(4) H-ADCP 推定流量の経年変化

H-ADCP 設置後の平成 26 年以降の H-ADCP 推定流量精度の経年変化について図 5 に示した。H-ADCP 推定流量は，堰倒伏時・倒伏時ともに平成 26 年度に設定した春日屋の式の定数で，有効計測幅を 12～29m とすることで経年的にも精度が保たれていることが示された。

## 5.　考察

感潮域かつ可動堰のある環境において H-ADCP による流量推定を行い，経年的な精度について確認した。その結果，堰倒伏時・堰起立時のいずれにおいても同じ定数の式（春日屋の式）で精度の高い流量推定が可能であることを明らかにした。これは，堰起立時の鉛直流速分布も堰倒伏時と大きく変わらなかったことを意味する結果と考えられるが，越流状況によっては，鉛直流速分布が異なることも想定されることから，形状や稼働方式の異なる他の堰への適用については，今後さらなる知見の蓄積が望まれる。

一方，推定流量精度を経年的に確認した結果，ADCP 曳航観測による春日屋の式の定数変更の必要性は低く，有効計測幅にのみ留意すれば，経年的にも，精度の高い流量が得られることが示された。これは，大曲堰が網走湖下流に設置され，河床変動がそれ程大きくない環境であることが要因と考える。有効計測幅については，横断測線上の何割程度を把握できれば，精度の高い推定流量が得られるか等を今後，検討する必要があると考える。

また，塩水遡上を伴う逆流から順流に流向が変わるタイミングで一時的に表層が順流，下層が逆流の塩水くさび状の流速分布が現れており，本報告で用いた二次曲線形流速分布ではくさびを表現することができない。そのため，流速分布の推定の精度向上に向けては更に知見を深化させる必要がある。

## 6.　結論

本研究では，網走湖下流の感潮河川域においては，堰倒伏時・堰起立時のいずれも同じ定数の春日屋の式から H-ADCP によって精度の高い流量推定が可能であることが示された。また，経年的な精度管理には，H-ADCP のノイズデータに着目した有効計測幅に留意することが重要であることが示された。

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**P6-4**

# Analysis of Statistical Methods for Water-level Forecasts of Niger Inner Delta in Mali

Barry Kassambara[1], Homayoon Ganji[1] and Takamitsu Kajisa[1]

[1]Graduate School of Bioresources, Mie University, Japan

Keywords: Niger Inner Delta, water-level, wetland, simulation model

**ABSTRACT**

Niger Inner Delta (NID) is a wetland that was selected as International Important Wetland under the Ramsar Convention (on February 1st, 2004) still can be considered as a hotspot of biodiversity in the Sahel. The Niger River as main source of water for the NID is also used for urban life and irrigation. Therefore, the sustainable use of water to ensure the environmental flow in the NID is under discussion. In this paper, we evaluate the performance of our model established with Water Balance Method (WBM) and make a comparison with different others approaches for the NID water-level forecasting. The result show that our WBM model present a good result very close to the Levenberg Marquardt Artificial Neural Network which is the best and much better than Multilinear Regression and Gaussian Process Regression models.

## 1. INTRODUCTION

For many decades, water shortage has been a dire problem for millions of people living along the southern fringe of the Sahara Desert [1]

The Niger river take its source on the Fouta Djallon Mountains in the South of Guinea (West Africa), it flows Northeast through the Upper Niger basin and enters the Niger Inland Delta (NID) in Mali with a large floodplain ranging from 30,000 to 40,000 km2 along the Niger River in Mali [2] (See Fig 1).The annual flooding of large alluvial plains is a vital resource for many ecosystem services, including agriculture, livestock, groundwater recharge, and biodiversity(see Fig 2). The rapid expansion of irrigation upstream, by the diversion dams on Niger river and its subsidiary (Bani), have a significant impact on the Water-Level (WL) in the DIN downstream [3].

The main objective of this study is to develop stochastic and deterministic statistical models for the Niger Inner Delta Water Level forecasting and make a comparison between these different Models. The evaluation and forecasting of Water-Level Fluctuation (WLF) is increasingly important for the NID owing to its close relation to human living & production, and socio-economic & environmental sustainable development.

## 2. STUDY AREA AND DATA SOURCE

Beyond the town of Ségou, the Niger River forms a vast inland delta (41,800 km²); it joins with its main tributary, the Bani, at Mopti and then forms several lakes. The watershed area of this Inner Delta covers 130,000 km² [15]. The NID is extremely flat and contains many lakes and streams of varying morphology. The altitude of the river bed decreases only by approximately 10 m over the 350 km between the entry and exit of the delta [5]. For the purpose of this study the data are from different sources: The Niger river flow at Mopti and the Water Level at Akk are from the Malian Government Hydraulic Service, the meteorological data are from Mali-Meteo & Atmospheric Science Data Center (NASA)

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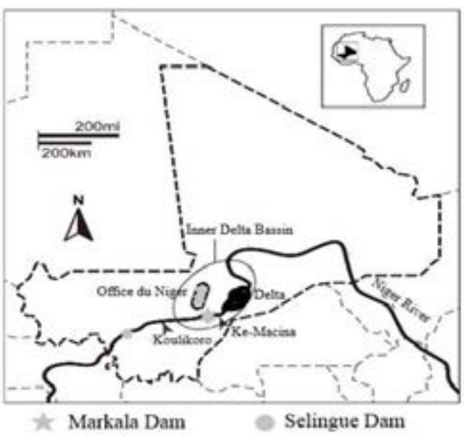


Figure 1: The Niger Inner Delta in Mali

Figure 2: NID during dry season(Source Google)

## 3. METHODS

The most common methods for river flow and WL forecasting is the application of physical, conceptual and/or statistical rainfall-rainoff methods [4], [5], [6]. In recent years the Artificial Intelligence (AI) as a modern approach for data series analysis have received a great attention for hydrology modeling like Artificial Neural Network (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS) [4], [7], [8], [9], [10], [11], [12], [13],.

### 3.1. Water Balance Model (WBM)

The water depth in the NID may be obtained as follow:

$$\boldsymbol{H_{i+1} = Max(H_i + (Q_{i+1} - Q_{out})\frac{D}{A_1} + \left(R_{i+1} - ET_{0_{i+1}}D\right)\frac{(A_1+A_2)}{A_1}, \gamma)} \quad (3.1)$$

The outflow $Q_{out}$ is $\boldsymbol{Q_{out} = \beta Max(H_i, 0)^{\alpha}}$ **(3.2)**

The wet soil area is given as $\boldsymbol{A_2 = \delta\sqrt{A_1}}$ **(3.3)**

Time, monthly maximum inflow from Mopti station upstream ($Q_i$), monthly rainfall ($R$) the daily potential Evapotranspiration ($ET_0$), the number of month day ($D$), pond water surface ($A_1$) data was fed into the spreadsheet. To estimate the maximum Water Level ($H_i$) at various time steps using the equation 3.1 based on the parameters $\alpha$, $\beta$, $\gamma$ and $\delta$.

### 3.2. Multiple Linear Regression (MLR)

As opposed to simple linear regression models, which describe the linear functional relationship between a single explanatory variable $X$ (inflow, Rainfall, $ET_0$) and the response variable $Y$ (NID Water-Level), multiple linear regression models comprise the use of a collection of explanatory variables for describing the behavior of $Y$ [15]. In formal terms $\boldsymbol{y = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij}}$ (3.4)

Parameter estimation in multiple linear regression is based on the least squares methods.

### 3.3. Artificial Neural Network (ANN)

An artificial neural network (ANN) is a non-linear black box statistical approach [11], its main objective is to find the optimum architecture of an ANN that can model the relationship between input and output variables. The most commonly used ANN structure is the feed-forward multilayer perceptron (MLP). It is a network formed by simple neurons called perceptron. The perceptron computes a single output from multiple real-valued inputs by forming combinations of linear relationships according to input weights and even nonlinear transfer functions [4]. Mathematically, the MLP can be express as:

$$\boldsymbol{y = f(\sum_{i=1}^{n} w_i p_i + b)} \quad (3.5)$$

The previous studies indicated that the Lavenberg-Marquardt algorithm produces reasonable results for most ANN application [17], [4]. For the present study we considered the three algorithms available in Matlab: Lavenberg-Marquardt (LM), Bayesian Regularization (BR) and Scaled Conjugate Gradient (SCG) algorithms.

### 3.4. Gaussian Process Regression (GPR) Model with Matlab Regression Learner

Gaussian process regression (GPR) models are kermel-based probabilistic models [16].

A linear regression model is of the form:

$$\boldsymbol{y = x^T \beta + \varepsilon} \quad (3.6)$$

Where $\varepsilon \sim N(0, \sigma^2)$. The error variance $\sigma^2$ and the coefficient β are estimated from the data. A GPR model explains the response by introducing latent variable, $f(x_i)$, $i = 1,2, \dots n$, from a Gaussian Process (GP), and explicit basis functions, h

## 4. RESULTS

The results of the different models develop in this study. use the data from 1960 to 2010 (the inflows from the NID inlet station at Mopti, the Water-Level of NID in the middle station located at Akka and the meteorological data from Mopti station (Fig.3). To evaluate the models, Correlation Coefficient (CC), squared R (R2) and Root mean squared Error (RMSE) were used (Table 2). The monthly data from 2011 to 2015 were used to evaluate each of the models; the result is shown in table3. The plot of the monthly maximum WL (Hmax) variation for different models is shown in figure 2.

***Appendix:*** *About discussion conclusion and reference, we would like to show them at the presentation place.*

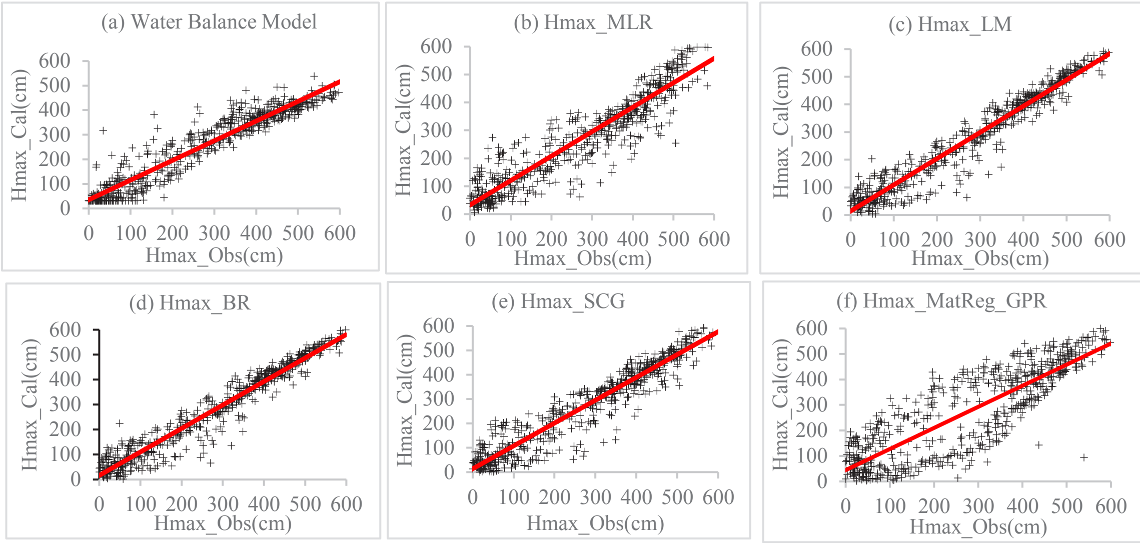


Figure 3: Scatter plots of observed versus modelled Water Level. (a) Water Balance Model (WBM), (b) Multilinear Regression model. Stochastic models: (c) Levenberd Marquardt ANN, (d) Bayesian Regularization ANN (e) Scaled Conjugated ANN, , (f) Gaussian Process Regression,

Table 1: Models validation statistics (1960-2010)

| *N* | *Model* | *CC* | *$R^2$* | *RMSE(cm)* |
|---|---|---|---|---|
| a | Hmax_WBM | 0.95 | 91% | 60.00 |
| b | Hmax_MLR(exce | 0.93 | 87% | 65.02 |
| c | Hmax_LM | 0.97 | 94% | 41.47 |
| d | Hmax_BR | 0.97 | 89% | 59.00 |
| e | Hmax_SCG | 0.96 | 92% | 52.05 |
| f | Hmax_Mat_GPR | 0.85 | 93% | 46.88 |

Table 2: Models test statistics (2011-2015)

| *Model* | *CC* | *$R^2$* | *RMSE(cm)* |
|---|---|---|---|
| Hmax_WBM | 0.96 | 93% | 39.88 |
| Hmax_MLR(exce | 0.96 | 92% | 46.68 |
| Hmax_LM | 0.97 | 95% | 38.36 |
| Hmax_BR | 0.97 | 95% | 38.20 |
| Hmax_SCG | 0.96 | 92% | 46.99 |
| Hmax_Mat_GPR | 0.87 | 75% | 83.76 |

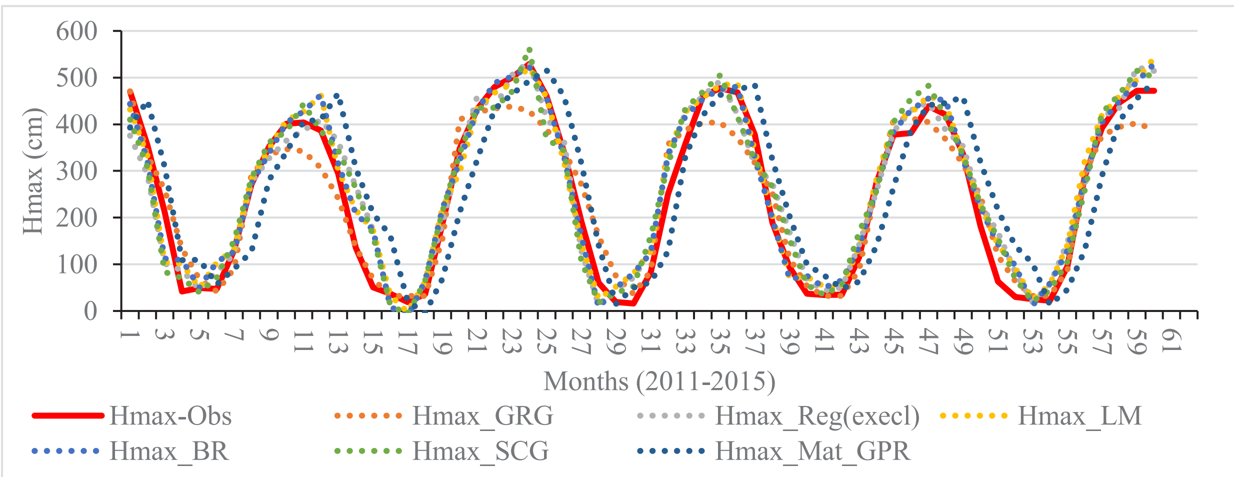


Figure 4: Monthly Maximum Water Level Fluctuation for different models

**P6-5**

# 効率的・効果的な湖沼管理に向けた河床変動メカニズムの分析・調査

池田　秀行[1], 清水野　豊[1], 槻山　敏昭[1]
[1]国土交通省　東北地方整備局　高瀬川河川事務所

キーワード：土砂移動調査，湖沼環境管理

**抄録**

小川原湖は，ヤマトシジミやシラウオ，ワカサギ等水産資源が豊富な汽水湖であり，青森県経済を第 1 次産業から支える重要な湖であるが，その汽水環境は高瀬川および湖口マウンドを通じた塩水遡上，湖に流入する支川流域からの流入量，洪水による湖内撹乱・塩水希釈・排出等がからみ合う複雑なバランスの上に形成されている．

本調査は，効率的・効果的な湖沼管理に向けて，高瀬川河床変動のメカニズムを分析し，予防保全的な河道・湖沼管理方策を検討していくための基礎資料として，着色砂を用いたトレーサー調査を行ったものである．その結果，下流部（1.4k）に投入した着色砂が満潮時の逆流の流れ等により約 2 週間で中流部まで移動し，さらに冬期間を経て湖口マウンドまで達していることが確認された．

## 1.　はじめに

小川原湖は，ヤマトシジミやシラウオ，ワカサギ等水産資源が豊富な汽水湖であり，青森県経済を第一次産業から支えている重要な湖であり，その汽水環境は，海域からの塩水遡上，湖に流入する支川流域からの流入量，洪水による湖内撹乱・塩水希釈・排出等がからみ合う複雑なバランスの上に形成されている．

小川原湖と海域は，高瀬川と湖口マウンドと呼ばれる浅水域で結ばれており，洪水の排水を担うとともに，入退潮による湖内への塩水侵入量をコントロールしている．そのため，効率的・効果的な湖沼管理には，高瀬川の河床変動メカニズムを把握することが重要である．

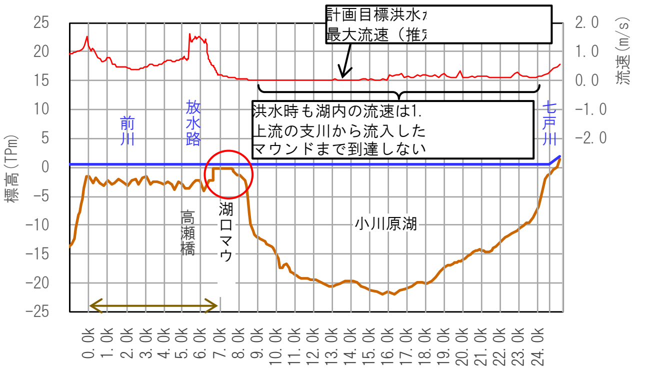


**図 1　洪水時流速と高瀬川・小川原湖の河道縦断図**

小川原湖は流入支川に対して広大な容積を有しているため洪水時も流速は小さくなる．数値シミュレーションにより，河川整備基本方針目標流量が発生した場合の洪水時流速を推定すると，湖中央部での最大流速は 0.1m/s を下回り，高瀬川や湖口マウンドへの上流からの土砂供給は望めないと考えられる．

横断測量成果を用いて高瀬川河床の経年変化を確認すると，平成 10 年～平成 20 年にかけて高瀬川の河床は急激に低下していることがわかる．この河床低下は潮位が高い期間と連動しており、逆に出水規模と明確な関連性は薄い．

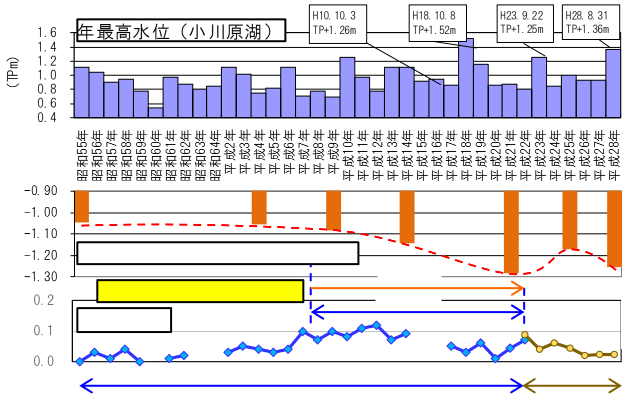


**図 2　高瀬川の河床および想定外力の経年変化**

高瀬川の河床粒径は 0.3mm 程度（60%粒径）と小さく，日常的な入退潮により発生する流速で容易に移動する河床となっている．

本調査は，海域より高瀬川河口に運ばれた土砂が，冬期の波浪等により高瀬川を通じて湖口マウンドまで運ばれ，湖口マウンドの形状が維持されているものと仮定し，着色砂を用いたトレーサー調査により，土砂移動の実態を把握したものである．

## 2.　調査地点・期間および調査手法

調査は平成 28 年～平成 29 年にかけて実施した．

着色砂の投入地点は，下流部，中流部，上流部の 3 地点とし，採取地点は投入地点上流を中心に設定した．

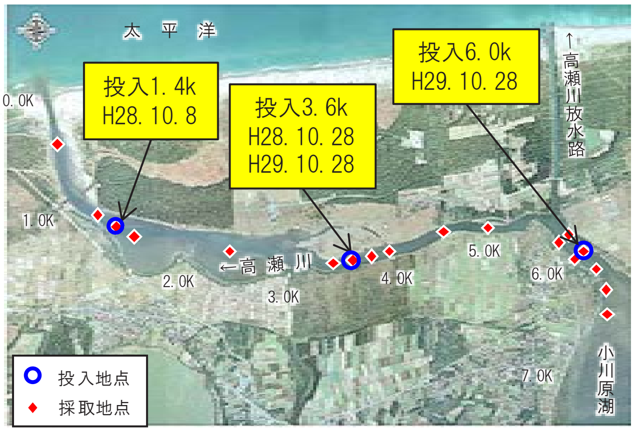


**図 3 トレーサー調査地点**

平成 28 年調査は，大潮 1 回での移動状況を把握するため，調査期間を 2 週間とした．平成 29 年調査は，前年度調査結果を踏まえ，調査期間を 4 週間に設定した．また，冬期波浪による移動状況を確認するため，春期に前年度に投入した着色砂の採取を行った．

着色砂は作業船より最深河床部に投入し，採取は採泥器を用いて，作業船上から行った．採取位置は，定期横断側線上の最深河床位置とし，平成 28 年度調査は概ね 1.0k 間隔で高瀬川全川(0.0k～6.6k)を調査対象区間とした．平成 29 年度調査は，平成 28 年度調査結果を踏まえ，高瀬川中流の 3.6k より上流区間(～6.6k)を調査対象区間とした．

## 3. 調査結果

本調査で，高瀬川を通じて湖口マウンドまで，土砂供給がなされていることが確認出来た．

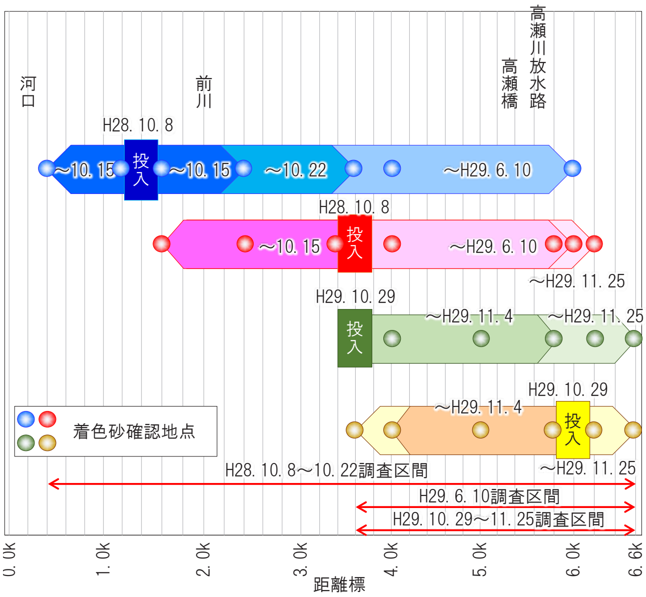


**図 4 河床材料移動追跡調査結果**

平成 28 年 10 月に投入した着色砂を投入後 2 週間で採取したところ，下流部(1.4k)に投入した着色砂は，上下流方向ともに移動が確認され，上流方向には 3.6k 地点までの移動が確認された．しかしながら，中流部(3.6k)に投入した着色砂は下流方向への移動しか確認出来なかった．平成 29 年 6 月に採取を行ったところ，平成 28 年 10 月に投入した着色砂は，下流部投入砂，中流部投入砂ともに，上流方向 6.0k まで移動していることが確認出来た．

平成 29 年 10 月に投入した着色砂については，3.6k 地点より上流区間のみを採取地点として，移動状況を確認した．その結果，調査地点の上流端である湖口マウンド(6.6k)まで着色砂が移動していることが確認された．

## 4. 考察

高瀬川河口部の河床材料(漂砂)の構成は 0.1mm～2.0mm であり，高瀬川 1.0k～6.0k 地点および湖口マウンド 7.4k 地点の河床材料構成と概ね一致している．

限界掃流力(岩垣の式)で評価すると，入退潮の掃流力により概ね 0.7mm 以下の粒径が上流に移動し、これも概ね河床の主要な構成材料粒径と一致している。

高瀬川は近年潮位が平均的に高くなったことで，入退潮の流れが大きくなり，河道が広くなった可能性がある．また，海岸施設等の構造物により，高瀬川河口付近に到達する沿岸漂砂が減少していることも考えられる．

入退潮による漂砂の移動･供給により高瀬川の河道が維持されていると考えられることから，今後も潮位や海域からの土砂供給の変化に注視していかなければならない．

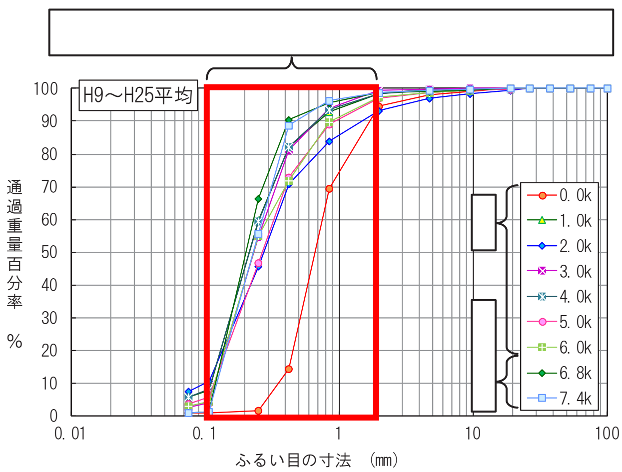


**図 5 高瀬川河床の粒度分布**

## 5. 結論

本調査で，高瀬川の河道変化のメカニムの一端が推定された．今後，海域からの土砂供給の実態や河道変化による湖内環境への影響を分析し，予防保全的な河道･湖沼管理に向けた対策を検討していく。

**P6-6**

# 農業用排水路の魚巣・魚溜に堆積する土砂の粒度分布

高木 翔太[1], 前田 滋哉[1], 吉田 貢士[1], 黒田 久雄[1]
[1] 茨城大学農学部

キーワード：魚巣，魚溜，流砂，データ解析とモデリング

**抄録**

霞ヶ浦流域内の農業用排水路の魚溜区間を対象として，魚巣・魚溜内に堆積している土砂と，コンクリート排水路から降雨時に採水した試料中に含まれる土砂の粒度分析を行った．魚巣内には採水試料中に含まれている比較的小さな粒径の土砂も堆積していた．また魚溜内の堆砂の中央粒径は魚巣のそれより大きく，細砂から礫までの分布が見られた．魚巣・魚溜は単調な排水路において多様な堆砂環境を創出していると考えられる．

## 1. はじめに

我が国の多くの農業用排水路はコンクリート 3 面張りの区間を有しており，土砂の輸送や堆積が頻繁に起こる自然護岸の水路とは環境が大きく異なっている．コンクリート 3 面張りのような特殊な環境では，そこに適応することの出来る生物種のみが卓越する単純な環境となることが指摘されている[1]．近年では上記のような状況を鑑み，農業用排水路においては，魚巣や魚溜といった環境配慮工が配置されてきた．これらの環境配慮工について，魚類の利用状況の調査[2]や乱流特性を考慮した流況の調査[3]などはなされているものの，堆砂に着目した研究はほとんどなされていない．また鵜木ら(2015)[4]は農林地流域での掃流砂，浮遊砂を観測しているが，環境配慮工は対象としていない．本研究では魚巣および魚溜内で採取した土砂と魚溜区間に上流から流入してくる土砂の粒度分析を行い，環境配慮工における堆砂の粒度分布の特徴を明らかにする．

## 2. 方法

**2.1 調査地概要**　対象地は霞ヶ浦流域内の農業用排水路で，魚巣と魚溜が設置されている．対象区間は全長約 15m，魚溜区間が 11m，魚溜区間内の片岸に 3 つずつ両岸で 6 つの魚巣が配置されている．魚巣は開口部が縦 1m，横 1.2m，奥行き 0.9m である．魚溜よりも約 100m 上流に水位計，濁度計，自動採水器を設置している．

**2.2 粒度分析**　水路床に堆積した土砂と，降水時に自動採水器によって採取した土砂を粒度分析した．粒度分析には島津製作所の SALD-2300 を使用した．堆積土砂は 2017 年 11 月 16 日に魚巣・魚溜内で採取した試料を，採水試料は 2017 年 10 月 29 日の降雨時に採水器によって採取した試料をそれぞれ用いた．また，2017 年 11 月 16 日に対象区間で横断測量を行い，iRIC[5]を用いて路床標高分布を推定した．Fig.2-1 に堆積土砂の採取地点を示す．堆積土砂の採取は魚巣内 2 地点（N1, N2）と魚溜内 3 地点（P1, P2, P3）の計 5 地点で行い粒度分析をした．また Fig.2-2 に 2017 年 10 月 29 日の流量の変化を示し，採水のタイミングを○で示す．採水時の流量は S1 が 2.2m$^3$/s，S2 が 2.3m$^3$/s であった．これら 2 つの試料（S1, S2）についても粒度分析を行った．

## 3. 結果

Fig.2-1 のように，魚巣の奥には土砂が堆積し，魚溜の右岸側の魚巣前部では洗掘が見られた．魚溜上流部（Fig.2-1 赤枠で囲った地点）には直径 5~10cm 程度の礫が堆積していた．粒度分析の結果，魚巣内 N1，N2 の中央粒径はそれぞれ 0.438mm，0.248mm，魚溜内 P1，P2，P3 の中央粒径はそれぞれ 0.953mm，0.646mm，0.643mm だった．また採水試料中の土砂 S1，S2 の中央粒径はそれぞれ 0.00917mm，0.00300mm だった．Fig.3-1 に各採取試料の粒径の頻度分布を示す．Fig.3-1 から魚巣内には魚溜内と比べ小さな土砂が堆積し，採水試料中に含まれるような小さな土砂も含まれていた．魚溜内には比較的大きな土砂が堆積し，採水試料中に含まれているような小さな土砂は堆積していない．また魚溜内では，一般的な河川同様，流下するに従い堆積土砂の粒径が小さくなっていることも確認出来る．

**4. 考察**

粒度分析の結果から，魚巣内には採水試料中に含まれる土砂が堆積していることが分かった．対象排水路に設置された魚巣は流速を減少させ，滞留時間を長くし，小粒径の土砂を堆積させる能力を有していると言える．また魚溜内には 0.3mm の細砂から 100mm の礫まで様々な粒径の土砂が堆積していた．魚巣内と合わせると実に様々な粒径の土砂が存在しており，コンクリート 3 面張りの排水路において，魚巣や魚溜は多様な堆砂環境の創出に役立っているものと考えられる．

**5. おわりに**

本研究では魚巣・魚溜を有する農業用排水路を対象として，堆積した土砂と流入土砂の粒度分布を調べた．その結果，魚巣・魚溜のような環境配慮工が路床内に多様な堆砂環境を生み出していることがわかった．

粒度分析にあたって茨城大学広域水圏環境科学教育センターの山口直文先生にご指導賜りました．また一部の図の作成に iRIC ソフトウェアを使用しました．記して感謝の意を表します．

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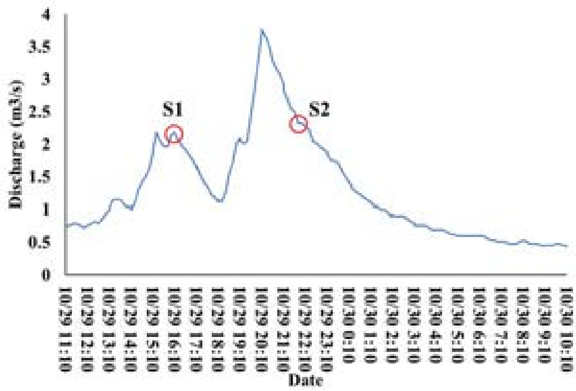


**Fig.2-2 10/29~10/30 の流量の変化と採水時点**

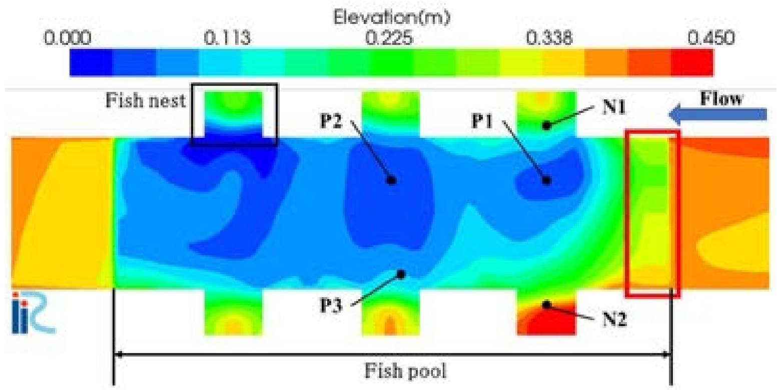


**Fig.2-1 対象区間の路床標高と採土地点**

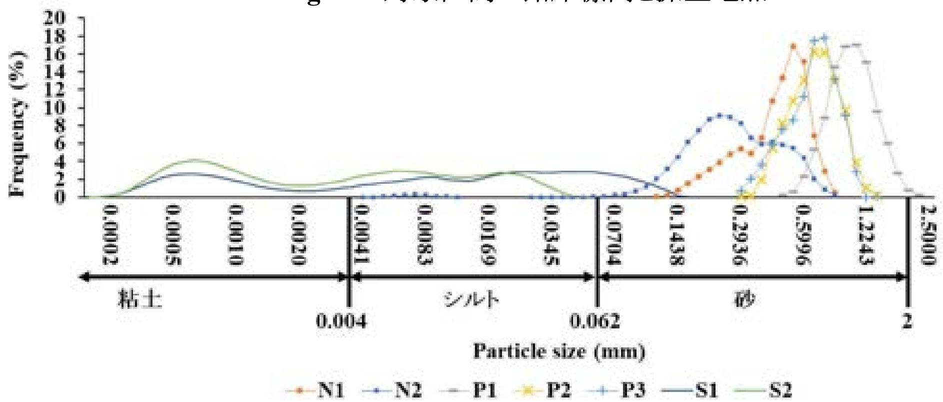


**Fig.3-1 各採土試料の粒径頻度分布**

**P6-7**

# Assessment of Harmful Cyanobacteria Growth Potential based on Hydrodynamic Modelling

Eunjeong Lee, Yongjin Kim, Ingu Ryu, Hwangjeong Choi, Myeongsub Byeon, Soonju Yu

Han-River Environment Research Center, National Institute of Environmental Research (NIER), Republic of Korea

Keywords: harmful cyanobacteria, growth potential, EFDC, streambed sediment, hydrodynamic modelling

**ABSTRACT**

This study was conducted to assess harmful cyanobacteria growth potential based on hydrodynamic modelling with EFDC (Environmental Fluid Dynamics Code) in Bukhan river (Korea) through culture experiments using streambed sediment. Akinetes of cyanobacteria have settled down on the streambed sediment in areas of low water velocity. We monitored the five sites where particles are likely to deposit due to slow flow rate from result driven by hydrodynamic analysis. Akinetes or resting cells are estimated to be germinated or recruited from streambed sediment in April/May when environmental conditions such as flow rate and residence time are appropriate, and it is considered that they are deposited into streambed sediments after September when water temperature decrease.

## 1. INTRODUCTION

Cyanobacteria have ecological characteristics such as forming resting cell or akinete when they are not in favorable environmental conditions, which sink to the lake bottom[1]. Sedimentation of particles is related to hydraulic characteristics such as flow rate of water body, and is likely to be deposited at a slower flow rate. The Ministry of Environment has operated the harmful algae alert system by designating the cyanobacteria belonging to four genera of *Anabaena, Microcystis, Aphanizomenon,* and *Oscillatoria* as harmful cyanobacteria and makes a lot of efforts to prevent the algal blooms. The main objective of this study is the assessment of potential harmful cyanobacterial blooms in Bukhan river (South Korea), based on hydrodynamic modelling through culture experiments designed using riverbed sediment.

## 2. METHOD

### 2.1 EFDC-based hydrodynamic modelling

Numerical model constructed in the study conducted by the National Institute of Environmental Research in 2016 was used to analyze the hydrodynamics of the Lake Paldang[2]. The numerical model was developed based on the EFDC(Environmental Fluid Dynamics Code) model, which was originally developed at the Virginia Institute of Marine Science and is continuously managed and developed under the support of US EPA and Tetra Tech. Inc. EFDC is applicable to various water systems including the river, lake, wetlands, estuaries and reservoirs[3].

A hydrodynamics was analyzed for about 23 km from Cheongpyeong Dam to the Lake Paldang. Analytical lines and points are selected as shown in Fig. 1 considering the followings.

- the water level gauge or water quality monitoring station is located.
- hydraulic dead zone is expected caused by wetlands, hydraulic structure and etc.
- mainstream impacts(discharge, velocity, water quality and so on) from tributary inflows are expected.

From numerical simulations of 2014 and 2015, hourly hydraulic data of selected analytical lines was extracted.

### 2.2 Harmful cyanobacteria growth potential

From April to November of 2017, riverbed sediments were sampled once a month using core sampler, and 30L of the surface waters of the site were filtered with a phytoplankton net(mesh size 20μm). Species identification was carried out using an optical microscope with a Lugol's iodine preservative solution.

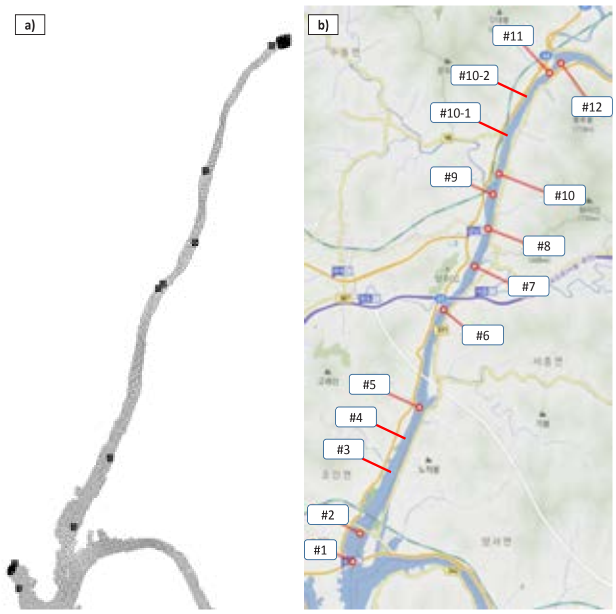


**Fig. 1 a) EFDC grid, b) Location of each section**

The sediment was cut into top to 5 cm, and after mixing equally, 75 g of sediment was mixed with 150 mL of BG11 cyanobacterial medium, and the mixture was treated with ultrasonic grinder for 30 seconds twice and then cultured for 7 days at a temperature 25 ℃, a luminous intensity of 40 μmol/m$^2$·S and light period 16(L):8(D) as shown Fig. 2.

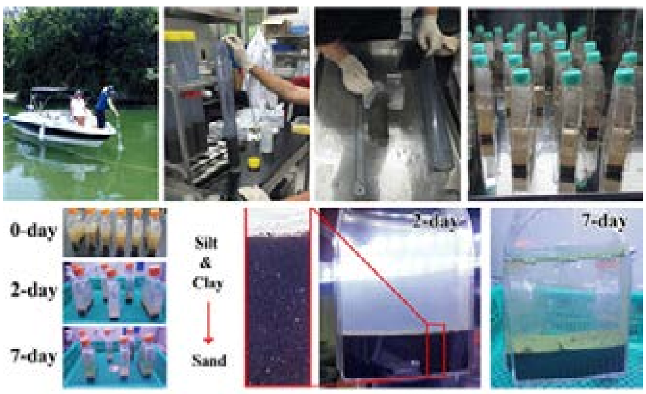


**Fig. 2 Harmful cyanobacteria growth potential test for sediment**

## 3. RESULTS

### 3.1 EFDC-based hydrodynamic modelling

In line #12 and line #11, the average annual flow rate of about 10~27 cm/s appears due to discharge of the Cheongpyeong Dam. The influence of discharge of the Cheongpyeong Dam gradually decreased as shown in Fig. 3, average annual flow rates from line #10-2 to line 1 below about 5 cm/s were calculated. The deviation of the velocity between left bank and right bank occurred significantly in four sections (line #12, line #7, line #2, line #1) except for the other sections. The average monthly flow rate was about 5 cm/s except during flood season, June to August.

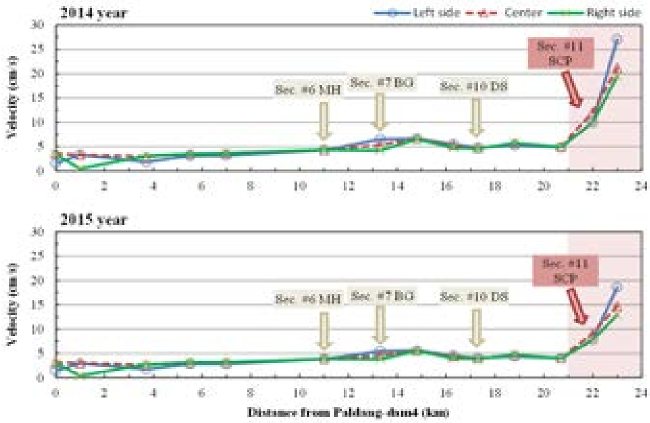


**Fig. 3 Sectional mean velocity for each point**

Based on the results of the hydraulic analysis described above, five sites after confluence of Mukhyun stream were selected as the monitoring sites with high possibility of harmful cyanobacterial blooms as shown in Fig. 4. The monitoring sites are MS(confluence of Mukhyun stream), SB(Sambong), SS(confluence of Sambong stream), SC(Songchon sewage treatment plant discharge point), and P4(Lake Paldang confluence area).


**Fig. 4 Monitoring sites of sediment and phytoplankton**

### 3.2 Harmful cyanobacteria growth potential

Experiment of potential growth of harmful cyanobacteria by riverbed sediment cultivation showed that 8 species of harmful cyanobacteria such as *Anabaena, Microcystis, Aphanizomenon* and *Oscillatoria* were geminated. The abundance of harmful cyanobacteria that occurred from sediment cultivation at each site ranged from 106 to 3,913 cells/mL in April, the highest in P4, and in May from 37 to 547 cells/mL. The average abundance in May at all monitoring sites decreased to 12.9 % from April. From June to August, abundance of harmful cyanobacteria was low at around 200 cells/mL at all sites, and was significantly increased at SC and P4 sites from September, reaching 21,024 cells/mL at SC in November (Fig 5). The pelagic harmful cyanobacteria rarely appeared below 10 cells/mL at all sites in April, started to increase from May and was highest abundance at MS. The potential for growth of harmful cyanobacteria in riverbed sediment was highest at SC.

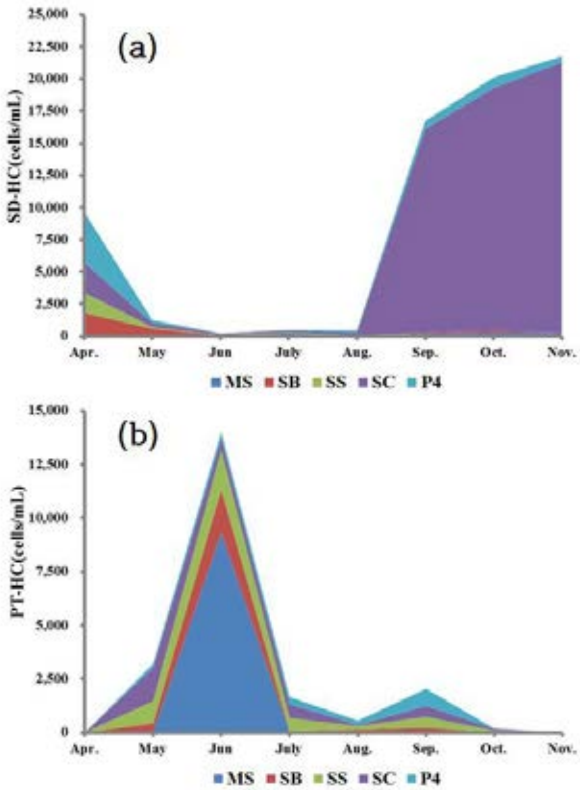


**Fig. 5 Standing crop of harmful cyanobacteria in Lake Paldang (SD-HC: Sediment Harmful Cyanobacteria; PT-HC: Planktonic Harmful Cyanobacteria)**

## 4. DISCUSSION

The harmful cyanobacteria are estimated to be germinated from streambed sediment in April/May when environmental conditions such as flow rate and residence time are appropriate, and it is considered that they are deposited into streambed sediments after September when water temperature decrease.

## 5. CONCLUSION

From this study, it is possible to predict the site where the possibility of blooming of cyanobacteria is high and to manage preliminary harmful cyanobacteria through riverbed sediment management.

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This work was supported by a grant from the National Institute of Environment Research (NIER), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIER-2017-01-01-080).

**P6-8**

# Simple and reliable Biological Monitoring of Lakes for Sustainable Services

**Shobha Jagannath and Vinutha G.P**
University of Mysore

**Key words**: Biological Monitoring, Multiple Water Uses, ecological succession and ILEC format.

**ABSTRACT**

Continuous monitoring of water bodies for multiple use such as drinking, fisheries, Horticulture, Agriculture, wildlife and Recreational activities are essential for the sustained quality of life.. Changing land use pattern in both urban and rural settlements in India are at the cost of water bodies and open spaces. Biological monitoring of water bodies using desmids, chlorococcales, diatoms and euglenoids are established methodologies which are cost effective, reliable and indicates ecological succession of water bodies. In this paper Chikkarasinakere in Maddur Taluk, Mandya district of Karnataka state, India has been monitored for four months in 2015 using phytoplanktons along with physicochemical parameters. The water quality has been assessed using Pearson's correlation matrix for physicochemical parameters and CCME WQI for biological monitoring of the water quality. Seasonal variations in the physicochemical and plankton diversity were observed. The abundance of diatom *Navicula cryptocephala* indicates organic pollution while *Synedra ulna* and *S. acus* are indicators of anthropogenic pollution. The water quality of the lake has been classified as poor for overall purpose such as drinking, aquatic and recreation and marginal for irrigation and livestock use. It is suggested that ecological succession of water bodies can be rapidly assessed by using micro biological parameters.

## 1. INTRODUCTION

Changing land use pattern in both urban and rural settlements in India are at the cost of water bodies and open space. Continuous monitoring of water bodies for multiple use such as drinking, fisheries, Horticulture, Agriculture, wildlife and Recreational activities are essential for the sustained quality of life to meet its functional needs. Phytoplanktons have long been used as indicators of water quality. Because of their short life span and quick responses to changing environmental changes their species composition indicate the quality of water in which they are found. Clean water supports a great diversity of organisms whereas very few organisms survive in polluted water with one or two dominant forms. As species composition of phytoplankton communities change in response to environmental variations, long term studies of plankton component in relation to fluctuations of water quality parameters are useful in developing and evaluating significant water resources for multiple uses. (Roy and Chattopadhyay, 2007)

Biological monitoring of water bodies using desmids, chlorococcales, diatoms and euglenoids are established methodologies which are cost effective, reliable and indicates ecological succession of water bodies. In this paper Chikkarasinakere in Maddur Taluk, Mandya district of Karnataka state, India has been monitored for four months in 2015 using phytoplanktons along with physio--chemical parameters. The lake has a catchment area of 105 hectares with maximum depth of 10 meters when full. The Cauvery river feeds the lake through a channel. The lake water is used for irrigation and villagers use it for domestic purpose and cattle rearing.

## 2. METHOD

. The water quality has been monitored for physio-chemical parameters for four months in 2015 following the method of APHA (1985). Correlation of various paramenters were done using Pearson's correlation matrix. To analyze the phytoplanktons water samples were collected form surface water at various places and preserved by the method described by Welch (1948) .The water quality Index of the lake has been done using CCME WQI

## 3. RESULTS

Seasonal variations in the physic-chemical and plankton diversity were observed. During the month of February, color positively correlates with sulphate, while in March Color positively correlates with fluoride and negatively correlates with DO and fluoride negatively correlates with sulphate. In April, sulphate positively correlates with DO. During May, pH positively correlates with color and temperature while iron shows negative correlation. Similarly colour negatively correlated with iron, phosphate and alkalinity negatively correlates with COD. .Among the phytoplanktons, the diatoms were the most predominant forms in all the four months. The abundance of diatom *Navicula cryptocephala* indicates organic pollution while *Synedra ulna* and *S. acus* are indicators of anthropogenic pollution. The water quality of the lake has been classified as poor for overall purpose such as drinking, aquatic and recreation and marginal for irrigation and livestock use.

## 4. DISCUSSION

There are eight core parameters such, as Temperature, pH and eighteen general parameters such as chemical species in physio-chemical analysis of lake water. It is inferred that biological monitoring using indicator species gives a definite indication on the health status of the water body. Further, a policy frame work for continuous monitoring of water bodies using biological parameters is found essential.

**P6-9**

# Ecological Health Assessment of Loei River and Tributaries by using aquatic insects under river continuum concept

Thanayaporn Katesuja[1], Panida Rahong[1], Chotiwut Techakijvej[1], Atinut Joradol[2], Rungnapa Tagun[2], Tatporn Kunpradid[2] and Chitchol Phalaraksh[1,3]

[1] Environment Science Program, Faculty of science, Chiang Mai University
[2] Department of Biology, Faculty of science, Chiang Mai Rajabhat University
[3] Department of Biology, Faculty of Science, Chiang Mai University

Keywords: river continuum concept, aquatic insects, Ecological health assessment and Loei River

**ABSTRACT**

The study is aimed to investigate the environmental factors that influenced the living organisms based on functional feeding groups from the upstream to downstream in Loei River. The study sites were selected to 10 sites based on the impact of human activities along the river. The sampling were collected from February to June 2017 to represent all three seasons. A total of 27,702 individuals, belonging to 112 Families in 9 orders of macroinvertebrates were found. The most number of individual was mayfly in order Ephemeroptera, family Baetidae. The River Continuum Concept analysis of Functional Feeding Groups (Collector, Grazer, Predator and Shredder) based on principle of The River Continuum Concept indicated that the proportion of Functional Feeding Groups from separation the study sites including 1 to 3 (Upstream), 4 to 8 (Midstream) and 9 to 10 (Downstream). Therefore, the Ecological Health of Loei River is moderate to good level. In addition, there are also correlations in the statistical analysis based on changes in biological, physical and chemical in each month.

## 1. INTRODUCTION

At present this has rising of the population and economic in the world. Accordingly, the passion to demand the water resource has increased all sectors. As a result, there is the risk to the crisis be highly probable of the water resource in the world. In addition, global warming and climate change. The average temperature of the earth's surface that increases and the global average sea level that rising [1]. These the cause above has an effect on the freshwater resource in the world to decrease.

Loei River at Loei province, Thailand. This is main the tributaries of Khong River. Consequently, Loei province has many human activity such as industries, agricultures, communities and usable area. As Loei River had interested to research about the water quality measurement by The River Continuum Concepts or RCC.

The River Continuum Concept or RCC is a conceptual model that predicts biological community responses to physical changes along the lengths of rivers. [2] As a river changes from headstream to the downstream, there will be a change in the relationship between the production and consumption. This one organism that interested in the river is benthic macroinvertebrates by functional feeding groups (FFGs). [3] Benthic macroinvertebrates are often utilized in studying the biological responses of the system because they clearly reflect changes in food resource availability in relation to stream size. [2]

In this study, we describe longitudinal variation in benthic macroinvertebrates community structure of Loei River. Because there has length river is 231 km[4] that this is appropriate for study along river. And Loei riverside areas has many human activity as a results to this has effect to change the community of benthic macroinvertebrates or not? The results it is the benefit for populations to development the RCC to base data for water quality measurement or knowledge for youth. These things will make to cause awareness them water resource and environmental for used in the future not endless.

## 2. METHOD

a. study areas

Benthic macroinvertebrates, chemical parameters and Physical parameters was collected at 10 study sites (Figure 1) along Loei River between 231 km by divided the river into 3 parts (1-3 study sites was Upstream, 4-8 study sites was Midstream, 9-10 study sites was Downstream)[2].

b. sampling

Sampling took place on March May and July 2017. Macroinvertebrates were collected by D-frame net (weight 30 cm cross size, 500 µm mesh size), Surber sampler and Sampler. Sampling duration was 1 min/point. D-frame net and Surber sampler was repeated the collect to 3 times/ bank (left and right) by Kick-sampling (the D-frame was used on high water level and this area had cover by the water plant around riverside. Surber sampler was used on low water level until saw the substrate). Current pH, velocity, total dissolve solid, conductivity, dissolve oxygen, temperatures (water and air) were measured in field. In addition, water sample were collected to measure biochemical oxygen demand, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, identified macroinvertebrates in laboratory.

c. statics

Analyzed of River Continuum Concept: RCC [2] by Functional Feeding Groups: FFG [5] on upstream (site 1-3), midstream (site 4-8) and downstream (site 9-10) from amount of benthic macroinvertebrates samples. According, Pearson's correlation was calculated between chemical-physical parameters with parts of stream and benthic macro-invertebrates. The significant of this relationship between chemical-physical parameters with each month of sampling the samples.


**Figure 1: The coordinates of 10 study sites**

## 3. RESULTS

In March was used represent to be dry season and May, July this both months represent to be wet seasons because those it was heavy flooding and flash flood between the sampling samples. As a result to important point this was used changing the value about chemical-physical parameters together with the macroinvertebrates community.

The individuals results of benthic macroinvertebrates part. The highest of the number is 21,939 (Family Chironomidae). This had 4,929 individuals. On May the highest of the number is 842 individuals (Family Tubificidae). And July the highest of the number is 489 individuals (Family Baetidae). Diversity of each month on March at upstream this had the highest, downstream and downstream respectively. Whole along river this was the highest of percentile is 61% in collector, grazer 22%, predator 14% and shredder 3% respectively. The upstream in March, May and July. The result of Functional Feeding Groups (FFGs) this was the highest is collector 48%, grazer 36%, predator 11% and shredder 5%. Range of midstream was found collector 60%, grazer 20%, predator 18% and shredder 2%. Downstream was found collector 79%, predator14%, grazer 6% and shredder 1% respectively.

The relationship between months of sampling (March, May, and July 2017) with ranges of stream (upstream 1-3, midstream 4-8 and downstream 9-10) was calculated by Pearson's correlation. That months was used on intensity, BOD, $NH_3$-N and orthophosphate parameters as not have relationship. According, another parameters are water temperature, velocity, conductivity, TDS and Turbidity was separated as 2 groups are May, July (1) and March (2). The relationship result between macro-invertebrates with parameters as not relationship. Results of ANOVAs of environmental factors (intensity, water temperature, velocity, conductivity, TDS and turbidity) of different ranges river (May, July (1) and March (2)) are significant difference ($p < 0.5$).

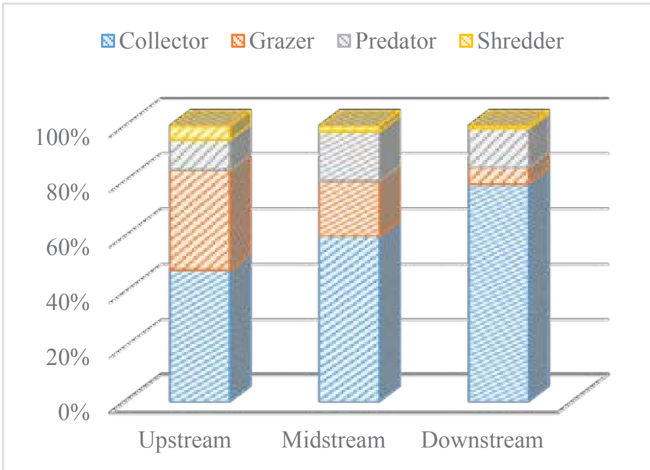


**Figure 2: The proportion of FFGs**

## 4. DISCUSSION

Shredders are an important ecological guild in headwater streams, playing a vital role in the process of leaf litter decomposition [6]. Che Salmah et al. (2013) documented a higher proportion of shredders (18.22% of total macroinvertebrates) in Malaysian forest headwater streams [7]. Shade conditions and substrate are important factors for shredder habitat. Our results were found the proportion of shredder and grazer to decreasing from upstream to downstream. This conform to the study of Lan Fu et al. (2016) that Shredders decreased and collector-filterers increased significantly, as predicted by the RCC [8]. According to the RCC, relative collector abundances should stay around 50% in the sampled portions of Quebrada Máquina [2].

Many collector-gatherers are tolerant to disturbance and organic pollution, such as Tubifex spp., Limnodrilus spp., Branchiura sp., and Chironomidae and abundant in polluted rivers [8]. However, predator populations only depend on the relative abundances of the other functional groups. Therefore, no matter how the grazers, shredders and collectors respond to resource availability, the relative predator population should stay the same [2]. So the results of this study show on midstream to downstream where have human activity to increase followed by land use. The number of Family Chironomidae this increased that according to above reasons and FPOM that have increase decomposition from upstream.

However, May and July this both months was flooding from heavy rain during sampling the samples. This factor is effect to changing chemical-physical parameters and drift the macroinvertebrates. So the result this shown to clearly separate into 2 groups are represent for dry season and wet season. But those factors did not relationship community of macroinvertebrates for Ecological Health Assessment of Loei River and Tributaries.

## 5. CONCLUSION

The river continuum concept (RCC) at Loei River and Tributaries accord with our results by increasing of the benthic-macroinvertebrates proportion. So this show to The Assess the Ecological Health of the Loei River under the River Continuum Concept (RCC) on March 2017. This the valuation to abundance river condition. The flooding is the most importance factors for inconstant to chemical, physical and biological determinants on May and July 2017.

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**P6-10**

# Spatio-Temporal Evaluation of Flood Impacts on Wetland Vegetation using Remote Sensing

Shara Grace C. ASTILLERO[1], Tomohito J. YAMADA[2] and Taro YAMAMOTO[3]

[1]M.Eng., Hokkaido University, [2]Associate Professor, Hokkaido University, [3]River Center of Hokkaido

Keywords: wetland, remote sensing, spatial assessment, spectral indices

**ABSTRACT**

Increase in sediment yield and nutrient-rich water in Kushiro Mire has intensified the vegetation in the area. Because of this, the wetland is becoming arid. It is therefore necessary to understand the preservation of wetland. As flood is relevant on the wetness condition of the wetland, preliminary investigation using satellite remote sensing data was conducted to spatially investigate the response of surface conditions to flood. Landsat 8 OLI TIRS and MODIS data utilized bands to acquire information on its conditions using the reflection and absorption to sunlight on the surface. This study aims to evaluate the response before and after extreme flood event. The variation of the surface condition response was quantified using spectral indices. The results show that there is a significant difference of response of the vegetation between non-flood and flood periods spatially. The results can provide helpful preliminary assessment for planning the restoration of Kushiro wetland.

## 1. INTRODUCTION

Wetlands play a significant role in the hydrological cycle, influencing groundwater, evaporation, water retention and flood control and protection. [1] Wetland ecosystem has been habitat for an enormous diversity of plants and animal species. In Kushiro wetland, it has been the home to the red-crowned crane, a special natural monument, and, the Japanese huchen, which is Japan's largest freshwater fish, and other rare organisms.

The Kushiro Mire is the largest wetland area in Japan with 18,290 ha in area. [2] It was discussed at the Ramsar Convention the importance of preserving the biodiversity of the Kushiro Mire wetlands. [3] The wetland mostly consists of fen covered with reeds and sedge grasses, and portions of the wetland are areas with sphagnum moss. It is covered with alder woodlands in the northern part of the wetland. [4]

The increase in sediment yield and nutrient-rich water in the wetland from the upper reach is due to development in the surrounding land, riverbed degradation and deforestation. With this, the number and density of alder trees have increased because the sedimentation and accumulation of soil favor its growth. [5]

Present issues raise in the wetland becoming arid, thus it is important to understand the preservation of the wetness of the wetland.

In August 21, 2016, flood event happened that inundated the Kushiro wetland. This flood event contributed relevantly on the wet condition of the wetland. As vegetation has largely influence in determining the wetland increase of land area, it is important to investigate also on how vegetation responded to flood events and determine the impact on the restoration of the wetland.

In-situ observations of the surface conditions is very relevant for wetland assessment, however, it is tedious to have field evaluation to assess a large area with various land cover types. Thus, wetland assessment using remote sensing data have been used for rapid evaluation.

Several case studies proposed application of remote sensing data in spatial assessment and classification of the alder tree and other vegetation in Kushiro Mire. [5,6,7] These studies have proposed different methods of vegetation classification on the wetland. It was determined in these studies that there is a dramatically increased in vegetation over time. However, there has been no studies on the spatial evaluation of the surface conditions and flood impacts on the vegetation of Kushiro wetland using remote sensing.

Thus, this study aims to evaluate the response of the wetland vegetation before and after flood events which is significant for planning of restoration of the wetland.

## 2. DATA AND METHODOLOGY

Remotely sensed data was utilized to have preliminary assessment of the land surface condition of the wetland. This study applied two remote sensing data. Landsat 8 data at 30-meter spatial resolution consist of sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) which collect nine spectral bands and two thermal bands and Moderate Resolution Imaging

Spectroradiometer (MODIS) provides bands 1 (620–670 nm), 2 (841–876 nm) at 250-meter resolution in an 8-day gridded level-3 product in the sinusoidal projection.

Remote sensing provides information in the reflection and absorption to sunlight on the surface which also acquires information on its conditions.

**Table 1 Equations used for evaluating surface conditions**

| Index | Equation | Definition |
|---|---|---|
| Normalized Difference Vegetation Index (NDVI) | $NDVI = \frac{NIR - Red}{NIR + Red}$ | NDVI quantifies vegetation. |
| Normalized Difference Soil Index (NDSI) | $NDSI = \frac{SWIR - NIR}{SWIR + NIR}$ | NDSI examines the soil conditions |
| Normalized Difference Water Index (NDWI) | $NDWI = \frac{Green - NIR}{Green + NIR}$ | NDWI maximizes the reflectance properties of water. |

These indexes provide information to determine the change of surface conditions of the wetland before and after flood.

## 3. RESULTS AND DISCUSSION

The impact of flood inundation on vegetation was determined on the peak date of the significant flood of Kushiro river as basis for the selection of remotely sensed images. On September 16, 2013 with peak discharge of 318.19 m3/s and August 21, 2016 with peak discharge of 469.10 m3/s were selected.

It is an important information to know wetland surface condition, to know the area of the concentration of the wetness condition of the wetland.

Fig. 1 shows the spatial distribution of the moisture of the ground after and before flood event based on NDSI. Dark brown relates with greater soil reflectance. Furthermore, in Fig. 2 shows the spatial distribution of water content in the surface of the wetland based on NDWI. Cooler color represents higher water content. It is shown in this visual information that in the central wetland shows the concentration of changes in soil and water conditions.

In the flood event, it is expected that flood inundation would bring significant influence on the growth of the vegetation. The variation of the vegetation response was quantified using NDVI. In order to investigate the impact of flood inundation on vegetation, non-flood period and flood period was compared.

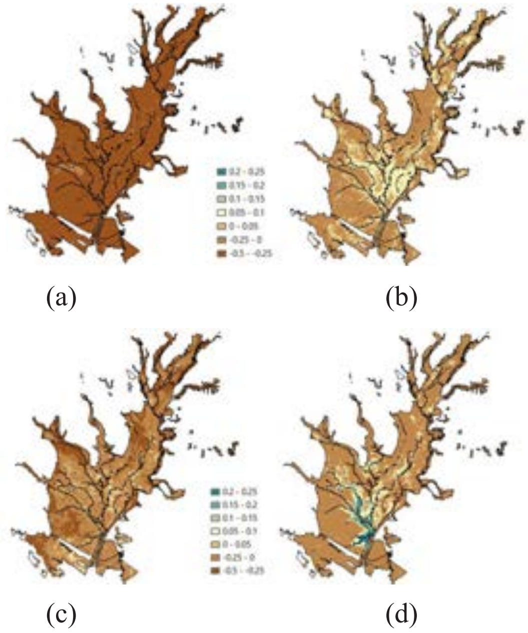


**Fig. 1 NDSI spatial distribution (a) before 2013 flood (08/02/2013) (b) after 2013 flood (10/12/2013) (c) before 2016 flood (06/07/2016) (d) after 2016 flood (10/02/2016)**

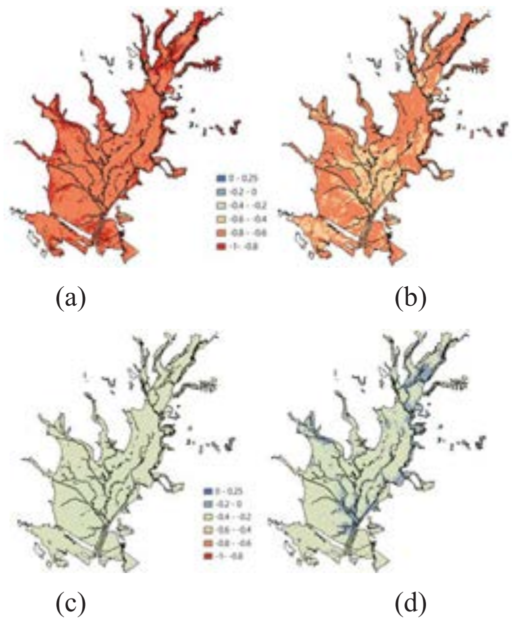


**Fig. 2 NDWI spatial distribution (a) before 2013 flood (08/02/2013) (b) after 2013 flood (10/12/2013) (c) before 2016 flood (06/07/2016) (d) after 2016 flood (10/02/2016)**

Based on the flow data, the non-flood period is selected. NDVI during non-flood period shows a variating trend on the vegetation as shown Fig 3. However, the NDVI index values are maintained in the positive values between 0.3 to 1, much it implies the dense vegetation canopy during non-flood period.

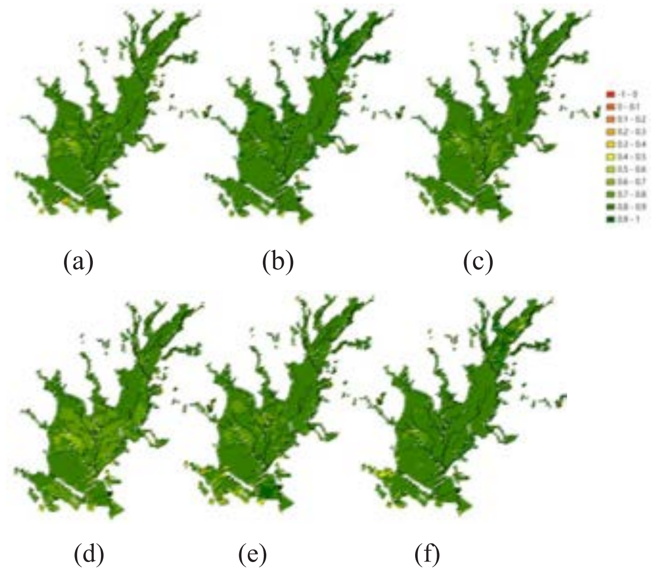


**Fig. 3 NDVI spatial distribution on non-flood period for 2013 (a) 06/26/2013 (b) 07/04/2013 (c) 07/28/2013 and for 2016 (d) 06/25/2016 (e) 07/03/2016 (f) 08/04/2016**

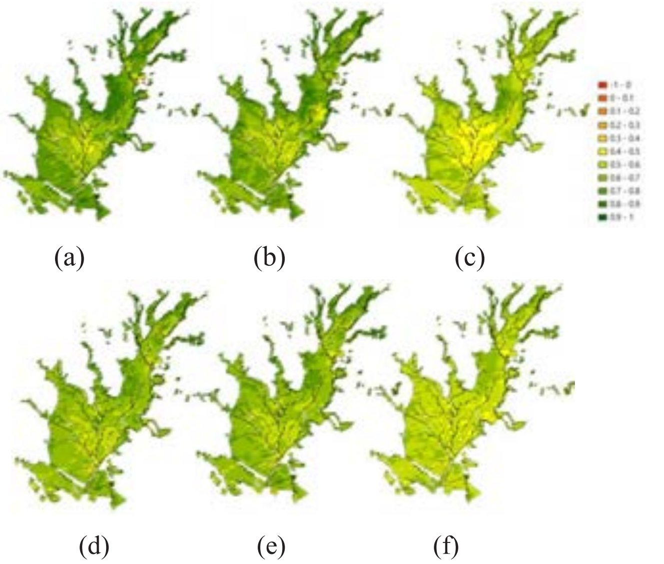


**Fig. 4 NDVI spatial distribution after flood event for 2013 (a) 09/14/2013 (b) 09/22/2013 (c) 10/08/2013 and for 2016 (d) 09/21/2016 (e) 09/29/2016 (f) 10/07/2016**

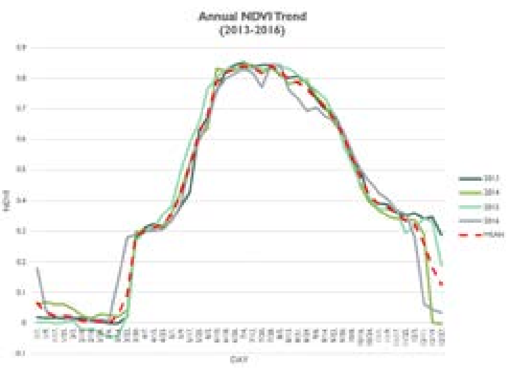


**Fig. 5 Annual NDVI Trend from 2013 - 2016**

Analyzing the effects of flood inundation on vegetation, NDVI after 8-day and 16-day interval was calculated as shown in Fig. 4. The results show decrease trend on vegetation based on NDVI both in 2013 and 2016 flood event unlike on the NDVI values of the non-flood period.

It is shown also in Fig 5 the annual NDVI trend of the vegetation in the wetland. It can be seen that from 2013 to 2015, the changes in the NDVI from the mean state follows almost the same trend, whereas in 2016, there is a drastic change in the trend around August 2016 where the flood event occurred.

The results show that there is a significant difference of response of the vegetation between non-flood and flood periods. The spatio-temporal evaluation on the wetland can provide preliminary information for planning in the wetland.

## 4. CONCLUSION

This study spatially evaluated the impacts of flood on the vegetation of the Kushiro wetland utilizing remote sensing data. The land surface conditions on the influence of flood was preliminary investigated using remote sensing. Further investigation is necessary. However, the spatio-temporal evaluation on the wetland can provide preliminary investigation that can be utilized for initial assessment on the wetland.

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**P6-11**

# Release of the Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J) Version 3

Hideyuki Tonooka[1], and Yudai Mizoguchi [1]

[1]Ibaraki University

Keywords: monitoring technologies for lakes and/or rivers, lake basin databases and knowledgebases

**ABSTRACT**

The Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J), released in July 2012, provides water surface temperatures around 10:30 am (JST) measured by thermal infrared bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA's Terra satellite, for 1,005 inland water bodies such as lakes and reservoirs in Japan (http://tonolab.cis.ibaraki.ac.jp/SatLARTD/). Because the mean frequency of successful measurements by ASTER for each water body is two or three times per year at most, SatLARTD-J also provides water surface temperatures regressively estimated with ground air temperatures from the Automated Meteorological Data Acquisition System (AMeDAS) in a five-day interval, using a regression equation obtained for each water body between the ASTER's water surface temperature and the AMeDAS ground air temperature corrected in spatial, temporal, and elevational. The version 2 of SatLARTD-J, released in July 2014, provided water surface temperatures only for a limited period from March 2000 to December 2013, but the latest version 3, released in January 2018, has a new function of near real-time updating, and the recent water surface temperatures for each water body are automatically added to the database. Water temperature is a key environmental factor for ecosystems in an inland water body, and the SatLARTD-J is expected to give some contributions to various fields including biodiversity conservation. As a next step, we are currently developing the world version of SatLARTD for future release.

## 1. INTRODUCTION

Many inland water bodies such as lakes, marshes and reservoirs are inhabited by many lives. For these lives, water temperature is an important environmental factor, because water temperature influences and regulates many chemical, physical and biological processes[1]. In addition, water temperature is also important in the aspect of global warming monitoring[2]. Thus, water temperature measurements of inland water bodies are important, but in Japan, they are insufficient except for some large lakes. Also, temperature measurements with contact-type thermometers are not realistic for monitoring many water bodies, because such water bodies are scatteredly located, and managed or owned by various people or organizations. Therefore, thermal infrared (TIR) remote sensing which can simultaneously observe surface temperature in a wide area is useful for these purposes. Under such background, our group developed the Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J) using TIR images (90 m resolution) observed by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA's Terra satellite, and released it in July 2012[3] [4] [5]. The version 2 of SatLARTD-J, released in July 2014, provided water temperatures only for a limited period from March 2000 to December 2013, but the version 3, released in January 2018, has a new function of near real-time updating, and the recent water surface temperatures for each water body are automatically added to the database. In the present paper, the overview of the SatLARTD-J version 3 is introduced.

## 2. SatLARTD-J VERSION 3

In the SatLARTD-J version 3, 1,005 inland water bodies such as natural lakes and reservoirs are registered (see Fig. 1). Since water surface temperatures are estimated using ASTER/TIR images with a spatial resolution of 90 m, most of water bodies have an area of 270 m square or larger for getting one or more pure pixels.

In the version 2, ASTER Data β products[6] provided by the National Institute of Advanced Industrial Science and Technology (AIST) were used for estimating water surface temperatures. But it is difficult to implement the function of near real-time updating using these products, because they are not regularly produced. Thus in the version 3, ASTER-VA products provided from the METI AIST Data Archive System (MADAS)[7] have been used in water temperature estimation for observation dates after January

2014. The updating module of SatLARTD-J checks and downloads a new ASTER image on MADAS automatically every day, and then estimates water surface temperatures for water bodies included in that image.

Water temperature estimation with ASTER/TIR images is performed by recalibration[8] , straylight correction[9] , atmospheric correction by the water vapor scaling (WVS) method[10] [11] , ASTER standard temperature and emissivity separation (TES)[12] , and screening. The details can be found in [3] [4] [5] . On the other hand, the mean frequency of ASTER observations is once per 48 days, and that of successful observations available for water temperature estimation is two or three times per year. Therefore, SatLARTD-J also provides water surface temperatures regressively estimated with ground air temperature from the Automated Meteorological Data Acquisition System (AMeDAS)[13] in a five-day interval, using a regression equation obtained for each water body between the ASTER's water surface temperature and the AMeDAS ground air temperature corrected in spatial, temporal, and elevational.

## 3. USAGE

Fig. 2 displays the top page of the SatLARTD-J version 3. In the left half, the locations of the registered water bodies are shown as markers on the Google map. The upper part of the left half has a function for searching a water body with its name and prefecture.

Fig. 3 shows an example of viewing plots and values of water temperatures for Lake Kasumigaura (lake center) in Ibaraki Prefecture (two points in one lake are selectable for only Lake Kasumigaura). The pop-up window on the left map gives the name, the latitude and longitude, and the elevation of the selected water body. The upper part of the right half shows the plots of water temperatures, where red points indicate ASTER estimates, and a blue polygonal line indicates regression estimates. The plot part of interest can be enlarged by clicking and dragging, as shown in Fig. 4. Enlarged plots can be returned to the original plots by double clicking.

The lower part of the right half displays all ASTER estimates and their corresponding regression estimates as values. The frequency of ASTER successful observations at Lake Kasumigaura is about 7 or 8 times per year which is higher than other water bodies, because the surrounding area of Lake Kasumigaura has been focused in ASTER scheduling.

## 4. CONCLUSION

The SatLARTD-J which provides water surface temperatures for 1,005 inland water bodies in Japan has been updated to the version 3 with the function of near real-time updating. Water temperature is a key environmental factor for ecosystems in an inland water body, and the SatLARTD-J is expected to give some contributions to various fields including biodiversity conservation. As a next step, we are currently developing the world version of SatLARTD for future release.

## ACKNOWLEDGEMENT

This project has been supported by Grant-in-Aid for Scientific Research (KAKENHI) of The Ministry of Education, Culture, Sports, Science and Technology (MEXT) (Research No. 21710003). The original ASTER data used were provided by the National Institute of Advanced Industrial Science and Technology (AIST).

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**Fig. 1 Locations of 1,005 inland water bodies registered in the SatLARTD-J version 3.**

**Fig. 2 Top page of the SatLARTD-J version 3 (http://tonolab.cis.ibaraki.ac.jp/SatLARTD/).**

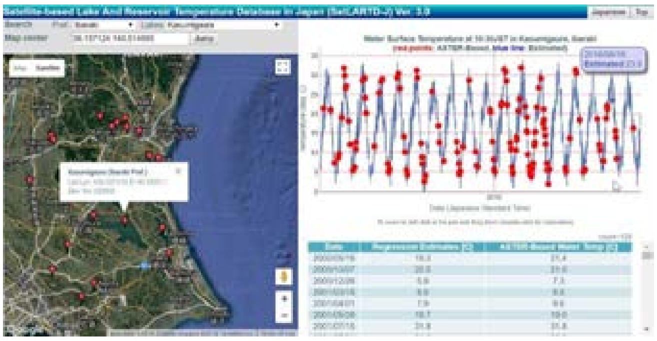

**Fig. 3 Example of viewing plots and values of water surface temperature for Lake Kasumigaura (lake center), Ibaraki Prefecture.**


**Fig. 4 Enlarged plots of water surface temperature for Lake Kasumigaura (red points: ASTER estimates, blue line: regression estimates).**

P6-12

# Improvement of hydrological and hydraulic model by applying satellite-based precipitation in the Tonle Sap Lake

Ichiro Yoneda[1], Hideto Fujii[1] and Yoichi Fujihara[2]
[1] Faculty of Agriculture, Yamagata University,
[2] Faculty of Bio-resources and Environmental Sciences, Ishikawa Prefectural University

Keywords: Satellite precipitation, Hydrological and hydraulic model, The Tonle Sap Lake, Monitoring technology

**ABSTRACT**

The Tonle Sap Lake in Cambodia is the largest fresh water lake in Southeast Asia. The diverse ecosystems of the Lake provides huge amount of fresh water and foods to humanbeing, animal and plants. However, hydrological and hydraulic conditions of the lake are changing by climate change and hydropower production in the upstream of the Mekong River. Hydrological and hydraulic models are powerful tools to understand these situations. Due to poor measuring density of gauge-based precipitation in Cambodia, the satellite-based precipitation GPCP is used in this paper with an objective to improve the reproduction accuracy of hydrological and hydraulic model of The Tonle Sap Lake basin in Cambodia. Since original GPCP tend to be larger value than gauge-based precipitation, bias adustment was carried out and then inputted to hydrological and hydraulic model. Nash-Sutcliffe efficiency (NSE) was used for the accuracy evaluation. Evaluation factors are precipitation, runoff discharge from each watershed to the lake and water level at Kg.Luong, which is a representative water level station of the lake. The findings are as follows. 1) NSE of GPCP before and after adustment against gauge based rainfall was improved from 0.043 to 0.748. 2) By replacing gauge-based pricipitation to adjusted GPCP, the NSE value of runoff discharge from the Chinit River watershed was improved from 0.694 to 0.817. 3) NSE of water level at Kg. Luong was improved from 0.971 to 0.986 by replacing gauge-based precipitation to adjusted GPCP.

## 1 Introduction

The Tonle Sap Lake basin in Cambodia is one of the major catchment of the Mekong River (**Figure 1**). It is the largest fresh water lake in Southeast Asia. The Lake has unique hydrological characteristics, where water area and storage volume changes greatly between wet and dry season every year. This is because water flows into the Lake from the Mekong via Tonle Sap River when water level of the Mekong is higher than that of the Lake in rainy season. The Lake plays important roles of rich biodiversity of aquatic ecosystems, in addition, it supplies highly productive aquatic animals with humankind [1]. Since it is driven by unique flood pulse, maintenance and understanding of hydrological and hydraulic conditions are necessary to sustain current ecological environment.

Recently, impact of climate change and development in Mekong is being assessed [2]. Current hydrological and hydraulic conditions of the Lake is predicted to change in the future.

Hydrological and hydraulic models support to grasp these current and future conditions. They need a lot of current meteorological data. However, in Cambodia, it is difficult to obtain enough number of gage-based meteorological data such as precipitation and evaporation. Without precipitation data, it is difficult to evaluate and assess the current hydrological situation by hydrological and hydraulic model.


**Figure 1 Map of the Tonle Sap Lake basin**

On the other hand, satellite-based precipitation data estimated by satellite have been developed in recent years. Applying satellite-based precipitation data is an advantage in an area where gauge-based observations are poor such as Cambodia [3].

The objective of this study is to improve reproduction accuracy of hydrological and hydraulic model by replacing gauge-based precipitation to satellite-based precipitation (GPCP).

## 2 Study area and period

Study area of the Tonle Sap Lake basin is shown in **Figure 1**. The minimum lake area is about 2,500km$^2$ in dry season, and it expands about six times larger to about

16,000km[2] in rainy season. The Lake has inflow from 12 tributaries and total catchment area is about 83,000km[2] (**Table 1**).

Study period for calibration is 1998-2002 and validation period is 2010-2015.

**Table.1 Catchment area of 12 tributaries**

| Name | Area[km²] | Name | Area[km²] |
|---|---|---|---|
| 1,Chinit | 8,240 | 7,Sisophone | 4,310 |
| 2,Sen | 16,360 | 8,M.K.Borey | 10,570 |
| 3,Staung | 4,360 | 9,Sangker | 6,050 |
| 4,Chikreng | 2,710 | 10,Dauntri | 3,700 |
| 5,Siem Reap | 3,620 | 11,Pursat | 5,970 |
| 6,Sreng | 9,990 | 12,Baribo | 7,150 |
| | | Total | 83,010 |

## 3 Methods

### 3.1 Hydrological and hydraulic model

In this study MIKE11 and MIKE-NAM, developed by DHI – Water & Environment, Denmark, are used as an 1-dimensional hydraulic and hydrological model [4].

### 3.2 GPCP

GPCP (Global Precipitation Climatology Project) one-degree daily [5] is selected as a satellite precipitation. It is based on satellite observation and its spatial and temporal resolutions are 1°×1° latitude/longitude and daily, respectively.

Since provided GPCP compared with gauge based precipitation tend to be larger than gauge based precipitation, it is adjusted and inputted to the hydrological and hydraulic model.

### 3.3 GPCP adjustment

Method of GPCP adjustment is as following equations.

$$C_{ij}=\frac{\frac{1}{n}\sum_{t=1}^{n} Robs_{ij}}{\frac{1}{5}\sum_{t=1}^{5} RGPCP_{ij}} \quad (1)$$

$$AGPCP_{ij}=C_{ij}*OGPCP_{ij} \quad (2)$$

Where i: cell number of longitudinal direction, j: cell number of latitudinal direction, C: adjustment factor, t: number of analyzed years, n: number of data existing years, Robs: accumulative gauge based precipitation in rainy season interpolated by Kriging method, RGPCP: accumulative original GPCP in rainy season, AGPCP: adjusted daily GPCP, OGPCP: original daily GPCP.

### 3.4 Evaluation function

Nash-Sutcliffe efficiency (NSE) [6] is applied as evaluation function. It is defined by the following equation.

$$NSE=1-\frac{\Sigma(X_{obs}-X_{cal})^2}{\Sigma(X_{obs}-\bar{X}_{0bs})^2}, \quad -\infty<NSE\leq 1 \quad (3)$$

Where $X_{obs}$: observed value, $\bar{X}_{obs}$: mean of all values, $X_{cal}$: calculated value.

### 3.5 Evaluation factor

Evaluation factors are as follows: 1. Precipitation at five stations (Kg.Thom, Siem Reap, Kg.Chhnang, Pursat, Battambang), 2.Runoff discharge from six watersheds (Chinit, Sen, Staung, Chikreng, Pursat, Boribo) to the lake, six watersheds which doesn't have enough gauge based water level are excluded, and 3.Water level at Kg.Luong, which is a representative water level station of the lake.

## 4 Result and Discussion

### 4.1 Precipitation

Monthly precipitation of Original GPCP and adjusted GPCP are compared against gauge-based precipitation at Kg.Thom in calibration period (**Figure 2**). NSEs of original and adjusted GPCP were 0.043 and 0.748 respectively. Mean NSE of GPCP at five stations are shown in **Table 2**. The NSEs of adjusted GPCP were better than those of original GPCP at almost stations.

**Table 2 Mean NSE of GPCP at five stations.**

| | Calibration | Validation |
|---|---|---|
| Original GPCP | 0.296 | 0.337 |
| Adjusted GPCP | 0.717 | 0.675 |

### 4.2 Runoff discharge

**Table 3** shows the meaning of term Obs, Cal-A and Cal-B. NSEs were calculated between Obs and Cal-A, and also between Obs and Cal-B. **Figure 3** shows comparison of runoff discharge in Chinit River basin in calibration period. NSEs of Cal-A and Cal-B were 0.694 and 0.817, respectively. **Table 4** shows mean NSE of runoff discharge in six watersheds. Mean NSE of Cal-B is better than that of Cal-A. In other words, hydrological model using

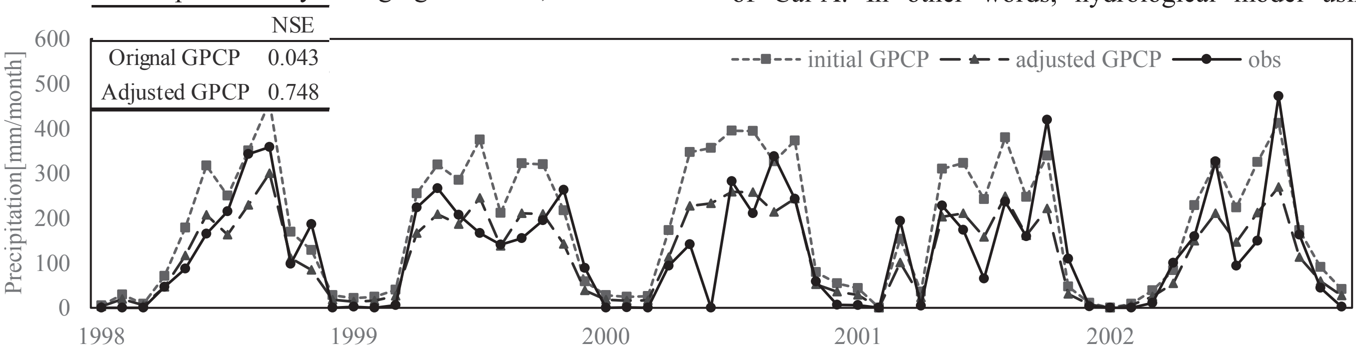


**Figure 2 Comparison of three kind of monthly precipitation at Kg.Thom in calibration period**

adjusted GPCP was improved the reproduction accuracy. This is because GPCP is able to supplement the precipitation in the upper part of the basin where has no gauge-based observation data. Runoff of Cal-B shows better NSE (mean NSE was 0.472 in both calibration and validation) than Cal-A, even though it doesn't show satisfactory accuracy. This may be due to the limitation of lumped model in large catchment areas.

**Table 4 Mean NSEs of runoff from six basins and NSEs of water level at Kg. Luong.**

| | Calibration | | Validation | |
|---|---|---|---|---|
| | Runoff | Water level | Runoff | Water Level |
| Cal-A | 0.420 | 0.971 | | |
| Cal-B | 0.472 | 0.986 | 0.472 | 0.976 |

* Cal-A calculate only calibration period.

### 4.3 Water level in the lake

**Table 4** also shows NSEs of water level at Kg. Luong. The NSE of Cal-A and Cal-B were 0.971 and 0.986 respectively in calibration periods. **Figure 4** shows the comparison of water level among observed, Cal-A and Cal-B at Kg.Luong in calibration period. The result of hydrological and hydraulic model using adjusted GPCP also has shown good accuracy both in calibration and validation. Cal-B was slightly better than Cal-A.

## 5 Conclusion

In this study through replacing gauge-based rainfall to adjusted GPCP, the reproduction accuracy of the hydrologic and hydraulic models were improved both runoff discharge from watershed and water level at Kg. Luong.

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**Table 3 Meaning of term Obs, Cal-A and Cal-B.**

| Name | Explanation |
|---|---|
| Obs | Runoff : Runoff discharge from rating curve[7].<br>Water level : gauge based water level at Kg Luong. |
| Cal-A | Calculated value by hydrological and hydraulic model using gauge based precipitation. |
| Cal-B | Calculated value by hydrological and hydraulic model using adjusted GPCP. |

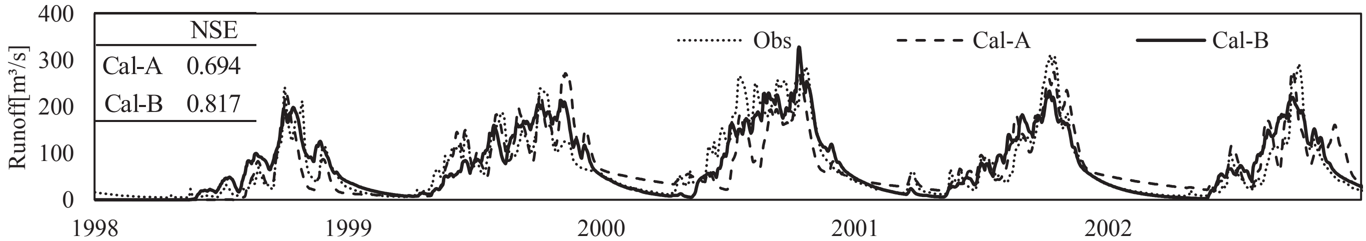


**Figure 3 Comparison of runoff discharge in the Chinit river basin in calibration period.**

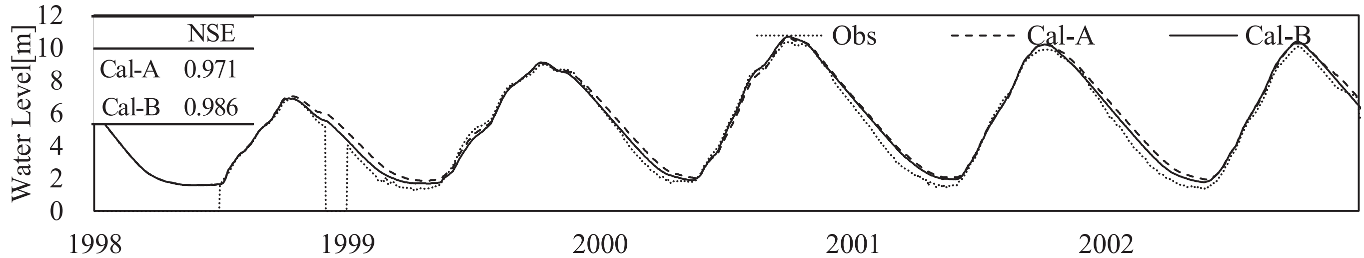


**Figure 4 Comparison among observed, Cal-A and Cal-B of water level at Kg.Luong in calibration period.**

**P6-13**

# Spatiotemporal Variability of Chlorophyll-a Concentration in Lake Malawi using MERIS Data

Augusto Vundo [1,4]*, Bunkei Matsushita[2], Takehiko Fukushima[3]

[1]Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, 305-8572, Japan

[2]Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, 305-8572, Japan

[3]Ibaraki Kasumigaura Environmental Science Center, Tsuchiura, Ibaraki, 300-0023, Japan

[4]Pedagogical University, Nampula Branch, Nampula, 256, Mozambique

Keywords: Chlorophyll-a, Remote Sensing, MERIS, Lake Malawi

**ABSTRACT**

Lake Malawi is one of the most important lakes in Africa, due to its biodiversity and usefulness to the adjacent populations. However, some anthropogenic activities can threaten its water quality and ecosystem services. Lack of a systematic regular monitoring of chlorophyll-a (Chl-a) concentration, and understanding of its spatial and temporal variation are some of the drawbacks. In this study we propose the use of MERIS Level 1B data to monitor the lake's Chl-a concentration, and its spatial and temporal distribution. Using the NASA's standard OC4E_v6 algorithm for clear water, Chl-a concentration was retrieved, during the 2003-2011 period. The highest mean concentration (> 1 mg $m^{-3}$ ) for the entire lake was found in 2003. Since then the values dropped to a mean value below 1 mg $m^{-3}$. Nevertheless, the results showed a slight increase along the years although in small concentration. The Western and Southern part of the lake proved to be the most affected, having a mean Chl-a concentration around 5 mg $m^{-3}$ , probably influenced by the anthropogenic activities in these areas, as the population pressure is high. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season.

## 1. INTRODUCTION

Freshwater accounts for around 2.5% of total global water from which surface fresh water is about 1.2% and lakes 20.9% of the surface freshwater[1]. As the numbers above show, lake water is part of a very small percentage of fresh water available for direct use on earth. Lake Malawi is one of the most important lakes in Africa along with Tanganyika and Victoria. It is the source of fresh water, fishery products, and a variety of benefits to the bordering countries of the lake basin. It is located between (09° 30' -14° 40' S, 33° 50' - 33° 36' E, 472 m amsl) and also known as Niassa in Mozambique and Nyasa in Tanzania, but internationally and scientifically known as Lake Malawi. This lake is the 3rd largest lake in Africa after Victoria and Tanganyika and the 9th largest in the world[2]. Due to its location, Lake Malawi experiences three different seasonal variations in temperature, wind, and precipitation, here after from November to April Season one (S1), Season two (S2) May to August, and Season three (S3) from September to October. Chlorophyll-a (Chl-a) is tested in lakes to determine how much algae is in the lake, and algae is important in lakes because it adds oxygen to the water as a by-product of photosynthesis. On the other hand, if there is too much algae in a lake it can produce a foul odor which can be harmful to the people[3]. Therefore, understanding Chl-a concentration, its spatial and temporal variation in Lake Malawi is of paramount importance.

## 2. METHOD

We propose the use of MERIS Level 1B data downloaded from [4] to monitor Lake Malawi's Chl-a concentration, and its spatiotemporal distribution. The outputs from the atmospheric correction Neural Network (NN) of Case 2 Regional (C2R) processor, water-leaving reflectance were used as input for the calculation of Chl-a concentration. The C2R processor underwent a validation process for atmospherically corrected water-leaving reflectance[5]. Due to the known characteristics of Lake Malawi (clear water), NASA's standard MERIS OC4E_version_6 [6] was found to be the ideal model to retrieve Chl-a. This is a blue and green band ratio algorithm aimed at clear waters. The algorithm is expressed as follows:

$$\mathrm{Chla}_{\mathrm{OC4Ev6}} = 10^{(0.3255-2.7677b+2.4409b^2-1.1288b^3-0.4990b^4)}$$

where $b$ is the $\log_{10}$ of the maximum band ratio of the three bands at the Rrs443, Rrs490, Rrs510 to
Rrs560 and the coefficients were derived using version 2 of the NASA bio-Optical Marine Algorithm Data set (NOMAD) [6].

## 3. RESULTS

In this study, periods of peak of Chl-a were detected as well as their seasonal variability, which was complemented with the long-term change variation. Chl-a mean value-based maps were produced for yearly data.

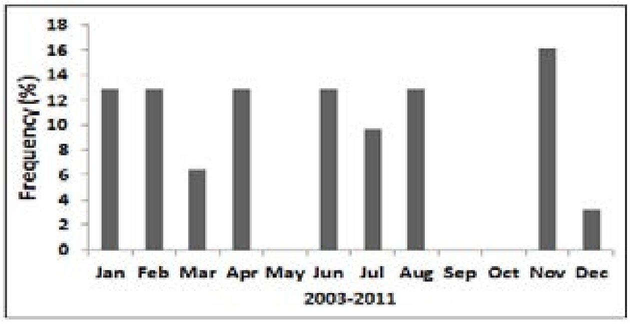


**Fig 1. Monthly mean distribution of chla peaks for the period from 2003 to 2011.**

As shown in Fig 1, no peaks were found in May, September, and October for the entire study period. However, March and December showed peak availability less than 10%. Contrary to previous months, November shows the highest peak frequency more than 14% followed by January, February, April, June, and August. These results go along with [7] regarding the peak found in April 2012 in their study and shows other peak seasons that were not detected by *in situ* measurements. The fraction of peak distribution throughout the months shows that S1 is the most active in terms photosynthesis in Lake Malawi. Fig 2 illustrates the Chl-a concentration range based on the annual mean value.

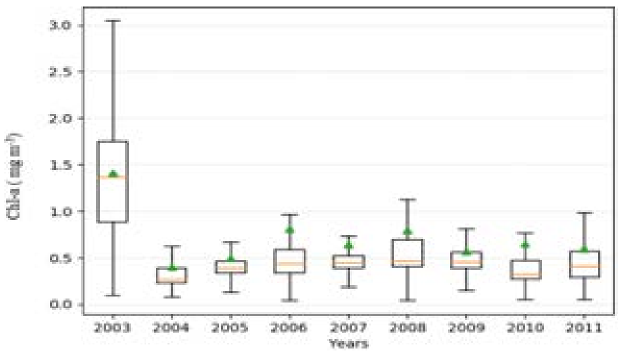


**Fig 2. Temporal Variability of Chl-a.**

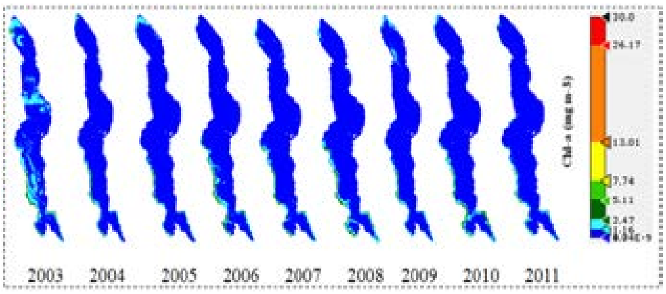


**Fig 3. Spatial Variability of Chl-a**

Figure 3, shows Chl-a spatial distribution during the 9 years of study. The first year of the study revealed to be the most spatially dynamic compared to other years. Generally, the mean Chl-a value in fig. 2 are (< 1 mg $m^{-3}$), represented by the green triangle.

## 4. DISCUSSION

After the abnormality in Chl-a spatial distribution in 2003, the yearly variation stabilized to a smooth but noticeable increase from 2004 to 2008 and an oscillation between 2009 and 2011. Throughout the 9 years of study, it was found that the highest values of Chl-a are found in the northern region of Lake Malawi, and in the central region with distinct attention to the West coast of the central and southern part of the lake. This is particularly true and goes along with formerly published papers [7,8] indicating the influence of anthropogenic activities. Chl-a detected in this corresponding area varies from 1.16 to 7.74 (mg $m^{-3}$).

## 5. CONCLUSION

During the 9 years of study using remote sensing data, S1 showed to be the most influential. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season. Although 2003 presented high Chl-a values the rest of the years show low Chl-a concentration values, therefore the lake can still be considered as clear (oligotrophic). However, this trend tends to change, suggesting an increase in Chl-a concentration in the Lake.

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**P6-14**

# Unmanned vehicle on water quality monitoring in reservoir

Sheng-Jie You[1], Ya-Fen Wang[1], Jui-Hsiang Liu[2], Yi-Han Chen[2]

[1] Department of Environmental Engineering, Chung Yuan Christian University, [2] Environment Protection Administration, Executive Yuan

Keywords: Water quality; Real-time monitoring; Unmanned vehicle; Internet of things (IOT)

**ABSTRACT**

Baoshan Reservoir supplies water to the Hsinchu Science Park in Taiwan, because the high-tech wafer process requires a lot of pure water. Therefore, how to ensure the water quality and stability of Baoshan Resevoir is particularly important. Due to that Baoshan Resevoir is an off channel reservoir, it can select the water source from Shig-Ping Weir to avoid Inferior quality water flows into Baoshan reservoir. There are many pollution sources because of prevalence of agriculture and a lot of residential buildings around Baoshan Reservoir. Monitoring the water quality of Baoshan Reservoir by unmanned vehicles, and establish the pollution hotspots to provide a scientific evidence to the reservoir management, and further set up appropriate pollution reduction facilities. At present, specific sites monitoring or manual sampling detection are the most common method in Taiwan. However, manual sampling is time-consuming and can not be monitored over a long period of time. Specific sites monitoring can not be adjusted according to the level of water level monitoring points. As the specific sites monitoring can not represent the whole area of water quality, and there may be aquatic organisms and plant attached, the cost of setting up number of specific sites monitoring point will be too high. It can be effectively lower the cost by using unmanned vehicles equipped with direct reading instrumentation MAX-RS485 multiparameter water quality detector, the data can through the Internet of things (IOT) back to the server, then remote control and give instruction to confirm the reservoir water quality changes and the source of nutrients.

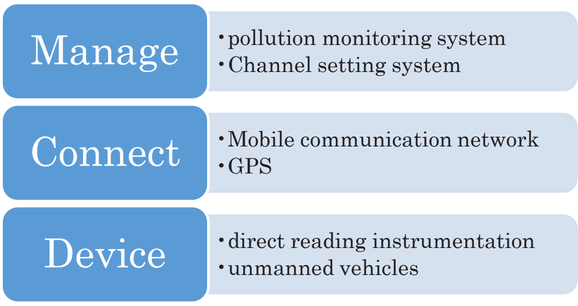
## 1. INTRODUCTION

Unmanned vehicle on water quality monitoring is mainly divided into two parts: water quality testing and unmanned the body of boat. This unmanned monitor utilize a commercial water quality detector to monitor the water quality on the route through the preset task route. By measuring the water quality data every 15 seconds via the underwater direct reading perceptron, the coordinates and data are transmitted to the database for analysis by the mobile communication network after the return to the surface buoy. Through the hull of t built-in GPS , unmanned vehicle can fix a double motor output power and adjustt direction back to set the task route, once the offset Angle is above 40 degrees electricity And while the battery is low, it will automatically go back to the setting point to charge it. In this study, seven main monitoring points were established after understand the geographical information of baoshan reservoir and further site investigation through GIS. These 7 main monitoring points are respectively: 1. the more domain the water outlet 2. drawbridge 3. densely populated residential areas 4. tourist restaurant 5. farmland 6. camp site 7. orchard. The 7 points are covered in the whole baoshan reservoir, and the data was collected through the unmanned water quality monitoring vehicle, which can be analyzed the contaminated hot zone of the whole area.

## 2. METHOD

MAX-RS485 multiparameter water quality detector is a circular cylindrical monitor that can be fitted with a variety of water quality parameter monitors, including pressure(SMR01), pH(SMR04), conductivity(SMR07), dissolved oxygen(SMR09), turbidity(SMR10), chlorophyll A(SMR35), potassium ion(SMR39).

The concept of this unmanned vehicles applies the internet of things, can be divided into three classes: Device, Connect, and Manage. In the Device section, there are six sensors and hulls, the sensed water quality data, GPS and hull walking routes and related hull data, will use the mobile network to transfer to the manager's server for calculation through the Connect section. In the Manage section, there are water quality monitoring management system and hull management system, water quality monitoring and management system will have been calculated in the server information, and presented in the monitoring program with immediate coordinates, pH, conductivity, dissolved oxygen, turbidity, chlorophyll A and potassium ions. Hull management system can plan the walking routes in advance, and get the direction of travel, location and speed data immediately. When the hull management system found that the hull is in the direction of deviation, it will send a modified order to the hull, to amend the direction of the direction.




This study used the interpolation method of Topo To Raster embedded in ARCGIS, The data was measured by the unmanned vehicles equipped with direct reading instrumentation, after calculating by interpolation, analysis the depth and pollution distribution of the Reservoir, then display by 2D plane space, so that the value of the parameters of the reservoir is very clear.

## 3. RESULTS AND DISCUSSION

At present, we utilize MAX-RS485 techniche to conduct the water quality monitoring, the monitored parameters includes pH, conductivity, DO, turbidity, chlorophyll-a, and potassium ion. The related results are shown as follows.

(1) pH

The PH value measured by MAX RS485 is between 9.1 and 9.7. In Fig. 1, The water quality in the reservoir is alkaline and a case of eutrophication as a result of intense photosynthesis. And the pH valua is increasing suddenly at 5, 6 and 7 point, bacause the water flow rate is not high and the distance is far from the inlet and outlet.

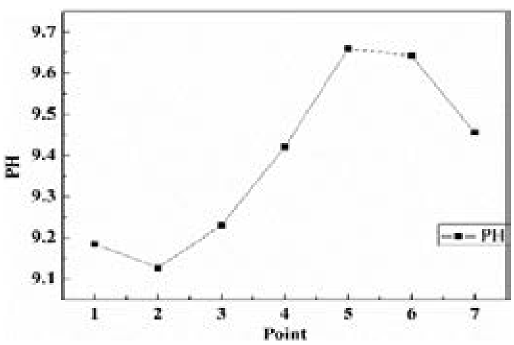



Fig.1 pH concentration distribution

(2) Conductivity

The conductivity measured by MAX RS485 is 190~205 µs/cm. As shown in Fig.2, the conductivity is much higher at 1, 2 and 3 point, because these points are located at the inlet and outlet path and have high concentration of pollutants. The 3 point is close to the residential areas, leading to a highest conductivity.

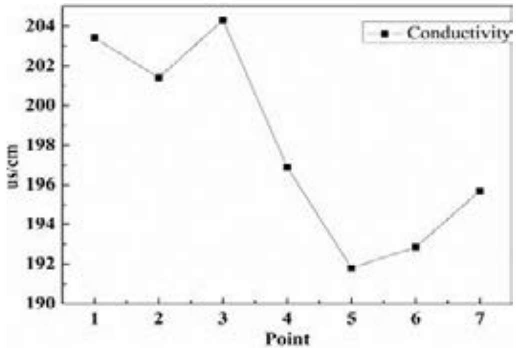



Fig.2 Conductivity concentration distribution

(3) DO

The DO value measured by MAX RS485 is 9~12 mg/L. In Fig.3, DO value is increasing orderly. Due to the slow flow and huge ammount of algae, direct solar radiation can cause the supersaturated state on water quality, it would be accompanied by high PH and the phenomenon of algal blooms. Turbidity

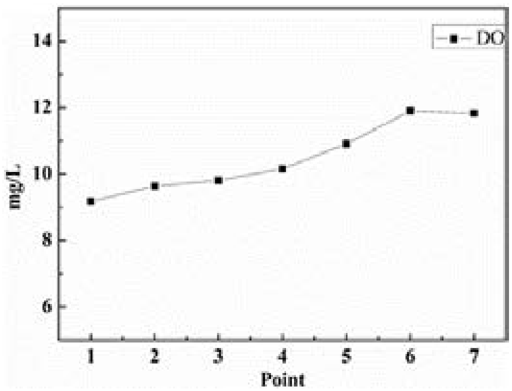



Fig.3 DO concentration distribution

(4) Turbidity

The turbidity measured by MAX RS485 is 5~7 NTU. In Fig.4, the overall turbidity value keep a good condition due to the sunny day and slow water flow.

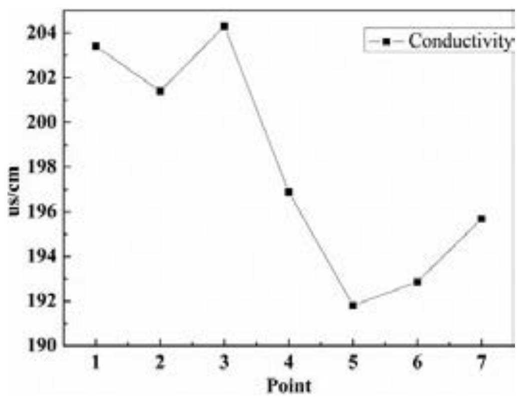



Fig.4 Turbidity concentration distribution

(5) Chlorophyll-a

The chlorophyll-a measured by MAX RS485 is 0~3 ppb. As shown in Fig.5 and Fig.6, If the status of the water quality status is only determined by Chlorophyll-a, the degree of the eutrophication is the ordinary level.

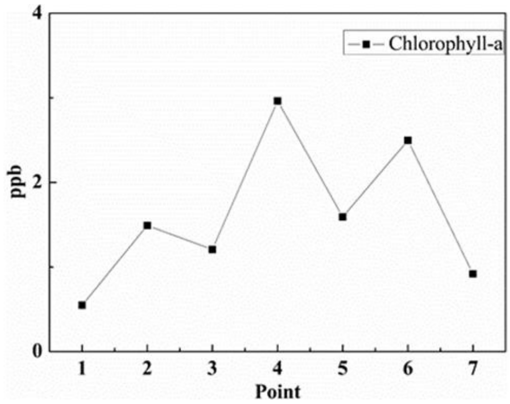



Fig.5 Chlorophyll-a concentration distribution

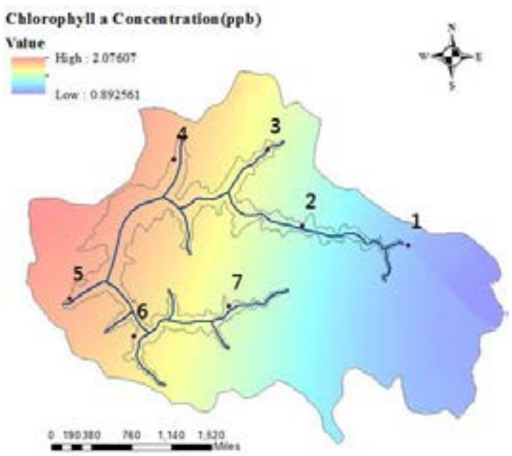



Fig.6 Chlorophyll-a concentration distribution by GIS

## 4. CONCLUSION

The tested resulted show that the temperature of water, pH, dissolved oxygen no obvious fluctuation. Conductivity is up to 204.31µs/cm at densely populated residential areas; Turbidity in orchard is up to the highest at 6.46NTU; Potassium ions at the more domain the water outlet were the highest at 0.29 ppm. Due to utilizing the public information supplied by government, we know that Baoshan Reservoir is at the edge of the eutrophication. Unmanned water quality vehicle can further help us research the source of pollution, analyze the proportion of pollution sources, real-time monitor of water quality for a long time monitoring.

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**P6-15**

# イラン国アンザリ湿原におけるドローンを活用した違法狩猟管理の試行

渡辺　仁[1], 青木　智男[1]

[1] 日本工営(株) コンサルタント海外事業本部 環境技術部

キーワード:ドローン、保護区管理、違法狩猟管理、ラムサール条約、モニタリング

## 抄録

One of the project activities supported by Japan International Cooperation Agency(JICA) under the Anzali Wetland Ecological Management Project - Phase II in Gilan Province, Iran, is to strengthen management capability for conservation of the wetland. Since many waterfowls such as wild geese and ducks come flying into the Anzali Wetland in winter, citizens are permitted to hunt them for food and recreation as an ecological service of the wetland. The hunting is permitted outside the protected areas of the wetland under limited license which is issued by Department of Environment of Iran. However, in practice, due to the large 193 km$^2$ area of the wetland and lack of human resource, capability, equipment, and budget for the rangers, illegal hunting activities are occurring both outside and inside of the protected areas. We will report on utilization of drones as conservation management tools for detection and monitoring of the illegal hunting and hunting nets hidden in the reeds.

## 1. はじめに

### (1) アンザリ湿原の概要

アンザリ湿原は、1975 年にラムサール条約湿地に登録されたイラン北部カスピ海南岸に位置する約 193 km$^2$ の湿地である。カスピ海と連動する広大な湿地は、渡り鳥や魚類等にとって国際的に極めて重要な生息地である一方で、過剰な狩猟、カスピ海の水位変動、土砂堆積、水質汚濁、外来水生植物の繁茂等の環境劣化を理由に、1993 年に優先的な保全措置が必要な湿地リスト(モントルーレコード)に加えられた。

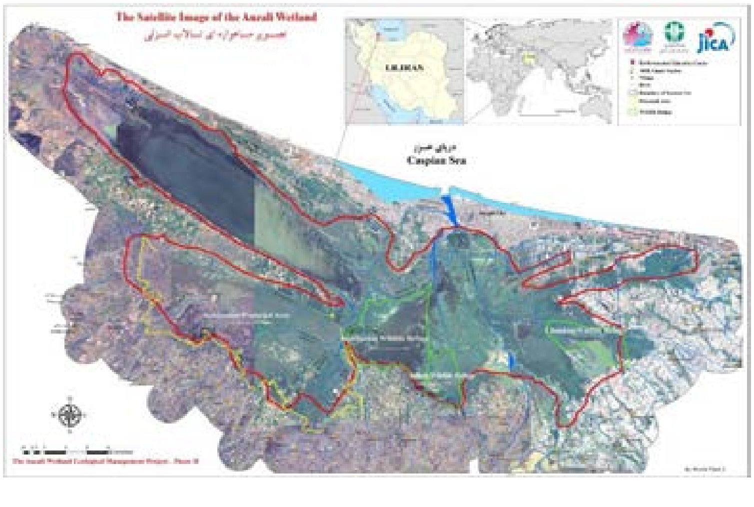


**図 1 アンザリ湿原マップ**(赤線はラムサール条約指定湿地の境界)

### (2) プロジェクトの背景

以上の状況を踏まえ、イラン国政府からの要請に応じ、JICA はこれまで「アンザリ湿原生態系保全総合管理計画調査」[1]および「アンザリ湿原環境管理プロジェクト・フェーズ I」[2]を実施支援してきた。今般、さらなるイラン国政府の要請に応じて、JICA は「アンザリ湿原環境管理プロジェクト・フェーズ II」(以下、本プロジェクト)を 2014 年から開始し、総合的な湿原管理の本格的な仕組み作りと保全施策の実施支援に取り組んでいる。なお、日本工営は JICA の委託を受けて当初より全般の業務を行っている。

### (3) プロジェクトの目的

本プロジェクトでは、アンザリ湿原の美しい水流、豊かな生態系の保全及び地域住民が関係機関との関係強化のもとワイズユースが実現できる事を目指すとともに、アンザリ湿原で確立される総合的な湿原管理システムがイラン国内に普及され、さらに近隣諸国においてもモデルとして認知されることを目指している。

プロジェクト目標は、「アンザリ湿原に関わる全関係機関の効果的な関与による湿原の総合的管理の確立」とし、以下の成果の達成に向けた活動を実施している。

・アンザリ湿原管理委員会の能力の強化
・日イ共同のパイロット活動(試行)の特定・実施
・プロジェクトで得られた知見と経験のイ国内および海外への共有

### (4) プロジェクト期間

2014 年 3 月～2019 年 5 月(約 5 年間)

### (5) プロジェクト内容

第 1 年次には、2005 年に JICA の支援で策定したマ

スタープラン（アンザリ湿原保全の総合管理計画）とその後のイラン側の取り組みを見直す形でプロジェクト期間中に実施すべき各分野（①湿原生態系保全（保全再生施策、モニタリング、ゾーニング及び土地利用管理）、②流域管理、③汚水管理、④廃棄物管理、⑤エコツーリズム、⑥環境教育）の施策のアクションプラン（実施計画）を策定した。その後、アクションプランの中から優先施策を共同パイロット活動として選定し、イラン国環境庁やギラン州政府などイラン側関係機関と共に実施することにより、「イラン国が独自に施策の継続実施を行っていくための技術移転」及び「プロジェクトサイクル（PDCA)の定着」を図ることを目的として現在実施中である。また、これらの結果を踏まえた上で、プロジェクト終了後のイラン国における継続的な施策実施のためのミッドタームプランの策定を今後行う予定である。

（6） 共同パイロット活動（レンジャーの管理能力の強化）

プロジェクトで行っている各分野の共同パイロット活動は数多くあり、そのうちの一つが、湿原生態系保全の分野で行っている保護区におけるレンジャーの管理能力の強化である。

## 2. 方法

(1)違法狩猟の背景

当湿地では、冬季にガンカモ類をはじめとする多くの水鳥が越冬のために渡来し、生態系サービスとして食料やレクリエーションのために市民は狩猟を行っている。市民は、保護区の外側でイラン国環境庁のライセンスを取得することで限定的な狩猟が許されている。しかし実際のところは、湿地の面積が 193 $km^2$ と広大であり、湿原内に 5 箇所あるレンジャーステーションでは 30 名がシフト勤務しているものの、レンジャーの人数、能力、機材及び予算の不足により、保護区の内外において、違法狩猟が十分には管理できていない状況である。レンジャーは、水域は主にモーターボートでパトロールしているが、水深が浅いためアクセスできなかったり、また予算不足で燃料が制限されたりして違法狩猟者を十分取り締まれていない状況にある。特に、水路から目の届かないヨシ原の中では、大規模なかすみ網の網場が設置されて、カモ類の違法な狩猟が行われていても発見するのが難しい。散弾銃やライフルによる狩猟と比較して、大規模なかすみ網は一度に数百羽を捕獲できることもあり、これらの管理が課題となっている。特に 2017～18 年は、鳥インフルエンザの蔓延から、イラン国環境庁により全ての狩猟ライセンスの発行が停止されており、あらゆる狩猟が禁止されているにもかかわらず、地元レストラン等に野生カモ類等の料理が普通に出回っている等、違法狩猟の管理が十分でなかった。世界中の水鳥のデータを解析した研究[3]でも、カモ類が最も減少しているのはイランを含む中央アジアとされており、その原因として保護区の違法狩猟の管理が十分でないことが挙げられている。これらの状況を踏まえると、10 万羽以上の水鳥が越冬するアンザリ湿原の違法狩猟の適切な取締りは国際的にも重要な課題であると言える。

**図 2 当湿原周辺でかすみ網により大量捕獲されたコガモ**

(2)ドローンによるパトロールの試験

イラン国環境庁のレンジャーと合同で、昨冬 2 月及び 3 月に計 4 度、市販のドローン（DJI Phantom 4 Pro）で湿原の保護区をパトロールし、発見後に取締り（網場や作業場の撤去）を行った。

具体的には保護区周辺から離陸させ、半径 2 キロ程度以内のヨシ原上空や岸沿いを低空（約 20 m程度）で飛翔し、標準搭載ビデオで録画を行った。当該湿地は広大であるため、離陸地点を移動し、なるべく広範囲をスキャンできるように録画した。録画映像は、事務所にて、大型モニター（Full HD 42 インチモニター）にて再生し、かすみ網を発見に努めた。

**図 3 イラン国環境庁レンジャーとの合同パトロール**

## 3. 結果

パトロールの結果、6 箇所での網場を発見した。発見後、ドローンの GPS ログデータや映像の地形的特徴から、網の位置を地図に記録し、レンジャーに連絡した。レンジャーは地図をもとに、速やかに現場に急行し、かすみ網や作業場を撤去した。ハンターが不在だったため、現行犯逮捕とはならなかったが全施設の撤去に成功した。


図 4 レンジャー事務所から 900 m 先で確認された網場

図 5 狩猟者の作業小屋（上空からでも発見しにくい）

図 6 レンジャーにより撤去中のかすみ網

## 4. 考察

ドローンからはリアルタイムで映像が転送されるものの、明るい屋外の現場では、タブレットのモニターは暗く小画面であるためかすみ網は見えづらく発見は難しかった。そのため、事務所での大型高精細（Full HD）モニターで再生確認作業が必要となった。かすみ網は Full HD モニターでは、確認することができた。

本手法は、GPS の飛行ログを使っての位置の特定も容易であり、十分実用レベルと考えられる。

なお、当該ドローンは 4K で録画可能であり、モニターも 4K 対応にすることで、Full HD のモニターと比較して 4 倍の画素数となることから、さらに精度を高めた確認作業が可能となる。

## 5. 結論及び今後の課題

レンジャーによる従来手法（徒歩やボートによるパトロール）では発見しにくい、ヨシ原内の網場の発見やモニタリングにはドローンが効果的である事が確認された。イランにおいては、このようなドローンを使った狩猟管理は初めての試みである。

今後は、レンジャーによる日常的なパトロールに組み込むために、操縦及び機材保守のトレーニングや映像データのハンドリング方法のトレーニングにより技術移転を図っていく必要がある。ただし、ドローンによるパトロールが日常化すれば、違法狩猟者の銃撃等の妨害行為が予想され、被害を防ぐための飛行高度や操縦方法の最適化や、ドローンを喪失した場合のバックアップ体制等も検討していく必要があると思われる。これらの経験を活用して、イラン全域の保護区管理にドローンを活用していけば、国内における違法狩猟数の減少ひいては国際的な渡り鳥の保全に寄与できる可能性がある

また、ドローンは違法狩猟だけでなく、その他一般的な保護区管理ツールとして有効であり、本プロジェクトでは違法な土地利用の発見、植生モニタリング、広報素材の撮影などにも活用している。

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**P6-16**

# LC-MS/MS DETERMINATION OF ANTIBIOTICS AND HORMONES AND ITS APPLICATION IN LAKE WATER MONITORING

Maria Pythias Espino, Jonalyn Madriaga

Institute of Chemistry, College of Science, University of the Philippines, Quezon City, Philippines

Keywords: water quality, water pollution, monitoring technologies for lakes, water quality instruments

**ABSTRACT**

Many water contaminants are relatively stable and are not completely removed during wastewater treatment and post-discharge processes. In this study, a fast and sensitive LC-MS/MS method was optimized for the direct analysis of trace antibiotics and hormones in water. Water samples taken from Laguna Lake (Philippines) were filtered and analyzed without enrichment. The chromatographic separation was done using a C18 column and gradient elution of water-methanol with 0.10 % formic acid or 0.10 % ammonium hydroxide. Detection and quantitation were done using multiple reaction monitoring. The detection limits were 0.01-0.42 ug/L for the antibiotics and 0.01-0.07 ug/L for the hormones. Correlation of determination was >0.98 for each analyte in 0 to 100 ug/L concentration range. This method is suitable for routine monitoring of water contamination considering detection capability, sensitivity and specificity. Preliminary analysis of lake water samples from nine sampling sites in Laguna Lake shows that these antibiotics and hormones are not detected. Determination of the occurrence of these emerging contaminants is important particularly in the use of the lake for aquaculture and potable water production. Monitoring potentially harmful water contaminants in lakes is important especially in areas where the implementation of environmental policies is still a challenge.

## 1. INTRODUCTION

Many lakes especially in Asia are a source of livelihood for the surrounding communities. Human activities, however, may cause deterioration of the quality of water in these lakes. Lakes can be threatened with contamination due to anthropogenic chemicals including the emerging environmental contaminants. Such impact may compromise the productivity of lakes and the benefits that lake systems provide. Among the emerging contaminants now being studied in the environment are antibiotics and hormones. These contaminants may affect the health of the lake ecosystem as well as human health. Antibiotic resistance, for example, is now a major global concern. Pharmaceuticals such as antibiotics, natural hormones and estrogen-based contraceptives are now seen as environmental contaminants contributing to the pool of endocrine disrupting compounds in water systems [1,2].

Laguna Lake is the largest and one of the economically important lakes in the Philippines. It has many uses such as in fish cultivation, source of water for industrial and agricultural purposes, raw water source for water treatment plants, in transport and recreation, floodwater reservoir and as a final sink for effluents from the domestic, industrial and agricultural activities around the lake. Similar to other lakes in the world, Laguna Lake is also affected by continuous urban development and population growth. The west part of the lake is polluted mainly by effluents from industries and the urban sprawl, while the east part which is less populated takes in mostly agricultural discharges [3]. Together with the local government units, this lake is managed by the government through the Laguna Lake Development Authority. The conditions of the lake water are monitored by this government authority. The water quality parameters that are currently monitored do not include yet other potentially harmful emerging contaminants such as antibiotics and hormones.

In our project on "Endocrine Disruptors, Antibiotics and Heavy Metals in Laguna Lake Water: Impacts on Food and Water Security" funded by the Philippine Department of Science and Technology, we aim to optimize and validate analytical methods to be able to determine the occurrence and concentrations of emerging water contaminants. In this study, we explored the use of an optimized LC-MS/MS method without pre-concentration to determine the possible occurrence of antibiotics and hormones in

Laguna Lake water.

## 2. METHOD

Surface water samples were taken in January 2018 from the nine sampling sites in Laguna Lake that are regularly monitored by the Laguna Lake Development Authority (Figure 1). The water samples were stored in amber glass bottles and transported to the laboratory in ice chests. The samples were filtered and 1.5 mL of each sample was transferred into an autosample vial where the internal standards (ciprofloxacin-d8 and ß-estradiol-d2) were added. The samples were directly analyzed using a LC-TSQ triple quadrupole mass spectrometer (ThermoFisher Scientific). Calibration solutions were prepared in concentrations of 0-100 ug/L for the antibiotics (amoxicillin, cephalexin, cloxacillin, ciprofloxacin, penicillin G) and hormones (ethynylestradiol, ß-estradiol, estrone, progesterone, testosterone) in 10% methanol in water. Twenty microliters of each of the samples and the calibration solutions were injected into the column. The analytical separation was done on a BetaSil phenylhexyl column (50 mm x 2.1 mm x 3 um) using gradient elution of 10 to 90% methanol-water containing 0.1 % formic acid for antibiotics analysis and 0.1 % ammonium hydroxide for the hormones analysis. The total run time is 8 min. The ionization was ESI-positive and ESI-negative for antibiotics and hormones, respectively. Using the optimum instrumental parameters, the analytes were determined by multiple reaction monitoring.

## 3. RESULTS

Table 1 summarizes the MRM transitions used in the mass spectrometric determination of the antibiotics and hormones in water. Using a specific quantitation mass for each analyte, the detection limits were 0.01-0.42 ug/L for the antibiotics and 0.01-0.07 ug/L for the hormones. Correlation coefficients for the analytes were >0.98 in the 0.1 to 100 ug/L range. The analytical measurements were reproducible in the 5-100 ug/L concentration range with % RSD of <10.5% except for ciprofloxacin. The recoveries of 50 ug/L of the antibiotics or hormones spiked in lake water, tap water and bottled water are also summarized in Table 1. Analysis of the lake water samples from the nine sampling sites did not result in the detection of any of the antibiotics or hormones studied.

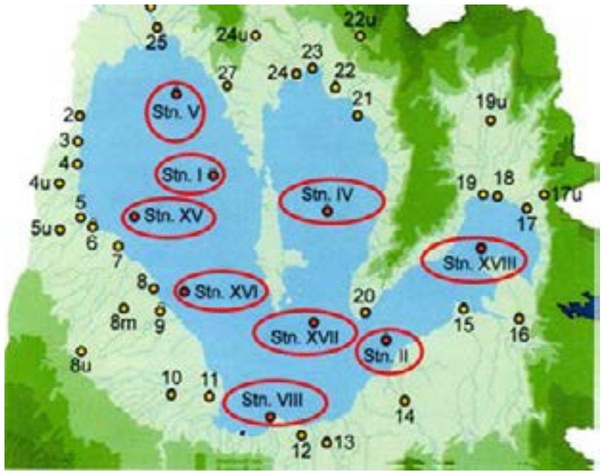


**Fig. 1 Sampling sites (encircled) in Laguna Lake**

**Table 1 Analytical determination of antibiotics and hormones in water**

| Compounds | MRM Transitions Precursor>Product[c] | Percent Recoveries[d] |
|---|---|---|
| Hormones[a]: | | |
| Ethynylestradiol | 295.2>*145.4*, 266.9 | 107-115 |
| β-Estradiol | 270.9>*183.0*, 147.2 | 107-108 |
| Estrone | 269>*145*, 143 | 98-117 |
| Progesterone | 315.1>*108.9*, 97 | 87-88 |
| Testosterone | 289>*109*, 106.9 | 88-92 |
| Antibiotics[b]: | | |
| Amoxicillin | 366.2>*160.41*, 114.11, 208 | - |
| Cefalexin | 348.3>*158.5*, 174.3 | 141-149 |
| Cloxacillin | 436.9>*277.7*, 160.1 | 79-109 |
| Penicillin G | 335.1>*160.1*, 176.1 | 82-88 |
| Ciprofloxacin | 332>*314*, 231, 288 | - |

[a]Recoveries calculated using internal calibration; [b]Recoveries calculated using external calibration; [c]Quantitation mass in *italics*; [d]50 ug/L spiked in lake, tap and bottled waters

## 4. 4. DISCUSSION

5. The analytical method presented for the determination of antibiotics and hormones in water without pre-concentration and using LC-MS/MS can be used in assessing contamination in lake water in terms of antibiotics and hormones. Since there is no pre-concentration involved, the method detection limits allow only for the measurements of the compounds above 0.01 ug/L or 10 ng/L. Below this concentration, the antibiotics and hormones cannot be quantified. Results of

this initial study suggest that the surface water in Laguna Lake does not contain the antibiotics and hormones in concentrations <10 ng/L. There is limited information on lake water contamination due to these compounds. For similar antibiotics, these compounds have been found in a lake in Turkey and in a lake China in concentrations below 4 ng/L (e.g., amoxicillin) and 2 ng/L (e.g., penicillin G), respectively[4,5]. For the hormones, a study in a lake in China showed concentrations between 0.03 and 0.28 ng/L for ethynylestradiol, ß-estradiol, estrone, progesterone, and testosterone[6]. The studies on these lakes show that antibiotics and hormones are found in low ng/L concentrations in the lake water. In the study on a lake in Turkey [4], the hormones were detected in between below detection limits and 11 ng/L. To date, these antibiotics and hormones are not yet detected above 10 ng/L in surface water samples from Laguna Lake. Extraction and pre-concentration using solid-phase extraction, for example, should be done to be able to determine the possible occurrence of these compounds in Laguna Lake water in concentrations below 10 ng/L. While antibiotics and hormones are not yet included in the regular monitoring of water contaminants in Laguna Lake, the method presented in this study can be used to quickly assess potential water contamination in the lake especially from water coming from the tributary rivers that run along urban, industrial and agricultural areas surrounding the lake.

## 5. CONCLUSION

Currently, emerging contaminants such as antibiotics (amoxicillin, cephalexin, cloxacillin, ciprofloxacin, penicillin G) and hormones (ethynylestradiol, ß-estradiol, estrone, progesterone, testosterone) are not yet detected above 10 ng/L in the surface waters of Laguna Lake.

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