# The Impact of Maintenance Dredging on Water Quality and Phytoplankton Standing Stock in Kwan Phayao Lake, Thailand

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Received 6 December 2006; accepted 30 April 2007

**Abstract**

This study focuses on the role of the lake dredging, the effect of seasonal changes and distribution of total suspended solids, changes in light levels, lake water quality and phytoplankton biomass in Kwan Phayao between November 2004 and October 2005. A water quality monitoring program was carried out in Kwan Phayao Lake, an internationally recognized wetland in the upper north region of Thailand, to determine the impact of lake dredging. Water samples were collected monthly from November 2004 to October 2005 at 10 stations. Results indicated extraordinary high total suspended solid (TSS) concentrations at the upper end of the lake during March and April 2005 when the inflow channel was being dredged. These high concentrations of TSS limited photosynthetic active radiation (PAR) light penetrating into the lake at depths of 60 cm and 40 cm in March and April, respectively. During July to October there were high water inflows into the lake with moderate TSS. During these months surface water was also partly covered by floating macrophytes, especially water hyacinth, resulting in low phytoplankton standing stock. Mean phytoplankton standing stocks, expressed as chlorophyll *a*, were higher than 100 mg $m^{-3}$ between March and May 2005 due to algal blooms. Among 10 stations where data were collected, the lowest chlorophyll *a* recordings were concurrently observed at the most turbid site. Dissolved oxygen (DO) concentrations near lake bottom of this sampling site were also usually lower than DO criteria for the survival of aquatic animals. No correlation between rainfall and TSS was found in this study. Results indicated that the dredging activity had a minor effect on surface water pH, DO, and water temperature. However, the impact on PAR, phytoplankton standing stock, and dissolved inorganic materials were locally prominent.
**Keywords**: Total suspended solid; Phytoplankton; Water quality; Kwan Phayao

## Introduction

Kwan Phayao Lake is one of the most important international recognition wetlands situated in the upper north of Thailand. It is a semi-natural wetlands including a permanent freshwater lake covering an area of approximately 1,980 hectars. At the northern end of the wetland is fed by the Nam Mae Ing river while at the southern end inflow is from the Nam Mae Tum channel. Ten small channels feed the western part of the wetland. Phayao city is situated on the south eastern fringe of the lake. The lake empties to the east, via the Nam Mae lng river which empties into the Mekong river in Chiang Rai Province. The water level of the lake is controlled by a sluice gate and a spillway at the Phayao Freshwater Fishery Research Station. Kwan Phayao Lake is a habitat for diverse aquatic living groups and services as a community source of freshwater fish, water supply, fresh water irrigation, and is also used for recreation. There are 13 local fishery communities around the lake which use primarily gill-nets. The standing crop of fish has been estimated at 159 kg/ha. Twenty-two species have been recorded, but just five species make up over 90% of the fish biomass. Chief among these are *Tilapia nilolica* (productivity 21.9 kg/ha/year) and *Anabas testudineus* (2.19 kg/ha/year) (Jintanugool & Round, 2005). It was reported that total fish catch in 2003 was 339.97 tones. (Kasetsart University, 2004)

Recently, Kwan Phayao Lake has experienced water quality problems due to population expansion in and around Phayao municipality. Moreover, many cultivations surrounding the lake, mainly rice crop, are also sources of agricultural pollutants. The lake itself is gradually becoming shallower as a result of high particulate deposition from inflow streams and the accumulation of aquatic detritus. In some places, poor water quality, particularly low dissolved oxygen, is near a critical level for the survival of fish (Phayao Freshwater Fishery Research Station, 2004).

Apart from water quality degradation, Kwan Phayao Lake has been subject to sediment infilling, which is threatening the habitat diversity and recreational opportunities. The Department of Fishery has approved a lake restoration plan which includes dredging the lake to remove sediment which had accumulated since 1984. This plan has been adopted by 3 principal natural water resources including Bung Borapet in Nakorn Sawan Province, Nong Harn in Sakon Nakorn Province, and Kwan Phayao in Phayao Province. As a result of budget limitations, spot dredging, instead of entire lake dredging, has been performed on an annual basis in 1-2 sites in each year.

Light and nutrient status are the major growth-limiting factors for phytoplankton (Wetzel, 2001). Light levels in inland shallow lakes such as Kwan Phayao that have inflows from many streams may also be affected by particulate matter from water inflows. This is particularly true in the rainy season. Light limitation for the photosynthesis of primary producers may also be caused by human activities, such as dredging. Maintenance dredging in Kwan Phayao Lake has been undertaken throughout the year by 2 hydraulic dredging vessels using 8- and 12-inch diameter pipes. Dredging activities are focuses on removing accumulated sediment and aquatic plants debris, especially at the north end of the lake where Mae Ing river empties into the lake. Thus this study focuses on the role of the lake dredging, the effect of seasonal changes and distribution of total suspended solid, changes in light levels, lake water quality and phytoplankton biomass in Kwan Phayao between November 2004 and October 2005.

## Materials and Methods

Collection of water samples and field survey were conducted monthly from November 2004 to October 2005 at 10 sampling stations around the Kwan Phayao Lake (Figure 1). Sampling stations were accessed using a GPS (Garmin Map 76s) and the landmarks with minor adjustments to improve sampling. Sampling stations names and UTM grids are shown in Table 1. Water temperature, dissolved oxygen (DO), pH, conductivity and total dissolved solid (TDS) were measured *in situ* at 30 cm below the surface and 30 cm from the bottom of the lake using a multi-probes water analyzer (YSI 556 Mps). Water surface and underwater solar radiations were measured using a Li-cor underwater quantum sensor in every 20 cm through 1 meter depth. Water samples for total suspended solid (TSS) and phytoplankton biomass expressed as chlorophyll *a* were collected using a 1.5 liter standard water sampler at a depth of 30 cm and were kept in an ice-box during transportation. TSS samples were analyzed by filtering an aliquot of water samples using pre-combusted pre-weighted Whatman GF/C filters. Samples were dried at 103-105 $^{o}$C to obtain TSS weight (APHA, AWWA & WEF, 1995). Phytoplankton biomass was determined using pigment analysis (chlorophyll *a*) by Lorenzen's spectrophotometric method (Lorenzen, 1967) as described in Parson et al. (1984). Rainfall data was obtained from Phayao meteorological weather station.

## Results

Dredging activities

According to the fiscal year 2005 lake dredging plan, two sites were selected for dredging. The first dredging spot was Mae Ing water channel located at the north end of the lake near station 6 where water from Mae Ing channel empties into the lake. This site was selected because sediment had clogged the water channels and obstructed water flow into the lake, resulting in flooding of the northward basin. Dredging activities at this site were carried out from November 2004 to May 2005. The second dredging point was located at the south end of the lake near

Rong Hai village where dredging took place from June to September 2005. The Department of Fishery planned to remove about 200,000 $m^3$ of sediment in each location.

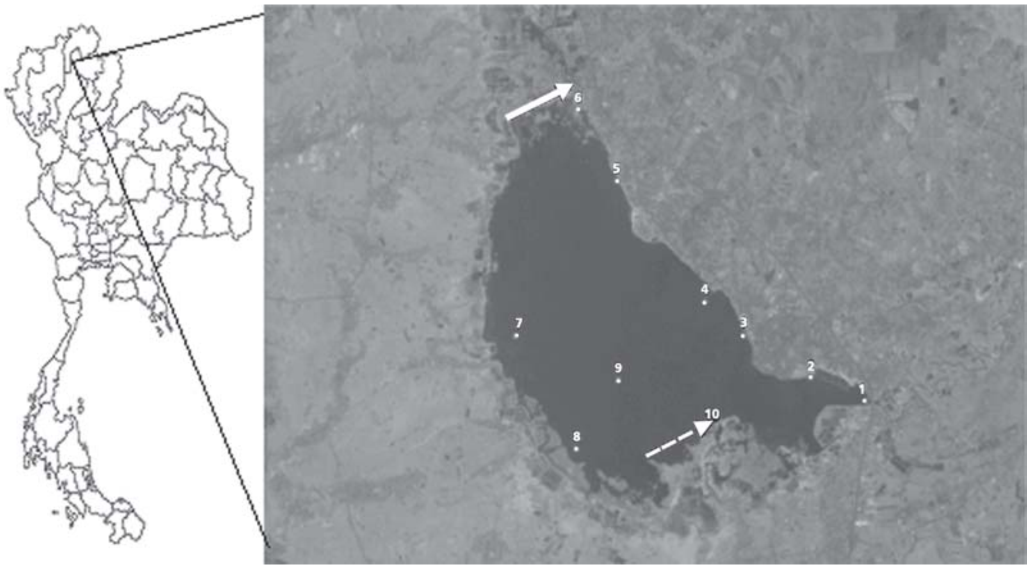


**Figure 1**. Sampling locations in Kwan Phayao Lake. The solid arrow indicates a dredging spot during November 2004 - May 2005. The dashed arrow indicates a dredging spot during June - September 2005.

**Table 1**. Stations names and geographic co-ordinations

| Station | Location | Co-ordinations | |
|---|---|---|---|
| | | X | Y |
| 1 | In front of fishery research station (southeast-ended) | 0596391 | 2118475 |
| 2 | Behind Phayao municipal office | 0595505 | 2118830 |
| 3 | In front of King Ngam Muang statute | 0594421 | 2119460 |
| 4 | Phayao water supply pumping station | 0593791 | 2119968 |
| 5 | Behind Phayao hospital | 0592361 | 2121776 |
| 6 | Rong Ha village - Khun Dej bridge (north-ended) | 0591564 | 2123226 |
| 7 | San Wieng Mai village | 0590717 | 2119444 |
| 8 | San Chang Hin village | 0591715 | 2117756 |
| 9 | Lake center | 0592385 | 2118782 |
| 10 | Rong Hai village | 0593907 | 2118054 |

Spatial and temporal variation in total suspended solids and light penetration

Significant increases of TSS were recorded in the water column during dredging. TSS data ranged between 0-106 mg/l. The maximum TSS data (106 mg/l) was observed at station 6 in April (Figure 2). At that time high TSS decreased photosynthetically active radiation (PAR) from 203.6 $\mu E\ cm^{-2}\ s^{-1}$ at the water surface to 0.41 and 0.01 $\mu E\ cm^{-2}\ s^{-1}$ at the depth of 20 cm and 40 cm, respectively. Again in July, after dredging that occurred near station 6 in May 2005, there was a peak of TSS. This was coincided with increasing monthly rainfall (Figure 2). The dredging of the second spot (station 10) began in June 2005. At this site, a non-significant increase in TSS was observed. The average TSS levels at the other sampling sites were at or just above the TSS levels measured at the lake center (station 9).

Phytoplankton standing stocks

Significant difference in chlorophyll *a* concentrations among sampling stations were particularly observed during a dry season. Chlorophyll *a* concentration of station 9, the reference site at the center of the lake, showed a single temporary peak of phytoplankton standing stock in

April 2004, while that of station 10 showed double peaks in March and May. Chlorophyll *a* concentration of station 10 dropped immediately after dredging activity was moved from station 6 to this site. On the other hand, Chlorophyll *a* concentration of station 6 was significantly low throughout the study period (Figure 3).

Apart from dredging activities, there were high water inflows into the lake with moderate TSS during the months of July to October 2004. During this period surface water was also partly covered by floating macrophytes, mainly water hyacinth. These floating aquatic plants obstructed light penetration into the water column, resulting in low phytoplankton standing stock as well. Mean phytoplankton standing stocks, expressed as chlorophyll *a*, were higher than 100 mg $m^{-3}$ between March and May 2005 due to the algal blooms. Among 10 stations where data were collected, the lowest chlorophyll *a* recordings were concurrently observed at the most turbid site (Figure 3).

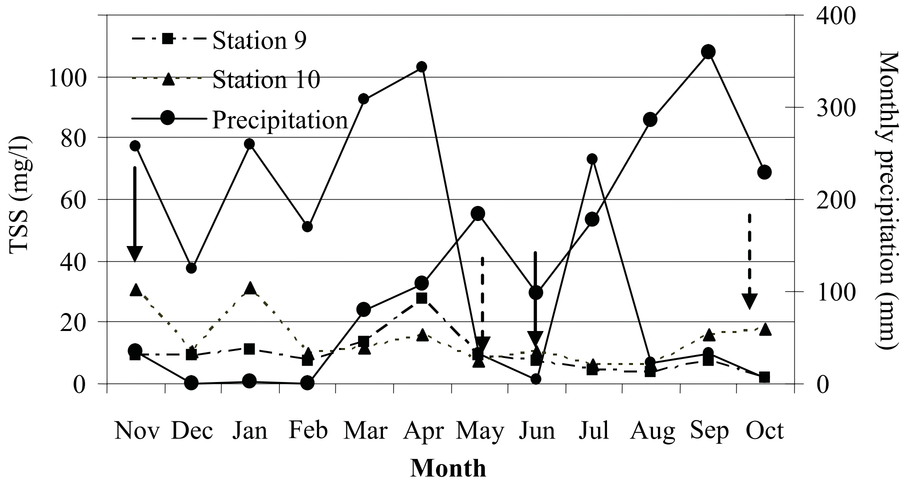


**Figure 2**. Changes in TSS at the first dredging site station 6 (north-end of the lake); at the middle of the lake station 9 (reference site); at the second dredging site station 10 (south-end of the lake) and monthly precipitation during the study period. Solid arrows indicate the beginning of dredging and the dashed arrows indicate the end of dredging.

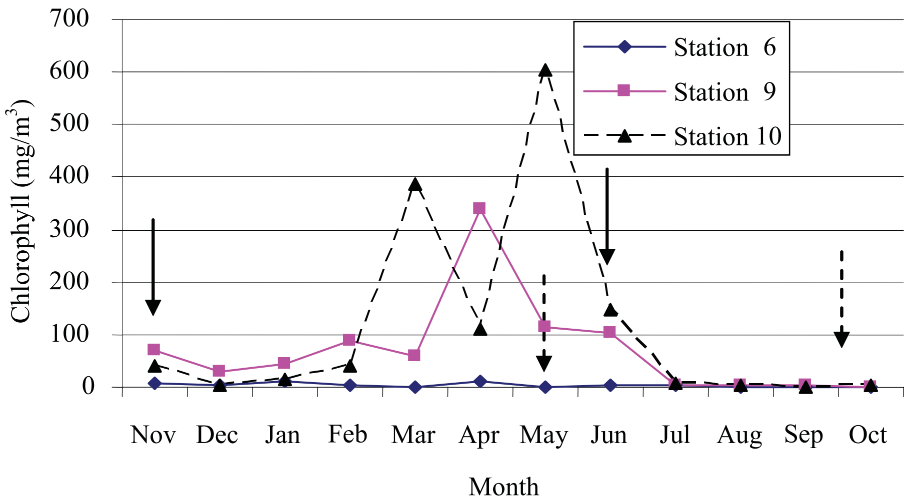


**Figure 3**. Seasonal changes in phytoplankton standing stocks expressed as chlorophyll *a* concentration at the dredging site station 6, station 10, and at the reference site station 9 during the study period. Solid arrows indicate the beginning of dredging and the dashed arrows indicate the end of dredging.

Seasonal changes in major water quality

During the study period, DO concentrations varied greatly. Critical DO concentrations near lake bottom in the dry season were observed at stations 1, 2, 3, and 6. DO degradation during the rainy season was recorded at station 5 since April 2005 and at station 6 since June 2005 (Figure 4A). It was also found that station 5 and station 6 were characterized by the poorest water quality in terms of DO concentration (Figure 4B).

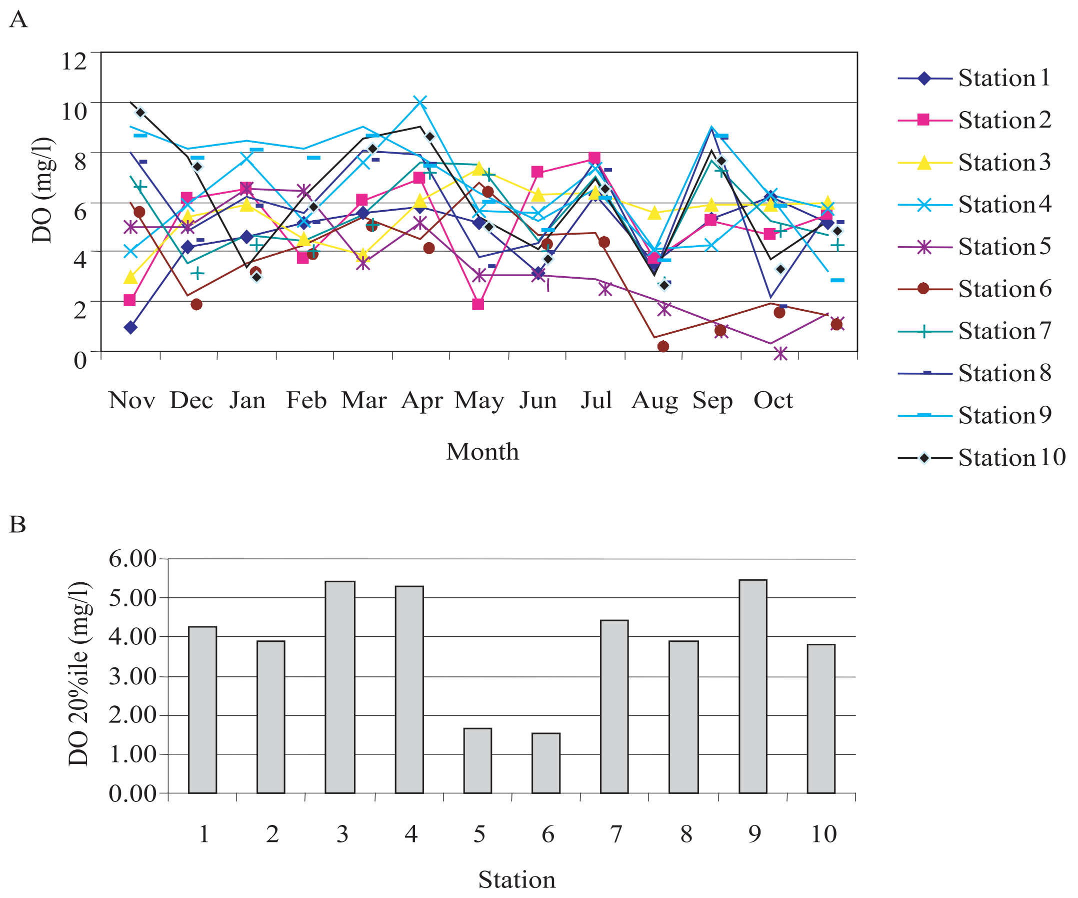


**Figure 4**. A) Changes in DO concentration at 10 sampling points during November 2004 to October 2005. B) DO concentrations at 20%ile during November 2004 to October 2005.

Water conductivity at station 6 during dredging activity was higher than other stations particularly between November 2004 to February 2005. Conductivity dropped from 128 µS/cm in May 2005 to 81 µS/cm in June 2005 immediately after dredging was stopped (Figure 5). Conductivity at station 9 and station 10 showed increasing trend coinciding with increasing rainfall. Maximum conductivity was observed at station 10 in September 2005.

## Discussion

Maintenance dredging refers to the routine removal of accumulated sediment from channel beds to maintain the design depths of navigation channels, harbors, marinas, boat launches, and port facilities. Dredging also is done to remove nutrient-rich sediments, remove toxic substances, reduce rooted aquatic plant growth, lessen sediment resuspension by winds and waves, and improve fish habitat (Illinois Environmental Protection Agency, 2006). Dredging is typically conducted by mechanical methods such as clam buckets, draglines or backhoes (Fisheries and Oceans Canada, 2005). Apart from mechanical methods, hydraulic dredging is an alternative way to remove sediment. Dredging machinery is generally incorporated onto a floating hull. A cutter with steel blades dislodges the sediment, and a slurry is piped to a disposal basin on land where the water is drained off and the sediment is left to dry. This method is faster than other mechanical methods and creates less turbidity than wet mechanical dredging (Illinois Environmental Protection Agency, 2006). However, improper use of the equipment can result in excessively high levels of turbidity (Cooke et al., 1986). From a fisheries perspective, the largest threat to fish habitat from these activities is the increased amount of suspended sediments introduced to the water column during the dredging process (Burnaby City Hall, 2002).

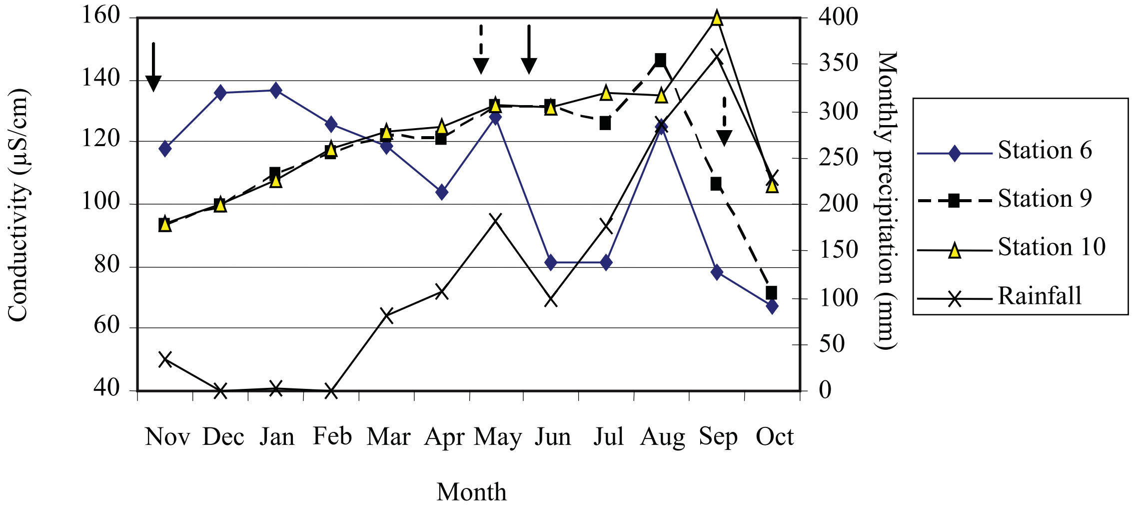


**Figure 5**. Changes in water conductivity at the first dredging site (station 6) at the middle of the lake (station 9) at the second dredging site (station 10) and monthly precipitation during the study period. Solid arrows indicate the beginning of dredging and the dashed arrows indicate the end of dredging.

TSS concentrations and turbidity both indicate the amount of solids suspended in the water, whether minerals (e.g., soil particles) or organics (e.g., algae). High concentrations of particulate matter affect light penetration and productivity, and recreational values, reduce habitat quality, and may cause lakes to fill in faster (Gijjapinun & Meksumpun, 2004). Particles also provide attachment places for other pollutants, notably metals and bacteria (Michaud, 1994). Increased turbidity can change an ecosystem significantly. The most obvious effect of increased turbidity is a reduction in PAR available for photosynthesis. Results from this study supports results found by Lewis et al. (2001) who studied the hydraulic dredging impact on benthos and algal periphyton in an urbanized Florida bayou. They found that dredging significantly reduced PAR at several stations.

It is natural for chlorophyll *a* levels to fluctuate over time. Chlorophyll *a* concentrations are often higher after rainfall, particularly if the rain has flushed nutrients into the water (Moss et al., 2006). Changes to systems which decrease (*e.g.* construction of canal estates) or increase (*e.g.* breakwaters, training water and dredging) flushing rates influence chlorophyll *a* concentrations because flushing dilutes nutrients and moves them away from plants, making them less available. In this study, the suppression of phytoplankton standing stock in the north part of the lake could definitely be a result of increased TSS from dredging (Figure 3 and Figure 4). However, the impact of dredging events in Kwan Phayao Lake, based on the selected parameters, are likely to be localized.

Elevated chlorophyll *a* levels in other sampling sites during the summer time indicated high numbers of phytoplankton. Excessive water column productivity, expressed by high chlorophyll *a* concentrations, can also contribute to high amounts of easily decomposed (*i.e.* labile) organic matter to the sediments (Michaud, 1994). Moreover, oxygen depleting substances could be released during dredging, which could lower dissolved levels in the water column. However, no specific relationship between phytoplankton bloom, DO depletion and dredging event was found in this study. It appeared that low levels of DO were naturally found near the bottom of the water column. The effects on surface water pH, DO, and temperature were negligible but the effects on PAR and dissolved inorganic materials as shown in conductivity data were prominent.

## Conclusion

It can be concluded from this study that the current spot hydraulic dredging maintenance program in Kwan Phayao Lake has negatively affected some water quality parameters, particularly TSS and PAR at the sites where dredging has been undertaken. The impact of dredging events in Kwan Phayao Lake, based on the selected parameters, are likely to be localized. The effects on surface water pH, DO, and temperature were negligible but the effects on PAR, phytoplankton standing stock, and dissolved inorganic materials were prominent. It is suggested that measures to reduce the impact of dredging on changes in biotic community composition should be carried out.

## Acknowledgements

The author thanks Dr. Daniel Kraushaar for reading this manuscript and for his useful suggestions. I am grateful to Mr. Pratipat Atitanakul, director of the Phayao Freshwater Fishery Research Station for his permission to use a motor boat and a water analysis laboratory. I would like to thank Ms. Suthida So Been, Mr. Metha Kachapichart, Mr. Sompet Chaitong fishery biologists for their kind assistances during the field observations. I also thank Ms. Wanwisa Utumporn for her assistance in sample preparation and water analysis.

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