Use of Nutrients and Chlorophyll-*a* for Fish Catch Estimation in Srinakarin Reservoir, Kanchanaburi Province

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ABSTRACT

The study aimed to: 1) formulate a fish catch estimation model for Srinakarin Reservoir in Kanchanaburi Province, using nutrients and chlorophyll-*a* as indicators for fish catch estimation; and 2) develop a sustainable management policy for the reservoir area and its fisheries resources. From April 2008 to March 2009, water samples were collected every two months at 15 selected sampling stations representing upstream, midstream and downstream areas that included point sources and non-point sources, and for the same period, samples of fish species were collected from six private fish landing ports every month.

The results showed that the Srinakarin Reservoir was oligotrophic, containing an average of 4.099 mg/m^3 of chlorophyll-*a* and its water quality was appropriate for aquatic animal life. The distribution of nutrients and chlorophyll-*a* varied, depending on the period and collection area. Nutrient and chlorophyll-*a* concentrations upstream were higher than those in the middle and downstream sections. The average concentrations of nutrients were highest in the rainy season (June to September), average in summer (February to May) and lowest in winter (October to January), whereas the average chlorophyll-*a* concentrations were highest in summer (5.307 mg/m^3) and average in the rainy season and winter (4.591 and 2.399 mg/m^3, respectively). The ratio of forage to carnivorous fish was estimated as 1.813:1. All parameters used to estimate the fish catch (FC) showed that the catch had a low positive relationship to chlorophyll-*a*, whereas nutrients could be used to estimate the fish catch, especially, ammonia nitrogen (NH$_3$-N), which was suitable for fish catch estimation throughout the year. A suitable linear regression model was FC = 29,892 - 90,509 (NH$_3$-N); (R^2 = 0.44). Ammonia nitrogen had a moderately negative relationship to the fish catch and could explain up to 44% of the fish catch.

Based on the equation developed in the study, the results could be used to estimate the fish catch satisfactorily and also the resultant environmental changes in the Srinakarin Reservoir. This model could be applied to predict the fish catch in other reservoirs in Thailand with the same topographical features.

Keywords: nutrients, chlorophyll-*a*, fish catch, Srinakarin Reservoir

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INTRODUCTION

The Srinakarin Reservoir is a vast fresh water ecological system covering an approximate area of 419 km^2 in Kanchanaburi, a province in the west of Thailand. It abounds in diversity of aquatic animals and plays a key role as an important source of protein food from aquatic biota, in addition to its uses in electricity generation, irrigation, and flood alleviation. At present, the aquatic environment and its inhabitants are suffering, owing to human activities in and around the reservoir, namely, tourism, agriculture, and industry, as well as fishery activity, with more advanced processes having adverse effects on the environmental quality and aquatic animals, the production levels of which tend to be decreasing constantly. According to Chukhajorn *et al*. (1984), who made a survey of the fish population in the early period of water storage, fish products used to be up to 255.31 kg/ha/y. In 1994, there was another study on the change in the fish population that indicated that production had decreased to 83.63 kg/ha/y (Chansawang *et al*., 1994). Later, Dumrongtraipop *et al*. (2002), conducting a survey of aquatic biology and fishery resources, found that the water quality differed and changed, depending on which survey station was sampled and the month of sampling, and that the average quantity of phytoplankton was 23.021×10^6 unit/ m^3 and the average production of the aquatic animals was only 9.56 kg/ha/y. The decrease in the production of aquatic animals in the reservoir is a result of the physical, chemical and biological changes of the environment in the aquatic ecological system, including the constant change in the nutrient quantity needed for the growth of the aquatic biota, which influences their production potential and causes imbalances in the aquatic ecological system.

Nutrients, along with the physical, chemical and biological properties of the water, correlate with fishery products, due to the fact that any reservoirs that provide sustainable amounts of aquatic animal products have a balance in the fertility of the water which is influenced by every environmental factor and by all producers, consumers, decomposers and supporters. Each of the environmental factors plays its role effectively in transforming inputs into outputs and transmitting energy through the food chain to the large aquatic animals that can be harvested, which in turn indicates the reservoir s role or potential in generating products. In this respect, nutrients support the life and growth of the aquatic animals, especially such important nutrients as nitrogen and phosphorus that are needed for the growth of the primary producers or phytoplankton, all of which are important to the aquatic ecological system. The phytoplankton and other components of the aquatic biota use the nutrients through the process of photosynthesis to generate tissue and transmit energy to other aquatic animals. The primary product of the water body is the biomass of the phytoplankton resulting from photosynthesis. All species of phytoplankton use chlorophyll-*a* as the main input for photosynthesis and it is possible to use this to indicate the biomass of the phytoplankton (Wongrat, 1999). A change in the nutrients can have an impact on the quantity of chlorophyll-*a* produced, its potential for growth and the multiplication of aquatic animals in the reservoir.

Scientists are interested in and are trying to identify appropriate methods for estimating the fish yield from reservoirs. Different methods and theories have been developed, based on the type and size of the reservoir. Moreover, methodology has been developing continuously, as reported by Hayes and Anthony (1964), Ryder (1965; 1982), Oglesby and Jenkins (1982), Ranta and Lindström (1989; 1990; 1998), Nissanka *et al*. (2000), amongst others, to identify and use the best method for yield estimation and sustainable resource management.

Therefore, nutrients and chlorophyll-*a*

were used in the present study to estimate the fish catch in the Srinakarin Reservoir to gain information on their variability and distribution, as well as the physical and chemical properties of the water. These factors are environmental indicators that might be applicable to forecast amounts of aquatic animals in the reservoir and be used in a database for effective reservoir management for additional sustainable fishery resources.

MATERIALS AND METHODS

A complete set of data covering water samples and analysis, fish catch records and field facilities were used in this study. Micronutrients, chlorophyll-*a* and some surface water quality data were collected at a depth of 30 cm from the water surface at 15 selected sampling stations (SR1-SR15) throughout the reservoir, representing upstream, midstream and downstream areas that

included point sources and nonpoint sources (Figure 1). All environmental indices were calculated soon after data collection and determined using standard methods for the examination of water and wastewater (APHA *et al*., 2000), as described in Table 1. Six samples were collected from April 2008 to March 2009, with a 2-month interval between samples.

Fish catch statistics were collected every month from six private fish landing ports located around the reservoir (Figure 2). Fish species were identified and classified into two groups (forage and carnivorous) based on their feeding behavior.

The data obtained were studied to identify correlations among fish catch, micronutrients, chlorophyll-*a* and water quality parameters using Pearson s correlation coefficient, while environmental indicators with high correlation for future fish yield estimation in the reservoir were determined using linear regression analysis.
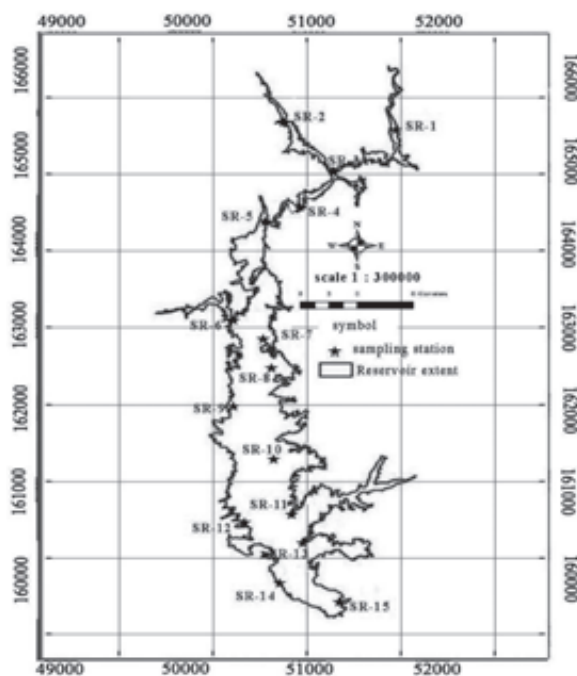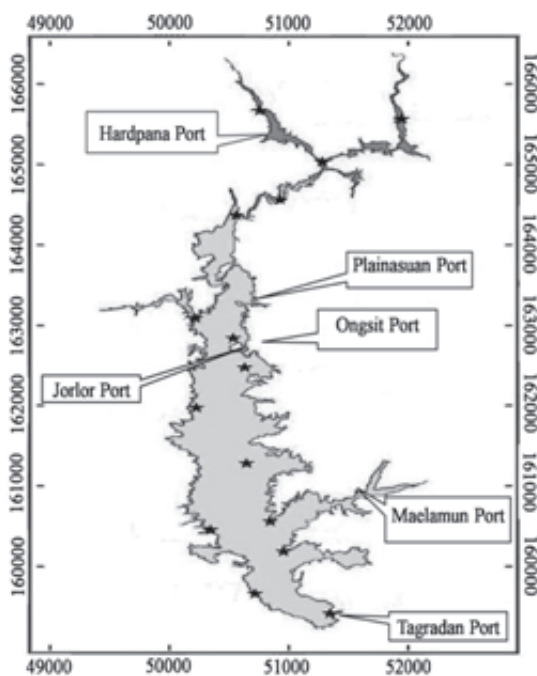

Figure 1 Surface water quality and ecological aspect sampling locations in Srinakarin Reservoir.
Source: Royal Thai Survey Department

The correlation ranking used for fish catch and all other environmental parameters are shown in Table 2.

RESULTS AND DISCUSSION

The yearly average value over the study period (Table 3) of each of the environmental

Figure 2 Private fish landing ports located around the reservoir in Kanchanburi province. (The average standing crop is 6.8 kg/ha/y.)

Table 1 Environmental factor analysis. Analytical methods based on APHA *et al.*(2000).

	Environmental factor	Analytical method
1	Chlorophyll-*a*	Spectrophotometric method
2	Ammonia-nitrogen	Phenate method
3	Nitrate-nitrogen	Colormetric method
4	Inorganic-nitrogen	Total of ammonia, nitrite and nitrate
5	Organic-nitrogen	Total nitrogen
6	Total nitrogen	Kjeldahl nitrogen method
7	Orthophosphate-phosphorus	Ascorbic acid
8	Total phosphorus	Ascorbic acid
9	Alkalinity	Titration
10	Water temperature	Multiprobe
11	Transparency	Secchi disc
12	Electrical conductivity	Multiprobe
13	Dissolved oxygen (DO)	DO meter

Note: Environmental factors 10-13 were analyzed immediately on collection in the field.

factors of the reservoir was at an acceptable standard to support aquatic animal life, except for transparency, which was higher than the standard.

The variation and any correlations in the environmental factors are detailed below.

Variation in environmental factors

   Chlorophyll-*a*

   The average yearly distribution value of chlorophyll-*a* around the reservoir was 4.099 mg/m^3 (Table 4), being highest in the upstream area (8.989 mg/m^3), followed by the middle and downstream areas, with average values of 1.876 and 1.431 mg/m^3, respectively (Figure 3). On a seasonal basis, the chlorophyll-*a* concentration

was highest in summer, average in the rainy season and low in winter, with values of 5.307, 4.591 and 2.399 mg/m^3, respectively (Figure 4). This corresponded to the studies conducted by Horabun (1997) and Prasetsom *et al*. (2001), who found that in summer, the average concentration of chlorophyll-*a* was high based on the increasing quantity of total phytoplankton, and by Sanders *et al*. (2001), who reported that the quantity of the chlorophyll-*a* changed according to the season in the areas influenced by nitrate and phosphate. The differences mentioned resulted from geographical differences, (the upstream areas of the reservoir were supplied from Kha Khaeng Creek and Jone Stream which were shallow and narrow, compared

Table 2   The correlation ranking used for fish catch and all parameters.

Correlation coefficient	Correlation level
0.71 to 1.00	Highly positive correlation
0.31 to 0.70	Moderately positive correlation
0.01 to 0.30	Low positive correlation
-0.01 to -0.30	Low negative correlation
-0.30 to -0.70	Moderately negative correlation
-0.71 to -1.00	Highly negative correlation

Table 3   Yearly average of all determined parameters in Srinakarin Reservoir between April 2008 and March 2009.

| Environmental factor	Parameter			
	Minimum	Median	Maximum	Mean± SD
Chlorophyll-*a* (mg/m^3)	0.103	1.702	25.121	4.099 ± 5.607
Ammonia-nitrogen (mg/L)	nd	0.065	0.155	0.067 ± 0.044
Nitrate-nitrogen (mg/L)	nd	nd	0.069	0.013 ± 0.017
Inorganic nitrogen (mg/L)	0.013	0.083	0.177	0.085 ± 0.041
Organic nitrogen (mg/L)	nd	0.246	1.925	0.336 ± 0.323
Total nitrogen (mg/L)	0.102	0.280	2.080	0.421 ± 0.332
Orthophosphate-phosphorus (mg/L)	nd	0.011	0.067	0.02 ± 0.022
Total phosphorus (mg/L)	nd	0.050	0.511	0.146 ± 0.151
Alkalinity (mg/L)	90.00	127.50	142.40	124.60 ± 10.86
Water temperature (°C)	26.00	29.70	32.00	29.2 ± 1.4
Transparency (cm)	60.00	190.00	490.00	193 ± 84
Electrical conductivity (µS/cm)	141.50	210.50	228.50	205.19 ± 18.39
Dissolved oxygen (mg/L)	5.63	7.54	10.60	7.84 ± 1.13

Note: nd = not detected.

Table 4 Concentration of chlorophyll-*a* in terms of time and zone in Srinakarin Reservoir from April 2008 to March 2009.

Time and Zone	Chlorophyll-*a* concentration (mg/m^3)			
	Minimum	Median	Maximum	Mean ± SD
Month				
April	1.154	2.865	21.188	4.976 ± 5.490
June	0.476	1.607	24.465	4.611 ± 7.412
August	0.937	1.604	25.121	4.571 ± 6.664
October	0.291	0.582	18.645	3.162 ± 5.743
December	0.103	0.976	8.354	1.637 ± 1.997
February	0.474	3.696	15.051	5.639 ± 4.699
Season				
Summer	0.474	3.165	21.188	5.307 ± 5.033
Rain	0.476	1.606	25.121	4.591 ± 6.926
Winter	0.103	0.922	18.645	2.399 ± 4.296
Zone				
Upstream	0.474	8.229	25.121	8.989 ± 7.389
Middle	0.103	1.202	8.049	1.876 ± 1.898
Downstream	0.258	1.442	5.626	1.431 Ø 1.039
Yearly average	0.103	1.702	25.121	4.099 ± 5.607

Note: Summer = February to May; Rain = June to September; Winter = October to January.
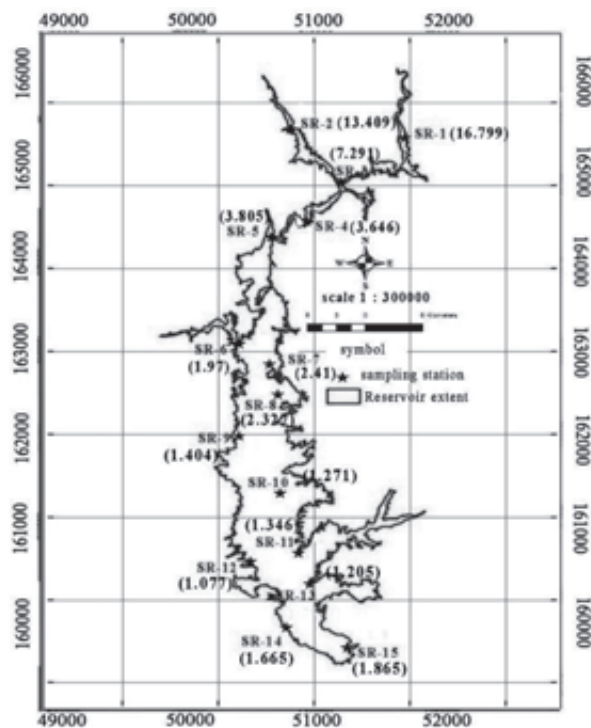
Figure 3 Distribution of average chlorophyll-*a* (mg/m^3) concentration in Srinakarin Reservoir between April 2008 and March 2009.
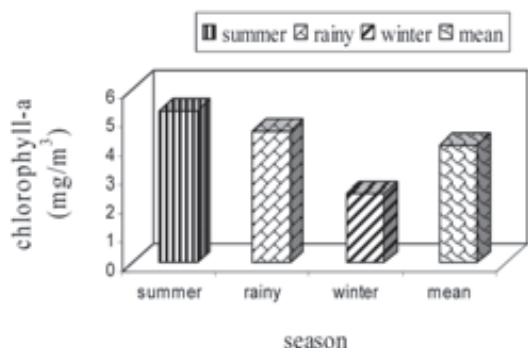
Figure 4 Average seasonal chlorophyll-*a* concentration in Srinakarin Reservoir between April 2008 and March 2009.

with the middle and downstream areas that were deeper and wider) and from weather factors, such as being hot in summer with high light intensity and transparency, leading to high photosynthesis by the phytoplankton (Wongrat, 1999). Furthermore, in the rainy season, additional nutrients were added to the water from soil erosion caused by flooding of land around the reservoir, leading to growth of the phytoplankton. As a result, chlorophyll-*a* concentrations in summer and in the rainy season were higher than those in winter.

Nonetheless, the average chlorophyll-*a* concentration around the reservoir was low, which indicated low nutrient fertility due to the fact that the reservoir was large and deep which impacted on the phytoplankton distribution. Based on the classification of water nutrient fertility by Ryding and Rast (1989), the chlorophyll-*a* concentration could be used to indicate the fertility of the water source; a water source with low fertility has a chlorophyll-*a* concentration less than 4.7 mg/m^3; a water source with medium fertility has a chlorophyll-*a* concentration between 4.7 and 14.3 mg/m^3, while in a water source with high fertility, the chlorophyll-*a* concentration is over 14.3 mg/m^3.

Nutrient

Nitrogen was analyzed in terms of ammonia, nitrate, inorganic nitrogen, organic nitrogen and total nitrogen, and phosphorus in terms of orthophosphate-phosphorus and total phosphorus, Almost all of the nutrients were detected around the reservoir at a range of concentrations, depending on the location and the month of data collection. In upstream areas, the overall average nutrient concentration was high and tended to distribute to the middle and downstream areas. Seasonally there was average nutrient distribution in the rainy season, with less in summer and winter, respectively. The difference was probably due to the fact that the upstream area was the water source and that during each period, the decomposition of organic substances into inorganic substances was different; in summer, high temperatures led to the decomposition of organic substances into inorganic substances that the phytoplankton could utilize fully, whereas the lower temperatures in winter resulted in less decomposition (Wongrat, 1999). Meanwhile, in the rainy season, nutrients were eroded from the land into the reservoir, leading to overall high nutrient levels compared with other periods. In addition, in the upstream areas with high nutrient concentrations, the chlorophyll-*a* concentration was high. The nutrients detected could be used for the growth of phytoplankton, which corresponded to the report by Alam *et al*. (2001) that the concentrations of nutrients, especially ammonia and nitrate, affected the increase and variations in the levels of phytoplankton.

Water Quality

The overall status of both physical and chemical water quality (important for the growth of the phytoplankton and aquatic animals along the length of the reservoir) was average, based on the second surface water quality standard and the water quality standard for the protection of freshwater animals, except for the water transparency, which was somewhat high compared with the appropriate level for aquatic animals, namely between 30 and 60 cm (Duangsawasdi, 1987). Water transparency was a factor indicating the concentration of phytoplankton; any areas with high water transparency values and low nutrient

distribution values, as a consequence, had low concentrations of phytoplankton. However, a high water transparency value had a small effect only on the aquatic animals, since Srinakarin Reservoir is very large and deep. As a result, any change in the environmental factors took place gradually.

In summary, the distribution of nutrients (nitrogen and phosphorus) and water quality (total phosphorus, ammonia nitrogen, organic nitrogen, electrical conductivity, alkalinity and transparency) were appropriate for sustaining phytoplankton and aquatic animals. The water transparency measure was higher than the standard value for sustaining aquatic animals. The yearly average of chlorophyll-*a* concentration was low (4.099 mg/m^3). This result showed the rather low level of natural food richness, due to the large size, great depth and wide surface area of the reservoir. Levels of nutrients and chlorophyll-*a* varied according to the sampling month and site. The concentrations of nutrients and chlorophyll-*a* were high in the northern-most part of the reservoir, followed by the middle and the dam site, respectively (Figure 3).

Fish catch

In total, 39 species of fish belonging to 17 families were harvested from the reservoir, weighing 23,869.3 kg/month, with an average of 6.8 kg/ha/y and the forage to carnivore ratio (F:C) was 1.813:1. The F:C ratio indicates whether there is a balance in the ecological structure, so the result for the present study shows that the population was unbalanced, compared with the standard (3˘6:1) reported by Swingle (1950).

Correlation between fish catch and environmental factors

The correlation between the fish catch and all determined parameters was determined, (* and ** indicate the correlation was significant at the 0.05 level and the 0.01 level, respectively).

The fish catch had a positive correlation with total phosphorus ($r = 0.418^{**}$), dissolved oxygen ($r = 0.266^*$) and orthophosphate-phosphorus ($r = 0.245^*$), and had a negative correlation with ammonia-nitrogen ($r = -0.663^{**}$), inorganic-nitrogen ($r = -0.635^{**}$), transparency ($r = -0.477^{**}$), electrical conductivity ($r = 0.353^{**}$) and alkalinity ($r = -0.264^*$), respectively. Chlorophyll-*a* had a very low ($r = 0.027$) correlation with the fish catch as shown in Table 5 and Figures 5 and 6.

Estimation model for fish catch

The study showed that a suitable equation for fish catch (FC) estimation was Equation 1:

Table 5   Correlations between the fish catch and all determined parameters in Srinakarin Reservoir from April 2008 to March 2009.

| Parameter	Average	Correlation coefficient
Ammonia-nitrogen (mg/L)	0.067	-0.663**
Inorganic-nitrogen (mg/L)	0.085	-0.635**
Orthophosphate-phosphorus(mg/L)	0.020	0.245*
Total phosphorus (mg/L)	0.146	0.418**
Transparency (cm)	193.28	0.477**
Electrical conductivity (±S/cm)	205.19	-0.353**
Dissolved oxygen (mg/L)	7.84	0.266*
Alkalinity (mg/L)	124.6	-0.264*
Chlorophyll-*a* (mg/m^3)	4.099	0.027

Note: * = correlation is significant at the 0.05 level.

    ** = correlation is significant at the 0.01 level.
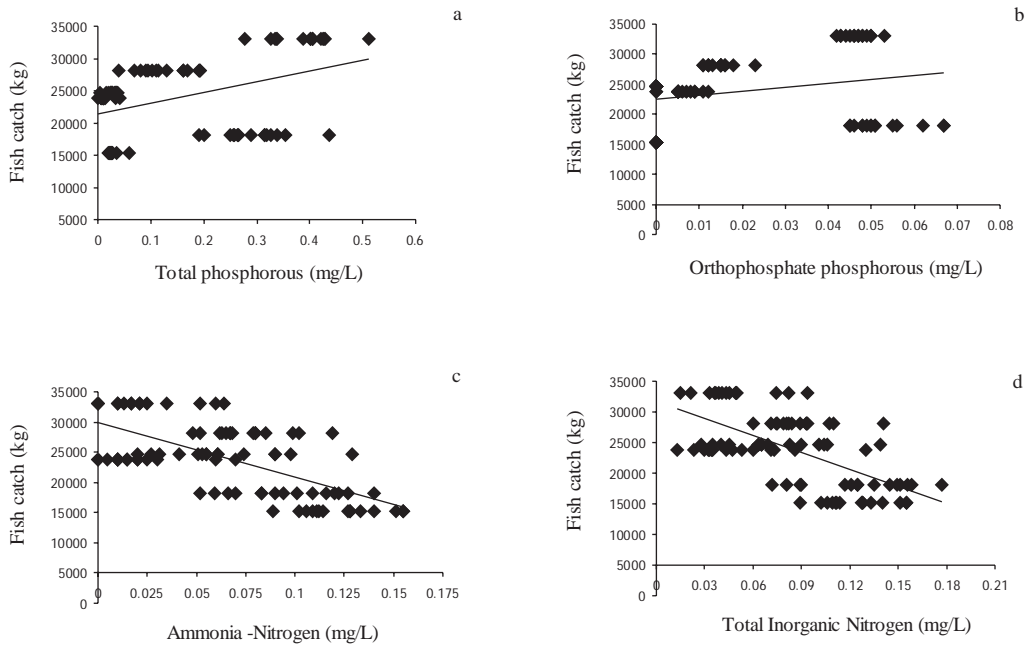
Figure 5 Correlation between fish catch and nutrients in Srinakarin Reservoir: (a) total phosphorous;
(b) orthophosphate phosphorous; (c) ammonia nitrogen; (d) total inorganic nitrogen.
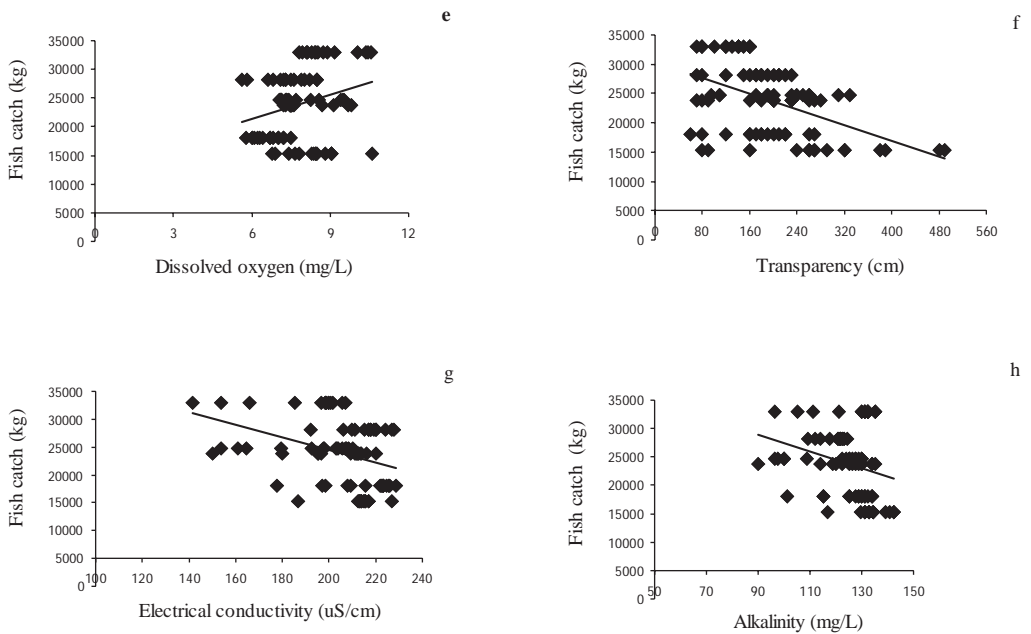
Figure 6 Correlation between the fish catch and surface water quality in Srinakarin Reservoir: (e)
dissolved oxygen; (f) transparency; (g) electrical conductivity; (h) alkalinity.

$$FC = 29,892.2 \check{} 90,508.9\ (NH_3\text{-}N)\quad(1)$$

where: FC is measured in kilograms and NH3-N is measured in mg/L.

The ammonia-nitrogen parameter explained the fish catch best ($R^2 = 0.44$). The results showed that nutrients can be used as an indicator for fish catch estimation in the reservoir, particularly nitrogen which is naturally the major component of protein in aquatic biomass. The sources of nutrients were from all types of material in the water (waste from the village, fertilizer from agriculture and wastes that accumulated in the sediment), being circulated through the bio-chemical process using energy from sunlight. Nitrogen in the form of organic nitrogen is decomposed by bacteria and converted into ammonia, nitrite and nitrate, which can be used as essential nutrient for life by the aquatic biota (Figure 7). However, if the ammonia-nitrogen concentration increases, it would be unfit for aquatic animals because of its effect on obstructing and reducing the effectiveness of oxygen necessary for respiration, resulting in reduced biotic growth rates and more serious weaknesses and diseases (Montoya et al., 1999). Thus, if the concentration of nitrogen in the water can be kept at a suitable level, then the water quality will be appropriate for sustainable growth and multiplication of the fish population.

CONCLUSION

Over the study period, Srinakarin Reservoir had an average value of chlorophyll-*a* of 4.099 mg/m³ and so could be classified as oligotrophic. The chlorophyll-*a* concentration upstream was higher than in the midstream and downstream areas and was highest in summer, average in the rainy season and low in winter. The
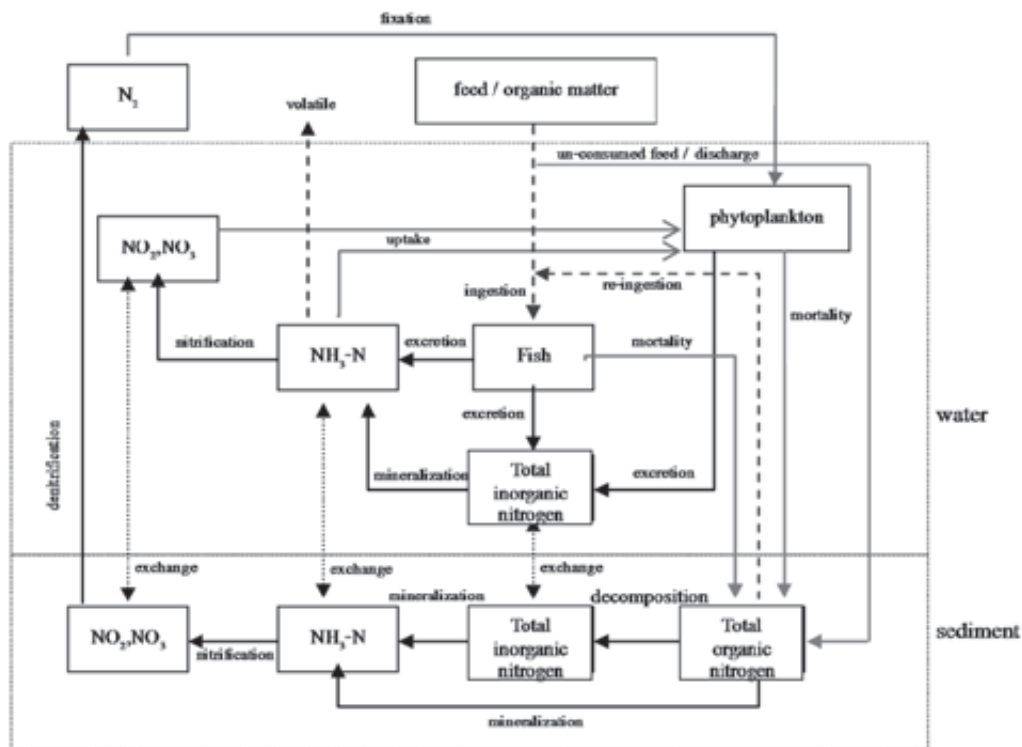
Figure 7 Structure and relationship of nitrogen and other components in the reservoir ecosystem. Source: Applied from Montoya et al. (1999)

status and distribution of nitrogen and phosphorus around the reservoir did not exceed the second surface water quality standard and were not hazardous to the aquatic biota, nor were the variations resulting from different locations and months of data collection.

Nutrients were an important factor that could be used to estimate the fish catch. Ammonia (NH_3-N) provided the best prediction of fish catch (FC) when compared with the other factors (FC = 29,892.2 - 90,508.9 × [NH_3-N]), even though it had a negative correlation with the fish catch. An estimation equation that requires fewer factors can shorten the time spent in data collection and also saves costs in analysis compared with using more environmental indices. However, estimation of the contamination of water resources is also recommended. The equation for approximate fish catch can be applied also to other reservoirs in the country. In addition, its use can provide information that forms part of the important database of departments responsible for the management of any reservoir for ongoing sustainable fish yields, along with an awareness of the worthy uses of the natural resources in the reservoir.

ACKNOWLEDGEMENTS

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