Pertanika 6(1), 78–82 (1983)

Photosynthetic quotient relationship to inorganic nitrogen of rivers in Trengganu

LOKMAN SHAMSUDIN
Department of Fisheries, Technology and Marine Science,
Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia,
Mengabang Telipot, Kuala Trengganu, Trengganu.

Key words: Photosynthetic quotient; inorganic nitrogen.

RINGKASAN

Nilai quotien fotosintesis (P.Q) pada tiap-tiap kedalaman bagi sungai-sungai di Trengganu didapati dalam keadaan rendah disebabkan oleh ketinggian paras-paras nitrogen ammonia semula jadi dalam air, nilainya diantara 1.2–0.8. Berlain dari keadaan-keadaan terdapat di kawasan berhawa sederhana didapati ketinggian kadar-kadar kandungan nitrat akan menambahkan nilai-nilai P.Q dari 1.5 kepada 2.0. Penjelasannya ialah nitrat bukannya ammonia akan menghasilkan dua molekul oksigen tambahan bagi tiap-tiap molekul nitrogen nitrat yang telah diassimilasikan menghasilkan penambahan ketinggian nilai-nilai P.Q Walaubagaimana pun kajian-kajian tertentu sekarang menunjukkan perseimbangan dengan keadaan terdapat pada phytoplankton merin (yaini, P.Q 1.2) apabila ammonia adalah sumber utama bagi nitrogen.

SUMMARY

Photosynthetic quotient (P.Q) values with depth of rivers in Trengganu were found to be lowered by high levels of indigenous ammonium nitrogen, ranging from 1.2–0.8, contrary to temperate conditions where high levels of nitrate increase the P.Q values from 1.5 to 2.0. This is attributed to the fact that nitrate, in lieu of ammonia, produces two extra molecules of oxygen per atom of nitrate nitrogen assimilated, culminating in higher P.Q values. Nevertheless, the present findings tally well with that of marine phytoplankton (ie. P.Q is 1.2) when ammonia is the prime source of nitrogen.

INTRODUCTION

Studies on photosynthetic quotient values in the tropical aquatic environment, especially estuarine or brackish waters which act as a nutrient trap or sink are limited. In this connection an investigation on the correlation of photosynthetic quotient values with nutrient contents and other related environmental factors of rivers in Trengganu was undertaken. This paper discusses the findings of this investigation.

METHOD

The study was carried out on rivers in Trengganu at three predetermined stations, *viz.* Manir Bridge, Nerus Bridge and Mengabang Telipot moat water with regard to productivity quotient values, inorganic nitrogen contents and other related parameters according to their depth profiles in August 1981. Water samples from depths of 0.3, 0.7, 1.5 and 2.0 meters were brought back in carboys immediately for analysis.

Photosynthetic values (μg C/l/h) of the samples were determined on incubation of 125 ml of sample water either in the dark or activic irradiation of 30,000 lux over a period of three to four hours at a constant temperature of 25° C. Photosynthetic oxygen measurements were carried out according to the method of Bryan, Riley and Williams (1976) which has a Winkler titration coefficient variation of 0.1%. The 14C technique used is that described by Steemann Nielsen (1952). Here, a 1/0.5 ml aliquot of stock $NaH^{14}CO_3$ with an activity of 5 μg/μl was added to the samples prior to incubation. The experiments were terminated by filtering the water samples through 0.5 μ membrane filters, dried, and fumed over HCl for five minutes before calibration with a

Key to author's name: L. Shamsudin

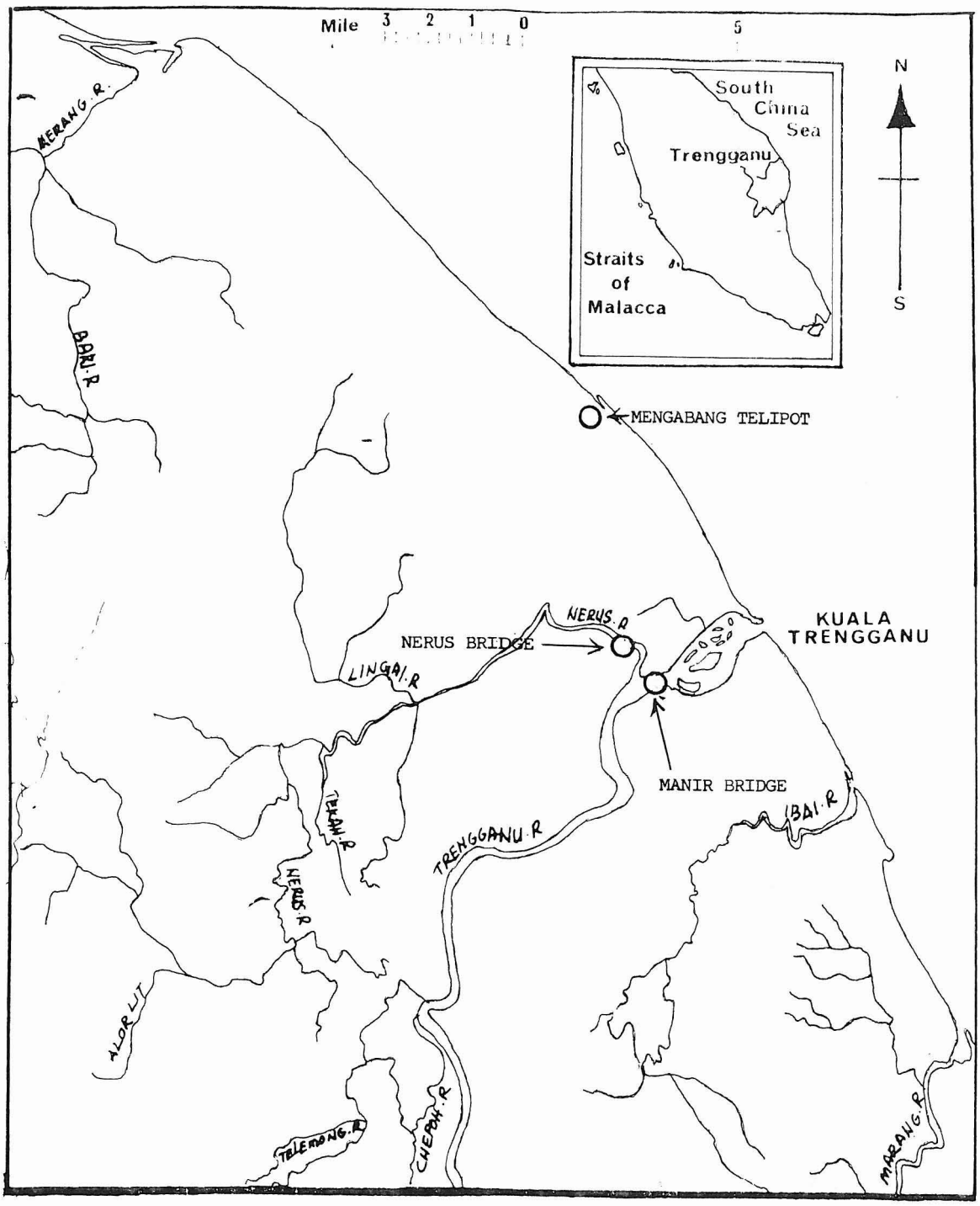

Fig. Map showing sampling stations from various rivers in Trengganu.

liquid scintillating counter. The calibration of the radioactive counting counter, the determination of stock $NaH^{14}CO_3$ activity, and determination of 14C extracellular dissolved organic material were carried out according to the method of Williams *et al.,* (1976) and Raine (1973). Chlorophyll 'a' concentration of the sample was determined according to the method by SCOR/UNESCO working group 17 (1966).

Determination of ammonium was carried out by the Shamsudin (1979) modified method of Solorzano's (1969). Nitrate nitrogen was determined by the colorimetric cadmium-copper amalgam reduction method while reactive phosphorus by the colorimetric ascrobic molybdate method (Strickland and Parson, 1972). Salinity, conductivity and temperature of the stations were determined using the normal standard method.

RESULTS

The photosynthetic quotient (P.Q) values ranged from 1.20–1.14, 1.10–0.87, and 1.05–0.84 with depth at Manir Bridge, Nerus Bridge and Mengabang Telipot moat water respectively, indicating higher values in surface water (Table 1a, b, c). Similar tendencies were also observed for respiration values which ranged from 42.2–41.9, 43.3–37.9 and 50.6–46.3 as percent of gross photosynthesis.

Chlorophyll 'a' values for the three stations ranged from 31.4–21.1, 30.5–18.4 and 32.8–27.3 μg/l with their maximum at the 0.7 meter depth. On the contrary, the ammonium nitrogen content ranged from 13.5–11.1, 21.0–14.2 and 24.0–16.2 μg at NH_4^+ –N/l at the three stations with the tendency of increment with depth. In all instances the ammonium nitrogen content for the three stations was much higher than the nitrate nitrogen content which ranged from 4.2–4.0, 5.4–4.8 and 2.1–1.5 μg at NO_3^- –N/l respectively.

The surface temperature, salinity, pH and extracellular 14C– dissolved organic matter with depth, were relatively constant at all stations throughout the study period.

DISCUSSION AND CONCLUSION

It is obvious from the investigation that the photosynthetic quotient values are generally higher in surface waters and tend to decrease with depth. Such high photosynthetic quotient values would only be attained if the molar oxygen concentration exceeded that of the carbon dioxide utilised during the photosynthetic process. In this relation, profile studies at the three stations indicate a decrease in photosynthetic values from the mid water column of *ca* 0.7 m to deeper water. However, the subsurface water of *ca* 0.3 m has a lower photosynthetic value than that of the mid water layer. Similarly chlorophyll 'a' content at the three stations shows trends similar to that of the photosynthetic values. This could be attributed to the inpenetrability of radiant energy resulting in reduced rates in photosynthetic values with depth. Hence, it is suggested that the increased dissolved oxygen content near the surface increased the molar oxygen concentration culminating in an increased photosynthetic quotient.

It is noted that there is a relationship between the photosynthetic quotient and the type and concentration of inorganic nitrogen source present in the aquatic environment. The high ammonium nitrogen content tends to lower the photosynthetic quotient value. Hitherto, the effect of the nitrogen supply on a photosynthetic quotient of growing algal cells has not been fully recognised. However, experiments with *Chlorella* (Cramer and Myers, 1948; Syrett, 1956) have shown that the photosynthetic quotient, which is near to 1.0 with ammonia as a source of nitrogen, may reach 1.6 or greater in a nitrate containing medium. Raine (1973) found that when a culture of *Dunaliella* was grown in a culture medium containing no nitrate and only ammonium as the nitrogen source, the photosynthetic quotient value was 1.3. However, he also found that if ammonium is omitted from the culture medium, and when only nitrate is present, the photosynthetic quotient increases to 1.8 and 2.0. Eppley (1969), has further shown that the uptake velocities of ammonium and nitrate are not independent of one another. Bienfang (1975), however, gives evidence to suggest that under nitrogen limiting conditions, the uptake of ammonium and nitrate is competitive, not suppresive. Similarly, Antia *et al.,* (1963) using algal populations in a large volume plastic sphere, found that the uptake of nitrogen source was also competitive. Ryther *et al.,* (1971) in his investigation of primary production in the upwelling area of Peru observed that the concentration of nitrate in the water was 20 μg at NO_3^- –N/l and its photosynthetic quotient value was 2. Unfortunately, no datum is available for ammonium nitrogen concentrations, but it can be assumed that competitive uptake of nitrate and ammonium might have occurred.

Antia *et al.,* (1963) working in a temperate situation obtained a photosynthetic value of 2.4. Raine (1973) working on a temperate estuary found the indigenous content of nitrate

Table 1
Productivity of Trengganu rivers

Stations depth (m)	Temp. °C	pH	Sal %	Chl'a' µg/l	NH^+ μg^4 at/l	NO^- μg^3 at/l	Extracellular 14C–D.O.M. (%14C–PS)	Resp % Gross PS	Net PS % Gross PS	Gross PS µg O_2/l/h	14C-PS µg C/l/h	P.Q
(a) Sg. Manir												
0.3	28.0	7.0	4	21.1	11.1	4.0	3.8	42.2	57.8	190.3	158.6	1.20
0.7	27.5	7.1	4.5	31.4	12.4	4.1	4.0	43.7	56.3	400.9	342.7	1.17
1.5	27.5	7.0	4	23.7	12.7	4.2	3.9	40.8	59.2	216.5	188.3	1.15
2.0	27.5	7.0	4	23.1	13.5	4.1	4.1	41.9	58.1	223.8	196.3	1.14
(b) Sg. Nerus												
0.3	28.0	7.1	6.0	18.4	15.7	5.2	3.8	39.1	60.7	175.4	192.8	1.11
0.7	27.5	7.0	6.5	30.5	14.2	4.9	3.9	43.3	56.7	390.1	354.6	1.10
1.5	27.5	7.0	6.0	18.9	16.1	4.8	4.0	38.0	62.0	214.9	204.7	1.05
2.0	27.5	7.1	6.5	18.2	21.0	5.4	4.1	37.9	62.1	176.7	203.1	0.87
(c) Mengabang Moat												
0.3	28.0	7.0	3	29.4	16.2	1.5	4.1	50.6	41.4	341.7	325.0	1.05
0.7	27.5	7.1	3.5	32.8	18.2	1.9	3.9	46.3	53.7	453.2	487.3	0.93
1.5	27.5	7.1	3	28.0	19.5	1.7	3.7	47.0	53.0	352.3	391.4	0.90
2.0	27.5	7.1	3	27.3	24.0	2.1	4.2	47.6	52.4	322.6	384.1	0.84

Note: D.O.M: dissolued organic matter
PS: Photosynthesis.

to be much higher than that of ammonia by a factor of 5 (i.e. indigenous nitrate as 20 μg. at N/l and that of ammonium as 4.5 μg at N/l and its photosynthetic quotient value as 1.8–2.0). Williams (1976) suggested that utilisation of nitrate, in place of ammonia, would result in the production of two molecules of oxygen for every molecule of ammonium nitrogen assimilated, if one assumed nitrate assimilation to obey the following stochiometric

$$NO_3^- + 2H_2O \rightarrow NH_3^+ + OH^- + 2O_2$$

The effect of nitrate utilisation is to increase the molar oxygen produced and as such its photosynthetic quotient values increased. Hence this investigation verifies the fact that there is an intimate relationship between the ammonium nitrogen content and nitrate nitrogen content in tropical estuarine water columns in relationship to the P.Q values. In the water columns of Trengganu rivers, the governing factor appears to be ammonium nitrogen content which increases with depth.

ACKNOWLEDGEMENT

The author wishes to thank Universiti Pertanian Malaysia for providing the necessary funds for the project. He also wishes to thank the laboratory technicians of the Department for their help.

REFERENCE

ANON, (1976): Standard methods for the examination of water and wastewater. (14th. Edition). America Public Health Association, Inc. New York.

ANTIA, N.J. MC ALLISTER, C.D. PARSONS, T.R. STEPHENS, K. and STRICKLAND, J.D.H. (1963): Further measurements of primary production using a large volume plastic sphere. *Limnol. Oceanogr.*, **8**: 166-183.

BIENFANG, P.K. (1975): Steady state analysis of nitrate ammonium assimilation by phytoplankton. *Limnol. Oceanogr.* **20**: 402-411.

BISHOP, JOHN, E. (1973): Limnology of a small Malayan River, Sungai Gombak. 485 pp. Dr. W. Junk B.V. Publishers. The Hague.

BRYAN, J.R. RILEY, J.P. and LeB WILLIAMS P.J. (1976): A Procedure for making precise measurements of oxygen ocncentration for productivity and related studies. *J. Exp. Mar. Bio. Ecol.* **21**: 191-197.

CAPERON J. and MEYER J. (1972): Nitrogen limited growth of marine phytoplankton and changes in population characteristics with steady state growth rate. *Deep Sea Res.* **19**, 601-618.

EPPLEY, R.W. and SOLORZANO L. (1969): Studies of nitrate reducatase in marine photoplankton. *Limnol. Oceanogr.* **14**: 194-205.

HO, SINN CHYE (1973): A Preliminary study of the ecology of a polluted stream, the Sungai Renggam. In 'Proceedings of the symposium on Biological Resources and National Development.' 5th-7th May 1972. E. Soepadmo and K.G. Singh. (Eds) pp 85-81. *Malayan Nature Society,* Kuala Lumpur.

LAW, A.T. and MOHSIN A.K.M. (1980): Environmental studies of Kelang River. Chemical, Physical and Microbiological parameters. *Malay. Nat. J.* **33**: 175-186.

NELSEN, E. STEEMANN (1952): The use of radioactive carbon for measurement of organic production in the sea. *J. Conseil Exp. Mer.* **11**: 117-140.

RAINE, R.C.T. (1972): The 14C and oxygen methods of measuring primary productivity, M.Sc Thesis. University of Southampton.

RYTHER, J.H. (1969). Photosynthesis and fish production in the sea. *Science.* **146**: 72-76.

SHAMSUDIN, L. (1979): Productivity measurements of algae using C-14 technique and oxygen technique under the influence or inorganic nitrogen source. M.Sc thesis. University of Southampton.

SHAMSUDIN, L. and SALLEH, U. (1982): Photosynthetic values and inorganic nutrient contents of Sungai Ibai. *Pertanika.* **5(1)**, 58-65.

SOLORZANO, L. (1969): Determination of ammonia in natural water by the phenolhypochlorite method. *Limnol and Oceanogr.* **14**: 792-801.

STRICKLAND, J.D.H. and PARSONS, T.R. (1968): A practical handbook of seawater and analysis. *Fish. Res. Ed. Can. J.* **167**.

SYRETT, P.J. (1956): The assimilation of ammonia and nitrate by nitrogen starved cells of *Chlorella vulgaris. Physio. plant.* **9**: 19-29.

WILLIAMS, P.T. leB. and YENTSH C.S. (1976): An examination of photosynthetic production, excretion of photosynthetic products, and heterotrophic utilisation of dissolved organic compounds with reference to results from a coastal subtropical sea. *Mar. Bio.* **35**. 31-40.

(Received 5 November 1982)