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淡水河系河口感潮段水理、水質及生態系統模擬之研究(2/3)

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計畫主持人：許銘熙
共同主持人：柳文成，吳俊宗，黃將修

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淡水河系河口感潮段水理、水質及生態系統模擬之研究**(2/3)**
九十一年度計畫期中報告

國科會計畫編號：**NSC 91-2211-E-002-067**

(民國 **91** 年 **8** 月至 **92** 年 **5** 月**)**

執行單位：國立臺灣大學生物環境系統工程學系

中華民國九十一年五月三十一日

淡水河系河口感潮段水理、水質及生態系統模擬之研究(二)

Simulation of Hydrodynamics, Water Quality and Ecological System in the Tidal Danshuei River System (II)

參與工作人員

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目錄

摘要

本研究計畫自九十年八月一日開始執行，預定執行期間爲三年，第一年度完成之工作包括：

(1)淡水河系海水入侵變遷之研究；(2)模式河川斷面資料之更新與模式之重新驗證；(3)兩次現場觀測採樣與數據之分析；(4)生態模式之撰寫與偵錯。以上工作成果已於第一年之成果報告中詳加說明。

第二年之工作於九十一年八月一日啓動，至目前爲止，已完成之工作有下列諸項，加以說明如下：

A. 完成「Modeling Salt Water Intrusion in Tanshui River Estuarine System: A Contrast Between Now and Then」爲題之論文，投稿至 Journal of Hydraulic Engineering, ASCE。

B. 撰寫四篇英文摘要，將發表於 PACON (Pacific Congress of Marine Science and Technology) 2003, June 30-July 2, 2003, Kaoshuong, Taiwan.

    (1) Toward the simulation of Ecological System in the Danshuei River Estuary.
    (2) Water Column Light Attenuation in the Danshuei River Estuary.
    (3) Modeling Water Quality Control for Fish Survival in the Tidal Hsintien Stream.
    (4) Zooplankton Abundance and Distribution in the Danshuei Estuary and Adjacent waters.

C. 現場觀測採樣與分析

分別於民國九十一年十月十五日及九十二年五月六日完成兩次全潮觀測採樣。

D. 生態模式之測試

第一年撰寫之生態模式，經偵錯完成後，以虛擬河川作爲模式之測試，證實模式無誤，演算結果合理，又以淡水河實際資料測試，結果良好。

A. 淡水河系海水入侵變遷之論文稿

鹽分濃度爲感潮河川中最重要之環境參數，它的長期變化對水體中之生態結構有決定性之影響，淡水河數十年來，因環境之改變，已引起海水入侵之增強，其中人爲因素，包括石門、翡翠兩座水庫之興建而產生長期流量之減少、河床高程變化等。已利用數值模擬，對此等因素所引起之海水入侵程度加以探討，撰寫論文一篇，投稿至 Journal of Hydraulic Engineering, ASCE，以下僅附該論文之摘要。

Modeling Salt Water Intrusion in Tanshui River Estuarine System－A Contrast between Now and Then

Wen-Cheng Liu[1], Ming-Hsi Hsu[2,*], Chi-Ray Wu[3], Chi-Fang Wang[3], and Albert Y. Kuo[4], Member, ASCE

Abstract : A vertical (laterally integrated) two-dimensional numerical model was applied to study the salt water intrusion in the Tanshui River estuarine system, Taiwan. The river system has experienced dramatic changes in the past half century because of human interference. The construction of two reservoirs and water diversion in the upper reaches of the river system significantly reduces the freshwater inflow. The land subsidence within the Taipei basin and the enlargement of the river constriction at Kuan-Du lower the river bed. Both changes contribute to the farther intrusion of tidal flow and salt water in upriver direction. The model reverification was conducted with the earliest available hydrographic data measured in 1977. The overall performance of the model is in reasonable agreement with the field data. The model was then used to investigate the change in salt water intrusion as the result of reservoir construction and bathymetric changes in the river system. The model simulation study reveals that significant salinity increase has resulted from the changes combined. It is believed that the long-term increase in salinity is the driving force altering the aquatic ecosystem structure in the lower reach of the estuary and the Kuan-Du mangrove swamp, particularly the enlargement of the mangrove area and the disappearance of freshwater marshes.

Keywords: Salt water intrusion; Tanshui River system; Numerical model; Kuan-Du mangrove swamp; Reservoir construction; Bathymetric change.

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B. PACON 2003 之摘要

PACON (Pacific Congress of Marine Science and Technology) 2003 研討會將於民國 92 年 6 月 30 日至 7 月 2 日在高雄舉行，由台灣主辦，本計畫團隊總共投稿四篇論文摘要，全部將由研究生以英文發表，藉機訓練學生參與學術成果發表會之能力，以下付列此三篇論文摘要。

Toward the Simulation of Ecological System in the Danshuei River Estuary

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ABSTRACT

The Danshuei River system is the largest estuary in Taiwan. To get a better understanding of the ecological system in the Danshuei River, a multi-disciplinary study including the physical transport processes, nutrient dynamics, primary production, and the zooplankton population is being carried out. In this study, a calibrated and validated two-dimensional hydrodynamic model is used and expanded to simulate the interactions between physical, chemical, and biological factors in the estuary.

To make the model more realistic, there should be field data to accompany the development of the numerical model. Two slackwater surveys and one intensive survey have been conducted to collect simultaneous data of physical properties, nutrient concentrations, and phytoplankton and zooplankton populations at predetermined stations along the axis of the lower reach of the estuary. The physical properties measured include salinity, temperature, total suspended sediment concentrations, and PAR (photosynthetically active radiation). Concentrations of various forms or species of nitrogen, phosphorus, silica, phytoplankton, and zooplankton were also analyzed.

According to the surveyed data, the simulation model is designed to include three groups of phytoplankton, diatom, green algae and the others, and two groups of

zooplankton, copepod and others. The formulations of the relations between the ecological state variables are constructed through literature reference. The calibrated and validated two-dimensional hydrodynamic model has been expanded to include nutrient dynamics, phytoplankton growth and the zooplankton predation. With the field data, and the appropriate values of parameters and rate coefficients, the numerical model may properly simulate the ecological system in the Danshuei River Estuary.

Water Column Light Attenuation in the Danshuei River Estuary

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ABSTRACT

The penetration of sunlight into the water column plays a critical role in the aquatic ecosystem of a water body. Insufficient light is often the principal limiting factor for primary production in many turbid estuaries. The Danshuei River is the largest estuarine system in Taiwan. This study investigates the light attenuation through the water column of the Danshuei River estuary and explores the models for quantifying it. The light penetration into water column is measured by two methods, the Secchi-depth measurement and the measurement of PAR (Photosynthetically Active Radiation). The PAR measurements indicate that the conventional exponential attenuation of light with depth is a very good model. A light attenuation coefficient may be derived from the PAR measurements at each of the stations. The simpler measurements of Secchi-depth provide an approximate estimate of the attenuation coefficients through inverse linear relationship.

Light attenuation through water column is controlled by the amount and kinds of materials dissolved and suspended in the water. A model often used in predictive water quality and ecosystem modeling is to assume that the light attenuation due to dissolved matter is relatively constant and include it with water itself, and that the contributions due to chlorophyll and suspended particles are proportional to their concentrations. However, the linear regression with such a model results in very poor correlation, and relatively large constant term in most cases. The regression with salinity yield much better correlation, indicating that the fraction of sea water might be a good parameter for estimating light attenuation coefficient for practical

application in the Danshuei River.
Key Words: light attenuation coefficient, model, estuaries.

Modeling Water Quality Control for Fish Survival in the Tidal Hsintien Stream

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ABSTRACT

The Hsintien Stream is one of the major branches of the Danshuei River system, which is the largest estuary in Taiwan. It runs through the metropolitan capital city of Taipei and receives large amount of wastewater. The dissolved oxygen is generally low in the tidal portion of the Hsintien Stream. Hypoxia/anoxia occurs often, particularly during the low flow period when the Feitsui reservoir impounds the freshwater for municipal water supply. Fish kills happen from time to time.

The purpose of this study is to develop and apply numerical hydrodynamic and water quality model for the Danshuei River, with special attention on the Hsintien Stream. The model is calibrated with the prototype conditions of year 2000. Daily freshwater discharges are specified as the upstream boundary conditions at the three major branches. Hourly tidal heights are derived from field data at the river mouth for the downstream boundary conditions. The hydrodynamic portion of the model has been recalibrated with measured surface elevation and velocity at various stations in the river system. The water quality portion of the model requires the input data of point and nonpoint sources as well as the boundary conditions of the concentrations of various forms of nutrients, CBOD and dissolved oxygen. The model is being calibrated with respect to the field data provided by Taiwan EPA.

Through this study, we may understand the dissolved oxygen dynamics in the Hsintien Stream, apply the model to develop the appropriate strategy to make sure the dissolved oxygen level suitable for fish survival, and propose effective methods to improve the general water quality of the Hsintien Stream.

Zooplankton Abundance and Distribution in the Danshuei Estuary and Adjacent Waters

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ABSTRACT

The Danshuei River is the most important estuarine ecosystem in northern Taiwan. Huge amount of derived substances and wastewater from Taipei city and county are discharged into the Danshuei ecosystem daily. The transportation process and the terminal destination of derived substances and wastewater are influential on zooplankton abundance and distribution in this ecosystem. However, relatively few studies of zooplankton were carried out in this important ecosystem. The purpose of this study was to investigate zooplankton abundance and distribution in the Danshuei estuary and adjacent waters. Zooplankton was sampled in 5 stations along the Danshuei river from fresh waters to the river mouth. The abundance, distribution, grazing rate, carbon and nitrogen contents of zooplankton were investigated in 5 stations. The results showed that copepods usually were the most dominant composition of zooplankton with high station variations in terms of abundance and distribution. The chlorophyll a contents in the gut of Copepods were relatively low indicating low grazing rate on phytoplankton. However, the C/N of copepods was relatively constant e.g 7. in the Danshuei ecosystem. Occasionally, the barnacle larvae became dominant in the Danshuei ecosystem. Nonetheless, it appeared that the discharge of wastewater from Taipei city and county has great impact on the distribution and abundance of zooplankton in the ecosystem of Danshuei.

C. 現場觀測採樣與分析

本計畫第二年預定作兩次全潮之觀測、採樣與與分析，第一次原於九十一年九月二十五日執行，但是執行一半時，天氣驟變，下起傾盆大雨，持久不停，只得放棄。復於十月十五日執行，配合計畫協同主持人吳俊宗教授之另一計畫，同步觀測與採樣，量測物理、化學與生物等方面之數據。又春季之觀測採樣工作原定於九十二年四月二十四日執行，因颱風之威脅，乃改於五月六日執行。兩次全潮觀測採樣之測站與時間如附表 C-1-1 與 C-1-2 所載。以下附列九十一年九月及十月觀測採樣所得之數據，九十二年五月之樣本尚在分析中。

(1) 物理數據

物理性質之數據，包括鹽分濃度、溫度、懸浮顆粒濃度與光度等，量測所得數據以下列諸圖展示，九十一年十月十五日之鹽分分佈圖顯示當日水體分層現象非常明顯，當日為陰曆九月十日，屬小潮(neap tide)，潮汐混合力較弱，除高潮時段外，整個水柱由水面至水底分層厲害，低潮時在關渡站之垂直鹽度差有 14 *ppt* 之多，竹圍站水深較淺，垂直鹽度差亦有 8 *ppt*，皆屬強分層(strong stratification)型水體，在高潮時段，則因海水大量入侵，將淡水頂托水面，僅最上面約兩公尺之水層有明顯分層現象，兩公尺以下呈均勻水體。又數據顯示，鹽度隨潮時之變化甚巨，以中層水估計，高潮時鹽度可高於低潮時鹽度 10 *ppt* 左右。

懸浮顆粒(TSS)濃度則不高，尤其表層水之濃度皆在 10 mg/l 左右，估計它們對光度衰減係數的影響約 1.0/m 左右，約為觀測所得數據的 2/3 至 1/2 之間。高懸浮顆粒僅存在於河水深處，在關渡站發生於高潮時段，在竹圍站則發生於低潮時段，可能有一高濃度的水團在兩者之間隨潮流來回移動。

光線隨水深之變化則顯示呈指數函數(exponential function)隨水深遞減，相關係數(R^2)大都在 0.9 以上，詳細分析見 B 部分之第二篇摘要。

表 C-1-1 民國九十一年十月十五日全潮觀測採樣時間表

潮汐表

民國91年10月15日(二)農曆9月10日

淡水(121°24'E, 25°11'N)

潮時(時 分)		潮高(公尺	潮類
0	31	1.46	L
6	**8**	**2.56**	**H**
12	38	0.95	L
19	23	2.9	H

預測各站高低平潮時間

	SBE(時 分)				SBF(時 分)	
河口	6	26	19	41	13	8
竹圍	6	31	19	46	13	16
關渡	6	35	19	50	13	23
重陽橋	6	38	19	53	13	35
士林焚化爐	6	44	19	59	13	34

預計抵達各站時間（預估操作時間**30**分鐘）

關渡	6	30
竹圍	7	10
關渡	8	0
竹圍	8	40
關渡	9	30
竹圍	10	10
關渡	11	0
靠岸午膳休息		
關渡	12	30
竹圍	13	10
關渡	14	0
竹圍	14	40
關渡	15	30
竹圍	16	10
關渡	17	0

表 C-1-2 民國九十二年五月六日全潮觀測採樣時間表

潮汐表

民國92年5月6日(二)農曆4月6日

淡水**(121^{o}24'E, 25^{o}11'N)**

潮時(時 分)		潮高(公尺	潮類
1	33	3	H
7	42	1.26	L
13	16	2.71	H
19	41	0.61	L

預測各站高低平潮時間

	SBE(時 分)		SBF(時 分)			
河口	13	34	7	51	20	16
竹圍	13	39	7	59	20	24
關渡	***13***	***43***	**8**	**6**	***20***	***31***
重陽橋	13	46	8	17	20	43
士林焚化爐	13	52	8	17	20	42

預計抵達各站時間（預估操作時間**30**分鐘）

關渡	6	30
竹圍	7	10
關渡	8	0
竹圍	8	40
關渡	9	30
竹圍	10	10
關渡	11	0
靠岸午膳休息		
關渡	12	30
竹圍	13	10
關渡	14	0
竹圍	14	40
關渡	15	30
竹圍	16	10
關渡	17	0

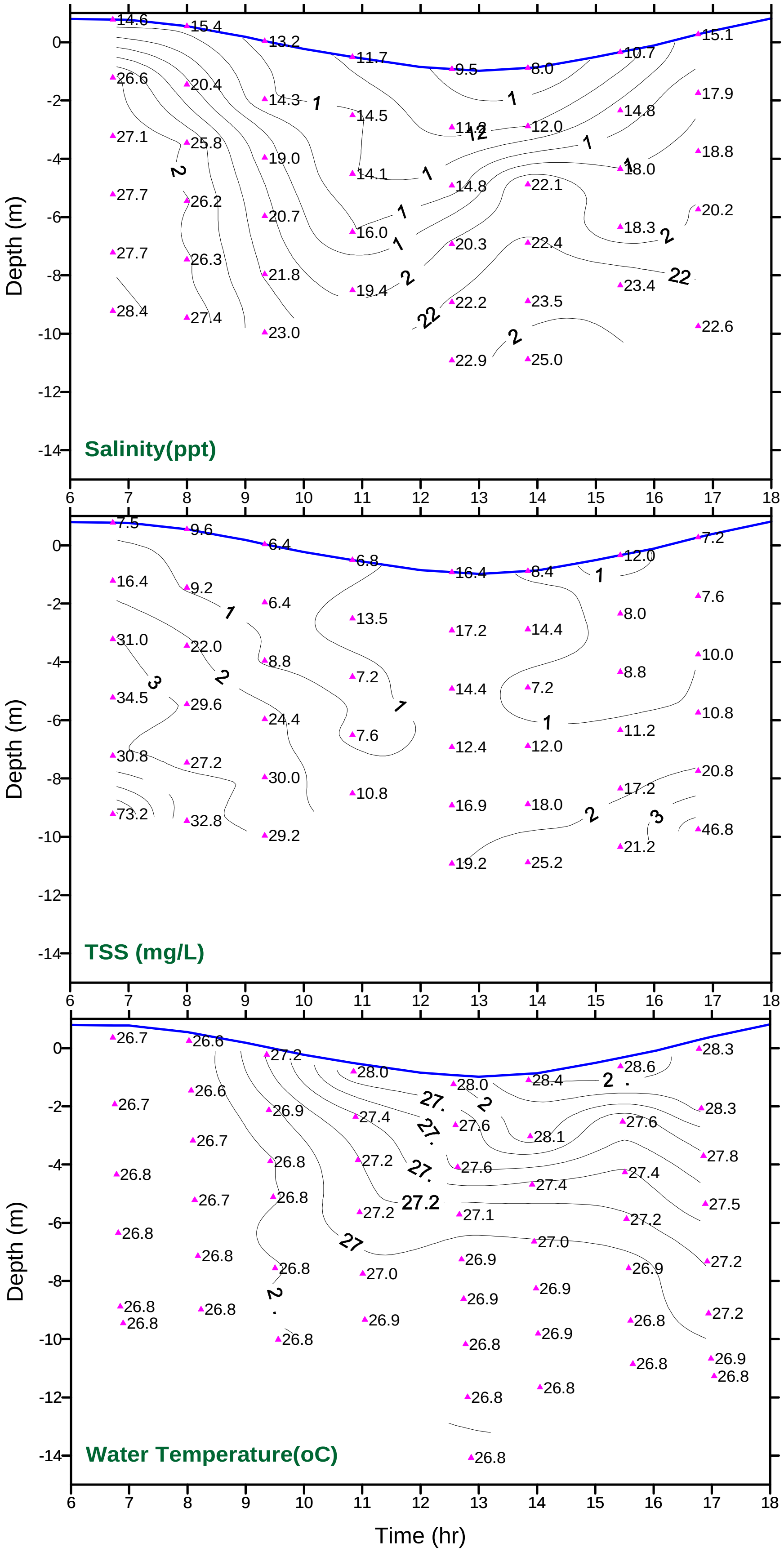


圖 C-1-1 關渡測站鹽分濃度、懸浮顆粒濃度及水溫（九十一年十月十五日）

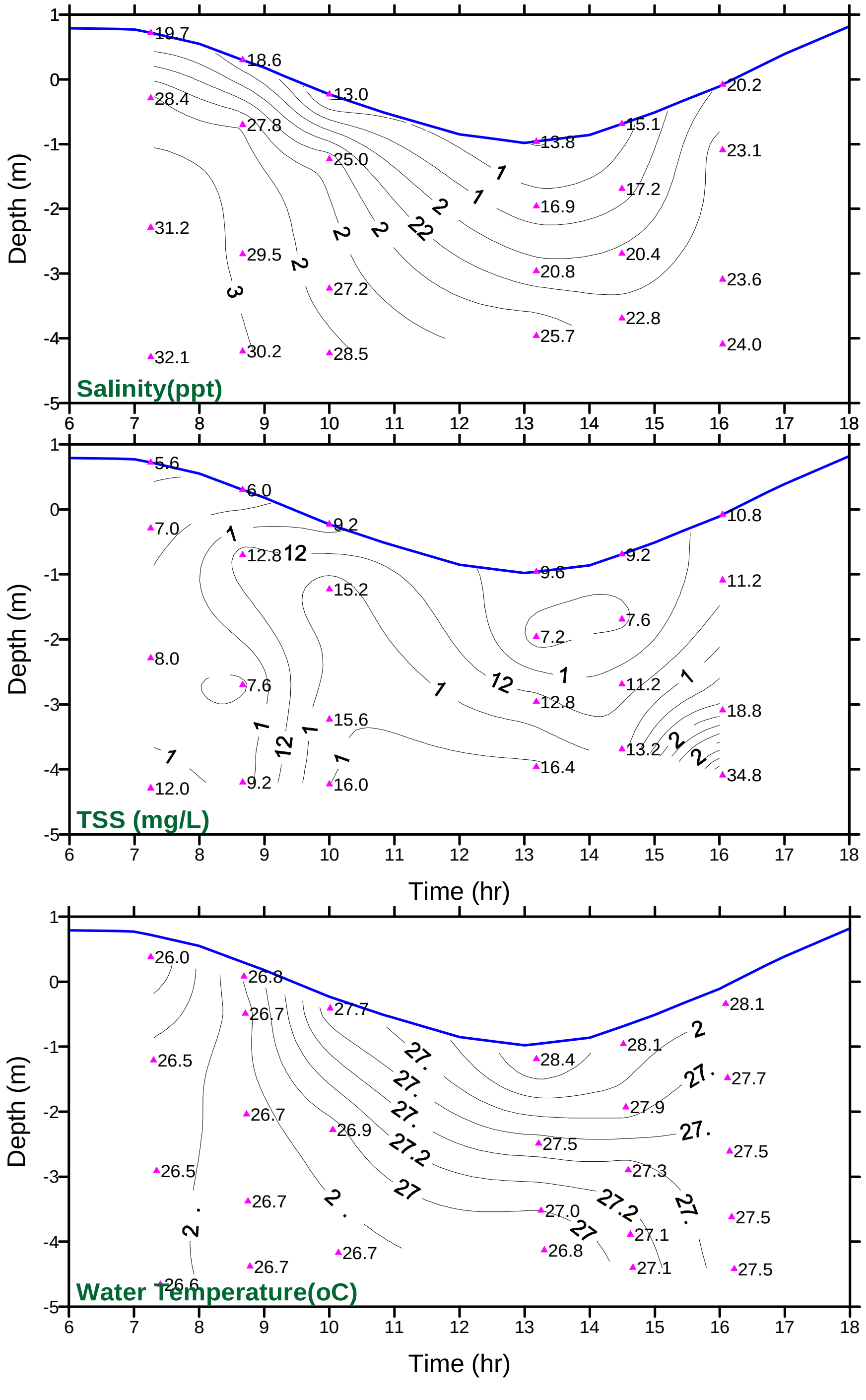
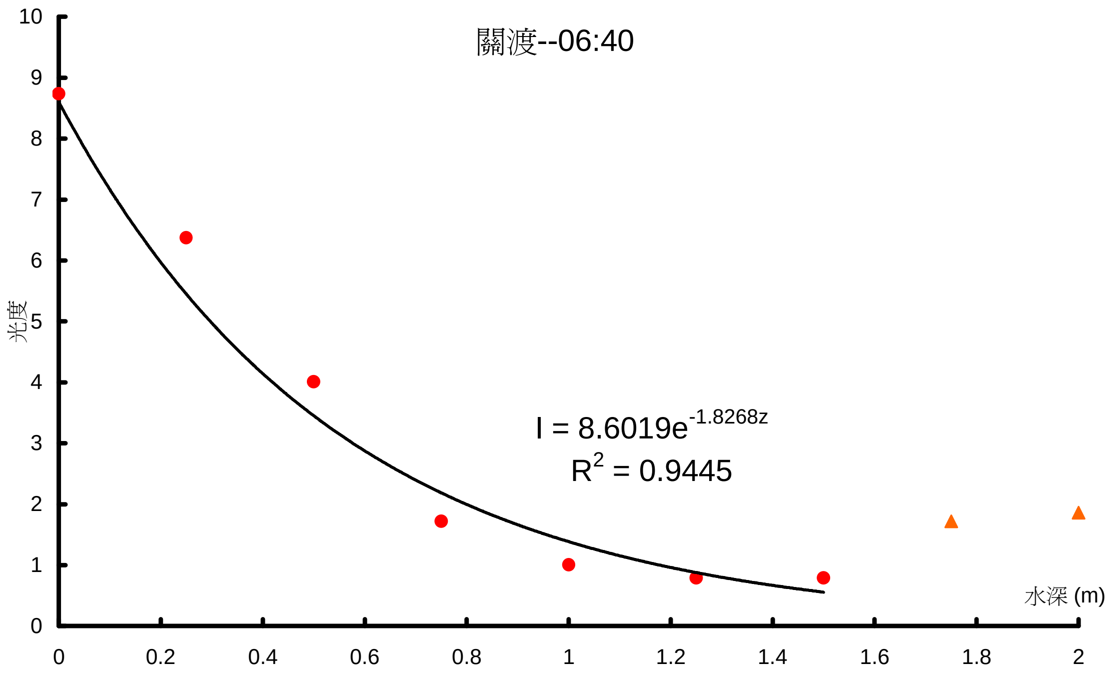
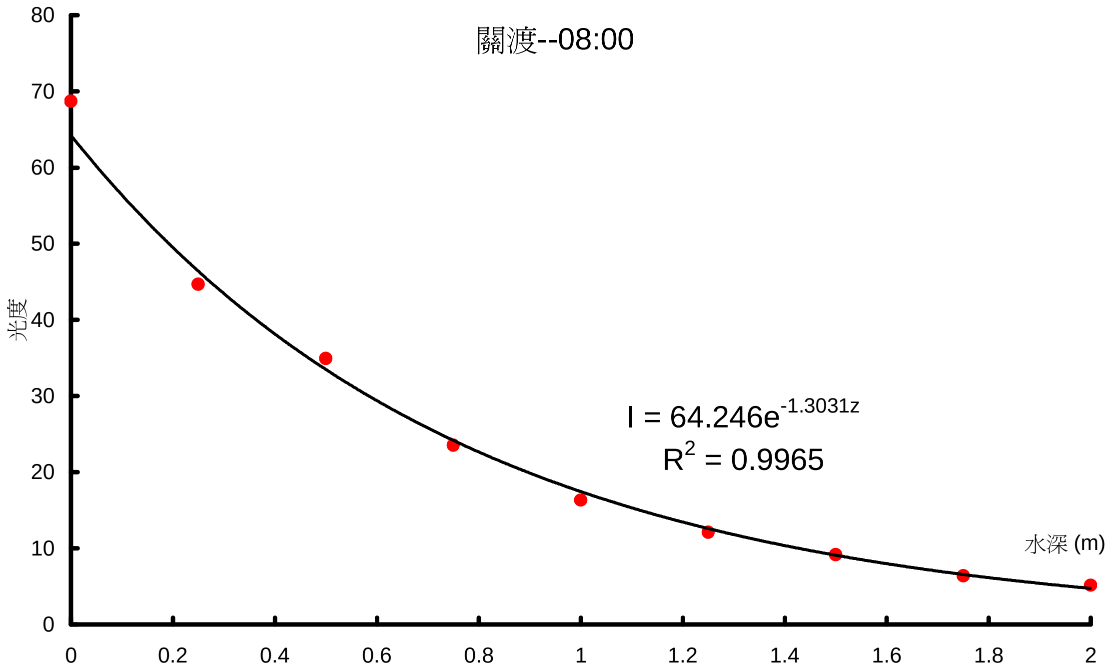
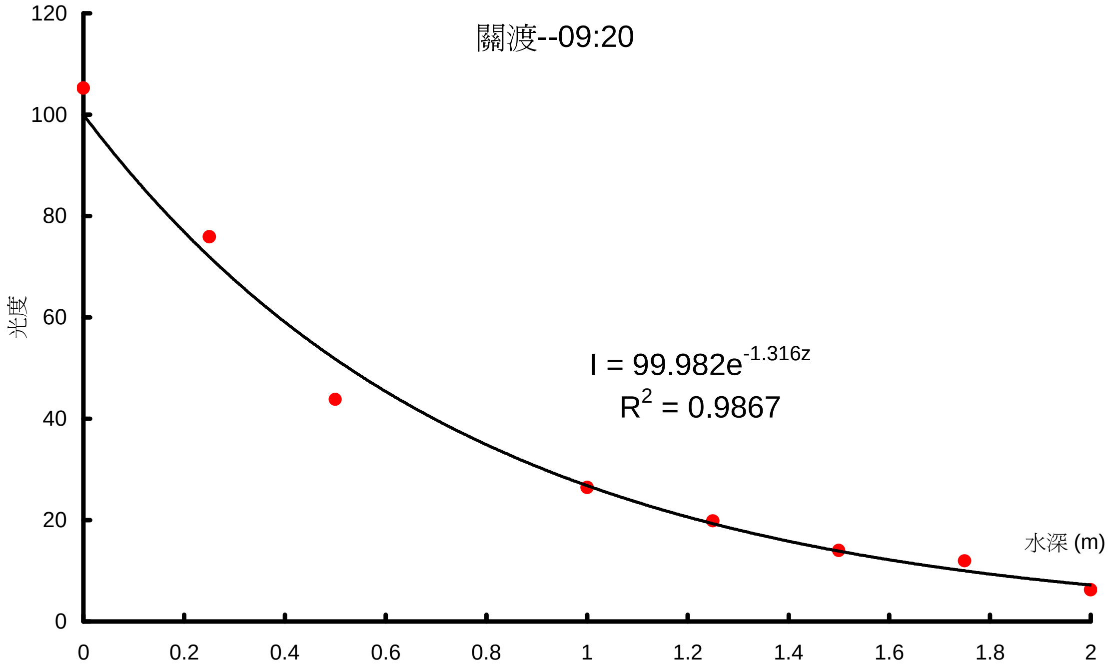


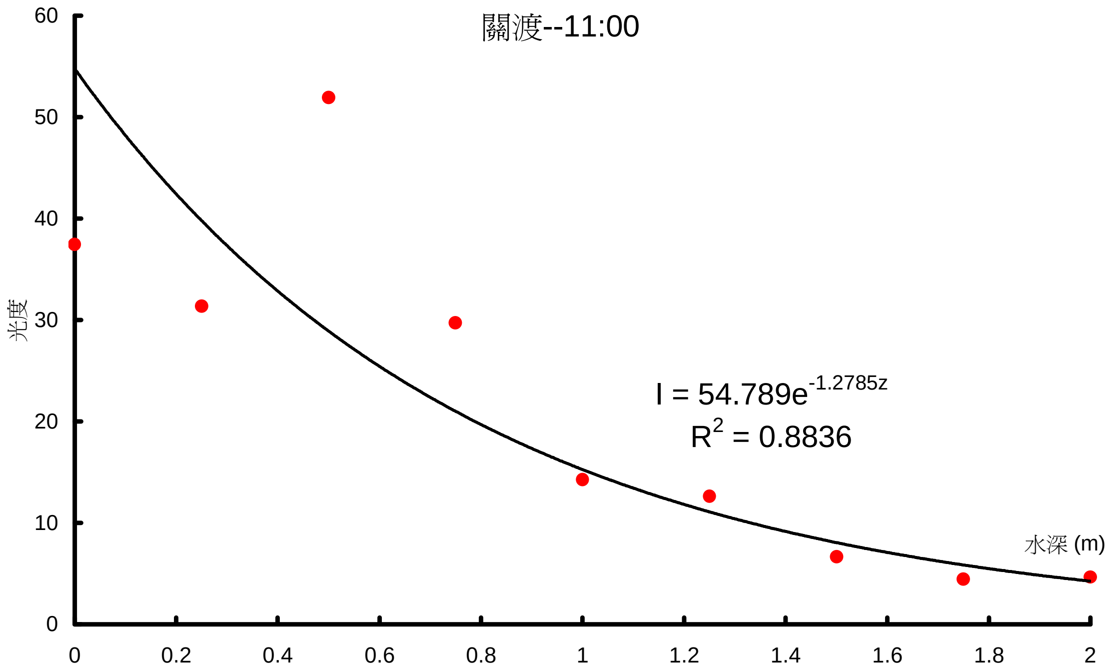
圖 C-1-2 竹圍測站鹽分濃度、懸浮顆粒濃度及水溫（九十一年十月十五日）


闊渡--06:40
光度
I = 8.6019e-1.8268z
R2 = 0.9445
水深 (m)
10
9
8
7
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

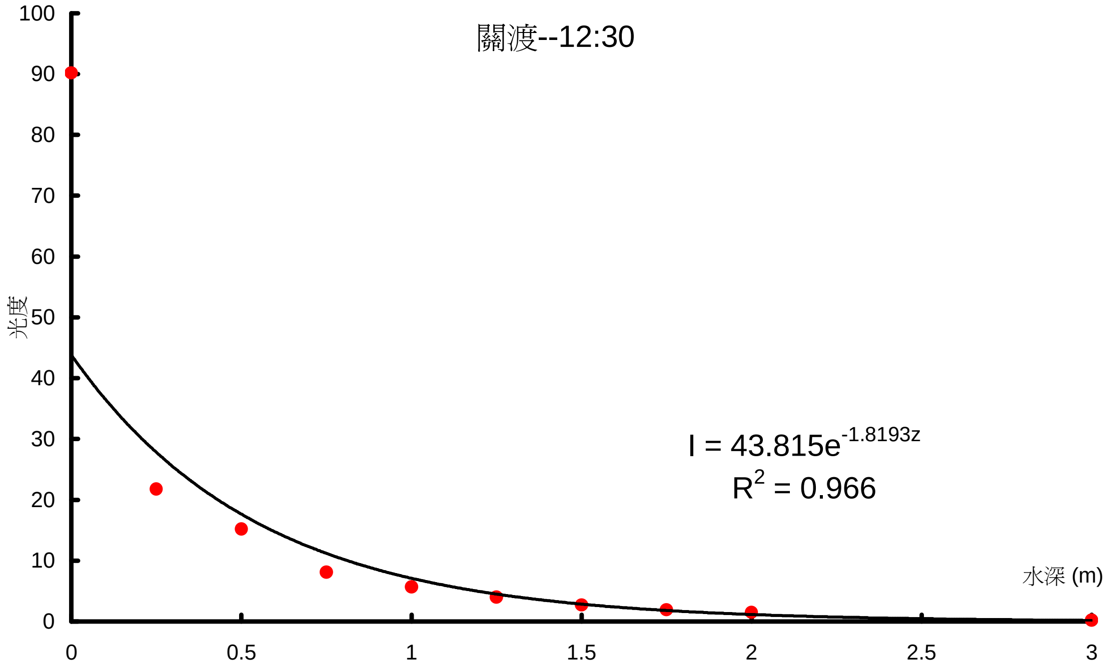

闊渡--08:00
光度
I = 64.246e-1.3031z
R2 = 0.9965
水深 (m)
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

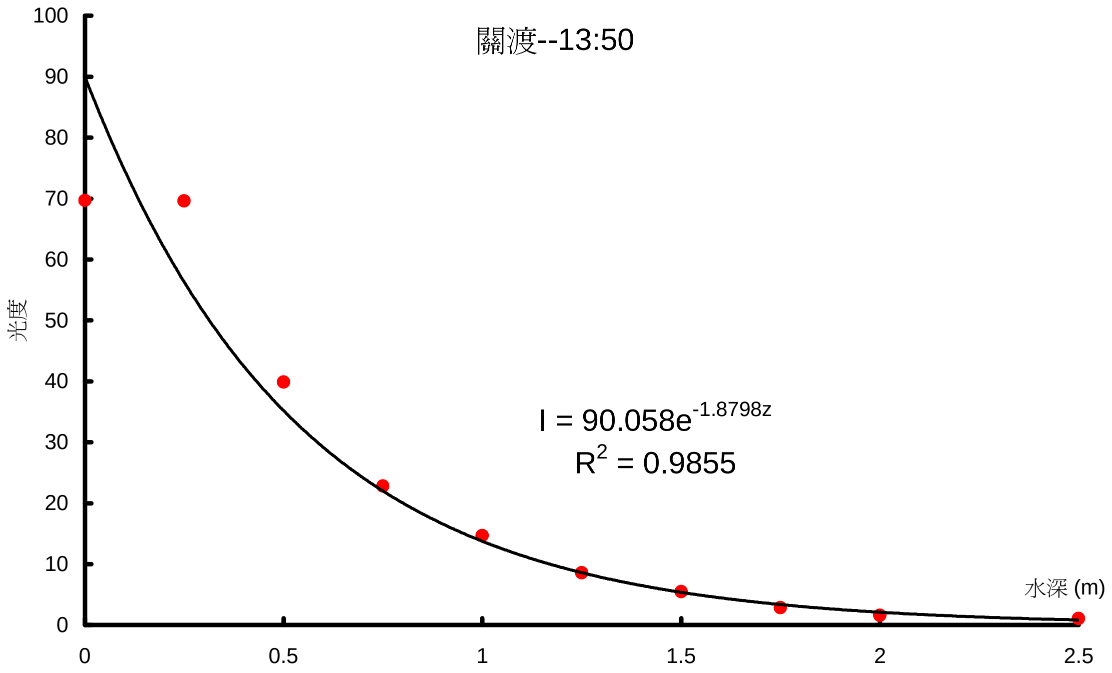


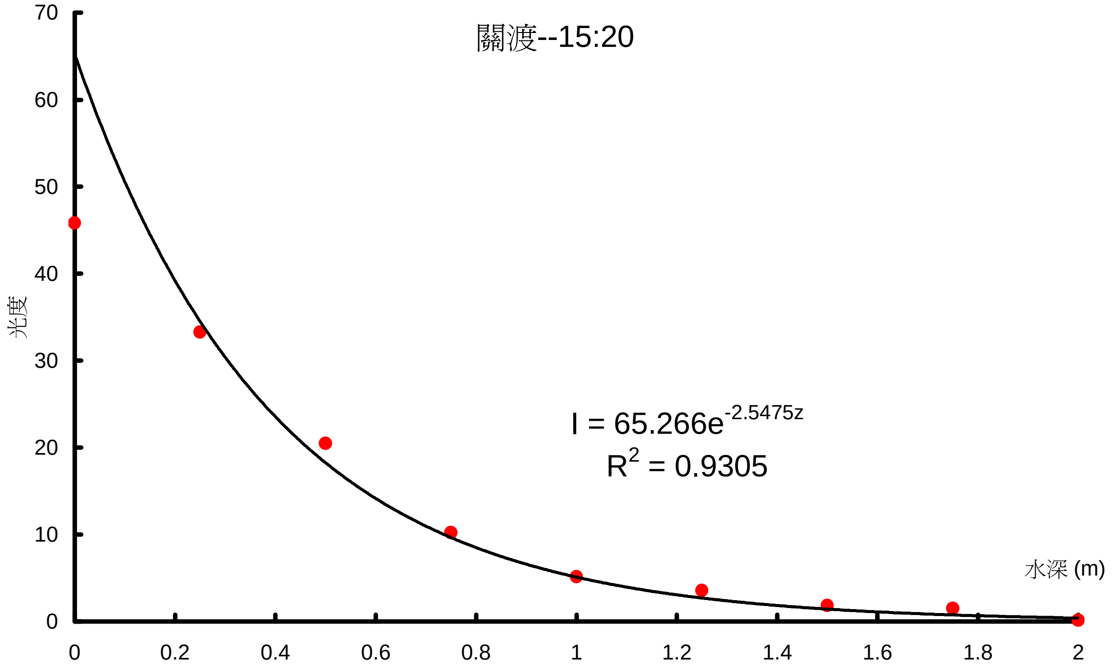
關渡--09:20
光度
水深 (m)
I = 99.982e^-1.316z
R^2 = 0.9867
120
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

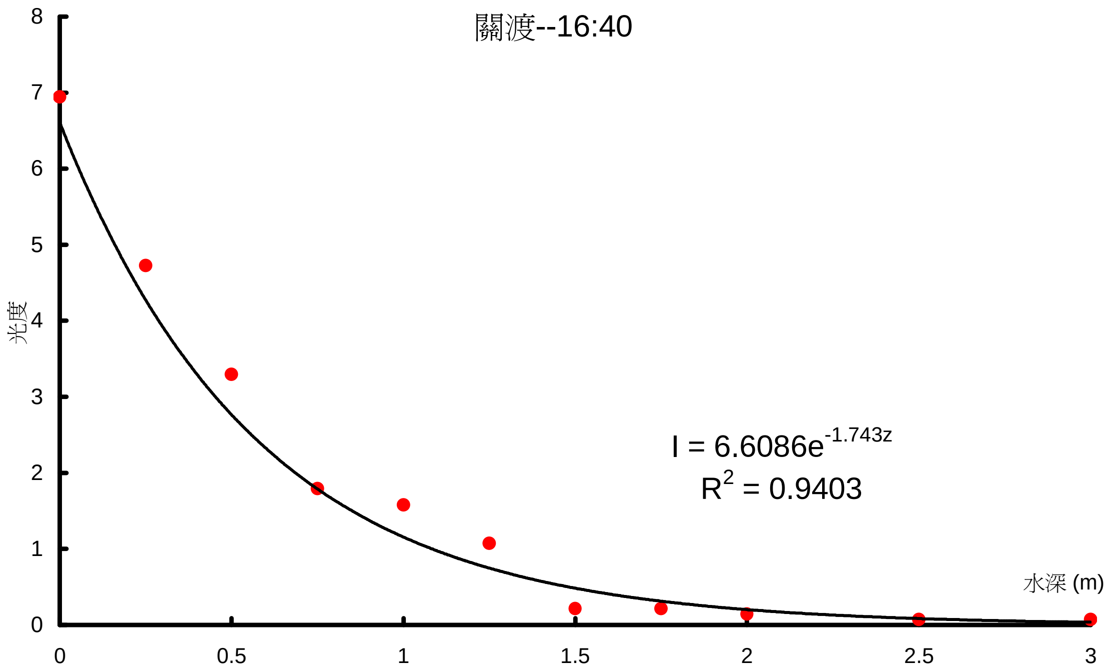


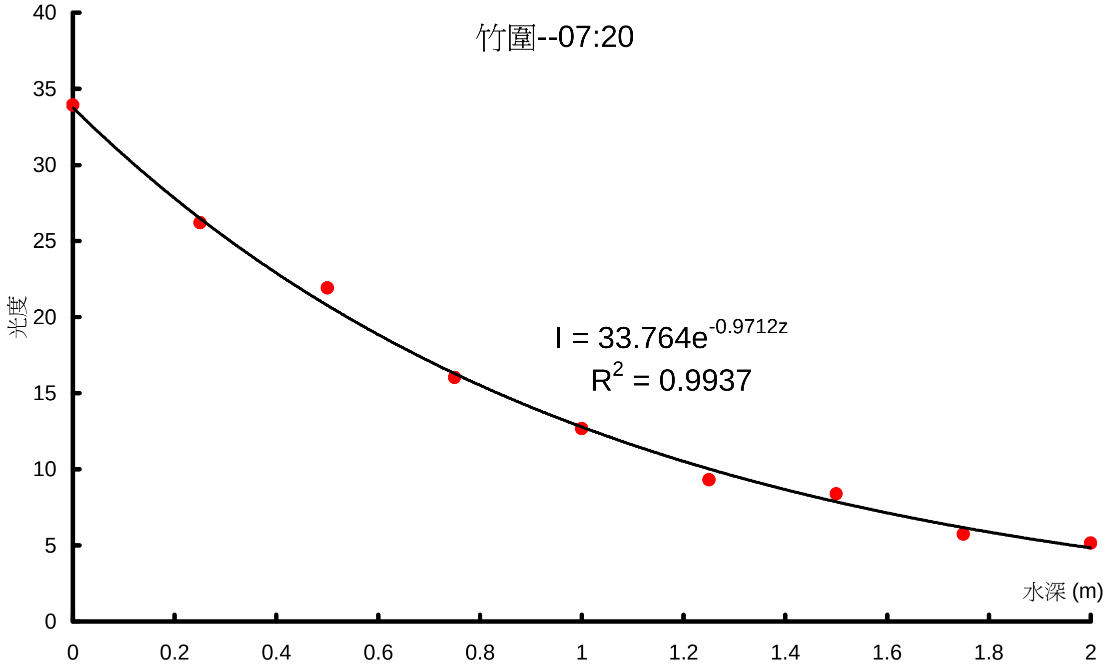
關渡--11:00
光度
水深 (m)
I = 54.789e^-1.2785z
R^2 = 0.8836
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

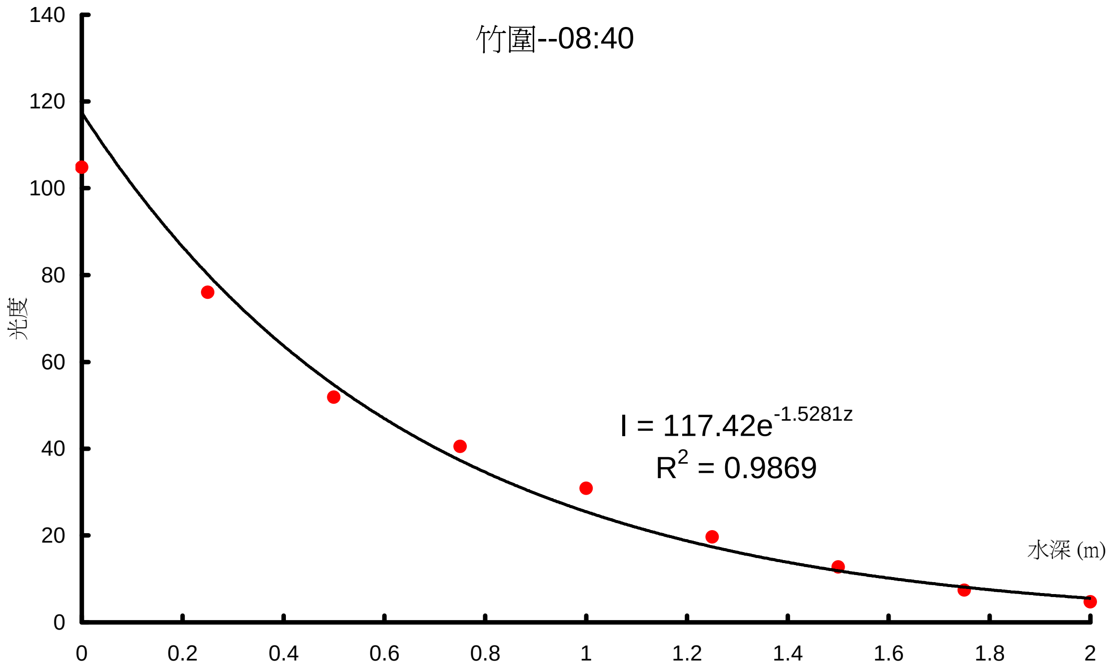

關渡--12:30
光度
水深 (m)
I = 43.815e-1.8193z
R2 = 0.966
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3

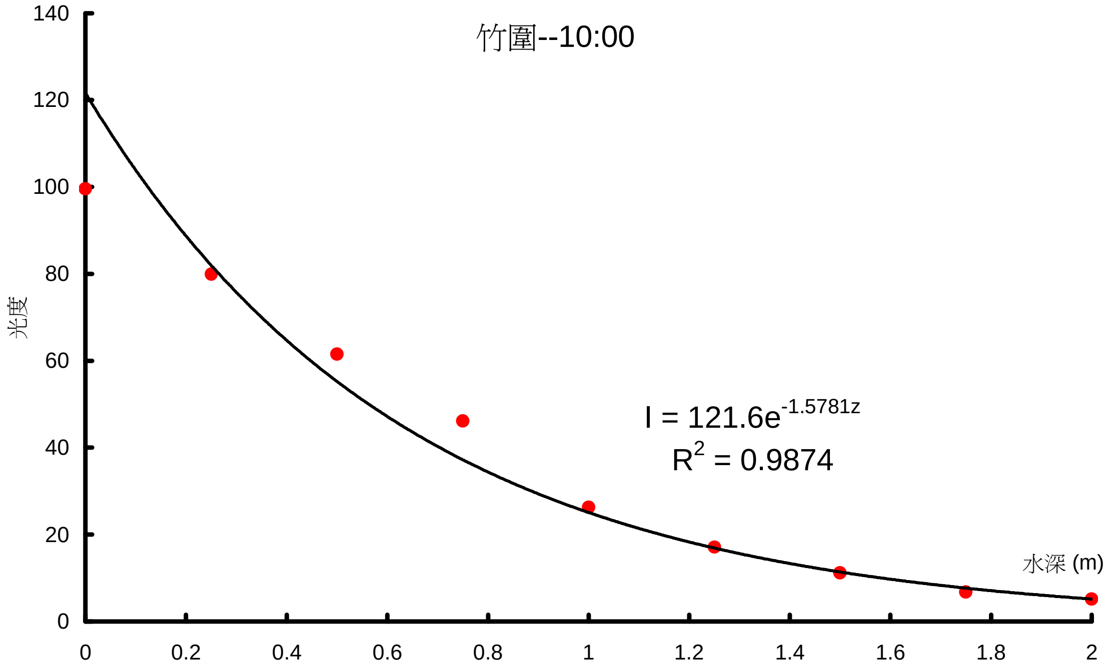

關渡--13:50
光度
水深 (m)
I = 90.058e-1.8798z
R2 = 0.9855
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5

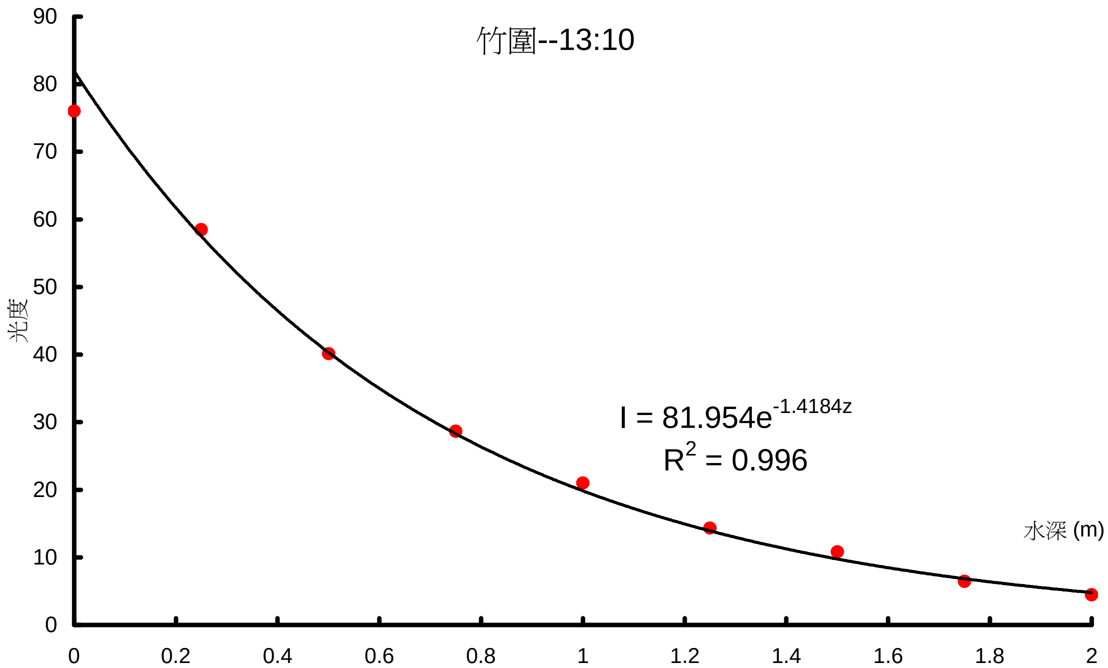

關渡--15:20
光度
水深 (m)
I = 65.266e-2.5475z
R2 = 0.9305
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

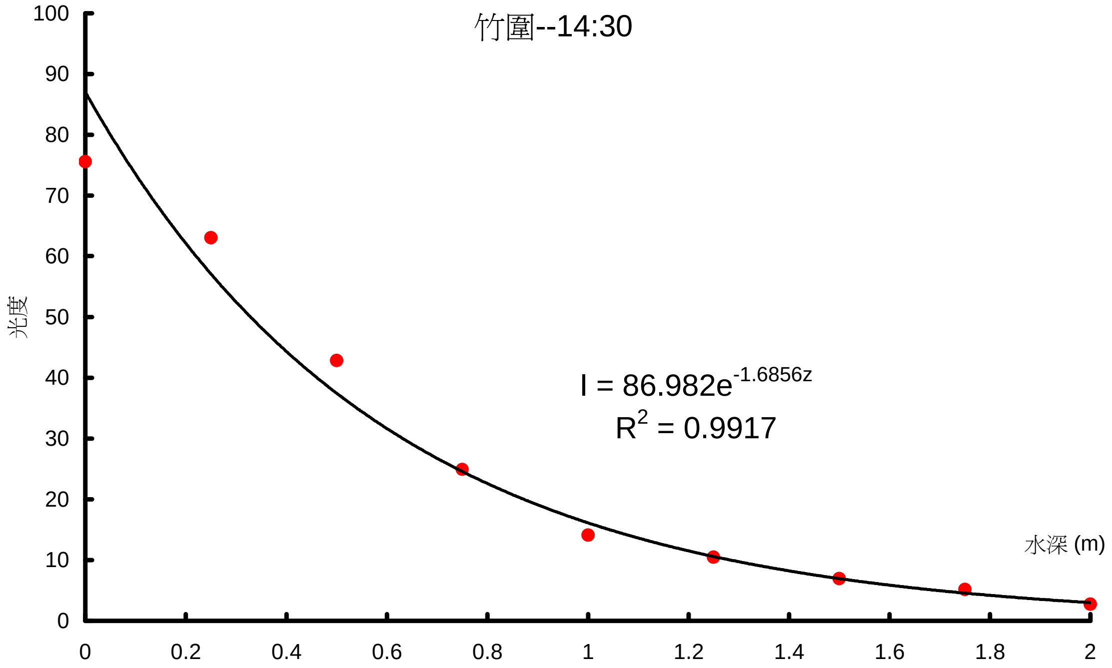

關渡--16:40
光度
水深 (m)
I = 6.6086e-1.743z
R2 = 0.9403
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3

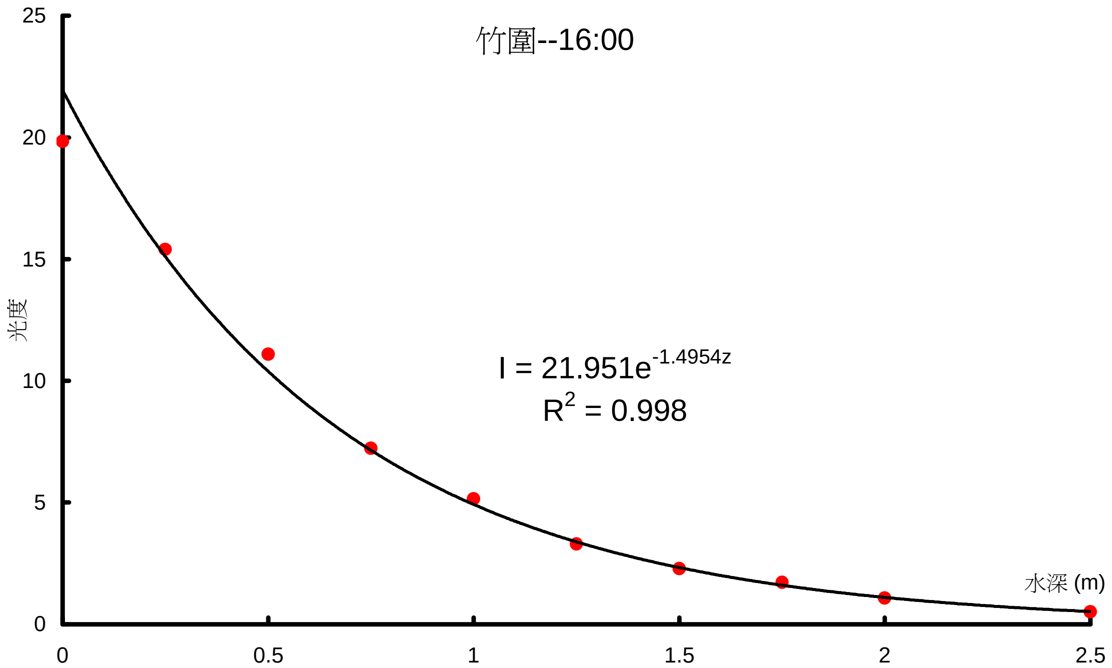

竹圍--07:20
光度
水深 (m)
I = 33.764e-0.9712z
R2 = 0.9937
0
5
10
15
20
25
30
35
40
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


竹圍--08:40
光度
水深 (m)
I = 117.42e-1.5281z
R2 = 0.9869
0
20
40
60
80
100
120
140
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


竹圍--10:00
I = 121.6e-1.5781z
R2 = 0.9874
光度
水深 (m)
140
120
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


竹圍--13:10
I = 81.954e-1.4184z
R2 = 0.996
光度
水深 (m)
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


竹圍--14:30
I = 86.982e-1.6856z
R2 = 0.9917
光度
水深 (m)
100
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


竹圍--16:00
I = 21.951e-1.4954z
R2 = 0.998
光度
水深 (m)
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5

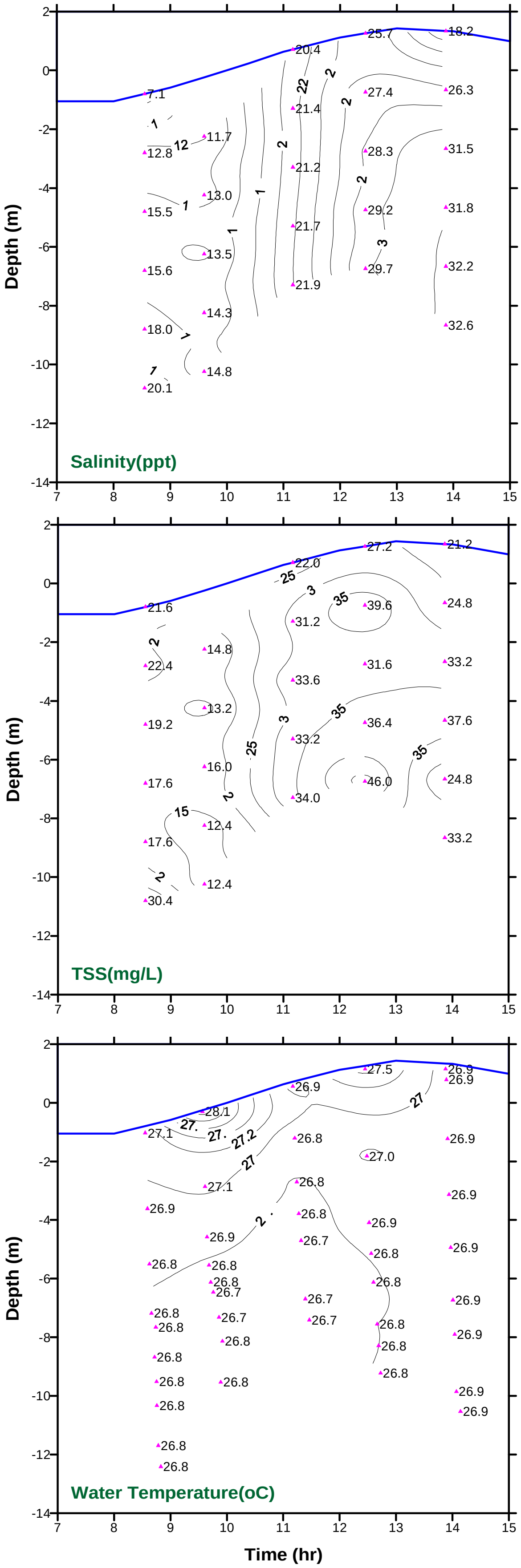


圖 C-1-3 關渡測站鹽分濃度、懸浮顆粒濃度及水溫（九十一年九月二十五日）

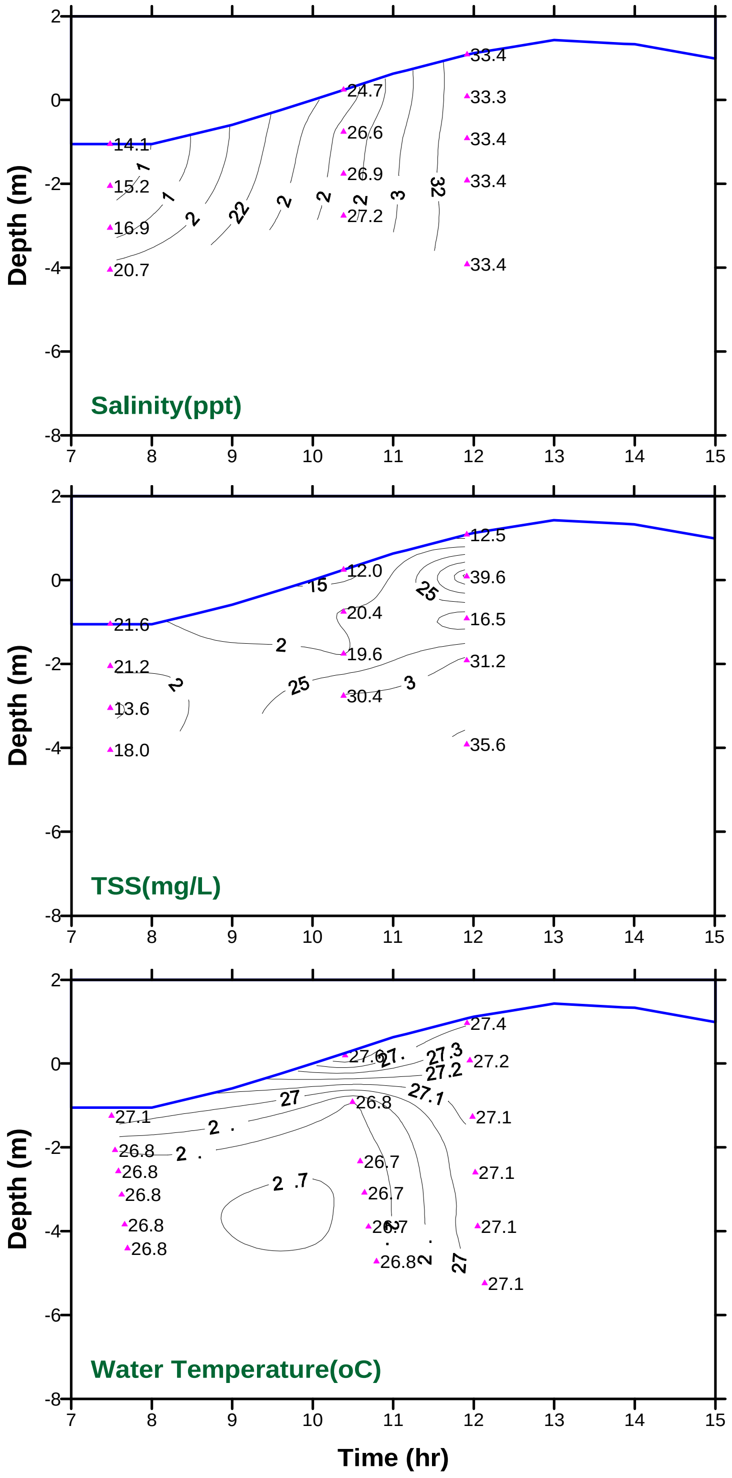
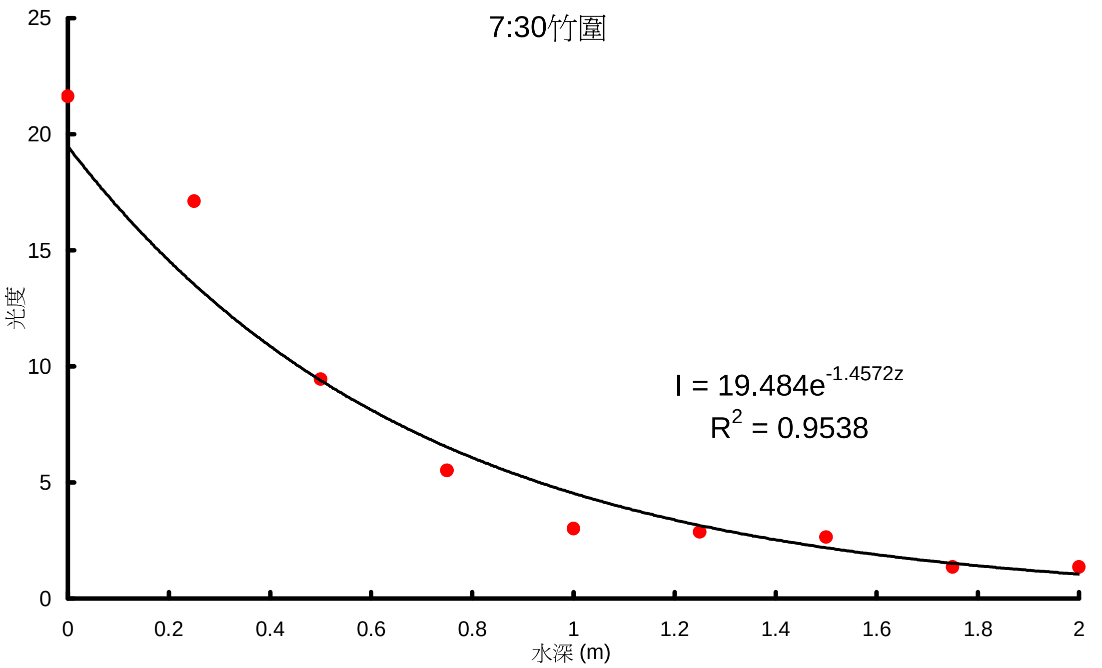
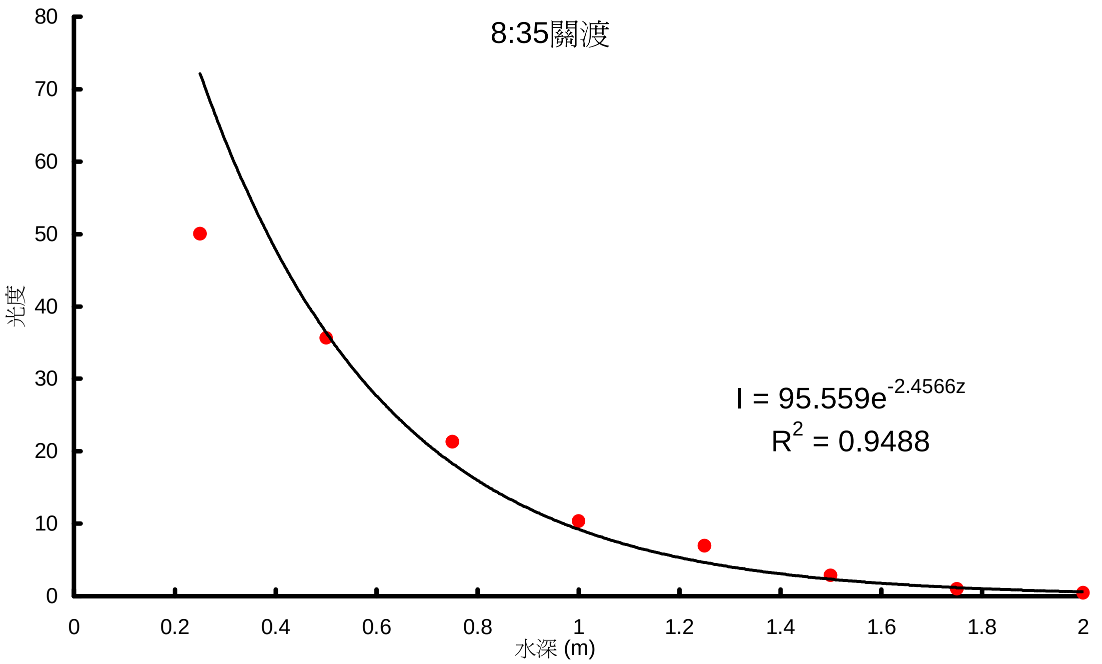
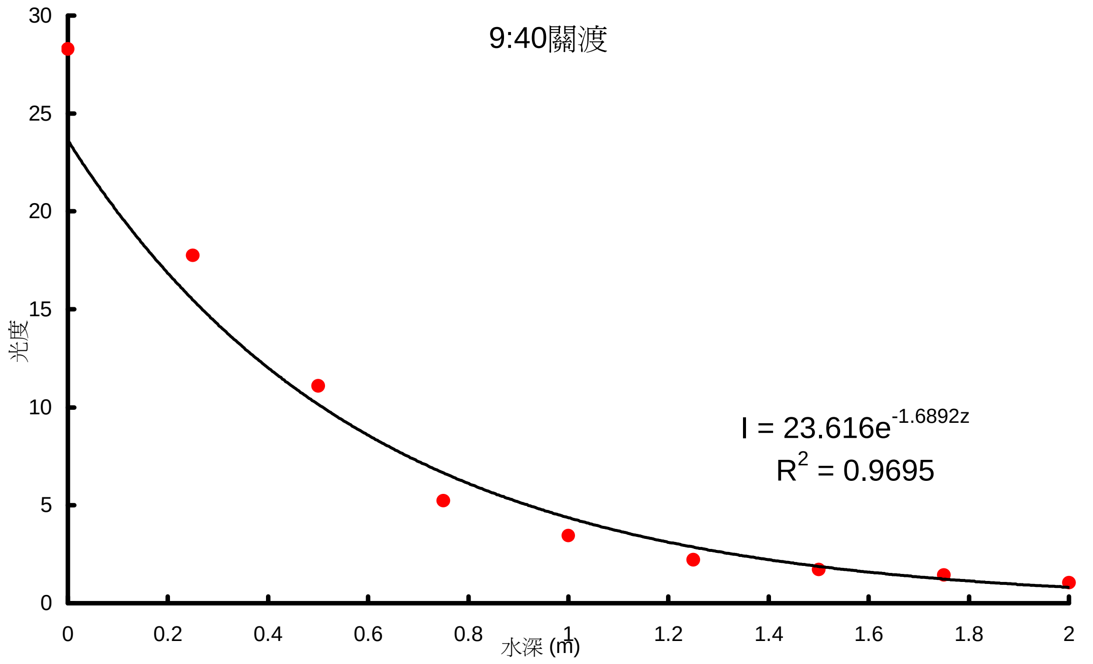
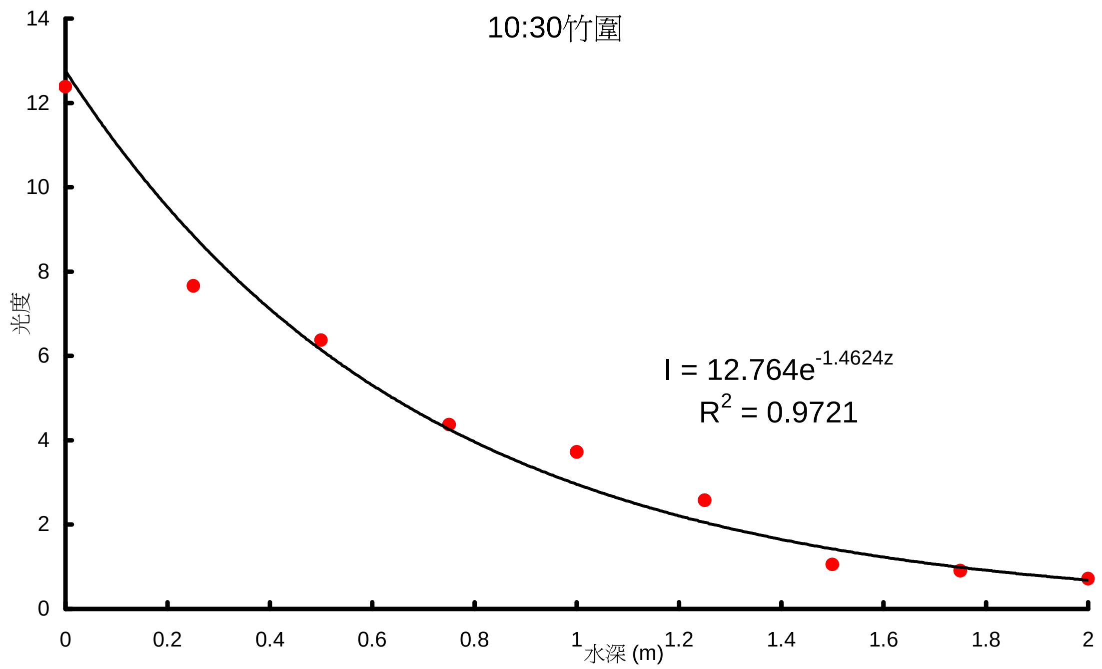


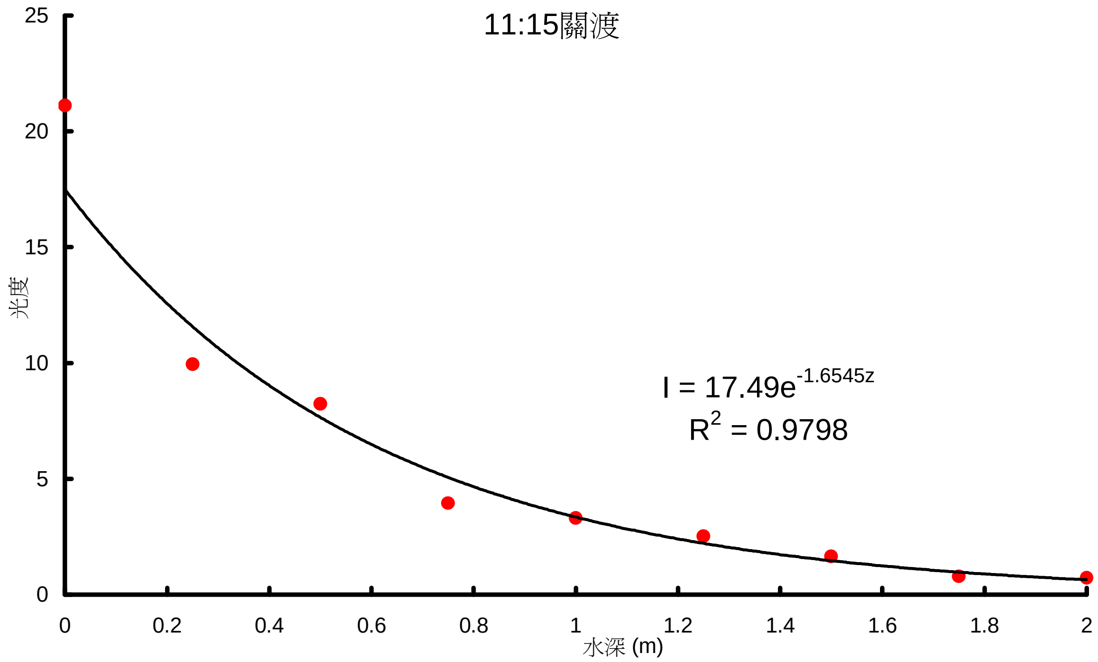
圖 C-1-4 竹圍測站鹽分濃度、懸浮顆粒濃度及水溫（九十一年九月二十五日）

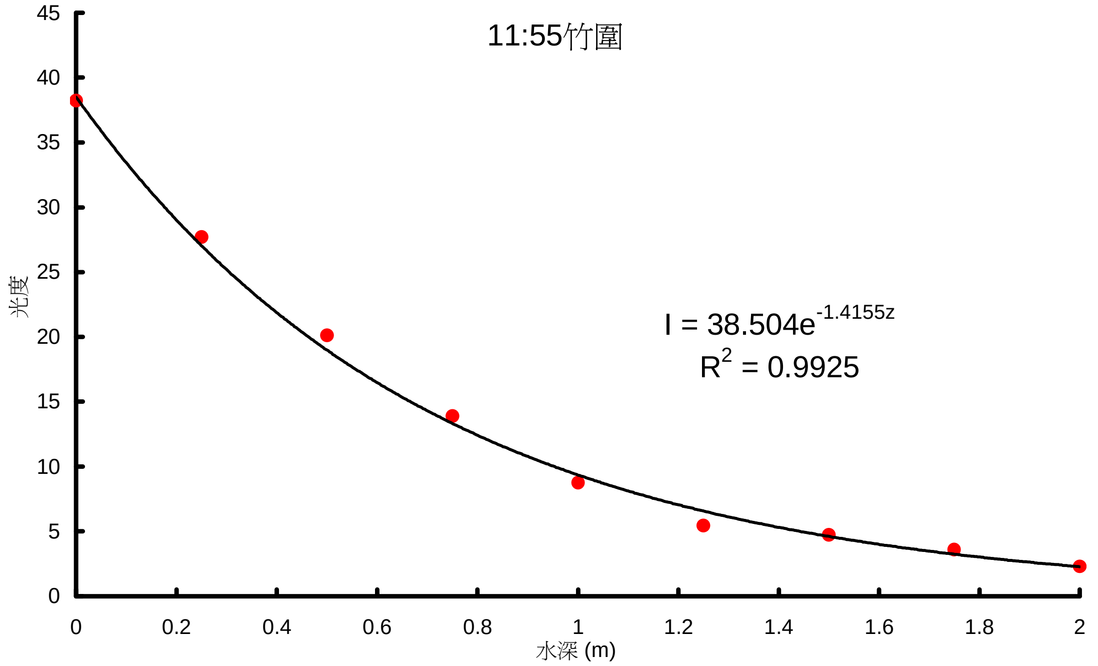

7:30竹圍
25
20
15
10
5
0
光度
I = 19.484e^-1.4572z
R^2 = 0.9538
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深 (m)

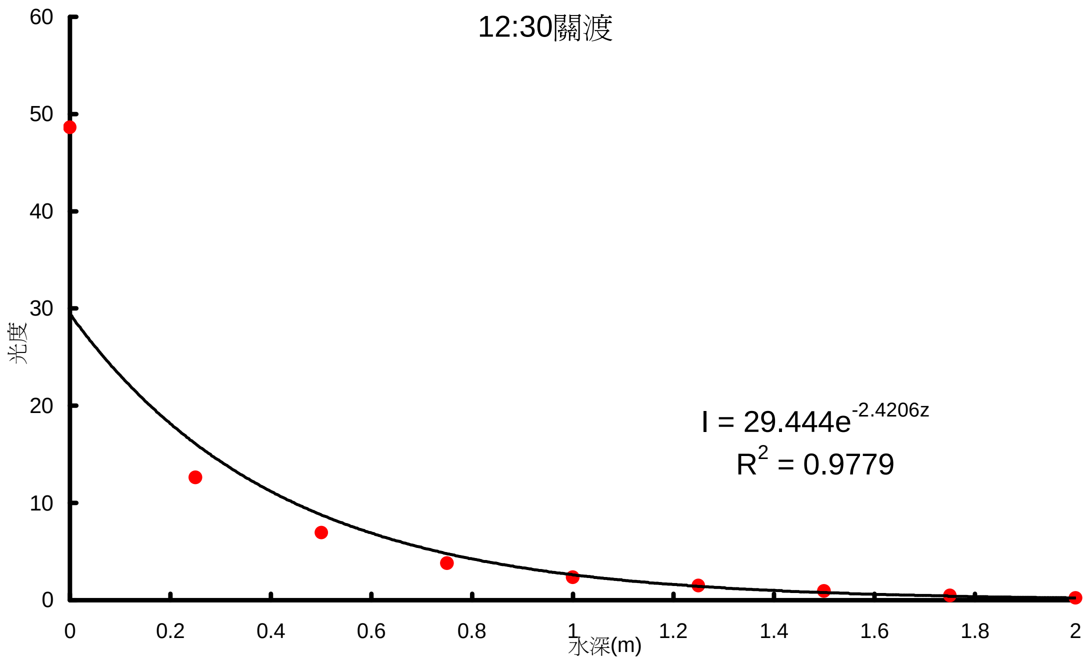

8:35關渡
80
70
60
50
40
30
20
10
0
光度
I = 95.559e^-2.4566z
R^2 = 0.9488
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深 (m)

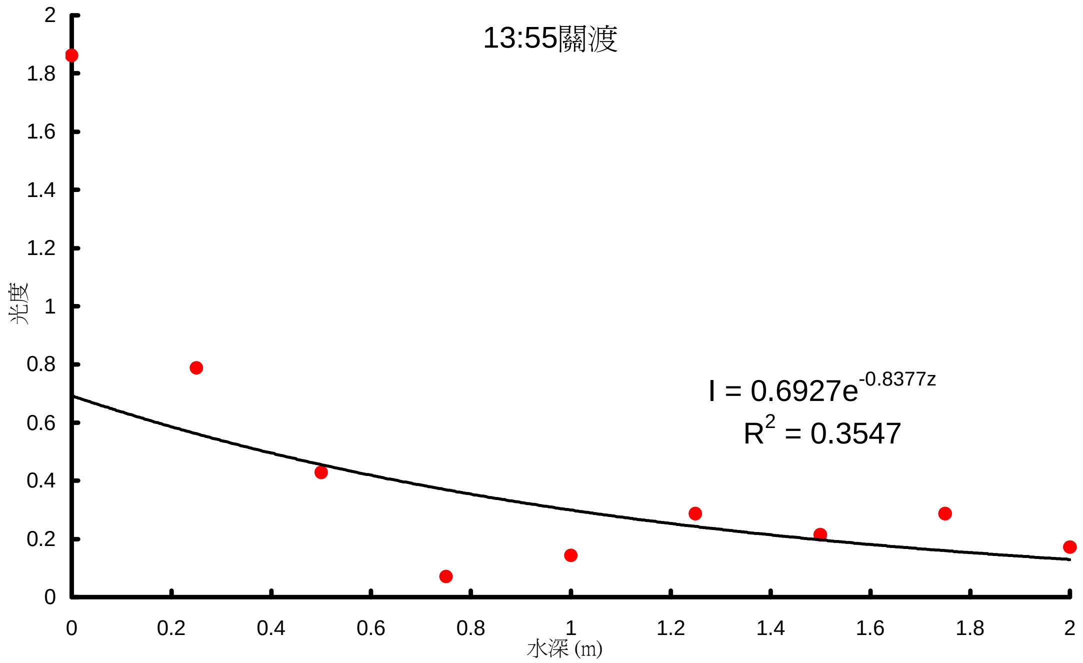

9:40關渡
光度
水深 (m)
I = 23.616e-1.6892z
R2 = 0.9695
30
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


10:30竹圍
光度
水深 (m)
I = 12.764e-1.4624z
R2 = 0.9721
14
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


11:15關渡
25
20
15
10
5
0
光度
I = 17.49e-1.6545z
R2 = 0.9798
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深 (m)


11:55竹圍
45
40
35
30
25
20
15
10
5
0
光度
I = 38.504e-1.4155z
R2 = 0.9925
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深 (m)


12:30關渡
60
50
40
30
20
10
0
光度
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深(m)
I = 29.444e^-2.4206z
R^2 = 0.9779


13:55關渡
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
光度
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
水深 (m)
I = 0.6927e^-0.8377z
R^2 = 0.3547

(2) 浮游動物數據

浮游動物樣本以 200μ之拖網採集，因採集所需時間較長，約 30 至 40 分鐘，故每個測站只能採取接近水面之樣本。

(a)九十一年十月十五日之數據

表C-2-1與表C-2-2分列各類浮游動物在每一單位水體中之個數及個數百分比，圖 C-2-1 與圖 C-2-2 則將此數據以圖形展示，除高潮時段在竹圍站所採得之樣本以外，皆有大量之「其他」類浮游動物存在，經鑑定，此乃藤壺類之幼體，因其存在只限於偶有之繁殖期，且懸浮於水體中之時間短暫，故對整個食物鏈不重要，把它們扣除後仍以橈足類佔優勢。又表 C-2-3 和圖 C-2-3，列示單位水體中的質量，並將橈足類及非橈足類之浮游動物的質量濃度分別單獨表示，其中碳的濃度將爲模擬時代表生物質量(Biomass)的變數，此次觀測所得，最高濃度 0.37 mg/m^3(橈足類及非橈足類的總和)，爲歷次觀測所得最低。

(b)九十一年九月二十五日之數據

本次採樣只取得一部份之數據，分列於表 C-2-4 至 C-2-6 與圖 C-2-4 至 C-2-6 中。如表 C-2-5 所示，在每一個測站，皆以橈足類佔絕對優勢，最高達 99 %。又單位水體中浮游動物含碳量有高達 4.5 mg/m^3者，應是一組較好的數據，然因天候因素而未能完成全潮採樣，甚爲可惜。

表 C-2-1 淡水河各測站浮游動物組成（*Ind.*/ m^3 ，九十一年十月十五日)

	關渡								竹圍					
	6:40	8:00	9:20	11:00	12:30	13:50	15:20	16:40	7:20	8:40	10:00	13:10	14:30	16:00
夜光蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
有孔蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
放射蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
水母類	0.00	0.02	0.08	0.00	0.14	0.35	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
櫛水母	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
多毛類	0.08	0.12	0.15	0.31	0.33	1.05	0.00	0.00	0.28	0.00	1.96	0.68	0.00	0.00
翼足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
異足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
端足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
螢蝦	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
櫻蝦	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
其他十足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
枝角類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
介形類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
甲殼類幼生	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
哲水蚤	6.07	4.87	14.11	23.07	1.75	0.41	0.46	1.98	43.58	31.42	8.15	7.43	6.43	1.07
劍水蚤	14.24	0.89	6.03	1.69	0.76	1.28	0.03	0.30	0.84	0.72	2.28	0.00	0.00	0.13
猛水蚤	0.89	0.00	0.00	0.00	0.00	0.00	0.03	0.04	1.12	0.00	0.33	0.00	0.00	0.04
糠蝦類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
磷蝦類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
棘皮幼生	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
毛？類	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.04	0.33	0.00	0.00	0.00
有尾類	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.28	0.00	0.00	0.00	0.02	0.00
海樽類	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
魚卵	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
仔稚魚	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
其他	51.52	33.06	146.86	117.02	8.15	11.17	3.68	14.22	0.00	2.65	62.92	18.24	2.30	106.13
total	72.80	38.97	167.32	142.11	11.14	14.28	4.22	16.55	46.10	34.85	75.96	27.02	8.74	107.38

表 C-2-2 淡水河各測站浮游動物數量百分比 (九十一年十月十五日)

	關渡								竹圍					
	6:40	8:00	9:20	11:00	12:30	13:50	15:20	16:40	7:20	8:40	10:00	13:10	14:30	16:00
夜光蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
有孔蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
放射蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
水母類	0.0%	0.1%	0.0%	0.0%	1.3%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%
櫛水母	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
多毛類	0.1%	0.3%	0.1%	0.2%	3.0%	7.3%	0.0%	0.0%	0.6%	0.0%	2.6%	2.5%	0.0%	0.0%
翼足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
異足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
端足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
螢蝦	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
櫻蝦	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
其他十足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
枝角類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
介形類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
甲殼類幼生	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
哲水蚤	8.3%	12.5%	8.4%	16.2%	15.7%	2.9%	11.0%	12.0%	94.5%	90.2%	10.7%	27.5%	73.5%	1.0%
劍水蚤	19.6%	2.3%	3.6%	1.2%	6.8%	9.0%	0.7%	1.8%	1.8%	2.1%	3.0%	0.0%	0.0%	0.1%
猛水蚤	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.3%	2.4%	0.0%	0.4%	0.0%	0.0%	0.0%
糠蝦類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
磷蝦類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
棘皮幼生	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
毛?類	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.0%
有尾類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.6%	0.0%	0.0%	0.0%	0.2%	0.0%
海樽類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
魚卵	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
仔稚魚	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
其他	70.8%	84.8%	87.8%	82.3%	73.2%	78.2%	87.3%	85.9%	0.0%	7.6%	82.8%	67.5%	26.3%	98.8%

表 C-2-3 顆粒性質濃度 (mg/m^3 ，九十一年十月十五日)

Total zooplankton

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	6:40	0.0116	0.1102	1.0273	26.2816	9.3067
	8:00	0.0031	0.1585	0.5384	3.9239	30.7426
	9:20	0.0159	0.1218	0.6182	4.4750	7.9356
	11:00	0.0490	0.3347	1.4157	15.0990	6.6505
	12:30	0.0052	0.0375	0.1906	1.5101	6.2711
	13:50	0.0042	0.0438	0.3286	1.4305	9.1665
	15:20	0.0009	0.0098	0.0809	0.7029	11.1686
	16:40	0.0035	0.0302	0.2294	2.0904	8.8140
竹圍	7:20	0.0066	0.0607	0.2654	4.4229	9.3413
	8:40	0.0055	0.0586	0.2014	3.6877	10.4849
	10:00	0.0097	0.0774	0.3741	6.4776	7.7052
	13:10	0.0034	0.0333	0.1018	1.4953	9.7321
	14:30	0.0075	0.0242	0.1126	0.6457	2.1889
	16:00	0.0384	0.3726	1.3048	12.6221	8.7397

zooplankton (copepods)

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	6:40	0.0020	0.0182	0.2532	2.8842	9.0378
	8:00	0.0005	0.0053	0.0669	0.9309	10.8317
	9:20	0.0023	0.0201	0.1445	0.8915	8.8801
	11:00	0.0070	0.0443	0.1894	3.1116	6.3208
	12:30	0.0036	0.0193	0.0638	0.5942	5.3083
	13:50	0.0014	0.0112	0.0264	0.5742	7.9107
	15:20	0.0003	0.0041	0.0336	0.0695	13.3080
	16:40	0.0010	0.0101	0.0872	0.5087	9.8270
竹圍	7:20	0.0060	0.0552	0.2550	3.8881	9.2231
	8:40	0.0048	0.0514	0.1832	2.9540	10.6829
	10:00	0.0020	0.0138	0.0715	1.8285	6.8137
	13:10	0.0008	0.0075	0.0390	0.2842	9.4742
	14:30	0.0024	0.0175	0.0880	0.4454	7.2644
	16:00	0.0017	0.0137	0.0312	0.3743	8.0284

zooplankton (non copepods)

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	6:40	0.0096	0.0920	0.7741	23.3974	9.5810
	8:00	0.0026	0.1533	0.4715	2.9929	59.7770
	9:20	0.0136	0.1018	0.4737	3.5835	7.4785
	11:00	0.0420	0.2904	1.2263	11.9874	6.9114
	12:30	0.0016	0.0182	0.1268	0.9159	11.5421
	13:50	0.0028	0.0327	0.3022	0.8563	11.7103
	15:20	0.0006	0.0058	0.0473	0.6334	9.5590
	16:40	0.0024	0.0201	0.1422	1.5817	8.2189
竹圍	7:20	0.0006	0.0055	0.0105	0.5347	9.4635
	8:40	0.0007	0.0072	0.0181	0.7336	10.2553
	10:00	0.0077	0.0636	0.3026	4.6491	8.2746
	13:10	0.0026	0.0257	0.0628	1.2111	9.8708
	14:30	0.0051	0.0067	0.0245	0.2003	1.3177
	16:00	0.0367	0.3589	1.2736	12.2477	9.7770

圖 C-2-1 淡水河各測站之單位體積水體浮游動物組成（*Ind./ m*^{3}，九十一年十月十五日)

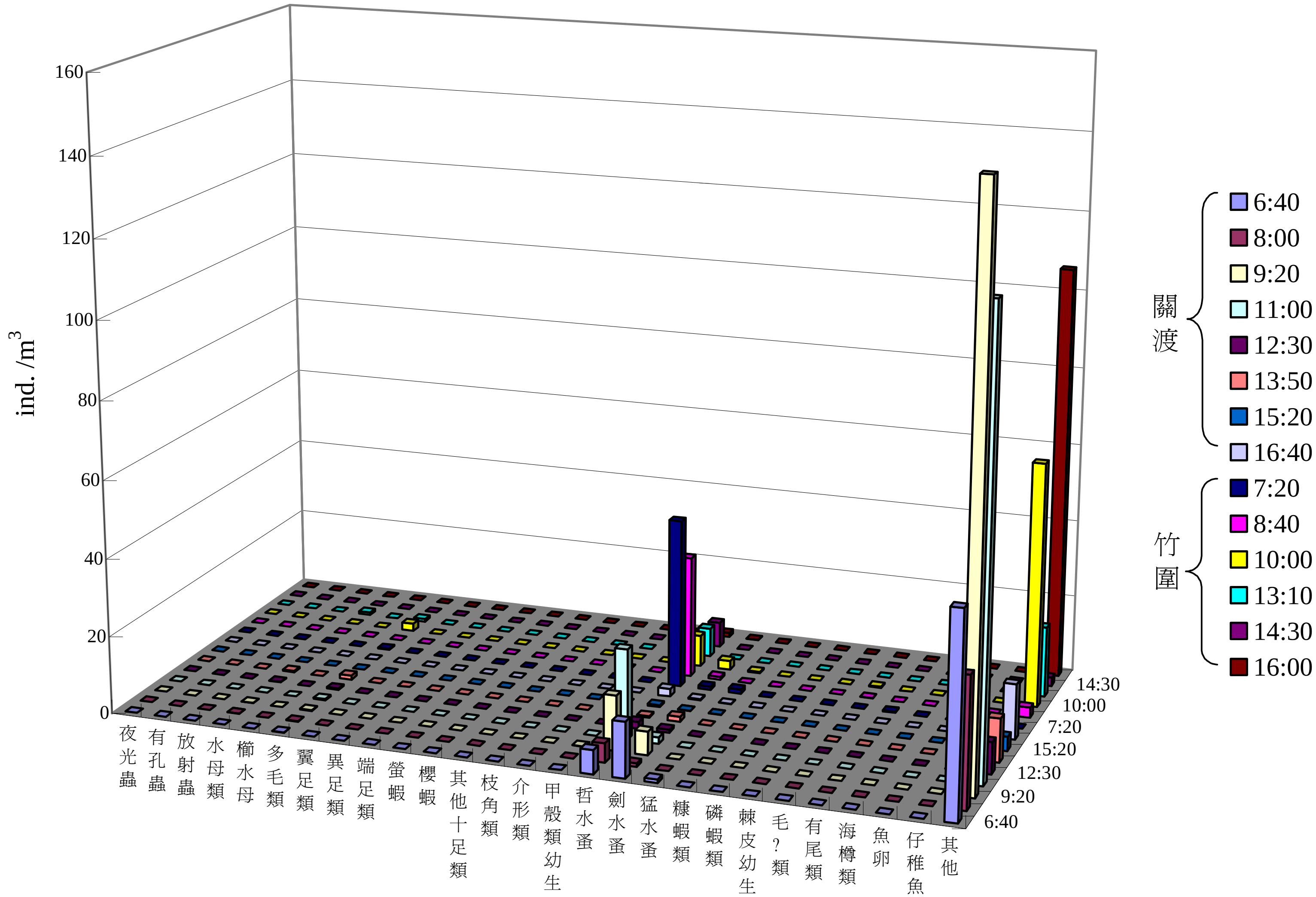


圖 C-2-2 淡水河各測站之浮游動物百分比組成 (九十一年十月十五日)

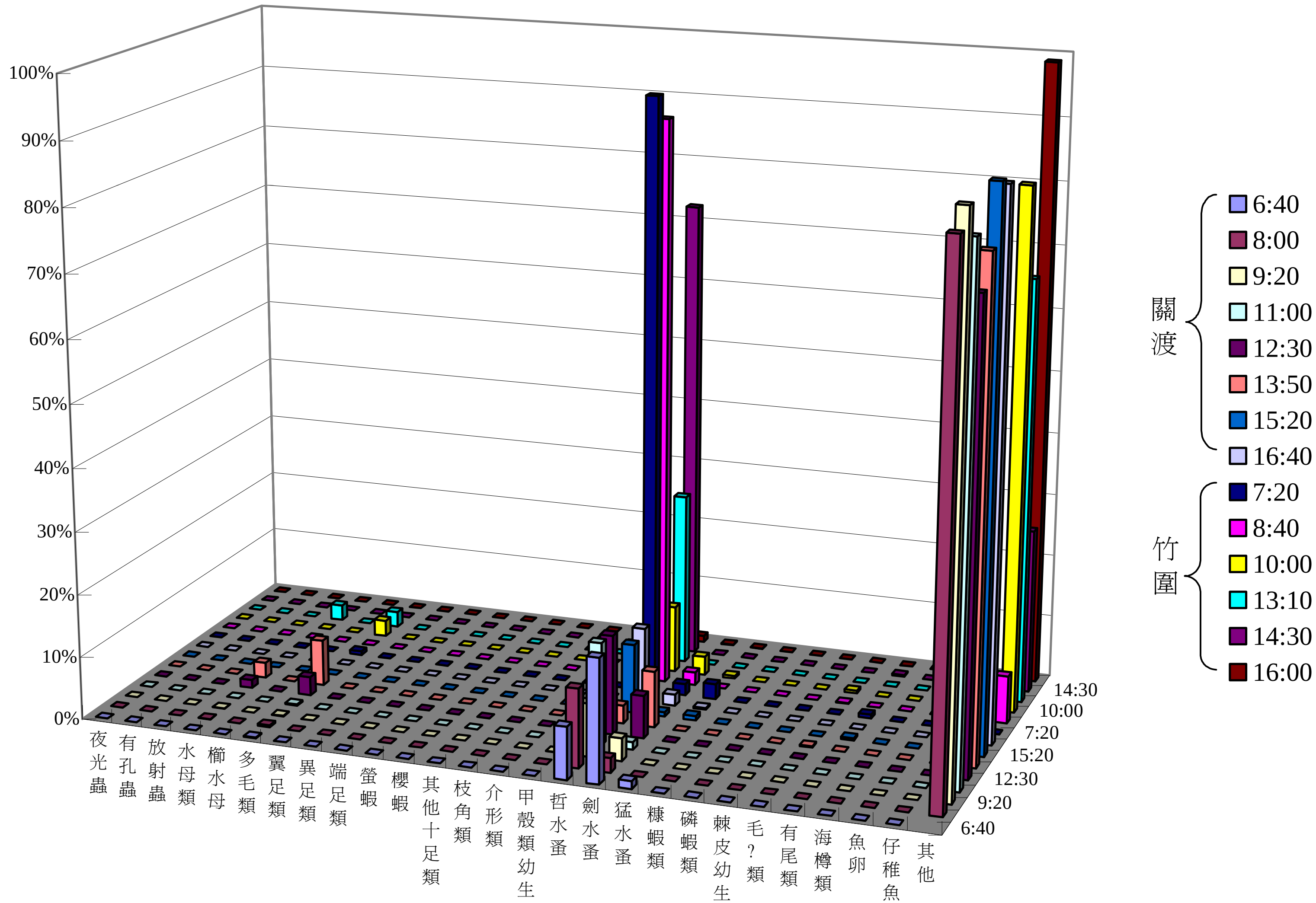


圖 C-2-3 淡水河浮游動物拖網碳、氮組成之分析 (九十一年十月十五日)

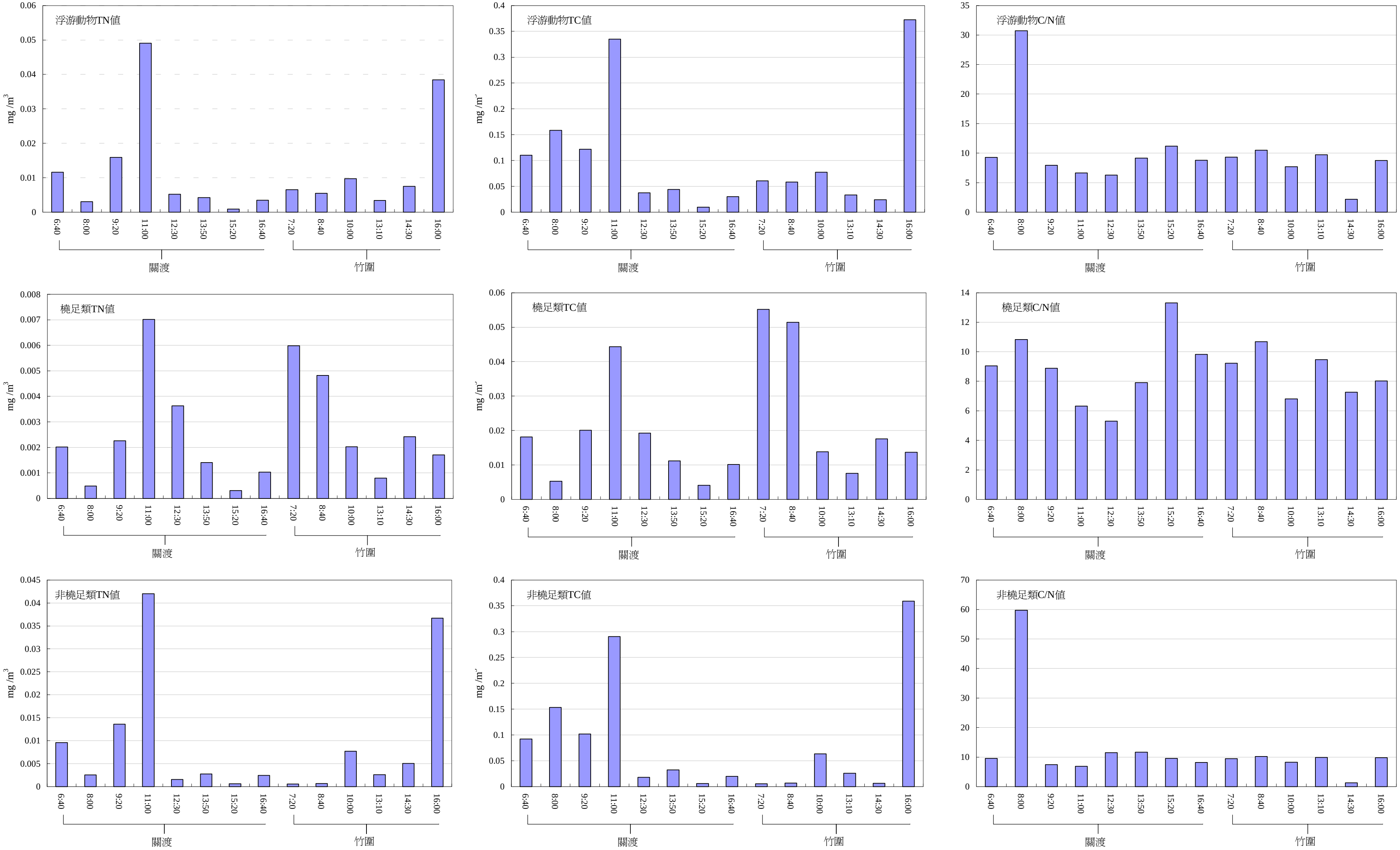


表 C-2-4 淡水河各測站浮游動物組成（*Ind.*/ m^3 ，九十一年九月二十五日)

	關渡					竹圍	
	8:35	9:40	11:15	12:30	13:55	7:30	10:30
夜光蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00
有孔蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00
放射蟲	0.00	0.00	0.00	0.00	0.00	0.00	0.00
水母類	0.00	0.04	0.00	0.00	1.15	0.00	0.00
櫛水母	0.00	0.00	0.00	0.00	0.00	0.00	0.00
多毛類	0.07	0.18	0.00	0.00	0.00	0.72	0.00
翼足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
異足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
端足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
螢蝦	0.00	0.00	0.00	0.51	0.00	0.00	0.00
櫻蝦	0.00	0.00	0.00	0.00	0.00	0.00	0.00
其他十足類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
枝角類	0.07	0.00	0.00	0.00	0.00	0.00	0.00
介形類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
甲殼類幼生	0.00	0.00	0.46	0.51	0.00	0.00	0.00
哲水蚤	19.15	7.33	626.57	418.10	1447.17	118.77	2122.02
劍水蚤	0.03	0.00	0.46	62.19	6.32	0.00	3.73
猛水蚤	0.00	0.00	0.00	11.31	31.60	0.00	7.46
糠蝦類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
磷蝦類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
棘皮幼生	0.00	0.00	0.00	0.00	0.00	0.00	0.00
毛？類	0.00	0.00	0.00	0.51	0.00	0.00	0.00
有尾類	0.00	0.00	0.00	5.65	0.00	0.00	0.00
海樽類	0.00	0.00	0.00	0.00	0.00	0.00	0.00
魚卵	0.00	0.00	0.00	0.51	0.00	0.00	0.00
仔稚魚	0.00	0.00	0.00	0.00	0.00	0.00	0.00
其他	0.00	0.00	0.00	0.00	0.00	0.00	0.00
total	19.31	7.55	627.48	499.31	1486.24	119.50	2133.21

表 C-2-5 淡水河各測站浮游動物數量百分比 (九十一年九月二十五日)

	關渡					竹圍	
	8:35	9:40	11:15	12:30	13:55	7:30	10:30
夜光蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
有孔蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
放射蟲	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
水母類	0.0%	0.5%	0.0%	0.0%	0.1%	0.0%	0.0%
櫛水母	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
多毛類	0.3%	2.4%	0.0%	0.0%	0.0%	0.6%	0.0%
翼足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
異足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
端足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
螢蝦	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
櫻蝦	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
其他十足類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
枝角類	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
介形類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
甲殼類幼生	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
哲水蚤	99.1%	97.1%	99.9%	83.7%	97.4%	99.4%	99.5%
劍水蚤	0.2%	0.0%	0.1%	12.5%	0.4%	0.0%	0.2%
猛水蚤	0.0%	0.0%	0.0%	2.3%	2.1%	0.0%	0.3%
糠蝦類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
磷蝦類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
棘皮幼生	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
毛？類	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
有尾類	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%
海樽類	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
魚卵	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
仔稚魚	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
其他	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

表 C-2-6 顆粒性質濃度 (mg/m^3 ，九十一年九月二十五日)

Total zooplankton

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	8:35	0.0059	0.0300	0.0789	2.7524	5.2806
	9:40	0.0039	0.0215	0.0520	0.6658	5.6149
	11:15	0.0953	0.6261	1.5291	27.3295	6.9855
	12:30	0.1382	0.9359	2.7104	28.8667	6.8590
	13:55	0.4314	2.1535	5.4151	145.4600	6.1371
竹圍	7:30	0.0415	0.2400	0.6709	9.8640	6.3536
	10:30	0.7513	4.4248	14.7305	291.0445	6.4798

zooplankton (copepeods)

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	8:35	0.0054	0.0272	0.0681	2.2766	4.9993
	9:40	0.0034	0.0170	0.0414	0.4045	4.9691
	11:15	0.0944	0.6198	1.5060	26.8781	6.5628
	12:30	0.1338	0.9056	2.6082	28.3702	6.7677
	13:55	0.4279	2.1335	5.3463	144.4989	4.9862
竹圍	7:30	0.0408	0.2345	0.6592	9.5908	5.7428
	10:30	0.7508	4.4207	14.7191	290.7562	5.8883

zooplankton (non copepods)

站名	採樣時間	TN	TC	總乾重	總濕重	C/N值
關渡	8:35	0.0005	0.0027	0.0108	0.4758	6.0079
	9:40	0.0004	0.0045	0.0107	0.2612	10.3882
	11:15	0.0008	0.0062	0.0230	0.4513	7.5092
	12:30	0.0044	0.0303	0.1022	0.4965	6.9409
	13:55	0.0035	0.0200	0.0688	0.9611	5.6730
竹圍	7:30	0.0007	0.0055	0.0118	0.2732	8.3346
	10:30	0.0005	0.0041	0.0114	0.2883	7.8362

圖 C-2-4 淡水河各測站之單位體積水體浮游動物組成（*Ind./ m*^{3}，九十一年九月二十五日)

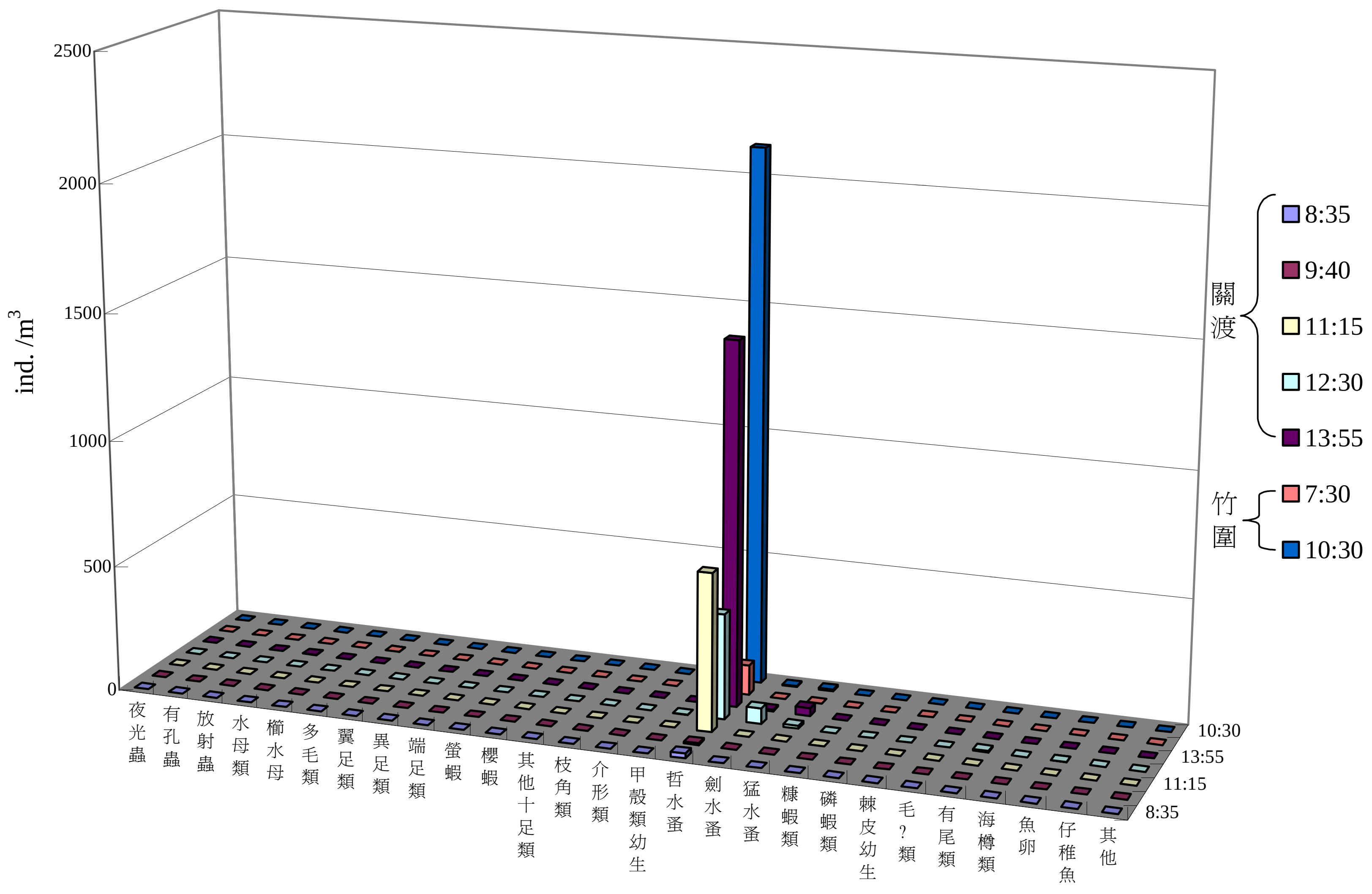


圖 C-2-5 淡水河各測站之浮游動物百分比組成 (九十一年九月二十五日)

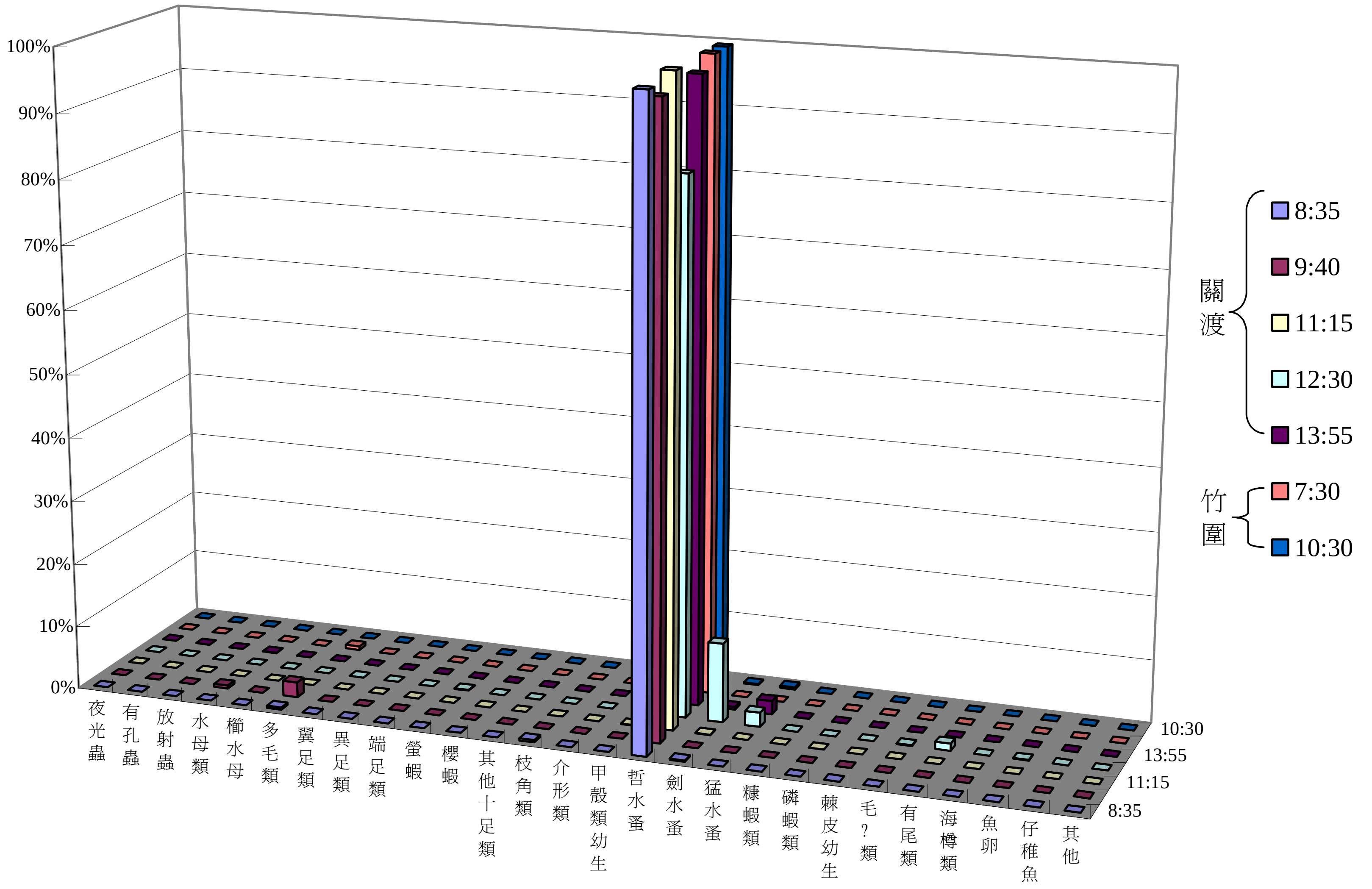
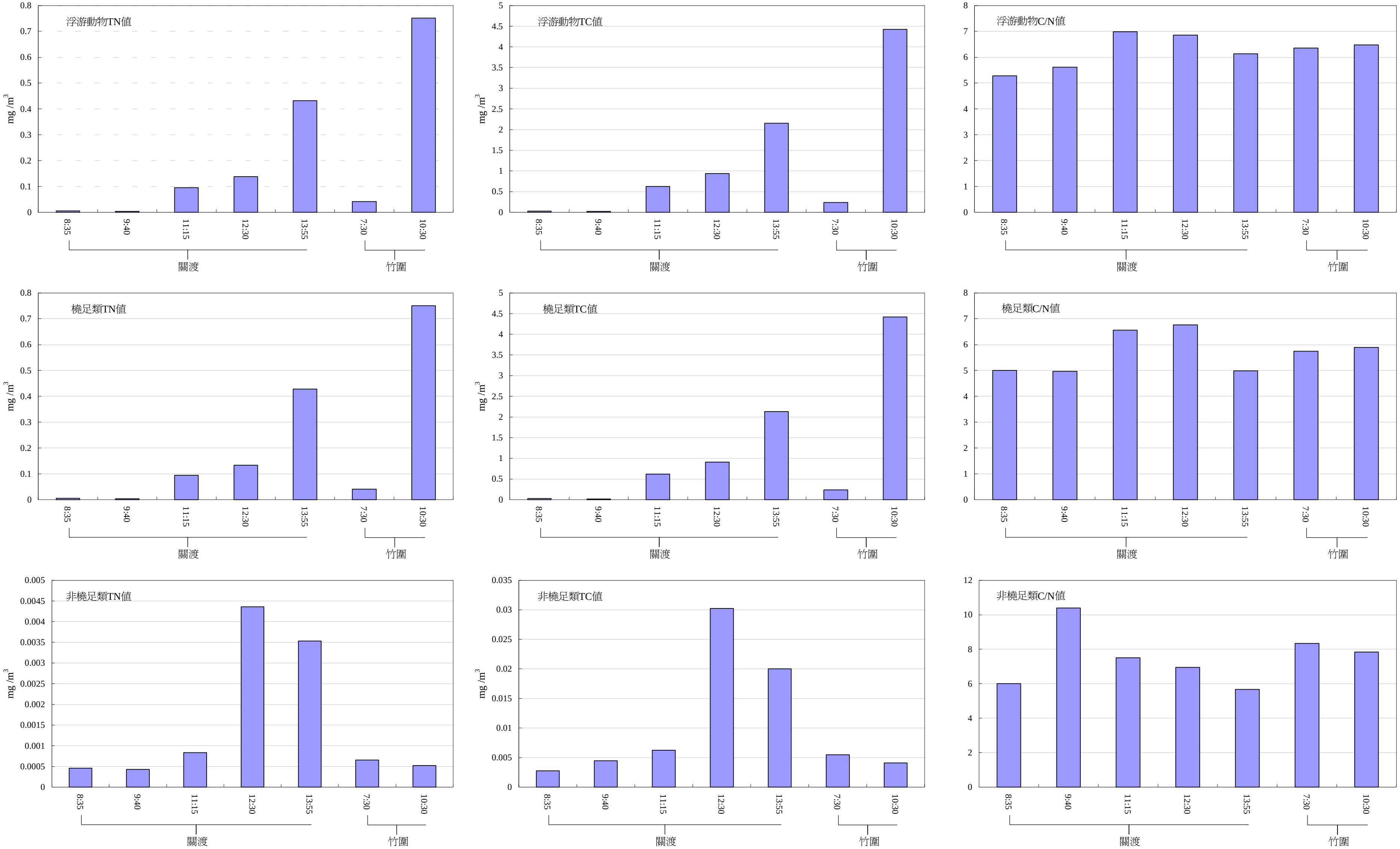


圖 C-2-6 淡水河浮游動物拖網碳、氮組成之分析 (九十一年九月二十五日)



(3) 浮游藻類與營養鹽

此類數據之採樣與分析乃是由本計畫協同主持人吳俊宗教授之另一國科會資助之計畫執行，採樣時與本計畫同步作業。分析所得數據，由該計畫另行列報。

D. 生態模式之測試

A series of test runs were conducted to make sure that the model program was coded correctly. A fictitious estuary with simple geometry was used for the test. The following gives the pertinent information for the test runs.

Geometric Information:

Length from mouth to the head of estuary = 150 km,

Uniform rectangular cross-section,

Constant width = 200 m, constant depth = 5 m.

Hydrodynamic Information:

Tidal amplitude at the mouth = 30 cm, tidal period = 12.42 hours (i. e., M2 tide),

Salinity at the mouth = 35 ppt,

Freshwater discharge at the head = 25 cms.

Computational Information:

Äx = 2 km, Äz = 1 m,

Ät = 108 sec.

Water Quality Information:

Upstream boundary conditions: DO = 7.5 mg/l, and everything else is zero.

Downstream boundary conditions: DO = 7.5 mg /l, PB1 (diatom) = 0.3 mg/l, ZB1 (copepod) = 0.05 mg/l, everything else is zero.

Pollutant loading: a point source is located at 30 km from the head of estuary with flow rate = 1.0 cms.

In each of the model test run, all input conditions were held constant and the model was run until the equilibrium state was reached. The model was first run with the kinetic coefficients specified in such a way that the newly developed model was equivalent to the original HEM-2d (i. e., with 8 water quality state variables). The results of the new model were compared with that of the HEM-2d, and it was proved that the two sets of results are identical. Then the input file was modified to bring in the new state variables one or a few at a time, and made sure the model results were in accordance to expectation at each step of modification. This process continued until the full set of 21 state variables were in operation simultaneously. Then the model was run by changing the value of kinetic coefficient one at a time to check if the model response was reasonable. The following figures present the results of one model run as an example, of which the point source loading is shown in table D-1. The figures show the spatial distribution of the concentrations of state variables. The horizontal axis is distance from the estuarine mouth in kilometers, and the vertical axis is depth in meters. All the iso-concentration contours are in mg/l.

表 D-1　test run 點源污染排放量

水質類別	水質因子	模式中使用代號	排放量(kg/day)
碳	難分解顆粒態有機碳	RPOC	10,000
	易分解顆粒態有機碳	LPOC	10,000
	溶解態有機碳	DOC	10,000
氮	難分解顆粒態有機氮	RPON	500
	易分解顆粒態有機氮	LPON	500
	溶解態有機氮	DON	500
	氨氮	NH4	8,000
	硝酸氮	NO3	2,000
磷	難分解顆粒態有機磷	RPOP	200
	易分解顆粒態有機磷	LPOP	200
	溶解態有機磷	DOP	200
	磷酸根	PO4t	1,000
矽	生物源顆粒態矽	SU	500
	可用性矽	SAt	10,000
	化學需氧量	COD	10,000
	溶氧	DO	430

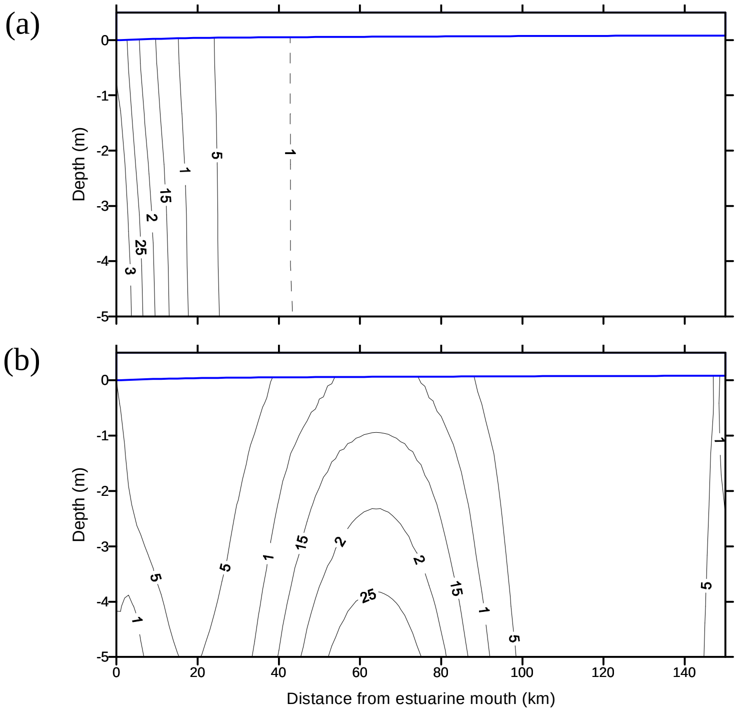


圖 D-1　潮平均模擬結果 — (a)Salinity, ppt ; (b)TSS, mg/L

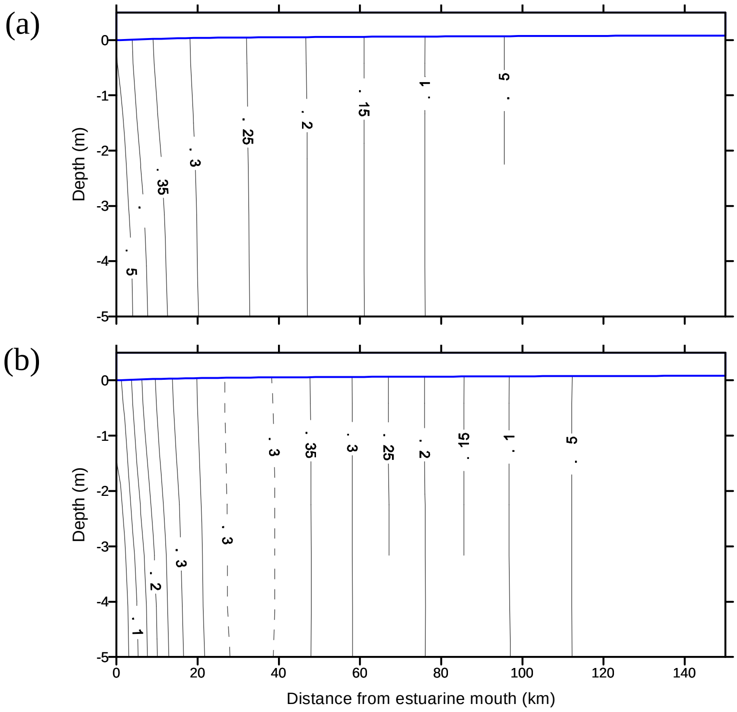


圖 D-2　日平均模擬結果 — (a)ZB1; (b)ZB2, mg C/L

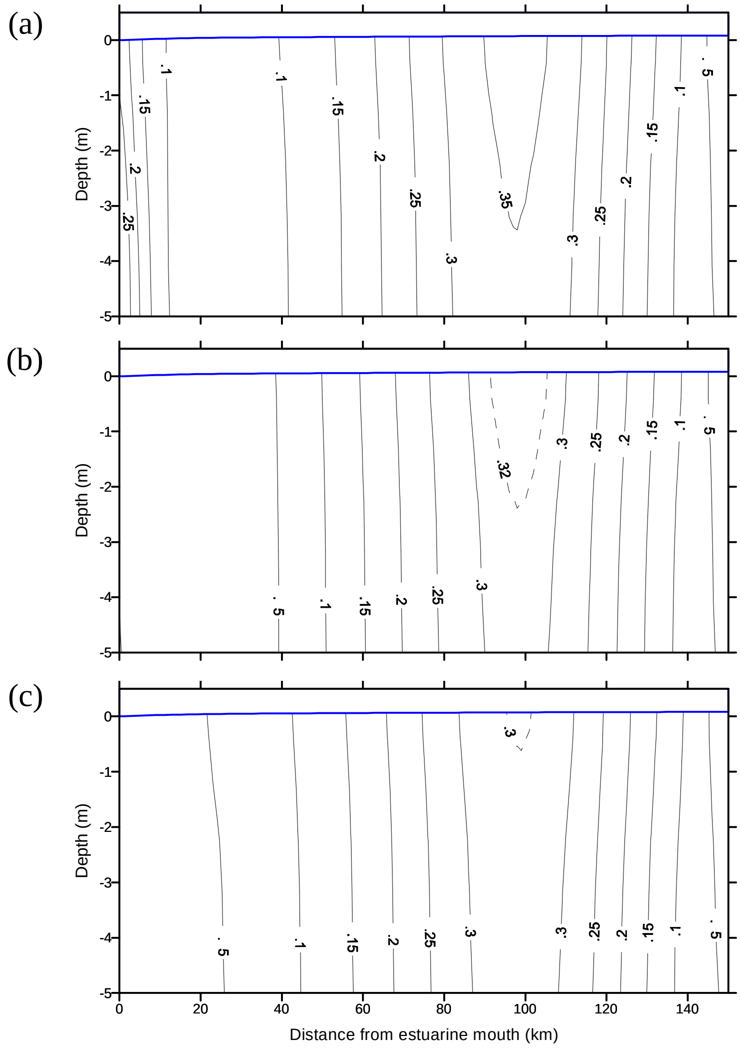


圖 D-3　日平均模擬結果 — (a)PB1; (b)PB2; (c)PB3, mg C/L

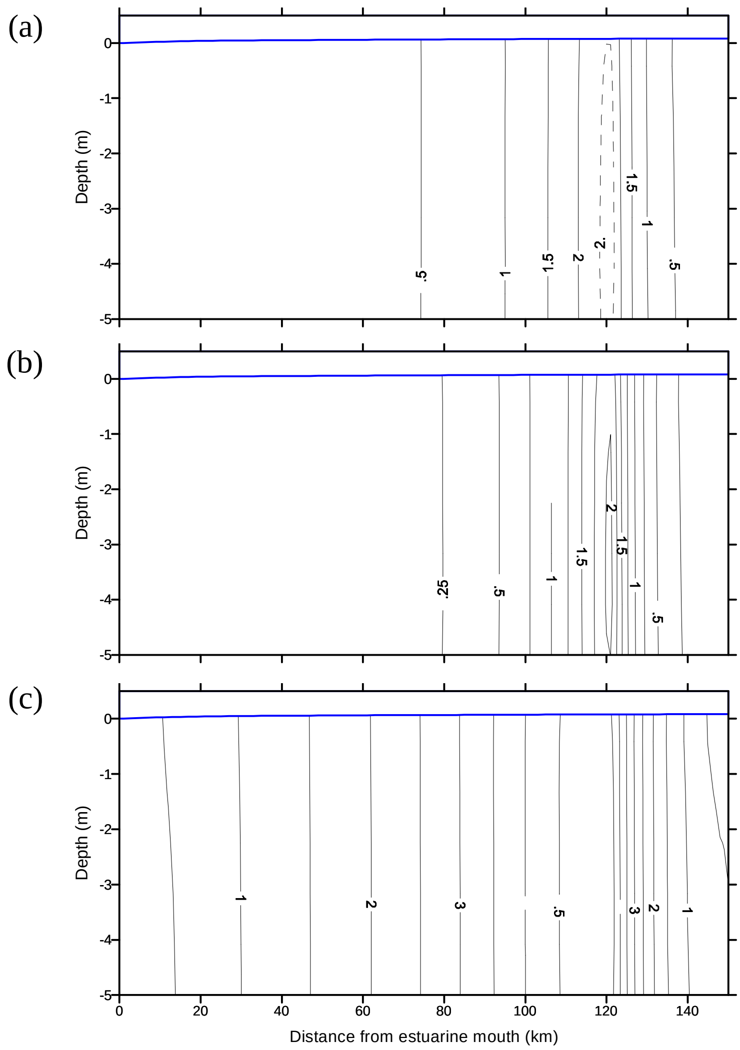


圖 D-4　日平均模擬結果— (a)RPOC; (b)LPOC; (c)DOC, mg C/L

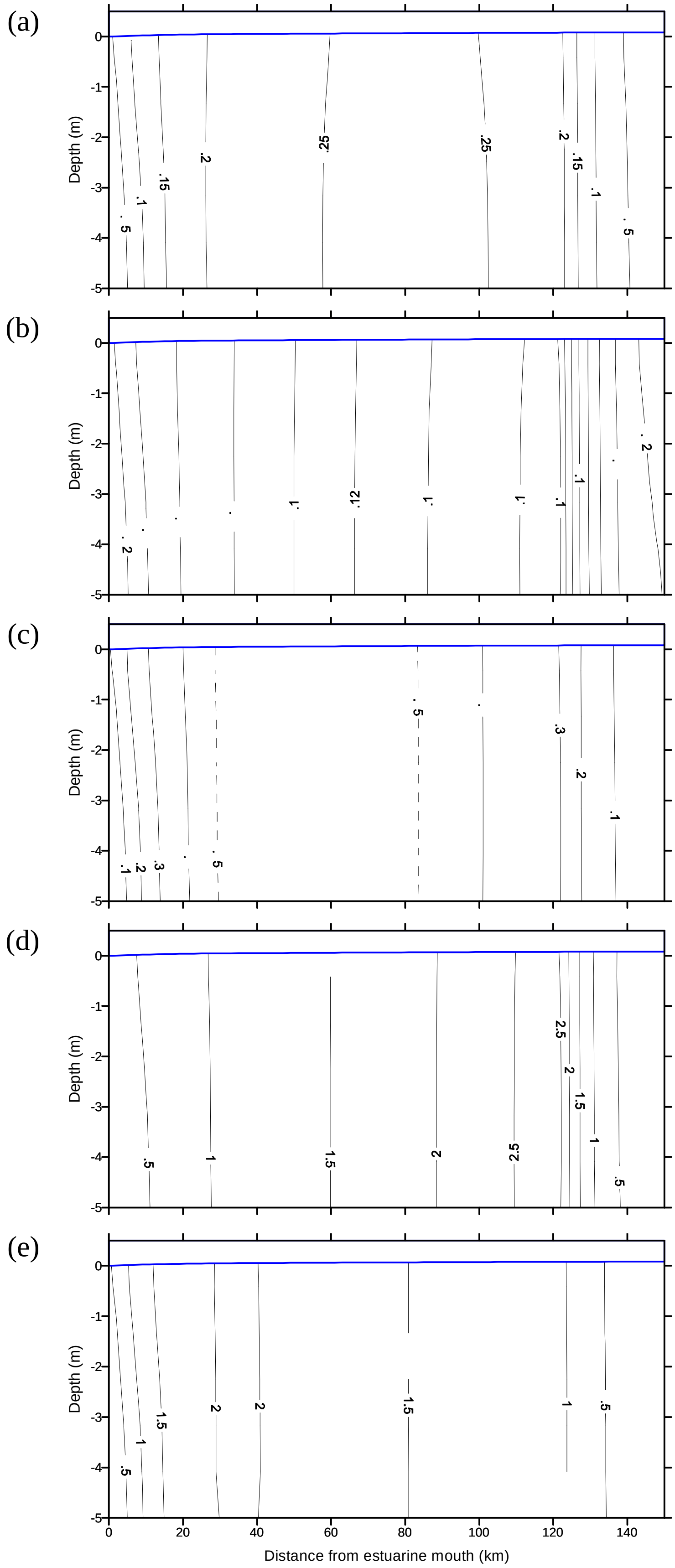


圖 D-5　日平均模擬結果— (a)RPON; (b)LPON; (c)DON; (d)NH4-N;

(e) NO_2+NO_3-N, mg N/L

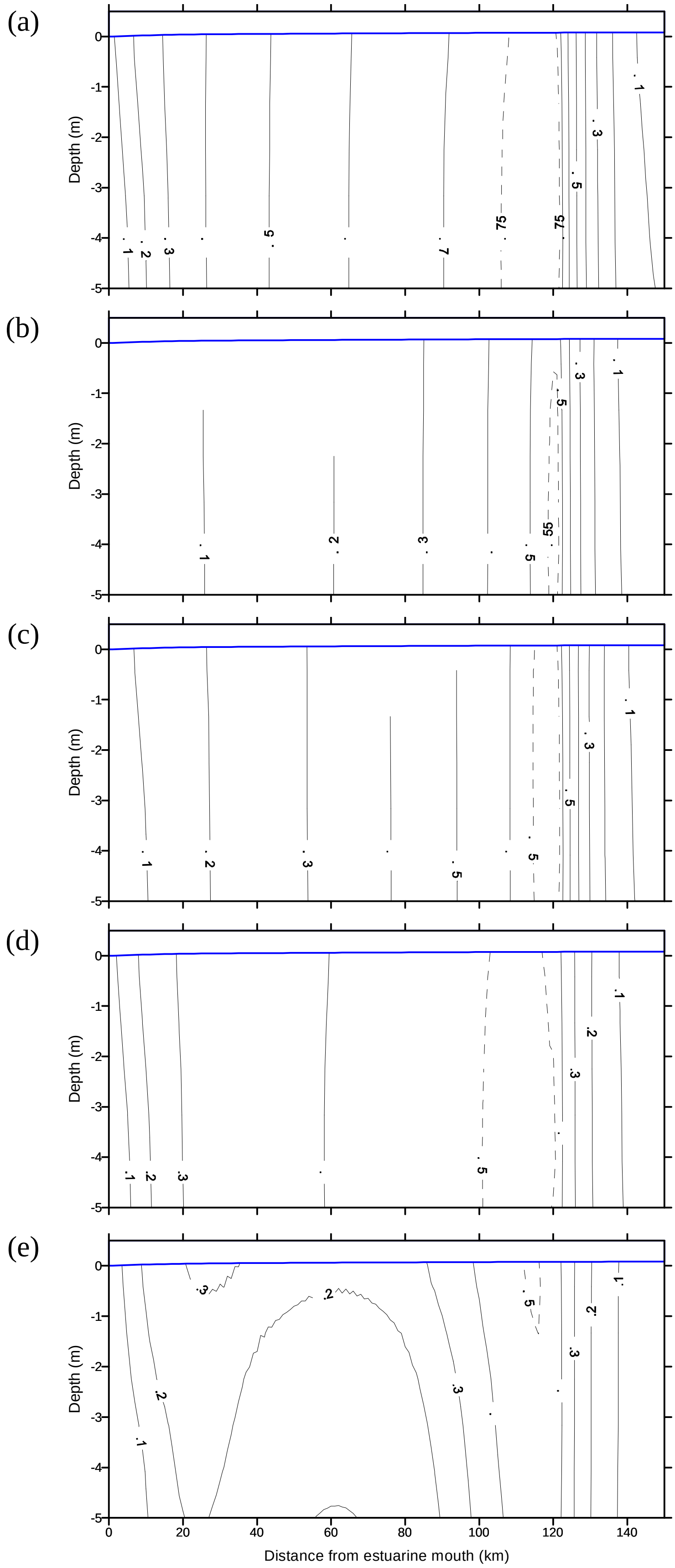


圖 D-6　日平均模擬結果— (a)RPOP; (b)LPOP; (c)DOP; (d)PO4t; (e)PO4d, mg

P/L

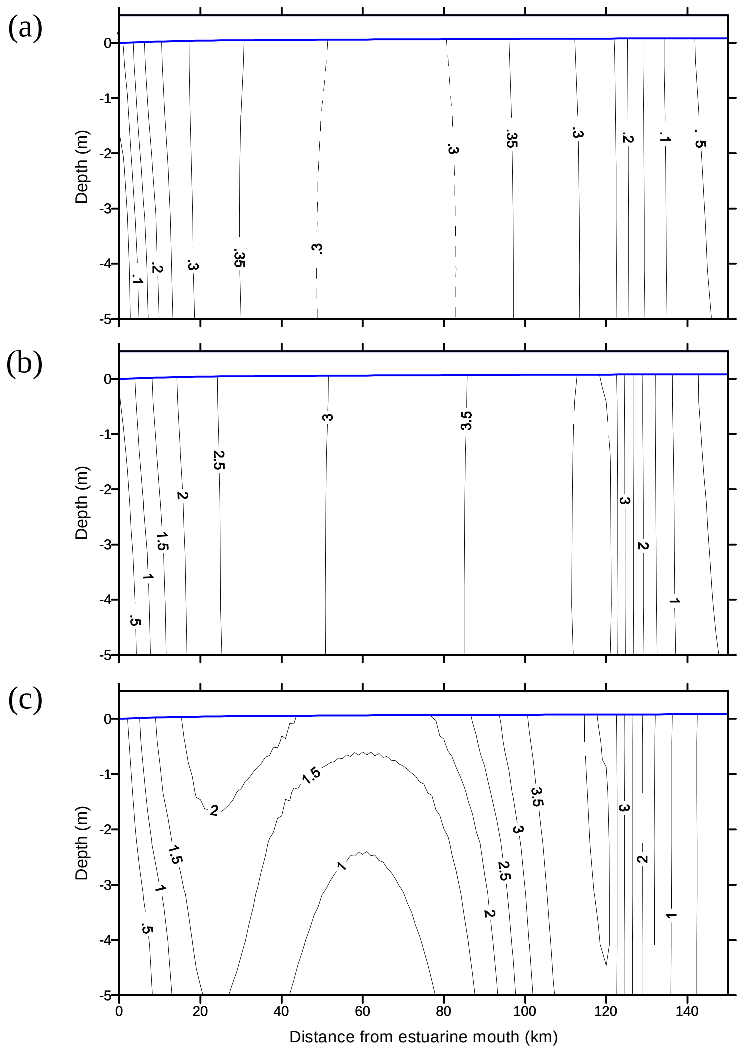


圖 D-7　日平均模擬結果 — (a)SU; (b)SAt; (c)SAd, mg Si/L

(a)

(b)

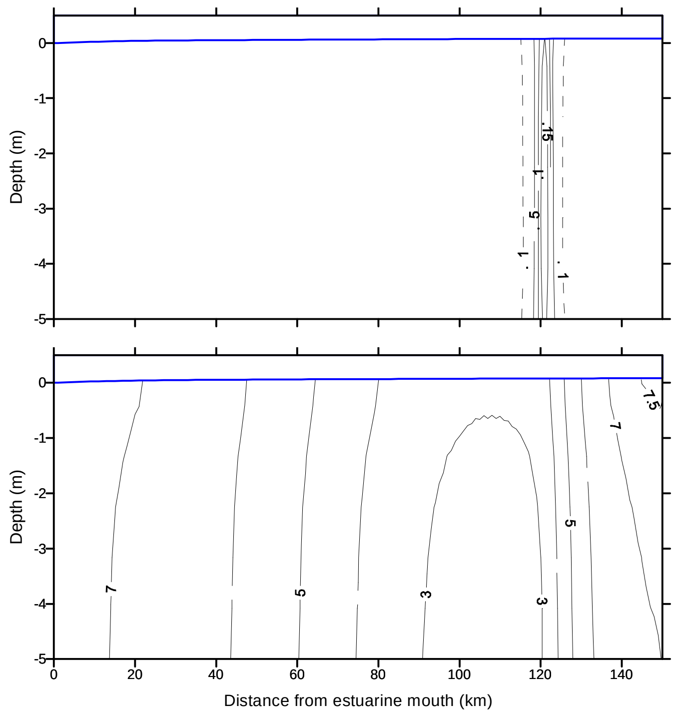


圖 D-8　日平均模擬結果— (a)COD; (b)DO, mg O_2/L