Chinese-American
Joint Commission On Rural Reconstruction
Fisheries Series: No. 9

REPORTS OF FISH CULTURE RESEARCH SUPPORTED BY ROCKEFELLER FOUNDATION

Taipei, Taiwan, China
February 1970

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Third Series of Five Technical Reports of Studies
Carried Out In Taiwan
1968-1969

Taipei, Taiwan, China
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STUDIES ON CHIRONOMID CONTROL IN MILKFISH PONDS

PART I. ECOLOGICAL ASPECTS OF THE DEVELOPMENT AND DISPERSION OF CHIRONOMID MIDGES IN TAINAN MILKFISH PONDS

By Shan-ching Tsai*

Abstract

The Chironomid larvae in the Tainan milkfish ponds begin their diapause in mid-November when the temperature drops below 20°C and resume their development and reproductive activity in late February when the temperature rises above 20°C again. In April, the midge population grows to a density destructive to the benthic algae in the nursery ponds in the western part of the Tainan milkfish ponds and begins to disperse eastward. The population grows during this eastward dispersion. The salinity of pond water exerts some effect on the growth of the larvae and the dispersion speed of the midge population. The infested area of midge expands 3.0 km eastward from the Old Fort to the west boundary of downtown Tainan in two months.

Introduction

The 16,000 hectares of milkfish ponds in Taiwan amount to only 2.5% of the total area of milkfish ponds in the world. Although the total area of milkfish ponds in Taiwan is far less than that in Indonesia and the Philippines, yet the yield per unit area stands the highest, reaching 2,500 kg/ha/year due to better management.

According to Tang's (1967) estimate, the yield of milkfish pond under natural conditions is only 200 kg/ha. By using fertilizers, the yield may be increased to 800 kg/ha. The yield may be further increased to 1,000 kg/ha when the benthic algae pasture, an essential fodder for the milkfish, is put under effective protection against Chironomid larvae by application of insecticides. The yield may still be increased further to 2,000 kg/ha or even 2,500 kg/ha by stocking manipulation and selective

* Chemist, Fish Culture Research Project supported by the Rockefeller Foundation Grant and sponsored by the Joint Commission on Rural Reconstruction.

fishing, provided an excellent bottom algal pasture can be maintained throughout the growing period. It is obvious that Chironomid larvae control is an important step in maintaining the high yield of milkfish in ponds.

A characteristic management of milkfish culture in Taiwan is the care of benthic algae, mainly blue-green algae, such as *Lyngbya*, *Phormidium*, *Oscillatoria*, etc. (Tang and Chen, 1966; Chang, 1969), since such benthic algae serve not only as food to milkfish but also as suppliers of dissolved oxygen which is an end product of photosynthesis. Benthic algae can also make pond water clear by assimilating the dissolved organic matter and preventing nannoplankton bloom, a condition for maintaining the good health and normal growth of milkfish. Without such care milkfish production would have remained low.

After the fish farmers finish harvesting the milkfish in November each year, they drain the pond water to expose the mud to air and sunlight, so that the bottom soil may be oxidized and become suitable for the growth of algae again. Then the pond is fertilized with rice bran and filled with water to the depth of 15 cm. The algae, mostly *Nitzschia*, begin to grow. After the pond has evaporated to dryness, the pond is fertilized the second time with rice bran and filled with water to the same depth again. This procedure is repeated four times, and as a result a layer of bottom algae 0.5 cm in thickness is obtained in early April. This is the so-called algal bed. During this period of algal bed preparation (usually from December to March), no milkfish are stocked in the pond. Then in April when the water temperature rises above 22°C, fresh sea water to about 20 cm deep is admitted into the pond which is now stocked with fish in mid-April. The milkfish now have plenty of bottom algae, but unfortunately at the same time Chironomid larvae also begin to develop and compete with the milkfish for food.

This Chironomid larva, *Tendipes* (*Chironomus*) *longilobus* (Kieffer), is the most destructive pest of milkfish ponds (Tang and Chen, 1959). The life cycle is as short as 15 days under favorable conditions and one female midge can lay as many as 400 eggs. Therefore, the population density can reach up to 50,000 larvae/m^2 in number and 500kg/ha in weight. They consume the benthic algae at the rate of 60-90 kg/ha/day (Lin, 1968). Besides, the larvae consume dissolved oxygen and make many mud tubes in the algae bed. Through these tubes, the organic matter

in the mud percolates into the water causing it to become turbid as the result of nannoplankton growth.

The growth of Chironomid larvae stops in late November when the temperature drops and they begin their over-wintering diapause. This diapause continues till the following spring when the temperature rises again. The larvae then emerges into adults to set off their life cycle. There is a scarcity of adults in the ponds. However, in some regions Chironomid midges swarm in early April. They lay eggs in the night. One end of the egg mass sticks to the earth clod of the bank or the grass, and the other end floats on the water. When the earth clod or

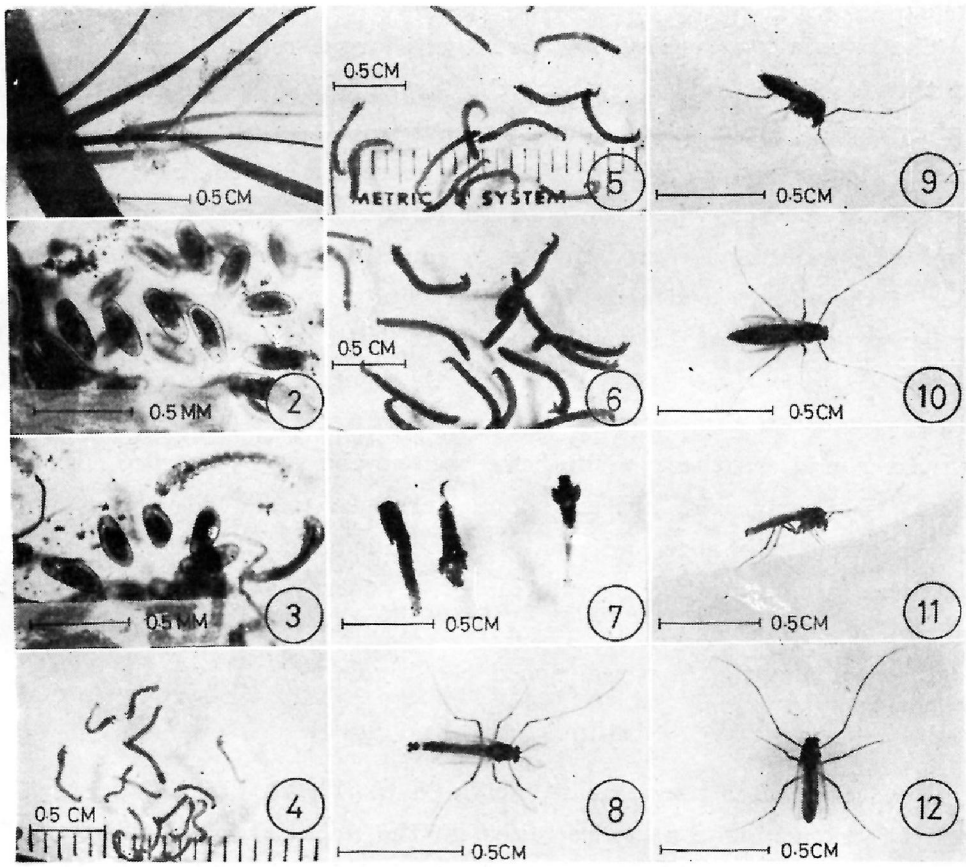

Plate I. Life history of *Chironomus longilobus* (Kieffer).

1. egg masses sticking to bank weed and floating on water; 2. embryos in eggs: 3. embryos and first stage larvae; 4, 5 and 6. larvae at various stages; 7. pupae; 8. male adult; 9-10. dorsal and lateral view of female adult; 11-12. dorsal and lateral view of female adult after oviposition.

blades of grass are occupied by the egg mass of one midge, other midges come to stick their egg masses upon the first mass (plate I, 1). The eggs hatch in three days and the larvae (plate I, 3-6) feed on the algae of the ponds. They form tubes of mud and algae, and live there for 15 to 31 days before changing into pupae which do not last more than 48 hours. The adults emerge at night and ther live on the bank for 3 days. During the prolonged diurnal period the adults rest quietly on the grass, bushes, wall of buildings or any other place where they can be protected from direct sunshine and wind. The adults swarm and mate in the air during the auroral and vesperal periods. Female adults die within one day after laying eggs.

The population density of Chironomid larvae reaches its peak in July and then declines. By November, the larvae have disappeared from most of the rearing ponds (Tang and Chen, 1959). It is observed that midges appear all of a sudden when salinity is decreased by the rainfall in early June. In November, when the cold air reaches this area, a sharp decrease of midge population occurs, thus it is generally believed that the emergence of the midges is affected by salinity and temperature. In the winter, the larvae in most of the rearing ponds are killed because of high salinity up to 140‰ due to evaporation. On the contrary, the salinity of the nursery ponds on the western coast in Tainan area is kept at 30‰ to 40‰ the year round, so these ponds have become the overwintering site of the larvae. In April, the nursery ponds produce many adults, scattering eastward from this site and finally spreading over the whole area. This study was aimed at the formulation of a control program based on the findings of the effects of temperature, salinity and photoperiod on the development and the dispersal speed of Chironomid midges.

Methods and Procedure

When the water temperature declined to 20°C in late October 1967, the light traps caught no more midge in the milkfish pond district. This was the beginning of the overwintering period for the Chironomid larvae. About 5,000 overwintered larvae were collected in early December 1967 and stocked in a 250-liter concrete pond containing sand and sea water at salinity levels of 35 to 45‰. The concrete pond situated in the open yard of the laboratory was completely covered with a screen cage to prevent the emerging midges from escaping. The overwintered larvae became adults

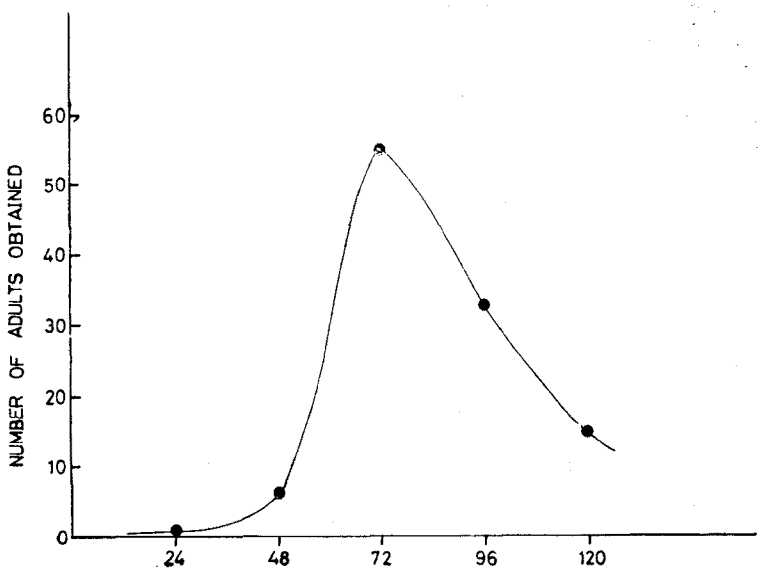

Fig. 1. Adult emergence of *Chironomus longilobus* at temperature 30°C, salinity 33‰ and 13 hrs. photoperiod.

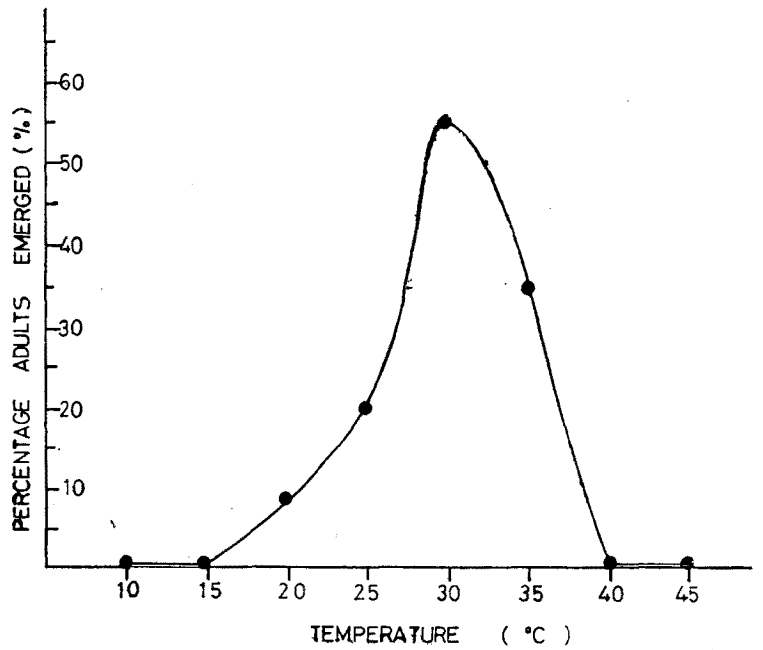

Fig. 2. Adult emergence of *Chironomus logilobus* when the over-wintered larvae were exposed to different temperatures.

when the water temperature rose to above 20°C in late February 1968 which was the end of the overwintering period.

The effects of temperature, salinity and photoperiod on the emergence of adults from overwintered larvae were determined as follows: The overwintering larvae of 0.8 cm in length used for this experiment were collected from large ponds early December 1968 and first stocked in a small pond with the salinity level at 35 to 45‰ till January 1969 to be used as test animals in different experiments. First, eight treatments under 10°C, 15°C, 20°C, 25°C, 30°C, 35°C, 40°C and 45°C were set up to determine the effect of temperature. Then, to determine the effect of salinity, 12 treatments of 0, 10, 20, 30, 40, 45, 50, 55, 60, 70, 80 and 90‰ were made. As to photoperiod, five treatments of 4, 6, 8, 10 and 13-hour exposures to fluorescent light were made. Each of the treatments had four replications. The basic rearing unit for an emergence experiment was modified from that described by Biever (1965). It consisted of a 3-liter beaker containing 300 cc of sea sand and 2 liters of marine phytoplankton culture medium (Ukeles, 1962). Inoculation of 0.5 cc (wet volume) of benthic algae (*Lyngbya* sp) which had been isolated (Gerloff, 1950) from the pond, was made and the benthic algae grew vigorously after three days. Then 50 Chironomid larvae were introduced into each rearing unit at 8:00 A.M. As ideal environment for the emergence of adults from larvae, the rearing units were incubated at 30°C in salinity of 33‰, and hours of photoperiod with light intensity at 4,000 lux in a photosyn-

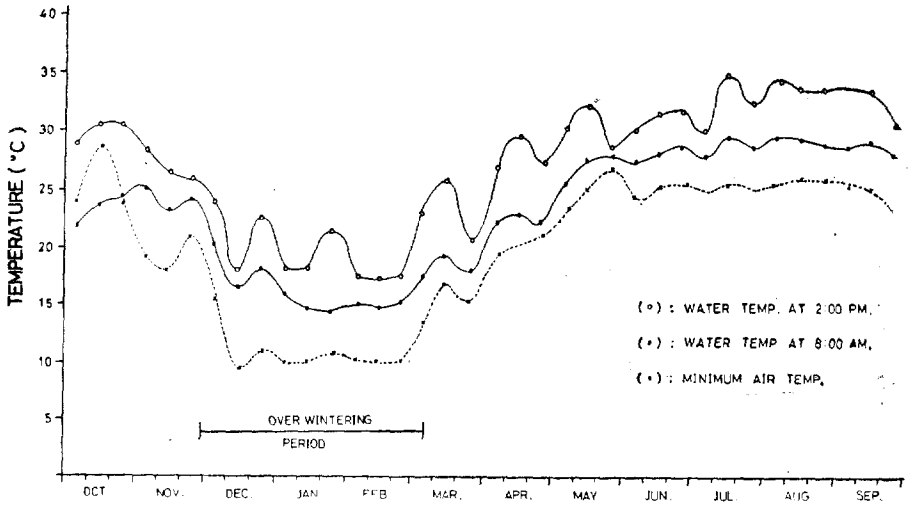

Fig. 3. The relationship between the over-wintering period of the Chironomid larvae and temperature.

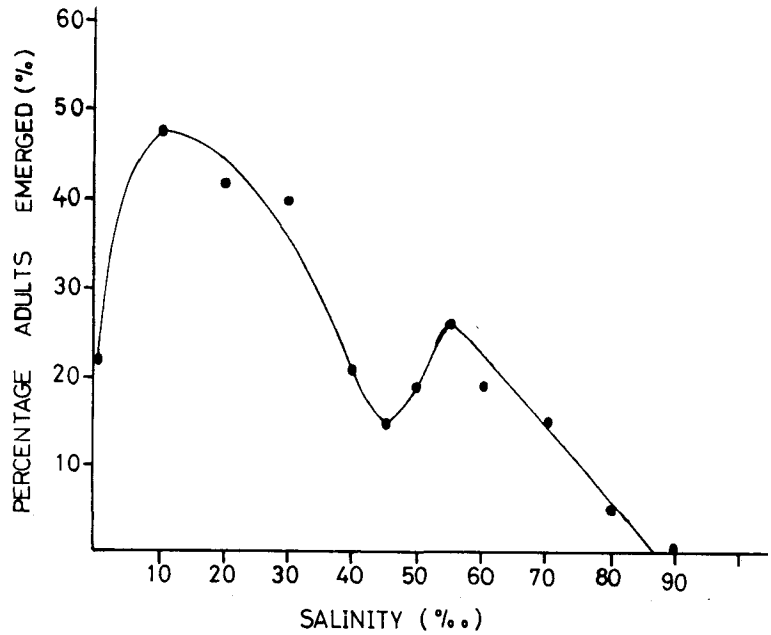

Fig. 4. Adult emergence of *Chironomus longilobus* when the over-wintered larvae were exposed to different levels of salinity.

thesis incubator (Precision Scientific Co., Model 806). But, in actual experiments only one factor was determined at a time and was subject to change as planned while the other factors were kept at the optimum. The beaker was covered with nylon net to prevent the midges from escaping, then the number of midges emerging the night before were counted at 8:00 A.M.

In the case of salinity experiment, a 12-hour acclimation time was allowed to let the larvae orientate to the higher levels of salinity, step by step.

The dry season came after the overwintering period. The hatching of Chironomid eggs and the development of the larvae were affected by the high salinity of the pond water. The procedure for determining hatching rate was as follows: 3 liters of marine phytoplankton culture medium was put into a 45-liter glass trough which was covered with cheese cloth; the female adults were collected (plate II,5) with a midge collecting tube (plate II, 4) and introduced into the glass trough during the day. The females laid their egg masses into the culture solution at night. The egg masses were collected and the number of eggs in each egg mass was counted under a microscope.

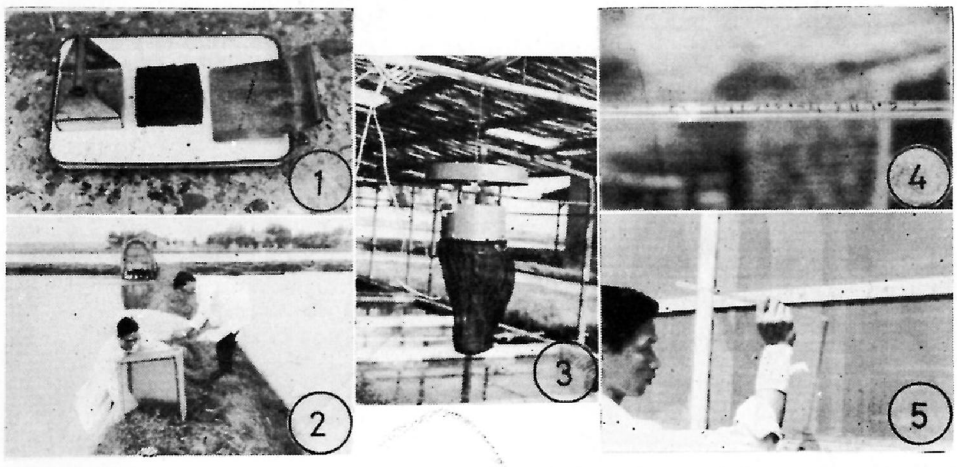

Plate II. Apparatus for collecting Chironomid larvae and adults:

1. the mud sample and a sampler for estimating population density of larvae in the bottom mud.
2. a light trap for estimating population density of adults.
3. a screen cage for estimating density of adults on the embankment.
4. collecting the midges from a mosquito screen with a glass tube.
5. midges in the collecting tube.

Six egg masses (about 2,500 eggs) were put into each glass trough containing 10 liters of filtrated pond water at different levels of salinity. The number of larvae was counted after incubation at 30°C after 5 days and the body length was determined under the microscope with a micrometer.

The effect of salinity on the growth of larvae was determined by placing the eggs to hatch in the phytoplankton medium of 33‰ salinity. After 5 days the hatched larvae were transferred to glass troughs each containing 15 liters of culture medium at various levels of salinity after 2 hours of acclimation. Each trough was stocked with 1,500 larvae. After 10 days of culture at 30°C, the remaining larvae were counted and their body length measured.

The life cycle of the Chironomid population was affected by the salinity of pond water. A comparison of the time to complete a life cycle in high salinity and low salinity was made by taking advantage of the salinity difference before and after rainfall in early summer 1969. Four ponds with a total area of 12 hectares near Anping Ferry were used for this experiment. The ponds lay east to longitude 120°09' E and south to Anping town (fig.9). On the horizontal axis set in fig. 9, the abscissa

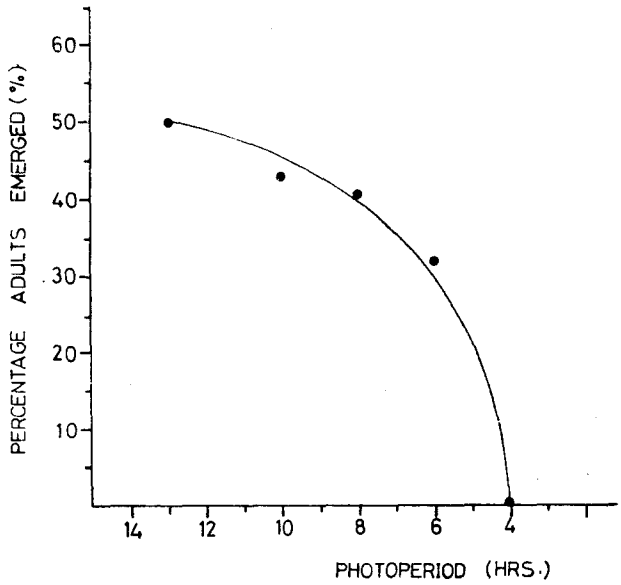

Fig. 5. Adult emergence of *Chironomus longilobus* when the over-wintered larvae were exposed to different photoperiods.

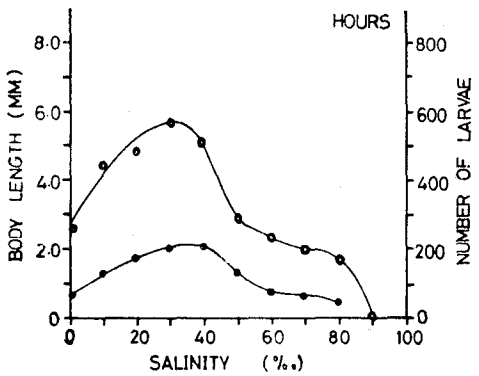

Fig. 6. The effect of salinity on the hatching of Chironomid eggs and subsequent growth of larvae.
(o) and (.) indicate the number and body length of larvae, respectively.

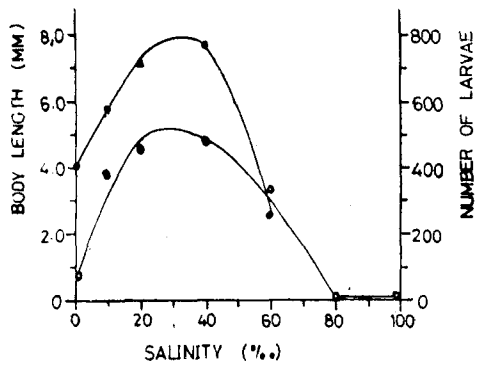

Fig. 7. The growth of Chironomid larvae exposed to different levels of salinity.
(o) and (.) indicate the number and body length of larvae, respectively.

range of these ponds was from 800 meters to 1,150 meters. At the beginning of April in 1969, the ponds were filled with sea water and stocked with fish; the water temperature and salinity were recorded every day and the change in Chironomid population observed.

On May 9, 1969 the larvae at the pond bottom numbered 3,700 larvae/m^2. The population density of the adults on the bank was about 2,500 midges/m^2. Meanwhile, there was a lot of puparium floating about the corners of the ponds, and the egg masses were found floating along the banks. This showed the possibility that the Chironomid larvae had completed the first life cycle. At this time, 0.05 ppm of Abate 50 E.C. (O, O, O', O'-tetramethyl O, O'-thiodi-p-phenylene Phosphorothioate) was applied to pond water. All the larvae in the ponds were killed by the insecticide, but the eggs remained alive on the water surface. The adults laid eggs and died in 3 days after insecticide application. It took 31 days for the Chironomid larvae to repopulate the ponds. On June 9, 1969 the population density of the larvae was found to be 4,000 larvae/m^2. Some of the larvae had already reached the last instar with the puparium heaped at the corners of the ponds and the egg masses floating on the

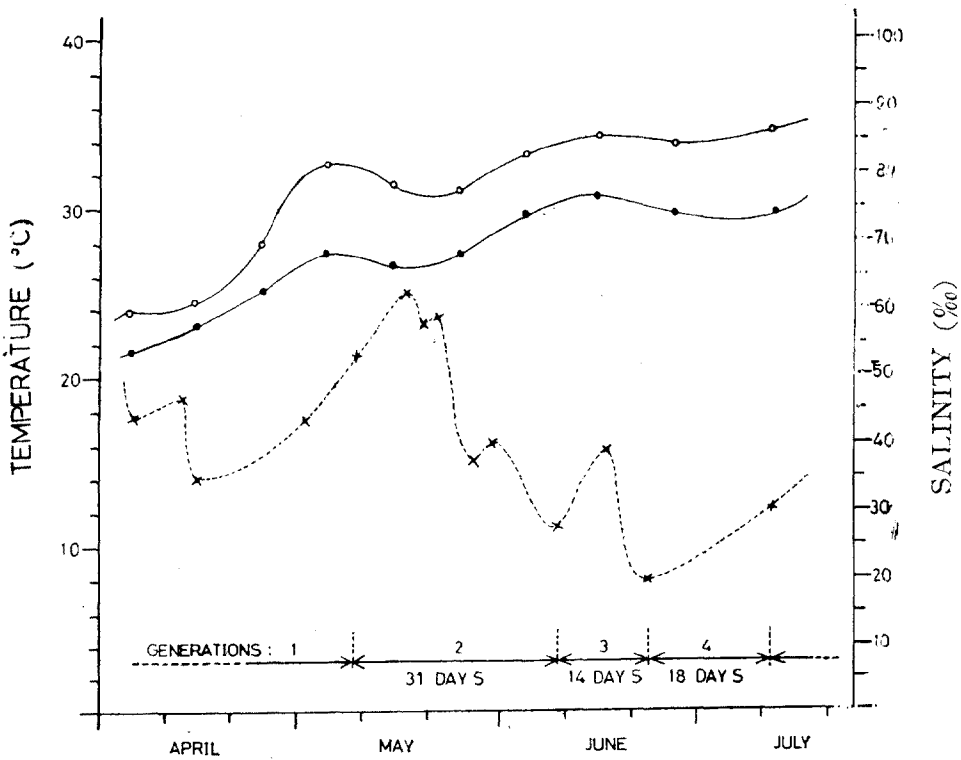

Fig. 8. The relationship between salinity and the occurrence of *Chironomus longilobus* in milkfish ponds.

a. (o)=water temperature at 2:00 P.M.

b. (.)=water temperature at 8:00 A.M.

c. (X)=salinity.

pond water, too. The midges thronged in the ponds. This was supposed to be the second life cycle and the duration of this life cycle was thus considered to be 31 days. In the same way, the days needed for the third and the fourth life cycles were obtained. The relationship between life cycle duration and salinity was shown in fig. 8. The population density of larvae in the ponds was measured at the end of each life cycle in order to understand its growth under insecticide pressure (table 1).

Table 1. The salinity of milkfish ponds and the population growth of Chironomid larvae in 1969

Life cycle	Date of larvicide application (month-day)	Salinity*	Population density (larvae/m²)		Days needed for repopulation
			Before insecticide application	After insecticide application	
1	5—9	53	3,700	0	—
2	6—9	29	4,000	0	31
3	6—22	21	7,500	0	14
4	7—11	30	43,000	0	18

* Salinity was measured at the end of the life cycle when Abate larvicide was applied.

After the midge population build-up at the overwintering site of the larvae in April, the infested area expanded, extending eastward. The speed of the eastward movement was determined by measuring the horizontal distribution of midge periodically. Collecting screen cages (plate II, 2) were used for estimating the population density of midges. The cage was 66 cm long, 50 cm wide with a bottom area of 3,300 cm². All the sides except the bottom of the screen cage were covered with nylon netting. A sleeve was attached to the lateral side of the cage. The midges were collected in the morning. First, 0.33 m² of grass was enclosed in the cage. The grass was then agitated with the operator's hand extending through the sleeve in the collecting cage. The disturbed midges flew out and gathered beneath the nylon netting top. Then, the cage was removed to a nearby spot after the bottom was closed with another piece of nylon netting. The midges in another 0.33 m² of grass were collected. They flew to mingle with the first batch and rested beneath the top of the collecting cage. After the collection was repeated three times, the midges in one m² of grass were obtained. They were

then killed with pyrethrins aerosol and stored in a polyethylene bag for weighing. One gram of midges was counted and multiplied by the total weight to obtain the total count per m^2. Then the average weight of one midge was calculated. Pyrethrins are liable to photodecomposition (Cheng and Casida, 1969), so the screen cage can be reused after being exposed to sunlight for an hour.

Along the line connecting the opposite angles of a rectangular pond, four bottom mud samples (plate II, 1) were taken to estimate the population density of Chironomid larvae in the pond. The sampler (plate

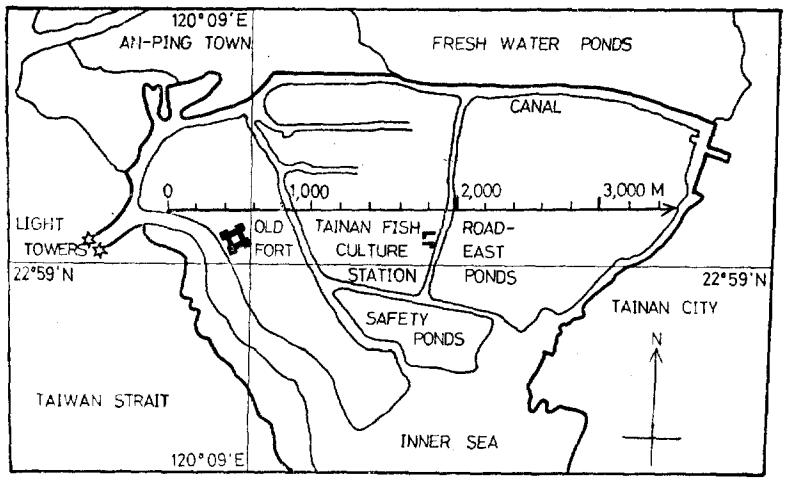

Fig. 9. Map of Tainan milkfish ponds. (the bold black line shows the boundary of the ponds.)

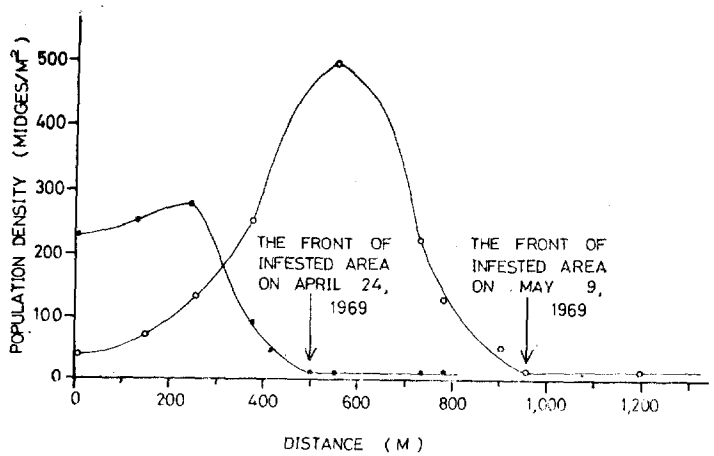

Fig. 10. Horizontal distribution of Chironomid midges from the over-wintering site.

II, 1) was made of stainless steel sheet. The mud sample taken by this sampler was 100 cm^2 in area and 2.5 cm in height. The mud sample could be taken easily from a bamboo raft because the pond was only 20 to 40 cm in depth. The mud samples were washed over a sieve of 80 mesh to remove the clay. Then the larvae were sorted and counted with Anderson's (1959) modified flotation method.

The ponds used for the dispersal experiment of Chironomid population lay between Tainan City and Taiwan Strait. The total area of the ponds was about 1,000 hectares. The area was surrounded by Tainan Canal in the north and east, and by sea in the south and west (fig. 9). All the surrounding neighborhood of Anping town, Tainan City, the freshwater ponds, inner sea and Taiwan Strait was not suitable for the development of the midge. So the ponds shown in fig. 9 were an isolated area for the development of the Chironomid larvae.

For the convenience for illustrating the distance the midges dispersed from their original abode, a horizontal axis of mathematical coordinate system was employed in fig. 9. The origin was set on the opposite embankment of the light towers on the west shore. The origin was also the original population center of midge in early April. From this origin, the horizontal axis directed eastward through the north of Old Fort and the north of the Tainan Fish Culture Station, reaching the west boundary of downtown Tainan. The figures above the horizontal axis were abscissas, the distance in meter between the origin and a line perpendicular to the horizontal axis at that point. According to this description, the abscissas of Old Port, the main building of the Tainan Fish Culture Station and the center of Road East Pond were 500, 1,800 and 2,200 meters respectively.

A sample of midges was taken every 100-150 meters along the horizontal axis in fig. 9. Then with the distance of the sampling spot from the origin as horizontal axis and the population density of midges as vertical axis, a horizontal distribution graph of midges was formed and the front of the infested area shown (fig. 10). The horizontal distribution graph was drawn every two weeks or so. The movement of the new population front of midges along the horizontal axis was shown in fig. 12. The population density of midges at every new population center was measured at the same time (fig. 13) to show the population growth of midges. In addition, a light trap (plate II, 3) was fixed at the Tainan

Fish Culture Station to measure the build-up speed of Chironomid midge population at a fixed spot in early summer. The trap consisted of a 6-watt black light trap (Frost, 1953; 1954) and a 30-watt electric fan to blow the midges into a collecting bag. The trap operated for two hours after sunset every day. The catches served as the index of population density of midges.

The survey on the dispersal of Chironomid larvae was held at Safety Pond (fig. 9). On June 10, 1969 the front of midge infested area reached the central demarcation of ponds. This area consisting of nine ponds totalling 40 ha, was surrounded by the inner sea. The abscissas of these ponds ranged from 1,050 to 2,200 meters. Each pond number was written in Roman numeral in fig. 11. The population density of Chironomid larvae, larvae/m^2, was written in Arabic numeral under each pond number. As the larvae population migrated from west to east, the population density in the western ponds was much higher than that in the eastern ponds. A dotted line was plotted in fig. 11 to distinguish the heavily infested ponds from the lightly infested ponds.

Results

The factors governing the diapause of larvae were examined. After incubation the overwintered larvae began to transform into pupae and then emerged as adults during the night. The number of emerging adults reached the peak on the third day. Most of the emergence took place in five days (fig. 1). This incubation time was followed in all subsequent experiments. The pupal stage lasted 24 to 48 hours according to the specimens dwelling in the algae tubes lining the wall of the beaker. Two hundred larvae were incubated at 8:00 A.M. on January 8, 1969. There were 19 pupae and 44 larvae remaining in the rearing units on January 13 besides the 110 adults the last of which were shown in fig. 1. Fig. 2 shows that the optimum temperature for emergence was 30°C; all the tested larvae died after being incubated at 40°C for 5 days; when the incubating temperature was lower than 15°C, there were no adults nor pupae. The survival rates of tested larvae at 15°C and 10°C were 91% and 84% respectively. The midges disappeared from the field when the air temperature dropped to 20°C. The light trap could not catch any more midges on November 28, 1967. In fig. 3, the water temperature was obtained from the well sheltered overwintering pond in winter, so

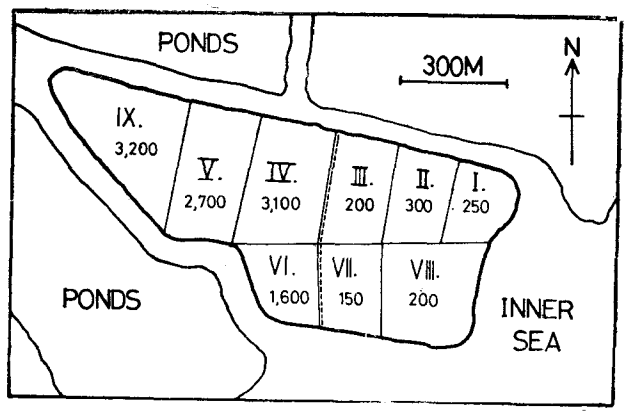

Fig. 11. The distribution of Chironomid larvae in Safety Ponds on June 10, 1969.
a. pond number : I, II, III,.....IX.
b. The numeral in each pond indicates population density, larvae/m^2.

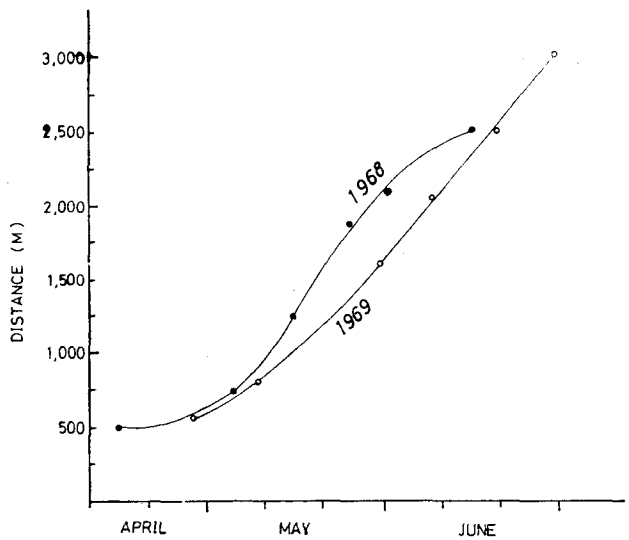

Fig. 12. Eastward movement of Chironomid midges in early summer.

the water temperature at 8:00 A. M. was much higher than the lowest air temperature. The water temperature in the unsheltered rearing pond where Chironomid larvae lived was similar to the air temperature. The highest air temperature was not shown in fig. 3, because it was quite similar to the water temperature at 2:00 P.M. The overwintered larvae stocked in a concrete pond remained in the larval stage for three months. They were transformed into adults in early March when the temperature

rose again. The results of field tests checked with the laboratory data indicated in fig. 2.

The effect of salinity on the metamorphosis of overwintered larvae was shown in fig. 4. When the larvae were transferred from the stocking pond at 45‰ salinity and incubated in culture media of lower salinity levels, the emergence rate was generally high. However, the emergence rate was poor in fresh water. When the salinity of the culture media for incubation was increased from 45‰, the emergence rate increased slightly at first. When the salinity level was increased to 55‰, the emergence rate began to decline and all the tested larvae died when salinity rose to 90‰.

The emergence rate of those larvae exposed to a photoperiod of 10 hours was slightly lower than that of those exposed to 13 hours (fig. 5). The photoperiod in Tainan area was from 10.5 hours to 13.5 hours throughout the year (Taiwan Provincial Weather Bureau, 1968). Therefore, the photoperiod did not seem to be the limiting factor for emergence. There was no emergence in five days when the photoperiod was reduced to four hours. Eighty-three percent of the tested larvae were transformed into pupae, but only 42% of the pupae were alive and 58% of them dead at the end of incubation.

Fig. 6 shows that the eggs could hatch whenever the salinity levels were less than 80‰. The optimum salinity for hatching was 30‰. It was

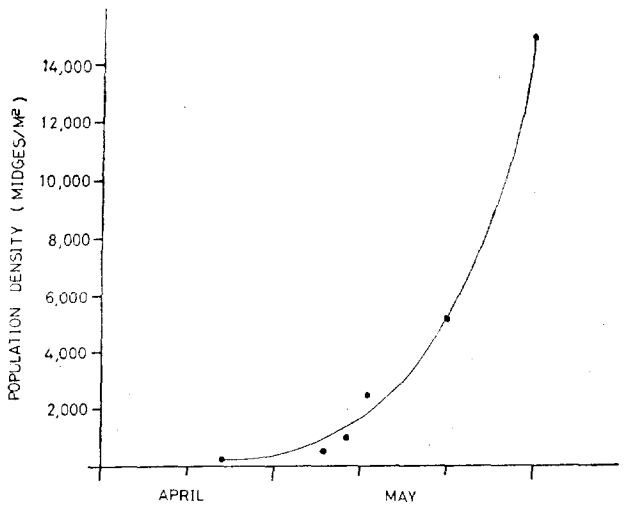

Fig. 13. Occurrence of Chironomid midges in early summer.

noticeable that hatching was still possible even under a high salinity of 60‰ in the ponds in early summer. Salinity also affected the growth rate of larvae. The larvae had higher growth and survival rates at salinity from 20-40‰ (fig. 7). All the larvae died under salinity 80‰ in 14 days.

High salinity in pond water in early summer depressed the normal development of Chironomid life cycle (fig. 8). It took 31 days for the development of the second life cycle when the average salinity was about 53‰, while the third life cycle took only 14 days under average salinity of 30‰. The data checked with the laboratory experiment showing that the Chironomid eggs developed into adults in 15 days under 33‰ salinity in June 1969. The temperature difference between these two life cycles is small. Table 1 shows that the population of Chironomid larvae grew slowly under high salinity in the second life cycle, while it grew rapidly in the third and fourth life cycles when the average salinity dropped to 30‰ or so.

The Chironomid midges broke out in the west part of this area and then dispersed eastward. In early spring, the midges were abundant in the nursery ponds west of the Old Fort (fig. 9) and began to move eastward. At first, the distribution of midges in the original abode was rather even. Although the population center was vague, the population front was clear on April 24, 1969 (fig. 10). Then as the algae bed was destroyed, the midge population density at the original abode declined. But it increased in the newly infested area. Both the population center and the population front became clear on May 9, 1969 (fig. 10). The population center was often vague because of insecticide applications. That was why the population front, instead of the population center was used in this paper to indicate the position of the midges. The population front existed in the larvae population, too. The population density of Chironomid larvae in Safety Pond was surveyed when the population front of midges reached the western banks of pond IV and VI in fig. 11. It was clear that the population density of larvae in the ponds west of the dotted line in fig. 11 was much higher than that in the east ponds. This was proof to support the fact of the eastward movement of midge population.

The eastward movement of midge population front was shown in fig. 12. The movement was slow in April 1968. However, after the rainfall in May 1968, the midges spread rapidly owing to the larger population

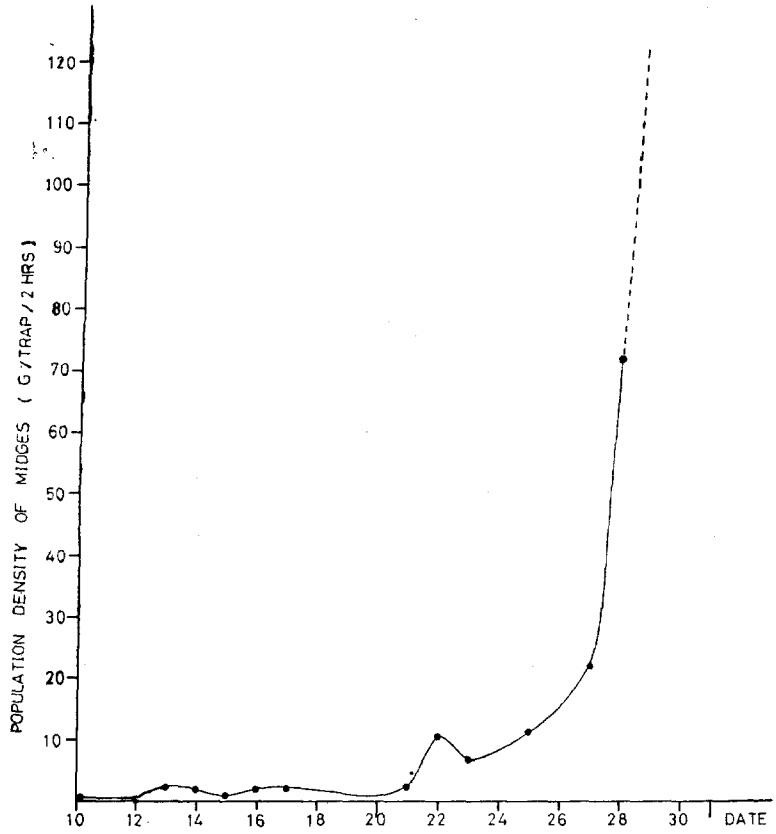

Fig. 14. Build-up of Chironomid midge population late May 1969, at Tainan Fish Culture Station.

and favorable salinity for their growth. Until June 1968, the dispersion speed slowed down due to the intensive applications of insecticides, especially the BHC adulticide applied to Road East Pond (fig. 9) on June 2, 1968. In 1969, the embankment grass of the Tainan Fish Culture Station and Road East Pond (fig. 9) were treated with DDD adulticide at the rate of $2g/m^2$. The midges could not survive in the treated area, hence the midge population was smaller than that in 1968. This small midge population dispersed eastward through the narrow path along the canal. The dispersion speed was slower than that in 1968, too. As the midges dispersed eastward, its population grew simultaneously. The growth curve of the midge population in early summer of 1969 was shown in fig. 13. The increase of the midge population in the Tainan Fish Culture Station ponds (fig. 14) was far more rapid than that of the whole Tainan milkfish ponds (fig. 13). This phenomenon serves as another evidence of the dispersion of the midges from the nearby ponds.

Acknowledgements

Professor Y. L. Chen and Dr. I-chiu Liao of the National Taiwan University gave me many valuable suggestions. Mr. R. S. Pan of the Taiwan Sugar Experiment Station helped me in preparing the manuscript. Professor S. Y. Lin read the manuscript and offered many valuable comments. To all of them, thanks are due. The author is also indebted to the staff at the Tainan Fish Culture Station, especially K. Y. Lin and R. S. Ho for their help since 1966. This work could not have been carried out without their assistance.

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經濟蝦類之生殖器官研究——1

生殖補助器之外形及其內部之比較

台灣省水產試驗所東港養蝦中心

廖 一 久* • 陳 惠 彬**

(1969年11月15日受理)

Reproductive Organs of Five Prawns——1

External and Internal Structures of the Copulatory Organs

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Summary

Prawn culture has been intensively practiced recently and promises to become a new important industry in Taiwan, but little information has been reported on the basic study of prawn biology. The present study was undertaken to observe the different copulatory organs of the five kinds of commercially important prawns, *Penaeus japonicus*, *P. monodon*, *P. semisulcatus*, *Metapenaeus monoceros* and *Penaeus teraoi*. All these prawns were obtained in the Fish Market of Tungkang, south Taiwan. The results obtained are summarized as follows:

(1). Besides the fundamental reproductive structure of genital pores in the prawns, the male and female also possess another special organ as tools for copulation, respectively. The female copulatory organ is called thelycum, and the male petasma. The male by means of the petasma passes the spermatophores into the seminal receptacle through the thelycum during copulation.

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(2). The grown females caught from the open sea have already received spermatophores in their seminal receptacles, especially during the spawning season, regardless of the maturity of the ovaries. Therefore, it is unnecessary to worry about the possibility of fertilization at ovulation.

(3). All the females of these five prawns cast off the spermatophores in the seminal receptacle together with the old shell at each moulting, and the females will receive new spermatophores from the males in new copulatory act.

(4). The thelycums of *P. monodon* (Fig. 2-A, Pl. II-1) and *P. semisulcatus* (Fig. 3-A, Pl. II-3) look alike morphologically but both are somewhat different from that of *P. japonicus* (Fig. 1-A, Pl. I-1, I-2). The thelycum of *P. japonicus* has two large stoppers inserted in it, while there is no stopper nor its remains to be found in that of *P. monodon*.

(5). Parts of the stoppers are found as a hard black piece in the central slit in the thelycum of *P. semisulcatus* (Fig. 3-B) indicating the existence of spermatophores stored in the seminal receptacle. In *P. monodon*, the spermatophores are believed to be in the seminal receptacle if the thelycum is somewhat convex and soft. There are some remains of stoppers which can also be found in the central slit in the thelycum of *P. teraoi*. However, it is not easy to know whether the spermatophores are present or not just from the appearance of the thelycum in *Metapenaeus monoceros*.

(6). The petasmas of all the four kinds of the prawns in the genus of *Penaeus* resemble one another in structure, appearance and also in length (Fig. 1-D, 2-D, 3-D, 5-C; Pl. I-3, II-2, II-4, II-6).

(7). Spermatophores have been found in the thelycum of the female of *P. monodon* grown in a fish pond. Because of this it is believed that copulation can also take place in the fish pond.

前　　言

近年來，國民生活水準普遍提高，國際市場蝦類供不應求，蝦類研究因而頗受各界之重視。本省有關經濟蝦類之養殖，已由於蝦苗人工繁殖之試驗成功[1, 2]，正向生產大量化邁步。然最重要之基礎研究，即有關蝦類生物學方面之報告則尚少[3, 4, 5]。筆者等爲研究有關蝦類繁殖問題而作一系列之研究計劃，此次先觀察並解剖本省經濟蝦類中之斑節蝦、草蝦，熊蝦、砂蝦及白鬚蝦等五種蝦之生殖補助器，以探討其構造及外形之異同，及與交配前後之關係。茲將所獲二、三心得報告如下：

觀察●解剖結果

蝦類之生殖器構造頗爲奇特，除雌蝦在第三對步脚（3rd Pereiopod）基部、雄蝦在第五對步脚基部各具有生殖開口（Genital pore）外，雌雄蝦皆另具有所謂之生殖補助器（Copulatory organ）以爲交配之用。此種生殖補助器在雌蝦稱之爲雌性生殖補助器（Thelycum），位於第五對步脚之間；雄蝦者稱之爲雄性生殖補助器（Petasma），位於第一對游泳脚（Ist pleopod）之間。當雌雄蝦進行交配時，雄蝦利用雄性生殖補助器之助將其貯精囊（Spermatophores）由其生殖開口送進雌蝦之雌性生殖補助器之藏精器（Seminal receptacle）內。

蝦類之交配發生於雌蝦進行脫皮（Ecdysis）之際。據 Hudinaga [6] 觀察斑節蝦（*Penaeus japonicus* Bate）之交配，爲當雌蝦進行脫皮之際，雄蝦追逐其後，雌蝦脫完皮後即將體軀傾斜作側游狀，此時尾隨之雄蝦即向前跟上，與雌蝦作腹對腹之擁抱 *，進行交配之動作，歷時約三、四分鐘。

貯精囊並非永久儲存於雌蝦之藏精器內。雌蝦在進行脫皮之時，不僅將舊體殼脫去，並且將其貯精囊一併脫掉。惟伴同脫皮而行之交配再使雌蝦由雄蝦處獲得新的貯精囊。當雌蝦之卵巢（Ovaries）成熟後行排卵（Ovulation）時，精蟲即由雌蝦第四對步脚基部之出精口處被壓擠出，而與水中之卵接合完成受精（Fertilization）

一、斑節蝦（*Penaeus japonicus* Bate）

⑴雌性生殖補助器

Hudinaga [6] 對此曾有頗詳之闡述。外形似一方袋，開口於上（Fig. 1-A, Pl. I-1, I-2），左右兩部份在中央處完全癒合而留有痕跡。內部成爲空室，在交配後之雌蝦，此處即插有兩片大型、葉狀、堅硬且略帶黃色之交尾栓（Stoppers）。此交尾栓頗爲特殊，在雄蝦輸精管內即已附着於貯精囊上，已甚肥厚且皮堅硬。空室背後另有由薄膜構成之密室，此即爲儲存貯精囊之藏精器（Fig. 1-C）。交尾栓之尾端與貯精囊連結一起，成"V"字型狀（Fig. 1-B）。

⑵雄性生殖補助器

左右各與第一對游泳脚基部相連，中央完全癒合，兩邊稍向內捲，邊緣堅硬如骨狀，前端各曲成鈎狀。兩鈎之間另有突出之結狀構造，頗爲顯著（Fig. 1-D, Pl. I-3）。其他無甚特徵可述。

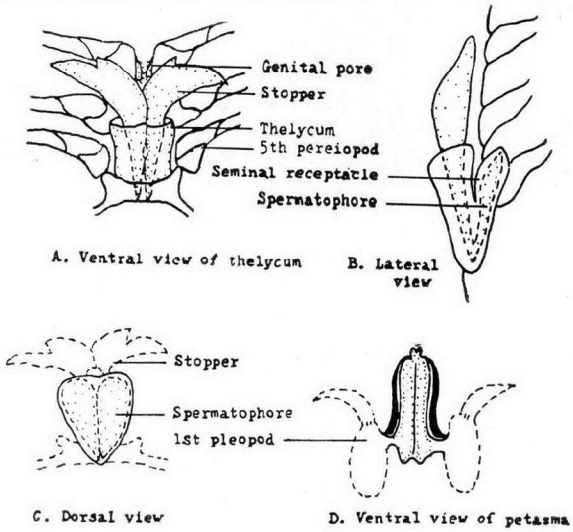


Fig. 1. Structure of thelycum and petasma of Penaeus japonicus BATE

* 據謝隆聲君之觀察，草蝦之交配情形異於斑節蝦，但詳情有待今後之繼續觀察研究。

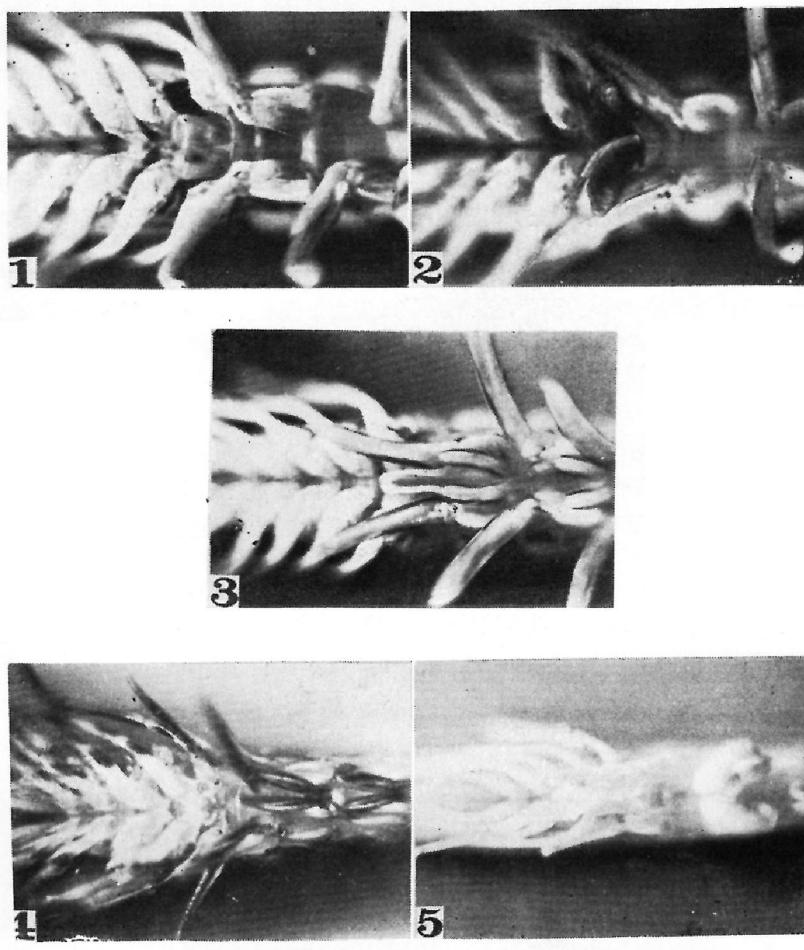


Plate I-1. Ventral view of thelycum, before copulation, of *Penaeus japonicus*.

I-2. After copulation, *P. japonicus*.

I-3. Ventral view of petasma, *P. japonicus*.

I-4. Ventral view of thelycum, *Metapenaeus monoceros*.

I-5. Ventral view of petasma, *M. monoceros*.

二、草蝦（*Penaeus monodon* Fabricius）

⑴雌性生殖補助器

外形略方（Fig. 2-A, Pl. II-1），惟愈成長大型之蝦，其補助器往往是底寬上窄，且底寬大於縱長。邊緣堅硬。左右兩部在中央相接，但不完全癒合，形成"Y"字狀縱縫。補助器內不藏交尾栓，此點與斑節蝦者不同。後部之藏精器可與縱縫相通，貯精囊成雙併存於內（Fig. 2-B），惟排卵後因日久漸乾癟癒合爲一，且鈣化爲乳白色，此時可由補助器外表隱約察知。

雄蝦輸精管內之貯精囊在構造及形狀上與斑節蝦　頗爲不同（Fig. 2-C），其附着之交尾栓則爲一片狀薄膜構造物，在進入雌蝦生殖補助器後常易掉落，故由雌性生殖補助器外表無法發現交尾栓之存在。但欲知雌蝦是否已交配，據筆者等之經驗，可由生殖補助器外表之肥凸或瘦凹程度來辨識。若外表肥凸柔軟富彈性者，其內必藏有貯精囊。惟一般成長之雌蝦，不論其卵巢已達成熟否，多半皆已交配藏有貯精囊。筆者等曾解剖過18尾雌草蝦，雖各尾之卵巢成熟度不盡相同，但發現僅兩尾內無貯精囊，且其中之一爲魚塭中養大　。

又曾在魚塭養大之雌蝦之生殖補助器內發現有貯精囊之存在，由此可知養殖池中之草蝦亦有交配現象，只是其卵巢發育不甚發達，此是否與環境有關則有待今後之研究。

⑵雄性生殖補助器

除稍短、邊緣較粗硬、前端無明顯之兩結狀突出物，及顏色較深紅外，其他構造則與斑節蝦之補助器大同小異（Fig. 2-D, Pl. II-2）

三、熊蝦（*Penaeus semisulcatus* De Haan）

⑴雌性生殖補助器

外表略呈圓形（Fig. 3-A, Pl. II-3），中央亦有一縱縫，其兩邊緣高突，成一縱褶狀。裂縫內亦如同草蝦者，與藏精器相通。交尾栓部份露於縫內而多鈣化爲似刀狀堅硬之縱片（Fig. 3-B），與藏精器之貯精囊癒合爲一。貯精囊並非成雙分存於藏精器內，兩者皆呈癒合狀態（Fig. 3-C）。通常可由縫內縱片物之有無來判斷雌蝦是否已交配。

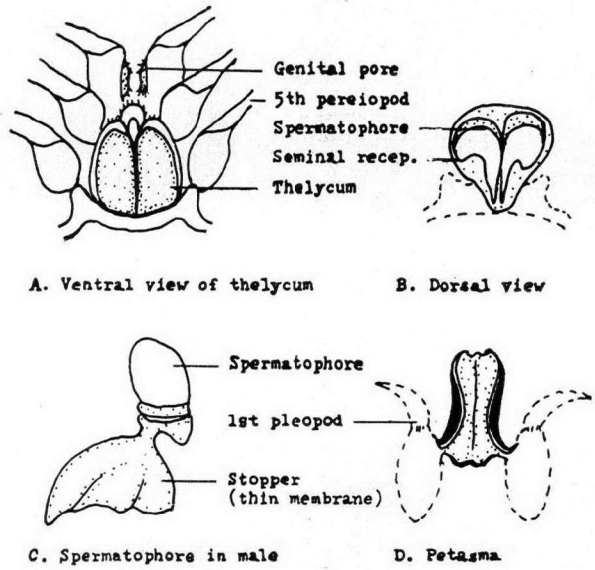


Fig. 2. Structure of thelycum and petasma of P. monodon FABRICIUS

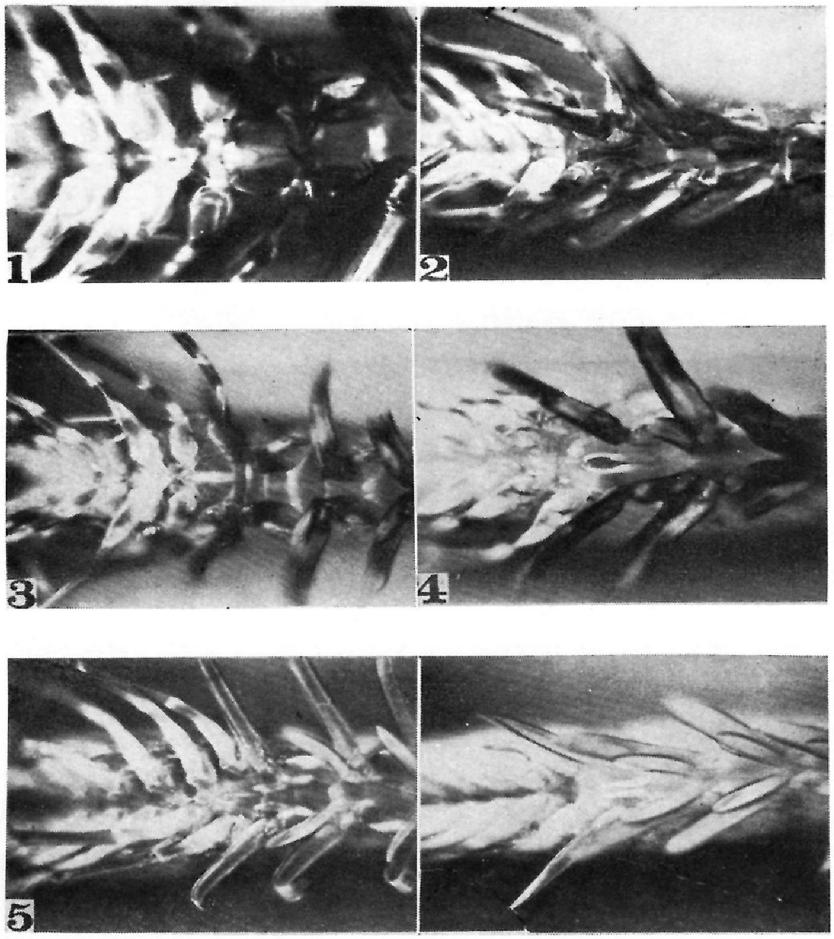


Plate II-1. Ventral view of thelycum, *P. monodon*.

II-2. Ventral view of petasma, *P. monodon*.

II-3. Ventral view of thelycum, *P. semisulcatus*.

II-4. Ventral view of petasma, *P. semisulcatus*.

II 5. Ventral view of thelycum, *P. teraoi*.

II-6. Ventral view of petasma, *P. teraoi*.

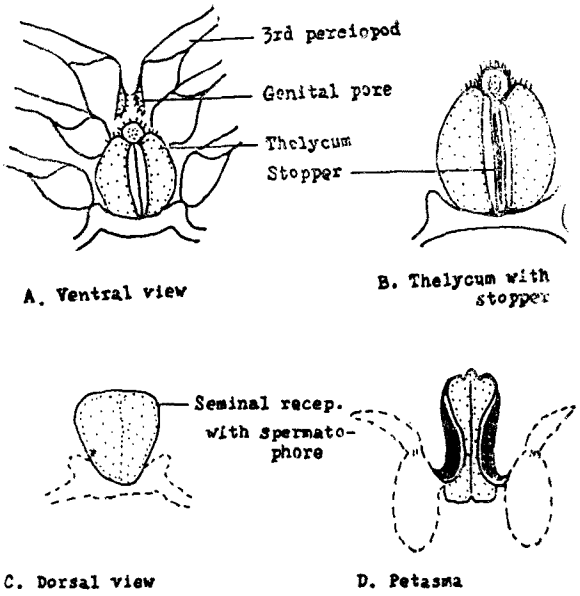


Fig. 3. Structure of thelycum and petasma of P. semisulcatus DE HAAN

雄蝦輸精管內之貯精囊構造與形狀酷似草蝦之貯精囊，亦附有薄膜狀之交尾栓。惟此交尾栓在進入雌性生殖補助器後，並非全部脫落。部份遺留於裂縫中而鈣化成爲縱片物（如上述）。

(2)雄性生殖補助器

外形構造與前述之草蝦很近似（Fig. 3-D, Pl. II-4）

四、砂蝦［*Metapenaeus monoceros* (Fabricius)］

(1)雌性生殖補助器

外形不甚顯著，左右兩邊隆起，中央內凹，開口於下，形同一盆狀（Fig. 4-A, Pl. I-4）。補助器內無袋狀構造。其背後則有雙角突起，此即爲藏精器所在（Fig. 4-B）。此蝦是否交配，目前尚不易由生殖補助器外表辨別，仍有待今後之觀察。

(2)雄性生殖補助器

外形頗爲特殊。兩邊內捲成筒狀，十分堅硬。前端突出成三角形狀，其後有兩堅硬之鈎狀物（Fig. 4-C, Pl. I-5）

五、白鬚蝦（*Penaeus teraoi* Kubo）

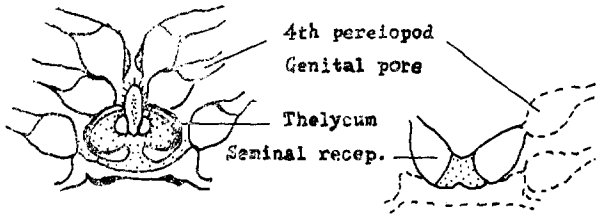
此蝦之成蝦體長約爲20公分，體色橘紅透明。額角（Rostrum）棘式多爲上10下2，額角隆起緣之兩側溝延伸約至頭胸殼（Carapace）之後緣，尾節（Telson）兩側緣各有三小棘。第二觸角顏色雪白爲其特徵，故其俗名稱之爲白鬚蝦，爲本省前未曾紀錄之蝦類，經鑑定結果似可定名爲 *Penaeus teraoi* Kubo [5]。

(1)雌性生殖補助器

外形與熊蝦之生殖補助器頗爲相似，但較小型且不顯著。中央部份亦有隆起之縱褶（Fig. 5-A, Pl. II-5）。列縫中亦有交尾栓之殘餘物，惟不如熊蝦者列縫內之縱片物明顯堅硬。補助器內之藏精器窄狹，貯精囊則亦多呈癒合狀態（Fig. 5-B）

(2)雄性生殖補助器

亦與前述之斑節蝦、草蝦、熊蝦之生殖補助器相似，無甚可述（Fig. 5-C, Pl. II-6）。



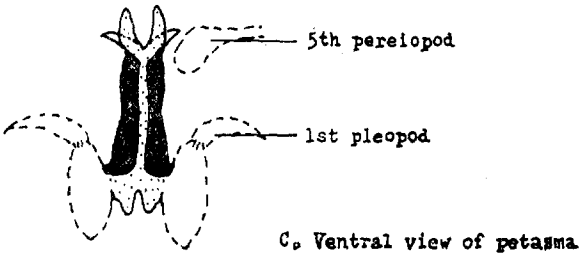
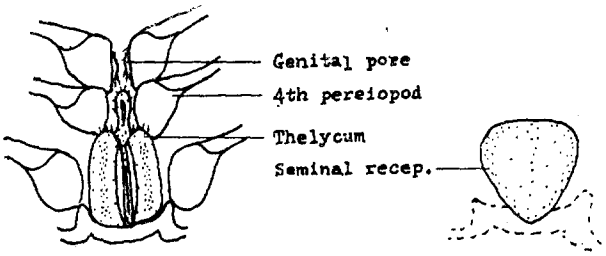


Fig. 4. Structure of thelycum and petasma of *Metapenaeus monoceros* FABRICIUS



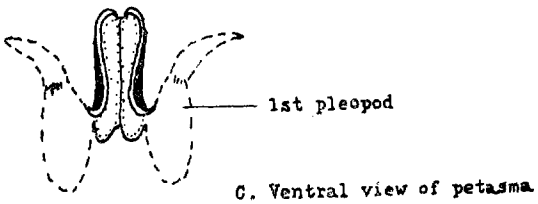


Fig. 5. Structure of thelycum and petasma of Penaeus teraoi Kubo

摘　　要

爲研究有關蝦類繁殖問題之第一步，此次觀察並解剖本省經濟蝦類中之斑節蝦、草蝦、熊蝦、砂蝦及白鬚蝦等五種蝦之生殖補助器獲得下列結果：

(1)蝦類除具有生殖開口外，皆另具有生殖補助器，各有其不同之外形與構造。在雌蝦者謂雌性生殖補助器（Thelycum），在雄蝦者謂雄性生殖補助器（Petasma）。雄蝦利用雄性生殖補助器之助將其貯精囊（Spermatophores）送進雌性生殖補助器內之藏精器（Seminal receptacle）裏

儲存以備受精之用。

(2)斑節蝦、草蝦、熊蝦、砂蝦及白鬚蝦皆於脫皮時將藏精器內之貯精囊隨同舊體殼脫去，而再於交配中獲得新的貯精囊。

(3)草蝦與熊蝦之雌性生殖補助器在外形及構造上頗爲相似，且兩者之貯精囊與交尾栓構造上亦很相似。白鬚蝦之雌性生殖補助器亦和熊蝦者近似，但較小型且不明顯。砂蝦因不同屬，雌雄生殖補助器構造皆廻然不同。斑節蝦雖與草蝦、熊蝦同屬，但雌性生殖補助器及其交尾栓之構造則頗爲特殊不同。

(4)斑節蝦、草蝦、熊蝦及白鬚蝦四者之雄性生殖補助器之外形與構造彼此極爲近似。

(5)斑節蝦可由雌性生殖補助器上附着有兩巨大之交尾栓或其殘餘而知其已交配。草蝦則由其雌性生殖補助器外表之肥凸富彈性，或隱約可看到其內有兩白物而判斷其已交配。熊蝦則由雌性生殖補助器中央縱縫內夾塞之硬黑縱片物（由交尾栓部份鈣化而成）而知其已交配。白鬚蝦亦可由此裂縫內之交尾栓殘餘物而知其已交配。砂蝦因雌性生殖補助器構造特殊之關係，是否已交配，目前尙無法由外表知之。

(6)一般成熟之雌蝦十之八九皆已交配藏有貯精囊，尤以在產卵季節所捕獲之雌蝦皆然。

(7)魚塭養大之草蝦，其雌性生殖補助器內亦曾被發現有貯精囊存在，可知其亦有交配現象發生。

謝　　辭

此項工作之所以能順利進行乃由於洛氏基金之補助，並蒙農復會陳組長同白、林技正書顏和省水試所鄧所長火土之鼓勵，以及東港養蝦中心各同仁予以莫大之協助，謹誌此藉表謝忱。

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THE POPULATION OF GRACILARIA IN YUANCHANG RESERVOIR, PUTAI, CHIAYI

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Introduction

The reservoir of Yuanchang located in Putai, Chiayi, is 28 hectares in area. It is the largest *Gracilaria* farm in Taiwan. There are two important species in this reservoir, *Gracilaria gigas* and *Gracilaria chorda*. But, in this reservoir, the production is getting less year by year (Table 1), and the production per hectare less than in other places. The aim of the present study is to find out why the unit production in Yuanchang is less than that in other places and why production is decreasing so that plans could be made for improvement.

During the period from September 1968 to July 1969 the study was carried out with emphasis on the estimation of abundance and growth rate of *Gracilaria* in the reservoir.

Methods

1. 100-150 plants were taken once every month by random sampling to determine the growth rate.
2. Estimation of abundance:
   The reservoir was divided into twenty blocks (Fig.1). In each block 25 plots of one m^2 each were designated for random sampling. The methods for estimation of abundance[1] used in this article refer to a study of abundance of *Gracilaria* by 桶作博之, 佐佐木茂. Using their methods, the CV is always less than 10%. The results are very valuable.

   N = area of the reservoir
   $= 280{,}000 m^2$ (28 ha)
   n = area of all the plots
   $= 500 m^2$
   X_i = the weight of *Gracilaria* in each plot
   f_i = frequency of X_i

$$\bar{X} = \frac{\Sigma f_i X_i}{n}$$

S^2 = unbiased dispersion

$$= \frac{N}{N-1} \cdot \frac{1}{n} \cdot \Sigma f_i \ (X_i -)^2 \bar{X}$$

$$V = \frac{N-n}{N-1} \cdot \frac{S^2}{n}$$

CV = Coefficient of Variation

$$= \frac{\sqrt{V}}{\bar{X}}$$

X = estimative value of the standing crop

$$= N \cdot \bar{X}$$

$$= \frac{N}{n} \cdot \Sigma f_i X_i$$

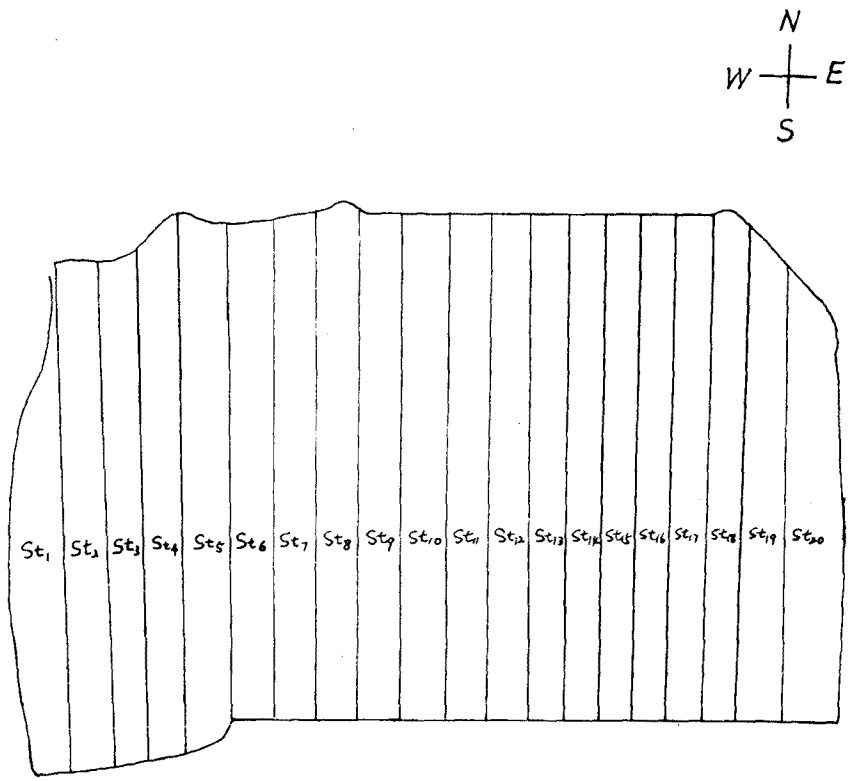

Fig. 1. The reservoir of 28 hectares was divided into twenty blocks for estimation of abundance.

Results and Discussions

1. The growth rate:

The growth rate was determined by measuring the length of the longest

buds of plants and the number of branches in one plant. 100-150 plants were taken once every 30 days by random sampling to determine the growth rate from September 1968 to July 1969.

2. Production:

The production of *Gracilaria* from the years 1965 to 1968 is shown in Table 1. Usually, one kilogram of dried algae is obtained from 10 to 12 kilograms of wet algae.

Table 1*. *Gracilaria* production in Yuanchang Reservoir, 1965-1968

Date	Production (kg): dried algae
1965	37,500
1966	31,250
1967	25,000
1968	12,500

* Table 1 is contributed by the culturists of the reservoir.

3. Estimation of abundance:

$\bar{X} = 502.4\ g/m^2$

$X = 140,672 kg$

According to the estimated value on July 11, 1969, the standing crop was about 5,000 kg per hectare, an amount equivalent to the initial stocking in other places in Taiwan. In general, culturists stock their plants in March. Between June and September, the rainy season, the salinity is lower than that in any other season (about 15‰-25‰). At this time, *Gracilaria* grows very well[2], it may increase 4 to 10 times in weight. In this period, culturists harvest the plants about once every ten days. They remain about 5,000 kg in each hectare when winter comes; dwarfing takes place from November to March because of lower temperature (less than 20°C) and higher salinity (more than 35‰). From May to November, *Gracilaria* growth is achieved through vegetative reproduction by means of breaking the branches of the plants into small pieces[3]. Cultured this way, 3 tons or more of dried algae can be obtained.

In Yuanchang Reservoir, *Gracilaria* growth is different from that mentioned above[4]. The plants grow through normal reproduction by tetraspores and carporspores[5]. The germinating process of the spores takes place from September to April, and the spores release is usually

between July and September, but culturists start harvesting the plants in July and have them completely removed by the end of September when no plants are left in the reservoir. On the basis of data obtained as shown in Appendix 1 the following observations are made:

1. In Yuanchang Reservoir, the season of spores release is the main reason why the production is getting less year by year. (Table 1)
2. In Yuanchang Reservoir, the period of harvest only lasts three months each year, and when harvest begins, the standing crop is only about 5,000 kg per hectare, the same amount as the initial stocking in March in the other places of culture. Besides, the harvest period at Yuanchang Reservoir is only three months, whileas that in the other places is four months or more.
3. The *Gracilaria* in the experimental zone starts to grow from spores, whereas in the other places it grows by vegetative reproduction. The former requires about seven months for the plants to grow to 7 cm in height, while the latter starts to grow from 5 to 7 cm in height. (Fig. 2)

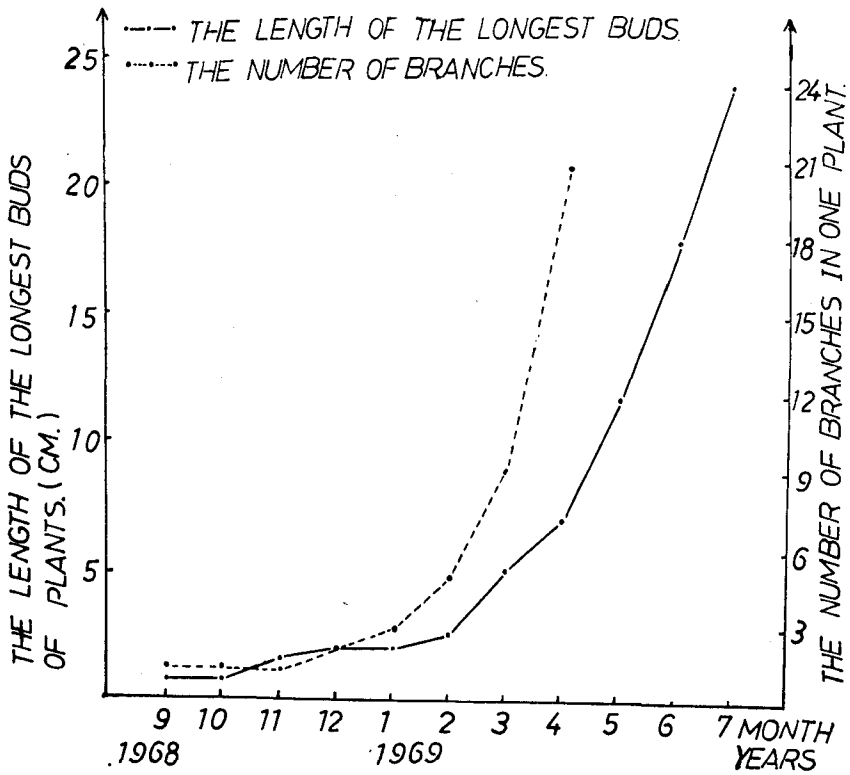

Fig. 2. The growth rate of *Gracilaria* in the reservoir during the period of September 1968 to July 1969.

4. These are the main reasons why the production per unit area in Yuanchang Reservoir is less than that.of the other places.

Summary

In order to find out the main reasons why the production of *Gracilaria* in Yuanchang Reservoir declines from year to year and is less than that in the other places, the resource and the rate of growth of *Gracilaria* were investigated in this area during the period of September 28, 1968-July 11,1969. The results are summarized as follows:

1. It takes about 7 months for the plants to grow to 7 cm in length in this reservoir.
2. On July 11, 1969, the standing crop was about 5,000 kg.
3. In this reservoir, the season of spores release is the same as that of harvest, thus a longer period is required for the *Gracilaria* to grow to harvestable size.
4. In Yuanchang Reservoir, when harvest begins (in July), the amount of the standing crop is equal to that of initial stocking in March in the other places. Furthermore, the growth of *Gracilaria* in this area starts from spores, whereas in the other places it is by vegetative reproduction, thus the former requires a longer period to grow to harvestable size than the latter.

Acknowledgements

The author wishes to express his thanks to Dr. I-chiu Liao, Shan-ching Tsai and Yun-yuan Ting, Tainan Fish Culture Station, for close consultations, and Prof. S. Y. Lin of the National Taiwan University for his valuable comments and suggestions. The author is also grateful to Dong-liang Lee for his technical advice and assistance.

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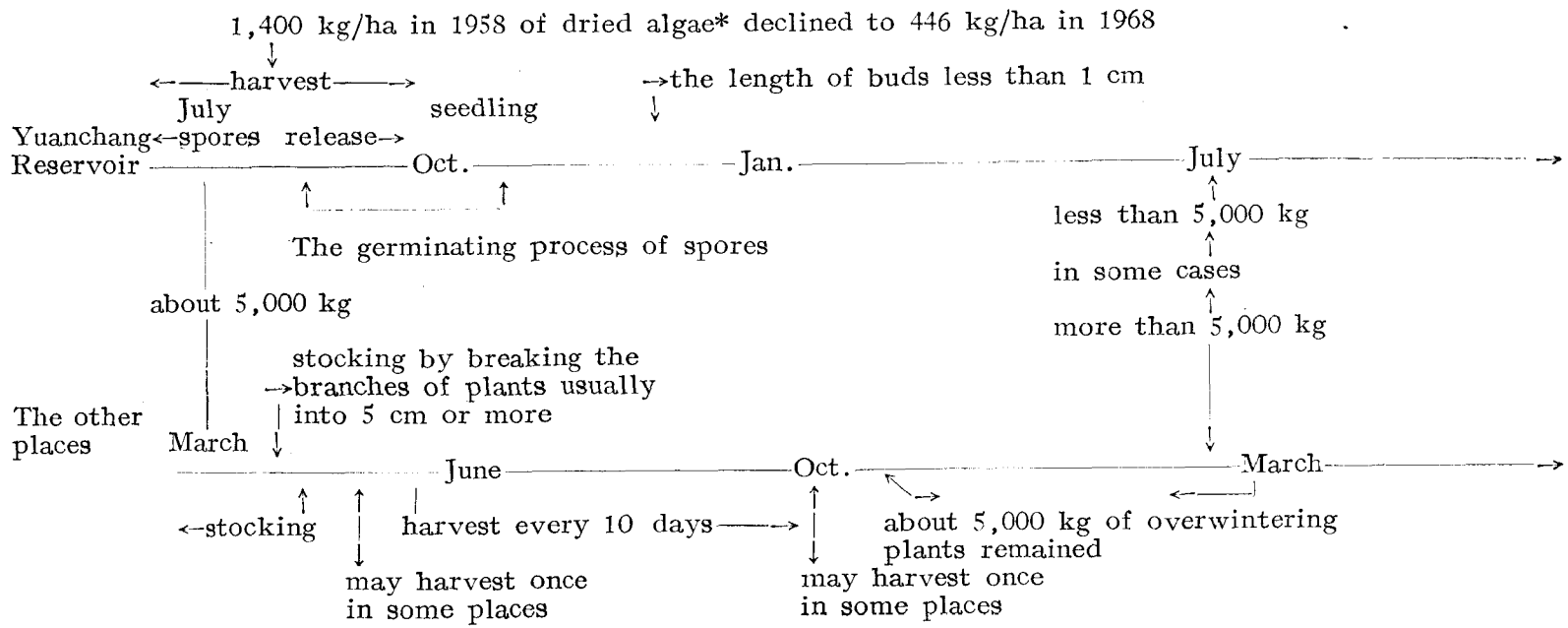
Appendix 1. *Gracilaria* culture in Yuanchang compared with that in the other places



Three tons or more of dried algae may be obtained from each hectare every year.

* 10-12 kg wet algae —→ 1 kg dried algae (moisture less than 20%)

Appendix 2. Class distribution of *Gracilaria* population based on sampling of 500 plots from 20 blocks

Unit: 50g. Date: 1969.7.9.

Class	St_1	St_2	St_3	St_4	St_5	St_6	St_7	St_8	St_9	St_{10}	St_{11}	St_{12}	St_{13}	St_{14}	St_{15}	St_{16}	St_{17}	St_{18}	St_{19}	St_{20}	Σf_i
0 1	10	6	5	1	2		1	5	3	4	5	3	2	7	8	4	1	2	4	9	82
1 2				1	2						1	1	1	4	2	2	1	2	1		18
2 3		1	1	1	1		1	2	3		1			2	1	2	1		2		19
3 4		3	1				1				2	2		3	4	5	2	1			24
4 5	1	1	2	4	2	1				4	3		2		1	2	1	3	1		28
5 6	1		2		1	1			1		1	4	1	3	1	2	2	3	1	1	25
6 7		2	1	4	1		4			3	1	1	3		2	2	1		2		27
7 8		1					1					2	3		3		2	3	3	1	19
8 9				1	2	2		1	2	1	1	2	1		1	2	3		2		21
9 10		1	1			2					1						2				7
10 11			1			1															2
11 12								1				2	1		1	1	1	4	3		14
12 13	1			2	1	2	1	1	1	1		1					1				12
13 14			1									1					1				3
14 15						1	1		1	1	1		1								6
15 16			1								1	1	1			1	1	2	1		9
16 17		1	1	2	1	1			1	1		1									9
17 18		1									2	1					3		1		8
18 19					1			2	1	2	1										7
19 20											1	1				1					3
20 21								4		1	1			1					1		8
21 22				1		1	1					2									5
22 23		1		1		4	2	1		1											10
23 24																					0
24 25						1	1		1												3
25 26											1		2								3
26 27							4		1				1								6
27 28					1														1		2
28 29										1											1
29 30													1		1	1				1	4
30 31			1																		1
31 32																					0
32 33				1	1			2		1											5
33 34											1							1			2
34 35							1		1				1								3
35 36							1													1	2
36 37							1		1												2
37 38																	1		1		2
38 39					1																1
39 40																		1			1
40 41						1		1													2
41 42													2								2
42 43					1		2	1	1												5
43 44																					0
44 45							1	1													2
45 46																					0
46 47						1															1
47 48																					0
48 49																					0
49 50																					0
50 51																					0
51 52																	1				1
52 53				1	1																2
53 54																					0
54 55																					0
55 56																					0
56 57										1											1
57 58																					0
58 59																					0
60 61					1	1															2
61 62														1							1
72 73					1																1
77 78														1							1
97 98													1								1
100 101													1								1
0	12	7	7	5	4	5	1	3	7	3				3				3	1	12	73

Unit: 50g

$$\Sigma f_i X_i = f_1X_1 + f_2X_2 + \cdots\cdots + f_nX_n$$
$$= 5{,}024$$

$$\overline{X} = \frac{\Sigma f_i X_i}{n}$$
$$= 10.048$$

$$X = N \cdot \overline{X}$$
$$= \frac{N}{n} \cdot \Sigma f_i X_i$$
$$= 2{,}813{,}440$$

$$\therefore X = 2{,}813{,}440 \times 50g$$
$$= 140{,}672kg$$

$$S^2 = \frac{1}{n} \cdot \Sigma f_i (X_i - \overline{X})^2$$
$$= 173.07$$

$$V = \frac{N-n}{N-1} \cdot \frac{S^2}{n}$$
$$= 0.034$$

$$\sqrt{V} = 0.058$$

$$\therefore CV = \frac{\sqrt{V}}{x}$$
$$= 0.0057$$

龍鬚菜果胞子之培育試驗

臺灣省水產試驗所臺南分所

李 棟 樑

The germination of the carpospores in Gracilaria gigas Harv. in Hsin Ta Kang

By D. L. Lee

Tainan Fish Culture Station

SUMMARY

The germination of the carpospores of *Gracilaria gigas* was studied in Hsin Ta Kang from 1968 to 1969.

1. Carpospores are discharged from the carpostome of the cystocarp together with white mucus. Carpospores are spherical and about 17～35μ in diameter.
2. The first division of the carpospores takes place one day after the discharge. It divides into two equal parts.
3. Three days after discharge of the spores, the second division runs perpendicular to the first one, but sometimes, the second division runs parallel to the first one to 3～4 cells which are arranged in zonate manner.
4. The third and successive divisions are somewhat irregular, and the sporelings observed from the surface are composed of 16 or more cells.
5. Thirteen days after discharge of spores, cells of the sporelings increase in number concentrically to form a discoid thallus. The central portion of the thallus upheaves hemispherically and becomes a meristem.
6. Fifteen days after the discharge of spores, the embryo becomes chrysanthemum-shaped by radial growth of marginal cells.
7. Thirty-six days after discharge of the spores, the embryo produces a protuberance from the central portion, about 85～105μ in diameter.
8. When embryos develop lying close to one another, they come gradually to form an irregularly-shaped compound thallus.

一、前　　言

龍鬚菜爲製造洋菜主要原料之一，近年來龍鬚菜養殖，普遍受到本省中南部鹹水養殖業者的重

視，成爲一種新興的養殖事業，唯本省水產界對於龍鬚菜生態很少加以研究，而影響及龍鬚菜養殖技術之改進，筆者有鑒於此，從事有關龍鬚菜生態之研究。

龍鬚菜（*Gracilaria*）是屬於 Florideae（眞正紅藻綱），Gigartinales目，Gracilariaceae科。其生活史（life cycle）分成有性生殖及無性生殖相互循環的世代交替（Alternation of generations）。無性生殖則以四分胞子（Tetraspores）行之；有性生殖則以果胞子(Carpospores)行之，果胞子是由成熟之囊果（Cystocarp）中放出。囊果由雌性配偶體（Female gametophyte）

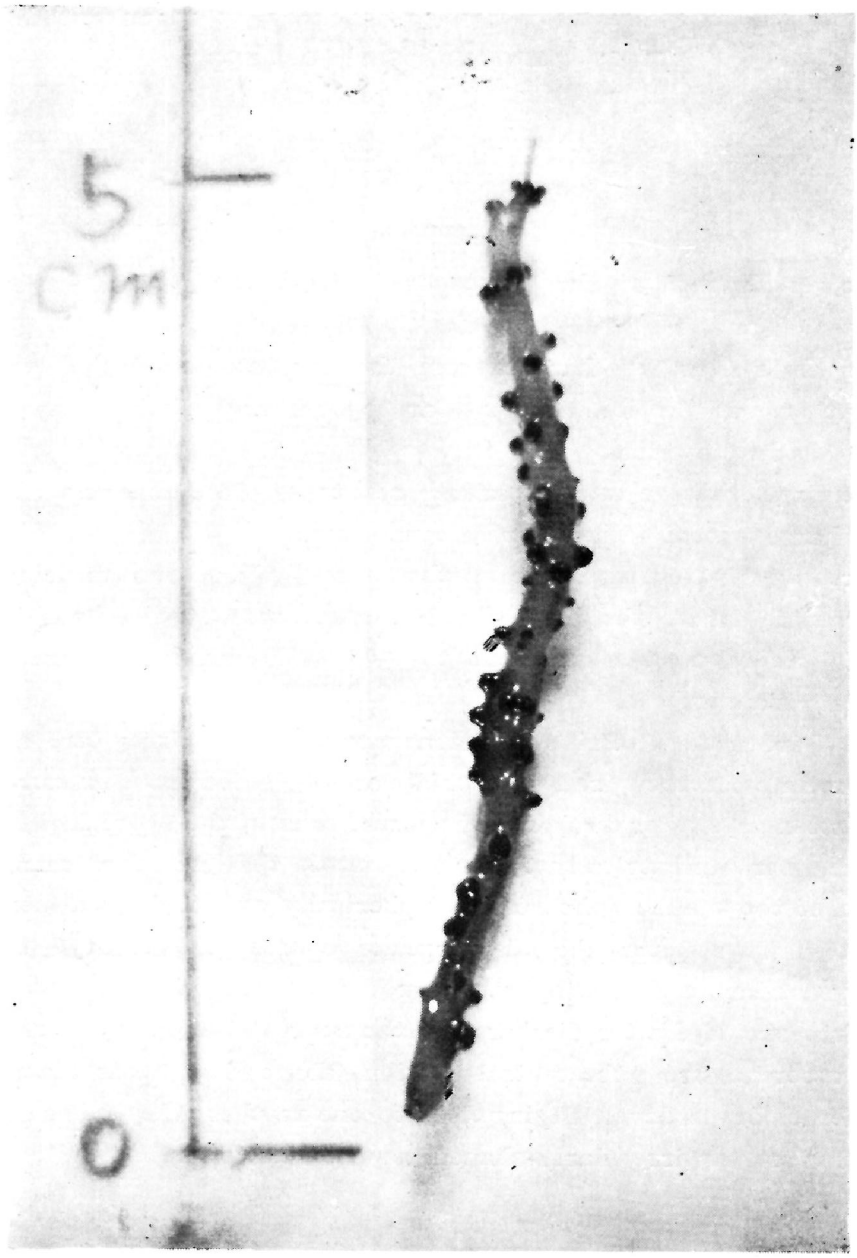


圖1. 有成熟囊果之 *Gracilaria gigas* 枝

枝上的Carpogonium 和雄性配偶體（Male gametophyte）的精子囊（Antheridium）所放出之雄性配偶子（Spermatium）接合發育而成。本試驗僅以龍鬚菜果胞子培育爲研究對象。

二、方法及材料

台灣龍鬚菜囊果出現期間，因龍鬚菜的種類及地域環境的不同而異，一般以2～5月爲最多，本試驗係於1968年4月採集於高雄縣新打港的野生長種（*Cracilaria gigas*），採集時選擇有大量成熟囊果之胞子體，裝於塑膠袋中，搬運時並時常更換新鮮海水以防止溫度增高，同時要避免日光照射。携回後立即以過濾之海水，將果胞子體洗淨，再放於蔭凉地方滴乾二小時，然後放入玻璃缸（高12cm×直徑20cm），缸內注入 Erd-Schreiber 培養液，鹽度爲25‰，並於缸底鋪滿載玻片（Slide glass），然後靜置於蔭凉處八小時，則有果胞子放出，附着於缸底之載玻片上。

再將附着有果胞子之載玻片取出，分別在盛有 Erd-Schreiber 培養液之燒杯中培養，溫度爲20～25°c，並以60燭光之日光燈照射。每隔三天更換培養液的$\frac{1}{2}$，每一至二天以顯微鏡觀察。

三、觀察結果

囊果成半球狀或橢圓狀的突出（圖 1），分佈於枝之表面，直徑約爲 0.7mm至 2mm，囊果頂端有一果孔（圖 2），果胞子放出時並且有白色的粘質物共同由果孔放出。

果胞子爲圓球狀，附着時最大者約爲35μ，最小者約爲17μ，平均約爲25μ，在放大六百倍表面觀察時中間有一個不太清楚的細胞核，果胞子整體呈黃褐色，中心部有時成黃紅色（圖3,a）。

附着後第二日則開始第一次細胞分裂，分裂時通過細胞中心部，分裂成兩個細胞（圖三3,b）。

3日後開始第二次細胞分裂，第二次分裂與第一次分裂成十字型的交叉成爲四個細胞（圖3,c）。有時第二次分裂與第一次分裂平行，成目字型，此時則成爲三個細胞（圖3,d）。五日後開始第三次分裂，第三次分裂成不規則性，果胞子成六個細胞（圖3,e）。

七日後開始第四次分裂，此次分裂亦如第三次分裂的不規則，此時成爲八個細胞。（圖3,f）

接着有數次不規則的返復分裂，果胞子內之細胞不斷的增加，同時果胞子之體積亦隨着增加。（圖3,g,h）。

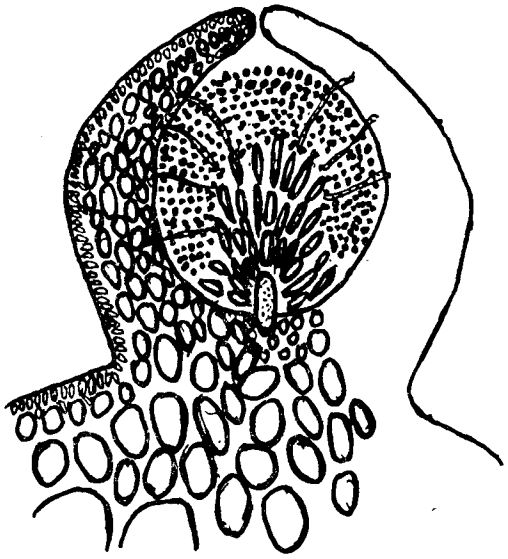


圖2. 囊果之構造

13日後果胞子周圍細胞成同心圓狀增加，同時胞子中央部亦成半球狀的隆起（圖3,i）。

15日後中央部的半球狀降起越加顯著，同時周圍的細胞數成同心圓狀增加，幼苗體積亦增大成菊花狀的盤狀發生體（Typus discalis mediatus）（圖3,j）。

21日中央部的半球狀隆起部之頂端，有數個稍大之生長點細胞出現，而部份呈濃褐色，容易與其他細胞區別（圖3,k）。30日後並沒有很大的變化，僅在生長點比前突出增大，在表面上可看出數個較大的生長點細胞，同時生長點和盤狀基部之間稍內凹。

36日後成長之幼芽，由側面看時成葫蘆狀，此時發生體約爲 85～105μ，幼芽約爲 35～52μ（圖3,l）。

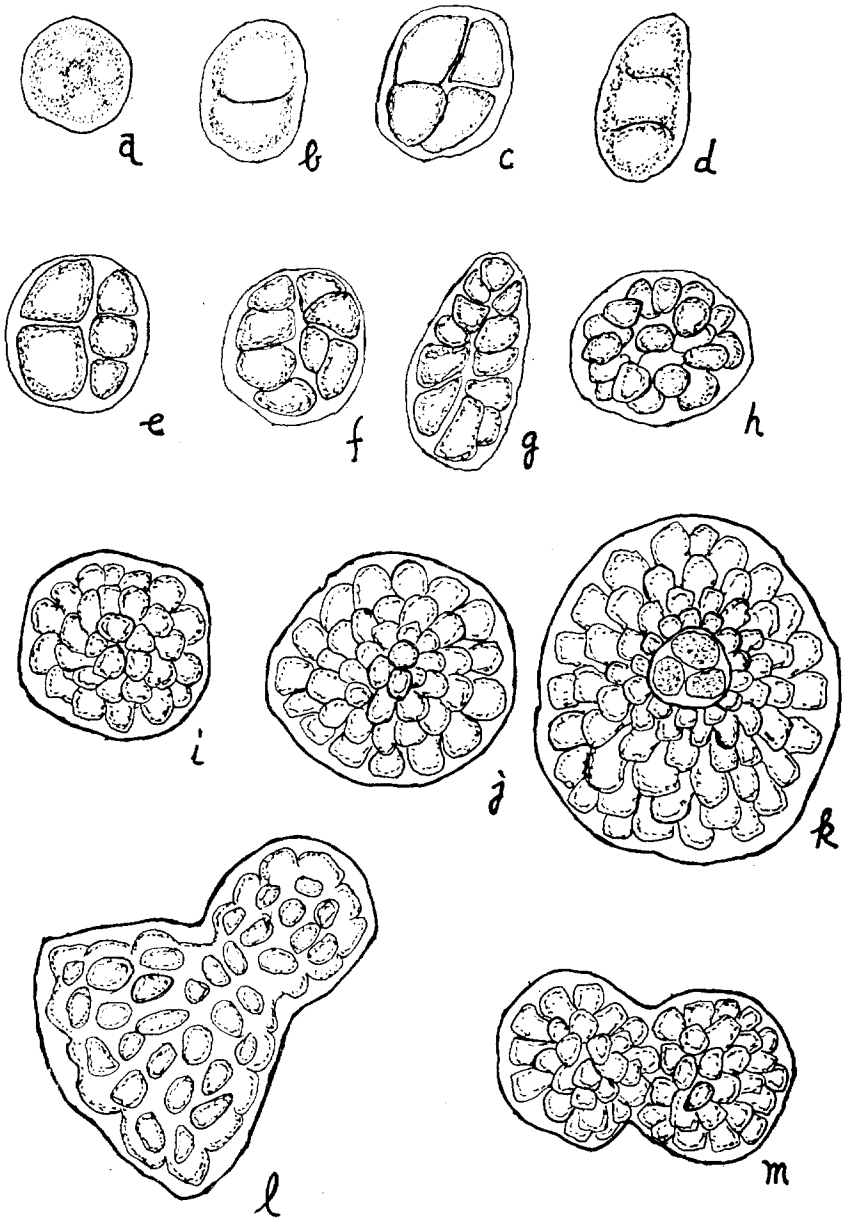


圖3. 龍鬚菜果胞子發育過程

果胞子由囊果放出附着時，有數個果胞子很接近，附着細胞分裂時，各個體的直徑亦增加最後互相接連癒合而成爲不規則的合同發生體(An irregularly-shaped compound thallus)(圖3,m)。

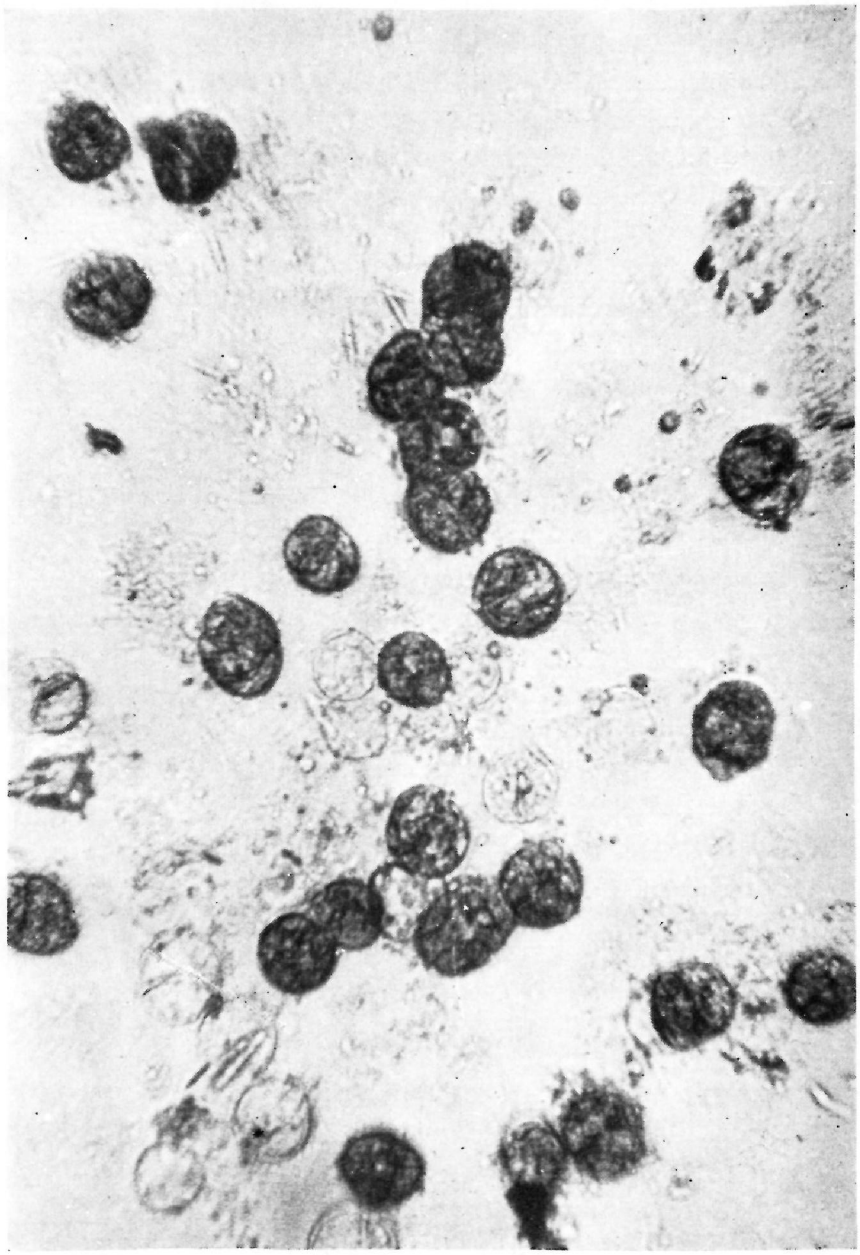


圖4. 果胞子羣落

a. 果胞子已發育成6～8細胞

b. 白色圓圈爲死亡者

c. 連在一起者爲合同發生體

四、討　　論

由以上實驗結果，果胞子在室內培育，較在天然環境生長緩慢而且困難，此可能由於光照度，光週期及水質環境的不同而異。果胞子與白色粘質物共同由囊果放出粘着在果孔附近，然後果胞子以自身重量下沉，在母體附近附着發芽而無遠距離移動，因果胞子自體無運動性，如在流水中果胞子不易下沉附着，筆者曾以流水式採集，果胞子仍然由囊果放出，但發現無果胞子附着。

在培育時，果胞子放出附着後常發現死亡，死亡時先成爲黃綠色，再變成透明，此時僅存細胞膜。大量死亡的主要原因可能爲囊果未完全成熟，未成熟之果大多成圓錐狀，果孔細小而不明顯，成熟之囊果成半球狀或橢圓狀而且豐滿，果孔略爲外突，有時有白點。同時在不適當的環境會抑制果胞子的放出，筆者曾以有成熟囊果之龍鬚菜放於鹽度42‰的培養液中，則果胞子放出量很少。

近江氏（1948）關於 *Gracilaria confervoides* 的果胞子培育報告中在十數天後由發生體生出數根無色透明的毛狀物，但本次試驗沒有發現此物的發生。同時在果胞子培育時，矽藻極易繁殖，甚至遮蓋果胞子，影響果胞子生長，如在果胞字附着後24小時，使培養液不停流動似可減少矽藻的繁殖。

五、摘　　要

1. 爲研討本省龍鬚菜生態，而做龍鬚菜果胞子培育試驗，以供養殖技術改進之參考，以新打港之野生長種（*Gracilaria gigas*）爲材料，以蔭乾放出法採集果胞子，用Erd-Schreiber 培養液培養。

2. 果胞子爲圓球狀呈黃褐色，平均約爲 25μ，第二日開始第一次分裂成二個細胞。第三日開始第二次分裂，第二次分裂與第一次分裂成交叉或平行而成四或三個細胞。第三次分裂以及以後的分裂成不規則狀。

3. 培養13日後，細胞成同心圓增加，同時中央部或半球狀的隆起。15日後果胞子發育成菊花狀的盤狀發生體（Typus discalis mediatus）。

4. 21日後中央部成半球狀隆起處，有數個生長點細胞。30日後生長點和基部之間稍稍內凹。

5. 36日後，幼苗由側面看時成葫蘆狀，此時發生體約爲85～105μ。

6. 數個果胞子附着很接近時，由於細胞分裂而互相接連癒合成合同發生體。

六、謝　　詞

本試驗在進行期間，曾蒙林明男先生之協助，水試所鄧所長火土提供文獻，台南分所謝分所長錫欽及中央研究院江永棉博士的指導，農復會林書顏先生的鼓勵，特在此一併誌謝。

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SUITABILITY OF GRACILARIA FOR CULTURE IN TSENG WEN TIDAL LAND AREA

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Introduction

Five species of *Gracilaria* are found in Taiwan[1]. They have different compositions and growth rates[2]. This experiment was designed to find out what species of *Gracilaria* was suitable for culture in the sandy and windy ponds of Tseng Wen tidal land area.

Material and Methods

Three blocks A,B,C were selected from Tseng Wen tidal land ponds, each of which was divided into 6 plots marked as A_1, A_2, A_3, A_4, A_5, A_6, B_1……B_6 and C_1……C_6. Each plot was 1.5 m^2 in area. The way of dispersing is shown in fig. 1. Block A was 47x35 m^2, Block B 43x36 m^2 and Block C 45x38 m^2. The average depth of water was 60 cm in A, 22 cm in B and 20 cm in C. The bottom characteristics: Block A was of mud, Block B and C were sandy. The general layout of the experimental plots is as follows:

A_1	A_3	A_5	B_1	B_3	B^5	C_1	C_3	C_5
A_2	A_4	A_6	B_2	B_4	B^6	C_2	C_4	C_6

N
W+E
S

Three species of *Gracilaria* were used for the experiment:

(1) *Gracilaria conforvoides*:
It was transplanted from Hsia K'un Sheng, Tainan. The local name of this species is "Chu Hua"[3] meaning chrysanthemum. A_5, A_6, B_5, B_6, C_5, C_6 were planted with this species.

(2) *Gracilaria compressa*:
It was transplanted from Hsin Ta Kang (a gulf located at Lu Chu, Kaohsiung). The local name of this species is also "Chu Hua", sometimes known as "Niao Kung"[3]. A_1, A_2, B_1, B_2, C_1, C_2 were planted with this species.

(3) *Gracilaria lichenoides*:

It was transplanted from Tungkang, Pingtung. The local name of this species is "Tungkang Sha"[3]. A_3, A_4, B_3, B_4, C_3, C_4, were planted with this species.

The following analytical methods were employed:

1. Yield of algae after alkali treatment: $\frac{A}{10} \times 100\%$.

   Sample (10 gm)-->250 ml beaker-->add 5% NaOH solution 150 ml.

   $$\xrightarrow[90\text{-}95^\circ C,\ 2\ hrs]{dry} A\ gm$$

2. Jelly content of algae: $\frac{A}{B} \times 100\%$

   Sample (A gm;-->250 ml beaker-->add 150 ml water using alkali treated algae.

   $$\xrightarrow[\text{add 5\% acetic acid, pH 6}]{\text{heat 1.5 hrs}} \text{filtering} \rightarrow B\ gm$$

3. Jelly strength:

   Determined by measuring apparatus of jelly strength[6].

4. Yield of algae after cleaning with water:

   $$\frac{A\ (100\text{- moisture of A})}{100(100\text{-moisture of sample})} \times 100\%$$

   Sample 100 gm-->cleaning with water-->dry-->A gm

Results

Gracilaria was weighed once every 30 days after planting. The results are shown in tables 1-4.

Table 1. Growth in weight of *Gracilaria* in block A.

Date	Species	*G. compressa*		*G. lichenoides*		*G. conforvoides*	
	Plot	A_1	A_2	A_3	A_4	A_5	A_6
9.11	weight of algae (gm)	300	300	300	300	300	300
10.11	〃	1087	1650	300	300	900	975
11.11	〃	1600	1725	375	787	712	712
12.17	〃	1537	2437	0	0	937	1275
1.17	〃	1500	2400	0	0	937	1275
2.17	〃	1300	2200	0	0	900	1200

Table 2. Growth in weight of *Gracilaria* in block B.

Date	Species	*G. compressa*		*G. lichenoides*		*G. conforvoides*	
	Plot	B_1	B_2	B_3	B_4	B_5	B_6
9.11	weight of algae (gm)	300	300	300	300	300	300
10.11	//	937	750	562	300	1500	1687
11.11	//	1350	1200	0	0	2325	2512
12.17	//	1762	1350	0	0	2287	2775
1.17	//	1700	1200	0	0	2250	2700
2.17	//	1650	1200	0	0	2200	2700

Table 3. Growth in weight of *Gracilaria* in block C.

Date	Species	*G. compressa*		*G. lichenoides*		*G. conforvoides*	
	Plot	C_1	C_2	C_3	C_4	C_5	C_6
9.11	weight of algae (gm)	300	300	300	300	300	300
10.11	//	825	900	337	300	1050	1012
11.11	//	900	900	262	112	1612	1050
12.17	//	1012	1087	0	0	1650	2101
1·17	//	900	950	0	0	1650	2100
2.17	//	900	950	0	0	1600	2000

Table 4. Mean growth in weight of *Gracilaria* in the present experiments.

Date	Species	*G. compressa*	*G. lichenoides*	*G. conforvoides*
9.11	weight of algae (gm)	300	300	300
10.11	//	1025	350	1187
11.11	//	1112	256	1487
12.17	//	1531	0	1837
1.17	//	1440	0	1818
2.17	//	1366	0	1766

There was plenty of *Hetero chordaria obietina* (Rupr) Setch et Gardn, *Enteromorpha* sp., and *Chaetomorpha* sp. in block B during the experimental period, which hindered the growth of *Gracilaria* when they covered the *Gracilaria* and deprived it of its light and nutrients. There was *Hormiscia penicilliformis* in block A, which also hindered the growth of

Gracilaria. When *Gracilaria* was covered with these undesirable algae, the apexes of *Gracilaria* were somewhat curly at first, then they appeared pink and became white in 2 to 5 days.

From October 11 to 18, buds were found in the branches of *Gracilaria conforvoides* in block A; the buds remained 0.5 cm in length and they didn't get longer during the period if the salinity was less than 5 ppt.

The pH values in the different blocks varied; for instance, at P.M. 2.00, block A had a pH reaction of 8.90, block C 8.49 and the water canal 8.15.

The temperature of the blocks and the water canal remained nearly the same during the experimental period, but the salinity was different. From July to October, because of heavy rainfall, the salinty of all the blocks was less than 25 ppt (fig. 1 and table 5).

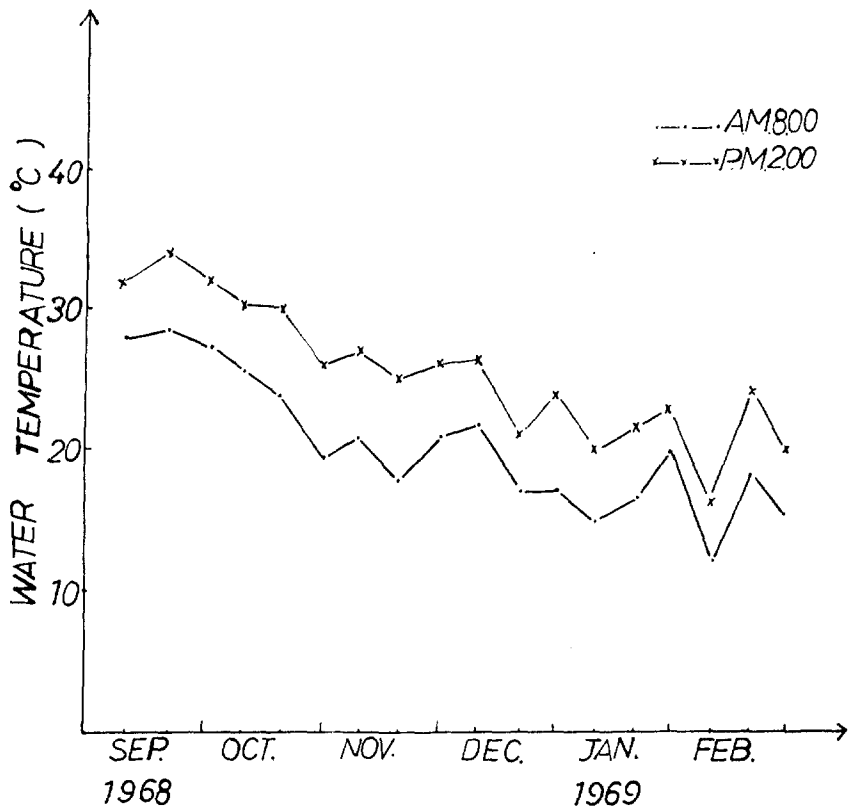

Fig. 1. Changes of temperature of all the blocks during the experimental period.

Table 5. Changes of salinity of all the blocks from July to December.

Month	Block	Mean value of salinity ‰	The lowest salinity ‰	The highest salinity ‰
July	A	11.33	6.55	20.96
	B	9.69	6.55	17.03
	C	11.33	7.86	19.65
Aug.	A	8.77	7.86	11.79
	B	8.64	6.55	10.48
	C	9.03	6.55	11.79
Sept.	A	8.90	6.55	11.79
	B	7.99	5.24	13.10
	C	7.07	5.24	10.48
Oct.	A	7.72	3.93	13.10
	B	7.99	3.93	14.41
	C	7.99	3.93	13.10
Nov.	A	25.50	32.73	33.40
	B	25.50	30.73	33.40
	C	24.00	30.75	32.04
Dec.	A	28.50	24.00	39.50
	B	31.50	24.00	39.00
	C	27.00	22.50	39.50

Discussions

In the period of experiment, the author found the growth rate of *G. conforvoides* to be the best, and *G. lichenoides* the worst (table 4), especially the latter the weight of which was reduced from October 11 and died off before December 17.

Between September 11 and October 11, the salinity and the temperature did not change too much (table 6 and fig. 2). At that time, *G. lichenoides* increased a little in weight. But, between October 11 and November 17 the salinity changed from about 8 ppt to 24 ppt, and the temperature was much lower than that of September11-October 11. During that period, the weight of *G. lichenoides* was getting less conspicuous. So it appears that high salinity (more than 25ppt) and low temperature were the main factors preventing the growth of *G. lichenoides*. In addition, *G. lichenoides* grow by creeping along the pond bottom, which is different

from the radial growth of *G. conforvoides*. Therefore, the entire plant of the former can be easily covered with *Enteromorpha* and *Chaetomorpha*. *Gracilaria* will die off if the *Enteromorpha* and *Chaetomorpha* are not removed in a few days. For the latter, because the green plants tend to attach themselves to the upper portion of *G. conforvoides*, the lower portion can still grow even if all the upper portion is covered with the green plants, and the green plants can be taken apart easily. For *G. lichenoides*, it is very difficult to take out the green plants.

During the period September 11-October 11, the weight of *G. compressa* increased by 3.4 times, *G. conforvoides* increased by 3.9 times (tables 1,2,3). This result is better than that of *Gracilaria* culture in the other places in Taiwan. As a rule, the plants increase in weight 1-1.5 times in suitable salinity between about 11 ppt-15 ppt. Actually the range of salinity suitable for the growth of *Gracilaria* is 10-25 ppt with the optimum at 15 ppt[4].

From the values shown in tables 1, 2, 3 and 4 the author recognizes that even the same species change their weight in different seasons and localities. For instance, (a) *G. conforvoides* increased 3.95 times from September 11-October 11, 1.25 times from November 11-December 17 in weight, but decreased after December 17, (b) *G. conforvoides* increased 3.12 times in weight in block A, 4.13 times in block B and 3.43 times in block C from September 11-October 11. From December 17-February 17, because of higher salinity (about 32-39 ppt) and lower temperature (lower than 20°C), both *G. conforvoides* and *G. compressa* decreased weight in the experimental area as well as in the other places; as usual *Gracilaria* was dwarfed in the winter season[3]. In October, *G. conforvoides* had many buds, but the buds remained 0.5 cm in length throughout the winter. This is a condition also found in rainy seasons when the salinity is less than 5 ppt for about 10 days. On October 11-20, the salinity is less than 5 ppt in block A, so low salinity can be considered as one of the main reasons for explaining the dormancy of *G. conforvoides* during the period of experiment.

G. conforvoides and *G. compressa* are all locally known as "Chu Hua". In culture and marketing no distinction is made between the two. In the present experiments *conforvoides* and *compressa* actually showed somewhat different rates of growth, yet the test of significance with Welch's v method (table 6) points to no significant difference at all. However,

there is a decisive significance in the difference of growth rate between *conforvoides* and *lichenoides*.

Table 6. The significance test of the growth rate among three species of *Gracilaria* by Welch's v method* in which *lichenoides* and *compressa* are tested against *conforvoides*.

Date	Species	n	$\bar{X}$	SE	v	df	t 0.05	Significance
	G. conforvoides	6	1187	—	—	—	—	
10.11	*G. lichenoides*	6	350	139.01	6.02	6	2.447	significance
	G. compressa	6	1025	184.59	0.88	10	2.228	no significance
	G. conforvoides	6	1487	—	—	—	—	
11.11	*G. lichenoides*	6	256	334.21	3.68	5.43	2.571	significance
	G. compressa	6	1112	361.90	1.03	7.35	2.365	no significance
	G. conforvoides	6	1837	—	—	—	—	
12.17	*G. compressa*	6	1531	350.54	0.87	9.36	2.262	no significance
	G. conforvoides	6	1818	—	—	—	—	
1.17	*G. compressa*	6	1440	362.10	1.04	9.61	2.228	no significance
	G. conforvoides	6	1766	—	—	—	—	
2.17	*G. compressa*	6	1366	337.22	1.18	9.33	2.262	no significance

* Welch's v method:

$$S^2\bar{X}_1=\frac{\Sigma x^2}{n_1(n_1-1)},\quad S^2\bar{X}_2=\frac{\Sigma x^2_{2i}}{n_2(n_2-1)},\quad MS(\bar{X}_1-\bar{X}_2)=S^2\bar{X}_1\ S^2\bar{X}_2,\quad SE(\bar{X}_1-\bar{X}_2)$$

$$=\sqrt{MS(\bar{X}_1-\bar{X}_2)},\quad C=\frac{S^2\bar{X}_1}{S^2\bar{X}+S^2\bar{X}_2},\quad f_1=n_1-1,\quad f_2=n_2-1,\quad v=\frac{\bar{X}_1-\bar{X}_2}{SE(\bar{X}_1-\bar{X}_2)},$$

$$df=\frac{1}{\frac{c^2}{f_1}\ \frac{(1-c)^2}{f_2}}$$

From appendix 1, the author recognizes that the constitution of agar-agar of *G. conforvoides* is much better than that of *G. lichenoides* and the constitutions change with different seasons and localities. For instance, in September the jelly strength of *G. conforvoides* in the experimental area was 470-520% and it was 330% in Tainan, the original area of the plants (appendix 1 nos. 1, 4, 8, 16). The jelly strength of *G. conforvoides* is considered the best in Taiwan, and that of *G. lichenoides* the worst. In addition, the agar-agar made from the latter can not be bleached easily by CaO, Na_2CO_3, etc[5]. From appendix nos. 10, 11, the author

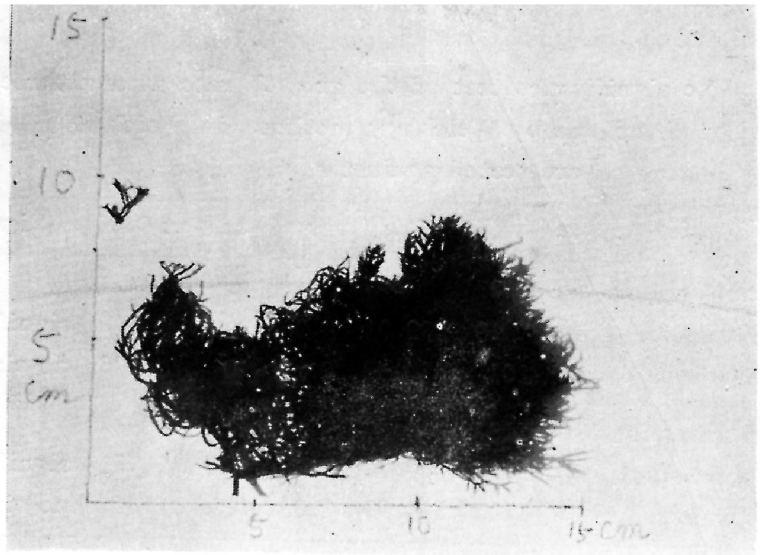

Fig. 2. One kind of abnormal growth of *C. conforvoides*.

finds out that the constitution of agar-agar in the upper portion and that in the lower portion of the plants are not quite the same, and the jelly strength of the upper portion is better than that of the lower portion. This finding is contrary to the general belief that the jelly strength of the lower portion is better than that of the upper portion, a mistaken supposition that has remained in the mind of the algal culturists for a long time. The undesirable algae, for example, the green plants *Enteromorpha* and *Chaetomorpha* hinder the growth of *Gracilaria* very much. How to control them is one of the serious problems in *Gracilaria* culture.

Summary

Ponds constructed in Tseng Wen tidal land are sandy and subject to strong wind action. To culture *Gracilaria* in this area is very difficult. A special species suitable for this area must be selected. At this point, the author carried out a comparative culture experiment of different species of *Gracilaria* from August 1968 to February 1969.

The results are summarized as follows:

1. *Gracilaria lichenoides* increased a little in weight during the period of September 11-October 11. The weight began to decrease from October 11, and all of them died off before December 17.
2. *Gracilaria compressa* increased 3.4 times in weight between September 11 and October 11, 1.08 times between October 11 and November 11,

Appendix I.

The constitutions of agar-agar of *Gracilaria* in Taiwan[5)]

No.	Month	Area	Species	Moisture of crude algae %	Yield of algae being cleaned with water %	Yield of alkali treated algae %	Jelly content of algae %	No moisture of pure agar-agar %	Yield of no moisture agar-agar 1*	Yield of no moisture agar-agar 2*	Jelly strength %
1	May	K'ou Hu	*G. conforvoides*	14.37	32.36	32.4	5.4	11.6	13.5	35.85	120
2	〃	Tungkang	〃	19.28	44.99	33.9	21.8	8.9	11.0	19.78	410
3	〃	〃	*G. lichenoides*	16.54	36.64	31.4	12.5	9.0	10.8	24.56	147
4	July	K'ou Hu	*G. conforvoides*	18.90	28.24	21.3	13.5	5.4	6.7	19.12	720
5	〃	Chia Tung	〃	17.44	44.95	24.3	30.1	5.5	6.7	12.24	270
6	〃	Tainan	〃	12.47	48.06	28.5	26.4	11.6	13.2	24.14	350
7	〃	Pingtung	〃	11.50	39.94	39.5	5.6	14.5	16.4	36.30	660
8	Sept.	K'ou Hu	〃	17.00	41.29	34.0	15.8	12.6	15.5	30.52	520
9	〃	Tainan	〃	23.31	35.16	35.0	10.9	12.9	16.8	36.69	330
10	〃	3*	〃	18.29	48.48	37.0	22.3	13.5	16.5	28.05	520
11	〃	4*	〃	20.12	48.66	31.0	29.9	13.1	16.4	26.92	470
12	〃	Hsing ta Kang	*G. lichenoides*	33.55	25.40	18.0	20.2	5.2	7.9	20.42	310
13	〃	Tungkang	*G. conforvoides*	21.80	53.64	44.0	24.6	6.9	8.8	12.86	630
14	Oct.	Tung Shih	〃	7,18	57.44	35.0	34.4	12.3	14.9	21.41	320
15	〃	Pingtung	〃	11.42	66.05	45.0	29.6	11.6	13.1	17.56	930
16	Nov.	K'ou Hu	〃	24.13	45.33	35.0	24.7	14.3	18.9	31.55	330
17	〃	O Liao	〃	19.18	45.03	33.0	23.1	10.5	13.1	23.32	620
18	〃	Chia Tung	〃	20.80	38.08	30.0	18.0	12.6	15.9	33.09	270

* 1. Compared with crude algae without moisture (%)

2. Compared with yield of algae after cleaning it with water (%)

3. The upper portion of plants with light color

4. The lower portion of plants with dark brown color

and 1.3 times between November 11 and December 17. The weight began to decrease after December 17.

3. *Gracilaria conforvoides* is the best species for culture in this area, they increased 3.9 times in weight from September 11 to October 11, 1.2 times between October 11 and November 11, 1.7 times between November 11 and December 17. They began to decrease their weight after December 17.

Acknowledgement

The author wishes to express his thanks to Dr. Liao I-chiu, Chemist Tsai Shan-ching, Tainan Fish Culture Station for close consultation, Prof. S. Y. Lin of National Taiwan University and Dr. Y. M. Chiang of Academia Sinica for their valuable comments and suggestions, and the author is grateful to Mr. Lee Dong-liang, Specialist, Tainan Fish Culture Station for his technical advice and assistance.

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淡水魚池施氮磷肥之比較

林曜松

The Effect of Phosphorus and Nitrogen Fertilizers on Fish Production in Freshwater Ponds

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Summary

In the Chupei Fish Culture Station, experiments were carried out with the objectives to show whether the production of Chinese carps could be further increased (1) by excessively increasing the dosages of superphosphate and (2) by the addition of nitrogen fertilizers. The results show that phosphorus fertilizer does strikingly boost fish production in freshwater ponds, especially that of silver carp at the dosage of 2,000 kg/ha of calcium superphosphate which gives the best results. Application of $(NH_4)_2SO_4$ shows no effect on the production of Chinese carps.

一、引　　言

本試驗係1969年2月至11月在省水試所竹北分所舉辦。試驗設計原由林書顏教授擬定，目的在釐定單純施放各級磷肥之濃度對於魚產之影響。由竹北分所長劉嘉剛，技士吳榮藩，彭弘光及洛氏基金助理研究員邱長吉、王芳祥、于廷立等分別負責魚池管理，施肥、水質分析、魚類食性及浮游生物變化研究工作。並請日本淡水區水產研究所專家里見至弘博士，伊藤時夫、東井純一、杉目宗尙等來竹北作技術指導。試驗開始後，里見博士認爲氮肥有重要性，應加施放以資與磷肥比較。因此本試驗之設計目的就改爲二方面：(1)試探各級磷肥濃度對魚產之影響。(2)磷肥加上氮肥對魚產之影響。

本文因水質分析及浮游生物變化資料尙未整理完備，只將施肥質與量方面作一比較討論，以供下年試驗設計之參考。並希望對實際施肥有所貢獻。

二、方　　法

試驗魚池計10口、分A、B二區。A區地勢較低，平均水深85公分，B區地勢較高，平均水深80公分。施肥時間爲每星期一，四。施肥量及魚池大小如表一所示，其中過磷酸鈣 [$CaH_4(PO_4)_2$] 全年分80次施給，硫酸銨 [$(NH_4)_2SO_4$] 全年分78次施給。

各池放魚尾數依魚池之大小及水深淺成正比例放養（即若干m^3的水量放多少尾魚苗）。魚種計有鰱、鯇、鱅、鯉及鯽五種。各魚池之平均放養率爲在水深1m每公頃鰱725尾，鱅124尾，鯇75尾，河內鯽、鯉各605尾。表二爲各魚池之放養尾數及試驗期間之死亡數。

三、結　　果

表三爲各魚池經換算至面積爲一公頃水深一公尺之生產量。表四爲各魚池各種魚之每尾平均增重量。

表一　試驗池面積與施肥量表

池號	面積m²	各池每次施肥量（g）		全年施肥量（kg/ha）	
		$CaH_4(PO_4)_2$	$(NH_4)_2SO_4$	$CaH_4(PO_4)_2$	$(NH_4)_2SO_4$
A_1	485	0	0	0	0
A_2	1115	1232	0	1040	0
A_3	970	2104	0	2040	0
A_4	1067	6902	0	6090	0
A_5	611	6643	0	10230	0
B_1	582	0	0	0	0
B_2	485	504	970	1040	1950
B_3	679	1385	1358	2040	1950
B_4	485	2953	970	6090	1950
B^5	388	3968	775	10230	1950

* 全年施肥量：以水深 1 m，面積 1 公頃之全年施肥量。

表二　各試驗池之放魚尾數及死亡尾數（括弧內之數字）

池號	鰱	鯉	鯽	鯇	鱅	和
A_1	29	29 (5)	24	3	5	85 (5)
A_2	67 (3)	56 (1)	56	7 (3)	11	197 (7)
A_3	58	49 (8)	49	6	10 (3)	172 (11)
A_4	64	53	53	6	11 (1)	187 (2)
A_5	37 (3)	31 (8)	31	4 (2)	6	109 (14)
B_1	35	29 (6)	29		6	103 (7)
B_2	29	24 (14)	24	3 (1)	5	85 (15)
B_3	41 (1)	34	34	4	7	120 (3)
B_4	29 (3)	24	24	3	5	85 (3)
B_5	23	19 (1)	19	2	4	67 (1)

四、討　　論

生　存　率

五種試驗魚之生存率之卡方測驗(X^2-Test)除鯉之 $X^2=77.58^{**}>X^2\left(\frac{9}{0.01}\right)=16.92$之呈極顯著外，其餘四種魚之生存率之$X^2$值均小於理論值。此說明鯉之生存率隨魚池而有極顯著差異，而其餘四種魚之生存率各池間沒有差異存在。尤其在B_2池，鯉死亡率達58.3%，其原因不明。

生　長　度

自表三之 F-Test 實測值可知，施磷肥與否或量之多少，足可影響各種魚之增產量。在本試驗中，鰱、鱅及鯇之增重量以每公頃施2040公斤者最好。而鯉以不施肥區最好。此與 Lin and Chen (1966) 在桃園地區之施肥試驗結論一致。其原因仍足施磷肥可增加植物性浮游生物量，而遮住光線使底層藻類繁殖不良，致使以植物性浮游生物爲餌料之魚類如鰱、鱅、鯇生長良好，而使底藻生

產減少，因而靠藻類以繁殖之底植動物，就不能大量產生。鯉就缺少了底棲動物爲餌料，結果生長不良。又在施氮肥區的魚類生長情形普遍較不施氮肥區者差。此與歐美國家甚多之施肥試驗結論相似。亦即是磷氮肥共施對魚之增產量往往不如單施磷肥者結果良好。且氮肥過量往往有相反作用。

表三　試驗池各種養殖魚之年生產量（kg/ha）

N / P	水深1m每公頃之施肥量（kg） 0	1040	2040	6090	10230	實測F值
鰱 0	637.1	438.4	850.1	794.7	736.7	Fp=8.49*
1950	187.6	239.7	643.5	491.3	590.5	
鯆 0	156.6	110.9	173.2	182.8	130.6	Fp=2.23
1950	16.5	45.1	119.7	113.2	110.2	
鯇 0	28.3	33.0	53.4	21.0	10.8	Fp=2.22
1950	14.3	47.0	28.7	16.6	16.8	
鯉 0	191.5	224.9	205.4	134.2	71.6	Fp=0.04
1950	135.8	45.9	98.5	147.6	198.5	
鯽 0	84.5	73.2	138.1	114.5	110.2	Fp=4.17
1950	43.9	58.7	92.4	90.9	130.9	
雜魚 0	136.7	246.6	221.2	299.4	438.8	Fp=0.45
1950	103.1	369.1	416.8	218.2	163.7	
和 0	1234.6	1127.0	1641.6	1546.7	1498.7	Fp=9.16*
1950	501.1	759.6	1199.6	1077.9	1210.5	

* 理論$Fp=\binom{4}{4\ 0.05}=6.39$

表四　各試驗池之每尾魚之平均增重（g）（1969年2月至11月）

N / P	水深1公尺，面積1公頃之施肥量（kg） 0	1040	2040	6090	10230	實測F	重複尾數
鰱 0	980.5	764.1	142.2	1324.9	1324.7	Fn=30.11** Fp=11.67**	
1950	321.5	460.9	1092.8	925.2	996.2	Fnp=1.08	n=10
鯉 0	490	453.3	486.9	270.2	191.8	Fn=7.46** Fp=2.12	
1950	344.8	229.3	196.7	300.7	428.0	Fnp=25.85**	n=6
鯆 0	1519.4	1124.3	2403.4	1951.4	1330.1	Fn=273.62** Fp=62.20**	
1950	160.1	437.4	1355.1	1107.4	1069.4	Fnp=13.91**	n=4
鯇 0	456.7	1032.5	863.3	373.3	480	Fn=34.58** Fp=9.92**	
1950	207.5	190	700	270	325	Fnp=5.36**	n=2
鯽 0	170.7	145.5	273.4	498.7	224.8	Fn=4.46* Fp=4.85**	
1950	88.0	118.6	184.6	185.3	267.5	Fnp=0.71*	n=6

** 顯著差異

(Mortimer, 1954) 在亞洲的 Malacca 的養殖研究中心施肥試驗之結果亦證明了磷肥對於增加魚產十分重要，但加施氮肥却不見有顯著效果 (Lin, 1969) 。美國Auburn大學經五年氮磷肥試驗同樣認爲氮肥對池中生物生產沒有什麽影響，磷肥則十分顯著。

又B區魚池面積及水深比A區均小，魚生長不如A區，恐與此也有關係。此在Malacca 的魚之生存空間試驗亦有此一結論。故在本試驗中，筆者未能判別A及B區的魚之生產量好壞，究因足不施氮肥抑足因魚池大小水深的關係，或二者共同作用所致。正確之判斷尚待1970年重複施肥試驗結果後才可得知。

生 產 量

表四中若以A、B二區當做磷肥各變級之重複，以逢機完全區集統計分析法進行顯著性測驗。則除鰱之生產對磷肥呈有顯著效應外，其他各種魚之生產對施肥效應不顯著。鰱的生產是在魚池每公頃施肥量2,000公斤以上與不施肥及施肥量每公頃1,000公斤者有顯著差別。而2,000公斤到10,000公斤施肥量，鰱生產沒有差別。故只要適量之施肥便可達到增產的目的。過量施肥不但不能增產，，浪費肥料且有反效果發生。

五、結　　論

(1)磷肥施量之多少，對鰱魚之生產量有極顯著效應。對其他四種魚之效應正顯著。在單位公頃水深1m的魚池全年施放過磷酸鈣2,000公斤最適當。

(2)對照池沒有施氮或磷生產亦很高，可見竹北之池原來就很肥了。

(3)氮肥之施放似無必要，因凡施氮區魚之生產量均較低。唯須考慮此項結論恐受魚池大小之偏性因子所促成。則尚待進一步之求證。

六、謝　　辭

本報告之完成，實有賴於農復會之經濟協助，竹北水產試驗所吳榮藩先生提供資料，林書顏先生之時賜指導，及臺大漁試所李嘉彬、趙秦育二位之協助核算，筆者於此一併致謝。

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魚池基礎生產與魚產之關係研究

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Primary Productivity and Fish Yield

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Summary

In this study attempt was made to determine the relationships between mineral nutrients, primary productivity and fish yields. Four ponds A3, A4, B3 and B4 in the Chupei Fish Culture Station were selected for investigation during the period September to November 1969. The results show the average PO_4-P concentration at 0.27-0.56 ppm because of regular fertilization, is high as compared with that in the other ponds, and that the oxygen content at sunrise varying from 6.18-6.87 ppm in all the ponds is adequate for fish growth.

Pond A3 has the highest fish yield but the lowest in concentrations of Ca^{++}, Mg^{++} Na^{+} and alkalinity value. Pond B3 to which N-fertilizer was regularly added contained less NO_3-N and NO_2-N than pond A3 which received no N-fertilizer at all.

Gross primary production of the four ponds was measured by McConnell's method over the experimental period. The average values are 726.85 Cg/m²/year in A3, 719.54 C g/m²/year in A4, 978.87 C g/m²/year in B3 and 894.86 Cg /m²/year in B4. These values are as high as those in Israel and Athens, Georgia, U.S.A. fish ponds. From the data it is found that there is significant difference between A and B series of ponds. The gross photosynthesis is especially high in September and low in February.

Chlorophyll *a* concentration is the highest in A3 reaching a maximum value of 213.5 mg/m3 on November 25, which is comparable to 212.3 mg/m³ in Israel. The average chlorphyll *a* concentrations from September to November in these four ponds are 95.9 mg/m³ in A3, 66.8 mg/m³ in A4, 117.4 mg/m³ in B3, and 111.4 mg/m³ in B4, but there is no significant difference among these ponds. The chlorophyll *a* concentration is 50-74% of the total chlorophyll $a+b+c$.

More studies are required for adequate interpretation of the relationships between primary productivity, mineral nutrients and fish yields in fish ponds.

前　　言

本實驗室承蒙美國洛氏基金與農復會之補助，廖文光教授之啓蒙，筆者會同江婉，李嫣彬，趙秦育及余成增等於民國五十八年九月在新竹水產試驗所施肥試驗魚池進行水質化學分析及基礎生產

量之研究，以估算各魚池之基礎生產量。

此次實驗應用之魚池計4口，此4口之環境及施肥量如表一所示。施肥實驗自1969年2月起至同年11月止。其間磷肥分80次施放，氮肥分78次施放，施放時間爲每星期一、四。

表1. 竹北魚池施肥量及魚獲量

池號	每次施肥量 (g)				魚獲量 kg/ha						
	面積m^2	水深cm	$CaH_4(PO_4)_2$	$(NH_4)SO_4$	鰱	鯉	鯽	鯇	鱸	雜魚	總計
A_3	970	76	2104	0	856	208	143	63	174	221	1665
A_4	1067	70	6902	0	800	137	119	29	184	299	1568
B_3	679	66	1385	1358	649	101	97	38	120	417	1422
B_4	485	62	2953	970	497	150	95	26	114	218	1100

方　　法

自1969年9月2日開始，筆者每隔二星期採水一次。採水時乃利用直徑10cm，高100cm的塑膠直圓筒採全層水，注入500cc的塑膠瓶中，隨即携回實驗室離心處理，以去除水中的一切懸浮物質，並貯放於5°C冷冰箱內，欲測定時再取出，使之還原至室溫，而後再作各項水質測定。葉綠素測定，亦採全層水，用HA47mm的Millipore濾紙過濾100cc的水，而後取濾紙上物質作測定。

各項測定方法如下：

(1) Conductivity——用Model (M-IDB) 的Conductivity meter直接測定。

(2) PO_4-P——用 Modified Single Solution Method。

(3) NO_3-N——用 Hydrazine 將 NO_3還原爲NO_2^-，再加Sulphanilamide及N-(1-Naphthyl)-Ethylenediamine 使 NO_2^-形成紅色的 Azodye，然後用 520mμ波長測定。

(4)NO_2-N，SiO_2，及Alkalinity 均採用Standard Methods for the Examination of Water and Wastewater (1967) 中所列的各項測定法。

(5) K^+、Na^+、Mg^{++}、Ca^{++}——直接用 Atomic absorbance Spectrophotometer測定。

(6)葉綠素——用 Richard & Thomson's method。

(7)基礎生產量：

(a) 採用McConnell (1962) 所提出之日落日出之O_2變化估算。

(b) 採用 Odum 及 Hoskins (1958) 所提出的每3小時O_2之連續日夜變化量估計。

結　　果

(1)水質

表2爲測定期間各項水質八次測定的平均值與信賴間隔。

表3爲各魚池間水質的相差及顯著性測驗結果。

表4爲各試驗池間之O_2量、最大值、最小值及差距。

圖1爲各魚池之O_2日夜變化表。其單位爲ppm。

圖2爲各魚池上下層水溶氧週日變化之比較。

(2)基礎生產量

(a) 葉綠素　表5、表6爲各魚池各測得之葉綠素a及全次葉綠素量。其單位爲g/l。

(b) 光合作用速率　以 McConnell (1962) 的估算法所求得的如表7，表8所示。另表9爲Odum 與 Hoskins (1958) 與 McConnell (1962) 法所求得之基礎生產量之比較。

Table 2. Mineral Nutrient Concentrations (ppm) in four ponds of Chupei Station

	A_3	A_4	B_3	B_4
Mg^{++}	6.519 ±1.231	11.924 ± 2.951	14.123 ± 4.6542	13.249 ± 8.861
Ca^{++}	25.957 ±1.936	34.676 ± 7.823	34.708 ± 6.433	36.710 ± 7.487
Na^{+}	10.180 ±1.125	12.161 ± 1.984	12.051 ± 2.155	12.365 ± 2.307
K^{+}	1.481 ±0.331	2.014 ± 0.401	1.700 ± 0.473	1.781 ± 0.241
SiO_2	11.437 ±4.105	10.526 ± 3.125	12.607 ± 3.322	14.331 ± 3.360
PO_4-P	0.351 ±0.223	0.563 ± 0.331	0.271 ± 0.089	0.504 ± 0.120
NO_3-N	0.2506±0.0141	0.0049± 0.0057	0.0153± 0.0166	0.0103± 0.0118
NO_2-N	0.0048±0.0057	0.0033± 0.0014	0.0093± 0.0083	0.0040± 0.0026
Alkalinity	49.816 ±7.599	86.197 ±18.796	80.288 ±17.003	74.193 ±18.517

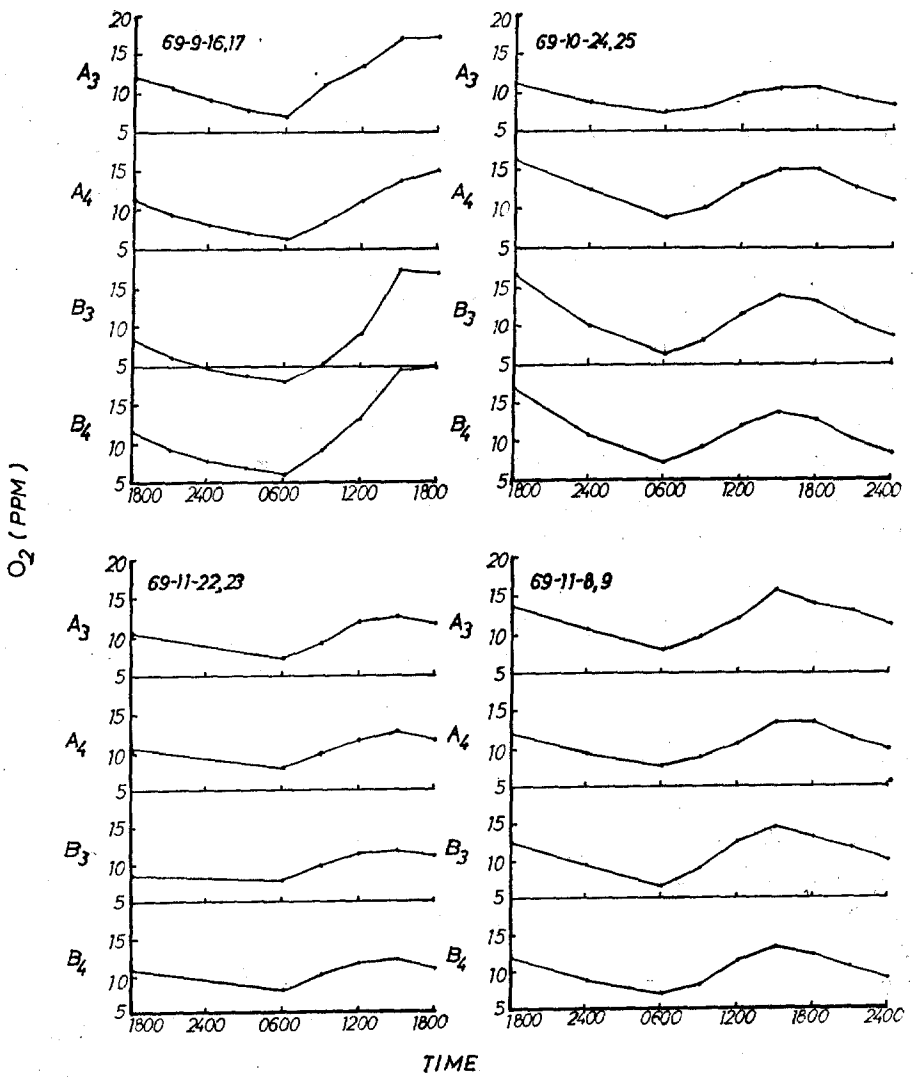

圖 1. 竹北施肥池溶氧週日變化

表3. 竹北魚池水質測定平均值之差異比較表 (ppm)

	A_3-A_4	A_3-B_3	A_3-B_4	A_4-B_3	A_4-B_4	B_3-B_4
Mg^{++}	−5.405**	− 7.064**	− 6.731**	−2.199	−1.326	+0.874
Ca^{++}	−8.719**	−17.751**	−10.754**	−0.033	−2.035	−2.002
Na^{+}	−1.982**	− 1.872**	− 2.186**	+0.110	−0.204	−3.314
K^{+}	+0.533	+ 0.219	+ 0.309	+0.313	+0.232	+0.081
SiO_2	+0.911	− 1.170	− 2.894**	−2.081*	−3.805**	−1.724
PO_4-P	−2.212*	+ 0.080	− 0.153	+0.292**	+0.059	+0.233
NO_3-N	+0.0056	− 0.0048	− 0.0002	−0.0104*	−0.0054	−0.0050
NO_2-N	+0.0015	− 0.0045	+ 0.0008	−0.0060	−0.0007	+0.0053

* 95%顯着。　　** 99%顯着。

表4. 各試驗魚池之O 之最大值與最小值及其差距(ppm)

日期	最大值與最小值				幅度				平均幅度
	A_3	A_4	B_3	B_4	A_3	A_4	B_3	B_4	
27/2	10.43 9.00	9.98 9.04	11.60 8.35	11.55 8.99	1.43	0.94	3.25	2.56	2.05
3/4	14.40 5.49	10.69 3.82	12.65 4.98	11.33 4.19	3.91	6.87	7.67	7.14	6.40
24/4	12.41 10.80	9.49 5.43	12.65 9.05	12.82 6.02	1.61	4.06	3.60	6.80	4.02
22/5	6.59 4.50	9.63 4.44	9.16 4.49	9.82 4.67	2.09	5.19	4.76	5.15	4.30
20/6	6.50 4.24	7.70 4.58	7.35 4.90	7.42 4.86	2.26	3.12	2.45	2.56	2.60
17/7	8.15 3.51	12.78 7.16	10.72 4.14	8.77 4.07	4.64	5.62	6.58	4.70	5.26
14/8	10.59 6.06	18.08 6.15	14.11 11.64	11.05 5.82	4.53	——	2.47	5.23	4.08
2/9	14.87 7.28	15.42 7.60	10.81 4.12	10.59 5.08	7.59	7.82	6.69	5.51	6.90
17/9	17.32 6.82	15.07 6.19	17.06 2.79	19.78 5.89	10.50	8.88	14.21	13.89	11.87
29/9	20.21 9.86	18.44 8.50	14.76 6.48	13.83 7.17	10.35	9.94	8.28	6.64	8.81
9/10	8.56 5.70	14.21 8.78	13.80 6.85	15.37 7.80	2.86	5.43	6.95	7.57	5.70
25/10	10.40 7.18	14.98 8.91	13.90 6.19	13.62 7.12	3.22	6.07	7.71	6.50	5.88
9/11	15.59 7.99	13.20 7.63	14.37 7.47	13.14 6.68	7.60	8.85	6.90	6.46	7.45
25/11	12.41 7.11	12.45 7.91	11.56 7.80	12.05 7.93	5.30	4.54	3.76	4.12	4.43

表5 葉 綠 素 a (mg/m³)

池號 \ 時間	1/9	16/9	17/9	30/9	14/10	26/10	10/11	25/11	平 均
A_3	199.4	22.3	71.6	85.7	207.0	32.7	121.0	213.5	95.9
A_4	95.3	66.3	30.3	23.8	22.5	99.0	121.0	76.1	66.8
B_3	132.2	138.7	99.3	76.0	100.4	135.3	204.0	53.1	117.4
B_4	102.3	192.2	129.6	50.1	55.8	131.5	76.5	99.8	111.4
平 均	132.3	104.4	82.7	58.9	49.9	89.0	130.6	110.6	97.9
$\frac{\text{葉綠素}a}{\text{全葉綠素}}\times 100$	63.0	49.9	57.55	51.62	67.71	74.29	53 70	51.63	56.0

表6. 總葉綠素 $a+b+c$ (mg/m³)

池號 \ 時間	1/9	16/9	17/9	30/9	14/10	26/10	10/11	25/11	平 均
A_3	334.5	136.5	128.5	158.5	25.8	52.7	231.1	437.5	182.7
A_4	171.5	119.9	76.4	50.6	31.2	162.0	242.0	121.8	121.9
B_3	194.2	245.0	159.7	147.6	164.2	235.8	342.5	113.6	200.3
B_4	139.6	339.4	210.0	99.7		28.8	157.2	184.0	194.1
平 均	210.0	210.2	143.7	114.1	73.7	119.8	243.2	214.2	174.8

表7. 竹北試驗漁池之單位基礎生產量測定值 (依 McConnell 法)

	O_2 g/m³/day				C g/m³/day			
	A_3	A_4	B_3	B_4	A_3	A_4	B_3	B_4
27/2	1.60	1.20	3.35	3.88	0.48	0.36	1.00	1.16
3/4	10.37	9.10	11.14	8.00	3.11	2.73	3.34	2.40
24/4	——	5.41	5.78	6.70	——	1.623	1.734	2.01
22/5	3.20	9.16	13.74	3.55	0.960	2.748	4.122	1.065
20/6	4.18	4.07	4.70	4.35	1.254	1.221	1.41	1.305
17/7	9.97	10.69	13.16	9.07	2.991	3.207	3.948	2.721
14/8	6.12	——	——	8.11	1.836	——	——	2.433
2/9	15.28	13.32	14.94	12.95	4.584	3.996	4.782	3.885
17/9	15.53	14.06	24.40	22.72	4.659	4.218	7.32	6.516
27/9	15.25	10.12	18.99	16.14	4.575	3.036	5.697	4.842
14/10	6.46	10.17	16.79	17.32	1.947	3.051	5.037	5.196
25/10	7.45	13.22	20.54	17.97	2.235	3.966	6.162	5.391
9/11	11.17	10.08	12.54	12.16	3.351	3.024	3.762	3.648
23/11	4.62	4.79	4.71	6.47	1.386	1.437	1.413	1.941
平均	8.55	8.88	12.75	10.67	2.566	2.663	3.826	3.201

(1) $Fp=6.88\ F\ (^{33}_{3}\ _{0.05})=4.44$

(2) $O_2\times 0.3\rightarrow C$ (Ryther 1956)

表 8　竹北試魚池之基礎生產量 kg/m²/day

	O_2 g/m²/day				C g/m²/day			
	A_3	A_4	B_3	B_4	A_3	A_4	B_3	B_4
27/2	1.20	0.95	2.14	2.48	0.36	0.28	0.64	0.24
3/4	7.88	6.92	8.47	5.60	2.36	2.07	2.54	1.68
24/4	——	3.62	4.39	4.69	——	1.09	1.32	1.41
22/5	2.37	5.40	9.48	2.17	0.71	1.62	2.84	3.78
20/6	3.80	2.73	3.48	3.09	1.14	0.82	1.04	0.93
17/7	7.48	7.27	8.95	5.71	2.24	2.18	2.68	1.71
14/8	4.77	——	——	5.84	1.43	——	——	1.75
2/9	9.63	7.99	10.52	8.16	2.89	2.40	3.16	2.45
17/9	12.89	9.70	16.35	15.22	3.87	2.91	4.90	4.57
29/9	11.92	7.79	12.34	10.19	3.57	2.34	3.70	3.05
14/10	5.23	7.22	10.41	10.56	1.58	2.17	3.12	3.17
25/10	5.96	11.59	13.56	12.28	1.79	3.45	4.07	3.72
9/11	8.04	7.76	8.53	8.39	2.41	2.33	2.56	2.52
23/11	3.09	3.45	2.97	3.75	0.93	1.03	0.89	1.13
平均	6.48	6.34	8.58	7.01	1.94	1.90	2.58	2.10

$Fp=4.53>4.44\ (^{3}_{35}0.05)$

表 9　二種毛基礎生產量估計值之比較 (O_2 g/m³/day)

	Odum & Hoskins				McConnell				$\bar{X}_2/\bar{X}_1$
	25/10	9/11	23/11	平均$\bar{X}_1$	25/10	9/11	23/11	平均$\bar{X}_2$	
A_3	7.78	11.25	13.03	10.69	7.45	11.17	4.62	7.75	72.5%
A_4	10.15	12.40	7.46	10.00	13.22	10.08	4.79	9.36	93.6%
B_3	17.442	10.17	10.85	13.08	20.54	12.54	4.71	12.59	96.3%
B_4	17.34	9.41	6.80	11.18	17.97	12.16	6.47	12.20	109.1%

討　　論

(1)水質部份

總鹼度——除A_3池之總鹼度平均值爲49.816ppm外，其餘各池之平均值皆達 74ppm以上。此數值比日本陸水的測定值要大。據Satomi (1962) 的資料計算，日本湖沼的總鹼度有60%是在10.0～30.03ppm之間。而魚產與總鹼度之間似有關係存在。(Satomi 1962)。而竹北此次實驗中，A_3池總鹼度雖較他池爲低，但其魚之生產量却最高。單就總鹼度而言，竹北各池均以達到富榮養池的水準。

PO_4-P——A_3, A_4, B_3, B_4之PO_4-P 含量比平均各爲0.35, 0.56, 0.27，與0.50ppm。A_3與B_3含量顯著的比A_4與B_4爲低。其原因乃在單位池水之施肥量不同所致。A_3與B_3每次施肥量是204g/m³

，A_4 與 B_4 則是 609g/m³。依西條(1962)的資料顯示，一般淡水湖中溶存之可溶性磷量爲0.005～0.05ppm。另外Hutchinson (1957) 則提出德國北部各湖中可溶性磷含量甚高，平均爲0.47ppm。又依廖文光1967～1969二年，調查全省各地區魚池及湖沼之PO_4-P之平均含量爲0.132ppm。(Liaw 1969) 比較上述PO_4-P量可說明竹北實驗池 PO_4-P 之含量甚高，純因大量施肥關係所致。另依竹北氮磷肥之施肥試驗結果亦可發現，以 A_3, B_3 池之魚生產量最好，其PO_4-P之含量在0.3ppm左右，此與廖文光引自 (Moyle 1946) 之魚池最適當PO_4-P爲0.1～0.2ppm之說法略有差異。

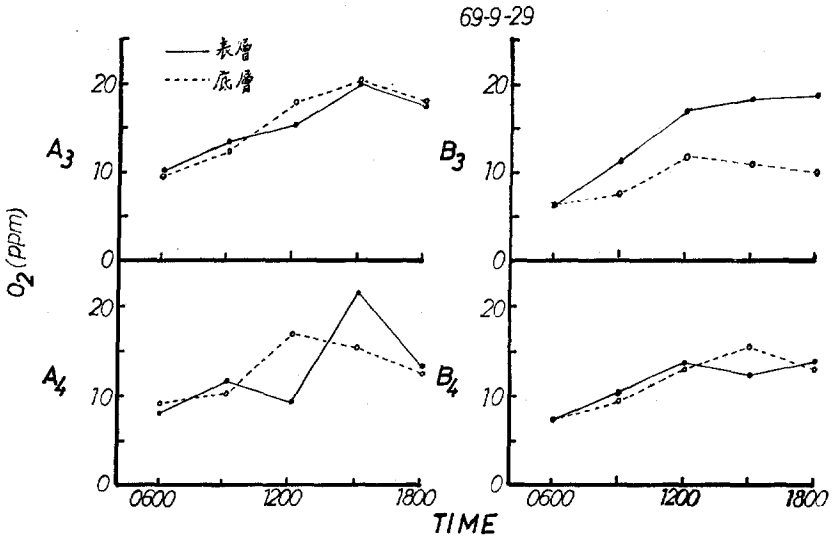

圖 2. 竹北施肥池表層底層溶氧之比較

NO_3-N——據1967～1969年廖文光全省各魚池及湖沼調查結果其平均值爲 0.056ppm。而竹北之A_3池其平均含量爲 0.25ppm，比上述值高，其餘之各池則均在0.015ppm以下，比上述值低。B區各池施有氮肥，但其含量反而較低，原因未明。且其魚產量也較A區魚產量差，此結果與世界某些施氮肥實驗的結果頗爲相似。

NO_2-N——各個魚池中之NO_2-N 平均值含量在 0.003～0.009ppm 之間，含量甚低。依Eppley (1969) 之研究，發現 *Chlorella*, *Anabaena*, *Gymnodinium Simplex* 等藻類在利用氮原時，都以NH_4^+-N爲優先，直到NH_4-N之濃度低至某一限度時，才會開始利用 NO_3-N 或 NO_2-N。竹北B區之施 $(NH_4)_2SO_4$於水中先以NH_4^+-N離子存在，可直接被藻類吸收，故 NH_4^+ 經由 *Nitrosomas* 及 *Nitrobecter* 等轉化爲 NO_3-N及NO_2-N之量便少了。竹北魚池之NO_2-N 含量甚低，藻類仍能生長良好，似可用Eppley 之試驗結果來說明。

Ca 及 Mg——由分析結果知Ca 與Mg含量與鹼度有密切關係，其關係用廻歸式表示如下：總鹼度$=-13.6848+2.2011$ $(Mg^{++}+Ca^{++})$。Mg^{++} 爲葉綠素分子的重要成分，但由測得結果中，看不出Mg^{++} 含量與葉綠素有何顯着關係。Ca^{++} 與水中之 PO_4-P 的沉澱速度有關 (Hepher 1958)。又自 Ohle (1934) 湖沼魚池之分類 (引自廖文光1969)，Ca^{++} 含量在10～25ppm 時屬於中級湖沼，25ppm時則屬於含量高的一級了。除A_3池含量爲25.9ppm 外，其餘各池均在34ppm以上。故於竹北魚池是不虞Ca之缺乏了。

Na 與K——水中之Na 對於魚之生長似有刺激作用。例如鯇、鰱、鱅等在近海之淡水魚池中，水中含Na 常爲 50～300ppm的地方，其生長較迅速，高地魚池含Na鹽較稀，除非施肥，否則魚類生長不會太好 (引自林書顏1969)。K屬於植物所需營養元素之一，不可缺乏。竹北魚池之平均K含量在1.48～2.0ppm之間，而平均Na含量在10～12.3ppm之間，已構成肥沃池。Na, K含量在所測定之4 口池之間並無顯着差異存在。而 Na、K 在水中之含量則於其彼此之間具有廻歸關係：$K^+=0.1243\ Na^++0.3175$。

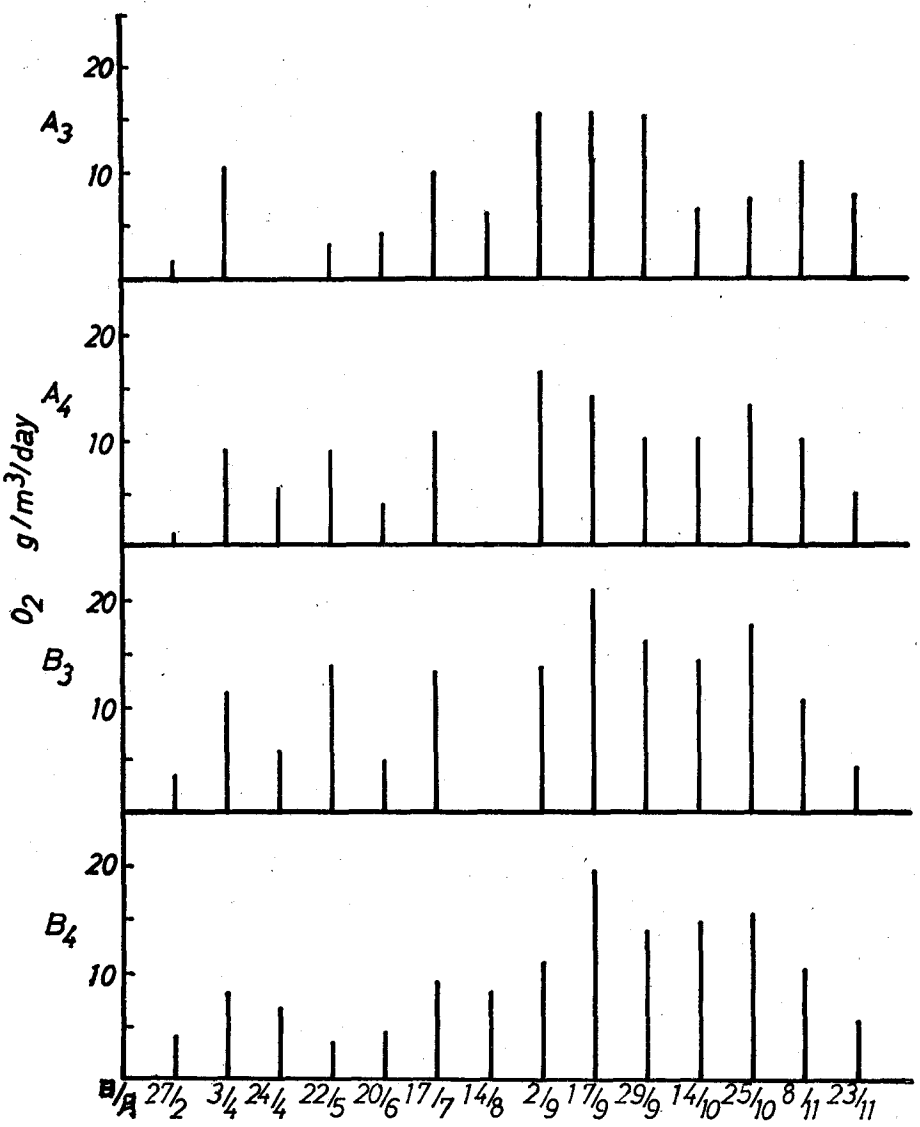

圖3. 竹北施肥池毛基礎生產量 Gross Photosynthesis 之比較

SiO_2——4口池之 SiO_2 含量平均是在10～14ppm之間。SiO_2 爲矽藻生長所不可缺少的元素。此4口池之含量較廖文光（1969）調查之全省湖沼之平均含量要高，就魚池養殖而言，也已不虞缺乏。

O_2——Odum（1956）曾提出：在靜止水中之氧氣改變量 $Q = P - R + D$，P爲水中藻類之光合率，R爲呼吸率，D爲擴散率。P之大小與藻類數量及日照量相關，R則受生物量多寡之影響，另外 $D = K(100-S)$，K爲擴散係數 S爲 O_2 之飽和度。廖文光（1969）亦曾指出，小魚池 O_2 之變化幅度較大魚池爲大，此幅度主要受藻類之量及光合率作用影響。由表4一日間之 O_2 最大與最小值之差距比較可發現，B區魚池比A區魚池稍大，此與表5、表6中葉綠素含量亦是B區稍大的結論相一致。又 O_2 之差距在下半年比上半年爲大，此與日照量有關，尤以9月時最大，各池 O_2 之一日變化幅度爲5.51～14.21ppm。而2月時變化幅度則只有 0.94～3.25ppm，此與當時藻類之現在量有關。

Tanner（1962）之施肥試驗曾提出 O_2 含量在施肥區比不施肥區爲低，且施肥量大者，O_2 含量亦低。但在竹北之施肥魚池並未有此種現象。A_3，A_4，B_3，B_4 池全年 O_2 含量於日出時之平均量爲6.82，

6.87, 6.37與6.18ppm。由此可知各魚池間之O_2含量相差有限。各魚池於日出(A.M. 6:00)之O_2量，在全年之調查結果中，其變動範圍，A_3爲3.51～10.80ppm，A_4爲3.82～8.91ppm，B_3爲 2.79～11.64ppm, B_4 爲4.67～8.99ppm，由此數值來看，各魚池之O_2含量均高，故知各試驗池內魚之生長均在安全界限以上。

觀察O_2之日夜變化圖，可發現各魚池O_2 含量在晚上隨時間變化之遞減率相近，由日出至P.M. 15:00 O_2時皆不斷上升，但15:00至日落時之O_2量改變其增減情形隨魚池時間等而不同。在10月24日～25日與11月8日～9日之B_3池雖相隔半月，但O_2含量及變化率則近乎相同。其他各池，不同月份時，比較其O_2含量雖是不同，但變化率常相近。因而吾人若能多研究O_2之改變現象，似可預言泛池之發生，進而防止之，以減少養魚之無謂損失。

由於池水甚淺，故而表底層溶氧量相差有限。依9月～11月之各池溶氧上下層之相差便可發現：除9月28日可測得的相差較大（如圖二所示），其他各池上下層平均相差在 0.5ppm 以內。另B區中，B_3池各次測定中均以表層爲大，B_4池則上下層大小不一致。

(2)基礎生產量

McConnell (1962) 及 Odum and Hoskins (1958) 二種方法測定竹北魚池之基礎生產量之值比較如表9所示。除A_3因11月23日二法之測定值差距大使前法測定值只有後法之72.5%，其他三個池二種方法之平均估值均甚相近。就以準確度而言，Odum 法較高，因它考慮到一天之內各個時間之O_2變化值，且可矯正擴散量 。McConnell 法則否 ， 但它省時省力，計算亦較簡，若以平均值相近之情形看，McConnell 法似較實用。 Welch (1968) 亦是採用 McConnell 法測定湖沼之基礎生產量值，並估得其因擴散而損失之量只佔全量之5%。筆者等認爲二法有時差距大之原因在於 P. M. 15:00至P. M. 18:00之O_2變化不一致關係，故若能考慮此點，則二法之估計值當更接近，且可求得比例關係。

自第7、8二表之F測驗可知，A、B二區間基礎生產量值 (C g/m³/day 或 C g/m²/day) 有顯著差異。B區平均較A區大，如表7、8中所示。魚池之全年生產量值 (g/m²/year) A_3 爲726.85, A_4 爲719.54, B_3 爲978.87, B_4 爲 894.86。

第10表是直接錄自現有文獻上的原來資料，世界各地區魚池或湖沼的基礎生產量及葉綠素 *a* 的濃度，比較第8表與第10表得知，竹北魚池的基礎生產量與以色列地區及美國喬治亞洲 Athens 的魚池甚爲接近，而全年最高生產量值爲4.9 Cg/m²/day。

基礎生產量之月變化值如圖3所示。直線之高度便爲基礎生產量值，其中以9月最高，爲3.03～7.32 Cg/m²/day，2月最低，爲 0.36～1.16 Cg/m²/day。此與當時之日照量及藻類相關。美國喬治亞洲的Athens魚池亦是以夏季數值3.75 Cg/m²/day，比冬季的0.90 Cg/m²/day 爲高 (Welch 1968)。

葉綠素

由表5、表6比較可知，B區魚池其葉綠素含量較A區魚池高，但由F一測驗則知A、B二區沒有顯着差異。9月30日～10月26日之葉綠素 *a* 測定值較低爲 65.9mg/m³，其他時間之平均則爲 112.2mg/m³。表5、表6中可求得葉綠素*a*佔全葉綠素量之50～74%。

在光合作用及單細胞藻類中，一般以葉綠素 *a* 佔比較重要之地位。而葉綠素*b*及*c*則次要，含量較少，由表5、表6中可求得葉綠素 *a* 佔全綠素量之50～74%。列之施肥池之含量相近。而竹北試驗池可測得之葉綠素 *a* 之最高值 213.5mg/m³，比廖文光 (1969) 之台灣各地區所測得之最高值 137mg/m³要高，此與竹北魚池之大量施肥有關。

表10　其他地區魚池湖沼及河川的毛基礎生產量及葉綠素 *a* 之濃度

	毛基礎生產量 C g/m²/day	葉綠素 *a* mg/m³	著　　者
以色列魚池			
未施肥池（1960年夏季）	1.31—1.81	8.8—115.5	Hepher 1962
施肥池（1960年夏季）	3.26—6.43	103.4—212.3	
日本湖沼			
富榮養湖	0.20—1.70	——	Ichimura 1964
中榮養湖	0.05—0.30	——	引自 Aruga 1968
貧榮養湖	0.03—0.10	——	
美國喬治亞州 Athens 魚池			
夏季平均	3.75		Welch 1968
冬季平均	0.90		
美國 Canyon Ferry Reservoir			
各月平均	0.85—1.62（平均1.44）	2.1—16.7（平均8.9）	Wright 1959
美國 Castle Lake	1.68	——	Goldman 1968
美國 Clear Lake	7.20	——	Goldman 1968
美國 Truckee River	0.49—1.41	——	Thomas & O'Connell
美國 Stream of Oklahoma	3.03—14.40	0.3g/m²	Frey & Stahl
加拿大 Southampton Island	0.01—0.12	——	
台灣各地區	0.32—6.25	1.16—137.0	Liaw 1969

結　　論

(1)竹北A_3, A_4, B_3與B_4池的水質測定顯示，各池水中營養鹽均已達到富營養池之水準。

(2)A_3, A_4, B_3 與 B_4之PO_4-P平均含量爲 0.35, 0.56, 0.27 與 0.5ppm。

(3)B池施N肥，但其NO_3-N平均含量爲0.0128ppm比不施N肥之A_3池 0.251ppm爲低，原因不明。

(4)A_3之魚池生產量最高，但其 Mg, Ca, Na, Alkalinity 之平均值含量比其他三池顯著低。

(5)A_3, A_4, B_3, B_4池全年O_2於日出之時平均量爲 6.82, 6.87, 6.37 與 6.18ppm，由9～11月之O_2日夜變化曲線發現除 9 月28日測得之O_2上下層有差異外，其他各次測得之O_2上下層相差有限。

(6)以 McConnell 法估得之魚池全年碳（c）基礎生產量值（g/m²/year），A_3爲 726.85，A_4爲 719.54，B_3爲978.87，B_4爲 894.86。

(7)9 月時之各池基礎生產量平均值爲 3.03～7.02Cg/m³/day，2 月平均爲 0.36～1.16Cg/m³/day。

(8)竹北魚池測得之葉綠素最高量爲213.5mg/m³，與以色列之最高值213.3mg/m³ 相近，且葉綠素 *a* 佔全葉綠素量之50～74%，各池之間葉綠素量沒有顯著差異。

謝　　辭

本文　承蒙林書顏教授、廖文光教授之殷切指導策勵，張貴洋先生之提供文獻及邱長吉、彭弘

光先生提供八月以前之O_2資料以供參考。並承農復會陳組長同白之推薦，得獲農復會之補助，及竹北各同仁予以工作之方便，使本試驗工作，得以順利進行，筆者等謹此申致謝意。

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