REPORT OF PARTICIPATION IN THE FAO TECHNICAL CONFERENCE ON AQUACULTURE AND SUBSEQUENT VISITS TO VARIOUS WORLD CENTERS IN AQUACULTURE

By D. Homer Buck

Illinois Natural History Survey
in cooperation with
THE UNIVERSITY OF ILLINOIS
at Urbana, Illinois 61801

TABLE OF CONTENTS

Cover Photo: Indian workers at Kalyani sampling composite cultures of Indian and Chinese carps.

INTRODUCTION

The purposes of the trip were to participate in the FAO Technical Conference on Aquaculture, including presentation of a paper covering results of experiments conducted in the recycling of swine manure, and to visit a number of important world centers of aquaculture conducting research in the use of animal and/or domestic wastes in aquaculture, following an itinerary proposed by experts in the Rome headquarters of the FAO. The trip was sponsored jointly by the University of Illinois,* the Illinois Natural History Survey, the National Science Foundation, and the Rodale Press.

THE FAO TECHNICAL CONFERENCE ON AQUACULTURE

This second world conference on aquaculture was held in the International Conference Hall in Kyoto, Japan, May 26 - June 2, 1976, to synthesize on a global basis the experience gained in aquaculture development, particularly since the first world symposium held in 1966. The conference was attended by 308 participants and 155 observers from 48 countries. Presentations were made in English, French, Spanish or Japanese, with simultaneous translations into the other three languages.

The formal program featured a total of 39 invited review papers developed largely from a total of 82 contributed experience papers. The program was presented in 12 plenary sessions, and 5 special sessions, dealing with all major areas of aquaculture. The two sessions most pertinent to our interests were (1) Integration of Aquaculture with Agriculture and Animal Production, and (2) Aquaculture in Recirculating Water and Recycling of Wastes in Aquaculture. The remaining sessions treated the following topics: The State of World Aquaculture and its Future Role; Problems of Vertically-integrated Aquaculture Industries; Pond Culture of Finfish; Culture of Crustaceans; Culture of Molluscs; Aquaculture in Raceways, Cages and Enclosures; Nutritional Requirements of Cultivated Organisms and Feed Technology; Artificial Recruitment and Transplantation; Culture of Algae and Seaweeds; Oyster Mortalities and Their Control; International Aspects of Disease Control in Aquaculture; Fish Genetics and Genetic Improvement; Legal, Social and Economic Aspects of Aquaculture, and Strategy for Future Aquaculture Development.

Five full days were devoted to the presentation and discussion of review papers by the invited panels of experts, with a reasonable time permitted for discussions from the floor. While no experience papers were presented in plenary session, the last two days of the conference were devoted to work sessions in the various areas of special interest, and I had the privilege of presenting our slides and data in the appropriate work session. The paper was well received, and I was later approached by delegates from many countries in search of additional information. It was significant, I think, that our particular work session was assigned to the main conference hall, rather than to one of the smaller meeting rooms, because of the great interest shown in this subject area.

One of the strongest impressions from the conference, later strengthened in my foreign visits, was the sudden, almost universal awareness among aquaculturists of the critical need to make an efficient use of the vast stores of energy available in our organic wastes, most specifically for the efficient and low-cost production of protein, and of the surprising paucity of documented information on the procedures and technologies involved.

One of the recurring themes throughout the conference was the increasingly critical contribution that aquaculture must make in meeting future world needs for protein, because of the continuing decline of our oceanic fisheries and the increasing population pressures. Fortunately, the potential for development is vast, particularly in our fresh waters, due to new technologies and concepts. It was widely agreed that one important area for development involves the recycling of organic wastes. The official view of the conference can perhaps best be expressed by excerpts taken from the final Summary Report of the conference, as follows:

> "Opportunities are recognized for combining fish culture and fish production with modern animal production systems, but the concept of animal waste utilization in aquaculture is poorly understood."

---

*Key initial support came from the Midwest Universities Consortium for International Activities; needed supplemental funding came from the Office of International Programs and Studies, the Office of International Agricultural Programs, and the University Research Board.

> ". . in spite of widespread concern over waste disposal, insufficient attention has been paid to the planned use of organic wastes in aquaculture."
>
> "There is a clear need for cooperative efforts with public health specialists and social scientists to promote the general acceptance of waste recycling through aquaculture."

Finally, I must say how deeply privileged I have felt to have been able to participate in this great conference. It was beautifully organized, for work, as well as for pleasure. The three official receptions were a marvelous experience in themselves, and I greatly enjoyed meeting the other delegates, socially, as well as professionally. But I think that the most impressive element of the conference was the intensity, dedication, and high degree of professionalism among the delegates, and their awareness of their responsibility in helping to meet the world's future needs.

Many delegates to the conference enjoyed one of the prearranged, post-conference tours to fisheries centers in Japan, but I was scheduled to go directly to Taiwan on an itinerary prearranged for me by our National Science Foundation, and by the National Science Council of the Republic of China, a report of which follows.

THE REPUBLIC OF CHINA, JUNE 3 - 9, 1976

The visit was approved by the National Science Foundation of the U.S., and by the National Science Council of the Republic of China, for the purpose of developing cooperative research proposals on the recycling of organic wastes by means of a polyculture of selected fishes. The visit occupied the period June 3 - 9, 1976, and quite closely followed the planned itinerary, with minor exceptions. Through a misunderstanding I was not met at the airport on June 3 and I was unable to keep the appointments scheduled for June 3 due to the time lost in contacting my hosts, learning where I was to stay, and in reaching the hotel. Fortunately, most of the discussions planned for June 3 were re-scheduled for June 5.

Activities of June 4 in the company of Mr. Daywen Shieh, an official of the JCRR*

At 9:00 a.m. I was picked up at my hotel by a smiling Mr. Shieh in a chauffeur-driven carry-all for an approximately hour-long drive to the Taoyuan Freshwater Fish Propagation Administration, located approximately 65 kilometers WSW of Taipei. This facility is allied with the Vocational Assistance Commission for Retired Servicemen, and had the original function of providing technical assistance to private fish farmers. However, as explained by our station host, Mr. S. M. Hsiao, the farmers have become so proficient through long experience that they now require little assistance, and the station's rather elaborate facilities are devoted primarily to research and development. Principal lines of development include: (1) eel culture; (2) the technique of continuous or multiple cropping (up to 10 times/year) of the faster-growing fish in polyculture (Chinese carps, mullet and tilapia), accompanied by restocking of fingerlings; (3) use of what might be called a two-pond system of polyculture, wherein the original stocking is with excessive numbers of small fish, so as to make maximum use of available resources (space, food, etc.), followed in 3 months by a division of the stock between 2 ponds of similar size so as to provide room and food for additional growth; (4) the propagation of all-male tilapia through selective hybridization (Tilapia nilotica male x T. aurea female); and (5) mass production of a blue-green alga (Spirulina sp.) as a food for tilapia, or as a source of protein for fish and other animal feeds, or as an additive to human foods. Contrary to the observation of certain Europeans, the Chinese believe that such blue-green algae are a suitable food for silver carp, as well as for tilapia, and worthy of selective production.

Waters used for the production of both fish and algae are enriched by manure, principally swine manure, but the additions are made principally on a "put and see" basis, rather than by a pre-determined formula. Through long experience, judged on such criteria as weather, the temperature and color of the water, the intensity of the algal bloom, predictable circulation by wind action, etc., the manure is added as needed to provide and maintain what is judged to be the maximum safe fertility. While this may be efficient and practical in the hands of an experienced practitioner, it generates little in the way of useful data that can be used by others. As a result, practically no published information is available, and it becomes necessary for others to develop their own knowledge and expertise within the framework of their own agricultural systems.

*Joint Commission on Rural Reconstruction

Following a delightful luncheon on typical Chinese food in the home of our station host, we made a visit to a local farm consisting primarily of small rice paddies, small vegetable plots, and two small fish ponds. The ponds were devoted to a monoculture of grass carp, possibly because the farm contained no livestock that could produce manure for the more intensive production of mixed species. The statistics provided by the farmer were extremely impressive. He normally raised four crops of grass carp each year. He stocked each approximately .4-acre pond with from between 500 to 1000 fingerlings, depending upon the size available (preferably about 6"). Grass was cut twice each day and fed by broadcasting it onto the pond. By feeding the right grass, and only grass, he claimed the fish achieved growths of from 6 inches to 1.5 kg in 40 days. He had also achieved gains of from .7 to 3.5 kg in 4 months.* He further stated that 500 grass carp averaging 1.2 kg in weight can consume 700 kg of grass per day. The carp brought a wholesale price at the pond site of approximately $1.00 U.S. per kg live weight. If we should assume that he was marketing a minimum of 500 fish every 3 months, averaging 2 kg each, he should be enjoying a minimum gross income of at least $4,000 U.S. from each pond, or more than $8,000 U.S. per acre of water. Such an income per acre of pond area would be on the order of at least 8 times that realized by one of our most efficient catfish farmers.

An extremely interesting sidelight was the fact that the farmer was able to sample his grass carp by angling. He demonstrated this by throwing in a hook baited with a small sprig of grass and almost immediately catching an approximately 1.5-kg fish, and then permitting the writer to do the same.

Our next visit on this date was to the Taiwan Pig Research Insitute, operated by the Animal Industry Research Institute of the Taiwan Sugar Corporation. Our host was Deputy Director Sen-chang Wung, D.V.M. This facility doubles as a production unit (40,000 hogs/year), and a research institute, primarily in genetics, pathology, nutrition, meat science, and physiology of swine. It also contains a large system of ponds which utilize pig manure in the production of Chinese carps. Time did not permit more than a very brief overview of this large facility, but it appeared typical of the large, efficient, highly-integrated agricultural centers now beng developed throughout the country, with fish production as an important element. Dr. Wung mentioned that he was not trained in fisheries, but recognized the important place of fish in such developments, and was anxious to increase his knowledge of fish production. I was then totally surprised when he emphasized the absence of literature available in Taiwan on the use of animal manures, and urged me to supply him with such information that might be available in the U.S. I informed him that our preliminary work in Illinois represented the total effort now being made in this country involving the use of animal manures in fish production, but that I would send him a copy of our report presented at the FAO Technical Conference on Aquaculture in Kyoto, which I have done.**

Our official itinerary for this day was now completed, and we returned to Taipei. I might add that through continuing conversations with my escort, the bright and ever-courteous Mr. Shieh, I gleaned many items of interesting and useful information, much of which is recorded in my notes, or on tape.

Activities of June 5

On Saturday morning, June 5, I was taken first to the National Taiwan University for a meeting with Dr. Liang-ping Lin, professor of microbiology and electron microscopy. Dr. Lin described his pioneering work in the isolation of various marine yeasts (excellent slides), described his progress in developing uses for the organic wastes associated with a national wine distillery, outlined their problems in oyster culture in organically enriched areas receiving waters from their larger, polluted streams, and provided a tour of the elaborate facilities within the University laboratories. The purpose of this visit was to demonstrate the range of facilities and technologies which would be available to any cooperative program which we might propose.

We then proceeded to a conference with Dr. Wang Chi-Wu, Director of International Programs, NSC, ROC. This very personable and knowledgeable man led me through such an animated, highly entertaining, and wide-ranging

*There was later comment by one of the scientists that the figures were surprisingly large, and possibly an exaggeration, but from talking with the farmer, and on the basis of our own experience with this species, I am convinced that his growth and production figures were indeed large.

**I have since learned that experiments were inititated in 1976 at Texas A. and M. University involving 3 pools containing a Tilapia which received raw wastes directly from swine, and one pool containing Tilapia which received manure from laying hens.

discussion of Taiwan, its problems, programs and opportunities, that it defies proper description here. Suffice to say that on parting I remarked that if I could have two more hours with him, I would not need to complete my itinerary.

Our next appointment was with Dr. S. W. Ling, the renowned authority on Chinese fish culture, the "father" of Macrobrachium culture, and former Professor of Fisheries at Taiwan University, who is now retired and living in Florida, but was in Taipei on a 6-month consultancy to either the NSC, the JCRR, or both. I had previously corresponded with Dr. Ling concerning my research, and had visited with him in Kyoto, and we engaged in a pleasant and useful conversation concerning my itinerary, current programs in Taiwan, and the potentital for future research and development.

Activities of June 6, 7 & 8 in the company of Mr. Sing Hwa Hu

At 4:00 p.m. on Sunday, June 6, I boarded a train for Chiayi, and was later joined on the train by Mr. Sing Hwa Hu, a biologist with the Taiwan Fisheries Research Institute, who was to be my escort, interpreter and friend through my excursions of June 7 and 8 in the middle and south of Taiwan. Mr. Hu was a delightful and energetic young man, extremely courteous, affable, and patient, and worked very hard and effectively to help me accomplish my ends.

We spent the night of June 6 in Chiayi, and were met at the hotel at 7:00 a.m. on June 7 by Mr. W. Y. Li, Chief of the Fish Cultural Department at the Tidal Land Reclamation Office. We boarded a taxi for the approximately 40-kilometer drive to the Au-koo Tidal Land Development Project of the government-owned Taiwan Sugar Corporation. This immense project, which will eventually involve 30,000 hectares, was designed to reclaim salt-laden tidal lands for conventional agricultural practices. The initial step was to construct a huge dike, 10.3 kilometers in length, to hold back the sea. The second step was to lay underground, perforated drainage pipes in the area to be reclaimed. These lands were then flooded with fresh water which drained through the soil, flushed out the salt, and was returned to the sea. The drainage water was released by a set of large gates in the dike which opened toward the sea during low tide because of the pressure of the accumulated drainage water on the inboard side, but were reclosed by the pressures of sea water brought in by the rising tide. With only 3 to 4 months of such flushing, the land was suitable for rice production. Following the additional flooding and flushing associated with rice production the land becomes suitable for such additional crops as sugar cane, cotton, napier grass and vegetables. The totally integrated system also produces sheep, cattle, hogs (20,000 per year), plus a variety of fish cultures grown in waters enriched by the swine manure. At the time of my visit the investment in this project had reached 3 billion N.T.s (about $75,000,000 U.S.), but had already proved so successful that plans were being developed for the reclamation of an additional 30,000 hectares. It was my impression that the project was totally state-owned and state-operated, with the profits being turned back into the project, but that there was also some provision through which at least a part of the reclaimed land would eventually be made available to small farmers.

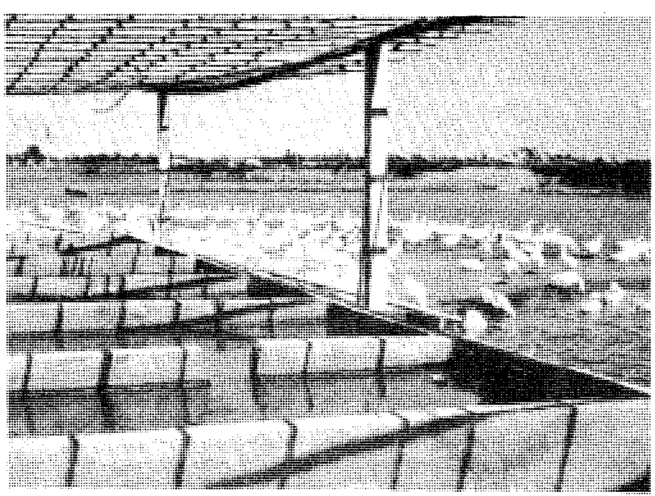
Cultures in progress at this station included (1) eels; (2) polycultures of silver carp, grass carp, bighead carp, common carp, mullet, tilapia, plus a predatory sea bass (Lateolabrax sp.) which is captured as fry from the sea and readily transferrable to fresh water, as are the mullet; (3) polycultures of mullet, shrimp and an alga used to produce Agar-agar, a solidifying agent for various medias used in the culture of bacteria; and (4) a polyculture of clams and milkfish. In terms of area, primary emphasis was on the polyculture including the Chinese carps in large ponds enriched by swine wastes. Here the application of manure was quite well controlled, and on less of the "put and see" basis as seen in some earlier operations. The concrete swine floors were pitched so that the liquid manure ran into a concrete channel which carried it into a reservoir holding irrigation water, and from which it flowed to the fields containing field crops. The remaining solids were removed and sun-dried for about 3 days, and then placed in the polycutlure ponds, with each hectare of water receiving all of the dry wastes from 100 fattening pigs.

Here, as in other state-operated facilities visited, much emphasis seemed to be placed on profit. The products are sold, and the profits are apparently turned back into the operation. Thus, the primary incentive for improvement is somewhat more as it might be in one of our commercial catfish operations than in one of our research stations where emphasis is placed on producing data for publication, and where profit is not a direct motive. While the profit motive may be highly efficient in improving production, and in developing advanced techniques, it frequently fails to produce the documentated data that can be instructive to others.

During the noon break we joined the station director and several of his aids in a small on-station refectory for an elaborate luncheon featuring such delicacies as mushrooms, squid, sea cucumbers, hog legs, meat balls, hog liver and chicken feet, plus an attrative variety of vegetables. The food was excellent, the atmosphere was gay and lively, and it was a very enoyable affair.

Following lunch we were taken on a whirlwind tour of a variety of small, highly integrated private farms in the area, many of which we saw only in passing. One farm specialized in eel cutlure, but most featured a combination of a polyculture of the Chinese fishes in ponds enriched by one or more varieties of animal manures. One approximately 1.5-ha pond received all of the wastes from 1500 ducks, a small flock of chickens, and about 30 hogs, but most ponds received wastes from one principal species, usually either ducks or pigs. I was particularly impressed by one operation featuring geese over a polyculture pond, for which some statistics were provided. The pond appeared to be slightly larger than 1 hectare, and received all of the wastes from 1500 fattening geese. The farmer owned a large, modern incubator for the production of his own goslings. He fattened 1500 geese at a time, and the geese were ready for market in 3 months. Each goose brought an average of $12.50 U.S., and the investment for feed was at a rate of about $2.50 U.S. per goose. Thus, this farmer was selling 1500 geese 4 times each year at a gross profit of $10.00 U.S. per goose, and turning a total gross profit in the vicinity of $60,000 U.S. per year. He had the additional profit from the sale of fish, but the amount of such profit was not learned.

We were returned to Chiayi to catch the 6:15 train for Tainan City. On reaching our hotel I learned that I was to have the special privilege of



Goose-cum-fish farm in Taiwan.

meeting the distinguished Dr. T. P. Chen, former head of the JCRR, and now President of Taiwan Fisheries Consultants, Inc. He, together with Dr. Herminio R. Rabanal, a high-echelon scientist with the FAO, whom I had met in Kyoto, were staying in the same hotel. Although quite late, they very kindly came to my room to share an extremely pleasant and rewarding hour with Mr. Hu and me.

Early on June 8 we were joined at our hotel by a Mr. Yeng and driver for a visit to the Taiwan Fish Culture Station of the Taiwan Fisheries Research Institute, located partly on tidal lands 15 or 20 kilometers out of Tainan City. This complex contained two units, one of 46 ha, devoted entirely to the production of milkfish, and one of 76 ha devoted to the production of prawns, milkfish, and to polycultures of prawns, milkfish and an alga used in the making of Agar-agar, as previously described. While research is a primary function, both units also strive for a high return on the capital investment through the sale of the products produced. The larger unit is located on lands reclaimed from the sea in the manner previously described. Both stations feature elaborate facilities involving the extravagant use of concrete in large, outdoor production ponds, as well as in a great many smaller concrete pools or tanks, both indoor and out, for research and development of specific culture techniques. While milkfish production is highly advanced in this area, and possibly the most advanced in the world, much development is needed in the culture of prawns, particularly in the artificial propagation and the culture and feeding of young. Gravid females from the sea are the present source of young prawns. The intensity of the program is indicated by the fact that the research institute has payed commercial fishermen as much as 32,000 N.T.'s (about $800 U.S.) for a single gravid female. The normal price range is between 6,000 and 32,000 N.T.'s. As elsewhere, production ponds in this area are enriched by organic wastes, either domestic or of animal origin, and the large number of ponds creates a demand that sometimes exceeds the supply.

In late morning we were shown a number of private fish farms in the area, all involving polycultures enriched by organic wastes. In this area tilapia are often used as a primary species in combination with grass carp, silver carp, bighead carp and common carp. I was particularly impressed by one large, private farm engaged in the large scale production of hogs and chickens (baby chicks, broilers and layers), and with 30 ha of fish ponds providing a productive use for the manure. The buildings were modern and neat, the pond banks were attractively landscpaed with small palm trees, and the overall atmosphere was one of neatness, efficiency, and high profit.

Following a late lunch in Tainan City, we were again driven into the country for a tour of the Taiwan Livestock Research Institute, conducted by the Director, Mr. T. Y. Chow. This large facility, together with its several branch stations, is conducting an impressive range of studies under eight departments: Cattle, Swine, Poultry, Forage Crops, Animal Nutrition, Artificial Insemination, Milk and Meat Processing, and Slopeland Livestock Production. Its activities did not involve fish culture, but a new, apparently rather intensive effort was underway involving the fermentation of animal wastes for the production of methane as a source of energy for the production of fuel and electric power. A description was provided of a demonstration area where methane was used to power a generator which provided the electricity used by a small farming community. This was a cooperative project with our NASA.

In late afternoon Mr. Hu and I were returned to Tainan City for our return by train to Taipei, arriving at about 11:30 p.m.

Activities of June 9

The morning of June 9 was devoted to final discussions with Mr. J. D. Lee, of the JCRR, Dr. C. T. Chueh and Mr. Charles W. Li, of the NSC, and with Dr. S. W. Ling, consultant to the NSC. The talks were very cordial. I expressed my admiration for the Chinese people in general, because of their intelligence, efficiency, resourcefulness, and their great courtesy, and for the Chinese scientists in particular for their high levels of technology and many great accomplishments. While it was recognized that the time involved was much too short to permit me to fully evaluate and understand their many large, complex programs, they expressed the hope that I could produce an optimistic report, and offered extremely strong encouragement for me to prepare a proposal that would provide for simultaneous studies in both countries on problems of mutual need and interest, involving continuing studies by me and my staff in Illinois, and by a counterpart group in Taiwan.

While the Taiwan experience was extremely rewarding, I left that beautiful land with the feeling that I had viewed a paradox: namely, (1) their obvious success in producing massive quantities of usueful protein through the recycling of organic wastes by means of their various polycultures of fishes, as learned through centures of experience, and (2) the almost total absence of scientific data of the type gained through controlled experiments, and which can be instructive to aquaculturists all over the world who are literally crying for such information. The simple answer seems to be that the farmers have been so successful in using the methods passed down by their ancestors that the scientists have felt that their time can be more profitably spent in the consideration of other more urgent problems. I was made to feel, however, that the scientists in Taiwan now recognize the need to better understand these complex systems, and to work through controlled experiments toward further progress in this important area.

HONG KONG, June 10 - 12

The visit to Hong Kong was prearranged through correspondence with Mr. E. H. Nichols, Director of Agriculture and Fisheries, in the Agriculture and Fisheries Department of the Hong Kong government. Mr. Nichols kindly approved my request to visit over the period June 10 - 11, 1976. I was actually able to extend my discussions through the morning of Saturday, June 12.

I arrived in Hong Kong from Taiwan on the evening of June 9. The morning of June 10 was occupied by a wide-ranging discussion of special problems and developments in Hong Kong with Mr. A. Murray, Assistant Director for Fisheries, and Dr. William Chan, Director of Research, who was to be my principal host throughout my Hong Kong visit.

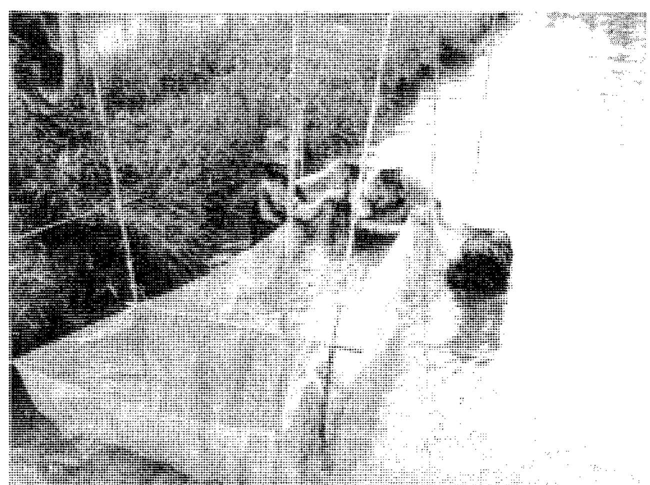
One is soon made to realize that the dominant force influencing all phases of life in the Colony of Hong Kong is the existence of more than 4 million people in an area of only 398 square miles. This is an average density of more than 10,000 per square mile, and would be equivalent to cramming 12 million people into Champaign County. Much of this tiny parcel is mountainous and non-productive, which makes the population dependent upon the outside world for more than 90 percent of their food (100 percent of their dairy products), most manufactured items, and all of their raw materials. As an example, 90 percent of the fish consumed in Hong Kong (mostly Chinese carp) are brought in from mainland China in boats coming out of the Pearl River. The Mahjong parlors, and other gambling halls, are constantly jammed, the amount of money bet on horse races in Hong Kong is greater than the total wagered over all of the British Isles, and the sociologists believe that the extremely high incidence of gambling is due to the absence of recreational space.

All agricultural, fisheries, and other water-oriented interests are further influenced by the weather cycle, which brings a 6-month rainy season, and 6 months in which the stream beds become totally dry. Seasonal shortages of water create major problems in fish farming, and even greater problems in the treatment of domestic sewage. The problem of domestic wastes has in fact been so great that the problem of animal wastes has been largely ignored. A rather large amount of poultry manure has always been used by the fish farmers, but most of the poultry manure, and practically all of the swine manure, has been simply dumped into the stream beds to eventually be swept out to the sea. My hosts informed me, however, that new legislation is anticipated that will be highly restrictive upon swine and poultry farmers, and that the agriculture and fisheries people will soon face the additional problem of managing the wastes from 450,000 swine, and 4,000,000 poultry. As a result, the almost total energies and resources of the agriculture and fisheries people in the Hong Kong government are now directed toward the development of methods for the management of these vast quantities of organic wastes.

I mentioned to Dr. Chan that when in Taiwan I had been surprised to find an almost total absence of documented data on the use of organic wastes in fish ponds. He acknowledged that this was also true in Hong Kong, where the farmers use traditional methods, and the scientists themselves have never conducted controlled experiments, but that the need for such information has been recognized, and that much of their present effort is directed toward that end.

Current studies in Hong Kong involve the use of chicken manure, and various types of domestic wastes, but do not yet involve swine manure. Test species of fish include Tiliapia nilotica, Clarius sp., and polycultures which usually include silver carp, grass carp, bighead carp, common carp, and gray mullet. Production data is valued, but primary emphasis is being placed on determining the influence of the organic wastes on "summer kill," trying to determine the maximum loads of wastes that can be placed in the fish ponds without killing the fish. Some ponds in the series will be purposely overloaded in order to study the specific factors responsible for fish deaths. They also want to compare the production gained through a maximum use of the various types of wastes with the production gained by fish farmers using traditional methods in commercial fish ponds, which primarily involve the use of chicken or duck manure, plus supplementary feeding.

On June 11 I was taken by Dr. Chan for a visit to the Au Tau Fish Culture Research Substation, out in the New Territories. Work in progress involved 8 ponds, 1/6-acre in size, each of which was stocked with a polyculture including 50 silver carp, 50 bighead carp, 60 grass carp, 100 common carp, and either 500 or 1000 gray mullet, and two 1-acre ponds which were stocked with the same species at the same density. The fish were fed a diet consisting primarily of peanut cake (40 percent protein), but received no manures or other fertilization. The dual purpose of the experiments was to measure the influence of pond size on production, and to gain basic information on the production to be gained through feeding only, and without the use of manures. These data were to be compared with that from subsequent experiments involving the use of manure or domestic wastes only, and manures or domestic wastes plus supplementary feeding. I was told that the production to be anticipated from the ponds receiving food, but no manure, would be at a rate of about 2400 pounds per acre per annum.



Sampling experimental polyculture ponds at the Au Tau Fish Culture Research Substation in Hong Kong.

Later in the same day we observed a duck-cum-fish operation having a feature new to me, but said to be common in Hong Kong. The fish farmer owned ponds and fish, but no swine or poultry, and so he built a duck-feeding platform and a duck-sheltering house over his pond and invited a neighbor who owned only ducks to put his birds over the fish pond. A wire fence in the pond confined the ducks to the feeding platform and shelter, and to about 1/3 of the pond area, thus preventing them from damaging the pond banks. Unfortunately, the fish farmer was not available to supply details on the number and types of fish stocked, the number of ducks, etc. I did learn, however, that such ducks are fed twice daily with boiled grain (usually sorghum), plus a small daily ration of dried, chopped fish. The ducks are placed on the pond at an age of 3-10 days, and are ready for market in 70 days. We were unable to estimate the density of the ducks, but my hosts told me that the number used were highly variable. They had no firm knowledge of what constituted "too many" ducks, but believed that anything over 100 ducks per acre might be too many, although they knew that the duck farmers usually exceeded this number. I was further told that the Hong Kong farmers prefer using ducks to pigs as a source of manure, because ducks are easier to care for, less expensive to feed, and require less investment in the form of housing or pens. Experiments are planned which will evaluate the traditional methods used by the fish farmers in an effort to improve their efficiency.

In addition to my lengthy discussions with Dr. Chan, and Assistant Director Murray, I had the privilege of meeting with staff members Dr. Michael Chiu, Dr. G. B. Thompson, and Mr. Y. W. Chan. All were very cordial, and extremely generous with their time and knowledge. I was particularly grateful to Dr. Chan for his many valuable contributions to my education, and for the great pleasure of his company through the full 2½ days of my Hong Kong experience.

In the course of my field observations, and the various discussion alluded to above, I gleaned many useful impressions, and various specific items of information, as are briefly detailed below.

The Hong Kong workers believe that the addition of manures, or other organic wastes alone, cannot supply the total needs of the fish, and that maximum production requires supplementary feeding.

The principal food used is peanut cake, very high in digestible protein (about 40 percent), and which is formed from the residue from peanuts, after extraction of oil, into discs ½-inch thick and about 12 inches in diameter; other foods include rice bran, wheat bran, corn meal, wheat, mungo bean fragment, mixed bean fragment, silkworm larvae and faeces.

The gray mullet is the dominant fish in polyculture because of its availability and high preference in the market.

Black carp is much less popular in Hong Kong than in mainland China because of its dark flesh, whereas Tilapia nilotica is favored because of its light flesh.

Our yields from polycutlure in Kinmundy are higher than those obtained in Hong Kong, possibly because we use much larger numbers of silver carp, which feed on phytoplankton, and are our most productive fish.

Grass carp in Hong Kong are fed duckweed (Lemna sp.) when small, and elephant grass when large.

Polycultures in Hong Kong are usually maintained 1 full year before harvest, and the grass carp are usually the largest because they grow continuously through the mild winter, whereas the companion species grow at a reduced rate during the short "winter."

The commercial fish ponds are usually harvested in March and restocked at about the beginning of the rainy season in April.

In mainland China, and to a lesser degree in Hong Kong, treatment of fish diseases and parasites is by herbs, extracts from plants, etc. For example, tea seed is commonly dissolved in pond waters to control such ectoparasites of fish as the very troublesome anchor worms (Lernea spp.).

As in Taiwan, Chinese carps are sold in such separate parts as the head, the tail, the body meat, the intestines, and the stomach wall with "ribs," which brings the highest price of all, and each is prepared in a special way.

Very little direct use is now made of pig manure, which is dumped into the stream beds. Some indirect use is made, however, because many fish ponds are filled at the beginning of the rainy season with water that is carrying the accumulated swine manure, and other wastes, toward the sea.

The price of fish in Hong Kong is established by the price of fish imported from mainland China, which are delivered live in large live wells located in the holds of ships.

Many Hong Kong restaurants have closed in the past 3 or 4 years due to the increasing cost of fish and other foods.

Most fish fry used to stock polyculture ponds in Hong Kong are imported from mainland China or Taiwan.

Fishery workers at Au Tau use small mesh seines up to 20 feet in depth to sample experimental ponds only 4 feet deep. The extra bag in the seine helps reduce escape of the extremely active Chinese carps.

Fish farmers in Hong Kong use small ponds of only about 1/6-acre, which are smaller than those used in Taiwan, or mainland China, probably because of the limitations of space.

Approximately 40 percent of the manure produced by 4,000,000 poultry (mostly chickens) in Hong Kong is used in fish production. Chicken manure is sold to fish farmers in large baskets holding 133 pounds at the rate of $3.00 Hong Kong (about 60 cents U.S.) per basket. The baskets are placed in the edge of the fish ponds to permit a slow leaching of the manure. The fisheries scientists believe this method is poor because high ammonia and low oxygen in the vicinity of the baskets reduces the usable area of the pond, and they are encouraging the farmers to dry the chicken manure so that it can be broadcast over more, or perhaps all of the pond. Dry poultry manure could be more easily stored, and could be utilized as a direct feed since analyses show it to have a protein content about equivalent to much of the food now being used.

A new aerator, described as a cavitation aerator, had just been received from Britain and was to be used in new experiments in the control of eutrophication. The aerator creates turbulence with a propellor, but also contains a "gang" of small tubes which rotate rapidly in the air and sucks air down into the stream of turbulence produced by the propeller. Some special feature in the design creates a profusion of minute air bubbles that are pushed through the area of turbulence. In addition to providing highly efficient aeration, it is hoped that the tiny bubbles will cause flotation of the algal cells in the water column, permitting them to then be swept off of the water surface. It might prove to be an efficient system for removal of nutrients, and control of eutrophication.

At the close of one long, interesting, and somewhat philosophical discussion with a group of my Hong Kong hosts, Dr. Chan expressed the view that the future of oceanic fisheries appears to be quite dismal when compared to the prospects for future developments through aquaculture in fresh water, particularly through the use of organic wastes to produce polycultures that would include the Chinese carps. There were no dissenting views.

SINGAPORE - June 14, 1976

Singapore was not originally on my official itinerary, but I was persuaded to attempt a brief visit when I was informed in Kyoto that the Singapore government was initiating a major program in the management of animal wastes. I was advised to contact Mr. Chen Foo Yen at the Changi Fisheries Complex, some 20 miles outside the city of Singapore. Unfortunately, the time lost because of the failure of one vehicle, followed by the inability of my taxi driver to find the right address, permitted me only approximately a 50-minute conversation with Mr. Yen, and a very fast tour of a part of their research facilities. I therefore gained only a very incomplete view of their problems and activities. I was informed by Mr. Yen, however, that they were indeed planning a major program under the title "Animal Waste Management and Utilization," but due to a curtailment of funds had not advanced beyond the planning stage. Their primary target will be the manure from a large population of swine, and they plan to attack it in a rather unique and forceful way. The normal swine population is estimated to fluctuate in the vicinity of 1,000,000 animals, which are now distributed throughout the island. The Republic of Singapore contains 225.6 square miles, which means that the swine population has an average density of about 4400 animals per square mile, compared to a human density of more than 9300 per square mile. The initial plan calls for the concentration of all swine-producing activities within one small area of 100 hectares, and this is to be accomplished through a government edict proclaiming that subsequent to a certain date all swine-raising activities within the Republic of Singapore will be conducted within a 100-hectare area that is to be designated by the government. Thus, they will not only concentrate such manure that is to be managed, but through such a forceful edict very probably will cause (1) a major reduction in the number of hog farmers in Singapore, and (2) a corresponding increase in the number of hog farmers across the bridge in the neighboring Republic of West Malaysia.

Any curtailment of pig farming will also curtail fish production since pig manure has always been extensively used by the fish farmers in Singapore. However, because of the increasing competition for space and water in Singapore. the government has been encouraging a gradual phasing out of fish farming in ponds, and has been encouraging the intensive use of large cages (5 m x 5 m) in both marine and fresh waters. Of the Chinese carps, only the bighead is commonly produced in cages in Singapore. Rates of production are not large, however, because it is not given artificial food, and must subsist on such plankton as may drift through the cage. It was of further interest that silver carp are stocked in the larger industrial and water-supply reservoirs, not, however, for the production of food, but for the control of eutrophication through their consumption of plankton algae.

In the early afternoon I was taken by Mr. Leslie Cheong, an associate of Mr. Yen, for a brief visit to one of their research centers. They were attempting to develop two new technologies here: (1) the raising of milkfish in high density populations in aerated plastic pools about 12 feet in diameter, somewhat in the fashion that eels were being raised in Taiwan, and (2) the culture of the large fresh-water prawn (Macrobrachium) in large, wire pens (about 20 m x 30 m) in a small impoundment filled with brackish water.

Pens used in the experimental culture of freshwater prawns in Singapore.

When en route to the station mentioned above, we had passed two approximately 1.5-acre ponds in which a number of people were fishing. Mr. Cheong acknowledged that these were indeed fee-fishing ponds, and that we could stop there very briefly on our return. While no fish were seen to be caught during the very brief period that we were at the ponds, I was both delighted and surprised to learn that these people were fishing for Chinese carps—not just the grass carp, but the silver carp and bighead carp as well. Catching grass carp was, of course, nothing new, but this was the only time and/or place, before or since, that I had seen or heard of anyone having mastered the technique of catching either the silver or bighead carp. The bighead was favored for the table, but the silver was the most exciting to catch because it fought harder, and jumped a great deal. The bait being used was cassava, either by placing a small cube of the raw cassava root on a small, single hook, or by forming a ball of cooked cassava (tapioca) around a small treble hook. I am anxious to try these techniques on our Americanized populations. We may have some new sport fish on our hands.

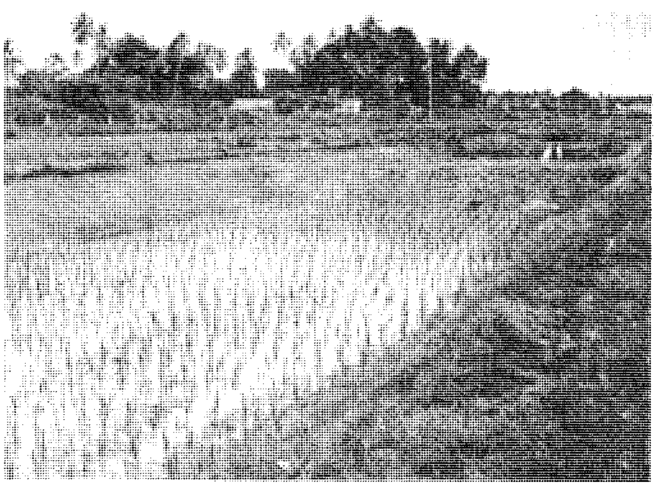
WEST MALAYSIA, June 15 - 16, 1976

My principal interest in West Malaysia was to visit the Freshwater Fisheries Research Station at Malacca, a primary facilitiy of the Malaysian Agriculture Research and Development Institute. This station had been made famous by the writings of the distinguished British fish culturist, C. E. Hickling, a former director of this station when it was known as the Tropical Fish Culture Research Institute. The present Head of Station, Mr. Ahmad Tajuddin Zainuddin, is continuing the traditon of research in the production of food fishes in freshwater ponds in this tropical region. Mr. Zainuddin enjoys the assistance of a multinational staff, including Dr. Eric G. Watts, a fish nutritionist, on loan from the International Development Research Centre, a Canadian counterpart of our AID program. Dr. Watts served as my principal host during my stay in Malacca, and was exceptionally kind and gracious throughout.

The Chinese carps are the most important species cultured for food in the ponds of Malaysia, using the traditional Chinese methods, but the production is limited by a shortage of "seed" for stocking the ponds. Since the Chinese carps are native to large rivers in more temperate regions of Asia (primarily China and Siberia), there are no native stocks in this tropical area, and fry must be imported or produced through induced breeding stimulated by injections of pituitary hormone, a process known as hypophysation. Although hypophysation is successfully practiced in Taiwan, Mainland China, Arkansas, Hungary, and many other temperate and sub-tropical regions, the rate of success is much less dependable in tropical climates not having the fluctuation of temperatures and cycles of rainfall needed to induce gonadal development in the parent fishes. Therefore, the development of techniques which will permit successful hypophysation, and the production of abundant and healthy fry of the Chinese carps for the stocking of ponds, now has the highest priority at the Malacca station. In addition to striving for improved techniques in the handling and feeding of the parent stock, they are repeating the procedures of hypophysation at four separate periods in the calendar year to determine if there is any one "season," or combination of conditions, that might be more advantageous than another. When I was there in mid-June they were quite elated at having just brought off a large and seemingly healthy brood of bighead carp, which seemed indicative of progress.

In addition to producing the fry, they must also develop techniques for the care and feeding of the young. The newly hatched fry feed well on egg yolk for the first 3 or 4 days, but then must progress to a live food of the proper size and quality, and which must be available in great abundance. They were putting a large effort into the culture of a species of Moina, and were having good success in producing very large numbers of this small cladoceran in bathtub-size cement water tanks enriched with fermented chicken manure. Their goal is to develop a combination of techniques of sufficient simplicity and reliability that they can be used by private fish farmers in commercial enterprise. In this way they hope to assure production of sufficient fry to permit the full development of their fish-farming industry.

Additional projects at the Malacca station included the culture of the freshwater prawn, Macrobrachium sp., and the culture of a small, native, stream species of fish that was highly valued, selling for approximately $10.00 U.S. per pound, but which had become rare and endangered through a combination of overfishing and excessive pollution. Studies also were underway of the production of fish in rice paddies.



Experimental ponds at Malacca used for studies of the production of fish in rice paddies.

As elsewhere in Asia, private fish farmers in Malaysia commonly use such manures as may be available to improve fish production, employing traditional Chinese methods of polyculture, but the researchers have attempted very little research and development involving the controlled use of manures. Very recently, however, funding had been approved for a study that would develop the techniques for a duck-cum-fish culture under the Malaysian conditions. Fences had been erected that were to contain the ducks within circumscribed areas, and the work was to have been initiated very shortly.

On the morning of June 16 I was invited by Dr. Watts and Director Zainuddin to make a presentation of the results of our work in the recycling of swine wastes in Illinois. This proved to be extremely interesting to my hosts, and was highly rewarding to me because of the discussion stimulated. It was of special interest to the Malaysians that our rather simple procedures had provided such high rates of production in our relatively short growing season, and in the absence of supplemental feeding, rates which in fact equalled those achieved in some tropical ponds receiving both manure and supplementary feeds. This seemed to suggest biological potentials not previously conceived or experienced in their tropical environment, and encouraged my hosts to offer some interesting speculations: (1) that the more temperate Illinois climate may afford more optimum temperatures for the growth of the Chinese carps than occur in tropical ponds; (2) that greater differences in day and night ambient temperatures may create convection currents which provide improved water circulation and an improved distribution of oxygen and nutrients in our Illinois ponds; and (3) such a combination of temperature and improved distribution of nutrients may favor the production of a more nutritious selection of planktonic plants and animals for the fishes, just as one pasture may provide more nutritious forage for grazing animals than another. It was generally recognized, however, that it might be imprudent to draw any extensive conclusions from only one year of observations in Illinois.

On the afternoon of June 16 I was taken by Dr. Watts and a colleague for a visit to a small, private farm operated by two Chinese families, with the assistance of 1 water buffalo. It was a highly intensive operation which produced chickens, pigs, a variety of small, caged birds, goldfish, rice, a variety of vegetables, a polyculture of food fishes (mostly Chinese carps), plus an impressive number of children, all on 7 acres, which included a 2-acre fish pond. The goldfish were raised in a series of small cement tanks and fed primarily on plankton produced in water enriched with swine manure. The 2-acre pond was stocked with grass carp, bighead carp, common carp, and a small, native fish (Trichogaster sp.) which was netted nightly in surprisingly large quantities, soaked in brine for 12 hours, dried in the sun and sold in the local market. The carps were also harvested rather continuously and sold locally. The total production was known only to be large and quite profitable. In addition to receiving the manure from the chicken and hog pens, the pond received the waste water from an adjacent small plant, described as a cottage industry, which processed soybeans for the production of a soybean concentrate sold in the local market and used for making soup. The wastes from this process were substantial, appearing to be a soybean "milk," and probably quite rich in protein. In addition, the pond produced an abundance of water hyacinth (Eichornia sp.) which the farmer harvested and fermented as a food for his pigs. He also operated a small barnyard pool for the production of duck weed (Lemna sp.), used to feed the grass carp. All in all, it was a highly intensive and extremely interesting operation. I was told that this 7-acre farm produced a "good" living for two families.

WEST BENGAL, INDIA - June 21 - 26

My activities in India centered around the village of Barrackpore in the State of West Bengal, which is one of India's principal fish-farming districts. The Indian fish cultures rival those of China in their antiquity, and in the importance of their contribution to the diet of the people. I was told that 95 percent of the people in West Bengal eat fish every day, and that every rural Bengali family either owns or shares in the use of a fish pond. The center of village life is very often the village fish pond. The Indian government fully recognizes the importance of fisheries to the rural economy, as well as its growing importance to the national economy, and operates a large and impressive program of research and development. One of the most important centers of this program is the Central Institute for Fisheries Research, with headquarters at Barrackpore, approximately 40 km north of Calcutta. This institute operates a large network of research stations located throughout much of eastern India. Individual centers pursue such special projects as the composite culture of mixed Chinese and Indian carps, fish production in sewage-fed ponds, culture of air-breathing fishes in derelict ponds (swamps), production of prawn and mullet in brackish water ponds, frog culture in ponds, and studies of the production of riverine fishes. Through the courtesy of Director J. V. Jhingran, I had the privilege of visiting several of these stations. My principal host throughout my stay at Barrackpore was Dr. P. V. Dehadrai, who functioned as Director-in-Charge in the absence of Dr. Jhingran.

Activities at Barrackpore on June 21

I was met at the Calcutta airport at about 8:45 on the morning of June 21 and the extreme and continuous congestion of pedestrians, cyclists, school children, cattle, water buffalo, chickens, trucks and buses on our 40-kilometer drive to Barrackpore verified that this is indeed one of the most densely populated areas in the world. Upon arrival at the Central Institute for Fisheries Research at Barrackpore, I was shown into the office of Director Jhingran, whom I had met in Kyoto, and had the further pleasure of meeting two senior administrators from the Indian Council of Agricultural Research. These dignitaries were on hand for the opening ceremonies of a short course in brackish water fish culture that was being offered to some 200 technologists and fish farmers. I was later to address this same group when they were assembled at the demonstration area at the Kakdwip station 160 km south on the Bay of Bengal.

I was extremely fortunate in being able to attend the opening sessions because they provided a broad overview of much that is current in Indian fisheries, as well as projected goals for the future. The primary purpose of this short course was to acquaint the trainees with the advances made in brackish water fish culture, primarily for prawns and mullets, and to encourage them to apply these procedures in private enterprise. New potentials in the use of composite cultures in freshwaters were also described, emphasized by a prize-winning film on new developments in this area of technology. Aside from a great deal of technical information, some primary points of general information included these:

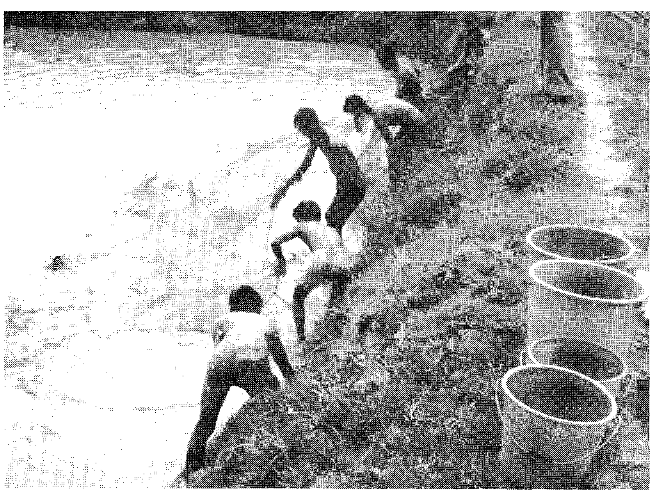
1. That oceanic fisheries are now known to be limited, are now declining, and must be replaced;
2. that developing new technologies will permit high levels of production in both brackish and freshwater ponds;
3. that procedures are now known that can produce up to 4000 kg/ha/year of prawns, up to 6000 kg/ha/year of a polyculture of prawns plus mullets, and up to 8000 kg/ha/year of composite cultures of mixed Chinese and Indian carps;
4. the potential for development in brackish water ponds is particularly promising in Bengal because of (a) the vast areas of lowlands bordering the sea that are presently unused in which ponds for brackish water fish and prawn culture can be constructed and operated very economically, and (b) the tremendous abundance of seed of both

prawns and mullets available for the taking in the bordering Bay of Bengal, which is a blessing without measure, and of which I will say more later.

I gained the strong impression from attending these sessions that the program had great vitality, was well funded, was based on sound technology, and held the promise of great benefits for the Indian poeple.

Activities at Kalyani on June 22

My escort for this day was Mr. R. K. Das of the Instutute staff, and our first visit was to the outlying station at Kalyani, which is one of six centers now experimenting with what the Indians refer to as composite fish culture. Polyculture, or the use of multiple species of fish, may be as ancient in India as in China, involving native species of Indian Carps, primarily the mrigal (Cirrhina mrigala), the Rohu (Labeo rohita), and catla (Catla catla). In recent years the Indians have greatly increased total production by combining certain of the Chinese carps with their own Indian carps—often designated as major carps—and it is this combination of the Chinese fishes with the Indian carps that is designated as composite culture.



Indian workers at Kalyani sampling composite cultures of Indian and Chinese carps.

As most commonly practiced it involves stocking the following species in these approximate percentages by number:

	(Silver carp	25%
Chinese	(Common carp	20%
	(Grass carp	10%
	(Rohu	25%
India	(Mrigal	10%
	(Catla	10%

In addition they may use small numbers of various native predator fish to feed on minnows, insects, shrimps and molluscs. The total stocking of all species might include from 5000 to 10000 fingerlings/ha. Experimental ponds observed at Kalyani had been stocked at rates of 6000/ha of fingerlings in the range of 4 to 6 inches total length. These particular ponds were to be harvested after a 6-month growing season because the rate of growth anticipated would permit all of the fishes to attain an optimum "table size" in that period. The ponds are fertilized with both organic (cow dung) and inorganic fertilizers, and the fish are fed such items as oil cake, rice bran, and ground nut oil cake, plus a variety of aquatic weeds or cut terrestrial vegetation for the grass carp. The specific areas of experimentation include variations of such parameters as: (1) The total numbers of fish stocked; (2) the sizes of fish stocked; (3) the percentages of individual species in the stocking ratio; (4) the use of predator fish; (5) types and amount of fertilizer; (6) types and amount of supplementary feed; (7) size and depth of ponds; (8) and harvesting procedures.

The Indians have learned that by combining the Chinese carps with their traditional culture of Indian carps, they can achieve yields as large as 8000 kg/ha/year, which more than doubles their previous range of production utilizing only the native species. With the use of supplementary feeding and heavy fertlization, the highest yield achieved to date has been 9363 kg/ha/year. This remarkable increase in production through the addition of the Chinese fishes is believed due to several factors: (1) the ability of the silver carp to utilize the phytoplankton; (2) the ability of the grass carp to make efficient use of the vegetation, either aquatic or terrestrial, added as supplemental food; (3) the "bonus" of food supplied to the common carp, and possibly to the mrigal, in the form of partially digested material in the faeces of the vegetarian silver and grass carps which have short guts and digest approximately only 50 percent of the materials consumed; (4) the beneficial influence upon water quality through the massive cropping of phytoplankton by the silver carp, and the cleaning up of faecal materials by the common carp.

Unfortunately, no general application of such composite cultures are yet possible. As in Malaysia, the Bengali climate is not conducive to successful hypophysation, and the availability of seed of the Chinese carps is a major constraint upon the full development of fish farming in the freshwater ponds of India. Until this problem is solved, production will be limited to that which can be produced by traditional cultures involving only the native carps.

To gauge the full scale and intensity of the fisheries activities in Bengali one should be there, as I was, during a period when the distribution of seed and the stocking of ponds is at a peak. The young fish are transported in cans having a very distinctive shape, best described as an oversized cuspidor, and in the course of a day's travel down the country lanes and through the villages one might see hundreds of these cans being transported by all available means. It was a very common sight in June to see them hanging in nets from the front or back of such public carriers as trucks or buses.

The station at Kalyani is also a center for research in the culture of frogs, and I was able to observe some of the work in progress, and to discuss the history of this development with the scientist in charge, Dr. A. K. Mondal. I was interested to learn that the Indians do not eat froglegs, due to a cultural taboo, but that India now ranks fourth among all nations in the export of frogs for the world market. The industry owes its start to a visiting American, Mr. Allen T. Sherman, who observed the abundance of wild frogs and in 1955 formed a company for the purpose of capturing and processing them for export to the U. S. The industry has grown to the point that in 1973-74 an estimated 58.5 million frogs were captured and processed for export. The frogs supporting this industry are Rana tigrina, R. crossa, and R. hexadactyla.

In India, as elsewhere, the industry is based primarily upon the capture of wild frogs because no one has yet developed the technology for the economical mass production of captive bullfrogs. The principal constraint derives from the fact that bullfrogs are carnivorous and require live food through at least a part of their life cycle, and it is too costly to produce or capture the amount of live food required. Dr. Mondal is much encouraged, however, by his discovery that the northern race of the green pond frog, Rana hexadactyla, feeds on common aquatic plants through much of its adult life, being carnivorous for a period of only about 2 to 3 months of its early life as a frog, following which it adopts a diet consisting almost entirely of aquatic weeds. Dr. Mondal believes that the phytophagous habit of this frog may supply the advantage that is needed for the development of a technology that will permit the economical culture of this frog in commercial quantities. The present research has two primary facets: (1) To develop the technology for the culture of the phytophagous green pond frog for the purpose of establishing an economically viable industry in the culture of commercial quantities of frogs; and (2) to use induced breeding to produce massive quantities of juvenile frogs to be released into the wild to support the large capture industry of wild frogs.

The Kalyani station is also the location of important new studies in the culture of air-breathing fishes in swamps, under the direction of Dr. P. V. Dehadrai. India has 0.6 millions of hectares of derelict waters that are so shallow and so choked with aquatic vegetation that they cannot support normal fish populations, and have little present value other than being a breeding area for frogs.

The purpose of Dr. Dehadrai's continuing investigations is to develop a culture that could make these waters productive, and his early results indicate good progress. The rather simple technology exploits the air-breathing characteristics of some of India's most unique native fishes, including Heteropneustes fossilis, Anabas testudineus, Ophicephalus marulius, and O. striatus, but of which the best known and most important is the magur (Clarius batrachus). This is the same species that was sensationalized as the walking catfish when a few escaped and became naturalized in some localized waters of southern Florida. These fishes literally breathe air at the pond surface, and can live in water having essentially no dissolved oxygen. The system requires no expenditure for manure, or fertilizer, or other pond management.

One such derelict pond at Kalyani was stocked at a rate of 40,000 magur fingerlings per hectare, which were fed daily with dried marine trash fish. At the last reported sampling the rate of growth indicated a projected harvest of 5000 kg/ha after a growing period of only 5 months. The combined cost of the fingerlings for stocking and the feed to be used projected to a total of about Rs 500 (about \$72.00), against an anticipated income from the sale of the fish of Rs 1900 (about \$228.00). Thus, the margin of profit would appear excellent. The fish are especially high in protein, low in fat, and bring a good price in the local markets. I was served magur for dinner one night in the guest house at Barrackpore, and thought it excellent.

One disadvantage in this type of culture is the difficulty of harvesting the fish from the weed-choked waters. The proposed method is to clear a section of the swamp of all weeds to permit seining, and to remove the fish from this cleared area by repeating seine hauls. The fish would be attracted to the cleared area by baiting.

The procedures would appear to be most applicable to relatively small ponds, but could be used in screened off sections of a larger swamp. The technology is simple and would appear to have good applicability in regions where investment capital may be scarce, and where labor is cheap and plentiful.

Activities at Kakdwip, June 23

This day would have been memorable if only for the experience of sitting beside an Indian driver in a jeep over some 320 kilometers of Indian roads, and in twice passing through the city of Calcutta, once in daylight, and once after dark. Fortunately, there were less terrifying rewards, including the professionally exciting visit to the research station at Kakdwip, and including the company of my escort, the extremely erudite Dr. A. Ghosh, who gave special significance to the day through his discourses on the economics, geography, history and culture of the region.

Our purpose was to visit the Brackish Water Experimental Fish Farm at Kakdwip, which is situated on the Bay of Bengal near the estuary of the Ganges river (known locally as the Hooghly), some 130 km south of Calcutta. The Officer in Charge was Mr. A. N. Ghosh, who, at the time of our visit was conducting a training course for a group of Indian fish farmers. This was the same group that had been assembled for the opening ceremonies and introductory lectures at Barrackpore, and were now reassembled for additional lectures, and a series of field demonstrations in the culture of prawns and mullet in the experimental ponds here at Kakdwip. The course was very intensive, running approximately 8 hours a day for 8 consecutive days, with no break for the weekend. The trainees appeared to range from eager young farmers to older, rather seasoned entrepeneurs. I was asked to offer a few remarks, and this was probably the most attentive and courteous group that I have ever addressed.

As in tidal zones over much of the world, those of India have a long history of brackish water fisheries. The traditional method is to inclose a space by constructing earthen perimeter dikes and providing water gates through which tidal water can enter and be impounded along with the young of a wide variety of prawns, fishes, and other marine organisms. The entrapping is done when the young are believed to be present in greatest abundance. After a period of 7 to 9 months the impoundment is dewatered and everything of value is harvested. It is a "hit or miss" system, and very inefficient. The purpose of the work at Kakdwip is to bring order and efficiency to this primitive system.

The Kakdwip investigations have produced many refinements in such areas as the location, construction and maintenance of ponds, the selection of species most amenable to management, the collection and segregation of prawn and fish seed, the nursery rearing of fish and prawn seed, the development of special management techniques such as the preparation of the pond prior to impoundment, a system for renewing the water and elimination of metabolites, the choice of feeds, methods of feeding, pond fertilization, etc.

The model system of Kakdwip operates in a very simple way. A battery of 0.6-ha ponds are arranged in a double row. The two end ponds in each row are bordered by a small feeder canal, and the series of ponds in each row are interconnected by small, screened channels so that each row can be filled or dewatered in series. The ponds and small feeder canal are separated from a main feeder canal—which might also be a lagoon, or an estuary stream—by a high dike. A single control gate in this dike opens to the small feeder canal so that one person can operate this gate and can fill the entire battery of ponds at high tide, or dewater them during low tide.

Some ponds are operated as nursery ponds to grow the seed prawn or mullets to stocking size, others are operated as growing ponds. The present procedure at Kakdwip is to exchange the water every 10 days in the growing ponds. A low barrier in the channels between ponds retains enough water to support the fish until the ponds can be refilled again on the high tide. This frequent exchange removes accumulated metabolites, and brings in fresh nutrients, and permits a much heavier stocking of the ponds than could be maintained in static water. The ponds can be fertilized, if desired, and the fish or prawns can be provided supplementary feed, or receive none, as desired, but the frequent renewal with water from the bay that is enriched by the heavy organic load provided by the mighty Ganges River assures high levels of production without extra fertilization or feed.

Of some 27 species of prawns that can be seined or trawled from the lagoons and estuaries, 3 have been established as superior, and the farmers have been shown how and where to collect these seed prawns, and how to identify and separate the desirable species. The preferred species are **Pennaeus monodon**, **P.** indicus, and Metapenaeus **monoceros**. The workers at Kakdwip have demonstrated that the prawn **P.** monodon grown in monoculture can produce two crops a year for a total of 1000 kg/ha/year. At the time of my visit prawns were bringing a wholesale price at the pondsite of $7.00 U.S. per kilogram, which would provide a gross income of $7000/ha with only a very modest investment. Seeds of mullet are also available in the area, and it has been demonstrated that a polyculture of mullets plus prawns can raise the production to 2500 kg/ha/year. Thus, the Indian fish farmer has the potential of a gross income per unit of water of something more than three times that of our most efficient catfish farmers in the U.S., and with a great deal less capital investment. I was told that an entire operation of this type can be carried out by a man and his wife, including the capture and selection of the seed, stocking, feeding, pond management, and the harvesting of the crop.

The exceptional character of this fishery is the bountiful supply of seed of both prawns and mullets available for the taking with simple fishing gear and relatively little effort. This contrasts sharply with the situation observed in Taiwan where the prawn farmers commonly pay in the range of from $150 to $800 U.S. for a gravid female in order to obtain seed for stocking.

I was told that India has an estimated 2 million hectares of neglected land that can be developed for such brackish water culture, and that such a development could not only support a rich export industry, but would supply a great deal of badly needed protein for the Indian people.

Visit to Sewage Ponds near Barrackpore, June 24

My escort for this day was Mr. L. H. Rao, one of the scientists in charge of the investigations in the use of domestic wastes in fish production. Mr. Rao made it clear that the Indians, as do most Asians, view their domestic wastes as a valuable resource, and not a problem to be disposed of. Raw sewage is very widely used, most heavily in the Calcutta area, but increasing amounts of sewage in urban areas receives primary treatment in settling tanks. The sludge is reclaimed as fertlizer for field crops, and much of the rich supernatant is used in fish ponds. Many fish farms are located adjacent to the treatment plants in order to exploit this valuable resource. Although the custom is extremely common, it is not yet conducted on a very efficient basis. We viewed one privately owned 2.5-hectare pond adjacent to the sewage treatment facilities at Barrackpore. Most such ponds are stocked only with Indian carps due to the shortage of seed of the Chinese carps. Stocking is with fingerlings at rates as high as 50,000/ha, usually in the ratio of 5 catla to 2 rohu to 3 mrigal. The procedure is to introduce one large initial "shot" of the sewage effluent, followed by subsequent smaller doses as appear to be needed. Cropping of the faster-growing fishes is begun about 3 months following the initial stocking, and continued as the remaining fish attain a useful size. Such operations yield an abundance of fish for the table, and a continuous income over the 7 or 8 months that the fish are cropped and sold on the local market.

The experimental program of the Central Institute for Fisheries Research is conducted in a series of small ponds utilizing supernatant from the treatment plant operated by the City of Barrackpore, and additional land has been purchased for the expansion of this program.

The supernatant from the settling ponds has a BOD_5 of between 300 and 400 mg/1. It is introduced into the experimental ponds at a ratio fo 1 part supernatant to 3 parts fresh water. The BOD is reduced to a range of 30 to 40 mg/1 in about 45 days, at which point the fish are introduced. Following the introduction of fish there is a further reduction of BOD to as low as 6 mg/1, which is credited to the influence of the fish in cropping the plankton and other organic materials. Additional supernatant is introduced after about 4 months, followed by smaller doses at about 2-week intervals, based upon continuously monitored water quality parameters, and the judgement of the operator. Two of the most productive populations tested to date have been (1) a composite culture of 3 Indian carps (rohu, catla, mrigal) and two Chinese carps (silver carp and common carp), which have produced yields as high as 6,450 kg/ha in 9 months, and (2) a stocking of Tilapia mossambica alone at densities of 17,000/ha, which have produced yields as high as 10,000 kg/ha in 12 months.

A disadvantage of this last culture is that the tilapia are extremely prolific, since they are capable of spawning every 3 to 6 weeks, and a major part of the production consists of fish smaller than 4 inches in total length. They had just initiated experiments with a combination of male tilapia and an air-breathing Clarias, the so-called walking catfish, in a ratio of 1 to 1 at a total density of 40,000 fish/ha. Both are excellent table fish, and both are highly efficient consumers of most things organic. The use of all male tilapia will eliminate the excessive production of small fish, and this is expected to be a highly productive combination.

Again, the purpose of these experiments is to develop simple, but efficient procedures that can be used by the Indian farmers. One effective method of publicizing their findings is to invite the public to observe the final harvesting operations and to purchase the fish at extremely attractive prices. The private fish farmers take a benevolent view of this competition because they are aware that the experimental programs contribute to their welfare. The fish are consumed very shortly following their removal from the sewage-enriched ponds with no apparent danger to the consumers.

Final Day in Seminar and Discussions, June 25

One important supplementary function of the Central Institute for Fisheries Research is to utilize their large and competent staff, and their extensive facilities, complete with dormitory and lecture halls, to conduct courses for prospective future scientists while on breaks from their Universities. A group of students was in residence at the time of my visit, and the morning of this last full day of my stay at Barrackpore, I was asked to present a seminar for the students and the regular research staff in their large lecture hall. This was an extremely edifying experience for me, and led to a series of interesting discussions throughout the remainder of the day. As experienced elsewhere in Asia, the Indian scientists were impressed that our rates of production utilizing swine manure and no supplementary feed were on a par with their rates of production using both organic wastes and extensive supplementary feeds. Again, one must wonder if our temperate climate may not be more suitable for the exploitation of the Chinese carps than the purely tropical climates of Bengal, Malaysia, and other areas visited in southern Asia.

I regret that I was unable to visit the famous research station at Cuttack, with its distinguished corps of scientists, but my days at Barrackpore were full and rewarding, left me much to contemplate and some very favorable impressions. I gained the definite impression that the full force of all energies and activities of the Institute were directed toward the immediate benefit of the people, as evidenced by the extremely practical nature of their programs. Each seemed designed to develop techniques that were appropriate to the environment, relatively economical to implement, simple to operate, and showed promise of high productivity. I also was strongly and favorably impressed by the scope and quality of the extension activities conducted in cooperation with the State of West Bengal. In addition to short courses, and other educational programs, such as those described at Barrackpore and Kakdwip, it features a large network of demonstration areas. The method of operation is to contract with pond owners to utilize their ponds to demonstrate new systems of culture, to invite all interested farmers in the area to observe the operation and the final harvest, and to reward the pond owner for his participation by permitting him to sell the fish produced in the demonstration program. A total of 150 such demonstration projects were in progress at the time of my visit, and this program was being expanded to include 300 demonstration ponds located throughout the State of West Bengal.

ISRAEL, June 28 - July 3, 1976

In terms of developed technology, and in the efficiency of production of edible fishes in freshwater ponds, the fisheries of Israel are probably the most advanced in the world, and the history of this development is hardly less exciting than that of the political development of this energetic young nation. It had its beginnnings at a Kibbutz founded at Nir David in 1934 by a small group of immigrants, including two energetic young men, S. Tal, from Poland, and S. Sarig, from Lithuania. They had chosen their location at Nir David because of the presence of a strong spring of water, with which they planned to irrigate the surrounding desert for the production of vegetables and other food crops. They soon learned, however, that the water was too brackish for such use, and they began to consider other possibilities. The idea of raising fish in the Israeli desert was considered to be such an impossible vision that it was two long years before the British magistrate could be pursuaded to authorize the construction of 3 ponds. While the ponds were under construction young Tal was sent to Yugoslavia to receive training in the culture of carp, and in 1938 Tal brought the first common carp to Israel. The project was an immediate success, and within 3 years a total of 1500 acres of ponds had been constructed and brought into production in various parts of Israel.

At the time of my visit 86 farms were producing fish, and Sarig reported that in 1974 a total of 4823 hectares (11,913 acres) of ponds produced 12,169 tons of fish actually sold in the markets. The consumption of pond-reared fish in Israel now exceeds that caught from the sea. Dr. S. Tal is now the Director, and Dr. S. Sarig is the Deputy Director of the Fish Culture Division of the Department of Fisheries in the Israeli Ministry of Agriculture, and both still live on the Kibbutz that they helped to found in 1934.

The Israelis utilized the German system for producing common carp in monoculture for about the first 10 years, with an average production of about 800 pounds per acre. Some of the first innovations were to increase the density of fish in monoculture, and to stock two sizes of carp in the same pond to better utilize available food and "growing space." Their first experiments in polyculture involved the combination of common carp with either the tench (Tenca tenca) from Europe, Puntius javanicus from Indonesia, Catla catla from India, or the grass carp (Ctenopharyngodon idella) from China. Their first major success in polyculture involved the combination of the common carp with mullet (Mugil spp.). Simultaneous experiments were being conducted with various species of tilapia, both in monoculture, and as a polyculture with carp and mullet, which proved highly successful. Further increases in yield were achieved through the use of all male tilapia, produced through hybridization. This eliminated unwanted reproduction by tilapia, and exploited the faster growth rate of the males. Finally, with the addition of the Chinese silver carp to their high denstiy polyculture, coupled with the use of both organic (either domestic sewage or liquid cowshed manure) and inorganic fertlizers, supplementary feeding, and intensive aeration, they have raised the levels of production in static ponds to the highest achieved anywhere in the world, with the possible exception of certain Asian cultures utilizing air-breathing species of Clarias. They first feared that the consumption of plankton algae by large numbers of silver carp would decrease the biomass of algae and decrease the production of bottom fauna important as food for the common carp, and the accumulation of detritus for the tilapia and/or mullet, and thereby decrease the production of these companion species. However, in a series of experiments conducted by one of Israel's most distinguished scientists, the late Dr. A. Yashouv, who was well known in the U.S., they discovered that the production of each species was actually greater when they were combined, than when each was raised separately. Dr. Yashouv demonstrated that the common carp and tilapia benefited through ingestion of partially digested plankton algae in the faecal pellets rained down on them by the silver carp, a bonus food not ordinarily available to them, and that the silver carp benefited through the burrowing activities of the common carp in the pond bottom. Burrowing by the common carp benefits the silver carp in two ways: (1) it stirs up organic particles useful as food by the filter-feeding silver carp, and (2) it prevents the growth of filamentous algae on the pond bottom which would compete for nutrients and decrease the production of plankton algae utilized as food by the silver carp.

One becomes immediately aware in Israel of the quality and intensity of their effort, and the dedication of their workers. The Israeli scientists are exceptionally capable and strongminded and are now rather decisively divided in their opinions as to the lines of research and development that should be pursued. One group favors a maximum exploitation of both domestic and animal wastes in the production of fishes, with the justification that it would permit savings in both labor and money, and would place lighter demands on such critical resources as protein and energy. The dissenting school takes the view that their most immediate responsibility is to obtain the maximum possible production from available land and water, utilizing whatever might be required in terms of initial investment, labor, protein and energy, arguing that higher total production could be achieved at the same cost per unit of the product produced. The opposing philosophies surfaced at the meetings in Kyoto, and I was told then by Dr. Tal, the leader of the Israeli delegation, that when I visited Israel he would expose me fully to both sides of the controversy so that I might make my own evaluation as to the merits of the opposing views. I was privileged to visit both centers of research that are involved and concluded that it was to the considerable advantage of the rest of the world that both lines of research are being followed.

June 29, in the company of Dr. B. Hepher

My first field trip in Israel was in the company of the distinguished Dr. B. Hepher, whom I had first met at a conference on waste management in Oklahoma City in March, 1974, and with whom I participated in a work session at the Kyoto meetings devoted to the use of agricultural wastes. Dr. Hepher is one of Israel's best known scientists, and its chief proponent of the use of organic wastes in fish production.

Our first stop was at the Gan Shmuel Kibbutz located about 45 miles north of Tel Aviv, and 6 miles inland from the Mediterannean Sea. As do a number of the kibbutzim, Gan Shmuel functions both as a production center and a satellite research facility. Dr. Hepher was cooperating with Kibbutz personnel in the hybridization of tilapia, the spawning of the Chinese carps through hypophysation, and in polyculture experiments. The polyculture in use at this kibbutz included two sizes of common carp, silver carp, grass carp, mullet, and two sizes of tilapia. Ponds were stocked in June, were harvested in October or November, and were immediately restocked to provide a second harvest in June-July. By such double cropping, they had achieved a total production of as high as 10 tons/ha/year.

At Gan Shmuel we also saw a highly automated system for harvesting, weighing and packaging the fish. After the pond was partially dewatered the fish were concentrated by seine. A powered conveyer system on wheels was then situated so that a moving "bucket" transported the fish from the seine to the top of a track where they were dumped into a tank truck and moved to a nearby fish handling complex. The fish are first separated by size, those too small for market falling through a screen into a tank in which they are returned to the pond for further growth, the marketable fish enter a tank of very cold water to be immobilzed by cold shock. The common carp are sent to market alive; all other species are boxed in ice. If only a single species is being handled, the fish can be weighed and boxed without being touched by human hands. When polycultures are harvested, the various species must be pushed from the main conveyer belt into their special slots from which point the system becomes automatic. The entire process moves very rapidly, and the fish go through the nearest of 26 separate distribution centers to reach the retail market before noon of the morning in which they left the pond.

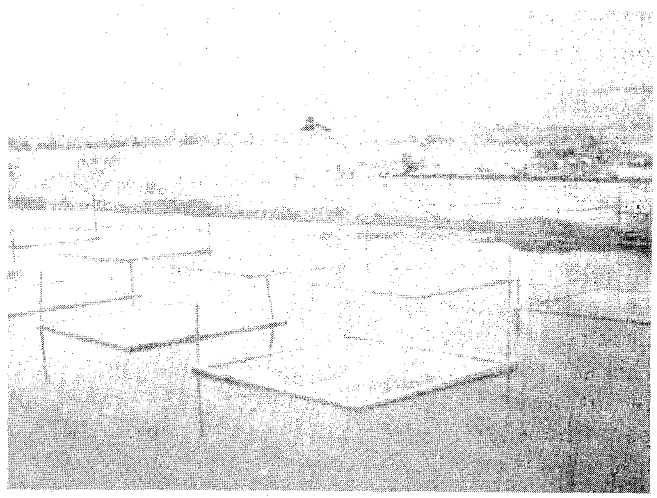
We next visited a kibbutz having the intriguing name of Ma' Ayan Tzui. Our purpose was to see the latest version of a highly sophisticated fish feeder. Unlike most automatic, or demand feeders, which drop feed in a single spot below the food bin, this feeder distributed food over a transect of about 100 feet by means of an augur turning in a perforated tube extending horizontally from the feed bin out over the water. By means of electronic controls it could be operated as an automatic feeder, dropping feed for, say, 15 minutes at intervals of 90 minutes, or at whatever interval was desired, or it could be programmed to operate on demand by the fishes. Two sensors, several feet apart, projected from near the middle of the food-conveyer tube down into the water, and when sufficient fish were on hand to activate both sensors, or receptors, it dropped food as long as the fish continued to feed.

Our final destination was the famous research station at Dor, on the Mediterranean shore approximately 50 miles north of Tel Aviv, where I was amazed by the variety and intensity of the work being conducted.

In the field of genetics they are continuing their efforts to combine the best qualities of the European carp, which is most efficient in high quality water, with the toughness of the Chinese carp, which excels in highly enriched waters. They have narrowed their testing to 5 different combinations of the two blood lines.

In the field of nutrition, Dr. Hepher has devised ingenious methods of measuring energy used, energy lost, nitrogen retained, and nitrogen excreted, in assessing the digestibility of foods by fishes. The laboratory evaluations are tested in a large outdoor pond partitioned by screens to provide a large number of individual testing areas.

In one polyculture pond they were studying the potential for feeding large numbers of grass carp on a floating duckweed, Lemna sp. The plant is extremely prolific, and to confine its growth, and to prevent excessive shading and elimination of photosynthesis in the pond waters, the floating plants were confined in large floating frames so that only a fraction of the pond surface was shaded.



Ponds at Dor, Israel, showing duckweed being cultured in frames as food for grass carp in polyculture experiments.

In comprehensive studies of what might be called oxygen dynamics, they have greatly improved our understanding of the delicate balance between oxygen production and consumption in ponds enriched by organic wastes, and have illuminated the complex interactions, both with the environment, and with associated species, of the various fishes used in polyculture. As an example, they can calculate the organic load that can be oxidized in a pond without fish, the additional amount that can be safely consumed (oxidized, metabolized, etc.) by a certain combination and density of fish, and the still greater amount that can be consumed through the addition of the silver carp. The major flow of energy is from the manure to the plankton algae to the silver carp, and secondarily into the companion fishes, primarily through the ingestion by the common carp and tilapia of undigested plankton algae in the fecal pellets of the silver carp. A synergistic interaction is developed whereby such species as the silver carp, the common carp and the tilapia can be shown to each produce greater poundages when combined than when each is cultured separately, while at the same time exercising a beneficial influence on water quality.

Major studies are continuing in the use of both cow manure and domestic sewage in ponds containing polycultures. The latest addition to their polyculture is the Chinese bighead carp, a filter-feeder on zooplankton, which increased the total used in some experiments to seven species.

At the time of my visit Dr. Hepher and his collegues were developing a master design for what will probably be the most comprehensive studies ever made of either polyculture, or the use of organic wastes. It will involve simultaneous studies in 50 contiguous ponds each 0.1 ha in size. The principal thrust of the experiment will be to compare the yields from (1) populations that receive only a standard ration of a pelleted feed; (2) populations receiving only manure; and (3) populations receiving both manure and a supplemental feed. All of the above treatments will be conducted at a standard density of 4800 common carp, 1500 silver carp, 500 grass carp, and 2500 tilapia per hectare. In a second complete series the population density of all species will be doubled. Also within this same experimental design they will test 5 different strains of the common carp, and will compare the efficiency of both Tilapia aurea and a hybrid of T. aurea x T. nilotica.

This extremely rewarding day ended most pleasantly in the sharing of a meal with Dr. Hepher and his wife, two daughters and a grandson in their home in Hadera.

June 30, in the company of Dr. S. Tal

On my second excursion in Israel I was taken by Dr. S. Tal to the largest of Israel's 26 fish distribution centers located in Tel Aviv, to view the second stage in the marketing and distribution system. There are no private fish farms in Israel. While each kibbutz can make the decision as to if, and how it shall raise fish, all belong to a marketing association which is completely coordinated by the Ministry of Agriculture. The fish farm advises the distribution center in its district that it will have so many fish ready for harvest by a certain date, and it is then advised on what day the fish can be delivered. The demand is large and the center is certain that all fish delivered will be sold on the same day. The fish are taken from the pond early in the morning and are passed through the distribution center before noon of the same day. The common carp are sold at a price established through negotiation with the government, all other species are sold at auction. The live carp proceed very quickly into the fish trucks of the retailers, other species iced in boxes pass immediately by conveyer belt into an auction room where the fish-buyers are assembled. While the fish are in continuous motion the bids are made and the boxes coded for each buyer and moved on to an area where they can be loaded into the buyers' trucks. By late morning the action was over, and I was then taken by Dr. Tal into the large, open-air retail market to see the final stage in the marketing process. We visited a number of fish shops, each with its displays of fresh, iced fish, both marine and fresh water, and each with its aerated tank containing live carp. We watched as one Israeli housewife chose her fish, saw it netted from the tank, and then supervised its preparation for the kitchen. There are 350 retail fish markets in the City of Tel Aviv, which would seem to testify as to the importance of fish in the Israeli diet.

July 1, with Doctors Tal and Sarig at Nir David and Genosar

On my next excursion in Israel I joined Dr. Tal for an early morning drive through irrigated valleys and dry hills to the Kibbutz of Nir David, approximately 100 miles northeast of Tel Aviv, which is the oldest fish farm in Israel. In addition to fish farming, and standard agricultural pursuits, it now operates a turkey farm, two small factories, and a laboratory which is the center for fish disease studies in Israel, under the direction of Dr. S. Sarig. Following a brief inspection of the facilities at Nir David, I joined Dr. Sarig for a drive of some 50 additional miles to Israel's newest research station at Genosar. I was told that Israel's Secretary of State is a member of the Genosar kibbutz, and when at home takes his regular turn at serving meals or clearing tables in the communal dining hall just as any other kibbutznik.

The Genosar station has a very picturesque location on the shores of the beautiful Sea of Galilee, now also called Lake Kinneret, which is the source of water for Genosar's large battery of experimental ponds. This station was constructed in 1972 for two principal functions; (1) to propagate fingerlings of tilapia, mullet and silver carp for stocking Lake Kinneret in support of its captive fishery, and (2) to conduct experiments in intensive fish culture.

In the Israeli context, intensive culture involves the maximum utilization of all such available resources as fertilizer, food, aeration, and high density of fishes, to achieve the absolute maximum production per unit of water area. Doctors Tal and Sarig believe that with anything less than maximum production the nation might be better served by utilizing the space and water for the production of other crops. Within the past 2 years they have, in fact, reduced the area of ponds in Israel by about 2 percent in order to use the land and water for what they believed to be more productive purposes.

The Israelis have found that in their climate a growth period of 200 days is normally adequate to produce a useful crop, and they have adopted the 200-day interval as their standard growth period. While many experiments are conducted over periods as short as 45 to 100 days, they use the growth curves obtained in the shorter period to project the production that could be obtained in 200 days.

The earliest experiments at Genosar involved monocultures of either tilapia or common carp at extremely high densities, and yielded some rather spectacular results. Perhaps the most striking finding was that in ponds receiving intensive aeration the individual growth rate of tilapia was independent of density up to a density of 80,000 fish per hectare. At this maximum density they achieved growths over an experimental period of 100 days that would have produced yields of between 33 and 36 tons/ha if the rate of growth could be sustained over the 200 day growth period. Common carp stocked at densities of 50,000/ha over experimental periods of 45 to 50 days had daily growth increments that would have produced 30 tons/ha if maintained over a full growing period of 200 days. These rates of production would be truly phenomenal if actually achieved. The Israelis have found, however, that a growth inhibiting factor develops after periods of from 50 to 70 days when the ponds are stocked at such high densities. They have found that if the fish are transferred to a pond having fresh water the fast rate of growth will be resumed. The elimination of this growth-inhibiting factor is a high-priority project at Genosar. Other high-priority investigations include: (1) comparing the efficiencies of six different systems for aerating pond waters; (2) evaluations of various types and combinations of feed; (3) evaluations of 3 types of manure, including liquid cow-shed manure, dry "corral" manure, and poultry manure; (4) investigations of the optimum amount of supplemental feeding in ponds enriched with manure ; and (5) the use of new species in intensive culture. Many of the replicated experiments are conducted in small ponds having an average depth of 80 cm, a total volume of 200 m^3. They would now prefer that the ponds have a volume of 500 m^3. The work is supported by the Ministry of Agriculture, the Association of Fish Breeders, and through the sale of fish.

Following the observation by Dr. Sarig that "man does not live by fish alone," I was taken for a pleasant interlude at the nearby site of Capernaum, or so-called "City of Jesus," to view the ruins of the temple where Jesus is believed to have begun his teaching. We then went to a small restaurant on the Sea of Galilee to enjoy a late lunch featuring an excellent preparation of Tilapia galilaea, which is said to be the same species caught by Peter in the time of Christ.

We returned in the late afternoon to Nir David, where I joined Dr. Tal for a refreshing swim in the spring-fed stream which bordered his living quarters, followed by the sharing of the "family hour" with Dr. Tal and his wife, daughter, son-in-law, and two small grandchildren. At Nir David the work day ends at 4:00 p.m., and the hours of 4 to 8 are devoted to the children. These are the most important hours of the day at Nir David because beginning at the age of 3 months, all children live separately from their parents. At about 6:30 p.m. we joined the rest of the kibbutzniks for dinner in the communal dining hall, where the meal was excellent, and the atmosphere was refreshingly gay and social. I gained the strong impression that the Nir David Kibbutzniks live a very happy and productive life. Those not finding it so, of course, are free to leave at any time. We later strolled through much of the kibbutz on pleasant, shaded lanes, and stopped by the very active social center where a late American film was being shown. At about 10:00 p.m., after an extremely full and rewarding day, I was made comfortable for the night on the day-bed in the small living room of the Tals' pleasant but modest quarters. It was interesting to me that this distinguished and important man lived this simple life on a kibbutz, to which he relinquished his salary and all other worldly goods. Yet he was, without doubt, a very proud and happy man.

Early on July 2, following a typical Israeli breakfast, featuring eggs, cheese, yogurt, a variety of fresh vegetables and two kinds of fish, I was placed on a bus for a 5-hour ride to Jerusalem, from where, two days later, I left this pleasant land.

ROME — YUGOSLAVIA

Following a brief layover in Athens, en route from Israel to Rome, I undertook a review and evaluation of my experiences with Dr. T. V. R.

Pillay and his colleagues in the fisheries branch of the FAO headquarters in Rome. It was they who had planned my original itinerary, and the exchange was very rewarding. I was particularly pleased to have a discussion with Dr. Y. A. Tang, a Taiwanese, who had conducted fisheries investigations in Taiwan, and was helpful in evaluating some of my observations in his native land.

In Rome I also received confirmation from Budapest that my request to visit Hungary had finally been approved.

While in Israel I had been advised by both Tal and Sarig that I would find it extremely rewarding to visit Dr. N. Fijan in Zagreb, Yugoslavia, if it could be arranged. Dr. Fijan was trained as a virologist, but has become a chief fisheries administrator in Yugoslavia, and one of the rising stars in the world of fisheries. I therefore made plans to drive into Yugoslavia in the company of my wife and two friends who had met me in Rome. Visas were easily arranged through the Yugoslavian embassy in Rome, but I found it impossible to reach Dr. Fijan by phone, either from various points in Italy, or after entering Yugoslavia. We reached Zagreb late in the evening of July 15 only to learn that Dr. Fijan either had no phone, or had an unlisted number, and was leaving on holiday early the next morning following a final, brief visit to his laboratory. Wishing to make at least the briefest of contacts, I managed to be waiting in Fijan's office when he arrived the next morning. After recovering from his surprise, he was extremely apologetic that the circumstances permitted us so little time together, and that he was unable to have me escorted into the countryside without the time to obtain clearance, and make other necessary arrangements. We soon uncovered mutual friends because Dr. Fijan had studied in the U.S. where he had made the first identification of the catfish virus, which was an extremely important contribution to our catfish farming industry. He very graciously permitted me to record our approximately 40-minute conversation as briefly summarized below.

Dr. Fijan pointed out that unlike Israel, Yugoslavia has abundant water and a surplus of marshy and otherwise marginal farm land suitable for fish ponds. They therefore practice extensive, as opposed to intensive fish culture, finding it more economical to use very large ponds, with a minimum expenditure of feed and fertilizer. The fish farms range in size from 300 to 3000 hectares. Nursery ponds may be as small as 50 ha, but the fattening ponds never contain less than 100 ha. Organic fertilizers are sometimes used in the smaller nursery ponds, and inorganic fertlizers may be used sparingly in the large fattening ponds, but they find it impractical and unnecessary to extensively fertilize such large ponds. Their average production is only about 1500 kg/ha/year, but such a yield from a total of 10,000 hectares is adequate to meet their needs.

Whereas the common carp historically comprised 95 percent, and the European tench 5 percent of their national production, they are now using increasing numbers of silver, grass and bighead carps in polyculture. The silver and bighead carps have so far gained poor acceptance in the market, and are raised in only small numbers, but the grass carp has become highly favored, and is in great demand.

The grass carp was first imported to control weeds, which are a major problem in the large, shallow (1 to 1.5 m) Yugoslav ponds, and to eliminate the large, annual expenditure for importing and operating expensive, mechanical weedcutters. In addition to its major contribution in weed control, the grass carp has become not only the most popular food fish in Yugoslovia, but its most popular sport fish as well. Approximately 100,000 Yugoslav sport fishermen are now organized into clubs for the primary purpose of acquiring fishing rights in lakes, impoundments, and certain rivers, and of promoting the stocking of grass carp as a sport fish in these waters. The grass carp is caught primarily on worms and doughballs of various types, and is glorified for its fighting abilities, as well as its table qualities. Insofar as I could learn from Dr. Fijan, the grass carp had perpetrated no serious damage to the Yugoslav environment, or to its native fish species, and the Yugoslav scientists and conservationists seemed to share the public's enthusiasm for its introduction. This contrasts rather sharply with our American situation where many professional conservationists and sportsmen are concerned that the grass carp may prove harmful to our environment and associated species, and strongly oppose its introduction.

While the brevity of my formal exchange in Yugoslavia was regrettable, I found it to be both enjoyable and rewarding.

HUNGARY, July 18 - 20, 1976

While still in Italy I had phoned Mr. Imre Csávás, my official contact in Hungary, and completed arrangements for meeting in Budapest on the afternoon of July 18. In the meantime we had passed out of Yugoslavia, and on the appointed day I left my wife with friends in Graz, Austria, and caught a train to Vienna, from whence I flew to Budapest.

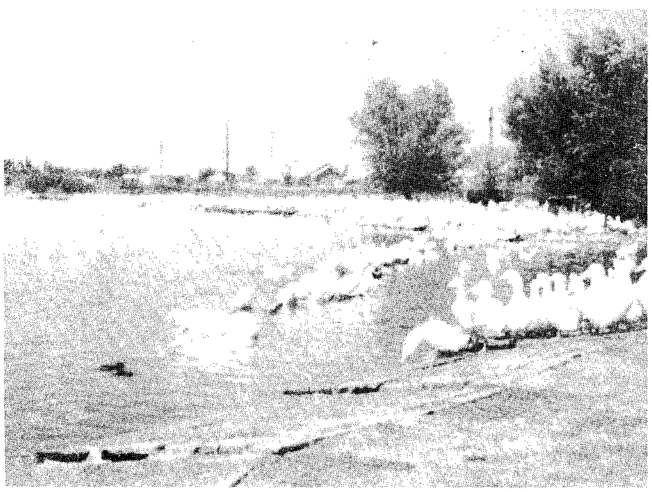
Mr. Imre Császás was trained as an agricultural engineer, and together with his colleague, Dr. Laszlo Vermes, has gained wide recognition over the past decade for the development of a number of large, highly integrated agricultural systems for the utilization of both agricultural and domestic wastes in the production of both fish and agricultural crops. Mr. Császás is now associated with the Fish Culture Research Institute in Szarvas and holds the position of Project Manager for a major program of fisheries and agricultural development sponsored in Hungary by the FAO. Mr. Csávás greeted my arrival with great cordiality, and in excellent English. With his great energy, vast knowledge, and matchless charm, he was to fill my next 2½ days with some of my most memorable and rewarding experiences.

<u>July 19 - Trip to Lake Balaton, Fonyod and Enying</u>

Our first objective early on June 19 was a research station on the shores of Lake Balaton, an approximately 2-hour drive southwest of Budapest. Lake Balaton has several notable characteristics: (1) it is the largest natural lake in Europe and a popular vacation center; (2) it occupies a long, narrow, shallow valley, with the unique dimensions of 74 km in length, a rather uniform 3 km in width, and an average depth of only 1.5 m; (3) it is surprisingly free of pollution, clear and attractive in view of the fact that its entire shoreline is congested with. summer houses, hotels, and other recreational developments. The sustained high quality of the water in such a heavily used recreation area is a considerable tribute to the Hungarian Water Board. This controlling agency eliminated all forms of industrial pollution (heavy metals, PCBs, etc.) by prohibiting the establishment of any industry anwhere in the watershed. It greatly minimizes pollution from domestic sewage by requiring all dwellings, summer houses, hotels, etc. to be connected to a sewage system with at least primary treatment facilities. Much of the effluent from the treatment plants now receives tertiary treatment in fish ponds, or is utilized on crop lands. They have an ambitious program of research and development whereby in 15 years the total sewage generated in the entire watershed will receive either tertiary treatment in state-owned fish ponds, or will be utilized to fertilize state-owned crop lands. The local center for this project is the Hungarian Water Board's research station at Fonyod. This station has two primary functions: (1) to monitor the water quality of Lake Balaton, all influent waters, and all sewage treatment plants in the watershed; and (2) to conduct research in the use of domestic wastes in fish culture. The station is now in its fourth year of investigations. Their first goal was to develop an efficient and practical method for introducing the effluent into the fish ponds, which led to the choice of an overhead sprinkling system. Their second goal was to determine the loads that could be oxidized without killing the fish. Their continuing efforts are attempting to determine the optimum combination of fishes to be used in polyculture. These studies are being conducted in a unique and extravagant array of ponds constructed especially for this project. The complex can be described as having the appearance of one-half of a wagon wheel. Within the hub of the wheel are pumps and valves for distribution of the wastes to the ponds. Radiating out from this hub, like the spokes of a wheel, are dikes which separate pie-shaped ponds. A semicircular dike divides the pie-shaped ponds so as to create two series or semicircles of ponds of two different sizes. The inner circle contains 6 ponds each 0.17 ha in size, the outer circle contains 6 ponds exactly 10 times larger, or 1.7 ha in size. The total of 12 ponds contains 11 ha of water area. This 11 ha of fish ponds receives all of the presettled sewage (supernatant) from a community numbering between 5 and 6000 people. In 1975 the total load was divided so that one large and one small pond each received similar loadings per unit of area at rates varying from 5 to 250 m^3 of supernatant/ha/day. The results indicated that the optimum loading was in the range of 50 to 80 m^3/day. In 1976 all ponds were being loaded at a similar rate (50 m^3/day), and randomly selected pairs (one large and one small) were receiving the different combinations of fishes that were to be tested. Results to date indicate an optimum stocking ratio per ha of sewage-fedpond would contain the following 5 species in these approximate numbers and sizes: 972 tench of 30 g each, two sizes of common carp (810 of 30 g and 1185 of 250 g), two sizes of silver carp (810 of 10 g and 1272 of 225 g), two sizes of bighead carp (810 of 15 g and 835 of 275 g), and 486 grass carp weighing 200 g each. The procedures developed at Fonyod will be used in production units to be constructed by the state throughout the lake Balaton watershed.

The Hungarians have long received special recognition for their expertise in the combined culture of ducks and fish, and at my request we next visited a neighboring state farm having such a duck-cum-fish operation. This particular farm was raising 11,000 ducks on one 47-ha pond, and

16,000 ducks on another pond of 43 ha. The ponds were stocked with common carp, silver carp and grass carp. Bighead carp would have been used if available. The duck raising is fully coordinated with the fish-growing season. This permits the production of three crops of ducks and one crop of fish between late April and late September. The ducks used here were an English breed, called Cherry Valley, which matured to a weight of 2.5 kg in 51 days. Mr. Csávás told me that most farms use a hybrid duck developed in Hungary which attains a weight of 2.8 kg in only 46 days. Mr. Csávás further stated that it was a common practice to hold between 5 and 600 ducks/ha of water in a pond having an optimum polyculture of fishes, and that this could yield as much as 2.5 tons of ducks and 2.5 tons of fish/ha in the period from April through September. At the time of my visit the gross income from ducks was about $2000 U.S. per ha.



This duck-cum-fish farm in Hungary produces three crops of ducks in each 6-month fish growing season.

Our next stop was at a large state farm near the town of Enying having a highly integrated system producing large quantities of hogs, fish, alfalfa, wheat and corn. The total area of this farm was 5000 ha, of which 500 was under irrigation. It produced 10,000 fattened pigs per year, and the entire production of pig manure was pumped as a slurry into some large holding tanks for distribution into 49 ha of fish ponds, or onto 500 ha of irrigated crop land. One 32-ha pond stocked with a polyculture of carps was receiving 1 m^3 of slurry (1 part solids, 2 parts water) per ha/day without loss of oxygen, and yielding an effluent of better quality than the small stream which fed the pond. The 32-ha pond had an annual production varying between 60 and 80 tons of fish. A common formula in Hungary is to distribute the manure from 5000 pigs over 500 ha of irrigated land. At Enying they were irrigating alfalfa and wheat. The wheat had just been harvested and the alfalfa was being irrigated by large overhead sprinklers. The sprinklers are served by a system of underground pipes with hydrants located through the fields in a pattern of 500 m between hydrants from north to south, and 90 m between hydrants from east to west. Irrigation "water" was 5 parts water and 1 part slurry—the slurry was 2 parts water and 1 part solids. From 5 cuttings the yield of alfalfa was about 10 tons/ha.

We ended our day in the field with a swim in Lake Balaton, and I was deeply impressed by the low level of eutrophication in an ancient lake completely surrounded by people, houses, and farm lands. If the Hungarians can do it, why can't we?

July 20 - Hungarian Water Board and Szazhalombatta

On the morning of July 20 I was taken by Mr. Csávás to the Budapest headquarters of the Hungarian Water Board for an exchange with Dr. Lazslo Vermes, a senior research associate and an international authority on waste management. Dr. Vermes had spent 6 months in the U.S. visiting our research centers. The exchange was rewarding in three special ways: (1) From his files Dr. Vermes provided much useful technical data on the results of their experiments in waste management and water quality control; (2) he described a particularly interestng waste management project; and (3) he was an extremely personable man.

I was much impressed by the waste management project referred to above, which provided for the complete utilization of the sewage from 75,000 people, plus some food industries, but no industrial wastes, from the city of Kecskemet (pronounced catch-ka-meet). It incorporated three separate systems, any two of which was capable of handling the entire sewage load, with the third unit for "security." The only previous treatment was mechanical, in a settling basin. The supernatant was then distributed to one or more of the following: (1) by overhead sprinklers on 400 ha of arable land (pasture, hay, and other crops fed to animals), receiving a total of 2,000 m^3/ha/year, with the supernatant having a BOD_5 in the range of 160 to 370 mg/1.; (2) to a 76-ha poplar plantation (providing pulp for paper), with the distribution made by surface furrows, and having a capacity for 20,000 m^3/ha/year, or 10 times that sprinkled on the arable land; and (3) by surface irrigation on an 8-ha grassed filter field having perimeter dikes for water retention. This filter bed was in sandy soil, with good drainage capacity, and contained an underground system of tiles at a depth of 1.5 m for transporting the filtered water to an adjacent stream. This system had a capacity for 80,000 m^3/ha/year. Tests indicated that all three systems could function indefinitely. The operation costs were about 2/3 of those for a conventional treatment system providing both mechanical and biological treatment.

In the late morning we drove about 30 km south of Budapest to visit Hungary's "showpiece," the new fish propagation unit with controlled water temperature at Szazhalombatta, constructed largely with funds provided by the FAO World Food Program. Its primary purpose is to provide fry and fingerlings of tench, pike, pike-perch, European catfish, common carp, silver carp, grass carp and bighead carp for stocking 10,000 ha of fish-rearing ponds on Hungary's state farms. The facility contains a large (1600 m^2), extremely modern, indoor spawning house and 70 ponds with a total area of 25 ha. The unit is located on the Danube River adjacent to a large power station. The special quality of the unit comes from its use of warm waters provided by the cooling towers of the power station. The warm water permits temperature control in spawning ponds and indoor hatching units, and an extension of the fish-breeding season. For example, the season begins with the spawning of pike in February, and continues into July with the Chinese carps. The staff is competent, their techniques are advanced, and the equipment is modern.

The staff at Szazhalombatta also conducts research. Special projects have included (1) the development of procedures for the mass production of the European catfish (Silurus glanis), and (2) the refinement of techniques permitting the production of natural foods having special value in the rearing of fry and fingerlings.

The visit to Szazhalombatta completed my official itinerary in Hungary. The total Hungarian experience was a genuine revelation because I had not anticipated that they would be so advanced in their concepts and technology. I was impressed by the competence of their personnel, and by both the quality and scale of their waste management projects. My observations suggest that in the control of pollution in such waters as Lake Balaton, and in the management and exploitation of their organic wastes, they are years ahead of the U.S.

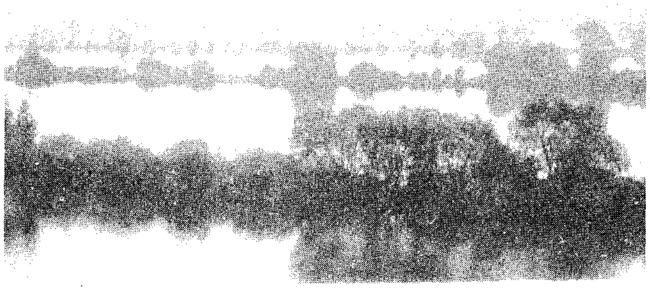
MUNICH

July 23 - Bavarian Research Institute and Munich Sewage Ponds

My last professional visits in Europe were to the Bavarian Research Institute at the University of Munich, and to the famous carp ponds of the Bavarian Power Company utilized as a treatment facility for the settled or partially treated sewage from the City of Munich.

By phone from Austria I had confirmed my previous correspondence with Dr. Manfred Ruf, Director of Bavarian Research Institute, that I could be in Munich on July 23. I was received by Professor Ruf at 10:00 a.m. on the appointed date, and after a brief conversation, and an invitation to lunch, I was introduced to a colleague, Dr. F. Braun, who led me through a tour of their research and analytical laboratories. I was also privileged to a brief conversation with the distinguished parasitologist, Dr. H. H. Reichenbach-Klinke, who apprised me of the latest in his field in Europe.

Following a very pleasant luncheon with Professor Ruf and two attractive female colleagues, I was taken by Dr. Braun some 20 km from the University to the carp ponds. The man in charge was a Mr. Beck, who very kindly gave us a tour in spite of the continuous rain. I had long been interested in this famous fishery which was established in 1929. For many years it provided final treatment of the pre-settled sewage from the entire city, with additional ponds being built as the city grew. Eventually, however, the city became so large that it became impractical to purchase the additional land needed and the present operation treats only 1/3 of the city's sewage. The complex consists of a 7-km chain of 30 large ponds ranging in size from 4.6 to 10 ha, and containing a total area of 240 ha. The chain of ponds parallels a fresh water canal which provides dilution water. These are in turn paralleled by the Spelcher Sea, an impoundment of 600 ha. The ponds are stocked with carp of 300 g initial weight at a rate of 500/ha, and are operated over a 6-month growing season. During the winter when the ponds are dry the sewage is diverted through the 600-ha Spelcher Sea, which serves as an oxidation lagoon. Throughout the growing season the sewage water is fed continuously into the ponds in a dilution of 1 part sewage water (supernatant from the settling tanks) to from 4 to 6 parts fresh water. The retention time in the fish ponds is only about 1.5 days. The BOD_5 is reduced from 60 mg/1 in the original sewage water to the range of 2 to 6 mg/1 when it leaves the fish ponds. The carp feed primarily on



The famous sewage ponds of Munich used for the production of carp.

an abundant invertebrate fauna. The increment in fish flesh is about 500 kg/ha without additional feeding. The cost of the installation has long been amortized, and the annual net profit from the sale of fish now probably exceeds the $12,500 that was being realized in 1970.

The fish are harvested in October but are held live until December in order to take advantage of the holiday market. In Germany, as in much of eastern Europe, a nice fat carp is commonly served as a special treat at Christmas, and on other feast days.

One must wonder how much both the production of fish and the efficiency of the sewage treatment could be increased through the use of a polyculture of Chinese carps. However, one must also recognize the virtue in the simplicity and efficiency of the present system. The entire operation is conducted by only three men, providing a yield of over 30 tons of fish per man year of labor.

Closing remarks

In addition to the experiences narrated above I gained a considerable amount of detailed, substantive information, as well as a great store of ideas and impressions that are highly valued, and should prove useful in the work ahead. The professional contacts and friendships made in so many places also are cherished. As inferred early in the text, the one overriding impression received from the total experience was that of the sudden and/or increasing awareness of aquaculturists all over the world of the importance of utilizing our vast stores of organic wastes for the production of protein, and the importance that aquaculture can play in achieving that end. I was also impressed by the evidence emerging in so many places as to the value of the Chinese carps, and the silver carp in particular, in the control of eutrophication. Certain species of tilapia also would appear to be useful in the maintenance of good quality water in ponds enriched by organic wastes.

Finally I must express my gratitude for the many courtesies and the warm and generous treatment received from so many fine people from so many cultures, and for the pleasure of their company. I also am deeply grateful to those who made the trip possible.

Special Acknowledgement

I wish to express my thanks to my former boss, and cherished friend, George W. Bennett, who encouraged our first steps into this line of research, and finally, on to this rewarding journey. I wish that he could have shared it with me.

This page is intentionally blank.