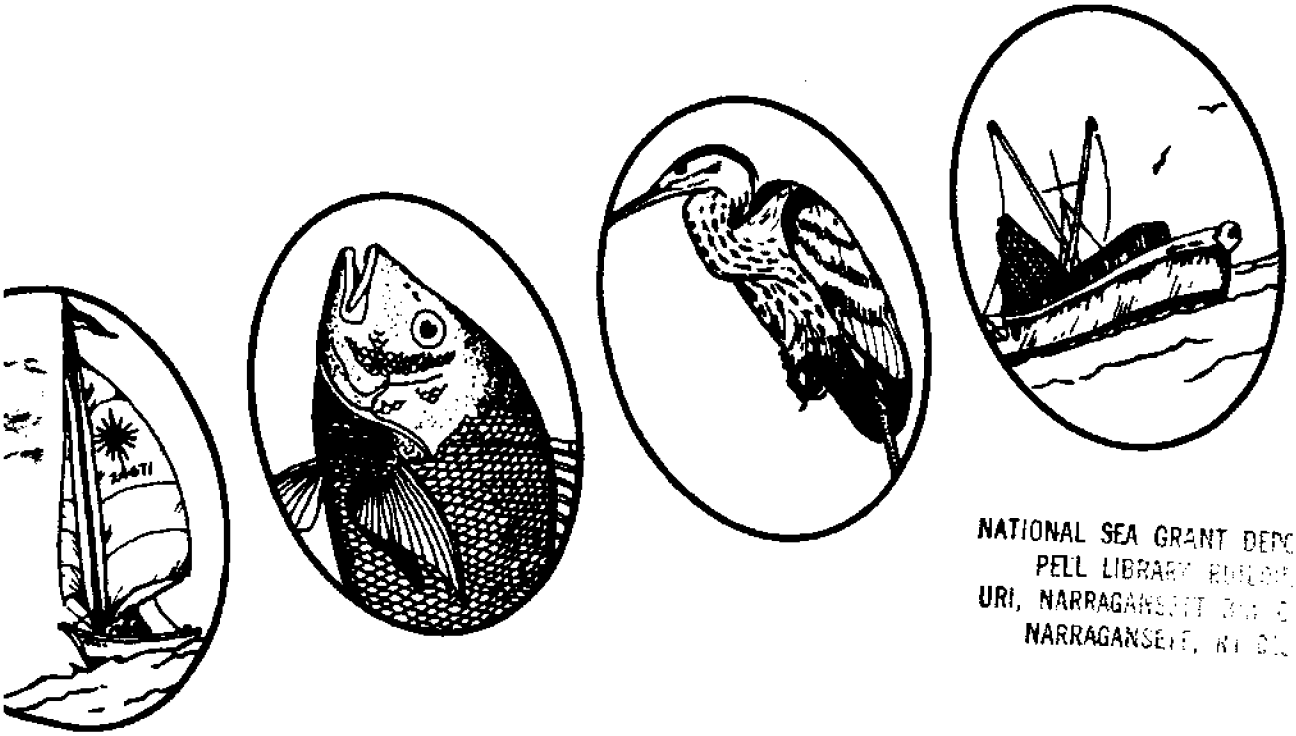

# TECHNIQUES OF EEL CULTURE IN GREENHOUSES

William L. Rickards, editor

Translated from the Japanese by Fumiko Gregg

Compiled by Kochi Prefectural Freshwater Fishery Institute

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# PREFACE

Since 1975, the University of North Carolina Sea Grant College Program has supported a research and demonstration project designed to determine the feasibility of eel farming. Emphasis has been placed on demonstrating eel culture techniques to potential farmers and researchers. While most technique demonstration has occurred through visitation to our eel culture facilities in eastern North Carolina, a considerable amount of technology transfer has been accomplished by the distribution of printed materials describing our work as well as current eel culture practices in other parts of the world.

This publication is a translation of a Japanese paper which describes the most advanced eel culture facility construction and management techniques in existence. While the farming of eels in covered enclosures with heated water (at least during the colder months) is becoming more common in Europe, the Japanese have successfully refined the technology to the point of continued profitability. Therefore, as part of our efforts to provide up-to-date information on eel farming methods, we have prepared this edited translation.

A few other comments regarding the text are also necessary. The section on diseases and drugs contains suggested antibiotics and chemicals for use in disease treatment. The reader should bear in mind that some of these chemicals have not been approved for use with food fish in the United States. Before any chemical is used, the legality of any such application should be determined so that the crop will not face possible seizure for being contaminated.

Finally, the section on diseases and treatments in this text is limited and does not include figures or photographs of infected eels. Detailed information and photographic examples of eel diseases are available in the UNC Sea Grant publication, A Diagnostic Manual of Eel Diseases Occurring Under Culture Conditions in Japan, UNC-SG-78-06 ($9.00 per copy from UNC Sea Grant, 105 1911 Building, N. C. State University, Raleigh, NC 27650).

William L. Rickards, editor

# INTRODUCTION

Since the "eel culture in greenhouse" method was developed in 1972, the eel culture industry in Kochi Prefecture has made rapid progress. Today, eel culture is considered to be one of the major industries of the Prefecture.

As is known, along with progress in the eel culture industry, we are faced with many problems: pollution caused by drainage and other factors, gaps in management, distribution, and so on. The outlook for the eel culture industry in our Prefecture is far from reassuring.

In addition, effective use of oil, water, and oceanic resources has recently been advocated. Taking these into account, it is necessary to research and develop more effective culture methods.

This booklet is a revised edition of the "Greenhouse Culture of Eels" published in 1974. Since 1974, techniques have advanced, but, at the same time, outbreaks of new fish diseases have been observed.

This booklet may not contain anything new to those with a great deal of experience, but I would appreciate it if you would glance over it.

For those who will start eel culture for the first time, I encourage them to read this booklet carefully before making a pond, and to carry out advanced research before they start. It is very dangerous to start eel culture with the simple idea that "eel culture is a profitable venture". Pollution problems are common, and I urge pond owners to make an effort not to cause damage to their areas.

Last but not least, I would like to express my gratitude to Professor Kusada of the Department of Agriculture, University of Kochi, who so kindly offered guidance for the Chapter "Diseases and Measures" in this booklet.

Susume Masuhisa, Director
Department of Marine Commerce
and Industry

December 1977

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# I. FACILITIES FOR EEL CULTURE IN GREENHOUSES

Today, methods of eel culture can be divided into three rearing procedures: (1) from whitebait* until medium-sized (20-60g); (2) from whitebait until medium-sized with part of them becoming full grown; and (3) from either whitebait or medium-sized until full grown. In this paper, I would like to talk mainly about (3), which deals with continuous production from whitebait to full-grown fish.

## I.1. Conditions of Location

Conditions of the location are fundamental for production, and include the location environment as well as volume and quality of water.

A) Location environment:

a. should receive plenty of sunshine

b. should not suffer from being flooded

c. should have a large drainageway and be convenient for drainage

d. should not have waterworks (water supply facilities) or private wells for drinking water in the vicinity

e. should be a place with easy access

f. should not cause noise pollution by boilers or other mechanical equipment to residential homes

g. should have access to a power line

h. should not be an area of strong acid soil

B) Volume and quality of water:

a. it should be possible to secure underground water or riverbed water to be pumped in an amount in excess of that needed for changing the volume of water in the ponds once a day.

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*Editor's note: whitebait is the translated term which is equivalent to the elver stage in the life cycle of the eel.

b. water temperature should be above 17°C throughout the year

c. pH (hydrogen ion concentration) 6.5 - 8.0

d. salinity should be from 0 (fresh water) to 1 part per thousand

e. alkali above 0.5 mg

f. ammonium nitrogen below 0.5 ppm

g. hydrogen sulfide below 0.1 ppm

h. iron content below 0.5 ppm

1.2. Structure of Ponds

The size and number of ponds varies depending on the production goals, but it is convenient in managing fractional stocking, gradings, and disease prevention if the size of a pond is about 100 "tsubo"* or less, and the number of ponds in each "bout"* is more than one (see table below). It is also a good idea to line up several ponds of about 20 to 60 "tsubo" each in size, since it has recently been difficult to obtain the necessary number of seed eels at one time. In addition, it will be handy to keep a small water tank of one-to-two tons capacity to be used as a temporary holding tank or for disinfection of eels. For efficiency in changing water and in heating, the tank should be 20 to 60 cm deep.

(Example) Percentage of pond area for each stage against the total area of a "bout" -

| | | |
|---|---|---|
| First pond | 5% | (whitebait) |
| Second pond | 10% | |
| Third pond | 13% | |
| Fourth pond | 32% | |
| Fifth pond | 40% | (final growth stage to market size) |
| TOTAL | 100% | |

* one "tsubo" = 3.954 sq. yds.

* a "bout" is the sequence of ponds required to pass through all grading and growing stages to market size.

A) Vinyl ponds using existing houses:

This method converts a vinyl house originally for horticulture into a rearing pond. This is done by making use of the house struts to make the outer frame of the pond with rafters and galvanized iron sheets, and by flattening the bottom of the house and lining it with vinyl sheets (Figure 1). Although this method has the advantage of low cost, there are shortcomings in terms of operating and structural weakness such as passageways, drainage and accident prevention.

B) Newly constructed vinyl ponds:

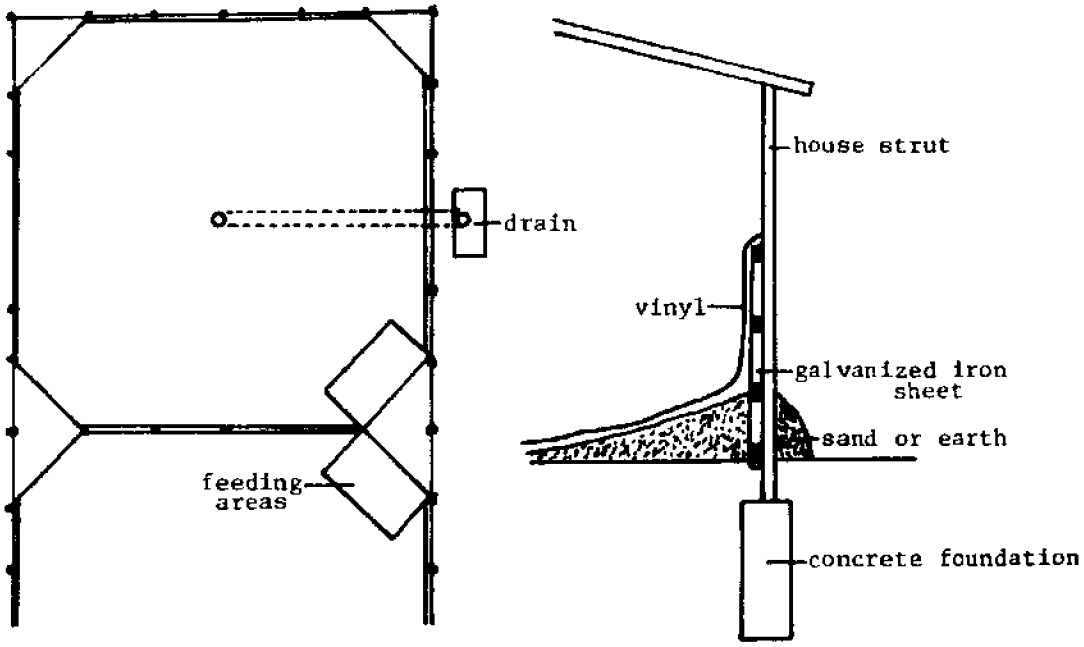
Recently, it has been more common to have a vinyl pond first designed with enough space for passageways, etc., and then to have a suitable house added. Compared with the vinyl ponds using existing houses, this method imposes some restrictions on how to use a building site and the cost will be higher, but it has advantages in terms of operation and structure (Figure 2).

C) Concrete ponds:

Compared with the vinyl ponds, concrete ponds cost more, but they are much stronger. In terms of management, concrete ponds have the advantage of longer durability and they are also safer. In recent years, more and more octagonal ponds have been constructed incorporating good points of square ponds and round ponds (Figure 3).

D) Other ponds:

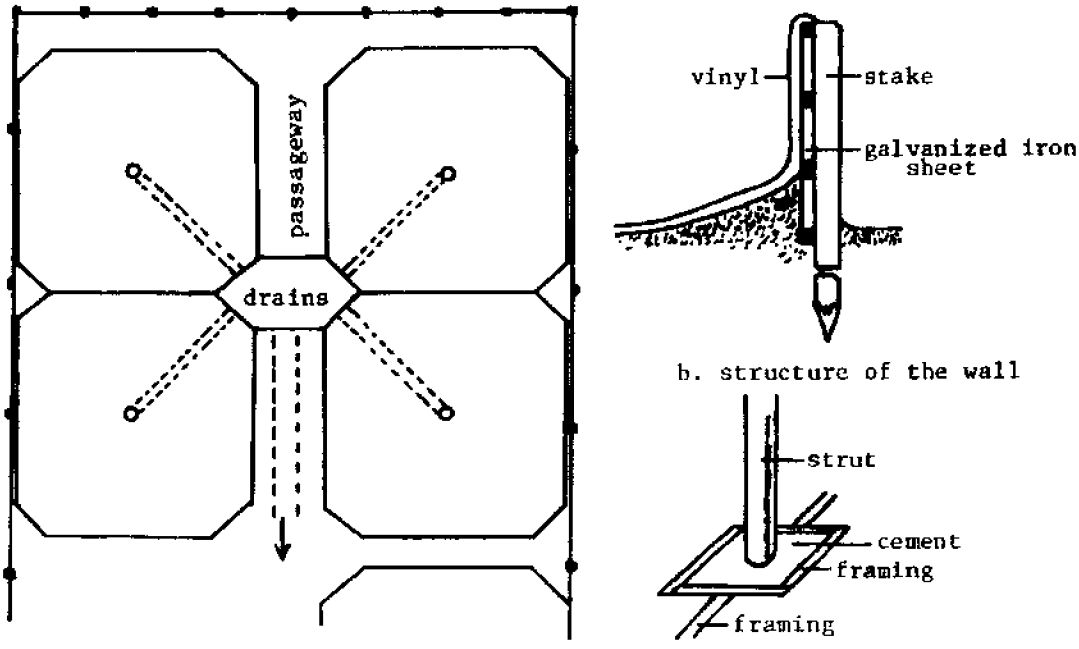
Besides the three types of ponds described so far, there are heated open-ground ponds, circular filter bed ponds and others, every one of which has strong and weak points. The description of these will be omitted here. However, regardless of structure, every pond should have an efficient circulation of water flowing into, through, and out of the pond.




a. ponds from above

b. structure of the wall

Figure 1. Vinyl ponds using existing houses

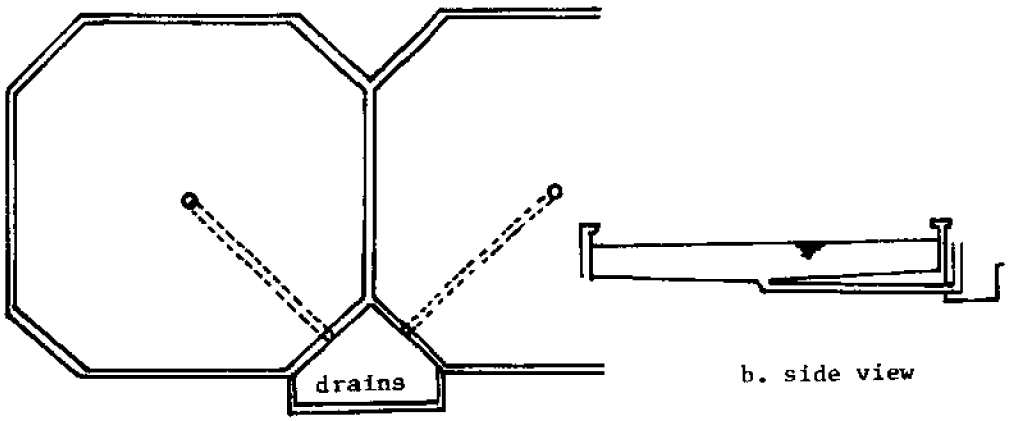



a. the ponds from above

b. structure of the wall

c. installation of strut

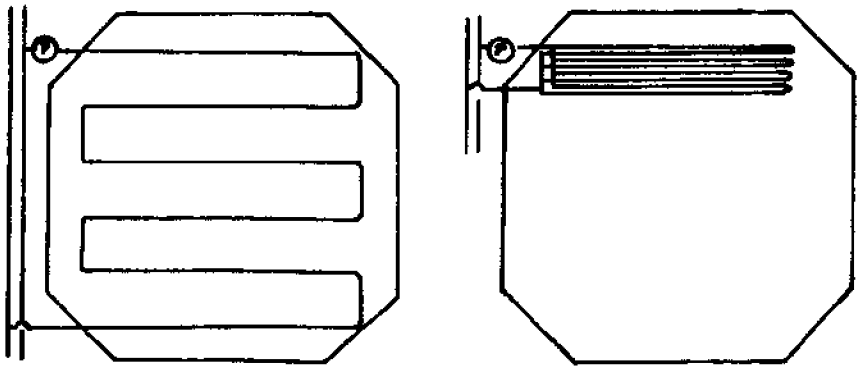
Figure 2. Newly constructed vinyl ponds.




a. from above

b. side view

Figure 3. Concrete ponds.



a. Overall method

b. Concentrated method

Figure 4. Methods of laying heating pipe.

## I.3. Heating Equipment

Warming of water by vinyl houses and/or by boilers, which are the two most widely used methods in our Prefecture, will be described here, although there are other warming methods such as electric heaters or waste warm water.

A) Vinyl houses:

Using a vinyl house can cut the fuel cost to between 1/2 and 1/3 of what it will cost to warm an open-ground pond. As for the structure of a house, it is desirable to consider: 1) the sun gets into the house well, 2) effective heat insulation, and 3) structural features will not hinder operations. For these purposes, attached pipe houses with arched roofs have an advantage over a detached house with a high gable roof. It will also be useful in terms of heat insulation to line the house from the inside with two layers of vinyl sheets whenever possible.

B) Boilers and pipe laying:

In our Prefecture, heavy oil boilers for horticulture are widely used. An approximately 400,000 K cal. boiler is needed for a 300 "tsubo" pond, with minor differences in the size of the boiler depending on the number of ponds and frequency of usage. For fuel, mainly "B" heavy oil is used.

There are both piping and direct hot water methods for using boilers. In this booklet, only the piping method will be described. Although its construction cost is higher, the piping method has better thermal efficiency and an advantage in operation over the direct hot water method. Piping method means to lay heating pipes, 2.0 to 2.5 inches in diameter, in a pond at intervals of about 6 feet. Water which is heated to 40 to 80$^{\circ}$C in a boiler passes through the pipes and indirectly warms the water in a pond. The water temperature is controlled by an

interlocking device of a thermostat set up in a pond, a circulating pump, and a boiler.

There are overall and concentrated methods in piping. Except in a small pond like the first pond in the "bout", the concentrated piping method has an advantage in management (Figure 4).

Heating pipes are made of zinc, tinplate, aluminum, pleated aluminum, or stainless steel. Each material has both advantages and disadvantages. Heating pipes used widely in our Prefecture are zinc pipes (galvanized iron). When using zinc pipes, it is necessary to paint the parts of the pipes which will be submerged in water (see p. 60, Convulsion disease - tentative name).

I.4. Attached Equipment

A) Water supply equipment:

Water supply equipment includes wells, pumps, water pipes, valves, and so on. The depth of wells naturally differs depending on the underground water level, but it is disadvantageous to have too deep a well because such a well requires a pump with large capacity. The capacity of a pump is decided by the volume of water consumption and the lift. It is at least necessary to install either two pumps, one for general needs in the rearing ponds and the other for filling the pond rapidly if the need develops, or one pump which can do both. It is desirable to install a spare pump in case of a emergency. Water pipes should be arranged so that the lift becomes as small as possible. Valves should be installed at places convenient for operating. Underground water, regardless of the water source, contains very little oxygen. Therefore, at the point where water pours into the pond, some type of device which adds oxygen to the water should be provided. From time to time, I find a pond where new water is poured in next to the feeding area, but this is showering the eels with unfavorable water because

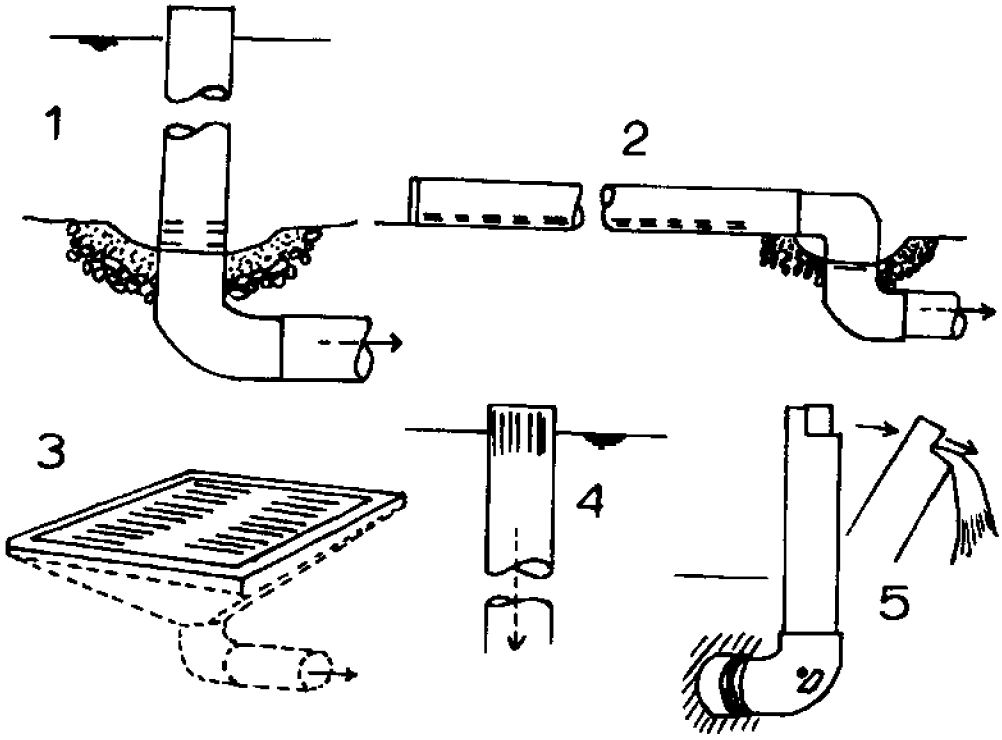
the new water is low in temperature and oxygen. If new water is to be added to a pond, it should enter the pond next to the water wheel or aeration device.

B. Drainage equipment:

One cannot expect resolution of sludge or purification of water by subsoil in a vinyl pond as in a mud pond. Therefore, it is desirable to swiftly discharge sludge components such as left over feed and excrement produced during rearing from the vinyl pond. For this reason, a device which collects sludge in one place in the center of a pond by circular water currents and then discharges the collected sludge together with the pond water is reasonable, and this type of device is designed in various ways (Figure 5). In addition, as days pass, a film and foam from oil and other food substances will form more easily on the surface of the water, thus preventing impurities such as nitrogen gas from leaving the water. Therefore, a device which will also discharge surface water is desirable. It is even more convenient if a place to discharge water when picking up eels is also built alongside.

C. Drainage treatment facilities:

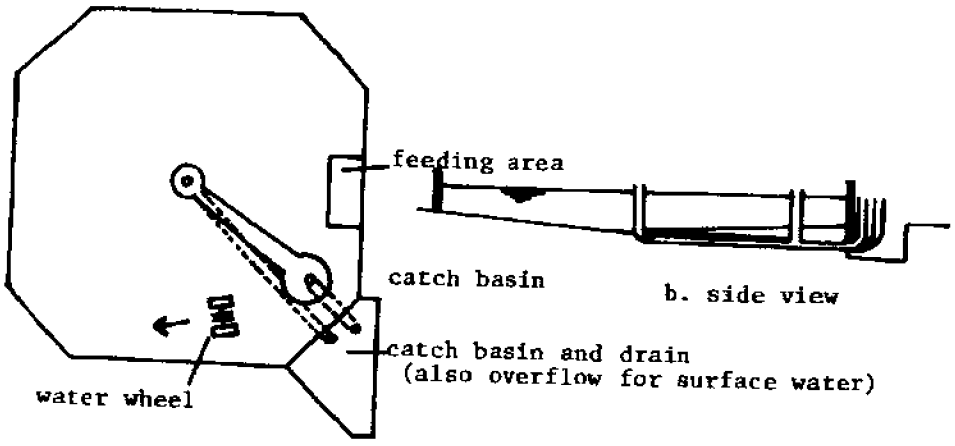
Most warm water eel culture uses the half-effluent rearing method, but some use the circular water method. In the half-effluent rearing method, sometimes the rearing water which is drained in a day may be equal to the volume of the water in a pond. Also, when the pond water is being changed, poor quality water with sludge must be drained all at once. Recently, because these drainage waters contain a high level of nitrogen and smell bad, they have become a pollution problem. To control this problem, business proprietors are asked to rely on their good sense in choosing a site and not to discharge polluted water. In choosing a site, as mentioned previously,




1,2,3 - Overflow standpipe in center of pond

4 - Overflow for surface water

5 - Overflow outside of pond (also used to adjust water level)




a. from above

Figure 5. Drainage installations.

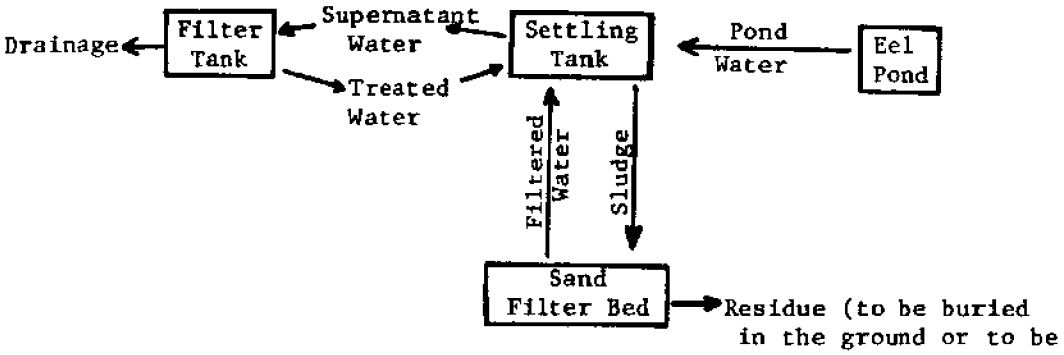
it should be located where water can be drained into a nearby overflow (not an irrigation channel) and where water is not being used downstream by existing industries or health-related places. An ideal purifier has not been perfected for drainage disposal facilities, but it is necessary to make efforts to discharge water as clean as possible. Now, we are in the midst of a study to design an improved disposal plant which will be constructed and maintained inexpensively, operated easily, and will not require a large area (Figure 6). This plant is expected to dispose of more than 50% of the sludge produced in the farm area.

D. Aeration arrangement:

Because only a small amount of sun enters the pond in a greenhouse, phytoplankton does not grow well. Therefore, the oxygen supply often depends on a water wheel, and a blower or compressor is used whenever necessary to aerate and reduce the lack of oxygen. Compressors will be sufficient for small ponds, but blowers will be better for a large area with many ponds, because blowers move more air. Blowers should be installed so that intakes will pull in fresh, outdoor air. Airstones which make bubbles as small as possible are more effective for adding oxygen to pond water.

E. Water agitator (water wheel):

The reason for using a water agitator are to add dissolved oxygen and to create currents. Motors are usually 0.5 - 2 PS (horse power) and turn water wheels set on floats. A water agitator set in a small pond usually just splashes water, but one in a large pond should splash water at the same time that it creates circulation currents. A water agitator should be located where the pond water circles throughout the pond in return currents, but it should not be at a place where it will send a rapid current to the feeding area. Agitators made from submersible pumps and screw-type agitators are being sold these days.



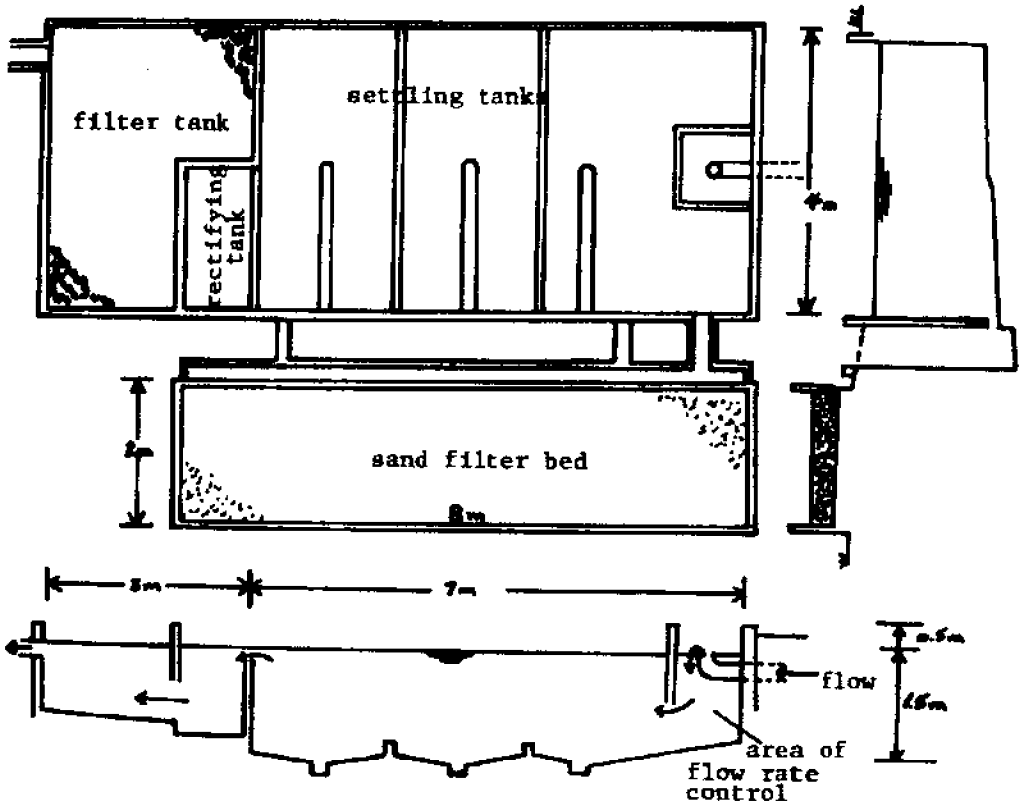




Figure 6. Drainage treatment facilities (pond size = 300 "tsubo" and pond drainage is 500 tons of water per day).

F. Generators:

Warm water eel culture uses many pieces of electric equipment such as water wheels, blowers, pumps and boilers. Thus, there have been many occasions when large numbers of eels died from lack of oxygen because of power failures and accidents. For this reason, a generator must be installed. The capacity of the generator depends on the amount of electricity consumed by the facility. An alarm should be installed in case the power goes off.

G. Other equipment, appliances and parts:

(1) Fan - It can easily get so hot and humid in a greenhouse that water temperature adjustment and operations are hindered. Also, humidity is dangerous to electric equipment. It is desirable to install fans at key places for ventilation.

(2) Refrigerator - A box freezer or a small refrigerator will be needed to keep feed fresh.

(3) Kneading tool - An appliance to knead formula food into the dough-like mixture.

(4) Chopper (mince) - For grinding fresh fish to be fed to the eels.

(5) Appliance to de-bone fish (optional) - removes meat only, leaving bones and skin from fresh fish.

(6) Boiling pot (optional) - for boiling fresh fish before feeding.

(7) Grader - for selecting various sizes of eels for fractional stocking or shipment.

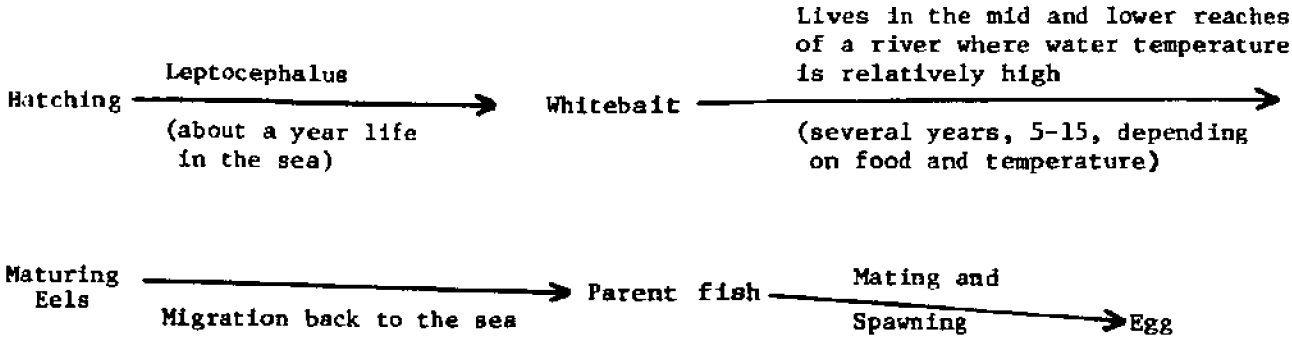
(8) Miscellaneous - submersible pump, dip nets, waders, etc.

## II. EEL CULTURE TECHNIQUE IN GREENHOUSE

### II.1. Life History and Nature of the Eel

A) Life History:

Life history of the Japanese eel (Anguilla japonica) in the natural habitat is presumed to be as follows:




Eel culture is an artificial shortening of the part of eels' natural life which would be spent in the rivers.

B) Physiology and ecology useful for culture:

(1) Response to light - Eels are naturally nocturnal fish and like dark places. However, during the elver stage, they are slightly phototactic and inclined to be attracted by light. This characteristic is utilized when eels are being domesticated (meaning to tame to eat feed or to become accustomed to feed), but they lose this characteristic as they grow.

(2) Rheotaxis - Eels, by nature, stem the current as far as possible wherever there is water. This characteristic is stronger with smaller eels and weaker with bigger eels. Eels cultured in ponds lose this characteristic especially quickly. However, if the pond is flooded, almost all the eels will escape.

(3) Response to salinity - Eels can adapt to either fresh water or sea water. They can, by nature, easily stand sudden changes in salinity. Elvers which were in sea water like to gather in the brackish water zone at the mouth of a river and stem the current into fresh water. On the other hand, eels cultured in fresh water ponds have a tendency to be attracted to salt water.

(4) Breathing - Eels breath not only through gills but also through their skin. The ratio of gill and skin respiration is said to be two to one. Because of this, eels can live out of water for a long time if their body surface is wet, and this characteristic is put to good use in live fish transportation. However, eels will die from suffocation in a pond if the oxygen content of the pond water gets too low. The limit of oxygen content eels can survive is around 1.0cc/liter. Compared with other fish, eels possess a great resistence to low levels of dissolved oxygen.

(5) Eating habits - The eel is an animal-eating (carnivorous) fish. The eel stomach is well-developed and the intestinal tract is short and nearly straight. Eels prefer animal feed even when they are kept in a pond. Therefore, formula feeds for eels are made of mostly animal ingredients. Eels also like to eat whole, fresh fish which has been placed in boiling water for a short time.

(6) Preying on each other - Japanese eels do not prey on each other except when there exist extreme differences in size among them. European eels are, on the other hand, quite strongly inclined to prey on each other.

(7) Digestion ability - Since eels are animal-eating fish, their ability to digest protein is strong and their protein digestive rate is 80 to 95%. As for their starch digestion, it is 50% or less for β (beta) starch (raw starch). For α (alpha) starch, the rate is almost as high as their protein digestive rate. It goes without saying that fresh fish is digested more completely than formula food.

(8) Slime (mucus) - The eel's outer layer of skin has well-developed mucilage cells and an active secretion of mucus. The amount of mucus secreted changes with the environment. Eels secrete more mucus as their environment deteriorates, and the pond water may become viscous or a great amount of foam may form. Eels may die when they secrete so much mucus that the slime falls off.

(9) Water temperature - The eel is a poikilothermal animal just like other fish, and changes in the water temperature affect every physiological aspect including breathing, eating, digestion, activity, and growth. The range of appropriate water temperatures for eels is 10 to 32°C, although the optimum water temperature for culture is believed to be 20 to 28°C. Since eel culture is an enterprise in which the eel's growth is important, water temperatures in the upper range of 20 to 28°C are recommended to induce good growth.

## II.2. Water Control

Even though it is different from water control for traditional eel culture in open-ground ponds, for which people used to say that water conditioning would take ten years, water control for eel culture in greenhouses demands artificial control. It is no exaggeration to say that productivity depends on daily control of the water.

A) Water purification:

Uneaten feed and sludge accumulated in the pond must be removed as swiftly as possible. At the same time, deterioration of water quality must be prevented by using semi-running water (approximates a complete water change once a day). If the accumulation of sludge is left sitting in the center of a pond, a great deal of oxygen will be consumed chemically to dissolve the sludge and ammonia will be generated. These conditions will cause stagnation of growth and sickness in the eels.

B) Oxygen supplement:

Oxygen is supplemented by flowing water, water wheels, and blowers. Oxygen is also generated by keeping phytoplankton in the ponds, although this is difficult in greenhouse culture. However, it is important to keep the appropriate density of phytoplankton (i.e. when you can see your fingernails faintly after putting your arm up to the elbow in the water) because if the phytoplankton becomes too dense they will reduce the oxygen levels at night. In addition, phytoplankton have the ability to consume nitrogen (such as ammonia) which is poisonous to eels, and a phytoplankton bloom provides eels with comfortable shading and prevents stress.

C) Water temperature in the pond:

The water temperature in a pond should be checked every day, and its daily fluctuation should be kept within $5^{o}C$. The relation between the growth of eels and the water temperature has not been made clear, but if the temperature is kept at $25^{o}C$ for elvers through "kuroko" eels, and 25 to $28^{o}C$ for mid-sized and "futo" eels, good growth should be realized. In addition, the water temperature must be carefully monitored because outbreaks of viral nephritis (tentative name) have been on the increase recently (see p. 55 ).

*"kuroko" means small eels weighing about 10 grams
** "futo" means eels weighing more than 20 grams

In any case, keeping the water temperature constant is very important, and sudden changes in temperature, even when they are within five degrees (C), are not desirable.

D) Other factors:

(1) pH - it is a good idea to check pH from time to time, because changes in pH between night and day will indicate the pond water condition. A pH below 7.0 or above 9.5 during the day is regarded as undesirable (see p. 38 ). A simple colorimetric apparatus will be sufficient for measuring pH.

(2) $NH_4$-N (ammonia nitrogen) - if it is possible to periodically measure $NH_4$-N in the pond water, this will indicate how dirty the water is. A value over 3 ppm will affect eels beyond just producing poor growth. It is desirable to measure both pH and $NH_4$-N at the same time since ammonia toxicity will affect eels more strongly as pH increases.

## II.3. Disinfection of Seed Eels

In many cases, elvers (whether they are harvested in Japan or elsewhere) are captured by many different people and reach farmers only after being handled by several more people. The eels are often injured during the times of capture and transport. Due to this damage, large numbers of elvers sometimes die soon after they are stocked in ponds. To minimize such losses, the elvers must be disinfected. Even when "kuroko" or mid-size eels are purchased as seed, they should be disinfected as would be done with elvers.

A) Facilities, tools and medicine necessary for disinfection:

(1) Water tank - a concrete or fabricated tank with capacity of one to two tons (the first-stage pond can be used as a substitute, but

it cannot be used many times and requires a large amount of medicine).

(2) Aeration - a blower or a small air compressor can be used.

(3) Salt - table salt or rock salt is dissolved at the rate of 5 kg per ton of water.

(4) Furan agent - Any Furan agent will serve as the medicine in the bath. The dosage for a long medicine bath should be applied to elvers, but with mid-size eels, the dosage for a short medicine bath can be followed for a specified time. For example, one may consist of a ten minute medicine bath for 100 kilograms of eels per one ton of water.

(5) Other materials - net baskets to hold the eels; waders.

B) Method of disinfection:

(1) Fill the tank with water, dissolve salt at the rate of 5 kg/ton of water, add the prescribed amount of Furan agent, and aerate the water. If some of the salt is difficult to dissolve, it should be dissolved beforehand in a bucket of warm water.

(2) Put 10 kg of eels (per ton of water) in a net basket, and submerge the basket. Be careful to have the same temperature in the elver transport water and water in the tank.

(3) Leave the eels in the medicine bath for about 12 hours, and then release them into the first-stage pond in which the water temperature has been adjusted to be the same as the bath. If this step is carried out during the day, measures should be taken so that the bath is not exposed to the sun because the Furan agent will lose its efficacy.

(4) Be sure to remove dead eels and those suffering from severe damage during the medicine bath, and keep close watch for contamination of the pond water. The water for a medicine bath has to be freshly prepared for each bath.

II.4. Quantity of Eels to be Stocked and Density of Rearing

The amount of eels to be stocked should be decided by factors such as heating capability, the size of ponds, culture technique available, etc. In the case of integrated production from elver through full-grown eels in a 300 "tsubo" farm, Table 1 can be used as a guideline.

However, at a site with good conditions, the grow-out period will be shorter and some of the eels will be shipped halfway through the grow-out time and the amount of eels to be stocked may be increased.

The quantity of eels stocked for the production of mid-size eels is different. A guideline for this type of production in a 100 "tsubo" farm is shown in Table 2.

Furthermore, when using integrated production and a part is to be shipped as mid-size eels, the amount of eels to be stocked and the rearing density change in proportion to the projected production ratio.

In any case, attention must be paid to rearing density, and it should be kept under 10 kg/"tsubo" for mid-size eels and 20 kg/"tsubo" for "futo" eels (more than 20 g ) at the time of harvest. As with other fish, the amount of oxygen consumed per unit weight is larger for smaller eels, and the amount per individual eel is more for larger eels. Therefore, the smaller the eels, the smaller the weight/"tsubo" should be. To be able to raise "futo" eels at the rate of 20 kg/"tsubo" does not mean to be able to raise mid-size eels at 20 kg/"tsubo". As the density gets higher, not only will costs be higher for pumping water, aeration and heating, but deterioration

TABLE 1. Quantity of eels to be stocked and density of rearing in the case of integrated production (300 "tsubo" farm).

| | First pond 15 "tsubo" | Second pond 30 "tsubo" | Third pond 40 "tsubo" | Fourth pond 95 "tsubo" | Fifth pond 120 "tsubo" | Ave. eel wt. |
|---|---|---|---|---|---|---|
| Jan. - Feb. | Elvers 7.5 kg (0.5 kg "tsubo") | | | | | 0.2g |
| Feb. - Mar. | Total 45 "tsubo", 60 - 75 kg (1.3-1.7 kg/"tsubo") | | | | 80% Survival | 2g |
| May - June | Total 85 "tsubo", 300-375 kg (3.5-4.4 kg/"tsubo") | | | | | 10g |
| Aug. - Sep. | Total 180 "tsubo", 3,000 kg (16.7 kg/"tsubo") | | | | | 100g |
| Oct. - Dec. | Total 300 "tsubo", 6,000 kg (20 kg/"tsubo") | | | | | 200g |

(Note: The volume of eels stocked in the first pond is usually set at 1.5 - 2.0 kg "tsubo", but due to the shallow depth (40 - 50 cm) in a heated pond, the figure is set here at 0.5 kg "tsubo".)

TABLE 2. Quantity of eels to be stocked and density of rearing for the production of mid-size eels (100 "tsubo" farm).

| | First pond 30 "tsubo" | Second pond 30 "tsubo" | Third pond 40 "tsubo" | Ave. eel wt. |
|---|---|---|---|---|
| Jan. - Feb. | Elvers 24 kg (0.8 kg/"tsubo") | | | 0.2g |
| Feb. - Mar. | Total 60 "tsubo", 200-240 kg (3.3-4.0 kg/"tsubo") | | | 2g |
| May - June | Total 100 "tsubo", 1,000-1,200 kg (10-12 kg/"tsubo") | | | 10g |

of the water, diseases, and depression in growth rate will also occur. There is also the danger that a large number of eels will be lost immediately if a power failure should occur.

II.5. Feeding

A) Domesticating:

The process of domesticating (taming eels to eat feed) should be started when the elvers finish the medicine bath and are released into the first pond at the appropriate water temperature. If the process of domesticating fails, growth variations among eels will become large and will adversely affect their future growth. Thus, this taming to feed must be supervised very closely. Elvers swim throughout the pond during the day (they will gather in a dark spot if it is too bright), and they will start to swim around the pond at dusk. Turn on a 20 to 30w light above the feeding area after sunset. Hang a small, closely-woven feeding basket close to the water surface at the feeding area, and put a small amount of threadworms in the basket. After about five days of being fed by this method, more than 70% of the elvers should be domesticated. During these training days, threadworms falling from the basket to the bottom of the pond should be picked up so that the eels may not feed at any place except the basket. After feeding at night has succeeded, adjust the lighting time gradually to get the eels accustomed to feeding during the day.

B) Switching to daily diet:

After the eels are completely used to eating threadworms from the basket, switch them to a daily meal diet. There are two varieties of daily meal diets: fresh fish and formula food. A daily meal diet made of mixing both of these is best for eels from the standpoint of their health.

The fresh fish diet is made by mixing 7 portions of ground fish with 3 portions of formula food and a small amount of threadworms. Knead the mixture to a non-runny consistency. Put the kneaded mixture in the feeding basket and give it to eels. Gradually decrease the amount of threadworms and increase the ratio of the formula food in the diet, and in several days completely stop adding threadworms. Eventually, bring the ratio to formula food 7 to fresh fish 3. Since this is just after the elvers are domesticated, the amount of the feed should be limited to what they will finish completely in about 30 minutes. The elvers should be fed about four times a day, eventhough feeding so frequently may be troublesome. Without taking these steps, the number of elvers which will not bite at the feed will increase and they will eventually turn into "hine"* The feed presented each day should be 5 to 6% of the weight of eels being stocked. The feed should be mixed just before each feeding. The feed for one whole day should not be prepared in a lump. It is best to promptly remove and discard the uneaten feed and feed which has fallen to the bottom of the pond. From the elver through this growth stage, the eels should be fed sufficiently and evenly so that their stomachs will develop because this will affect their growth in the future. This is almost like caring for a human baby.

C) Feeding amount:

Gradually increase the amount of food when elvers which have been eating their daily diet well turn into "kuroko" eels (about 10 grams). A daily criterion determining the amount of feed at a water temperature of 25°C is 6 to 8% of the total eel weight for formula food alone, 20 to 30% when using fresh fish alone, and 10 to 13% for a diet of 70% formula plus 30% fresh fish. Some changes may be made depending on conditions of

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*Editor's Note: Meaning not clear, but may be those elvers commonly called "pinheads".

both the eels and the water. It is not desirable at this stage ("kuroko" to mid-size) to give either formula food or fresh fish alone because of negative effects on growth of the eels and on water quality. Mixed feed should be given as much as possible. Fresh fish should be as fresh as possible. When freshness is in doubt, put the fish in boiling water to let impure fat come afloat before grinding the fish.

When eels grow close to the "futo" size (20 grams), the daily feed volume should be 2 to 3% (formula food). At this state, it is also best to feed fresh fish. However, since the total amount of feed is far greater now than it was during the "kuroko" period, the ratio of fresh fish can be decreased or fresh fish can be given once every several days. When changing the ratio for fresh fish, convert at the rate of 1 kg of formula food to 4 kg of fresh fish. In addition, feed oil added at the rate of 1 to 3% of the weight of the feed when eels are bigger than mid-size will help their growth. However, adding feed oil when eels are smaller than mid-size (or when the water temperature is low even though eels may be larger than mid-size) may cause indigestion.

D) Frequency and hour of feeding:

When eels are small, be sure to feed them frequently. As they get bigger, the overall feed volume increases, other operation chores must be carried out, and it becomes difficult to feed frequently. Therefore, the feeding frequency decreases from 4 to 3, and 3 to 2 times a day as eels get bigger so that eventually the eels are fed twice a day (once in the morning and once in the evening) or just once a day in the morning. Allow about 30 minutes for each feeding. It is not necessary to leave the uneaten portion of feed in the feeding area. Uneaten food only helps

contaminate the water. Mid-size eels are able to consume enough food if they are fed once in the morning and once in the evening for 30 minutes each time.

Feeding should occur when the oxygen content of the pond water is high, because eels move around vigorously while they eat and the amount of oxygen consumed increases sharply right after they eat. Therefore, if they are fed once in the morning and once in the evening, these feedings should be after sunrise and before sunset. When the pond is rather crowded, the pond should be aerated for several hours during and after feeding. I have heard that some farmers stop waterwheels before and after the feeding lest the food be carried away, but it should be exactly the opposite since this is like encouraging eels not to eat.

In addition, when the weather is bad (as in the case of a typhoon) or the water temperature is too low or too high, the feeding volume should be decreased to 70 or 80% of the regular volume and the feeding frequency reduced to once a day in order to avoid overfeeding. Overfeeding can cause stress from lack of oxygen and sickness.

II.6. Selection (Grading), Fractional Stocking and Medicine Baths

A) Selection and fractional stocking:

It is not an exaggeration to say that supervising the growth from elver through mid-size during May and June will determine that year's production performance. Selection and fractional stocking are essential parts of supervising and raising the eels.

After becoming domesticated, elvers weighing 0.2g each will grow to 0.5 to 1.0g in about 20 days. The rearing density in the first pond will increase and the water quality in the pond will worsen.

If the eels are left in these conditions, oxygen will become scarce, growth will slacken, and individual size variations will widen excessively. On the day before the first fractional stocking, the eels are not fed in order to keep them hungry. The eels may then be attracted with a small amount of bait (food) and scooped up with a net.

Fractional stocking should be completed in a day so that eels which have been painstakingly trained to eat feed will not lose the habit. After they are scooped up, the eels must be weighed quickly and released in the second pond. At this stage, a selection (grading) is not necessary unless the farmer has failed to domesticate the eels sufficiently which results in extremely large differences in size. In such a case, large eels should be removed. Selection or grading is usually undesirable at the first fractional stocking since the eels are very small. After the first fractional stocking, grading and fractional stocking will usually be necessary approximately once a month depending on the stocking density.

Starting with the second fractional stocking, a grader is used. Care must be exercised in handling eels with the grader, and overuse must be avoided to prevent stripping the eels of their mucus. Also, expecially when eels are small, these operations should not be conducted in a cold wind or under the direct sun. The temperature of the water for gradings should be the same as that of the pond. Colder water should be avoided.

B. Medicine baths:

Eels should be given a bath with a Furan agent for the purpose of disease control at each fractional stocking. When the eels are still small, one can save medicine by using a small tank as the one used for disinfection of elvers. Later, when the eels are heavier and the tank is too small, they will be bathed in a fractional stocking pond in which

the Furan agent has been dissolved. Bathing methods are as follows:

(1) When using a small tank for a medicine bath -

(a) fill the tank with water, throughly dissolve a Furan agent (to the concentration prescribed for a short bath) and table salt (5kg per ton of water), and aerate;

(b) leave eels (about 100 kg eels per ton of water) for 10 minutes in a net or basket in the tank;

(c) release the eels in a pond with water adjusted to the same temperature as that of the tank;

(d) pick up all eels which died during the medicine bath, and prepare a fresh bath if the first bath becomes dirty after being used.

(2) When giving eels a medicine bath directly in a pond -

(a) release eels in a pond which has been aerated for at least one day and in which the water temperature is adjusted;

(b) sprinkle the Furan agent (which has been dissolved beforehand in a bucket of water) all over the pond, and use the concentration prescribed for a long bath;

(c) let the pond sit overnight with aeration or a water wheel on, and start replacing the water the next morning.

In either case, sunlight should be avoided and food should not be given during the medicine bath. Eels do not eat much for a couple of days after the medicine bath; do not force them to eat a regular amount of of food. Increase the volume of food gradually in order to return to the regular volume in three days.

## II.7. Survival and Growth Rates

Unless there is a major accident (accidents usually occur due to lack of supervision), a survival rate of more than 80% can be anticipated. In a well-managed pond (free of disease, water contamination, or eels refusing feed), eels grow to weigh around 10g, which is about 50 times their original weight, by May or June. If fractional stocking is carried out properly, some of the eels will be market size and ready for shipping by August. One point which needs to be noted is the relation between weight increase and feed. This relationship is called either feed efficiency or meat increase coefficient. Feed efficiency shows the percentage weight increase of eels compared to the total volume of feed given. For example, if the volume of feed given totals 10 tons and eel production is 6 tons, then feed efficiency is $6 \div 10 \times 100 = 60\%$. The meat increase coefficient, on the other hand, shows how much feed was consumed in order to produce a certain volume of eels. For example, suppose that 10 tons of feed was given to produce 6 tons of eels, then the meat increase coefficient is $10 \div 6 = 1.67$. It goes without saying that both feed efficiency and meat increase coefficient vary with the growth phases of eels. The following is an example from eel culture in still water.

| | Feed efficiency | Meat increase coefficient |
|---|---|---|
| elver, eels up to 10g ..... | 30 - 60% | 3.0 - 1.67 |
| eels, greater than 20g ..... | 50 - 60% | 2.0 - 1.67 |

These figures are for formula feed. When live feed (fresh fish) is mixed, figures should be computed by converting the volume of live feed x ½ = formula feed. Generally speaking, the feed efficiency is somewhat higher and the meat increase coefficient somewhat lower for eels cultured in green houses than for those cultured in still water. Therefore,

production (i.e. yield) increases as the feed efficiency increases or as the meat increase coefficient decreases. Occasionally, eel farmers compare the volumes of feed their eels have eaten on that particular day, but this type of comparison is meaningless. Instead, they should learn to produce the same volume of eels with a minimum amount of feed. Production is affected more by a farmer's techniques than by differences in formula feed.

## II.8. Characteristics of Foreign-produced Eels and their Rearing

It is said that there are 19 kinds of eels in the world, including Asian eels, of which about six kinds are used for culture. The kinds which have been imported to Japan and tried for culture are European-produced (France), Korean-produced, Chinese-produced, Indonesian-produced, and American-produced. The Korean-produced and Chinese-produced eels are the same type as Japanese-produced eels (Anguilla japonica). French-produced (Anguilla anguilla), Indonesian-produced (Anguilla bicolor and A. pacifica), and American-produced (Anguilla rostrata) eels are of different types. In this chapter, I will discuss only the French-produced eels that are imported to Japan more than any other kinds and are raised throughout Japan.

A) Seedlings:

As illustrated in the table below, French-produced elvers are larger than Japanese-produced ones, and they number about 2,500 to 2,800 eels per kilogram. If they are purchased too early, there may be more than 2,800 per kilogram and many will be too young to be domesticated successfully.

Size comparison of French- and Japanese-produced elvers

| | French-produced | Japanese-produced |
|---|---|---|
| Full length (mm) | 63 - 79 | 55 - 60 |
| Weight (g) | 0.19 - 0.48 | 0.13 - 0.20 |

B) Quantity of eels to be stocked in a rearing pond:

A rearing pond of about 100 $m^2$ (about 30 "tsubo"*) to 300 $m^2$ (about 100 "tsubo") is a good size to manage. It is also best to arrange if water may be added to the pond easily so that the volume can be changed at least twice a day. Unlike Japanese eels, European eels tend to gather in a shaded place, and the feeding area should be made spacious (i.e. occupying 5 to 10% of the pond).

European elvers should be disinfected before stocking a pond just like Japanese-produced elvers. The quantity stocked should be 1.5 to 3 kg/"tsubo", but in a heated pond it can be as high as 5 kg/"tsubo". It is said that after eels become larger than mid-size, the density can be increased to 30 to 50 kg/"tsubo" in a stream-water pond (with water being changed more than twice a day), and 10 to 30 kg in a semi-stream-water pond (with water being changed once or twice a day). However, it is necessary to pump water into the pond during the hottest period of summer to keep the temperature below 26°C.

C) Food and feeding:

European eels are domesticated by using threadworms in 20 - 26°C water just as for Japanese-produced eels. Since European eels can be domesticated easily during the day, it is not necessary to carry out the domestication program during the night as in the case of Japanese eels. Also, European eels prefer fresh feed, and it is better to mix formula feed and fresh feed. The addition of vitamins and minerals is believed to improve the yield as well as immunity against disease.

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* one "tsubo" = 3.954 sq. yds.

However, French-produced eels tend to accumulate fat in their bodies and oil cannot be added very effectively to the diet to promote their growth. In any event, oil should never be added in summer. If a farmer decides to add oil, he should add only a small amount during the fall and winter. If the water temperature in winter is around 17°C, the eels will eat and grow well.

The time and frequency of feeding are the same as for Japanese eels. Be careful not to over feed them.

D) Selection and fractional stocking:

Growth differences occur in French-produced eels more easily than in Japanese eels. French-produced eels are more inclined to prey on each other than are their Japanese counterparts, and it is necessary to carry out selection and fractional stocking at appropriate times. However, these operations must be performed carefully to avoid damaging the eels (French-produced eels are said to have delicate skins). Handling the eels for grading should be avoided during the summer when water temperature is high. It goes without saying that eels should be properly disinfected at the time of grading and fractional stocking.

E) Growth and survival:

French-produced elvers usually weigh 0.3 to 0.4g. They are almost twice as large as Japanese elvers and are therefore more easily domesticated. They also grow well during their juvenile period. However, when their weight has increased 20 to 30 times, they begin to grow more slowly than their Japanese counterparts. However, they will grow at the same rate as Japanese eels if the changing of water and water temperature are carefully monitored and controlled.

Survival depends on the occurrence of diseases. Also, European eels have a tendency to escape which affects the yield. In other words, pond production depends on management. Generally, most farmers of European eels can expect survival rates of 50 to 70%.

European eels possess different growth and sex ratios from Japanese eels. In European eels, males and females grow to very different sizes. Female eels usually grow to over 200g, but male eels very rarely reach 200g. Most of the European eels grow close to the full market size (about 200g) or somewhat below that level because 60% or more of cultured European eels will naturally turn out to be male. Therefore, it is wise when rearing eels to thin out males when they are around 100g. This imbalance between the sexes is now under study in various research institutions.

F) Water control and disease prevention:

French-produced eels are more susceptible to parasites than Japanese eels. They are also more likely to die in the summer when water temperature is high. Eels often die under the following conditions:

1) when high water temperature continues in summer
2) following grading, fractional stocking and changing of the pond water
3) when water is contaminated due to sludge accumulation
4) when water quality changes
5) when over-dosage of drugs occurs
6) when eels are fed excessively to make then grow fast
7) when fluctuations occur in the pH level.

It is important to keep these points in mind in culture management.

## III. DISEASES OF EELS AND MEASURES FOR DISEASE CONTROL

Eel culture in greenhouses has great advantages over traditional eel culture in open-earth ponds in the areas of improved production, shortened production period, and lower incidence of disease during low water temperature seasons. On the other hand, eel culture in greenhouses has lead to one adverse effect: diseases which were seasonal in traditional open-earth ponds now occur irregularly. Thus, poor eel culture management in greenhouses tends to cause diseases more frequently.

A single disease often causes death, depreciation in value, or decreased growth. It may also cause high medical expenses. These factors, of course, directly and indirectly affect production costs. Furthermore, if the discovery of a disease is delayed and the disease has already reached an advanced stage, medication may not have any effect. Therefore, preventive measures against disease are very important.

### III.1. Diagnosis

The farmer must have an educated "eye" to differentiate between normal and abnormal (sick or unhealthy) eels.

Basically there are two types of eel diseases: parasitic (caused by parasites, bacteria, viruses) and non-parasitic (caused by water quality, lack of nutritive elements). However, the mechanisms of outbreaks are not yet clearly known. It is assumed that the presence of some of the elements from both types leads to an outbreak of disease (see Figure 7).

Accordingly, daily operations must include a close watch to determine whether or not there are any elements which may lead to an outbreak of disease. Every farmer must make it a habit to observe the conditions of eels and pond water closely every day.

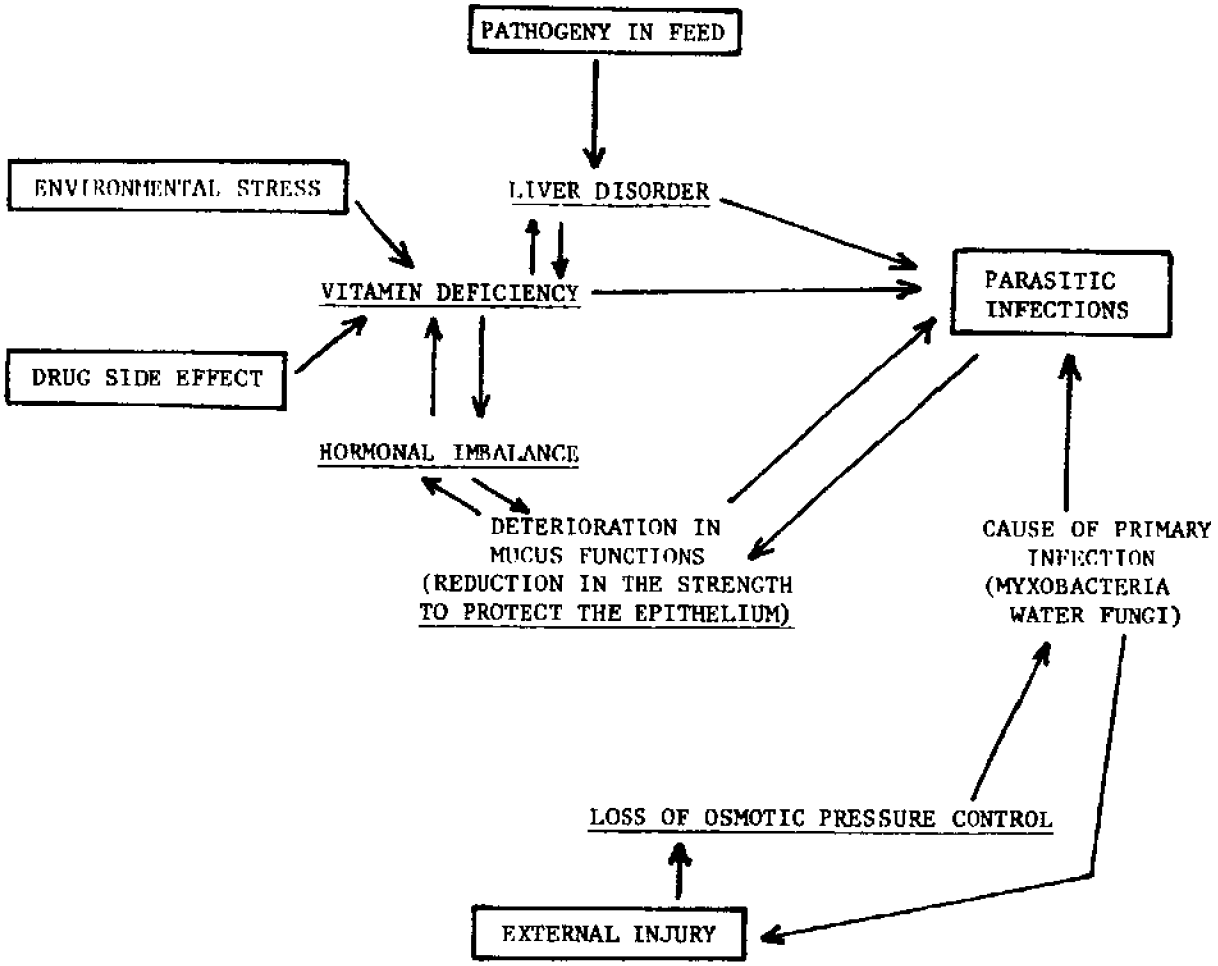


FIGURE 7. MECHANISMS LEADING TO OUTBREAKS OF DISEASE

A) Condition of eels in a pond:

(1) Are they swimming in an abnormal fashion such as tottering, spinning, or circling?

(2) Are they remaining in a shadow or by a feeding basket?

(3) Are the opercula swollen or is one of the opercula missing?

(4) Are any eels not eating?

(5) Are their bodies bumpy? Are any of them abnormally thin? Are there any eels with swollen bellies?

(6) Have they turned white? Do they have spots or is their coloring uneven?

(7) Do they have mold or mud on them?

(8) Are there any wounded eels?

If you see any eels which fit any of the above descriptions, remove them from the pond and examine them as described below.

B) Examination of eels (regularly once or twice a month, or when eels fit one of the descriptions in A):

(1) Place the eel on a towel and carefully examine the body surface. See Figure 8 for locations of body parts.

(2) Cut off an operculum with a pair of scissors and examine the gills. If possible, examine a section of the gill with a microscope at 50 to 110 magnification.

(3) Cut open the belly of the eel with a pair of scissors and examine the internal organs. When cutting the belly, be carefully not to damage the internal organs.

(4) Table 3 ill help in determining whether or not an eel is normal.

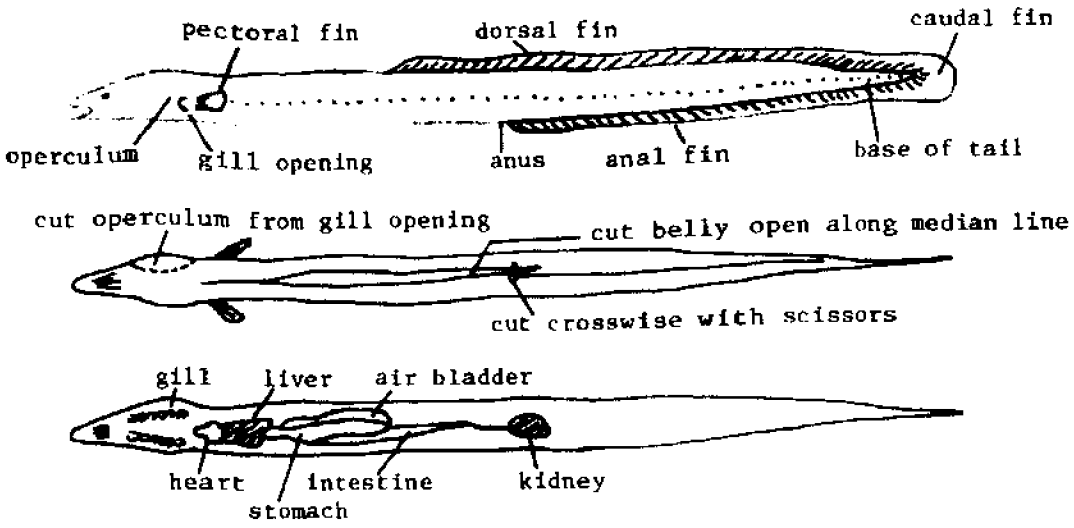


Figure 8. Parts of the eel.

TABLE 3. NORMAL AND ABNORMAL APPEARANCE OF PARTS OF EELS.

| | Parts | Normal | Abnormal |
|---|---|---|---|
| EXTERNALS | Figure | | Bumpy. Only the head is large. |
| | Body color | Dark blue to olive green. | The entire body is grayish white. Have opaque and/or white spots. |
| | Fins | No color, semitransparent. | Reddish, swollen, torn. |
| | Anus | No color, semitransparent. | Reddish, dilated. |
| | Belly | White. | Bleeding spots, and grooved or with depressions. |
| INTERNALS | Opercula | Red. | Pink, white, dark red, parts missing, uneven coloring, smeared with filth. |
| | Stomach | White, shrunk when empty. | Reddish, stretched and thinner, contains mucus and water. |
| | Intestines | Light pink. | Congested to really red, thinner and smaller. |
| | Liver | Dark red, even coloring. | Milky white, spotted. |
| | Kidney | Dark reddish brown. | Coffee color, enlarged, inflamed. |
| | Abdominal cavity | | Contains milky bluish fluid. |

III.2. Preventive Measures

The examinations described in A) themselves are preventive measures. In addition, the farmer should take the following precautionary measures.

A) Disinfection of the pond before stocking:

With the exception of a pond in which vinyl sheets have just been changed, ponds should be disinfected with a "kalk" bleaching powder (see p.71) two to four weeks prior to stocking eels in them. The steps in disinfection follow:

(1) Fill the pond with water (as high as or higher than the water level for rearing).

(2) Dissolve a "kalk" bleaching powder at the rate of 70 to 300 g/"tsubo" and mix well.

(3) Leave the water as it is for 4 to 7 days and then drain the pond.

(4) Dry the pond for about ten days.

(5) In the case of a mud pond, after the pond is disinfected with a "kalk" bleaching powder, spread hydrated lime at the rate of 1 kg/"tsubo", and plow the ground if possible.

B) Disinfection of eels before stocking:

Always disinfect eels in a medicine bath before stocking them in the pond and at the times of grading and fractional stocking.

(1) Methods of disinfection of elvers (see p. 17).

(2) Methods of disinfection at the times of grading and fractional stocking (see p. 25).

C) Checking the condition of pond water every day:

Since deterioration of the pond water weakens eels and may cause disease, it is important to check the water everyday.

(1) How much does the water temperature change in one day? You can either check the water temperature early in the morning and at noon, or use a maximum-minimum thermometer. Avoid more than a $5^{\circ}C$ difference in one day.

(2) How much does the pH change? Measure the pH at noon and at night (a simple colorimetric pH instrument will be sufficient). The following guidelines apply for pH -

a) When in good condition: daytime 8.0 to 9.5

night time 7.0 to 7.2

b) When in bad condition: below 7.0 during day and at night.

(3) Does it smell strange? Water smells bad as it gets stale. Change water ahead of schedule.

(4) Has the water color changed suddenly? Water color change in a pond can lead to lack of oxygen and depressed appetite in the eels. Change water ahead of schedule.

(5) Has the water turned slightly opaque, or has a lot of foam formed on the water surface? When the ammonia content in water increases, or when eels are agitated, they give off mucus which forms a great amount of foam. If left in the pond, the foam may contribute to an outbreak of disease. Change the water ahead of schedule.

(6) Is a lot of eel excrement floating on the water surface? This phemonenon is a danger signal that the eels are suffering from a digestive disorder. Switch to a more digestible feed.

(7) Is enough oxygen supplied? Lack of oxygen invites mass mortalities of eels. Increase the amount of aeration by blowers and/or by increasing the amount of water being pumped into the pond, or decrease the stocking density.

D) Checking the condition of the bottom of the pond every day:

(1) Has left over food or/and sludge accumulated? These accumulations are breeding grounds of disease organisms and cause poisonous gas to form; remove them as swiftly as possible.

(2) Are there dead eels lying at the bottom? This will cause the spread of disease. As soon as a dead eel is found, remove it and either burn it or bury it in the ground. Decomposition of dead eels in the pond way may cause a disease to recur.

(3) Does the oxygen supply reach the bottom of the pond? A large amount of oxygen is consumed by sludge which has accumulated on the bottom. In a mud pond the sludge rapidly deteriorates the quality of the bottom (the mud turns jet black), and if gas is generated, calcium carbide (200 to 270 g/"tsubo") or oxidized iron (100 to 130 g/"tsubo") should be spread to correct the situation.

III.3. Measures to be Taken When Eels are Taken Ill

A) Diseases caused by parasites:

Although eels do not often die because of parasites alone, this should not be taken lightly because complications involving secondary infections by bacteria often follow.

(1) Anchor worm infection -

Cause

The anchor worm resides mainly in the mouth cavity.

Symptoms

Anchor worms tend to invade eels weighing more than 100g. Infected eels exhibit spotty hemorrhages inside the lower jaw.

Heavy infestations make the fish unable to close its mouth and it is not able to eat; this is eventually fatal.

The anchor worm is visible to the naked eye. It has not been observed in a heated pond except in a few instances.

Disease-control measures

Spray Trichlorophon (see p. 70) in the breeding pond at a concentration of 0.2 to 0.6 ppm. It should be applied 3 or 4 times at two-week intervals. This drug is not effective against infesting adult anchor worms; it kills only larvae. One has to wait for the adult anchor worms to fall off.

(2) Dactylogyrus (Gyrodactylus) infection -

Cause

A trematode, Dactylogyrus or Gyrodactylus, infests the gills.

Symptoms

This infection breaks out frequently in a heated pond. The pathogen can be seen only by microscopic examinations (using a 40 to 100x magnification).

Heavily infested fish show poor appetite, but this parasitization alone is not fatal. French-produced eels, if infected, suffer grave consequences and damage will be severe.

Disease-control measures

Spraying Trichlorophon at a concentration of 0.3 to 0.5 ppm in the pond is effective. But its effectiveness will be reduced by half if the pond water is contaminated.

(3) Trichodina infection -

Cause

Trichodina, which is a ciliate protozoan, infests the gills.

Symptoms

This infection is not obvious externally, and diagnosis is by microscopic examinations (using approximately 100x magnification). Parasitization is found among all eels from elvers to "futo" regardless of their size. This infection is not fatal, but heavy infestations in elvers can cause great damage.

Disease-control measures

The use of formalin at a concentration of 30 ppm is effective. If the original pond is disinfected by a "kalk" bleaching powder, elvers seldom suffer from the Trichodina infection.

(4) Trichophrya infection (European eels only) -

Cause

Trichophrya, a kind of Suctorian protozoa, infests the gills.

Symptoms

The pathogen, Trichophrya, can be seen by microscopic examination using 40 to 200x magnification. Affected eels do not exhibit external symptoms, but they have a poor appetite and swim totteringly near the surface. Sometimes, they swim wildly and madly about. Trichophrya infection is sometimes fatal to eels, but usually does not cause great damage.

Disease-control measures

Formalin spray in a concentration of 30 ppm is effective.

(5) Glossatella* Infection -

Cause

Glossatella, which belongs to the Ciliata, infects mainly the gills and the tail.

Symptoms

The pathogen is seen by a microscope with 40 to 100x magnification. Diseased fish swim away from other fish and stagger close to the surface, but they seldom die from this infection. Glossatella infection tends to occur in a still-water heated pond.

Disease-control measures

Formalin spray at a concentration of 30 ppm is effective.

(6) Myxidium Infection -

Cause

Myxidium, a myxosporidian protozoa, invades the skin, kidney and gills.

Symptoms

Myxidium infection usually occurs only among eels being fed raw fish. Affected fish exhibit white spots as big as sesame seeds in a salt and pepper fashion on the body surface. As the infection progresses, the white spots spread over the entire body and small hemorrhages eventually appear all over the body.

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*Editor's Note: Apiosoma is a synonym for Glossatella.

This infection does not kill eels, but it can make them worthless.

The pathogen of Myxidium infection is seen with a microscope at 200 to 400x magnification.

Disease-control measures

There is no known way to exterminate the pathogen. The dermal parasitization heals spontaneously in a month or so after its outbreak. It should be prevented by disinfecting the pond with a "kalk" bleaching powder.

(7) Chilodonella Infection -

Cause

Chilodonella, a kind of ciliate protozoan, infests the body surface of elvers and "kuroko" eels.

Symptoms

Diseased fish have poor appetites, and fish which stop eating sometimes swim slowly and erratically close to the water surface or sometimes gather by the drainage. If left untreated, infected fish may die, but the damage is usually slight.

The pathogen is seen under the microscope with 40x magnification.

Disease-control measures

Formalin spray at a concentration of 30 ppm is effective. Immersing eels in a 0.5% saline bath is reportedly also effective.

(8) "Beko" Disease

Cause

"Beko" disease results from the infestation of muscle tissue by Plistophora anguillarum, a miscrosporidian, which invades the body.

Symptoms

Seed eels and "kuroko" eels which weigh about 0.5 to 10g are most susceptible to the infection. This disease causes irregular concave depressions on the body surface. Small fish such as "kuroko" exhibit slightly concave milky white spots. Since affected fish do not exhibit any peculiar behavior, this disease is often discovered late and the consequences are often serious.

Recently, "beko" disease has shown a tendency to occur frequently in heated ponds. The pathogen is seen with the aid of a microscope at 400x magnification.

Disease-control measures

At present there is no way to exterminate the pathogen of "beko" disease. Diseased eels should be picked up and incinerated as soon as they are found, and the pond should be thoroughly disinfected with "kalk" bleaching powder as a preventive measure.

(9) White-spot disease -

Cause

Ichthyophthirius, a ciliate protozoan, causes white-spot disease by infecting mainly the surfaces of the body.

Symptoms

Elvers weighing about 10g are very susceptible to white-spot disease. "Futo" eels do not get the disease very often. Diseased eels are easily observed because they are covered with white spots as if they were sprinkled with salt and pepper. As the disease progresses, some sick eels stop eating. However, this disease alone is not usually fatal.

White-spot disease does not occur easily in a pond with a bloom of green plankton or in a pond which contains salt. The pathogen is seen with the aid of the microscope at 400x magnification.

Disease-control measures

(a) The pond water temperature should be raised to 27 - 28°C and kept there for 4 to 7 days. This method is quite effective, but it must be applied when the water in the pond is clean or contamination of the water will simply increase.

(b) Methylene blue should be sprayed over the pond at a concentration of 2 to 3 ppm. This treatment must be repeated two to four times at intervals of 3 or 4 days. This method is not especially effective, and it leaves coloring in the eels (see p. 70).

(10) Anguillicola Infection -

Cause

Anguillicola globiceps, a nematode, resides mainly in the air bladder.

Symptoms

If the abdomen is cut open, up to ten blackish-brown nematodes will be found in the air bladder. Affected fish do not show any external abnormalities, but large eels tend to affected by this infection and some of them will lose market value. Infected European eels may not only stop eating, but they may even die. The same is not true of Japanese eels.

Disease-control measures

No effective treatment for this disease exists at present. The only preventive measures available are to disinfect the pond with "kalk" before stocking with eels or prevent the breeding of water fleas (Daphnia) because they are the intermediate hosts for the worms.

B) Diseases caused by bacteria and viruses:

(1) Cotton-covered (water fungus) disease -

Cause

The phycomycete fungus, Saprolegnia, causes cotton-covered disease. The optimum temperature for propagation of the fungus is 13 to 20°C, and it does not propagate well in the pond below 10°C or above 20°C. This disease seldom occurs in a heated pond.

Symptoms

The surfaces of the body and the gill become infested. At the beginning of the infection, affected parts of the eel exhibit indistinct white spots. As the disease progresses,

hyphae grow and flocculate. In most cases, spores of the cotton-covered disease invade the fish only after they have been infected by red fin disease as the primary condition. Cotton-covered disease usually occurs as a secondary disease.

Disease-control measures

(a) Red fin disease should be treated and, at the same time, the water fungus must be exterminated. Sulfa drugs or antibiotics should be administered orally for the treatment of red fin disease. To exterminate fungus, the pond must be sprayed twice with methylene blue (2 to 3 ppm) at two-day intervals. This will not kill the hyphae already invading the tissues of the eels; it merely stops propagation of the fungus. To produce satisfactory results, the treatments must be administered in the early phase of the disease.

(b) In a heated pond, water fungus will disappear if the water temperature is kept above 25°C.

(2) Red fin disease -

Cause

Red fin disease is caused by an infection of the bacteria, Aeromonas hydrophila. This infection develops easily and causes great damage when the water temperature is 15 to 20°C, but damage is slight when the water temperature is above 20°C. Red fin disease is often complicated by water fungus.

Symptoms

(a) Symptoms in mid-sized and "futo" eels include reddening of the anal, dorsal, and pectoral fins; reddening and enlargement of the anus are symptoms common to all affected fish. As the disease progresses, the belly becomes inflamed and red and begins to bleed. Visceral pathology includes reddening of the intestinal tract, congestion or hemorrhages of the liver, and bleeding, dilation and mucus repletion of the wall of the stomach. These symptoms are visible to the naked eye.

Diseased fish eat very poorly, and some of them remain still in the shade while others stagger near the surface of the water during the day.

(b) Symptoms in elvers and "kuroko" eels include having part of the body slightly opaque and they swim strangely. Most often the reddening which characterizes this disease is not visible, and one must depend on the microscope to detect it (40x magnification).

Parasites are sometimes found in elvers suffering from red fin disease. These eels usually stagger helplessly in a dark place or near the water surface.

Disease-control measures

(a) Treatment for mid-sized and "futo" eels:

If the diseased fish will eat, sulfa drugs or antibiotics should be mixed with the food for oral administration of the medication. The medicine should be continued until sick and dead fish disappear but not longer than 7 to 10 days.

If the treatment is effective, mortality will decrease in 4 to 6 days after the medication was started and sick eels will stop dying in ten days.

If the eels will not accept food, the disease is already quite advanced and the only available treatment is a medicated bath using a Furan agent.

(b) Treatment for elvers and "kuroko" eels:

A medicated bath with a Furan agent is effective. The medicated bath must be repeated after 2 to 3 days for eels with advanced symptoms. It will be more effective if a sulfa drug or antibiotic is administered orally at the same time as the bath is used.

When parasites are found in eels, the parasites must be exterminated first.

(3) Paracolo Disease ("Choman" = intestinal dropsy) -

Cause

Paracolo disease is caused by an infection of the bacterium, Edwardsiella tarda. This bacterium breeds easily during warmer months.

Symptoms

Symptoms of Paracolo disease are similar to those of red fin disease. Principal external symptoms include reddening and bleeding spots on the fins and belly, reddening and dilation of the anus. Principal internal pathology includes enlargement and congestion of the liver and kidney, and reddening and inflammation of the intestinal canal. An outstanding characteristic is the inflammation of the kidney.

There are cases of a mixed infection of both Paracolo disease and red fin disease. Therefore, a bacterial test is necessary to diagnose Paracolo disease accurately.

Diseased fish sometimes die en masse, but they usually die gradually in small numbers.

In a heated pond, elvers and "kuroko" eels sometimes develop Paracolo disease at the time of domestication. If this happens, it is difficult to discover the disease because the eels are still very small and the consequences may be serious.

Disease-control measures

Treat Paracolo disease in the same way as red fin disease.

(4) Red spot disease -

Cause

Red spot disease is caused by infections of the bacterium, Pseudomanas anguilliseptica.

Symptoms

Bleeding spots cover the entire body from the lower jaw to the belly and the tail. By the time these bleeding spots break out, the eel's entire body is infected, and these conspicuous spotty hemorrhages are a sign that the disease has already advanced to the terminal stage. It is characteristic of this disease that the initial stage has practically no internal or external symptoms. Thus, it is often discovered too late to prevent serious damage.

This disease develops only in ponds containing salt when the water temperature is below 25°C. Even if it occurred in a fresh water pond, it would cause only slight damage.

The distinction between red spot disease and either red fin disease or Paracolo disease is that spotty hemorrhages are observed with red spot disease, and if the farmer gently rubs the diseased eel the hand will become bloodstained.

Disease-control measures

In most cases the disease is discovered too late for the administration of drugs, either orally or by bathing, to have any positive effect.

In the case of a heated pond, the disease will dwindle and the damage it causes can be reduced by raising and keeping the water temperature above 27°C.

(5) Gill rot disease -

Cause

Gill rot disease is caused by infections due to the gliding bacterium, Flexibacter columnaris.

Symptoms

This disease mainly affects eels weighing more than 50g, and infected fish show no external symptoms. However, when the opercula are removed to expose the gills, one can often see that the tips of gill lamellae are missing and/or yellow masses of bacteria the size of sesame seeds are present. As the disease progresses, the gill lamellae

became covered with red and white spots and filth will adhere to them. In addition, the fish develop a severe anemic condition, and their bodies turn gray. Even when the belly is cut open only thin blood comes out and internal organs such as the liver are bloodless.

The infected eels eat well unless their condition is quite advanced. This fact usually delays discovery of the disease. This disease usually does not result in massive mortality, but the fish die in small numbers for one to three months. Over a long period of time this loss can result in a near total destruction of the crop.

Disease-control measures

Either add salt to a concentration of 0.5 to 0.8%, or spray a Furan drug in the pond. Oral administration of a sulpha drug or antibiotic is not very effective unless red fin disease or Paracolo disease is also involved.

In addition, the supply of fresh water, aeration and reduction of stocking density (the eels must be handled as little as possible) will help since diseased eels are very easily affected by a lack of oxygen. Also, the amount of feed must be reduced since over-eating is harmful to sick eels.

(6) Fin rot disease (tail rot disease) -

Cause

Fin rot disease is caused by the same pathogen as for gill rot disease. Lesions occur on the fins and at the root of the tail.

Symptoms

This infection is found among small eels. It does not affect mid-sized and "futo" eels very much.

In the initial stage of the infection, a white sticky substance appears on the edges of the fins. As the disease progresses, the lesions expand gradually and the fins wear off. With further development, the lesions advance to the muscles at the bases of the fins and the tail exposing red flesh or rotting the tail away.

Damage is usally not too severe, but eels may continue to die over a long period of time.

Disease-control measures

Same as for gill rot disease.

(7) Myxobacterial gill disease -

Cause

Myxobacterial gill disease is caused by a gliding bacterium which is different from the pathogens of gill rot and fin rot disease. It occurs during periods of low water temperature.

Symptoms

Myxobacterial gill disease usually infects large-size eels. Characteristics of this disease include bleeding from the gills, adhesion or white necrosis of gill leaflets producing a club-shaped form. This disease is quite severe. Once it develops and progresses, the affected fish die at an alarming rate, and they could all die eventually.

However, the occurrence of myxobacterial gill disease is less frequent than that of gill nephritis (see p. 55), and it is very rare in a heated pond.

Disease-control measures

Both sprinkling of rock salt (table salt) and oral administration of a sulpha drug and antibiotics are said to be somewhat effective.

(8) Abscess or abscessed infection -

Cause

This infection is caused by a Vibrio bacterium.

Symptoms

In the initial stage, white bumps appear on the sides of the body. As the infection progresses, red rims emerge around the white bumps. As the infection further spreads, the lesions become red and inflamed. However, the fins do not redden and the number of abscesses is small (usually one to three). The infected eels eat quite well.

This infection occurs only in ponds containing salt, and it is frequent during the seasons of high water temperatures. If the infection is left until it becomes advanced, it can cause great damage, and complications due to secondary infections (red fin disease or Paracolo disease) may occur.

Disease-control Measures

Oral administration of sulpha drugs or antibiotics is effective.

(9) Viral nephritis -

Cause

Viral nephritis is caused by infections of EVE virus.

Symptoms

This disease occurs during low water temperature seasons and the mortality rate may be 30 to 50% or more. The body of the diseased fish stiffens, and a groove or depression emerges along the median line on the belly. The belly turns slightly red, and the anal fin is sometimes bright red. In addition, bleeding, congestion and swelling of the kidney are observed.

Disease-control measures

No preventive measures are available at present. However, keeping the water temperature above 25°C may suppress the spread of viruses. (author's note: when viral nephritis occurs in a heated pond, the sick eels must be given a 0.5% brine bath. At the same time, the water temperature should be kept above 25°C until the eels stop dying. As fresh water is pumped into the pond, table salt should be added a little at a time.)

(C) Diseases of unknown etiology:

(1) Gill nephritis (gill-kidney inflammation) -

Cause

The etiology of this disease has not yet been determined. It is possible that a virus is responsible.

Symptoms

Marked pathological changes occur in the gills, kidney and blood characters.

(a) The gill .... hypertrophy of the gill leaflets occurs first. Then adhesion of the gill leaflets occurs, and the gill lamellae become clublike masses. The gills look swollen and dark red to the naked eye.

(b) The kidney .... although pathological changes of kidney cells take place, they are not recognizable to the naked eye.

(c) Blood characters .... the number of chloride ions in the blood plasma decreases drastically. In the last stage of disease, the concentration of chrloride ions is reduced to between 1/4 and 1/6 of that in healthy fish.

(d) External symptoms .... there is no apparent visible sign of this disease in the initial stage. As the disease progresses, dehydration occurs and the muscles stiffen. A groove or depression appears on the belly from the anus to the liver, and the part of the belly containing the liver appears slightly swollen.

Gill nephritis is sometimes accompanied by water fungus, red fin disease, and/or red spot disease.

Damage

The smaller eels suffer more severe damage. If the disease breaks out during the winter (December, January, or February), it usually results in the near-total destruction of the crop.

Gill nephritis does not usually occur if the pond contains salt. There is no record of gill nephritis in a heated pond, but something else with similar symptoms does occur, although the damage it causes is not severe.

Disease-control measures

There is no cure available for gill nephritis, but 0.5 to 0.7% salt water will prolong the lives of the eels. If possible, the water temperature should be raised above 25°C and kept there until the disease recedes.

Disease preventive measures include: (1) spread rock salt at 0.2% concentration at the time feeding is stopped; (2) diseases which occur before the time feeding is stopped should be completely cured; (3) feed which is enriched (e.g., by vitamins) should be administered before winter to build up physical strength; (4) feed the eels as long as possible before winter.

(2) Abdominal dropsy disease -

Cause

The cause of abdominal dropsy disease is not known at this time. A virus or poisoning by some toxic substance may be responsible.

Symptoms

Abdominal dropsy disease affects eels of all sizes. Diseased eels exhibit extremely swollen bellies, and their bodies turn grayish-white. When the belly is cut open, blue-green fluid flows out. Diseased eels stop eating and swim about erratically close to the surface of the pond. They are sometimes concurrently affected with

red fin disease or Paracolo disease and may die.

Abdominal dropsy disease seldom occurs in heated ponds.

Disease-control measures

Neither prophylaxis nor treamtnet is available. One can only minimize the damage from abdominal dropsy disease by treating or preventing concurrent diseases. Eels suffering from abdominal dropsy disease will sometimes recover if they are put in flowing water.

(3) Connected-hole disease (Hole-making disease) -

Cause

Unknown. It is thought that connected-hole disease is the result of "beko" disease as the primary disease with complications by another bacterium as a secondary infection. Few occurrences of this disease have been recorded.

Symptoms

Eels suffering from connected-hole disease exhibit body surfaces with red holes (ulcers) of different sizes. The eels look so grotesque that they are unmarketable. This disease develops among adult eels only.

Disease-control measures

Not available. If red fin disease and Paracolo disease are concurrent, it is necessary to treat them.

(4) Kidney tumor -

Cause

Unknown. This is a cancer in the kidney.

Symptoms

Externally, the area around the anus swells and looks like a bump. This illness has not presented a problem because there have been few cases in Japan although it has occurred in Taiwan.

Disease-control measures

Not available at present. Feed is suspected of being somewhat responsible.

(5) An unidentified disease of European eels -

Cause

Unknown.

Symptoms

Outbreaks are limited to rearing ponds with still water, and they tend to occur more easily in summer. Sick eels swim erratically in an upright position near the surface or swim madly around as if they are gliding. The eels do not eat, and they sometimes die in large numbers.

Disease-control measures

No treatment available. As a preventive measure, water contamination must be prevented and parasites exterminated when the water temperature is above $25^{\circ}C$.

(D) Diseases caused by water and feed:

(1) Gas bubble disease -

Cause

Gas bubble disease is caused by supersaturated oxygen and/or nitrogen. It occurs among elvers and "kuroko" eels.

Symptoms

Air bubbles develop beneath the skin on the head of diseased eels, and their heads look like balloons. Sick eels swim erratically in an upright posture near the surface of the water. However, this illness is seldom fatal and does not occur frequently.

(2) Convulsion disease (tentative name) -

Cause

A toxic substance in the pond water is believed to cause this disease. For instance, zinc leaching from hot heating pipes is a possible cause.

Symptoms

This disease breaks out among elvers and "kuroko" eels. Diseased eels go into a convulsive fit and die in the pond or when they are picked up in a net.

Disease-control measures

Prevent all toxic substance from entering the pond water.

(3) Histamine toxicosis (tentative name) -

Cause

Histamine compounds in mackerel flesh are believed to cause toxicosis when stale mackerel is fed as fresh food.

Symptoms

Reddening of the fins and sides of the body and sloughing of body mucus are often observed. Affected fish seldom die.

Disease-control measures

Red fin disease and Paracolo disease may develop as secondary infections if the mucus is sloughed. Cease using mackerel as feed and switch to other fresh or formula food.

(E) Use of medicines and drugs:

In fish culture, one cannot avoid the use of drugs for treating and preventing diseases. However, drugs are poisonous to the eels, and they also should not remain in bodies of eels which will become food for humans. Furthermore, if the drugs are used too much, they may result in resistant strains of pathogens and the drugs become ineffective. For these, and other reasons, overdependency on drugs in fish culture must be avoided, and caution must be exercised in using them.

(1) Furan drugs

Furan drugs may be applied as a medicine bath, by spraying in the pond, or by oral administration.

(a) Kinds of Furan drugs (see Table 4).

(b) Directions for use of Furan drugs.

(1) Medicine baths and spraying on the pond are more effective in the long run, but since Furan drugs are destroyed by light, 24 hours is the limit of their effectiveness. (Note: Medicine bath and spraying on the pond are essentially the same method. By spraying on the pond, the pond itself becomes a medicine bath tub).

TABLE 4. INFORMATION ON KINDS AND USE OF FURAN DRUGS.

| Generic Name | Brand Name | Effective Ingredient | Sales agent* | Directions For Use |
|---|---|---|---|---|
| Furazolidon | Furandasu | Pure powder 100% | Sankyō Kasei | |
| Furazolidon | NF Ueno C 20 | 20% powder | Ueno Seiyaku | Medicine bath |
| Nifurpyrinol | Furaneesu (Granulated) | 10% granulated | Dai Nihon Seiyaku | Spray in pond |
| Nitrofurazon | Monafurashin (Granulated) | 80% granulated | Dai Nihon Seiyaku | |
| Furazolidon | Furandasu 10 | 10% powder | Sankyō Kasei | |
| Furazolidon | NF Ueno | 10% powder | Ueno Seiyaku | |
| Furazolidon | Furazolidon 10 Kookin | 10% powder | Kōkin Kagaku | |
| Panolzon | Taizon | 2% powder | Taito Pfizer | Oral |
| Panolzon | Panazon 20 | 2% powder | Toyama Kagaku | Adminis- |
| Panolzon | Panazon | 1% powder | Toyama Kagaku | ration |
| Nifurpyrinol | Furaneesu (powdered) | 1% powder | Dai Nihon Seiyaku | |
| Dihydroxymethyl furatoridine | Furatorijin | pure powder 100% | Toyama Kagaku | |
| Dihydroxymethyl furatoridine | Furatorijin (powdered) | 10% powder | Toyama Kagaku | |

* Editor's Note: All sales agents listed are located in Japan.

Spray concentrations vary depending on the kind of medicine:

Nifurpyrinol .... 1 to 2 ppm (1 ppm = 1g/ton of pond water)

Furazolidon Nf Ueno C 20 ..... 10 to 15 ppm

Furandāsu ..... 2 to 3 ppm

Nitrofurazon .... 2 to 10 ppm

Short - time medicine baths are used for prevention (concentrations and times are stated on the instruction sheet accompanying the drug).

(2) Oral administration of Furan drugs cannot be expected to be very effective because absorption in the intestinal tract is difficult and they are quickly excreted. This method is used as a preventative before winter begins (for example, administration of Furazolidon at 20 to 40g per 20 kg of formula food per day for one to two months).

(c) Caution in use.

(1) Damage from medicines can result since strong antibacterial Nifurpyrinol has the strongest toxicity for eels. Furazolidon and Nitrofurazon are weaker in anti-bacterial power than Nifurpyrinol, but they are also lower in toxicity than Nifurpyrinol.

(2) Furan agents lose their efficacy when exposed to sunlight (medicine baths should be given either indoors or during the night). The effectiveness of Furan drugs increases as the water temperature increases. Their effectiveness decreases if the water is contaminated or if green plankton is too think. Furan drugs sometimes reduce phytoplankton blooms.

(2) Sulfa drugs -

Soda salt which dissolves in water can be used in a medicine bath, but it is presently given only by oral administration.

(a) Kinds - (see Table 5).

(b) Directions for use.

Most Sulfa drugs are produced in a powder form. They are either pure drugs or in concentrations of 10%, 20%, etc. There are two types of Sulfa drugs: soluble or insoluble. Read the directions for use before administering any Sulfa drug.

Daily dosage calculated in terms of the pure powder form (effective ingredient 100%) is 100 to 200g per ton of eels, and the drug should be mixed only with the food the eels will eat.

The drug is usually given for 5 to 10 consecutive days with no break, and the period of treatment should not exceed two weeks.

(c) Caution in use.

(1) Since the efficacy of the drug depends on the disease, a certain amount of experience is necessary.

(2) Loss of the drug will be less if one uses a pure powder form of insoluble soda salt than a form which dissolves easily in water, but the pure powder form is difficult to mix evenly (percent concentration forms of medicines are more voluminous than the pure form and are easier to mix evenly).

TABLE 5. KINDS AND DIRECTIONS FOR USE OF SULFA DRUGS.

| Generic Name | Brand Name | Form | Effective Ingredient | Directions for use* | Sales Agent** |
|---|---|---|---|---|---|
| Sulfamerazine | Romejinsoda | Powder | 10% | 1,000-2,000g | Tanabe Seiyaku |
| Sulfamonomethoxine | Daimeton | Powder | Pure Powder | 100-200g | Daiichi Seiyaku |
| " | Daimeton (Powdered) | Powder | 10% | 1,000-2,000g | Daiichi Seiyaku |
| " | Daimeton Soda | Powder | Pure Powder | 100-200 | Daiichi Seiyaku |
| Sulfadimethoxine | Sulkisin 10 | Powder | 10% | 1,000-2,000 | Chūgai Seiyaku |
| " | Aimexin BF | Powder | 10% | 1,000-2,000 | Nissan Gōseikō |
| " | Jimetoxin 10 | Powder | 10% | 1,000-2,000 | Mitaka Seiyaku |
| " | Sulkisin Natrium | Powder | Pure Powder | 100-200 | Chūgai Seiyaku |
| " | Sulkisin (Powdered) | Powder | 10% | 1,000-2,000 | Chūgai Seiyaku |
| " | Jimetoxin/Kōkin | Powder | 10% | 1,000-2,000 | Kōkin Kagaku |
| " | Jimetoxin/Kōkin/100 | Powder | Pure Powder | 100-200 | Kōkin Kagaku |
| " | Jimetoxin 20% liquid | Liquid | 20% | 500-1,000 | Mitaka Seiyaku |
| " | Jimetoxin (Powdered)PT | Powder | 10% | 1,000-2,000 | Taito Pfizer |
| Sulfadioxazole | Saiajin | Powder | Pure Powder | 100-200 | Yamanouchi Seiyaku |
| " | Saiajin liquid | Liquid | 10% | 1,000-2,000 | Yamanouchi Seiyaku |
| Sulfadiozole | Isuran | Powder | Pure Powder | 100-200 | Takeda Seiyaku |
| " | Isuran 10 | Powder | 10% | 1,000-2,000 | Takeda Seiyaku |
| " | Isuran soda | Powder | Pure Powder | 100-200 | Takeda Seiyaku |

*Directions: Daily dosage per ton of fish
**All sales agents listed are located in Japan (editor's note).

(3) There is a danger of damage from medicines if two or more kinds are used at the same time.

(4) If Sulfamerazine, Sulfadimethoxine, and/or Sulfadioxazole are used in large amounts, there will be damage from the medicine, such as broken bones. Therefore, caution is necessary.

(5) Eels should not be shipped to market for at least a week after medicines are administered.

(3) Antibiotics -

Since antibiotics dissolve easily in water, they can be used in medicine baths. However, they are mainly administered orally. Antibiotics generally possess stronger antibacterial power than Sulfa drugs, but they are expensive and will not keep for a long time.

(a) Kinds. (See Table 6).

(b) Directions for use.

Antibiotics are not available in pure powder form; they are produced in powder forms in concentrations of 2 to 10%.

Dosage per day calculated on the basis of a pure powder form (effective ingredient 100%) is 20 to 50g per ton of eels. The drug should be given for 5 to 10 consecutive days by mixing it with the feed the eels are going to consume each day.

Antibiotics are excreted even faster than Sulfa drugs. Therefore, they are more effective if administered twice daily, in the morning and in the evening, rather than once a day.

TABLE 6. KINDS AND USE OF ANTIBIOTICS.

| Generic Name | Brand Name | Form | Effective Ingredient | Directions for use* | Sales Agent** |
|---|---|---|---|---|---|
| Chloramphenicol | Chloromaisechin (Powdered) | Powder | 10% | 200-500g | Sankyo |
| " | Chemisechin (Powdered) | Powder | 5% | 400-1,000g | Fujisawa |
| " | Chemisechin (Liquid) | Liquid | 5% | 400-1,000cc | Fujisawa |
| Oxytetracycline | Terramycin (Powdered) | Powder | 10% | 200-500g | Taito-Pfizer |
| " | Junmycin | Powder | 5.5% | 400-1,000 | Tanabe |
| Chlorotetracycline | Oreomycin (Powdered) | Powder | 10% | 200-500 | Nippon Lederle |
| Cyanphenicol | Neomycin M | Powder | 2% | 1,000-2,500 | Eisai |

*Direction: Daily dosage per ton of fish
**Editor's Note: All sales agents listed are located in Japan.

(a) Caution in use.

(1) Continuous use of antibiotics encourages the creation of resistant bacteria.

(2) When a drug is administered, its effective date (labeled) must be checked.

(3) Drugs should be prepared just before feeding because antibiotics are degraded by high pH and light more readily than Sulfa drugs.

(4) Antibiotics should be used only after Furan and Sulfa drugs are no longer effective.

(5) Overdoses of antibiotics easily cause an opposite effect.

(6) Eels should not be shipped to markets for at least one week following use of an antibiotic.

(4) Other drugs -

(a) Synthetic antibacterial drugs.

(1) Oxolic Acid (Brand name - Parazan for Marine Use: Tanabe Pharmaceutical Company).

Directions for use:

-- This drug should be administered orally as with Sulfa drugs and antibiotics.

-- Daily dosage is 200 to 400g per ton of eels to be administered by mixing the drug with the amount of feed the eels are going to eat.

Caution in use:

-- The eels should not be shipped to markets for 18 days after medication administration has stopped.

-- This drug should be used only for bacterial infections such as red fin disease and red spot disease.

(2) Formalin

Formalin is a liquid with an irritant odor containing 37 to 40% Formaldehyde.

Directions for use:

-- Formalin must be sprayed at a low concentration in the pond to be used as a medicine bath.

-- The concentration should be 30 ppm (30 cc/ton of pond water), and the bath should be 24 hours long.

-- Do not feed the eels during the medicine bath, and water in the pond should be changed after the bath.

Caution in use:

-- The efficacy will be reduced by half if the water in the pond is dirty or if plankton is too dense.

-- Formalin may cause the plankton bloom to decline and the water quality may then deteriorate.

-- The eels may lose their appetite for one to three days after Formalin is applied.

-- If the Formalin concentration is too high, it may damage the body surface and gills of the eels.

-- Eels are not marketable for five days after a Formalin bath (after the water in the pond is changed).

(3) Methylene blue.

Methylene blue dissolves in water relatively easily and it is dark blue.

Directions for use:

-- Methylene blue must be sprayed in the pond at a concentration of 2 to 3 ppm and the bathing needs to be as long as three days.

-- The safety level of methylene blue for eels is high.

Caution in use:

-- Coloration due to methylene blue stays in the tissues of eels for a long time (about six months), and use of methylene blue should be limited to elvers and "kuroko" eels.

-- Methylene blue may be harmful to plankton blooms and may cause water quality changes.

(4) Trichlorophon.

Trichlorophon is marketed under the brand names "Masoten" and "Dylox".

Directions for use:

-- Trichlorophon should be sprayed in the pond at a concentration of 0.2 to 0.6 ppm.

-- The safety level of Trichlorophon for eels is high.

-- Eels should not be fed on the day this drug is applied.

Caution in use:

-- Trichlorophon may not be very effective if the plankton bloom is too dense or the water is dirty.

-- Lack of oxygen may be a danger because eels may lose appetite, their bodies turn grayish-white, and they float with their nose near the surface of the water within 1 to 3 days following application of the drug.

-- Since Trichlorophon remains in eels for seven days, they should not be shipped to market during that period.

(5) Rock salt (or table salt).

Directions for use:

-- Rock salt is used for giving a brine bath.

-- The concentration for spraying is 0.5 to 0.7% and rock salt is quite safe.

Caution in use:

-- As the length of the spraying period (application of the brine bath) is increased, the greater its effectiveness; but it may invite deterioration of the plankton bloom, water quality, and the condition of the pond bottom. One must be aware of these dangers.

(6) "Kalk" (bleaching powder).

"Kalk" is a powder drug with 40 to 60% effective chlorine.

Directions for use:

-- "Kalk" is used for its disinfectant and germicidal action.

-- Dosage for spraying is 20 to 100g per ton of water in the pond (this is equal to 20 to 100kg/¼ acre). "Kalk" is extemely poisonous for eels.

Caution in use:

-- "Kalk" requires 3 to 4 days for disinfection. However, effective chlorine sometimes remains at the time of the water change, and it is desirable to continue changing water more than seven days after the spraying.

-- Chlorine is harmful to humans. One must, therefore, be careful not breathe it when spraying.

## IV. CULTURE OPERATIONS

Since the oil crisis, prices have soared and profitable eel culture has become more difficult every year. Despite the fact that prices for heavy oil for heating, electricity and feed have doubled compared with those of 1972 (when eel culture in greenhouses began to become common), the price of market-size eels at the time of shipment has changed very little. In some years it has even dropped below the normal price. Therefore, an important problem confronting future culture operations is how to keep production costs down. For this, more elaborate production plans and more advanced culture techniques will be necessary.

### A) Basic data collection:

In addition to studying and improving his own culture techniques, the farmer should record and gather data pertinent to each of his ponds.

This is essential for research and improvement of culture technology. There are many instances where a farmer's eel production output would not stabilize and unnecessary pond management mistakes are made due to the lack of the following basic data.

(1) Temperatures of the source water throughout the year.

The temperature of the source water (underground water or subsoil water) must be taken regularly -- not necessarily every day, but at least three or four times each month throughout the year -- and recorded (this mainly affects the heating efficiency).

(2) Weather and temperatures.

If possible, these should be recorded every day. Eels do not eat very well and their growth rate will sometimes decrease during the rainy season. Temperatures affect heating efficiency.

(3) Water temperature in the pond.

The water temperature in each pond should be taken every day in the morning and at noon. This data is useful in caring for the health of the eels and it makes some forecasting of the growth possible.

(4) Number and weight of eels when stocked in the ponds and/or graded.

Without this information, production plans cannot be made. Eels are to be weighed according to sizes, and the sum total of the weights is the total production.

(5) Kind and volume of feed.

The kinds of feed for domestication, elvers, "kuroko", "futo", etc. as well as the volume of feed given should be recorded every day (including nutritive drugs and feed oil). When (5) is compared to (3) and (4), one can deduce whether the volume of feed is too much or too little and an estimate of feed efficiency can be made.

(6) Rearing density (number of eels, kg/"tsubo").

Rearing density must be recorded when the eels are moved from one pond to another. Whether or not added water supply and aeration are necessary will depend on the density. By accumulating data, one will come to know the appropriate density for each pond. Without this piece of data, the farmer may make an unexpected mistake (i.e. not being able to calculate the correct dosage when a disease develops).

(7) Weight (growth) curve.

A weight increase curve graphically represents the relationship of the weight at the time of grading and the number of days. This graph can help the farmer plan appropriate increases of feed volume and harvesting the ponds.

(8) Feed efficiency.

Feed efficiency is calculated with data on weight increases and total volume of feed given from one grading to the next or yearly. If food is being wasted this will show clearly and the farmer can pinpoint areas for improvement.

(9) Heating efficiency of boilers.

The farmer should know how much fuel oil is needed to raise the temperature of the pond water by $1^{\circ}C$. Heating costs can then be estimated on the basis of this figure.

(10) Disease, dosage of drugs, recovery and number of deaths.

This information helps the farmer devise countermeasures for the next item (11). It is important that the effect of these figures on the weight increase curve is examined by the farmer.

(11) Relation between water supply volume and water quality.

Whenever possible, water supply volume (liters or tons/minute), pH, growing conditions of the phytoplankton bloom, and ammonia level (if possible) in the pond water must be recorded. These records are very useful for supervising the pond water quality.

(12) Other items.

Anything which attracts your attention in the daily operations should be recorded in detail. These records may help later.

B) Computation of production costs:

Production costs are the foundation of a culture operation and should be calculated yearly (or for each production period). If one neglects these calculations, the operation will become an "I-intend-to-operation", and you may have to say, "I should have made some profit, but all I have is debt". The necessary information is listed below.

(1) Income

(a) Shipment sales

The number of eels, volume of shipment, unit price, and date should be recorded, and the categorized total computed.

(b) Interest from savings.

(2) Expenditures

(a) Cost of seedling eels

The purchasing cost, volume, unit price of elvers and medium-size eels, number of medium eels, and place of purchase should be recorded.

(b) Personnel expenditure

This includes the wages of helpers and laborers (except those of the owner himself).

(c) Cost of electricity

Calculate monthly electric consumption.

(d) Fuel costs

Record and total the amount used every delivery period and the unit price.

(e) Feed costs

Record and total the unit price and volume for each kind of feed.

(f) Medicine costs

Record expenditures for disinfection and treatment; do not include the unused portion of the drugs purchased.

(g) Mortgage interest

Interest on the mortgage for the construction of facilities.

(h) Depreciation costs

The total of the purchasing costs of facilities and machinery is divided by their usable years. Without adding these, one cannot plan for a continuous operation.

(i) Cost of repairs

Record expenditures for repair of broken facilities and machines.

(j) Other costs

Expenditures for expendable supplies, correspondence, transportation, and utilities for the administration office should be included.

Production costs are computed by dividing the sum of all the items in expenditures (a through j above) by the production volume of eels. For example, if the total of eels shipped to market is 10 tons and production expenditures are 15 million yen, then the production cost is 15,000,000 yen ÷ 10,000 kg = 1,500 yen/kg. If the average shipment price in that particular year is higher than 1,500 yen/kg. the operation is in the black. If it is lower, the operation is in the red.