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Transition of the Techniques and Diseases in Eel Culture

Abstract

The Japanese eel culture industry has passed a century in its history. Over the years, the industry innovated its culture methods and techniques several times to improve productivity. There had been several occurrences of diseases that produced serious damages to eel production. Some of the diseases occurred with the changes in feed and/or environmental conditions, which were related to the innovations of the culture methods and techniques.

Today, when the strength of the Japanese eel culture industry seems over, it may be appropriate to review the relationship between the occurrence of diseases and culture innovations. We report here the essential points of the review.

Key words: Eel culture in outdoor and greenhouse ponds, *Anguilla japonica, A. anguilla*, Eel diseases, Formulated feed

The Japanese eel culture industry commenced in 1879, when Kurajiro Hattori established an eel culture farm in Tokyo(1). From that time, Japan has an eel culture history beyond a century.

It was in the 1890s that eel culture farms opened successively in Shizuoka prefecture, situated in the Pacific side of Central Japan where the climate was genial and was rich in freshwater. Shizuoka prefecture has held the leading position not only in industry but also research and investigation consistently from the start to the present. We have carried out our studies principally in this prefecture.

The annual production had increased gradually since the start of the industry and reached around 8,000 tons in 1940 just before the Pacific War. It decreased to almost zero during the war and just after the war ended; after which, the annual production revived rapidly and reached around 40,000 tons in the 1980s (Fig. 1).

During the long history, there have been several innovations of the culture methods and techniques, which was intended to improve productivity.

On the other hand, there had been several occurrences of serious damages to the production due to diseases. Some of the diseases encountered are caused by new disease agents while others are due to already known agents. Disease outbreaks due to the changes in feed and/or environmental conditions or incomprehensible reasons, are often related to innovations of the culture methods and techniques.

We have studied these relations for many years. Essential points of the study are reported here.

The diseases which will be dealt with here are those which prevailed widely causing extensive

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damages. There have been many kinds of diseases of minor importance which occurred locally or sporadically, causing slight damage. These diseases will be not discussed here.

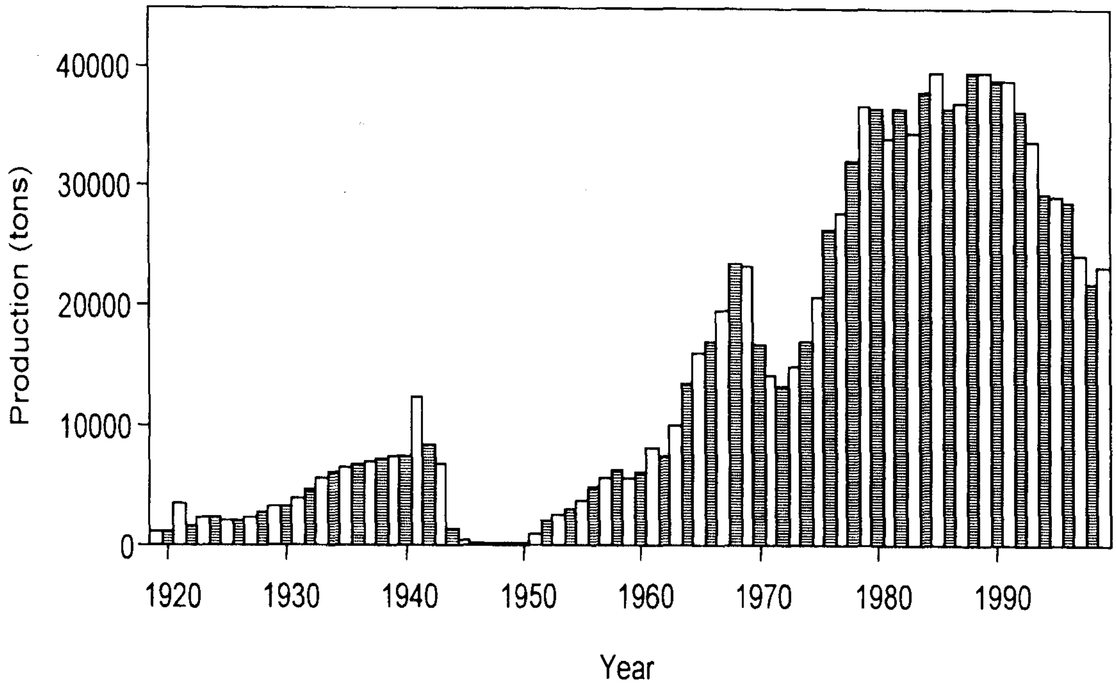

Fig. 1. Change in annual production of cultured eel in Japan (1919–1999).
Drawn with the figures from Agriculture Forestry and Fishery Statistics Bulletin of Japan.

Days of field pond culture between the early time of eel culture and the time just before the Pacific war

The ponds used for eel culture in Shizuoka prefecture in the early time from 1890s to 1900s were shallow and vast, with the area of some five to ten ha. using creek water. The water quality of the ponds was maintained at levels good for eels by planktonic blue-green and other algae naturally grown in the water. Shrimps, mud snails or mysids were used as food in the early days and then silkworm pupae were used, which were abundant and cheap byproduct of the silk spinning industry. The density of eels in the culture ponds at that time was so small, as low as 0.3 Kg/m^2 [2,3].

The eel culture area was extended in Shizuoka prefecture and in addition spread to the neighboring prefectures of Aichi and Mie. Thus eel farms and the products increased year by year. Keeping up with this expansion, the demand for the feed increased and the main feed was converted into low-priced salted and frozen marine fishes like the sardine. The above-mentioned eel culture method was practiced until about 1960s beyond the Pacific War. The total production increased continuously and reached about 8,000 tons in the 1940s.

In the meantime, the only serious disease of the eel cultured with the above method was anchor worm disease, caused by *Lernaea cyprinacea,* a parasitic copepod[4,5]. The worm parasitized mainly the mouth cavity of the eels. In most case, the number of worms was too high, making the fish unable to feed and respire. This condition together with the deterioration of the water quality mainly due to the death of the planktonic algae, resulted in mortalities.

The disease first broke out in eel ponds using surface water inhabited by wild fish carrying anchor worm. Both adult anchor worm parasitizing on wild fish as well as larvae were introduced into eel ponds. Anchor worm, once introduced, multiplied vigorously and repeatedly throughout the year and thus parasitizing the eels seriously.

The disease spread to other ponds by careless transplantation of parasitized eels. In those days, transplantation of eels was ordinarily practiced.

Treatment of the disease using seawater, chloride water, etc., were tried to no avail[5]

It was in 1955 that Dipterex (later named Mazoten), an agricultural chemical and a preparation of an organophosphate, was commercialized[6].

Days of field pond culture between the time after the war and the 1960s

As mentioned before, the eel culture industry developed to produce 8,000 tons of eels before the Pacific War[2]. Although the industry was almost suspended during and after the Pacific War, its activity was resumed just several years after the war. Production exceeded 1,000 tons in 1951; attained 3,000 tons and 8,000 tons in 1954 and 1961, respectively. Highest production was obtained in 1968 amounting to 23,640 tons, of which Shizuoka shared about 68%, Aichi, 20% and Mie, 5%. The high production in these three prefectures in the Tokai district was unchanged until around 1975. Since then, the production area expanded rapidly to Kyushu and Shikoku districts in the south of Japan.

The eel culture method and technique in this period were basically the same as that of the previous period. The only improvement was the use of electrically motorized waterwheel, which was very effective in maintaining the quality of pond water. The density of eels in most ponds increased year after year, exceeding 1 Kg／m^2 by the middle of the 1960s[2].

Fungal disease (Watakaburi-byo)

A strange disaster happened in the spring of 1955, in the Hamanako area in Shizuoka prefecture. Many eels appeared to the surface of the ponds with mould on their skin, particularly on the head. This caused mass mortalities which created panic among eel farmers. Mass mortalities occurred in all the eel culture areas in Shizuoka prefecture. The same happened in the spring of the following year and the year after. The disease was first called fungal disease[7] and later saprolegniosis[8]. Hoshina and Ookubo[7] identified the parasitic fungus as *Saprolegnia parasitica,* but later Hatai[8] pointed out that several species were involved in the disease and therefore the parasitic fungi should be called *Saprolegnia* spp..

Egusa had studied this disease for years and reported that a primary or preceding disease existed and its causative agent was thought to be a bacterium, *Aeromonas liquefasience* (later the name was changed to *A. hydrophila*)[10,11] which had been known as the pathogen of red-fin disease of eels since the old days[12]. Today, he thinks that there remains something disputable in that decision. For example, the disease broke out occasionally not only in eel farms but also in experimental aquaria at very low temperatures around or below 10 ℃ [10]. According to Hoshina[12], *A. hydrophila* does not grow at temperatures near and below 10 ℃ and this fact was confirmed by Egusa (unpublished). These findings suggest that any psychrotrophic agent other than *A. hydrophila* may also be involved in the disease.

The incidence and the magnitude of the disease became sporadic and small after 1965. Thus they became to be nothing to worry about for eel farmers, they became disinterested to the disease. The study of the disease ended and its nature and entity was not clarified at all.

Hoshina stated in his thesis[12] that red-fin disease had been known as a popular disease since the old days. Usually, it broke out sporadically and seldom prevailed widely and vigorously. In addition, fungus disease was often associated with this disease. In his report, he also stated that the disease is caused not only by *A. hydrophila* but also by another bacterium *Paracolobactrum anguillimortiferum* (later reidentified as *Edwardsiella tarda*). Later the symptom and the pathology of the disease by *E. tarda* were differentiated from those of the disease by *A. hydrophila* and a new name, Paracolo disease or Edwardsiellosis, was given to the former.

Saprolegniosis occurred suddenly in the springtime of 1955. It lasted for about five years, in a wide area, and decreased its strength afterwards. After ten years, the prevalence of the disease ceased. But neither the reason nor the cause of the sudden occurrence, gradual decline and disappearance of the disease were clarified. There were no noticeable changes in climate which might have affected the health of the eels in ponds.

As mentioned at the beginning of this chapter, no technical innovation was made in these days. Nevertheless, the saprolegniosis occurred, raged and ceased. This fact led us to consider that the appearance and disappearance of saprolegniasis was not brought by any innovation of eel culture method and technique. *Saprolegnia* spp. and *Aeromonas hydrophila* are both ubiquitous organisms, which ever since existed in most of the eel culture ponds.

Did sudden striking changes of virulence occur in these pathogenic microorganisms in 1955?

There were no scientific informations about it.

Then, what made the disease to occur suddenly?

As described before, the density of eels in the ponds had been becoming higher year after year in these days. It can be easily imagined that the loads of pollution in the ponds also became larger and larger. This disruption of the environment would have brought stress and slowing down of the physiological activity and lower the resistance of the eels, while the pollution might bring about multiplication of pathogenic organisms in the pond. Complicating each other, these factors would have made sporadic and slight disease into frequent and serious ones.

It could have been presumed that high densities of the cultured fish might have made the spread of these diseases easy. Also, it should be thought that the increase of the density of eels is a sort of change in the culture that would have affected to the outbreak and prevalence of the diseases.

Then, what made their influences to decline?

When a new epidemic disease breaks out, the influence of the disease is strong in a certain short period of time for one to two seasons. But it becomes weak after a long time, as if the energy of the disease exhausted, mortality become lower in prolonged pathogenic term[13]. For this reason, some compromise or trade shall come into existence between the host and the pathogen, in a certain time after their first contact. Therefore, the diffusion of the diseases may become wider, but the amount of the suffering becomes smaller.

Revolution in eel culture—Propagation of formulated feed

The study on the development of formulated feed was promoted actively in the 1960s. At last, a satisfactory formulated feed of mash type was completed and the practical distribution started in 1965[1]. Owing to its many advantages, the formulated feed became popular to all the eel farmers all over Japan[14]. The amount of the formulated feed produced and consumed increased rapidly year after year (Fig. 2).

Fundamentally, there was no case in which the formulated feed itself played the role of the direct cause of some certain disease. But, an inconceivable disease, which was suspected to be due to the adoption of the formulated feed, emerged.

Columnaris disease (Era-byo)

In the summer of 1966, many eel farms in the Yoshida area, one of the large eel culture areas in Shizuoka prefecture, had mass mortalities which had never been observed before. Abnormal features visible to the naked eyes were not observed on the exterior of the diseased fish or internal organs in the body cavity. But, the gill filaments were decayed. The study of the disease showed that this disease was columnaris disease caused by the bacterium *Chondrococcus columnaris* (today it is called as *Cytophaga columnaris*)[15,16]. Subsequently, the same disease broke out in many ponds not only in Shizuoka prefecture but also in neighboring prefectures. Although the existence of this bacterium in Japan had been known, the disease had never broke out in eel farms before. The reason for this sudden outbreak at that time in eel farms was not clear. Eel farmers had used the formulated feed at the all ponds where this disease occurred, and naturally they suspected the relation of the disease to the formulated feed.

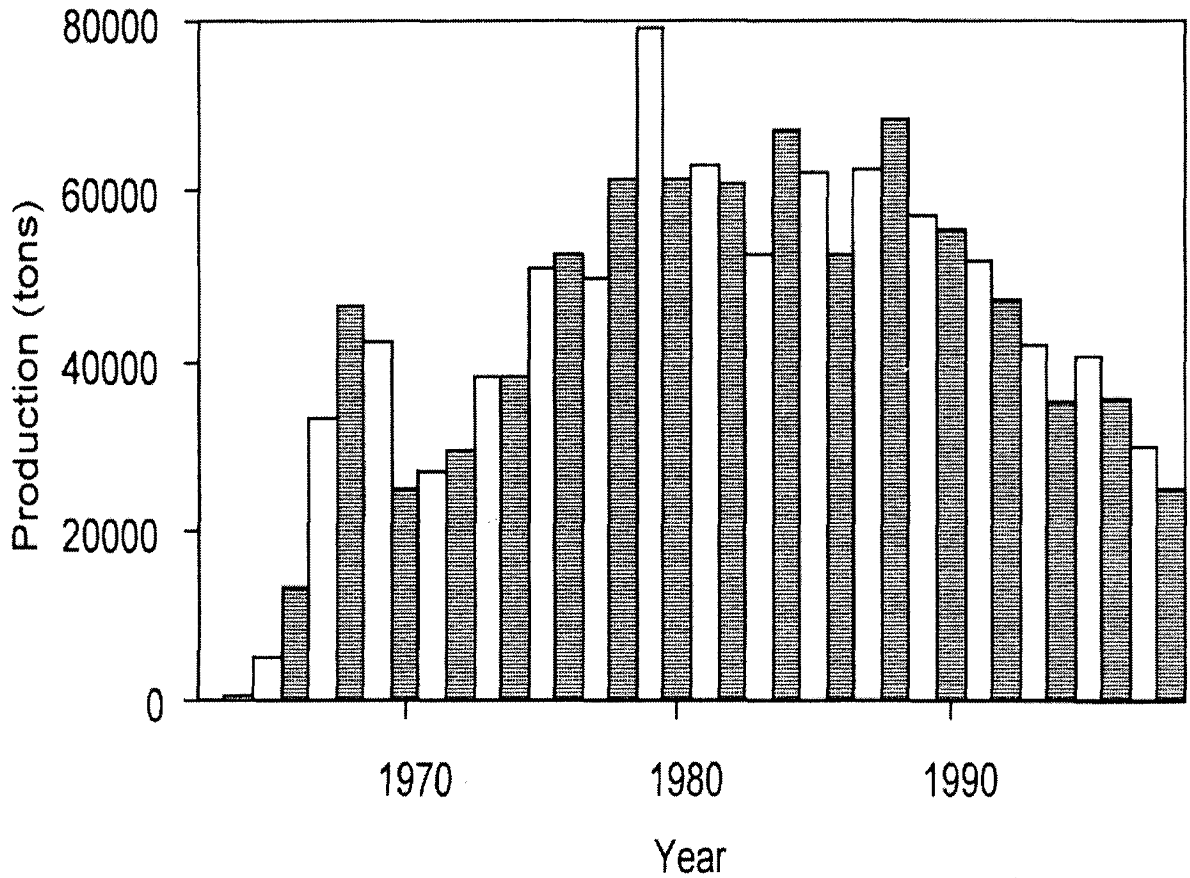

Fig. 2. Change of annual production of the formulated feed for eel culture in Japan (1965 – 1998) (Drawn with the data of Japan Fish Feed Association).

C. columnaris had never been observed in loach *Misgurnus anguillicaudatus* collected from rice fields or brooks. But when they were kept in tanks with flowing tap water, the disease frequently broke out[17]. This suggested the existence of competitive microorganisms in natural muddy or eutrophic waters. Then, the possibility was questioned that competitors which were once abundant in the water in eel ponds where frozen fishes were used as diet diminished along with the use of formulated feed. But no evidence was obtained.

It is a well-known fact that when eels take pasted formulated feed, particles of feed are discharged vigorously from the gill openings. This suggests that the particles, in particular bone dusts from the feed, may injure the gill filament surface, and the injuries become the site of *C. columnaris* infection. This conjecture may be correct but has not been tested.

Later on, Sugimoto et al.[18] published an interesting paper, which supported strongly the idea of concernment of the discharged eel formulated feed from the gill openings to the outbreak of the disease. They clarified that the bacteria grew highly on the formulated feed particles suspended in the water. This suggested that bacterial clusters developed densely on the surface of the feed particles suspended in pond water. Thus initiating infection on the gills upon contact.

Branchionephritis (Era-jin-en)

At the end of 1969, a new mass mortality of wintering eels happened suddenly in the Yoshida area in Shizuoka prefecture[19]. The affected eels showed no visible sign of abnormality externally or internally and even in the gills. Nothing could be found wrong in the pond water. The same mortalities occurred successively in many ponds in the same district until the end of March 1970. The damage was so great that eel farmers seethed with a panic again. Similar mass mortalities occurred in many eel farms in the next winter in various districts in Shizuoka prefecture.

Bacteria, mould and other parasitic organisms common to moribund and died fish were not detected. Histological examinations, however, revealed that marked proliferation of epithelial cells of the gill filaments and fusion of the lamellae were present. Hyaline droplet degeneration of tubules in various degrees and glomerulonephrosis in the kidney were also observed. Egusa predicated the disease as a new one and named it branchionephritis[19]. Similar mass mortalities occurred in many eel ponds in the same area in the winter of 1970-1971. Nishio et al.[20] and Egusa et al.[21] investigated the various aspects of eels collected from farms where mortality prevailed and confirmed the same phenomena as observed in the previous year.

On the other hand, Shizuoka prefectural fisheries experiment station (Japan)[22-24] and Ogami[25] examined characteristics of the blood of diseased eels and found out that plasma Cl^- concentration was remarkably low. In healthy eels, plasma Cl^- is roughly 110 to 130 mEq/*l* in the winter season. But the plasma Cl^- in diseased fishes were lower than 50 mEq/*l*, even below 30 mEq/*l* in extreme cases. On the basis of these findings, low plasma concentrations of Cl^-, pathological changes of gills, namely, hyperplasia of lamellar epithelium, fusing of lamellae and pathological changes in the kidneys mentioned above have been considered to be essential for the diagnosis of this disease, although no paper dealing with the diagnostic procedure was published.

This disease was said to occur every winter since then in almost all eel culture areas of the Tokai districts.

Various searches for the cause of the disease were carried on, without success. In 1975, Horiuchi and Sato[26] reported the observations of the disease that broke out among eels in the Yaizu area, Shizuoka prefecture, in winter from 1972 to 1973. This report was the final one on pathogenic findings of branchionephritis that naturally occurred. However, essentially noteworthy new findings were not described and any opinion on the cause of the disease was expressed.

A suspicion was cast on the possibility of IPN virus to be the cause[27], which was thought to have been brought into Japan with imported elvers of the European eel *Anguilla anguilla* and tentatively named as EVE. The importation began in 1969. Pathogenicity of the IPN strains isolated from diseased eels was studied and experimental inoculation of it into Japanese eels caused pathological changes in the kidney, but not in the gill[28,29]. Changes in blood characteristics were not examined. These results deny the possibility that IPN is the principal cause of branchionephritis. The results of field surveys did not support the possibility[30,31].

Egusa suspected a stress due to low temperature in the winter, as a possible cause of the disease[32].

Oka et al.[33] reported that these gill symptoms were often observed in wintering eels and histological abnormalities in the gills might be a normal reaction to the coldness and/or fasting in the hibernating eels in the pond. But, if the stress caused by low temperature and fasting was the cause of the disease, the suspicion remained why branchionephritis had not occurred during the winter seasons before 1969.

Oka concerning to this disease from the day of its outbreak, surveying eel ponds and doing experiments in the laboratory, came to attain some idea about the suspicion presented above.

From this fact, they built up a hypothesis that the disease was related to the coldness and / or starvation. Then, they conducted a field survey from September 1974 to April 1975. They monthly sampled several eels from two ponds (Fig. 3).

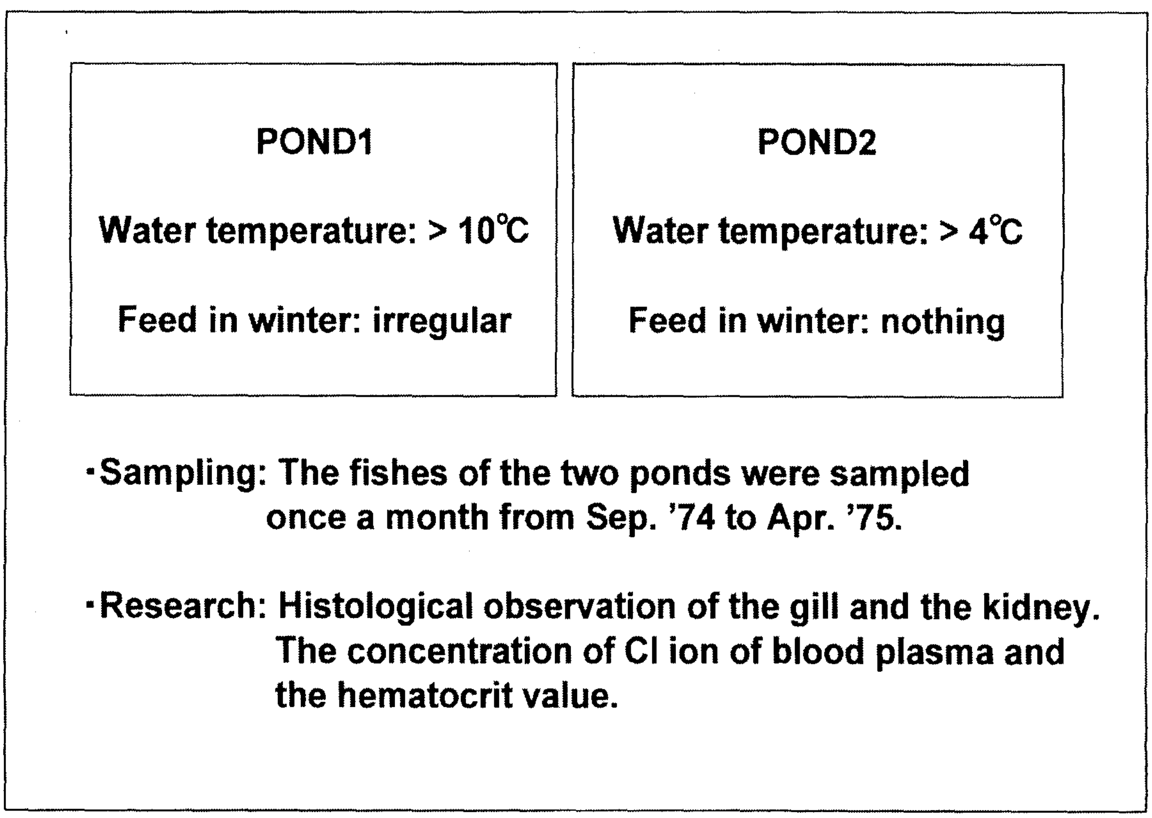

Fig. 3. The outline of the survey in two eel culture ponds in 1974–1975 (Oka, unpublished).

In one pond, the water temperature did not fall below 10℃ and eels there were fed irregularly during the winter. In the other pond, the water temperature dropped to 4℃ in the coldest month of February and eels there were fed nothing during the winter. Several fishes were sampled from these ponds monthly. On these fishes, histological samples of the gills and the kidney as well as the concentration of plasma Cl^- and hematocrit value were examined.

As a result, eels sampled from the pond where it was warm and eels there were fed showed no characteristics of the disease other than swelling of gill filaments, which was seen occasionally during the winter. While, the eels from the pond where it was cold and eels there were fed nothing showed the characteristics of the disease, especially the eels sampled in February, the coldest month. The result almost verified the hypothesis that the disease concerned to coldness and/or starvation.

Then, an attempt was made to reproduce the disease artificially. As mentioned before, if the coldness and/or the starvation caused the disease and killed the large amount of the wintering eels, it would occur the question why the eel wintered before 1969 did not die in the winter season.

Oka, thinking the possibility that the formulated feed involved in the disease, designed and started an experiment from September 1983 to April 1984, using the frozen fish and the formulated feed (mash), as the feeds for the eels in the experiment (Fig. 4).

·Group fish fed 1 : Feeding fish, outdoor pond (min. 4℃ in Feb.)
·Group fish fed 2 : Feeding fish, greenhouse pond (24℃ const.)
·Group mash* fed 1 : Feeding mash, outdoor pond
·Group mash fed 2 : Feeding mash, greenhouse pond
***mash : formulated feed**

***Sampling:* The fishes of the four groups were sampled once a month from Sep. '84 to Apr '85.**

Researches: Histological observation of the gill and measurement of Ht values and concentration of plasma Cl^- of the sampled fishes.

Result : Groups fish 1 & 2 : a few fish died during the winter. No symptom of the Branchionephritis.

Group mash fed 1 : Died many, with the symptom of the Branchionephritis.

Group mash fed 2 : Died many of the Edwardsiellosis. No symptom of Branchionephritis.

Fig. 4. The reproduction experiment of branchionephritis in 1984–1985 (Oka, unpublished).

Eels reared from the elver stage were separated into four groups. The group of fish fed 1 was put in an outdoor pond, where the lowest temperature was 4℃ in February and recovered to 18℃ in April; while the group of fish fed 2 was put in a greenhouse pond where the water temperature was 24℃ constantly during the experiment term. The group of mash fed 1 was put in another outdoor pond, while the group of mash fed 2 in another greenhouse pond. Several fishes were sampled once a month, and histological samples of the gills, concentration of plasma Cl^- and hematocrit value of the sampled fishes were examined.

As a sketchy result, in the group of mash fed 1, many eels died in the pond during the winter season, while in the histological samples and plasma Cl^-, the signs of branchionephritis were observed. Also in the group of mash fed 2, many fishes died due to Edwardsiellosis and no symptom of branchionephritis were observed. In fish fed groups, a few fishes died. Although swelling phase, a slight symptom of branchionephritis, was observed in the gills of the fishes of both groups, no abnormality was found in blood samples.

This result suggests the possibility that eels, which had taken formulated feed, may be subjected to branchionephritis under the coldness as compared with eels which had taken fish.

The chief characteristic which was preferred for the formulated feed at that time was to fatten eels highly in short time. The result of the above mentioned experiment suggests that the formulated feed has some defect in building up physiological strength for wintering. It may sound rather non-logical that the eel brought up with the formulated feed was feeble and had no strength to survive the bad conditions in the winter at that time.

The eels, which died of branchionephritis, died in reality of coldness and nutritional deficiency.

The culture of European eel in Japan

It may be said that the history of eel culture is that of the lack of seed for the eel farmers. Due to business expansion, eel seed was always in short supply. Seed suppliers of the Hamanako area in Shizuoka prefecture used to search for seed which were young eels larger than elvers by the 1920s[34].

It was around 1925 when elvers were used as the seed for eel culture[1]. Their catch had been unstable and often did not satisfy the demand of the eel culture industry in Japan, which had often suffered from shortage of the catch. Shortage of the catch was particularly serious in the later half of the 1960s. All Japan Eel Culture Association (the Nichimanren) has eagerly sought for elvers in foreign countries and knew that elvers of the European eel, *Anguilla anguilla*, are abundant in catch and cheap in price. Then, the Nichimanren started to import them in 1969[35]. In the spring of 1969, 9.5 tons of elvers were first imported mainly from France, and many eel farmers tried to culture them by the traditional method using outdoor ponds. The amount of the import, afterwards, increased to 23 tons in 1972. However, that was the maximum figure and the import decreased to around 5 tons after 1974. Since then, the importation of the European elvers has been continued but the amount has always been small. The cause of the decrease of the importation was the disrepute among the eel farmers who failed to culture the European elvers.

The intention of the trial to import the European elver was exclusively to know whether it was possible to culture them at the existing eel culture areas by the traditional method. Neither search for the suitable area nor the development of the suitable culture method was the subject of the trial.

As a result, the European elvers were found to be not suitable to the high temperatures in the summer in the eel culture areas and to the water quality of the ponds with heavy growth of phytoplanktons.

Furthermore, the European eel were highly sensitive to various parasites existing in the ponds as compared with the Japanese eel. They were parasitized severely very often or continuously, particularly in seasons of high temperatures. Thus, the culture of the European eel was generally abandoned, except for some special cases.

After the propagation of greenhouse culture—1. Condition of known diseases

Although the cause of the branchionephritis was not cleared eventually, eel farmers, manufacturers and dealers of the formulated feed and researchers of local fisheries experiment stations, had no doubt of the fact that the disease was related to the coldness of the winter apart from the question of the mechanism.

In the present outdoor eel culture, survival rates of elvers stocked in ponds of not heated from winter to the beginning of feeding in spring, was generally 50 to 60%. From 1963, the Nichimanren had begun to culture elvers experimentally in greenhouses using heated water to raise the survival rate(35). Survival rates were high, but the facilities and the method were too expensive for the eel farmers at that time, and the idea to culture elvers in the greenhouse did not become popular among the people concerned.

In the beginning of 1970s, greenhouse market gardeners in Kochi prefecture in the Shikoku conceived the idea to culture eels in the pond furnished in the greenhouse(36). Their greenhouse was 'Quonset typed' and the expenses for making and managing it were rather low. It was found that eel culture in the greenhouse by using heated pond water with the inexpensive heavy oil at that time, was very successful. This eel culture method was soon adopted by many eel farmers all over Japan from 1973 to 1974.

Traditional eel farmers accustomed to the traditional outdoor pond methods, lagged behind in adopting the greenhouse method. Rising culture areas, however, in Aichi prefecture and emergent regions of the Kyushu and Shikoku districts, southern part in Japan, adopted the new method rapidly, and the greenhouse culture has completely superseded the outdoor culture. Thus traditional regions declined.

Today, almost all the eel farms adopt that method. The water temperature of the greenhouse pond is being kept to around 28℃ through their experiences. They believe that this temperature is the best in many points.

The aspects of the disease in the eel cultured in greenhouse were changed thoroughly. The largest change was the disappearance of saprolegniosis, red-fin disease and branchionephritis, all of which were the diseases in low temperature seasons, in outdoor ponds.

Sekiten-byo (red spot disease) disappeared also, although being a local happening. This disease was first found out in Shizuoka prefecture in 1971 and was demonstrated to be a new disease caused by a new bacterium *Pseudomonas anguilliseptica*(37). The disease never occurred again in that prefecture but it prevailed in an eel farming area in Tokushima prefecture in Shikoku every year since 1971(38), causing much damage. The bacterium was unexpectedly detected in Europe later(39), and was proved by Japanese scientists to be serologically identical to the Japanese strain(40). It was, therefore, no doubt that the bacterium was introduced from Europe by the importation of the European elver(41). Interestingly, the pathogenicity of the bacterium changed with temperature and disappeared at high temperature above 27℃. In greenhouse culture propagated in Tokushima prefecture, Sekiten-byo disappeared, and the reason clearly lay in the high temperature of 28℃(42).

There was also a large change in the frequency of occurrence of Edwardsiellosis in elvers and commercial sized eels in greenhouse ponds. The disease caused by thermophilic *E. tarda* has appeared sporadically among grown or commercial sized eels during hot seasons in the outdoor pond(43). In the outdoor pond culture method, elvers and anguillets as seeds for the culture were usually kept in ponds of low temperatures in winter and early spring and never attacked by this disease. In the greenhouse culture, they are kept at high temperatures near

28℃ and therefore often affected by the disease. Although the damage is not small, the disease can be controlled by using chemotherapeutic agents[44].

The columnaris disease also disappeared in the greenhouse culture. Although the causative bacterium, *Cytophaga columnaris* is relatively thermophile, it does not occur to produce serious harm. The reason for this fact has not been made clear. *C. columnaris* is known to be feeble in competition with other coexisting microorganisms, particularly *Citrobacter* sp. which usually proliferates in polluted pond water[45]. This seems to be the main reason for rare occurrence of columnaris disease in the greenhouse ponds.

After the propagation of greenhouse culture — 2. Outbreak of new diseases

Although serious diseases known in the past became insignificant or disappeared in the greenhouse pond, two kinds of entirely new diseases appeared. One of them is the abnormality in the gill and the other is the abnormality in the body shape. Both abnormalities had been known in many greenhouse ponds in the early 1980s[46] . At least two types were known in the gill abnormality. One was a specifically marked gill congestion and often caused high mortalities[47]. The characteristics of the abnormality is a conspicuous congestion of the central venous sinuses of the gills[48]. Later the abnormality was studied etiologically and was confirmed to be characterized by systemic hemorrhage and degeneration of blood vessels of various organs. Most noticeable features were degenerations of the endothelial cell nuclei of blood vessels in many parts of the body. Electronmicroscopic observations revealed viral particles invading the nuclei of the degenerated endothelial cells. Although the virus was not yet isolated, it was thought to be the cause of the abnormality[48,49].

This abnormality or disease was never found out in the outdoor pond eels. This has aroused a great deal of interest as to the source or origin of the virus. We do not have any suggestive information about it and have no idea whether its appearance is related to the greenhouse culture method.

Another abnormality of the gill is the intensive congestion and marked swelling of blood channels of the gill lamellae in various parts of the gill filaments. Eels with this abnormality are often found in greenhouse ponds, but mortality due to it is regarded as low[44]. Electronmicroscopic observation revealed that this abnormality is caused by the infection of pillar cells of gill lamellae with a virus[50]. It was reported that the virus is Sp serotype of IPN and inoculation of the isolated virus induced the same symptom as that observed in natural occurrence. The disease had not been known in outdoor eel ponds.

Another abnormality that appeared among the eels of the greenhouse ponds is marked deformities of the body shape which are classified into two types[44]. An upward bend in the trunk is one type. This type is usually accompanied with a side bend. This type was occasionally observed in eels in outdoor ponds in the past. Another type is an upward bend of the tail without side bend. This type had never been observed in the past.

Neither mortality nor retardation of growth are recognized. Abnormal eels are salable, although the price is low. This seems to be the reason why eel farmers are unconcerned with these abnormalities, in spite of the fact that abnormal eels occur in many eel ponds all over Japan at considerably high occurrence rates around several percentages.

The cause of the deformities is not yet clear, although Egusa and his colleague have made investigations from various points of view.

There is no doubt that greenhouse culture has various defects which induce above mentioned abnormalities. Strangely enough, no research work has been done on this problem. An estrangement between the research workers and eel farmers in recent years seems to be a main reason for that.

Eel farmers are decreasing in number in recent years and, accordingly, the production has decreased year after year. It was around 40,000 tons in 1990 and decreased to about 20,000 tons in 1998 (Fig. 1). This tendency is expected to continue in the years ahead, while the amount of imported eels from foreign countries would continue to increase. In parallel with this decline, the number of papers related either to eel diseases or eel culture techniques and methods have decreased markedly in recent years.

Eel culture may no longer be attractive for research workers.

Conclusions

Although the precaution, prevention and treatment of fish disease are great concerns to fish culturists, it seems to be a matter of concern to the researchers of the fish disease whether or not the fish culturists may respect high regard to the results of their studies and advices. Generally, it costs much time to solve fish disease problems; fish culturists can not help waiting for the accomplishment of the study. Presumably, there exist differences in sense of concern about the significance of the time between the fish culturists seeking for fortune and the researchers seeking for the truth, in every case of fish disease in the field.

In almost all the diseases which were discussed in this paper, the fish culturists lost their interest against the diseases before the study has been completed.

Although it may be understandable for the fish culturists to lose interest to the diseases, it might develop some confusions to cost money in the occasion that the diseases happen again as in previous experience, to have left the study undone. Continuing the fundamental research will guarantee the future of their business.

On the contrary, the researchers should reconsider the study of fish disease. As fish disease occurs in a certain fish culture pond, the study of the disease should be fundamentally pragmatic, for fish culture is also a business. The basic research should be as a matter of course, but it should be differentiated from the matter going in the field. What is required by the people in the field is measured by the standard of business, not of basic research. Furthermore, in spite of its importance, epizootiology is the most insufficient branch of study in the scientific researches of fish disease. This applies to the researches of eel diseases. This is due to the difficulties for the research workers in acquiring accurate informations on the outbreak and disappearance of any disease, the damage due to it and the actual daily fish management, etc., in many farms. These informations can not be obtained without the cooperation of fish culturists.

More dialogue should be conducted between the peoples of the two worlds, the world of business and that of research.

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