RADICAL PREVENTION OF COSTIA NECATRIX IN SALMONOID FRY

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CONTENTS.

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[Translated from the German.]

CHARACTERISTICS OF THE DISEASE.

I insist upon the limitation to "salmonoid fry," because I have not directly observed *Costia*, nor have I seen the characteristic exterior appearances of costiasis, on any adult fish with one exception. I saw four years ago in June, in the Stara Voda, in a broad place in the stream where the current was very slow, a pike some 23 centimeters in length with a whitish covering on the skin resembling a veil, very like figures 12 and 13 in Dr. Bruno Hofer's "Fischkrankheiten," in which work appears a full description of this disease.[a]

The place where my observations were made was the fish-culture establishment at Laibach, Austria.

The appearance of *Costia* was noticed among the fry some five to ten days after they had begun to feed, i. e., after the resorption of the sac—never before this period—and equally whether the fry began to feed early or late, among the early feeding *Salvelinus fontinalis* and alike the late *Salmo irideus*. About the middle of June, sometimes ten days earlier, all trace of *Costia* disappeared as mysteriously as it had come. I have no reliable criterion as to whether the fish became immune against costiasis in June or whether *Costia* in the form of a flagellate is seasonal, but I suppose the latter to be the case, since the signs of disease disappear at the same time among the younger and older fry.

No difference could be found in the susceptibility of the young fishes; the fry of the three species regularly cultivated—*Salvelinus fontinalis*, *Salmo fario*, and *Salmo irideus*, obtained from brood fishes of the establishment (among which may be included the 100 kilograms of *Salvelinus fontinalis* and *Salmo*

[a] Hofer, B.: Handbuch der Fischkrankheiten, p. 115-121. Munich, 1904.

fario from the excellent stream of Stara Voda)—were attacked along with the embryonated eggs obtained from elsewhere.[a] The fry that were fed nothing but live crustaceans and larvæ of mosquitoes, their natural food, were infected as much as those which, on account of temporary lack of natural food, were fed partly with substitutes, such as pig liver or beef and veal spleen.

The infection must, consequently, be of the locality. The place, the water and its near surroundings, must be infected, the shores harboring *Costia* in the shape of cysts on the dry land, whence they are scattered everywhere by the wind.

Costia had already established itself at Studenec before my arrival in 1891. Costiasis thus did not begin during my direction, but it spread so rapidly and at last in such manner that none of the springs were safe from it. It was first recognized in 1904 by Dr. Ivan Robida, head of the hospital for the insane in Studenec, who was fond of the sport of fishing and who in his close relations with myself studied questions which interested me. By means of his microscope (my own not powerful enough) and Dr. Hofer's book, the identity of the disease germ was fixed in 1905.

We conclude, further, that we have found the cause of the abnormal mortality of fry in previous years, there appearing the same phenomena and symptoms and course of the disease from the very beginning that had characterized those great losses for which no cause was known from 1896 until this time. I had sufficient occasion and opportunity to observe all the phenomena and symptoms minutely, and likewise to remember them, for a large part of the feeding fry were placed for one to three months in larger hatching boxes, then in floating troughs, and in September and October in large ponds in which to pass the winter, while I spent each year 180 half days and 40 to 60 entire days in this establishment.

ACCIDENTAL DEVELOPMENT OF THE PREVENTIVE METHOD.

The radical means of preventing *Costia* was not "discovered," nor even "found," for it was not sought. It developed in the following manner:

In the one-story house occupied by Doctor Robida and other physicians of the insane asylum there is a tank under the roof with capacity of about 1,800 liters, into which was pumped water for household purposes from a spring situated in the cellar of a house about 80 meters distant, if sufficient water was coming to the ponds for the working of the pump. The spring in the cellar and the tank are well covered and the pumped water, coming in contact with the fresh air from without only by chance rifts in the cover, can not be much

[a] *Salmo fario* from Ilidze, Bosnia, 1902; *Salmo dentex* (Isonzo trout) from Idria, 1903–1907, inclusive.

contaminated by dust, etc. Doctor Robida took advantage of the vicinity of the tank to supply with water therefrom two small aquaria in his room (1905). From the main pipe, made of lead, the water passed into the aquaria through slender rubber tubes (3 millimeters in diameter at the outlet) with brass end pieces (about 1 millimeter at the opening), under pressure of about half an atmosphere. One of the aquaria consisted entirely of glass and had a bottom area of 35 by 25 and a height of 22 centimeters, while the other was somewhat larger and had a lead bottom and frame, with walls of glass. In the bottom of each was a layer of 5 to 6 centimeters of fine, white, well washed, calcareous sand, and a few shoots of water cress were planted in it. The water, falling in a slender jet, boiled up actively and sent out small bubbles in every direction, so that even in the corners they could be seen dancing in the water. In the first aquarium were placed more than 300 young *Salvelinus fontinalis* old enough to feed, while in the larger one were placed *Salmo fario* and *irideus*, also a few *fontinalis*, in all some 500 fry. More than any other fry these were fed with crustaceans exclusively, which were greedily devoured, especially by the American species, which fed until the body swelled quite out of shape and looked as if it would burst. The excrements were removed daily by means of a small suction tube, while once each week the aquarium was thoroughly cleaned, the sand washed, etc., the fishes being placed in other quarters during this proceeding. *Costia* had in the meanwhile appeared in the hatchery as in the preceding years, but there was no trace of the disease in the aquaria.

Ten diseased *Salvelinus fontinalis* were now put into the smaller aquarium. The infection had not as yet shown its full effect on them and *Costia* had established itself microscopically on other fishes looking like these. The diseased fishes differed from the fat, healthy ones, not only by the thinness of body but also by the coloring, which was more or less of a dark blackish blue hue, with a faint, almost invisible shading as compared to the light-colored and white markings of the healthy individuals, and the difference was apparent to the casual observer. The diseased fishes continued to live, seeking the bottom in the quietest places and rarely moving about, and looked at the last like a thin blackish thread with a thick knot. All died within 6 to 9 days after the fishes of the same lot and of the same appearance left in the hatchery. Expectation as to the results of this experiment was naturally great, but no effect was produced on the fishes in the aquarium.

A second experiment in the second aquarium gave the same result, and several more were made in each aquarium. Doctor Robida attempted to convey the infection by other means, i. e., by the infiltration of infected water and by the direct introduction of living *Costia*, but with no result. He changed the food freely, giving the fishes, when they had grown larger, grated meat from his own table, even chopped liver, thinking that in water so well aerated even such food could do them no harm.[a]

The abundant aeration of the water proved to be a radical prevention against *Costia*, all the fish remaining alive and healthy, not one being lost. When the action of the pump grew defective on account of scarcity of water, Doctor Robida used a small motor operated by alcohol for the purpose of obtaining a current in the aquaria. But the disadvantage increased and I put the fishes, which were from 3 to 4 centimeters long, into a rearing trough (8 meters long, 0.55 meter wide, and 20 centimeters deep), merely giving them three more salt baths, since this was the end of the critical period, in order to be safe from the danger of *Costia*.

I have never seen the white veil-like covering spreading over the skin, as shown in figures 12 and 13 in Doctor Hofer's book, except on the pike already mentioned; never on the small fry. So long as I fought *Costia* with potassium permanganate and not with cooking salt, as did Doctor Hofer, the fishes which had withstood *Costia* had white fungus spots near the gill openings, and these spots, in spite of the treatment with potassium permanganate, were in some cases fatal. Since I have begun to use common salt, I have not noticed this last phenomenon. I suppose that the fishes attacked by *Costia* are too small and consequently too weak to endure this condition until the white spots show on the skin, and die before this stage.

EXPERIENCE OF THE SEASON OF 1906.

It was impossible to arrange an aeration of the hatchery troughs by means of water under pressure, on account of lack of fall in the supply. The only fall periodically in operation was occupied by the already mentioned pump and not available for hatchery purposes by reason of its location. Thus I could not put into practice the new experience with aeration.

Since *Costia* was again to be expected in the hatchery, however, I arranged in a pond, which had not been used for fishes for four years and the water flow of which was used only to supply two rearing troughs, a place in the open for the hatching boxes. This small pond was repeatedly dry when the water was low in the springs. The bottom was cleaned of all vegetation, raked and washed out, highly saturated with potassium permanganate, and after this washed out with salt. All the small fry able to feed and destined for rearing in the establishment were brought to this pond. The water, as may be easily understood, never grows muddy, has a constant temperature of 9.8° C., and produces many green algæ, which are very cumbersome when the currents of the water become slow with low water in the springs.

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[a] In my opinion such food can not be given long, never exclusively, and of the latter sort not even to large fish.

These measures of precaution and a careful maintenance of cleanliness in the hatching boxes, etc., as well as the sole use of live natural food, brought about only the result that in the two boxes first installed the fry did not develop the *Costia* until four or five days later than in the hatching house, and that the infection did not spring up immediately in a violent form, but crept in upon them slowly and insidiously. It may be concluded thence that after the cleaning and thorough disinfection of the pond, etc., the water was free from *Costia*, but was reinfected by the nonsaturated ground of the banks, from cysts which must have been carried into the water by the wind. But whence come these cysts? The following explanation readily presents itself:

The dirt from the rearing troughs (during the first years of my direction there were eight of them at three different places, for the most part occupied by two separate lots of fish), the excrements, debris of food, and ooze from the algæ and the grounds were washed down into the pond water; there formed in the wintering ponds during eight to nine months at the places where the water did not course so freely a thick layer of fat, black, ill-smelling ground ooze, and the ponds could not be cleaned except by flushing them out, scraping, sweeping, and washing out the ground; all this carried off into the principal pond. The latter can be emptied only down to about five-sixths of its contents, and all the springs of the local systems flow into it, through it, and off by means of one lock. From the principal spring, which is easily accessible to the village of Studenec (three or four butchers, the cattle, etc.), much organic matter comes into the pond; it continually receives manure from this source, and incidentally from the well-frequented road during rainfall. Thus a rich bottom fauna and very abundant vegetation develop. The latter must be taken out partially several times a year and thoroughly once annually. Much ooze is naturally taken out with the *Chara fragilis*, and everything taken out of the pond is piled on the banks in heaps, where it remains sometimes for two entire years. As long as the springs were full and there was a corresponding flow of water, a total of 600 to 800 second-liters in the maximum and never less than 200 second-liters up to 1896, no bad effect was noticed on the fishes from the pollution of the ground and its oxidation. And, frankly speaking, I knew nothing, as so many others, about the importance in fish rearing of ground culture and ground sanitation. When the scarcity of water and lack of currents began to be felt and had grown quite noticeable in 1904, and the well-known effects of such conditions, among others the presence of *Costia*, appeared in the fish-cultural work, I was forced to look for explanation and remedies.

Conditions for the existence of *Costia* were rendered more and more naturally favorable by the decrease of water supply in the summer of 1905, the winter following, and later down to a very few liters, and by the fish-cultural operations; and the persistence of the infection was insured by the maintenance of old and the establishment of new piles on the bank whence *Costia* cysts would be derived. I can not find any other explanation for the infection of the pond.

Cooking salt was again our resort; by this means I carried through the critical period one-fourth of the fishes in the worst cases and three-fourths of them in the less severe.

PRECAUTIONS APPLIED IN 1907.

The same pond was again thoroughly cleaned and disinfected, then a part was partitioned off in a shallower portion by means of a wall of clay. The water for the fry flowed through a tube of rubber and lead through the dams into the distributing trough and thence through lead siphons into the hatching boxes. The covers for these were fitted better and more closely than in 1906, and supplied with glass openings in order to give the fishes both light and sun without having to take off the covers; the distributing trough was likewise kept covered as much as possible and the cover was lifted only for the cleaning of the boxes. The flow of water was increased by five, six, and eight times the ordinary amount for the cleaning of the boxes, by which means the sediment was whirled up, flooded through the closing screen, or deposited on the latter to be swept off by means of a soft brush; the whirling up and flowing off of the sediment was aided also by means of a feather.

At the end of March, some ten days later, no trace of *Costia* was found in two boxes of *Salvelinus fontinalis*; but only fourteen days later, on April 4, I saw two fishes the color of which was not quite satisfactory. On April 5, two fishes were dead and four or five had changed color. The naked eye and the microscope both testified to the unwelcome truth—it was *Costia* again. March was very dry and very windy during the latter days. I gave the fishes a salt bath of some fifteen minutes duration on April 5 and 8. Then there was no trace of the disease until the 18th, when I gave another salt bath. It again appeared necessary to give the bath on the 20th, 24th, and 28th of April, on the 1st, 3d, 19th, 24th, and 28th of May, for twenty-five minutes, and, lastly, on June 3 for thirty minutes, when the fishes were transferred to the rearing trough.

The covering of the water was not entirely useless, the infection in the two first boxes having had two long intervals, the first ten and the second twelve days. The three lots nearest to the outflow needed the salt bath most frequently, i. e., every other day without intermittence; these were *Salmo irideus* of May 3 to June 13. The explanation of this fact is the following: The cover of the trough had to be taken off every morning and every evening during cleaning time, and this admitted the dust and the cysts, caught up by the wind, which were brought by the current to the outflow in greater quantities than at the place where the water flowed in.

I carried through the critical stage about 4,000 *Salvelinus fontinalis*, which were kept in three boxes, the last 1,400 being taken by myself on August 17 to the Wocheiner Lake, a journey from 5.30 a. m. until 1 p. m., without incurring any loss; the fish were from 5 to 7 centimeters in length.

I could not detect that the salt water did any harm to the fishes. The water was of course aerated incessantly by taking it up in a 2-liter vessel and pouring it back from a height of 50 to 70 centimeters. Only the *Salmo fario* remained at the bottom during this proceeding; the *irideus* and the *fontinalis* had to be kept out of the way with a gauze hand net.

Doctor Robida did not take any part in my experiments in 1906 and 1907, and left Studenec last year.

THE SEASON OF 1908.

The drying up of the springs, which was no longer doubtful, in addition to the spreading of the *Costia*, decided those in authority to abandon the locality near Studenec. But my desire and hope that my fish-cultural difficulties would end with the year 1907 were not fulfilled, as the spawning season of the salmonoids came round before measures for abandoning the locality could be taken.

Since I could command my time, I wished to make use of my knowledge of the effect which the introduction of atmospheric air had upon *Costia*. I sought, first, suitable cylinders, similar to those of the Hydrobion; air was pumped into these and was to rise gradually from the bottom of the fish troughs in small bubbles to the surface. Two attempts to obtain the clay cylinders met with failure.

Salt baths are good, and capable of saving the fry from entire or enormous losses; but they can not be lastingly effective if the water is continually infected anew, and they must, consequently, be repeated; and even while applying them every forty-eight hours I had to register losses which amounted in time in the most favorable cases to one-fourth of the fishes placed in the basin. They also take much time, for a man can accomplish at the same time the necessary aeration of the water in but two or three hatching boxes at the most; ten boxes would thus demand four to five hours.

EXPERIMENTS IN THE HATCHING HOUSE.

The distributing trough in the hatching house stands some 48 centimeters above the ground and is 22 centimeters deep. I placed the hatching box on the floor and obtained thus a fall of 33 centimeters. A siphon having 8 millimeters interior diameter gives, by exact measurements, 4.2 liters per minute; the capacity of one box is 2,514 liters, and the water is changed therein in 5.98 (6) minutes with one siphon and in three minutes with two. I placed above the hatching box a basin 75 centimeters interior depth, containing 250 liters of water. The water flowed therefrom into the hatching box through a flexible rubber tube 1 centimeter interior diameter and with a conical nozzle of zinc with an opening of

2.5 to 3.5 centimeters. The pressure of the water in the basin varied between 130 centimeters at the maximum and 55 centimeters at the minimum. According to the opening of the zinc nozzle the upper basin was emptied in fifty to thirty-five minutes. The falling jet of water was so placed that the water in the hatching box began to rotate. The upper basin was filled two or three times daily for one hatching box.

I placed *Trutta lacustris* in the hatching box, fry obtained from very beautiful, large, eyed eggs, of which I received 5,000 from Schliersee in Upper Austria. The eggs were placed, on January 31, in two California hatching boxes (without the inner set of brass wire trays) between flat roof tiles. The first hatched fishes appeared on March 23 in the receiving boxes placed below. The two boxes in which the eggs had been placed were opened and 81 eggs were found thickly covered with ooze and fungus. Since the fry were very unevenly hatched, they were placed immediately in two clean and thoroughly darkened boxes, being transferred first to one and then to a second under the falling water and fed with live food. On April 28, when the fry hatched latest had exchanged their light coloring for a darker, and fed as greedily as the older fishes, they were sent to the Wocheiner Lake, which they reached "in faultless condition," according to the report of the recipient.[a]

The temperature of the water used in February was 4° to 5°, in March 5° to 8°, but rose later to 10°, then to 13° C. Until April 12 there were no losses; after this there were three in all, one fish being choked by a crumb. No *Costia* was apparent. On March 30, some seven days later, the second siphon was set flowing for the first lot, consequently 8.4 liters of water were received per minute; the same was done for the second lot.

As a control lot, on March 28, 30 fish had been placed in a small box (containing 1,362 liters of water, flow of 4.2 liters per minute) arranged as heretofore, i. e., on a level with the distributing trough without waterfall or increased pressure. On the 3d of April I noticed two weak fishes, one of which was found dead on the 4th, and I found *Costia* by a microscopic investigation of another fish showing signs of disease. After giving a salt bath to the remaining fishes I left them to their fate in a spring of the pond.

I saw *Costia* renewed between afternoon and the next morning in a control lot of *fontinalis* during the last third of April in spite of salt baths. For security and my own satisfaction I gave a salt bath of 1.5 per cent of 35 minutes' duration to a lot of *Trutta lacustris* in the morning of April 25 and 27 before shipping them away.

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[a] The transportation in two casks of 128 to 132 liters lasted 1½ to 2 hours by wagon, 2 hours and 22 minutes by rail plus 47 minutes and 13 minutes standing, a total of 6 hours and 35 minutes. The water was cooled in the hatchery and when placed in the railway carriage was of from 10° to 7.5° C. The day was warm and sunny. The dimensions of all the boxes were 52 by 33 by 22 centimeters. The depth of the water was 15 centimeters.

EXPERIMENTS IN THE POND.

It was not possible to arrange a waterfall there. I placed two barrels containing 200 liters, so that the water flowed, as in the hatchery house, through longer or shorter rubber tubes, according to necessity, and in slender jets into all the hatchery boxes. The board covering of the cut-off part of the pond had been removed in the preceding autumn and had not been renewed. The maximum of the pressure was 118 centimeters in both barrels, the minimum 33 centimeters. The filling of each of the barrels took place at least twice daily, later even as often as five times. During the first week the water had to be led up from the pond over a small scaffolding, as the spring was still too weak, but after some rainfall the water could be pumped straight from the pond.

On March 27 two boxes with *S. fontinalis* were set up. On April 4 *Costia* was noticed among them in spite of the jet of water from the barrels. The daily aeration of the water for 1½ hours to 2 hours was of too short duration and too little effective with the pressure obtaining. The outflow pipe of the barrel and the small opening of the nozzle were frequently clogged by things carried in by the wind and taken up by the pump.

There were seven boxes in all and in each of these the fry received a salt bath of 2 per cent for thirty minutes every other day. To all appearances the aeration and the streaming of the water from the barrels did not remain without effect. The boxes could be thoroughly cleaned during the whirling of the water, and it could not be denied that the fishes grew more lively in the currents, darting through the whirls after the food without paying any attention to the fact that the jet of water pressed them downward; and, the most important of all, losses were not so frequent as heretofore and amounted (by estimate) to not over one-quarter in the maximum, and in a lot of *S. irideus* it was very small, in fact inconsiderable.

This lot came from large, beautifully colored parents. I had, however, done a foolish thing with the eggs. Since it is very difficult and takes a great deal of time to place the eggs regularly on the tiles so that they will not touch each other, I had ordered flat, round depressions made in regular rows in two zinc sheets in order to facilitate the work. The placing of the eggs was effected beautifully, but think of my horror to see, after opening the breeding boxes, instead of the hoped-for 1,900 or 2,000 fry, only 378, although these were almost all large and fine. Ooze had settled in the depressions with the eggs and filled the spaces between them.

On April 14 these fry were put in the pond and were cared for more than the others in regard to food and aeration. Up to May 1 the losses amounted to 25 fishes; up to June 3 there were only three more. After June 11 there remained only three boxes to be taken care of, and the above mentioned *irideus* were treated to more frequent aeration, from eight to ten times daily. Beginning with June 24 I ventured to omit the salt baths, and since no losses resulted I decided to omit the baths entirely and confine myself solely to aeration; rightly, too, as I saw afterwards. On June 16 the fish were all sent away in a cask, fresh and healthy. The cask contained 63 liters of water without ice. Duration of transportation, 1 hour and 30 minutes by wagon, 1 hour and 30 minutes by rail, 2 hours and 30 minutes by wagon, in all 5½ hours. At the pond 3 fish were found dead, wounded by lumps of ice which were put into the water in the railway car without any ice bag.

SUMMARY AND CONCLUSION.

I come to the following conclusion from the above-mentioned experiments: A means for the radical prevention of *Costia necatrix* in salmonoids under culture is to be found in the abundant and constant introduction of atmospheric air into the living water; in other words, abundant and constant aeration.

Can deeply infected fishes be cured and saved? I doubt it. I have never seen that surface wounds and abrasions of the skin healed; fungus invariably assailed the injured places and extended over the neighboring areas more and more until there ensued weakness, difficulty of moving, and lastly death, while deep wounds, bites, thrusts, and cuts were often found healed and leaving scars.

Costia lives and increases on the skin and on the gills and destroys their tissue. Cure is always possible in the beginning of the infection, and the following phenomenon may be pointed out: All the fishes presenting a suspicious appearance—i. e., showing signs of weakness and discoloration and refusing food—were taken up by me with a gauze hand net and washed out in the water flowing from the hatching troughs. There was always water around the hatching boxes 3, 5, to 10 centimeters deep, according to the height of water in the pond. Here all around the breeding troughs and in the narrow waterflow to the pond there came again and again small fishes, mostly *S. fontinalis* of the same size as in the boxes, about 50 in June, and these seemed to be quite healthy, catching greedily at the crustaceans falling from the boxes. As it was impossible for them to come through out of the boxes, either these were cured fishes or I have taken uninfected fishes out of the boxes.

It need not be mentioned that *Costia* spreads more rapidly when the fry are crowded and that the rise of temperature above 10° C. accelerates the progress of the infection and its communication.