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Fish culture

AN ATTEMPT TO REAR REINBOW TROUT (*SALMO GAIRDNERI* RICH., 1863) IN A TEMPERATURE CONTROLLED TANK

PRÓBA HODOWLI PSTRĄGA TĘCZOWEGO (*SALMO GAIRDNERI* RICH., 1863) W BASENIE O REGULOWANEJ TEMPERATURZE WODY

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Rainbow trout were kept for 1 year in a tank of 2.5 m^3 capacity, protected from overheating in summer and heated in winter. No water change was applied during the culture period. The fishes cultured showed good weight increments: the average weight of an 18-month old specimen was 193.3 g.

INTRODUCTION

A strictly optimal range od temperatures for growth of rainbow trout is 12–16°C, whereas the range of 10–18°C can still be suitable to rear this species (Steffens, 1971). In the quoted author's opinion, a warranted culture of this species can be run within 8–20°C. The temperature of 22°C is, according to Steffens, an upper limit for rainbow trout, the species not being able to survive any higher temperature. Opinions regarding the increments workers (e.g., Suchoverov et al., 1963) found considerable incremets in winter; others, like Wojno (1974) described only slight increments ranging within 3.5–5.7%. Steffens (1971) came to the conclusion that, in our climate, the periods most suitable for rearing the species in open waters are March/April – June/July and Semptember – December. In order to eliminate the unfavourable periods in the culture, attempts are made to render the culture completely or partly independent from seasonal temperature fluctuations. A culture of rainbow trout run in heated colling waters in winter is such a partial solution. Completely independent from the climatic effects are closed – system cultures. These solution are advantageous but also do have some drawbacks. One of those is a risk incurred by a culturist since the water heated in industrial installations is often contaminated and, moreover, its temperature can change rapidly (Bontemps, 1975). Some instances of mass mortality of rainbow trout kept under such circumstances are known. The rainbow trout culture within a closed system of water circulation allows the temperature and other factors to be kept under a complete control, but also calls for large investments.

The work presented here was aimed at checking a possibility of maintaining, in a special tank, a temperature suitable to rear rainbow trout throughout the year. The set-up utilizes the cheaper night rates of electric energy to heat the tank water in winter. Shadowing and cooling through the contact with a cool deep layer of soil are the measures taken to prevent the tank from being overheated in summer. To check a possibility of keeping rainbow trout under the conditions created and to determine the possible duration of such a culture with no water change were the other aims of the project.

CONSTRUCTION OF TANK AND METHODS OF STUDY

A U-shaped (cross-section) tank (Fig. 1) measured 225 cm in length 120 cm in width, 112 cm in maximum dept and was of 2.9 m^3 maximum capacity. The tank walls were made of 3 mm thick iron tin and covered with epoxy paint. The upper, covering part was constructed as a typical garden hotbed: its side walls were made of timber, while the cover consisted of wooden frames coated with transparent plastic foil. The thermal insulation was made of 6 cm thick styrene foam plates; these stuck fast to the tank side walls and overlied the upper cover. The tank was dug into the ground. The rounded bottom with no insulation contacted the sandy substrate. The tank was electrified; a typical electric heater (630 W ,220 V) sunk to the bottom served as a water heating device. The atmospheric air needed to aerate the water was delivered by a compressor hose.

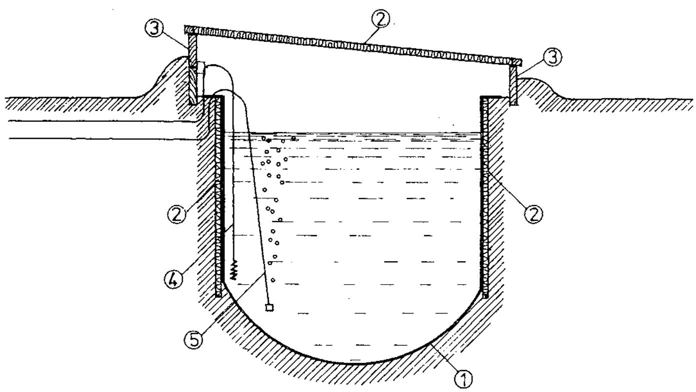

Fig. 1. Cross-section of the tank and its upper part (a schematic diagram)
1) iron tin tank, 2) styrene foam insulating plates, 3) timber lining, 4) water heater, 5) air hose

The thermal insulation was used to prevent the tank water both from cooling in winter and overheating in summer. No isolation plate was put under the bottom because – according to the assumptions adopted – the bottom wall was to act as a cooler in summer transferring the heat from the water to the cool layer of soil underneath, at 1 m depth. A fairly tight-fitting covers additionally supplied with styrene foam plates enabled a warm "air cushion" to be formed over the tank. In winter, this cushion prevented the heat to escape from the water to the atmoshere. During summer swelters the covers were slightly lifted so that they cast a shadow on the water surface and the sun rays could not reach it directly.

The main task to be performed was to maintain the tank water temperature at 12–14°C throughout the year.

The experiment was stareted on October 30, 1974 and was continued until October 20, 1975. A few days prior to the start of the actual experiment, the tanks was filled with 2.5 m^3 of tap water. 80 rainbow trout fingerlings of 36 g and 8.6 cm average weight and length, respectively, were planted in the tank on October 30. The length range of fishes was 5–18 cm; all the fingerlings (a home race supplied by the Bukowo hatchery) hatched about May 14, 1974. At first they were kept in an aquarium, and then (up to October 30, 1974) in a cage placed in a river. On October 30, 1974 the water heating was started. Throughout the whole experiment (almost 1 year) no water change was perfomed, the water being intensively aerated istead. The aeration, apart from introducing an oxygen supply, considerably stirred the water. In winter, when the tank was tightly closed, it was illuminated inside by an electric bulb. The fishes were fed twice a day, the food being supplied until the fishes ceased to feed. Various wet foods were tried: frozen fish (Cod, hake, mackerel, herring, carp), frozen cephalopods, fish viscera, cattle offals, fish mince with rye flour; but of these only frozen cephalopods were not readily eaten. The total weight of food used up during the experiment amounted to about 35 kg, with an average daily dose being equal to ca 100 g. A few crayfish (*Orconectes limosus*) and many gammarids (*Gammarus pulex*) were placed in the tank. The invertebrates had been assumed to utilize the remains of fish food, and the gammarids additionally were to serve as a live food.

RESULTS

The experiment was carried out over the period of rather a typical air temperatures illustrated by mean monthly air temperatures in Szczecin given in Table 1 (the data retrieved from the Sea Weather Forecasts). Particularly high temperatures were recorded in December and January: the deviations from the multi-year mean were respectively 4.3 and 5.9°C. Also the summer 1975 was considerably warmer when compared to the multi-year mean: July, August and September were warmer by 1.1, 2.5 and 3.3°C, respectively. Our own measurements made ad 8 a.m. and 3 p.m. in the immediate vicinity of the tank indicate an exceptionally warm summer. Numbers of days with temperatures exceeding 26°C in June, July, and August were 7, 19, and 15, respectively; for the same

Table 1

Mean air temperatures in Szczecin in 1974 and 1975.

Months	1974			1975									
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X
Monthly mean air temperatures (°C)	7.1	5.1	4.8	5.0	0.9	3.4	6.9	12.8	15.5	19.4	19.4	16.3	8.2
Deviations from a multi-year mean (°C)	–1.4	1.6	4.3	5.9	1.0	0.4	–0.6	–0.1	–0.7	1.1	2.5	3.3	–0.3

months number of days with temperatures of 30°C and more were: 2, 11, and 7. The highest air temperature recorded, 36°C, was noted four times in July.

The tank was under heating from October 30, 1974 till theend of April 1975, during which time the water temperature could have been accurately maintained within the thermal optimum planned, i.e., 12–14°C. To achieve this goal it was sufficient to switch on the heater for 5–10 hours a day depending on the air temperature. Mean working time of the heater during the period of heating was 6 hrs a day. An attempt to maintain the desired temperature during the warmer season was not very successful because, apart from lifting the tank's cover, no other possibility of temperature control existed. In May and June the mean water temperature was about 15°C, the range of fluctuations being recorded as 10–18.5°C. The thermal regime in October 1975 was similar (Table 2). The mean temperatures of the summer months (July – September) were: 18,5, 19.7, and 17.4°C with the range of 15.5–22°C. The temperature values exceeding 20°C were noted 10 times in August, while the maximum temperature od 22°C only once (August 9).

The oxygen conditions in the tank could be considered as sufficient. No decrease in the oxygen concentration below 7 mg/l was observed. However, this statement could hold true only during the period of reliable work of the aerating device. The latter ceasing to work, the oxygen content quickly lowered and the fishes began swimming upwards to the surface. The water turbidity was nearly always negligible (usually the bottom could be seen from above). Undoubtedly, this was brought about by a special substrate placed into the bottom screening the suspension. No algal bloom occurred in the tank. During the course of the experiment pH ranged within 7–8.

The chemical conditions in the water at the beginning of the experiment were consistent with standards set for drinking water. A year later the chemical analyses showed the following values of the parameters checked: 1.4 mg $N–NH_4$/1 0.062 mg $N–NO_2$/l, 176.2 mg $N–NO_3$/l, 55.12 mg N total/1, 0.71 mg PO_4/1, 63.8 mg Cl/1, 192 mg SO_4/1. The values of other factors were as follows: carbonate index 0.2 mval/1, hardness 17.9 German grades, oxygenation 20.8 mg $KMnO_4$/1.

Ichthyophthyriosis that burst out in March caused substantial losses in the fish population. Chloramine treatment applied completely exterminated the parasite. Five doses (370 g total weight) of this drug were administered over March 8–14. The fishes also died out as a result of hurting themselves with broken glass accidentally thrown into the tank. A rapid increase in mortality observed from mid-October 1975 was considered as a symptom of an environmental deterioration the continuance of the culture unfeasible.

On the last day of the experiment (October 20, 1975) only 12 fish specimens were caught (10 males and 2 females) of length and weight within the ranges of 15.5–32 cm and 91–394 g, respectively. The average length and weight were 24.6 cm and 193.3 g, respectively. The sizes given concerned 524-days old fishes after their 356-days stay in the tank. An average weight increment over the whole culture period amounted to 157.3 g. A diel weight increment calculated from a formula quoted by Wojno (1974) was 0.39%.

Table 2

Temperatures of tank water in over 1975

Months	III	IV	V	VI	VII	VIII	IX	X
Monthly mean temperatures (°C)	13.9	13.6	15.0	15.5	18.5	19.7	17.4	15.1
Range (°C)	12–16	12–15	10–18.5	12–18.5	15.5–20	18–22	15.8–20	13–17

The control weighings made when the fishes discussed were 1 year old revealed an average weight of 120 g. On completion of the experiment, both the female and male gonads were found to heve reached 4–5 maturity stage.

DISCUSSION

The tank constructed came up to our expectations. Almost throughout the whole year an optimal or suitable water temperature was maintained so that rainbow trout could be kept in this water. Only 10 days turned out to be unsuitable for the culture, i.e., those with temperatures exceeding 20°C, one day only showing a temperature of 22°C considered as critical for the rainbow trout survival. It should be emphasized that such good results were obtained during an exceptionally hot summer 1975 when temperatures of the air surrounding the tank reached 36°C. The temperature control was accomplished using quite straightforward methods 2.5 m^3 of water were heated by one "Selfa" heater (630 W) during approximately 180 days (6 hrs a day in average) making up 1080 hrs of work, 680 kW of energy having been used up. The cost of the electricity used was practically nil because the heating may be done at night when an excess of energy is produced by power stations. No instance of an overheating occurred in the tank, although no automatic control device was used. A high thermal inertion of the water required the heaters to work for many hours in order to increase the temperature by 1°C.

No energy whatsoever was used to maintain the relatively low temperature of the water in summer, the water being cooled only by the tank – soil contact and shadowing of the tank.

The oxygen conditions created in the tank, due to an intensive aeration, should be assessed as good. It should be stressed, however, that the aerating device is the most important element in the experiment for the rainbow trout survival. Thus a spare device is necessary to be readily available in order to diminish any risk should any break-down of the main device occur.

The self-purifying ability of the tank water should be highly appraised. The best evidence of it is fishes' survival for a year in 2.5 m^3 of unchanged water with 35 kg of high-protein food put into the tank during this time. Nitrogen compounds present in the food and in the fish excretes were mineralized to nitrates and accumulated as such. No vegetation, i.e., organisms capable of eliminating the dissolved biogenic salts, was present in the tank, thus the salts concentration reached a very high level (176.2 ml nitrates /1) during the final stage of the experiment. Such a high concentration resulted presumably in an increased mortality of fish leading to the cessation of the experiment. However, some fish survived under these circumstances, which should be emphasized. Grabda et al. (1974) found extensive lesions in liver and blood of rainbow trout kept at a nitrate concentration as low as 50 mg/l. The culture of rainbow trout in the tank could not be carried on because of the habitat deterioration; therefore rainbow trout could be kept with no water change in the tank described up to one year. The results and considerations point out the necessity of water change at some time intervals relative to the density of

Table 3

Actual weights and weight increments of rainbow trout under various conditions of culture

Source of information	Fish age (months)	Mean weight (g)	Diel increment (%)	Conditions of culture
Own studies	18	193.3	0.39	Temperature-controlled tank
Goryczko (1967)	18	149.3	0.45	Trout pond
Suchoverov et al. (1963)	18	97	–	Carp pond
Bartel et al. (1969)	17	150	–	Lake cage
Wojno (1974)	16	80	–	Lake cage
Bontemps (1975)	10.5	112	0.6	Warm water-supplied pond

fish and feeding intensity. In the authors' opinion, the self-purification processes occurring in the tank combined with the change of water should warrant a long-lasting purity of the tank environment suitable for dwelling of rainbow trout. This is our suggestion as to resolving the problem of water purification in the tank.

The results of the culture in terms of fish survival are thought to be negative. It should not be forgotten, though, that the majority of lethal cases was due to causes likely to be excluded (ichthyophthyriosis, self-injures). On the other hand, the culture had been planned to be carried on until the potentials of the system were exhausted, which would show as an increased mortality. Thus the culture was stopped only when the stock was decimated.

The results of the culture in terms weight increments are much more favourable. This statement is evidenced by the comparison comprised in Table 3. The results obtained can also be compared with various cultures referred to by Steffens (1971). The comparisons show the weight increments obtained to equal to the satisfactory culturing results. These increments were possible to obtain by treating the wintertime as a fully productive season owing to heating of the water. In this culture system consumptive fish of 120 g of average weight can be obtained as early as at the age of twelve months. It should be borne in mind when assessing the results of the culture that the stock kept in the tanks acted as biotest organisms bound to show the possibility of their survival under the conditions created. Therefore the particularly good results had not been anticipated.

The set-up presented was conceived as a prototype in need of further improvements. The habitat conditions in the tank can be changed to the better by changing the water. Owing to the small amount of water required, even the wells can be conceived as possible sources of water supply, cooling of tanks during summer swelters being an additional advantage. A systematic removal of food leftovers and fish faeces will also improve the habitat regime.

The tanks proposed make it possible to rear rainbow trout in places chosen fairly at will provided the mains and water supplies are available. The site a tank is designed to be built at should be well-sheltered, e.g., by a building or trees.

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PRÓBA HODOWLI PSTRĄGA TĘCZOWEGO (*SALMO GAIRDNERI* RICH., 1863) W BASENIE O REGULOWANEJ TEMPERATURZE WODY

Streszczenie

W specjalnym basenie próbowano utrzymać w ciągu całego roku temperaturę odpowiednią do hodowli pstrąga tęczowego. Basen o poj. 2,5 m^3 był wkopany w grunt i odpowiednio izolowany płytami steropianowymi (Fig. 1). Jako źródło taniej energii do podgrzewania wody w czasie zimy wykorzystano prąd elektryczny w godzinach nocnych. Ochronę basenu przed nadmiernym nagrzaniem w okresie letnim osiągnięto poprzez jego zacienienie oraz poprzez kontakt z chłodną warstwą gruntu. Doświadczenie trwało 1 rok. W tym okresie tylko podczas 10 dni utrzymywała się temperatura nieodpowiednia do hodowli (wyższa od 20°C), natomiast przez 9 miesięcy zdołano utrzymać temperaturę w granicach ścisłego optimum (12–16°C). Do podgrzewania wody zużyto w skali rocznej 680 kW energii elektrycznej. Woda była nieustannie i intensywnie napowietrzana. Przez okres całego roku hodowano w basenie pstrągi, nie zmieniając wody. W tym czasie ryby przyrosły średnio o 157,3 g, osiągając w wieku 18 miesięcy średnio 193,3 g. Dopiero w końcowym okresie trwania doświadczenia doszło do zatrucia środowiska (głównie azotanami), co spowodowało gwałtowny wzrost śmiertelności ryb. Zdaniem autorów proces samooczyszczania wody, zachodzący w basenie, połączony z okresową wymianą wody winien zapewnić utrzymanie się w basenie odpowiedniej dla pstrągów czystości środowiska. Proponowane rozwiązanie pozwala prowadzić hodowlę pstrąga w dość ściśle kontrolowanych warunkach środowiskowych. Walorami rozwiązania jest małe zużycie energii i wody.

ПОПЫТКА РАЗВЕДЕНИЯ РАДУЖНОЙ ФОРЕЛИ (SALMO GAIRDNERI RICH., 1863) В БАССЕЙНЕ С РЕГУЛИРУЕМОЙ ТЕМПЕРАТУРОЙ ВОДЫ

Р е з ю м е

В специальном бассейне в течение целого года пытались поддержать соответствующую для разведения радужной форели температуру. Бассейн ёмкостью 2,5 $м^3$ поместили в грунт и изолировали плитами из пенопласта (рис.1). В качестве дешёвой энергии для подогрева воды в зимее время использовали электроэнергию в ночное время. Для предупреждения перегрева воды в летнее

время бассейн защитили навесом. Опыт продолжался год. За это время только 10 дней в бассейне была несоответствующая для разведения форели температура (выше 20°C); в течение же 9 месяцев удалось поддержать температуру воды в пределах строгого оптимума (12°-16°C). Для подогрева воды израсходовали 680 квт электроэнергии в годовом расчёте. Вода постоянно и непрерывно аэрировалась. В течение целого года в бассейне находилась форель. Воду не меняли. За это время рыбы увеличилась в весе в среднем на 157,3 г, достигнув в возрасте 18 месяцев в среднем 193,3 г. Только на последнем этапе опыта произошло отравление среды (главным образом нитратами), что привело к резкому увеличению смертности рыб. По мнению авторов процесс самоочищения воды, происходящий в бассейне, в сочетании с периодическим обновлением воды, должен обеспечить в басейне необходимий для форели чистоты среды. Предлагаемое решение вопроса позволяет вести разведение форели в строго контролируемых условиях среды. Положительными моментами такой постановки дела является небольшие расходы воды и энергии.

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