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THE EFFECT OF ILLUMINATION ON ALEVINS OF ATLANTIC SALMON (*Salmo salar*) AND RAINBOW TROUT (*S. gairdneri*), INCUBATED ON DIFFERENT SUBSTRATES.

by

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ABSTRACT

Atlantic salmon (Salmo salar) and rainbow trout (S. gairdneri) eggs were incubated in plexi-glass aquariums. After hatching, alevins were kept in darkness, two groups of each species without substrate, two groups in gravel and two groups in Astroturf artificial substrate. Every three days after hatching, heartfrequencies or respirationrates were counted as measure of different activity and stress in the various groups, following a 10 minutes exposure to light.

The respiration rate and heartbeat frequence of Atlantic salmon alevins was generally lowered among all the groups, during the period of observation. The alevins reared in Astroturf, showed however the lowest and most stable respiration rate and heartbeat frequence, due to their low activity at the bottom of the aquariums.

The respiration rate of rainbow trout increased among all the groups during the same period. This fact reflects their early emergence from the bottom, and their subsequent swimming activity near the surface. Therefore, neither Astroturf nor gravel seemed to influence on their growth and development. The heartbeat frequence of rainbow trout showed a maximum the 7th day posthatching.

INTRODUCTION

In several Norwegian fish plants, artificial substrates has been introduced in full scale in the traditional Californian hatching systems. According to Hansen and Møller (1985) and Hansen (1985), Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) alevins, respectively, reared in Astro-turf artificial substrate, absorbes their yolk sac faster and more efficiently, has lower mortality both in the hatchery and during first feeding, and grow faster during first - feeding, than alevins reared on a flat screen. They assumed that the positive effects of using astro-turf, were due to the lowering of the activity of the alevins in this substrate.

This is supported by the observations of Marr (1963), which showed that trout alevins (*Salmo trutta*), reared on a plain surface, had a very high swimming activity compensating for their righting and falling. However, any irregular surface which supported their ventro lateral part of the yolk sac, reduced this locomotor activity.

At Matre Aquaculture Station the activity level of Atlantic salmon alevins (*Salmo salar*) in different substrates has been investigated and quantified (unpublished data R. Nortvedt). This investigation states the same tendency in behaviour for this species.

It is well known that light has an effect on the development of young salmon. Smith (1916) showed that light both advanced hatching and caused a continuous activity of alevins of Chinook salmon (*Oncorhynchus tschawytscha*) and of humpback salmon (*O. gorbuscha*), not shown by alevins kept in dark. The respiratory movements were consequently lower for those kept in the dark.

Woodhead (1957) found an increase in the activity with age of the alevins of brown trout (Salmo trutta) and rainbow trout (S. gairdneri). It was also claimed that this activity could be regarded as an index of development as it was shown to be related to the general growth of the embryo. The activity was, however, also found to be dependent on light intensity.

Marr (1965) investigated the influence of both light and surface contour on the efficiency of development of salmon embryoes, and found that locomotor activity was reduced both by a decrease in light intensity and by an increase in rugosity of the substrate.

Holeton (1971) found that struggling not surprisingly resulted in increased breathing and heart rate at all times.

The purpose of this experiment was, by measuring the heart-frequencies and respiration rates, to investigate the correlation between the behaviour and the metabolic response of the behaviour of both Atlantic salmon and rainbow trout, incubated on different substrates. This was done following a 10 minutes period of exposure to light. Such a stressor is as previously mentioned, not favourable to the early larval stages. It is, however, a handy tool when mapping the alevins metabolic respons of the cooperating effect between light and substrate.

Some preliminary investigations at Matre Aquaculture Station have indicated that the positive effect of rearing Atlan-tic salmon (Salmo salar) in Astroturf artificial substrate, was not nessessary similar for rainbow trout (S. gairdneri). It was therefore interesting to compare the heart frequencies and respiration rates of these two species.

To support these studies, a incubation experiment with rainbow trout in Astroturf was done in full scale.

MATERIALS AND METHODS

Source and incubation of eggs and alevins.

Atlantic salmon eggs from A/S Fiskekultur, Matredal, fertilized on 19/12-84 at Eros laks, Bjordal, were incubated in darkness in a plexi-glass aquarium 26/2-85, 4 days before 50% hatching. At 50% hatching, 150 alevins of normal appearance, which had hatched during the last day, were divided into 6 groups of 25 alevins.

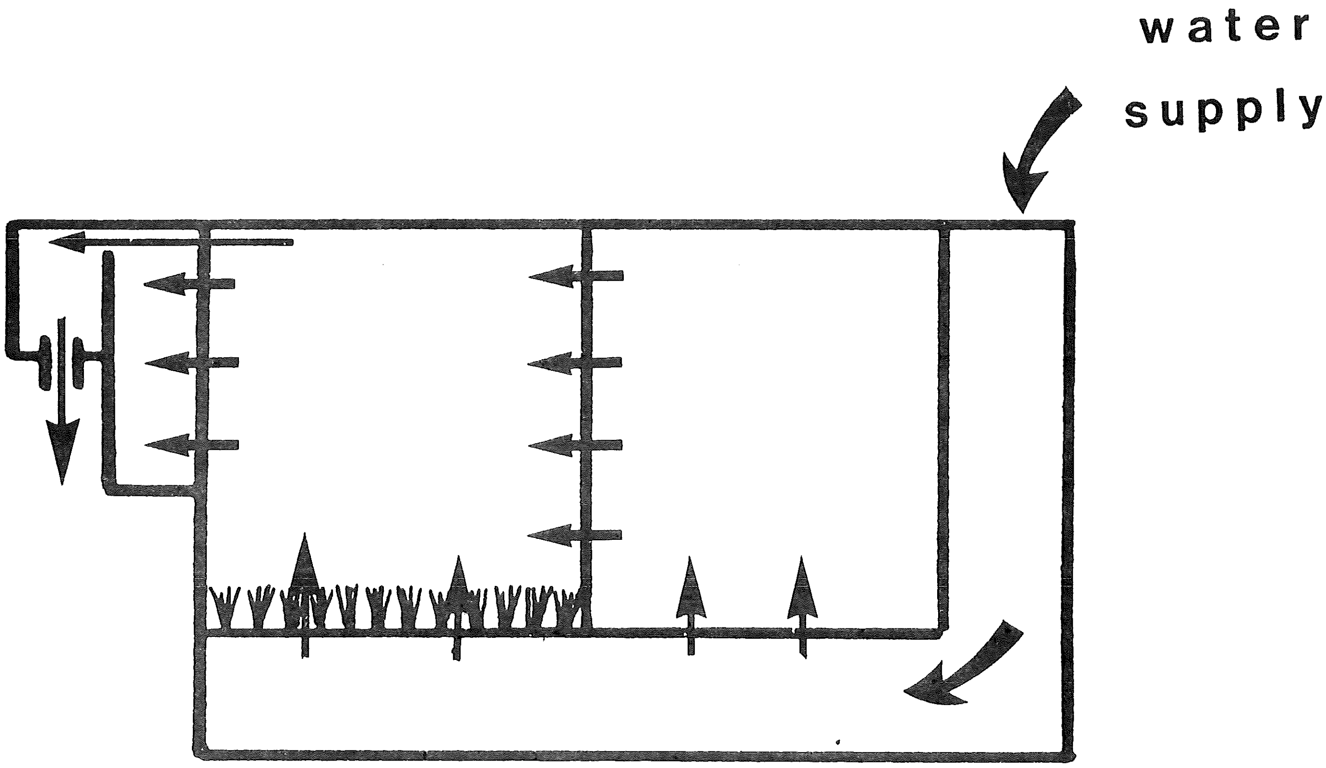
Each group were transferred to one of 6 compartments in 3 aquariums; two groups without substrate, two groups in gravel and two groups in Astroturf artificial substrate. The groups were still kept in darkness.

Rainbow trout eggs from Matre Aquaculture Station, fertilized 11/2-85, were incubated similarly 19/3-85; 2 days before 50% hatching. The size, handling and observation of the rainbow trout groups were the same as for the salmon.

The aquariums.

Six aquariums (50L x 11D x 25.5H cm) were made of 5 mm thick plexi-glass to permit observations from all sides. The plexiglass was glued with the polymerisationadhesive Røhm/Acrifix 90 + Røhm/Catalyst 20.

The aquariums were constructed after the upstream-principle (Fig.1), The water was coming up through a 1mm perforated, horizontally layed aluminium screen, 6 cm above the bottom.



FIGUR 1 Aquarium with two observationchambers; one with Astroturf and one without substrate. The arrows indicate the flow of water.

A vertically placed screen divided the aquarium in two 17.5l x 10d x 19h cm observationchambers. The construction of the outlet permitted a constant waterlevel; 1 cm from the top edge of the aquarium. The bottom screen of the observationchambers was either covered with gravel, Astroturf or nothing.

Gravel from Matre river, was washed under hot, running water, sorted and placed in the chamber as a double layer. Near the bottom, gravel of 3-9 mm in diameter made a layer of 1 cm's thickness. Above, gravel of 12-25 mm in diameter made a second layer 4 cm thick. The gravel was evenly distributed, but loosely packed, to permit the downward movement and later emergence of the alevins.

The backless Astroturf artificial substrate, modified as described by Hansen and Møller (1985), was glued to the perforated aluminium bottom with a acetic acid-based siliconglue, in such a way that watersupply to the observationchambers was secured and evenly distributed.

The aquariums of the rainbow trout were numbered from 1 to 3, and those of the Atlantic salmon, numbers 4 to 6. Following combinations of the 3 types of substrate were used in the 2 observationchambers:

Aquarium no. 1 and no. 4 :	Astroturf / without substrate
Aquarium no. 2 and no. 5 :	Without substrate / gravel
Aquarium no. 3 and no. 6 :	Gravel / Astroturf

The aquariums which were not under observation, were covered with a special adapted cap of canvas, coated inside with a black sheet of polyethylene, to prevent penetration of light.

Water supply.

The freshwatersupply in these experiments was cooling water from the turbines of the BKK hydroelectric powerplant in Matredal. Sodium hydroxide is added to all the freshwater supplied to the Matre Aquaculture Station, to keep the pH within the interval from pH 6.0 to 8.0 (Hansen, Torrissen and Ulgenes, 1984). During this experiment the mean pH value was 6.5.

Each aquarium had its own separate water supply from a common reservoir, and the flow rate through each one was kept steadily at 1 L/min., controlled every third day.

The flow rate through each observationchamber was investigated by adding malachite green to the incoming water, and mapping the flow speed by a Sony Trinicon colour camera and a Sony U-matic portable video. The flow was uneven, streaming along the bottom of the observationchambers and then right up the wall and out. The flow rate was especially low through the gravel when this was placed in the chamber furthest away from the water outlet. Taken into account the low number of larvae, the water exchange was however, assumed to be sufficient.

The temperature was measured daily by the Matre Aquaculture Station's crew, and varied between 6.0 and 7.6, with a mean value of 6.8.

The observations.

All the 6 aquariums were placed in the same dark room so that variations in daylight during the period of observation should not be a disturbing factor.

Heartfrequencies and respirationrates were counted , following a ten minutes illumination with a tilted lamplight of 60 W, 10 cm above and 10 cm in front of the aquarium.

Heartfrequencies were obtained between the 8th and the 16th day after hatching for Atlantic salmon, and between the 1th and the 22th day for rainbow trout, both every third day. Respirationrates were obtained every three days between the 11th and the 68th day, and between the 7th and the 46th day, for Atlantic salmon and rainbow trout respectively. At the 46th day of rainbow trout and the 68th day of Atlantic salmon, both had well passed swim-up, and the observations were ended.

For both species, supplementary observations of respiration and heartactivity were conducted under extremely stressing conditions, at least every 14th day during the whole observation period. 5 alevins of known age were randomly choosen for this purpose from the hatchery at the Matre Aquaculture Station, and the countings were done immediately after sampling, and 1/2, 1 and 2 hours after sampling the alevins, (see table 1). In this period each alevin was stressed in its own petri dish, continuously illuminated by a lamplight of 60 w in a distance of 40 cm.

The heartfrequence was mainly obtained by counting the puls of blood through the bulbus arteriosus, immediately in front of the yolk sac. However, the pulsating of the entire heart could sometimes be seen as well.

The respirationrates could be seen as regular movements as follows :

i) Movements of the entire head.
ii) The opening the mouth.
iii) Movements of one or both the opercula.

Rainbow trout incubation experiment

Eggs from eight females were pooled and were fertilized with pooled milt from three males. Data on the parent fish were not recorded. The fertilized eggs were incubated in hatching trays at Matre Aquaculture Station.

At the eyed stage the eggs were again pooled. After a mechanical shocking the dead eggs were removed using a sorting machine. Two liters of the live eyed eggs were incubated in a standard Ewos hatching tray. Following hatching, dead eggs were removed by sorting them out on a plastic screen with 3 x 20mm perforations. The live larvae were divided into 6 equal groups of 2500 which were incubated in 3 Ewos hatching trays. Each of these trays were partitioned into two equal sized compartments and one of these compartments were modified as described by Hansen and Møller (1985) by sewing backless astro-turf to the perforated aluminum bottom.

The water input in the hatchery was 10 L/min per tray and the temperature fluctuated between 7.5 and 9.6. The mean pH was 6.7.

15 to 20 larvae from each compartment were sampled with a dipnet twice a week. The larvae were anaesthetized with clorbuthol and preserved in 5% formalin. The larvae were later length measured to the nearest mm downwards (d = +/- 0.5mm) and also the yolk sac length was measured using a binocular microscope with a measuring ocular. Following this, alevins and yolk sacs were weighed separately on an electronic microbalance (d = +/- 0.1mg). Individual body weight (total weight minus yolk weight) was later calculated.

The data were statistically analysed by RS/1 statistical software (Bolt Beranek and Newman, Inc., Cambridge, Massachusetts). A confidence level of 5% was adopted in all tests.

RESULTS:

The respiration rate and the heartbeat frequence of the two species under extremely stressing conditions are given in the tables 1a and 1b.

Table 1a: Respiration rate (rate/min) during heavy stress of alevins of Atlantic salmon and rainbow trout. Mean values of 5 observations.

	RAINBOW TROUT				ATLANTIC SALMON			
Days Posthatching	start	1/2h	1h	2h	start	1/2h	1h	2h
9	88	110	130	153				
14					118	110	141	150
19					110	126	120	116
22					113	102	99	107
23	131	142	165	182				
37					109	119	120	129
46					120	113	124	132
47	95	124	129	147				
60	107	121	149	151	119	127	130	132
74	140	159	170	185				

Table 1b: Heartbeat frequence (rate/min) during heavy stress of alevins of Atlantic salmon and rainbow trout. Mean value of 5 observations.

	RAINBOW TROUT				ATLANTIC SALMON			
Days Posthatching	start	1/2h	1h	2h	start	1/2h	1h	2h
9	115	139	170	184				
14					130	113	140	126
23	113							
47	125	133	139	146				

After 2 hours with heavy stress, several of the alevins died, and the others seemed to be quite exhausted. At this moment, the respiration rate and heartbeat frequence reached a maximum level, and consequently showed the rates of nearly maximum activity and fatigue. These high levels were never found during the observations in the aquariums.

The respiration rate of Atlantic salmon alevins (fig. 2 and 3), showed distinguishable rates between the groups, reared on the different substrates, until massive swim-up on day 57. The Astroturf reared alevins showed very low activity until this day, with a generally low and stable respiration rate, varying between 49 to 39 opercular movements/min, with a mean value of 46. On the 50th day, all the Astroturf reared alevins had emerged from the substrate.

50% of the alevins in the gravel had emerged the 25th day, and on day 53, all the alevins had emerged. Their respiration rate was lower the first day of observation than that of the Astroturf reared. This was 11 days posthatching. Before that moment, they could be seen in the same pocket in the gravel near the plexi-glass wall every day. Later, they entered the crevices of the gravel. Of those alevins that could be observed, the mean value of respiration rate raised to a maximum of 64 opercular movements/min the 32th day. Their lowest average rate before swim-up of 42 opercular movements/min. was observed the 51th day after hatching.

Like the gravel reared alevins, the flat screen reared ones showed a significantly higher respiration rate than those in the Astroturf during the observationperiod before swim-up. They showed however a higher maximum rate at a earlier stage than those in the gravel, with a maximum of 73 opercular movements/min. at the 23th day after hatching. Their lowest rate of 41 opercular movements/min was observed the 57th day.

The respiration rate of rainbow trout (fig. 4 and 5), varied to a stronger degree between individual alevins, and from one day to the next, than that of Atlantic salmon. It is therefore difficult to destinguish between the groups. But all the groups showed a tendence of increased respiration rate during the observation period. The lowest value was 41 opercular movements/min the 7th day, and the highest value was 88 opercular movements/min the 47th day.

Fig. 6 shows the heartbeat frequence of alevins of Atlantic salmon from 8 to 16 days posthatching, reared in Astroturf or without substrate. The heartrate varied between 60 and 51 beats/min for alevins reared in Astroturf, and between 67 and 62 beats/min for those without substrate. The rate seemed to be quite stable, but showed a clear difference between the two groups.

The development in the heartbeat frequence of rainbow trout is shown in fig.7. It is difficult to destinguish between the rates of the Astroturf and the flat screen incubated alevins. Both curves, however, showed a remarkable maximum value the 7th day after hatching, with the highest value observed of 55 beats/min. The lowest observed value was 48 beats/min.

Rainbow trout experiment

The development in length of body and yolk sac and the development in weight of body and yolk are shown in figures 8 to 11. No significant differences was found between the Astroturf and the flat screen reared alevins in any of the recorded parameters at any time.

DISCUSSION:

Materials and methods:

Both respiration rate and heartbeat frequence were measures of activity. The respiratory movements could hardly be seen in the beginning of the observation period, when the heartbeats was easely seen. Later, it became difficult to observe the cardiac activity, because of the increased pigmentation of the alėvins. At this moment, the respiratory movements were however almost always visible.

Stuart (1953) believe that trout (Salmo trutta) recognises the presence of gravel of certain dimensions, when searching for a gravel bed suitable for redd construction. The author conclude however that if all other conditions are satisfied, the gravel size is not critical.

In our experimental design, gravel was choosen because of its natural use by the wild fish. It was interesting to see whether the activity of the alevins in gravel, reflected by the respiratory rate, differed from that in the artificial Astroturf substrate. According to Dill & Northcote (1970), movements of coho salmon alevins (Oncorhynchus kisutch) in aquariums of large gravel (3.2-6.3 cm) were more extensive, and area utilized per alevin was greater than in the small sized gravel (1.9-3.2 cm). We choosed an upper layer of gravel of 1.2-2.5 cm in diameter to avoid large activity. This was to ensure the possibility of comparing the metabolic rate, caused by the low activity of alevins from both Astroturf and gravel. Too fine sand will however be dangerous to the alevins. Peterson and Metcalfe (1981) showed that "fine sand (0.06-0.5 mm) was more effective than coarse sand (0.5-2.2 mm) in reducing numbers of emergent fry." Our lower layer of gravel of 3-9 mm in diameter was therefore assumed to be of no harm to the alevins. This gravel was used to separate them from the bottom aluminium screen.

Stuart (1953) observed that the heartbeat frequence was increased or lowered by altering the temperature or oxygen content of the water. As mentioned; the flow rate of water through each observationchamber was not evenly distributed in our investigations. It was however kept at constant level, and should thereby cause no variations in oxygen content near the bottom, where these observations were done at the alevins first stage of life. Despite the fact that the flowrate was unevenly distributed, there was always some water exchange in the entire water column caused by the relatively high rate of water supply of 1 ltr./min. Moreover, alevins have a very low oxygen demand (Ivlev, 1960). It is therefore probable that variations in oxygen content neither influenced the heartbeat frequence, nor the respiration rate. A flow rate as high as 1 litr./min. was the lowest possible rate, that could practically be controlled and kept stable over a period of several months. The stable water supply ensured that no aquarium had a different water supply from the others. The stream of water itself did not seem to affect the behaviour of the alevins.

The temperature and the pH level could also cause only minor variations in oxygen demand from day to day because these parameters were kept quite stable.

In behavioural investigations the possible disturbances caused by the observer should be eliminated. In our observationseries the aquariums not observed at the moment was shaded from the light and the observer. The removal of the cowl of canvas in darkness, was followed by a standardiced period of 10 minutes of silence and no illumination. During illumination of the alevins, the observer stayed in darkness, and as compared to a man looking out in the dark night from an illuminated room, the alevins could not possibly be aware of the observer.

The observations by Smith (1916) of respiration movements of Chinook salmon (Oncorhynchus tsawytscha), reared under either dark or light conditions, were carried out in waterfilled flasks with decreasing contents of oxygen. This is a rather artificial environment, and as expected, the respiration rate increased during the whole observation period for both groups, but the timelag of stressrespons could, however, be compared for the two groups. However, in that investigation, nothing was said about the variation in the samples, nor about how it was possible to measure the respiration rates of alevins in the dark. It is therefore difficult to say whether the investigations gave a true picture of the real differences in respiration rates, and thereby the cost of activity under different rearing conditions. In our investigations, however; a common stimulant of light were given, and the different responses of activity could directly be observed by the respiratory movements of the different groups of alevins.

Because the alevins was observed during illumination, they respond by a negative phototactic behaviour before the time of swim-up. This activity causes an elevated heartbeat- and respiratory rate. But accordingly to our prelimnary investigations of heavy stress (see table 1), it will never reach the peak of fatigue.

The method of observation during illumination was seen to raise the behavioural level of activity for all the groups of alevins, and after 10 minutes it is supposed to stabilize in a totally path of waves of respons, as reported by Woodhead (1957). The possibility of observing opercular movements and heart beat frequencies is dependent of clearly observable alevins, which thereby only could be observed if they were evenly and well illuminated. The alevins hidden in the gravel or in between the bristles of the Astroturf substrate, could therefore not be observed. Those actually observed would however probably show the same reaction to light, independent of the substrate. The differences in metabolic rate for alevins reared at different substrates, would then reflect the generally raised activity caused by the support or lack of support in the different substrates.

The alevins in a commercial hatchery are of course shaded from any light source during the period before startfeeding. They are, however, daily stressed by illumination due to routine control. Exposure to light is therefore a realistic instantaneous stress situation in addition to the substrate effect.

Results:

The increase in maximum respiration rate during heavy stress with increasing age of rainbow trout (Tab. 1a), is probably due to their increased scope of activity by their even better developed respiratory pumps. The Atlantic salmon however, responded by stronger movements of their opercula. There are however some uncertainty of the validity of the two last obsevationseries of Atlantic salmon, because none of the alevins died after 2 hours of heavy stressing conditions.

Brett and Groves (1979) point out that few systematic studies have been conducted on the effect of size on active metabolic rates of fish. They suppose that an increase in weight is followed by increasing activity. The increase in size of the Atlantic salmon alevins in my investigations, quite similar to those of Hansen and Møller (1985), cannot explain the development in respiratory rates. Our investigations show that the activity is lowered in the substrate, even if the weight is increased. The statement of Brett and Groves (1979) can therefore not be applied under substrate rearing conditions.

In another investigation of Brett (1964), the author reports that the relation between respiratory metabolism and swimming speed in young sockeye salmon (Oncorhynchus nerka) was found to be exponential. In our investigation, the close relation between a controlled, constant swimming speed and the metabolic rate was however not examined. The different rates of metabolic rate was, however, seen to correlate to the behavioural respons of activity to the different rearing environments. This phenomenon explains at least the metabolic rate of the Atlantic salmon alevins.

The alevins reared at the flat screen showed the highest swimming activity, until day 55, when most of the alevins had left their substrate, and was seen to handle their buoyancy problem in varying degree. Before this moment, the activity was due to the compensating for their righting and falling, as reported by Marr (1963). The activity of these alevins was however seen to be high during the whole period, and not actually in close correlation to the decreasing level of respiration. Ivlev (1960) showed that by an increase in the activity of salmon fry (S. salar) by 10 times, the general metabolic intensity increased by 7 to 14 times, depending on the average size, where the smallest fry showed the greatest increase in metabolic intensity, caused by its less perfect moving apparatus. This agrees with the high level of the metabolic rate at the beginning of the observationseries, despite a relatively low level of activity. The rainbow trout showed a respiration rate nearly equal to that of Atlantic salmon on the 10th day, both in Astroturf and without substrate. The lower respiration rate of rainbow trout at an earlier stage, could be due to its still vascularized yolk sac with possabilities of gas-exchange. Another fact, explaining the tendency of lowered respiration rate of Atlantic salmon after day 23, is that the alevins at this moment, when the yolk sac was prolonged and decreased in size, was clever in supporting themselves by one of the pectorals, just like a man resting at one of his elbows. It was moreover very interesting to observe that they changed the load from one pectoral fin to another after a while. But after some minutes they became restless again, resulting in increasing activity.

The generally low metabolic rate of the Astroturf reared alevins is in agreement with the investigations of Hansen and Møller (1985), who states that low activity probably causes a better growth and survival until day 53 of Astroturf reared alevins, compared to those reared in gravel or at the flat screen.

The intermediary metabolic rate of the alevins in the gravel (fig. 3) seems to agree with an investigation (T. Hansen, 1984), demonstrating that alevins reared in gravel under similar conditions, show an intermediary growth, laying between the growth of Astroturf reared and flat screen reared alevins.

In the gravel, energy was employed to penetrate through the crevices. According to the investigation of Stuart (1953): " Removal of the shading from the gravel tanks caused the alevins to retract towards the centre of the tank away from the light." This statement, seen in association with Bretts (1964) statement of exponential increase in respiratory rate with increasing activity, could however cause an error in overestimating the negative effect of gravel as artificial rearing environment from our investigation. The respiratory rate during illumination will therefore not give a true picture of the real differences in growth of the alevins of Atlantic salmon from different substrates, but it is probably increasing and thereby illustrating the very true difference between them.

The increasing respiration rate of rainbow trout through the entire observation period, was seen to correlate closely to their activity. Compared to Atlantic salmon, they started at a lower level, reflecting their smaller size. But even at this moment, they showed violent wriggling movements and restlessness by jumping up and down at the same location of the substrate. They tilted however not over to one of their sides to the same extent as the Atlantic salmon alevins did. At the 22th day, the first alevins were seen to swim up to the surface of the water, were they stayed most of the time. And at the end of the observation period, all the groups of rainbow trout showed a far higher respiration rate than those of Atlantic salmon. This fact reflects the differences in swimming activity, where the alevins of Atlantic salmon mostly stayed quiet at the bottom. This behaviour pattern explains why Astroturf reared alevins of rainbow trout probably not will achieve the same advantages compared to alevins reared in gravel or in the traditional flat screened hatching systems (fig. 8 to 11), as Atlantic salmon will. The variance in the observation series was however very large, and it was thereby difficult to distinguish between the different groups in one way or another.

The observations of heartbeat frequence shows a less varying metabolic rate than those of respiration rate, reflecting their more stable level of activity in the beginning of their life. Already at this moment, however, it is difficult to distinguish between the groups of rainbow trout. There is, however, an obvious difference in activity from the 8th day between the alevin groups of Atlantic salmon, showing that the Astroturf reared ones are deactivated in the substrate. The simultaneously increased heartrate at the 7th day, followed with a drop, for the two groups of rainbow trout , however, remains unexplained. Holeton (1971) reports a similar drop in heart rate of rainbow trout between the 9th and 18th day. The author gives a possible explanation that "inhibitory nervous control of the heart via the vagus nerve is established during this period". Stevens and Randall (1967) were, however, not able to find evidence for such a vagal tone in the heart of trout. In the investigation of Holeton (1971), the heartrate of rainbow trout alevins was generally higher than in our investigations. But this fact can probably be explained by the difference in temperature.

Both heart frequence and respiration rate should be closer investigated in the future, with respect to their connection to activity.

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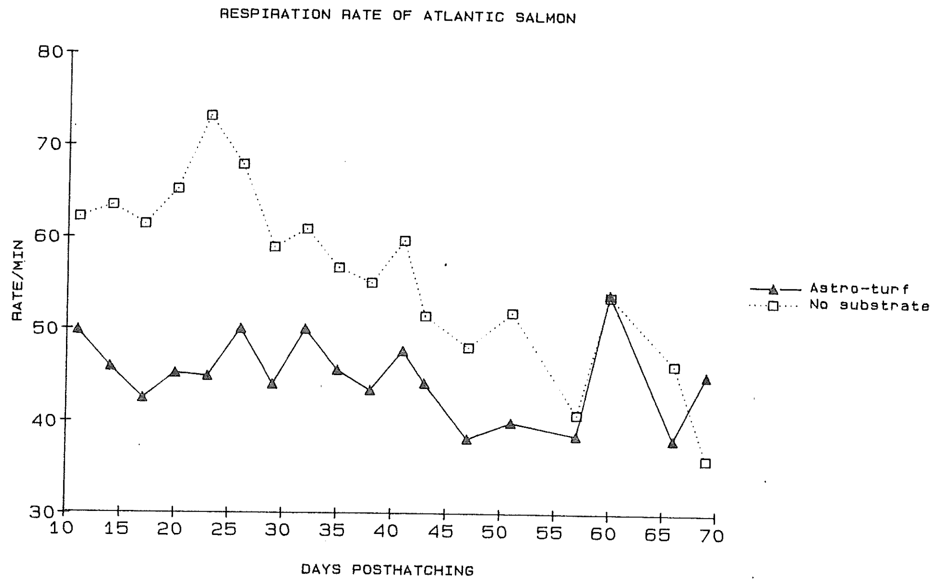

FIG. 2 Respiration rate of Atlantic salmon (Salmo salar), incubated in Astroturf or without substrate.

Each point in the figures of respiration rate and heart frequence represents a mean value of 6 to 10 observations, pooled from two different aquariums, depending on the possibility of observation within a observation period of 10 minutes. Extremes or outlayers are not omitted, causing some variation in the observation series.

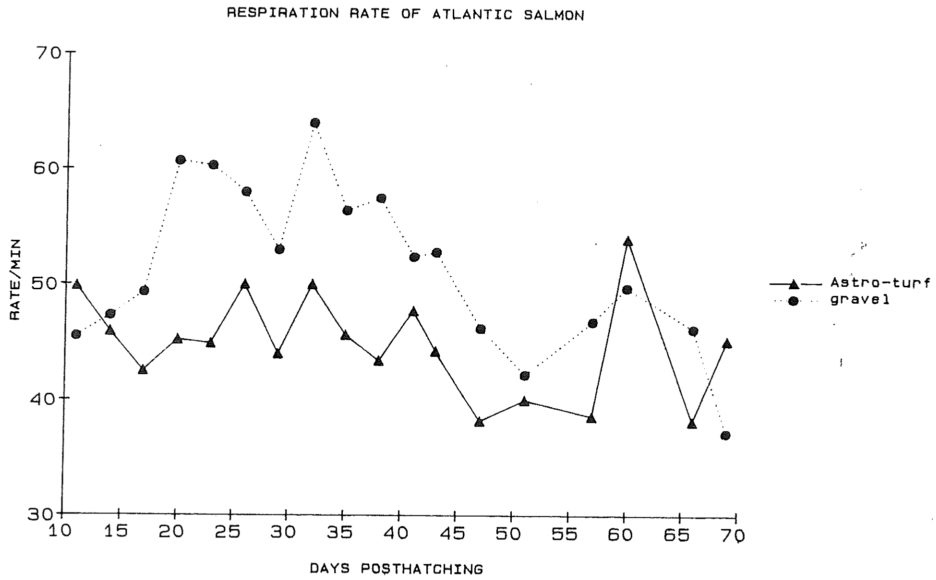

FIG. 3 Respiration rate of Atlantic salmon (Salmo salar), incubated in gravel or in Astroturf. See also fig.2.

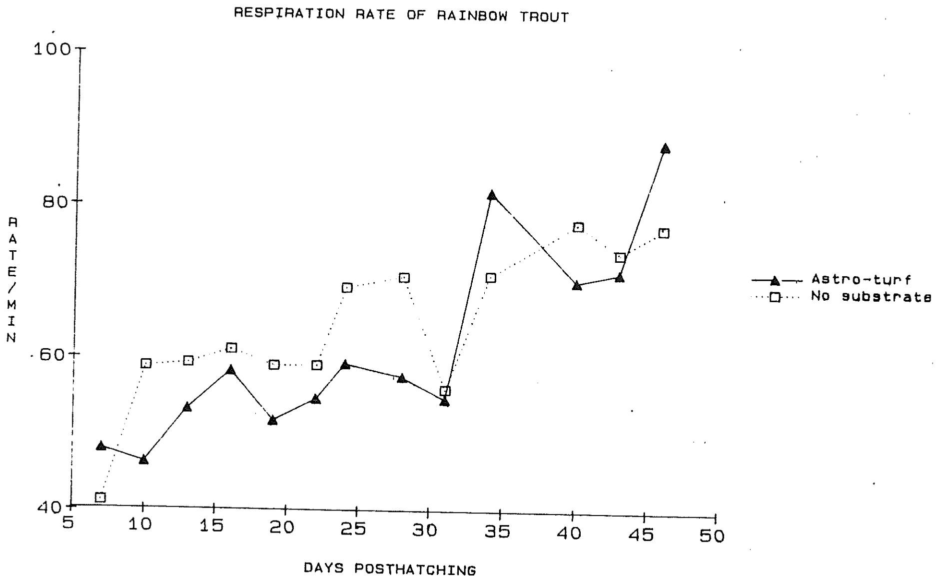

FIG. 4 Respiration rate of rainbow trout (Salmo gairdneri), incubated in Astroturf or without substrate. See also fig.2.

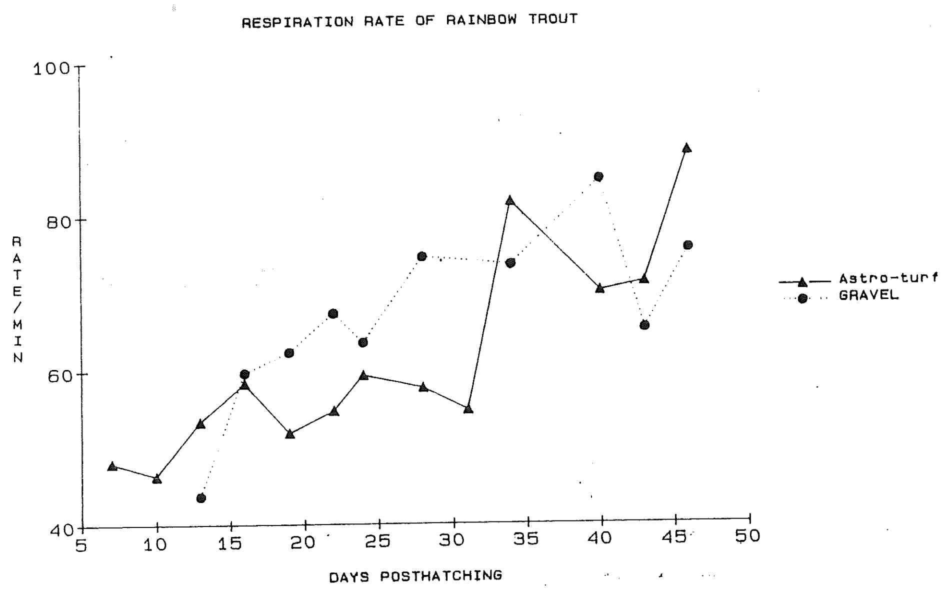

FIG. 5 Respiration rate of rainbow trout (Salmo gairdneri), incubated in Astroturf or in gravel. See also fig.2.

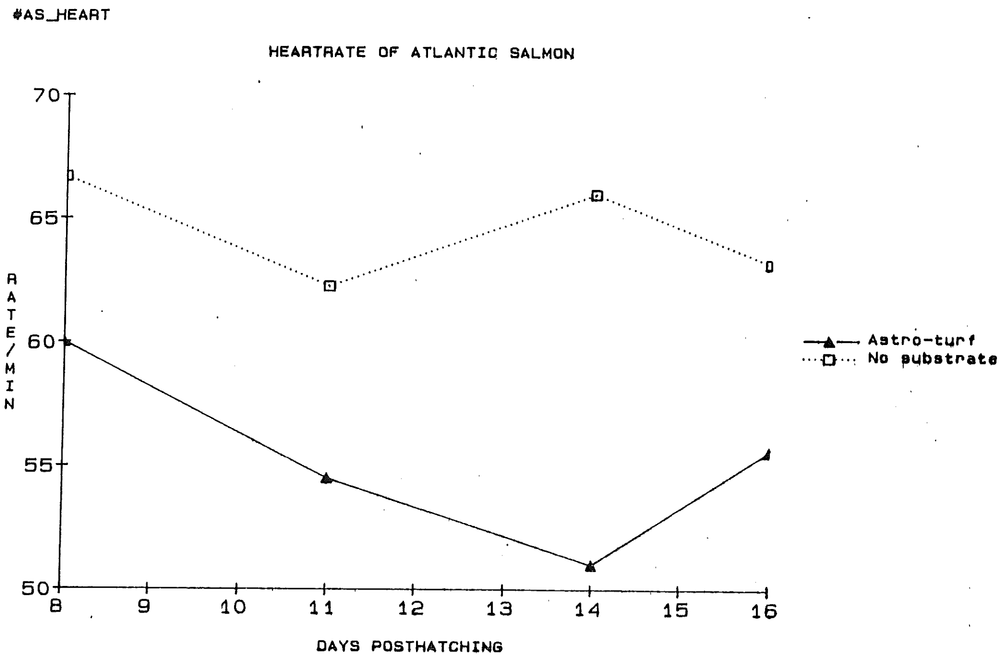

FIG. 6 Heartbeat frequence of Atlantic salmon (Salmo salar), incubated in Astroturf or without substrate. See also fig.2.

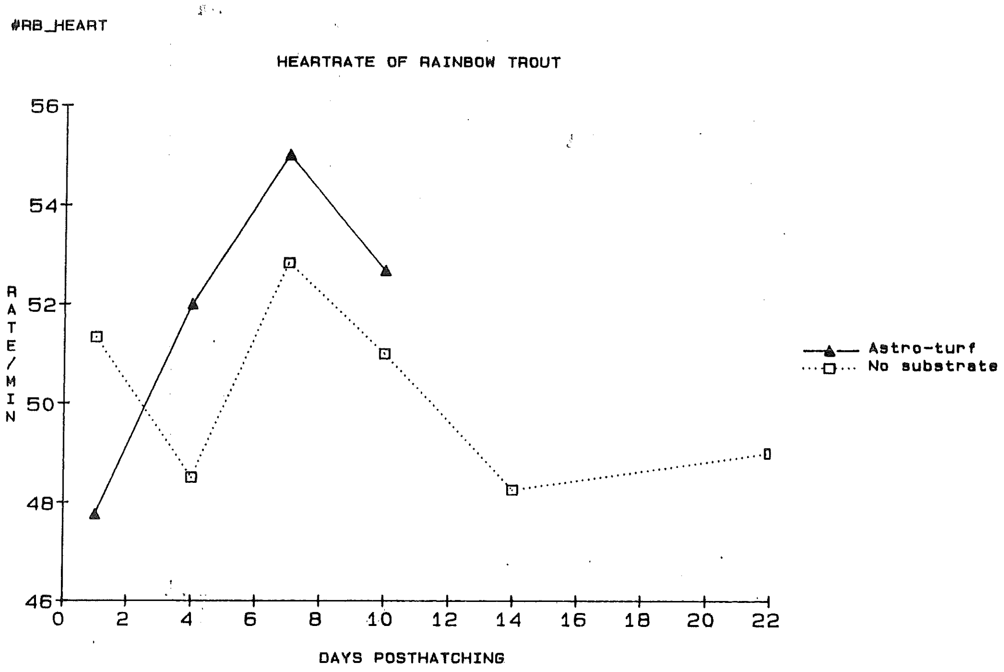

FIG. 7 Heartbeat frequence of rainbow trout (Salmo gairdneri), incubated in Astroturf or without substrate. See also fig.2.

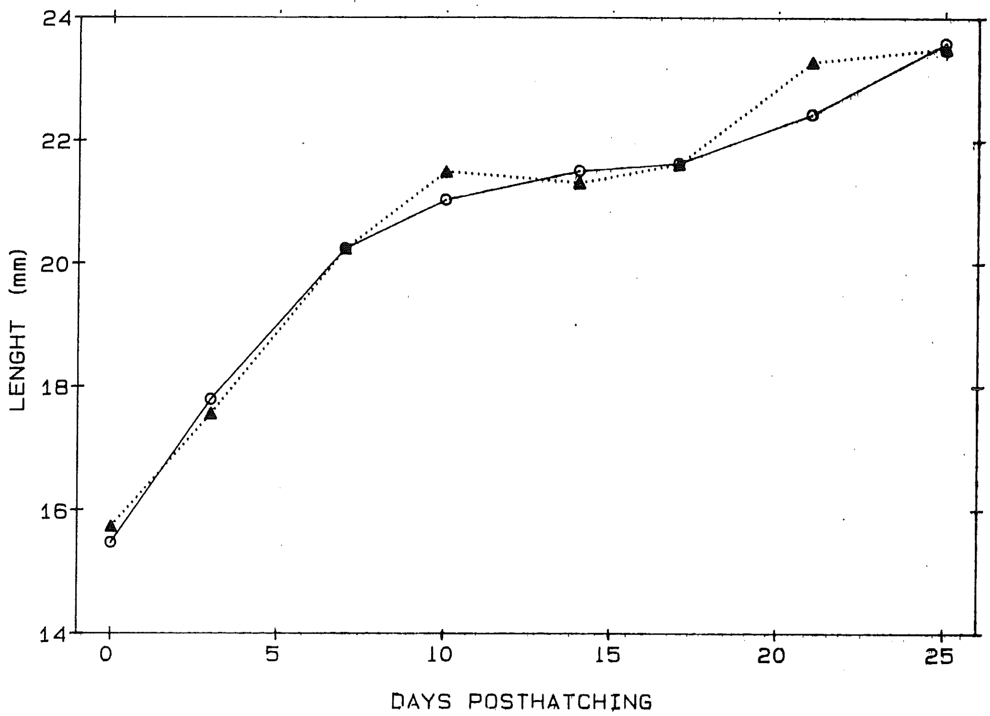

FIG. 8 Length development of rainbow trout (Salmo gairdneri), incubated in Astroturf (circle) and flat screened hatching trays (tilted triangle).

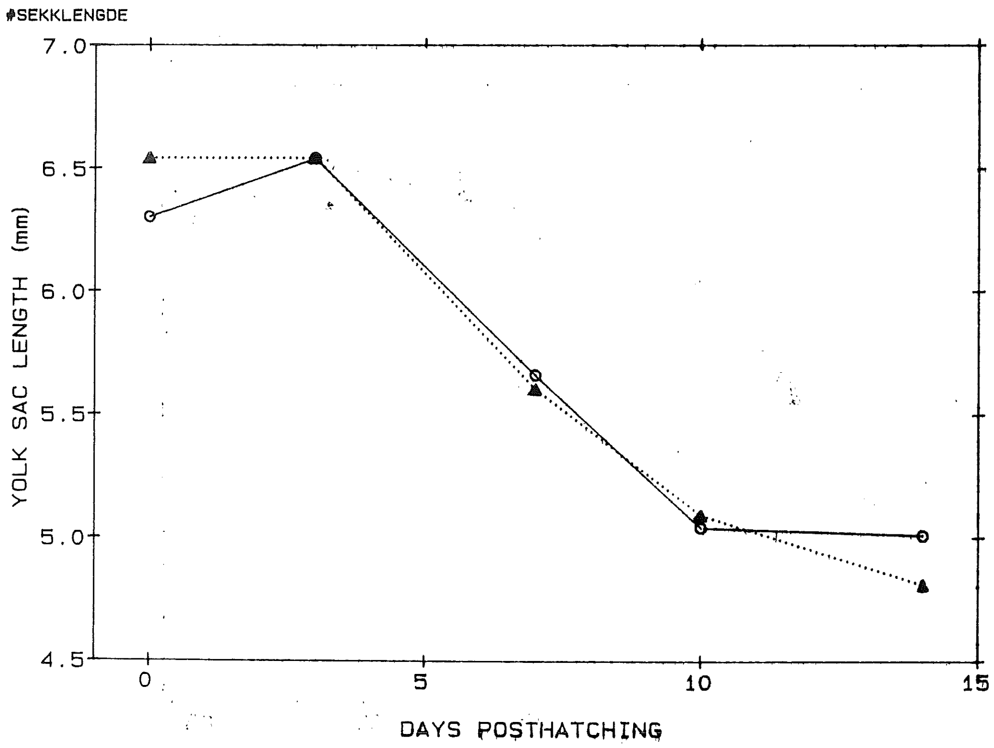

FIG. 9 Development of yolk sac length of rainbow trout (Salmo gairdneri), incubated in Astroturf (circle) and flat screened hatching trays (tilted triangle).

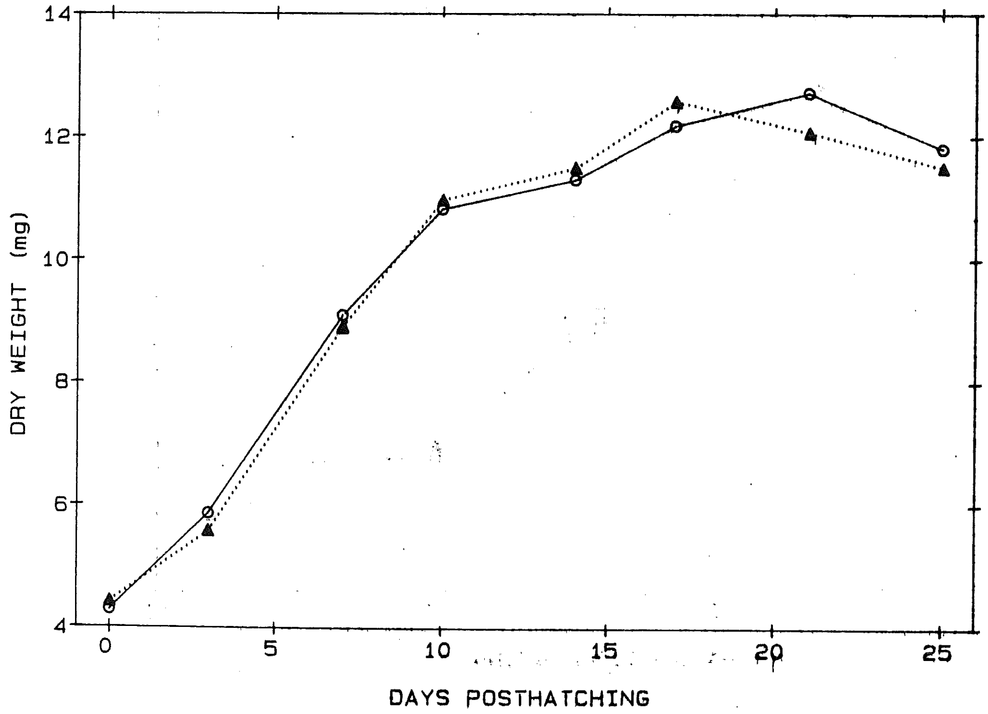

FIG. 10 Dry weight development of body of rainbow trout (<u>Salmo gairdneri</u>), incubated in Astroturf (circle) and flat screened hatching trays (tilted triangle).

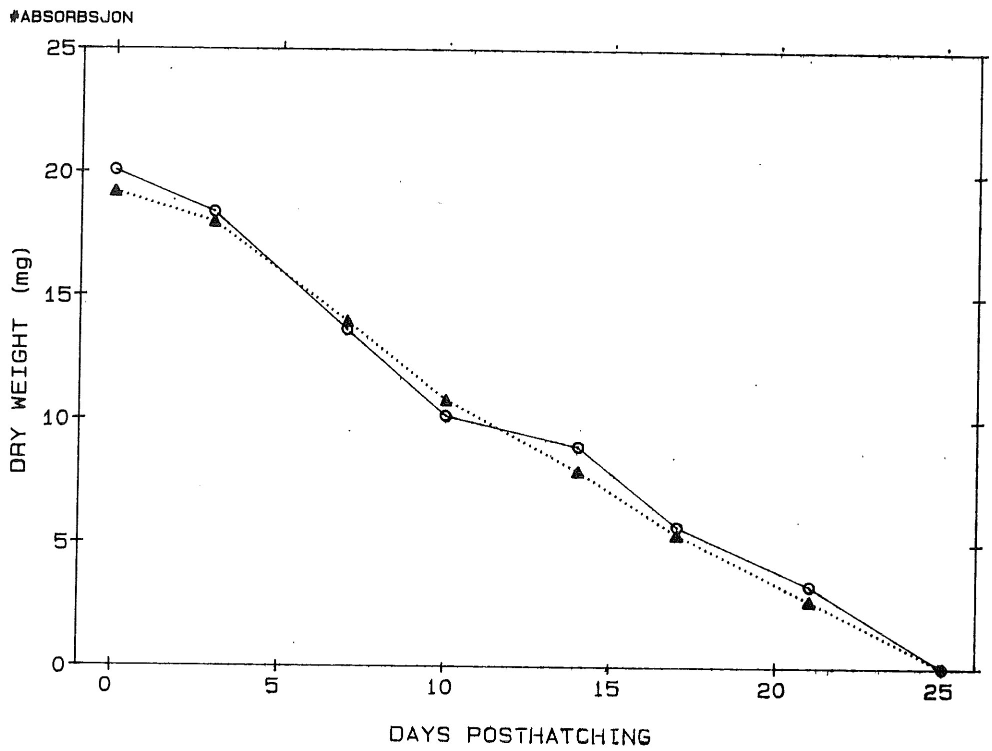

FIG. 11 Dry weight development of yolk sac of rainbow trout (Salmo gairdneri), incubated in Astroturf (circle) and flat screened hatching trays (tilted triangle).