International Council for the
Exploration of the Sea

C.M.1980/M:14
Anadromous and Catadromous
Fish Committee

Peculiarities in adaptation of hatchery and wild Atlantic salmon smolts to brackish water (13‰)

by

E.L.Bakshtansky, N.V.Safronov, V.I.Kozhdestvenskaya,
V.A.Lepskaya
All-Union Research Institute of Marine Fisheries
and Oceanography (VNIRO)

M.Ya.Yakovenko, A.A. Loyenko (PINRO)

and

A.G. Chernitsky (Glavrybvod)

ABSTRACT

Adaptation of hatchery and wild smolts to the brackish water with 13‰ salinity was studied during 12 days. The following indices were considered: natrium concentration in the plasma of blood, activity of succine dehydrogenase (SDH), time of narcotization, frequency of respiratory movements, reaction of muscles to electrostimulation, motorial activity.

Judging from the state of musculature and motorial activity sea water acclimation of hatchery smolts is going more slowly than that of the wild ones, the most significant changes are observed during the first three days. After acclimation wild smolts feel much better in sea water, than in fresh one; while the condition of hatchery smolts was getting better rather slowly. Differences between the two groups in natrium concentration in blood plasma and SDH activity which were noticed in fresh water dissappeared in one and a half day.

During sea water acclimation of wild smolts their SDH activity decreased greatly, while that of the hatchery smolts decreased only a little bit. In nature the mortality of hatchery young fish which are less prepared for living in the sea water will be much higher because of the predators. This experiment showed that hatchery smolts differ from the wild ones not only by a number of vital properties, noted before (Bakshtansky et al, I979) but also by the peculiarities of their acclimation to the sea water with the salinity of I3‰. Smoltification level of hatchery smolts is much lower, than that of the wild ones. It can be expected that in the water of higher salinity the differences between hatchery and wild smolts will increase.

Résumé

Il s'agit des recherches sur l'adaptation des smolts élevés et sauvages à l'eau de mer saumâtre (13% de sel) pendant 13 jours selon les indices suivants: concentration de Na dans le plasma du sang, activité du ferment du succinate déshydrogénase (SDH), temps de la narcotisation, fréquence respiratoire, réaction musculaire à la stimulation électrique, activité motrice.

L'état des muscles et l'activité respiratoire des poissons indiquent que les smolts élevés s'adaptent à l'eau de mer moins vite que les smolts sauvages, les plus sensibles changements ayant lieu au cours de trois premiers jours. La période d'adaptation terminée, les smolts sauvages se sentent dans l'eau de mer beaucoup mieux que dans l'eau douce, tandis que l'"état de santé" des poissons élevés ne s'améliore pas d'une manière aussi évidente. La différence de concentration de Na dans le plasma du sang et d'activité du ferment SDH qui existait entre ces deux groupes de poissons dans l'eau douce, a disparu 1,5 jour après. Lors de l'adaptation à l'eau de mer l'activité du ferment SDH a considérablement baissé chez les smolts sauvages, tandis que chez les poissons élevés cet indice n'a presque pas baissé. Dans les conditions naturelles le taux de la mortalité sera plus important chez les jeunes élevés moins adaptés à l'eau de mer que chez les smolts sauvages, ce qui est dû aux rapaces. L'expérience a démontré que les poissons élevés et sauvages ne diffèrent pas uniquement d'apres leurs caractéristiques importantes vitales étudiées auparavant (Bakshtanski et autres, 1979), mais d'après les particularités d'adaptation à l'eau de mer (13‰de sel). Le niveau de smoltification des poissons élevés est considérablement inférieur à celui des poissons sauvages. Il paraît évident que les différences entre les smolts élevés et sauvages s'accentuent dans l'eau dont la teneur en sel est plus importante.

The purposes and general methods of the work.

It is known that the survival rate of hatchery smolts is lower than that of the wild ones, because they differ from the latter by a number of vital properties.
The results of our experiments during which we studied the properties of hatchery and wild smolts in fresh water (Bakshtansky et al., 1979) confirm this fact. While transferring to the sea water salmon smolts suffer stress and it can be expected that less prepared hatchery smolts will suffer it even more intensively. That is why it would be very interesting to know how the properties of the hatchery smolts change after they transfer to the sea: do they come close to the properties of the wild smolts? And, if yes, how soon this takes place. Acclimation of the hatchery and wild smolts to the brackish sea water was studied with this purpose. Young smolts were caught by traps in the mouth of Luvenga River which falls into Kandalaksha Bay of the White Sea. From the mouth of the river cages with the young fish were dragged to the bay at the distance of 1,5 km from the mouth and fixed on a special raft. Water salinity in this area was 13‰ , water temperature changed from 14°C to 18°C. Natrium concentration in the blood plasma, activity of succine dehydrogenase(SDH), time of narcotisation, frequency of respiratory movements, reaction of the muscles to electrostimulation and motorial activity were studied as indices of acclimation. These indices were first studied for the young fish in fresh water, then after transition to the sea water in 3-6, 10-15. 36, 72, 216, 288 hours. After determination of motorial activity, time of narcotization was studied for the same smolt, then frequency of respiratory movements and muscles reaction to alectostimulation.

Natrium concentration in blood plasma.

photometer was used to determine natrium concentration in blood plasma. In 3-6 hours after the young fish was released to the sea water natrium concentration increased greatly in the blood of hatchery and wild smolts, in hatchery smolts the increase was greater (Table I Fig. I,A).

After I2 hours amount of natrium decreased up to the same level for both groups of the young fish. In 36 hours natrium concentration became higher again. During the I2th day natrium concemtration in the blood of hatchery and wild smolts returned to the initial level (about I50 *meq*). Changes in natrium concentration in blood plasma of the smolts went on as it was expected with the exception that after I2 hours of acclimation natrium concentration decreased. It is quite possible that up to this time part of natrium enters from the blood to muscles cells, which up to this time had coped with their work. Decrease of natrium concentration in blood in I2 hours after transition to the sea water (24%) in coho salmon smolts was observed by Miles and Smith (I968).

They explained this phenomena by the fact that during the first 6 hours water was leaving the organism, as a result, natrium concentration increased.

Changes in natrium concentration in the blood of hatchery and wild smolts ( ) in the process of acclimation.

Table I

Time	0	3 – 6 hours	I2 hours	36 hours	3 days	I2 days
Hatchery smolts	I46±6 (I7)	I73±2.9 (3)	I59±2.9 (6)	I72±I.7 (3)	I62±2.0 (7)	I53±3.2 (7)
Wild smolts	I46±3.3 (33)	I63±7.7 (5)	I60±4.3 (6)	I69±2.7 (3)	I66± 6 (3)	I54±4.6 (5)

After this excretion of salts by chloride cells begins and the level of natrium becomes lower. Fishes begin to swallow sea water to compensate water loss, this again in its turn makes natrium concentration higher. Our explanation seems more convincing because of the following reasons:

I. State of chloride cells of the smolts did not change during first I2 hours of their staying in the sea water.

2. According to the data of Miles and Smith the rise of potassium

level in blood was noticed just after I2 hours, which could be explained by the fact that natrium enters muscular cells.

The activity of succine dehydrogenase (SDH).

It is well known, that chloride cells are the main element of osmoregulatory system of anadromous fish. Increase of chloride cells fermenting activity in the process of smoltification reflects the young fish readiness to osmoregulation in hypertonic sea water. SDH ferment activity was used to judge about functional state of these cells. SDH ferment activity was determined by quantitative cytochemical method (Chernitsky, I979).
SDH activity in wild smolts in fresh water is much higher than in hatchery ones, this is the evidence of different levels of smoltification. In 36 hours after transition to the sea water indices of fermenting activity in both groups of the young fish decreased and became equal (Table 2, Fig I,B). The more a smolt differs from a parr by external signs the higher is SDH activity in fresh water. In real parr the level of ferment activity under such conditions becomes higher (Table 3). Sea water of I3‰ salinity is isotonic to blood, that is why it could be supposed that in isotonic environment waste of energy for osmoregulation decreases in comparison with hypertonic environment. The decrease of the chloride cells activity is the result of this.

SDH activity in chloride cells (conventional units).

Table 2.

Time	0	3 - 5 hours	I2 hours	36hours	2I6 hours	288 hours
Hatchery smolts	5I.5±I.38	47.8±2.I0	35.9±I.73	50.6±I.8I	45.3±I.3	40.0±I.9
Wild smolts	73.0±2.62	70.5±2.80	7I.3±2.60	5I.5±2.08	49.7±I.9	46.3±I.8

Proximity of SDH values for the young fish of different groups, adapted to the brackish water, speaks to the fact that this state of the chloride cells rather depends on the environment salinity, and not on the endogenic factors, as it was marked for smolts. (Chernitsky, I979).

Decrease of functional activity of chloride cells was observed by us also in I979: when wild young fish was hold in cages, the area of chloride cells decreased from I8I±5.5 to I26±5.0 μm^2 (Bakshtansky et al., I979). Similar phenomena - decrease of functional activity of chloride cells during fish adaptation to brackish water - was noticed also in Baltic salmon (Chernitsky, I979). Feeding individuals after spending I.5 years in the Baltic Sea (water salinity - 6‰) had the chloride cells with less area and SDH activity, than the smolts which had migrated to Baltic.

SDH activity in young fish of different groups in fresh water and in 9-I2 days after their staying in brackish water (conventional units).

Table 3.

Group of young fish	Fresh water	Brackish water
Parrs	35.0 ± I.30	44.3 ± I.94
Hatchery parrs just beginning to become silver	47.3 ± I.94	42.I ± I.64
Hatchery silver smolts	55.6 ± I.93	45.I ± I.7I
Wild smolts	73.0 ± 2.62	48.0 ± I.30
Wild smolts with lake fattening	93.2 ± 3.27	35.2 ± I.89

Reaction of musculature to electric stimulation

Electric fatigue of young fish could be one of the tests of its physical state. Unlike methods published before (Yarzhombek, Rozhdestvenskaya, I978) integrated records of muscles response was used. Musculature was affected by square impulses (with the amplitude

of 20 V and frequency 5 Hz. As indices of musculature state amplitude of muscles response to electrostimulation and period of time of full electrofatigue was observed.
In comparison with indices in young fish taken from the river, amplitude of muscles response in young fish of both groups increase sharply after 3-6 hours of adaptation to the sea water being larger in hatchery smolts.
In IO-I5 hours the amplitude decreases, in hatchery smolts being a little more than in wild ones.
After 36 hours the amplitude increases; in wild smolts it becomes more than it used to be in fresh water, and in hatchery smolts remains lower than normally.
After 72 hours the amplitude of muscles mechanogram in hatchery smolts remains lower than in wild ones (Table 4, Fig.I,E).

The time of full electrofatigue after 3-6 hours of adaptation to the sea water increases for both hatchery and wild smolts. In IO hours this index in hatchery smolts decreases nearly to the value in fresh water, and in wild ones continue to increase.

The time of elecrofatigue in the wild young fish during the experiment is much higher than that in the hatchery ones (Table 4, Fig.I,F).

Frequency of respiratory movements and time of narcotization.

In the process of preparation of young fish to the experiments on electrostimulation, the time of narcotization till the smolt lost ballance and fell down on the ground (narcotic - quinaldin solution - O.I gr./l) and amount of respiratory movements were fixed.
In 3-6 hours after transition to the sea water inwild and hatchery smolts the rhythm of respiration becomes more intensive, and the time of narcotization increases.
After I2 hours respiratory rhythm becomes slower, the time of narcotization decreases. By 36th hour respiratory rhythm of hatcher and wild smolts becomes stable . After 36 hours the time of narcotization increases almost to the initial level, and after 72 hours it is already longer than in fresh water.
For hatchery smolts the time of narcotization reaches fresh water indices only in 72 hours (Table 4,Fig.IC,D).

Changes of narcotization time , frequency of respiratory movements, amplitude of the electromechanograms and the time of musculature fatigue in hatchery and wild smolts in the process of adaptation to brackish water.x)

Table 4.

Indices of adaptation	Indices in the river	Indices in the brackish water after indicated time					
		3 - 6	I0-I5	36	72	2I6	288
Narcotization time (sec)	28.0 ± I.2 / 26.0 ± 2.9	40.8±3.6 / 41.8±I.3	23.9 ± I.9 / 23.0 ± I.6	26.9 ± 2.2 / 23.5 ± 2.4	34.8 ± I.4 / 26.0 ± I.9	30.5 ± I.4 / 3I.4 ± I.2	38.0 ± I.9 / 39.0 ± 2.5
Number of respiratory movements in a minute	I34.0 ± 7.5 / I55.0 ±I0.I	I83.3±7.5 / I80.0±I4.0	I20.0±8.3 / I27.I±I.9	I57.5±II.I / I52.5± 8.0	I46.6 ± 6.4 / I38.8 ±I0.0	I30.5 ± 6.3 / I45.0 ± 7.5	I26.0 ± 7.7 / I38.0 ± 8,I
Amplitude of electromechanogram (V)	2I.5 ± 4.5 / 22.I ± 4.2	6I.9 ± 6.4 / 82.5 ± 4.8	I0.I ± 3.6 / 2.6 ± I.2	38.3 ± 3.4 / II.7 ± I.6	75.I ± 3.I / 37.3 ± I.8	45.9 ± 3.9 / 32.8 ± 3.8	64.4 ± 3.I / 48.0 ± 4.I
Time of muscles fatigue (seconds)	42.7 ± 5.3 / 36.2 ± 7.I	79.0 ± 6.7 / 8I.3 ± 6.4	97.3 ± 6.2 / 46.7 ± 4.3	I08.I±4.I / 47.8±4.7	I03.2±4.5 / 57.0±3.2	II7.0 ± 3.5 / 53.2 ± 3.7	II7.0 ± 5.0 / 86.6 ± 2.3

x) in the numerator - indices of the wild smolts
in the denominator - indices of the hatchery smolts

Motorial activity

Motorial activity of young salmon was studied with the help of transparent hydrodynamic tube I3 cm in diameter, 50 cm long. One by one fishes were put in the tube, the speed of the flow was increased from IO to 80 cm/sec, 5 cm/sec every 30 sec. Observations of fish reaction in response to the water flow made it possible to reveal four types of motorial activity:

I. The fish is motionless, presses pectoral fins to the tube walls.

2. The fish makes lateral movements pressing itself to the tube.

3. The fish swims without touching the walls, does not make jerks.

4. The fish swims with jerks touching the walls.

Fishes showing motorial activity of 3 and 4 types were called " active ". Portion of "active" fish can serve as index of decrease of rate of young fish connection with substratum and it increases in the prosess of smoltification.

Swimming in the tube of different fishes differs in time and rate of movement. That is why activity of young fish can be characterized quantitatively by "conditional way" covered by the yung fish during certain number of experiments.

" Conditional way " is counted by dividing of the route covered in the tube by "active fish" by the total number of fishes in the set of experiments.

Besides, enumerated indices of motorial activity, with the help of hydrotube it is possible to determine thresholds of rate of movement ranges of four types of behaviour manifestation, mean and critical rate of fish movement.

As a result of these expariments it was found out that in the river among wild smolts share of "active" individuals cosists I9%, and among hatchery ones - 58% (Fig.I).
If we take "conditional" way of wild young fish in fresh water for I00%, then in hatchery young this index in the river was only 45%.

In 3 - 6 hours after transition of the young fish to the sea water portion of "active" smolts among wild ones increased up to 83%, and in the group of hatchery smolts - up to 7I%.
" Conditional way" in wild fish increased up to I85% and in hatchery ones - up to 50%.

After I0-I5 hours motorial activity diminished, especially in wild fish, among which only 29% were swimming during the experiment and among hatchery ones - 50%.

However, in "conditional way" the wild young fish surpassed hatchery ones (55% against 23%).
After 36 hours portion of "active" among wild fish began to increase again (up to 50%), and in hatchery fish "active" fish became more rare (33%). " Conditional way " of the hatchery young fish did not change, at the same time in wild young fish it increased up to I55%.
By 72 hours all wild fishes in the experiment are " active ", their " active way " was 240%. Among hatchery fishes: active fishes - 60%, and " conditional way" - 62 %.

Change of motorial activity of wild and hatchery Atlantic salmon smolts during adaptation to the brackish water x)

Table 5

Indices of fish	In the river	In the brackish water after determined time(hours)					
		3 - 6	I0-I5	36	72	2I6	288
Amount (individuals)	24 / 50	6 / 7	7 / 4	6 / 6	7 / I0	6 / 6	I0 / I0
Mean length	I35±5 / I4I±2	I39±5 / I44±3	I36±5 / I39±5	I42±4 / I37±5	I28±3 / I4I±4	I35±6 / I36±5	I34±6 / I32±3
Portion of "active" individuals, %	79 / 58	83 / 7I	29 / 50	50 / 33	I00 / 60	50 / 33	90 / 50
Mean "conditional way", %	I00 (0÷395) / 45 (0÷298)	I85 (0 ÷5I2) / 50 (0÷I02)	55 (0÷337) / 23 (0÷49)	I55 (0÷539) / 25 (0÷I95)	240 (80÷537) / 62 (0÷249)	I20 (0÷527) / I9 (0÷73)	325 (0÷544) / I25 (0÷544)

x) in the numerator - indices of the wild smolts
in the denominator - indices of the hatchery smolts

On the ninth day motorial activity of both groups decreased, probably as a result of hunger, as after the beginning of feeding on the twelfth day "conditional way" of the wild young fish reached 325% and that of the hatchery ones - 125%.

The data received during the experiment testify to the fact that during the first day of the young atlantic salmon adaptation to the sea water sharp decrease of motorial activity alongside with the increase of critical rate of movement is observed. At this time the wild smolts are more active than hatchery ones owing to the higher rate of movement. Reverse dependence between critical rate of movement and portion of "active" fishes was observed, it is probably connected with the fact that in extreme conditions only strong swimmer remain " active ".

It was not possible to obtain exact values of critical rates of movement of fishes in the sea water, because many individuals, especially wild ones exhibited maximum rate of movement, which could be expected - 0,8 m/sec.

Relatioship seems to appear between the critical rate of movement and linear size of fish. This relationship becomes reverse when the young change over for sea water.

Thus, if in wild smolts critical rate of movement in the river decreases with the increase of the body length, in the sea it increases.

In the hatchery smolts it is quite different: the larger the fish, the better it swims in the river, and worse - in the sea.

In this connection it could be supposed that in spite of external indications inherent to the smolts, the hatchery young fish are not prepared to live in the sea.

Conclusion.

Brackish water influenced greatly all the investigation indices of hatchery and wild smolts state. The most noticeable changes were observed during the first three days.

Judging from the musculature state and motorial activity, hatchery smolts adapt to brackish water slower than wild ones. Wild smolts feel in the brackish water much better, than in fresh one, while the condition of the hatchery ones is getting better slower.

Only differences in natrium concentration and SDH activity disappeared rather quickly - after I,5 days. High SDH activity in wild smolts in fresh water testify to the high level of smoltification and preadaptation to the transition to the sea water of high salinity. Low level of SDH activity of the hatchery smolts testify to the incompleteness of smoltification.

In brackish water the differences between two groups turned out to be rather clear. It can be expected that in water with higher salinity hatchery smolts will differ from wild ones in musculature state and motorial activity even greater. The mortality as a result of predation will increase.

Hatchery smolts differ from wild ones in the river so noticeably (Bakshtansky et al., I979) and during adaptation to the brackish water that they could be called "false" smolts.

In any case there is still a lot to be investigated before their properties will come close to the properties of wild ones.x)

This problem is especially urgent for the Atlantic where salinity is high and there are many pelagic predators, it is less pressing for the Baltic. It is quite possible that the survival rate of hatchery smolts could be increased by their adaptation to the sea water before they are released under controlled conditions.

x) For example it is not clear why hatchery smolts migrate to the sea more quickly, though judging from a number of indices process of hatchery smolts smoltification is not complete.

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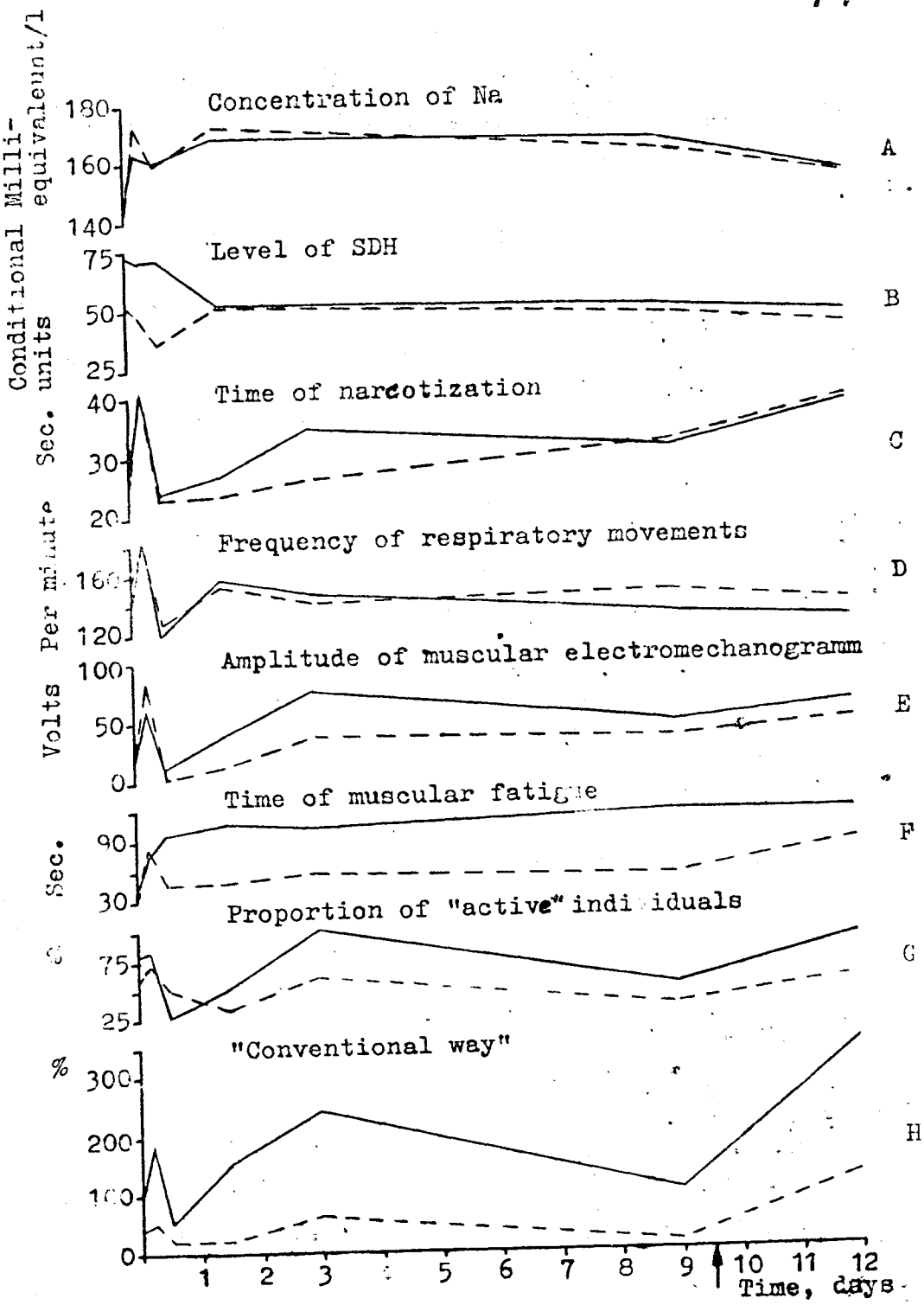

Figure 1. Changes in adaptation indices in wild (———) and in hatchery reared (- - -) smolts of the Atlantic salmon to brackish water (13‰). Arrow shows the start of feeding period.