This paper not to be cited without prior reference to the author

International Council for the Exploration of the Sea

C.M. 1977/E:19
Fisheries Improvement Committee

Spherical net cages - A pilot mariculture experiment in thermal effluents

by
H. Grave
Institut für Meereskunde
an der Universität Kiel

Abstract

In the years 1974 - 1977 experiments with floating net cages were carried out in Kiel Fjord. Fouling (upgrowth) and wave action proved to be the major problems throughout the experiments. A new spherical net cage has been developed and successfully tested in the thermal effluents of a conventional power plant. Preliminary data on growth and possible stocking densities are gained, which encourage to further experiments and practical application in the near future.

Introduction

The aim of this paper is to describe in brief the development of a pilot scale net cage farm for salmonids in Kiel Fjord. West Germany has only a few locations which enable us to carry out experimental aquaculture in marine environments by means of floating units, most of the convenient sites are found along the Baltic coast.

The project was supported by the Federal Minister of Research and Technology of the Federal Republic of Germany

On three different places net cage cultures were tested: in the Flensburger Förde, in the Eckernförde under a quay construction (KOOPS, 1972) and in Kiel Fjord in the thermal effluents of a conventional power station. The technical impediments which arose during the first experiments in Kiel are described by GRAVE, 1974.
Heavy upgrowth on the net bags forced us to change them every second or third week from the beginning of March to the end of October at the power plant. From the beginning of April onwards the same situation occurred in those cages anchored in naturally tempered water. Furthermore resistance against wave action and high labour costs were problems to be solved. This situation stimulated us to investigate unconventional solutions to overcome these difficulties.

Material and Methods

The new type of cage used in Kiel Fjord is described by GRAVE, 1975. A turnable globe shaped construction made of aluminum tubes filled with polyurethan foam is mounted in a flexible raft and covered with perlon nets (fig.1). When turned around the axis always 36 % of the netting material is exposed to the air. Young upgrowth dries off and is carried away by the wind. Dried filamentous algae are removed by beating the nets with a rod. During the season when heavy fouling occurs (fig.2) (in Kiel Fjord from March to the end of October) the globes are rotated once every two weeks.
By using these devices there was no need to change nets for the last two years.
The spherical constructions proved to be very resistant against wave action and choppy sea in the water outlet of the power plant where experiments took place.
The closed globe protects young fish against birds.
Harvesting is simple: a net is spanned out in the interior of the sphere in a plane parallel to the axis. With a rotation the fish are concentrated between the harvesting net and the water surface. They can be taken out through an opening in the cover net.

The size of the experimental globes is 4 m in diameter. The axis is slightly submerged in order to make better use of the water volume (18 m^3) which can be used for fish production. Three cages of a more commercial size (7 m in diameter and a usable water vulume of approximately 120 m^3) are under construction and will be used for culturing experiments from October 1977 on. The globes of these units can be submerged totally in order to protect them against drift ice.

During the winter months when upgrowth is less a bigger part of the globe can be submerged and the additionally gained volume can be used for growing fish. This may improve rentability if thermal effluents can be used.

Our experimental cages are anchored as shown in fig.3. The rafts can be moved along the moorings in order to keep the fish in the optimal attainable temperature range, close to the water outlet in the winter and far away from it during the summer when temperatures of the thermal effluents may exceed 28° C.

The power plant where our experiments take place is a conventional one producing up to 350 MW. The cooling water is pumped from 6 m depth from the Kiel Fjord and heated up between 7 and 10° C. The salinity varies between 12 and 20 °/oo.

This power plant has the disadvantage of switching off during several nights every month for three to five hours. These irregular interruptions of the warm water supply cause temperature changes up to 7° C within thirty minutes in the net cages.

Fig. 4 shows the water temperature in Kiel Fjord during winter 1976/77 (A) and the thermal effluents (B). The vertical lines show the nights when the power plant produced no heated effluents. For two days in February and three days in March the plant stopped completely. These curves are typical and can stand for others in the preceeding years.

Results

Growth of rainbow trout in thermal effluent compared with growth in the natural temperature range.

On 26. November 1974 two conventional net cages of 32 m^3 (GRAVE, 1974) were stocked extensively with 1.000 rainbow trout, Salmo gairdneri, of 65 g average weight. One of the cages was anchored in front of the Institut für Meereskunde in naturally tempered water in the Kiel Fjord and the other one was moored in the warm water effluent at the power station. The fish were fed with a commercial dry food (EWOS F49) containing:

raw protein	50 %
fat	6 %
ashes	10 %
water	8 %
cellulose	2 %
N-free extracts	24 %

(data obtained by EWOS).

The daily feeding rate was 2 % of body weight which ment a slight excess ration for the cage in normal water temperature during the winter months.
The pellets were distributed by means of automatic dry feeders in 4 rations per day. A subsample of approximately one hundred fish were anaesthesized, measured, and weighed monthly.
The growth is shown in fig.5.
The fish kept at the power station reached a marketable size of more than 250 g in March, while those in natural tempered water were growing slower (155 g average weight) in the same period. The condition factors $(k = \frac{w(g)}{l^3(cm)} \times 100)$ in both cages were nearly the same (1.20 at the I.f.M. and 1.19 at the power plant).
Losses in both cases were below 2 % until the experiment had to be finfished.

Stocking Density

In December 1976 four turnable cages were stocked with rainbow trout of 40 g and anchored in the thermal effluents of the powerplant. The stocking density in the cages (18 m^3 of water volume) was

cage I	:	4.000 trout
" II	:	2.000 "
" III	:	1.000 "
" IV	:	500 "

The water temperatures during the experiment are given in fig.4. 25, May the rafts were moved into the area outside of the warm water effluent (fig. 3 Pos. B).

The fish were fed with dry food at a relatively low rate of 1.5 % of body weight/day during the winter months. 15, March the feeding rate was increased to 2 % of body weight/day.

The growth is shown in fig.6, and the increasing amount of fish biomass in fig.7.

There was no significant difference in growth obtained in the different cages until middle of May, when the density in cage I exceeded 31.8 kg/m^3 of water volume.

Date	I	II	III	IV
2. 12. 1976	8.8	4.4	2.2	1.1
11. 1. 1977	14.3	7.2	3.0	1.5
8. 2. 1977	16.2	9.0	3.6	1.9
21. 3. 1977	17.5	11.6	4.9	2.6
25. 4. 1977	28.6	17.5	6.8	3.4
15. 5. 1977	31.8	20.7	9.1	4.7

Tab.1 Stocking densities in cage I - IV in kg/m^3 of water volume

In cage I a few fish (less than 2 %) showed fin lesions, but no losses were caused by fin rot. Nevertheless future experiments with high stocking densities should have more than one feeding place in order to avoid fin lesions during food uptake.

Growth in all four cages was remarkably slower than in the preceeding experiments. This is certainly partly due to the feeding rate. Also the fact that trout used in this experiment

came from a different stock than our usual one may attribute to the slow growth. Furthermore a food was used, which had not been tested in sea water before.
The condition factors did not differ from those obtained in previous experiments.

Date	I	II	III	IV
11. 1.	1.12	1.13	1.10	1.17
8. 2.	1.11	1.17	1.16	1.21
21. 3.	1.15	1.17	1.23	1.22
25. 4.	1.29	1.28	1.26	1.31
15. 5.	1.26	1.21	1.33	1.22

Tab.2 Condition factors during the density experiment

Beginning of June an unknown disease or pollutant caused 40 % losses in all four cages. The fish died without any recognizable symptoms. After one week losses stopped.

Economocal aspects

The landings of salmonids by German catch fisheries decreased from 241 tons in 1969 to 64 tons in 1976. During the same period the imports of trout increased from 3.000 to 11.000 tons (Jahresberichte über die deutsche Fischwirtschaft 1970, 1976). These figures underline the economical potential for aquacultural enterprises in Western Germany, if a reliable and economically reasonable system for salmonid production can be found. Most of the fish culture techniques used in coastal areas as described by MILNE, 1972 and IVERSEN, 1976, are usually very labour intensive. In countries with high labour costs a way of production has to be found, which is characterized by minimum labour requirements.
Taking the costs per 1 m^3 of water volume as basis for comparison one finds that the spherical net cages require almost 4 times more investment than the conventional ones (90.- DM compared with 25.- DM in 1977) but labour costs are reduced to less than

one third according to our experiences. Further positive characteristics of the spherical cages are their higher mechanical resistance, better water exchange because of less glogging and the possibility to submerge the cages in case of drift ice. Preliminary economical assesments indicate, that one and a half man power/year will be able to produce 60 tons of fish at a marketable price.

References

GRAVE, H., 1974: Muschelkultur und Netzkäfige in der Kieler Förde, Meerestechnik 5 97 - 100

\- 1975: A new type of net cage for fish culture used in Kiel Fjord, Ber. dt. wis. Kommn. Meeresforsch. 24, 209 - 211

IVERSEN, E.S., 1976: Farming the Edge of the Sea: London : Fishing News, 436 pp

KOOPS, H. 1972: Experiments on the Cage Farming of Trouts in the Western Baltic. ICES C.M. 1972 M.7: 1 - 16

MILNE, P.H. 1972: Fish and Shellfish Farming in Coastal Waters London: Fishing News, 208 pp

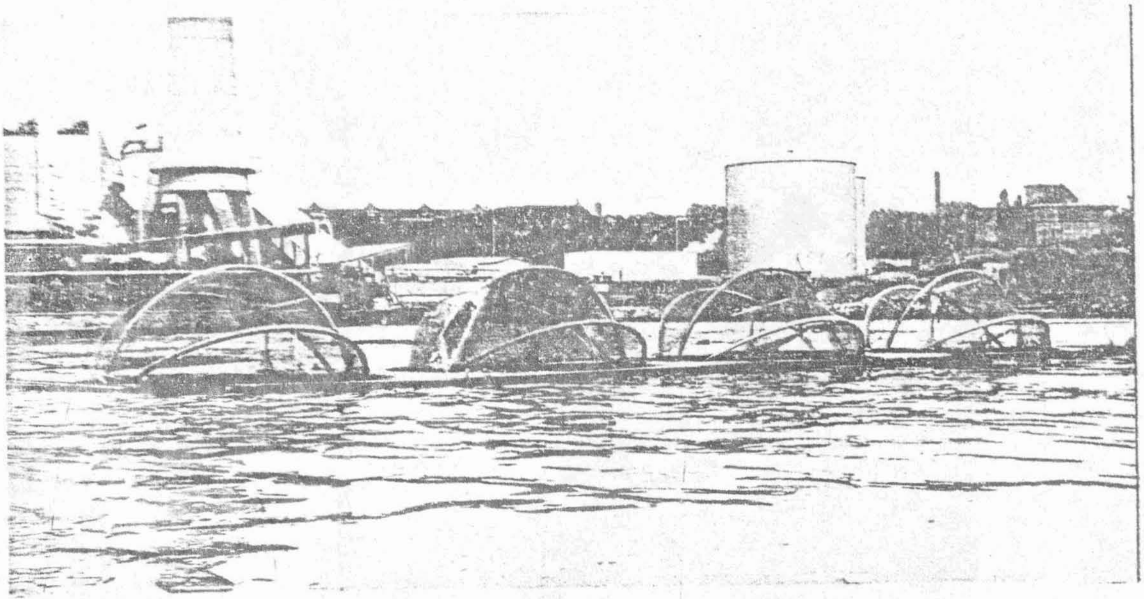


fig 1   Spherical net cages in Kiel Fjord at a conventional power plant

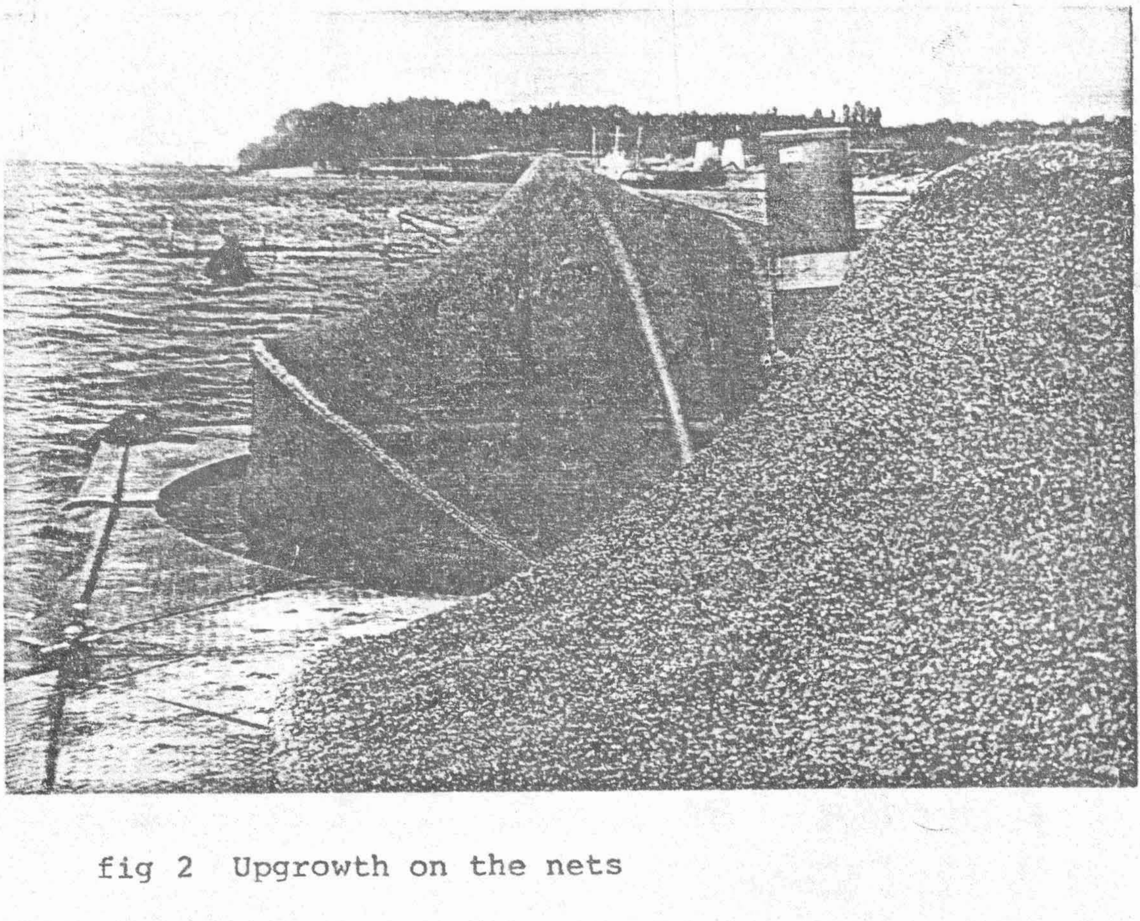


fig 2 Upgrowth on the nets

Position of the net cages at the power plant

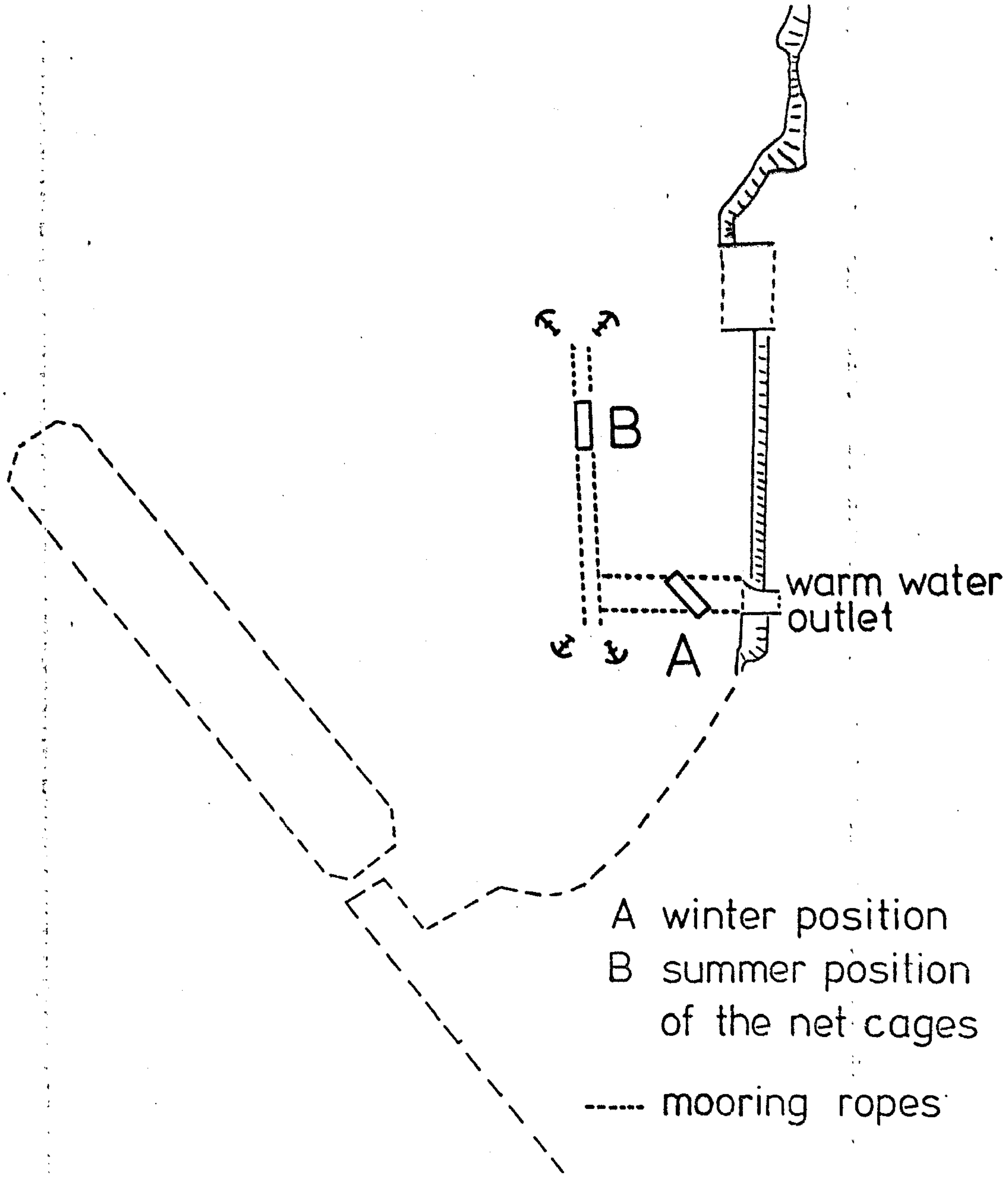


fig. 3

Temperatures during the 1976/77 experiment

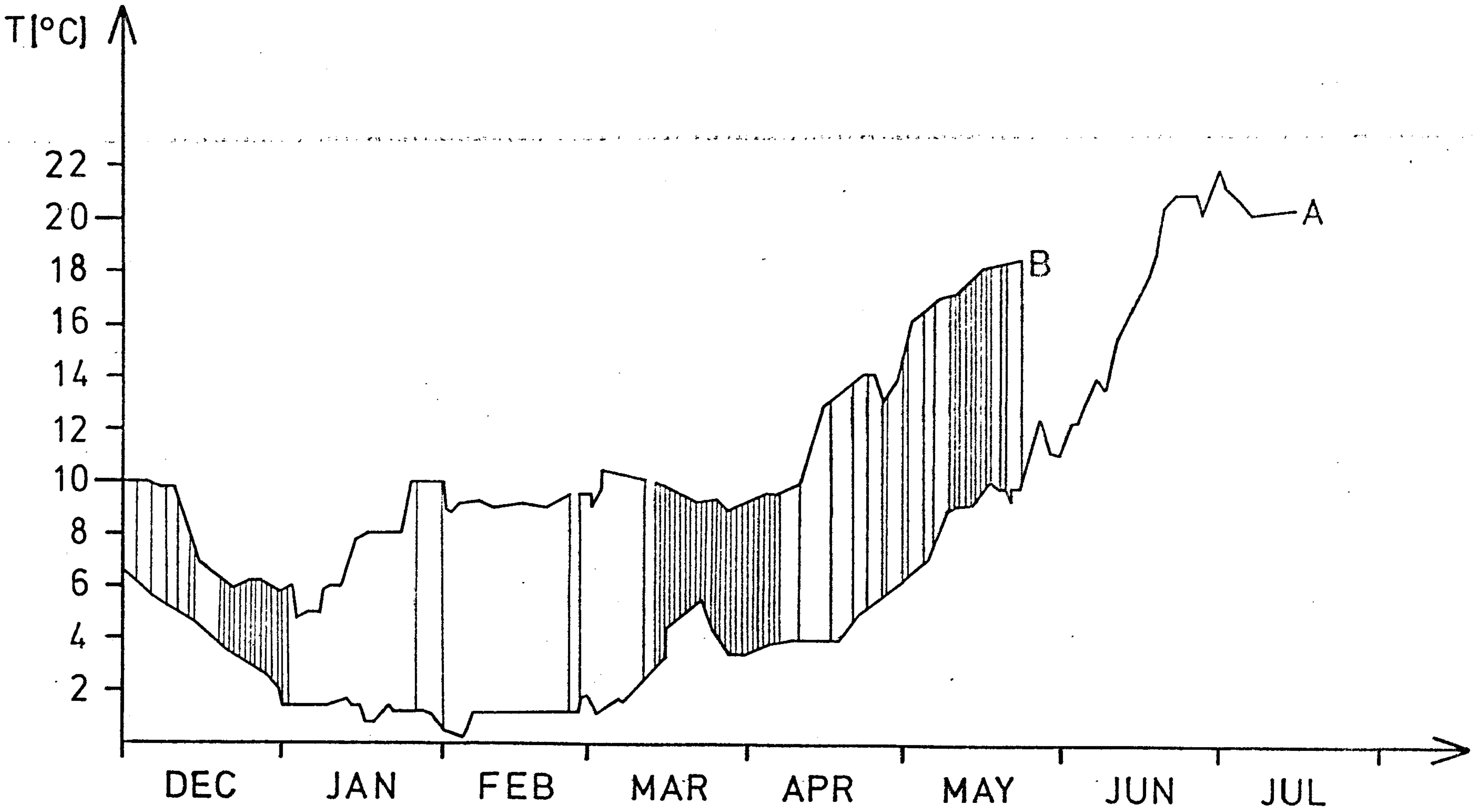


fig.4

A Temperature of the Kiel Fjord B Temperature in the net cages

Vertical lines indicate the nights when the power plant produced no thermal effluents. End of May cages were moved into unheated water.

Growth of rainbow trout in Kiel Fjord

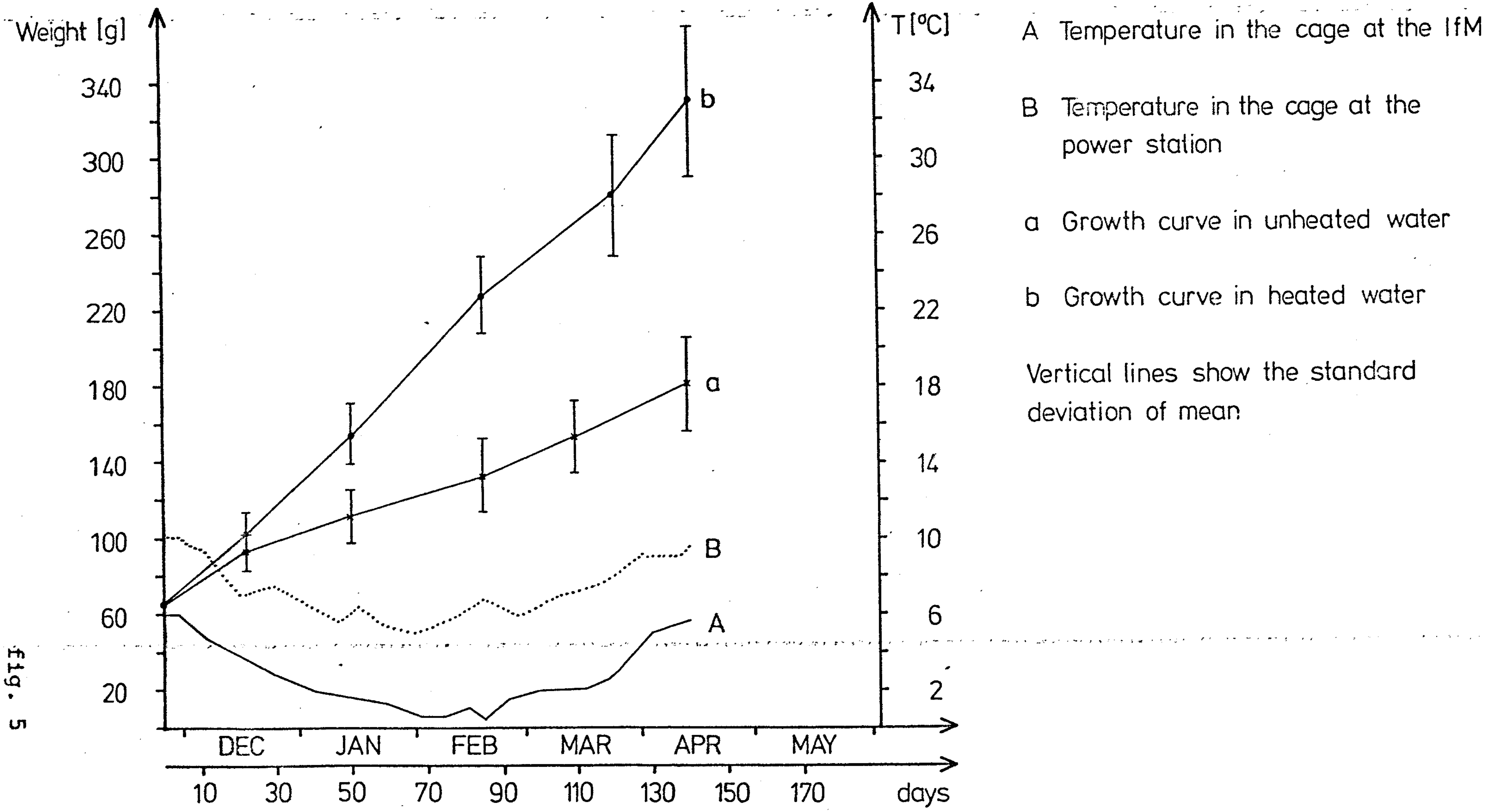
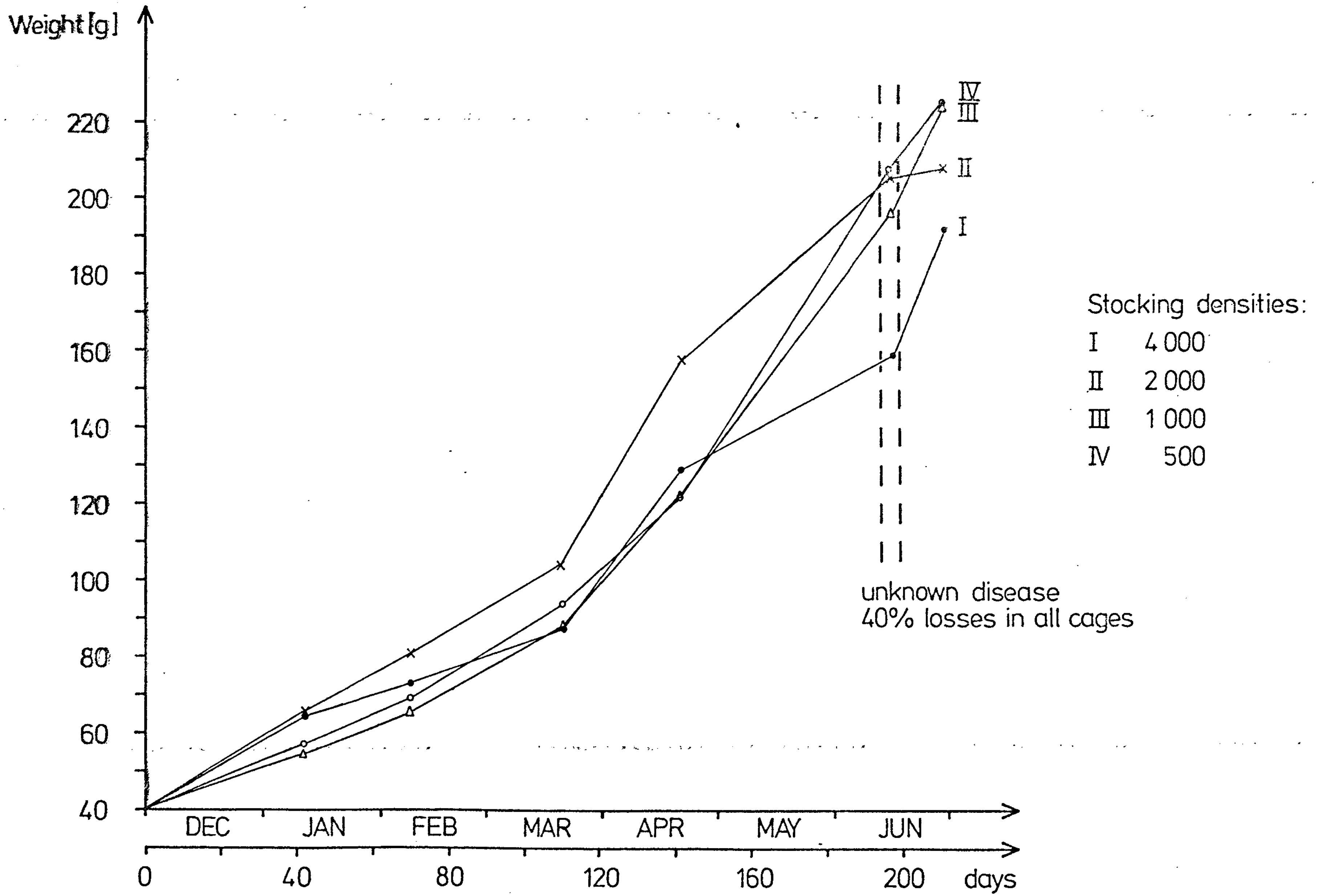


fig. 5

Weight gain of rainbow trout in the 18m^3 net cages



unknown disease
40% losses in all cages

fig.6

Density of fish [kg/m^3] in the net cages I-IV until beginning of June (outbreak of disease)

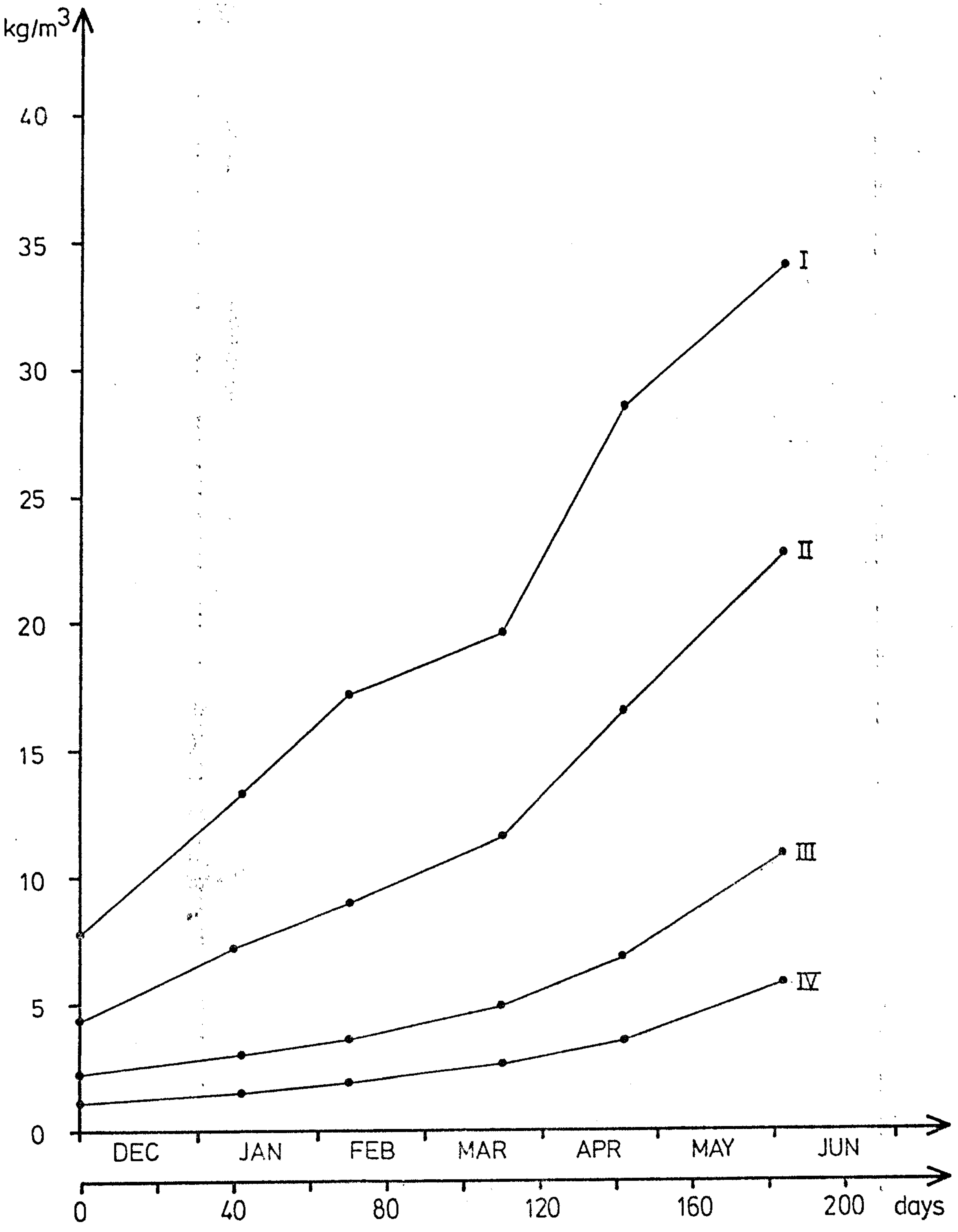


fig. 7