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ENVIRONMENTAL ASPECTS OF COHO SALMON (*ONCORHYNCHUS KISUTCH*) INTRODUCTION FOR AQUACULTURE IN FRANCE

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ABSTRACT

Coho salmon eggs have been introduced in France since 1971 to investigate the possibilities of developping marine salmon aquaculture. The production of small salmon (0.3 g to 1 kg) which started in 1974 (7 tons) reached 90 metric tons in 1980. The reasons conditionning the choice of the species, the reactions of coho salmon to the local environment, and the possible ecological consequences of the introduction in french waters are discussed.

ASPECTS ENVIRONNEMENTAUX DE L'INTRODUCTION DU SAUMON COHO (*ONCORHYNCHUS KISUTCH*) POUR L'AQUACULTURE EN FRANCE

RESUME

Des oeufs de saumons Coho ont été introduits en France depuis 1971 pour tester les possibilités de développement de l'aquaculture du saumon. La production de petits saumons (0,3 à 1 kg) qui débuta en 1974 (7 tonnes) a atteint environ 90 tonnes en 1980. Les raisons conditionnant le choix de l'espèce, les réactions du saumon Coho à l'environnement local et les conséquences écologiques de l'introduction de cette espèce dans les eaux françaises sont discutées.

In 1971, the Centre National pour l'Exploitation des Océans (CNEXO) started to investigate the possibilities of developing salmon farming along the coast of France.
The examples of the growing industries in Scandinavia (HARACHE, 1976), United Kingdom and United States (NOVOTNY, 1975) were studied and indicated two possible directions for the French approach to salmon aquaculture :

- Rearing of large size Atlantic salmon over a rather long period (2.5 to 4 years) with a fresh water life of at least 15 months.

- Rearing of small size Pacific salmon, characterized by a presumed lower market value, but with a rapid turn-over of the crop (12 to 24 months after hatching) and a short freshwater rearing period.

We will examine the reasons prevailing in the choice of coho salmon as a major goal for French aquaculture and the interactions between this species and local environment.

WHY COHO SALMON IN BRITTANY ?

The possible development of an important marine production depends upon :

- availability of large numbers of high quality smolts at a reasonable price,
- the environmental factors of the marine environment which must be compatible with the rearing of a given species and may influence the choice of the production cycles,
- good market demand with high prices.

Smolt availability

Due to the lack of Atlantic salmon smolt production in France in 1971 - only one experimental hatchery was producing limited numbers of smolts in Southern France - the first tests of salmon culture at sea, conducted by CNEXO, had to rely on smolt production from private trout farmers in Brittany.
The ability of private trout farms to produce salmon smolts was tested with two species : Atlantic salmon and coho salmon, the Pacific species which is

the most adaptable to sea water rearing, according to U.S. National Fisheries Service biologists.

The results obtained during the two first years revealed that it was fairly easy for the average trout grower to produce smolts of coho rapidly - 5 months to 15 months - without heating the water in traditionnal raceways with a high survival rate. These results were in opposition with those obtained with Atlantic salmon which led to very poor results in the same hatcheries. Although possible, it appeared that this species was much more demanding about water quality and rearing structures, and could not be easily produced in trout hatcheries.

This fact is clearly expressed by the difference in the market prices of the smolts of both species : coho smolts in United States (0.5 to 0.7 FF) each compared to Atlantic salmon smolts in Norway (8 to 10 FF each) at 1980 prices.

Environmental factors conditionning the marine rearing phase

The marine environment where sea farms can be developed in France must not be compared with that of Norway or Scotland.

Two factors create an important difference : high temperatures (8 - 10°C) and high salinities (33 - 35 $^{\circ}/_{\circ\circ}$). The growth observed in winter is generally excellent, due to the mild temperatures, but the hydrological conditions resulting from the combination of high salinities and temperatures may be considered as marginal in summer for most salmonids species.

Moreover, the average temperatures cited above may be affected by climatic accidents which are neither predictable nor unusual. Warm periods, especially if occurring in late spring induce a rapide rise of the sea water temperatures which may reach 19 to 20°C and stay above 18°C during 8 to 10 weeks as observed in 1975 and 1976 (AGUER, 1979).

During this "critical" period, the fish are highly vulnerable to any stress and disease outbreaks and may suffer serious mortalities, which makes this period risky for the French grower who needs a "normal" or "cool" summer to be successful.

If one may accept some mortalities at the post smolt stage, especially if the smolt price is reasonally low, very few growers will want to keep marketable fish during the second summer. Even a limited loss occurring in large fish induces drastic economical consequences.

Moreover, the first tests conducted with Atlantic salmon at sea seem indicate that the French environment allowing a fast growth during the early stages will favor the production of high rate of grilses like in Ireland.
These fish usually show a decline of growth during their second summer and thus would need to be sold before August to avoid mortalities which may not be compensated by the summer growth and avoid the possible decline of the prices which may be influenced by the arrival of wild or cultivated grilses on the market.

Economical factors

Consideration of all these parameters - environmental, biological and economical - influencing the production schemes, it seems that, at the present stage of knowledge and development, Salmon Aquaculture in France will be confined in the near future to the production of small size fish not exceeding 1.5 kg.
One of the prevailing economical criteria conditionning success or failure of salmon aquaculture production is the relation between the price of the smolt and the size or value of the marketable fish.
If producing large fish (over 4 kg) corresponding to a high market value, with a reasonable mortality between smolt stage and adult, the price of the smolt is of less importance, but when the production is limited to small size fish (inferior to 1.5 kg) for various reasons expressed above, the grower has to find species which allow to produce smolts at a low price. One may see that both species Atlantic salmon and coho are devoted to different types of aquaculture and may be conducted either at the same time, when possible, as complementary products or to the advantage of one species according to local parameters.
In this prospect, coho salmon, allowing to produce a pan size fish 11 to 13 months or 1 kg fish 18 months after swim up, constitutes to date the most advantageous opportunity for French growers.

However, drastic improvements in the production of large quantities of Atlantic salmon smolts at a lower price, inhibition of early maturation of grilses or collapse of the market value of small size coho salmon due to an increasing production, may leed to reconsider the present analysis, especially as the first tests seem to indicate a possible higher resistance of Atlantic salmon to summer conditions.

EFFECTS OF ENVIRONMENT ON COHO SALMON

Transplantation of a given species to a new and different environment often results in alterations of the natural processes, especially in cold blooded animals which are strictly dependant upon the ambiant water temperature.
The U.S. Pacific Northwest states and North Western France, in spite of an identical latitude present important climatic and hydrological differences, which appeared to modify largely the natural biological rythms of coho salmon.

Freshwater life

Within its natural geographic area, coho salmon lives in cold rivers from the Pacific coast from California to Alaska, and reaches smolt stage at one year, weighing 15 to 40 g, exceptionally at two years in the Northern rivers.
According to BRETT (1952), the preference of young coho salmon is in the range of 12 - 14°C with a marked avoidance for temperatures above 15°C. This corresponds generally with the natural habitat of the species in late spring and summer except in the Columbia river where the succession of hydroeletric dams creates an important thermal elevation in summer (superior to 18°C).
The temperature in rivers of Brittany fluctuates between 6 to 18°C with extremes of 4 to 21°C.
Eyed eggs received in December from United States usually reach swim up stage in January, and the fry, exposed to ideal temperatures during late winter and spring (10 - 14°C), presents a very fast growth.
The first "smolt like" fish appear in May and June of the first year for fish weighing more than 15 g. The silvery aspect shades partially in summer when the juveniles are kept in fresh water, but they continue to feed actively and in August usually exceed the size of yearling smolts released from U.S. hatcheries (15 - 40 g). No major problem was observed in fresh water during extremely high temperatures such as July or August of 1976, where cohos had a much better behavior than rainbow trout fingerlings of the same age.
Silvering of the fish reappears in September and October on larger fish (60 g minimum). If reared in fresh water over winter months, the smolted fish will continue to feed actively with only a slight decrease in growth whereas parrs will exhibit a very low weight increase between December and early March (HARACHE, 1974) resulting in a bimodal population in winter.
In March and April of the second year, all the fish become silvery and their

size usually ranges from 40 to 300 g.

Studies of the physiological mechanisms associated with this parr smolt transformation showed very interesting results which helped to precise the differences between the natural smolting process of the species within its original environment and the smoltification of coho salmon reared in France.
ZAUGG and McLAIN (1970, 1971) first described the activation of the gill Na^+-K^+-ATPase activity occurring during the spring in yearlings of various anadromous species and preceeding seawards migration.
The same authors (1972 - 1976) discussed the influence of high temperatures on the precocity and duration of the enzymatic activation in coho salmon yearlings.

We confirmed these observations in large yearling cohos reared in France (LASSERRE et al, 1978) and found that the activity was only transitory in the spring, and resumed rapidly in May or June, according to increasing temperatures (fig. 3), whereas at lower temperatures (6 - 10°C) the yearling smolts kept in freshwater present a constant high activity during early summer. Moreover, the O age juveniles presenting a silvery aspect during their first spring were found to have a high gill Na^+-K^+-ATPase activity which started later (mid May) and resumed in June-July.
Simultaneous studies (BOEUF et al 1978, HARACHE et al 1978 and 1979) revealed that these high activities were corresponding to the periods of highest salinity tolerance and confirmed the true smolt stage reached by these juveniles during their first spring.

Further investigation by the same authors showed that a new activation of the gill Na^+-K^+-ATPase was existing in September-October, both for O^+ and yearling fish kept in fresh water. For each sampling date, it was possible to establish a size limit below which the activation was not found, showing that this fall "smoltification" was strictly size dependant. Sea water challenges performed during this period showed again that high gill Na^+-K^+-ATPase activity was related to highest sea water tolerance of the fish and thus characterised true smolts (HARACHE et al, 1977, 1979).
However, of course, the ultimate criterion of smoltification : downstream migration could not be tested in France, but results obtained by GARRISSON (1967) with accelerated O age smolts in Oregon may reasonably allow to conclude that these fish would have migrated to sea if released.

These studies showed that the French environment was allowing some fish to smolt during their first year, either in spring or fall, but also, that the high temperatures were largely reducing the period of smoltification, and led to a very precocious reversion to parr condition after only a short and transitory smolt stage. We feel that these results might taken in carefull consideration in stocking experiments of other anadromous salmonids, including Atlantic salmon, in our temperate countries. High spring temperatures or thermal pollution may affect the physiological mechanisms of smoltification, migratory behavior and subsequently the efficiency of smolt release, if performed outside of the most favorable period.

Sea water environment

Temperature

According to MANZER et al (1965), the preferred range of sea surface temperature for coho salmon stands between 7 to 12°C with a tolerable range of 5 to 15°C. The preferred range corresponds to sea surface temperatures of the North Pacific during spring and summer whereas the tolerable range fits almost exactly with the conditions of the Puget Sound where industrial rearing of coho salmon is being practiced.
One may note that except in coastal areas or bays the surface temperatures of North Est Pacific are extremely stable in the vicinity of the North American continent.

A first look at the average sea surface temperatures existing in the North Atlantic near European coasts (JOYNER, 1973) shows that the tolerable range covers all Western Europe (except Scandinavia), from Spain to Scotland in winter. The same range would be limited in summer to the northern part of United Kingdom where as the coasts of France as well as Southern Ireland and England are quoted as marginal.
A more precise analysis must consider not only the offshore surface temperatures, but also the differences existing with coastal waters during summer and fall. AGUER (1979) established such a relation and showed that maximum temperatures of coastal waters of Brittany where cohos are reared (Bay of Brest) were in general at least one °C above the offshore temperatures. Moreover important annual variations may occur and result in differences of

5°C with the upper limit of tolerable range (1975 - fig. 1) and 2.5°C in offshore waters (1976 - fig. 2).
From an aquaculturist point of view, the rapidly increasing temperatures in spring must be considered as an adverse factor for sea water transfers of smolts and reduces the period of time where sea water adaptation is possible.

Salinity

At first, we did not consider the difference in salinity between Pacific coast waters and Brittany as an important factor susceptible of influencing the biology of coho salmon.
We then found (BOEUF et al, 1978 ; BOEUF, 1979) that coho salmon juveniles presented a deeper osmotic stress when exposed with sea waters exceeding 30 ‰, and that 35 ‰ sea water represents a very selective challenge.
Coastal waters of Northwest France usually present salinities always superior to 33 ‰ (except in estuaries), and to 35 ‰ at least 6 months of the year. These conditions differ widely from coastal waters of the Pacific coast which very rarely exceed 30 ‰.
Moreover, the combination of high temperatures and high salinities creates environmental conditions which may be considered as adverse during summer.

Duration of the life cycle

The accelerated growth, associated with the environmental conditions, results in shortening the freshwater life but also the entire life cycle. Almost all the fish from an early spawn, which produce a high proportion of 0 age spring smolts, will reach sexual maturation in captivity at the end of their second year at a weight of 1 - 2 kg. A late brood, which would produce only yearling smolts, will usually produce early maturing males (over 150 g) at two years and, eventually, some early maturing females, but the majority of the fish will reach maturity at three years. This fact has been already observed by BURROWS and COMES (1969 and comm. pers.) with artificially accelerated smolts of coho salmon reared in high temperatures, in a reuse system before release as large smolts. These fish usually produce a fairly high recapture rate, but only as jacks (2 years) whose size is comparable to that obtained in captivity in France.

Development of the French production

Sea water transfer

According to the physiological rythms of the species within the French environment, the sea water grower can select several cycles of production according to the growth of the juveniles, climatic conditions and characteristics of the salt water rearing site :

- transfer of 0 age fish in spring 15 May-10 June at 15-20 g,
- transfers of 0 age fish in September-October at 80 g,
- transfer of large subyearlings or yearlings during winter months (November-March) at 150 or more,
- transfer of yearling smolts of any size in April-May,
- transfer of large yearlings in the fall of their second year after removal of the early maturing males.

• Spring transfers although possible may be considered as a risky choice in some sea water rearing sites, and in any case the respect of a minimum size for transfer is of drastic importance. Survival exceeding 90 % have been obtained in 1977 but cannot be reproduced easily.

• Fall transfers seem to be more adapted to the hydrological conditions of the French sea shore and may allow winter production of coho salmon along all the coasts of France, including the Mediterranean sea. The present production is achieved almost exclusively with fall transferred fish.

Growth

Fish from an early brood who reach smolt size during their first spring usually reach pan size (300-350 g) 11 to 13 months after swim-up and 1 kg after 18 months.

All these fish reach sexual maturity at two years at a weight of 1 to 2 kg. Fish from a late spawning population will produce only a certain ratio of early maturing males 15-40 % at two years and the remaining part of the population will reach sexual maturity only at three years.

These results suggest that coho salmon is appropriate for producing small salmon only, with a rapid turn over of the crop.

Production

The production of coho salmon started from 7.6 tons in 1974 and reached 90 tons in 1980, exclusively with a winter production : October-July.

- Two farms using net pens in sheltered bays are operating in the bay of Brest and the bay of Cherbourg. These two companies are producing mainly rainbow trout but ran several limited trials indicating that coho production was feasible.

- The major part pf the production is issued from a diked tidal lagoon situated on the North shore of Brittany which provided 80 tons of pan size coho in 1980.

- The main reason of the slow development of the production is the smolt availability : due to the precise timing of sea water transfers and the critical sizes required, the production of smolts must be thinked and planned differently than rainbow trout rearing. This may include the development of appropriate tools such as incubation and fry rearing in recirculated spring water (9-12° C) to get rid of the risks of a late shipment of eggs or the effects of a very cold winter.
These problems always occur for the development of new fish productions and are usually solved progressively according to the increasing demand of the market which stimulates freshwater growers to adapt the demand.

EFFECTS OF COHO SALMON ON THE ENVIRONMENT

To be successful, the transplantation of Pacific salmon species to new geographic areas must satisfy two basic conditions :

- a marine environment which matches the preferendum or tolerable range of the species considered, allows a normal behavior, active feeding and respect of the timing of the homing migration,

- a freshwater environment corresponding with the stenothermic character of Pacific salmon and allowing a normal reproduction and freshwater life of juveniles to create a self sustaining smolt production.

In the last 100 years, overs 200 millions Pacific salmon ova and juveniles have been released cutside their natural habitat and have persistantly failed to establish self sustaining populations without massive and constant stocking programs, except in New Zealand (Mc DOWAL, 1968) and to a lesser level in the Barentz area with pink salmon (Oncorhynchus gorbuscha). Oncorhynchus have been released in most european countries between 1879 and 1891. Chinook salmon (O. tschawytscha), sockeye salmon (O. nerka) and coho salmon have been planted in several rivers of Normandy, Brittany and in the Seine river in large numbers. Numerous catches were observed in these rivers between 1886 and 1905, but none was reported after the first world war.

Introduction of Pacific salmon in New England

More recently, during the first half of the century, several attempts to introduce various Pacific species to the East coast of United States and Canada have occurred (chinook, pink and coho salmon).
According to JOYNER (1973) : "permanent runs from these plants did not become established, although in Maine, small returns were observed for several cycles". RICKER (1954), discussing the failure of chinook salmon transplantation attempts to New Brunswick rivers, suggested two desirable characteristics for any program of transplantation :

1 - "Relatively large plantings should be made to one or a few sites, at first, so that there will be an adequate expandable surplus while the selection process is weeding out genes whose effects are in poor adjustements to the new situation ...".

2 - "Donor stocks should be carefully selected in order to match up the freshwater and marine conditions of existence of the old and the new sites as closely as possible".

The more recent introduction attempts in New England conducted since 1967, led to various results. No return of adults were observed either in Connecticut or Rhode Island, but interesting returns (3% in 1972) have been observed in New Hampshire (both experiments were using smolts of the same origin).

However, further observations showed that self sustaining runs did not established in the Great Bay area (New Hampshire) because of unfavorable freshwater conditions, and the maintenance of a stock available to sport fishery would rely only on hatchery production of smolts for release.

JOYNER (1973) explained that the differences observed between Connecticut, Rhode Island and New Hampshire might be due to the existence of a temperature front (16°C) preventing the adults to migrate southwards to their home streams in late summer or early fall. Estuaries of New England, in the other hand could be reached by adults staying in Bay of Fundy during summer. JOYNER concluded that the choice of a special stock for introduction should be done in respect of the timing of the homing migration which must correspond to tolerable sea surface temperatures. He also suggested that late run cohos would have been able to return to Connecticut rivers whereas the early spawning stock selected (state of Washington) was more fitted to New Hampshire conditions.

The 1979 returns in the Lamprey river (NH) indicated a rapid adaptation of the species to the new environment for smolts of local F2 generation (2.29 %) compared to local F1 (1.3 %) and wild Pacific origin (0.55 %).

Coho salmon escapes in France

The first recent egg introduction was performed in 1970 by a private trout farmer whose objective was to replace "Rainbow trout" by a virus resistant salmonid after serious problems with Viral Hemorrhagic Scepticemia.
CNEXO then introduced coho salmon eggs in December of 1971 (60 000), for experimental purposes, to test the ability of the species to be reared intensively (fresh then salt water). Egg purchases increased steadily to reach about one million eggs per year after 1975.
Several private fish farmers obtained eggs either through direct contact with U.S. agencies or the National Fish Farmers Cooperative after 1972.
All eggs imported either by state or private organizations were desinfected with a Iodine compound (Wescodyne) before shipment.

In spite of the care of the growers, it is obvious that some escapes did occur since the first introductions, both from freshwater farms or sea water rearing structures. Some were recorded, some other remained unknown. Usually, the escapes from freshwater hatcheries can be considered as very limited during the normal rearing process, but major excapes (more than 10 000 juveniles) occurred at least on two occasions either during a winter flood or caused by screen damage.
The situation of the presumed accidental release points is precised in fig. 3, however, coho salmon have been reared in numerous sites and may have leed to small escapes in other points.

Escapes in Normandy (ARRIGNON, 1977 ; FOURNEL et EUZENAT, 1977)

The major escape recorded occurred from a private freshwater hatchery operating in the Varenne river which is a tributary of the Arques river flowing to sea in Dieppe. 200 000 to 600 000 ova were introduced in 1973-74 and 75. About 50 000 yearling smolts are estimated to have escaped in 1974 and 10 000 0 age parrs in June of 1975.
An important part of the escaped fish was most certainly destroyed during the obligatory passage through a hydroelectric turbine on their downstream migration as revealed by the accumulation of dead injured smolts at a hatchery weir below.

The electrofishing surveys conducted by the C.S.P. (Conseil Superieur de la Pêche) below two impassable weirs of the system led to the recovery of 32 adults between October and December of 1975 (Varenne : 25, Eaulne : 7). Characteristics of the cohos were 54 cm - 1 460 g with a weight ranging from 1 200 to 3 460 g.
In 1976, only one mature fish of small size was recovered in the Varenne after only 5 months at sea.
In 1977, non negligeable catches were done by anglers during late summer or early fall and 4 adults (900 - 4 300 g) were captured in November below an impassable weir of the Varenne.
25 0 age juveniles (52 to 90 mm) have been captured by electrofishing in June of 1976, at a time where no more cohos were reared at the hatchery. They most certainly originate from the natural spawning of December 1975. Numerous genitors were observed on spawning nests in December of 1977 and left few doubts about

the ability of the species to reproduce in rivers of Normandy.
2 adults were recaptured in the Bresle river, and one in the Canche river. It was found later than a hatchery situated on the Canche had been rearing cohos between 1974 and 1976.

No major escapes have occurred from the sea cages operating in the Bay of Cherbourg, however casual losses during grading operations led to the recapture of several adults in the vicinity of the cages in 1977 and 1978.

Escapes in Brittany

Incidental losses, probably limited have occurred from several hatcheries operating in the northern part of Brittany, mainly in the Leff or Jaudy rivers, but the main accidental release was in March 1976 in the Odet river. Due to screen damage, about 10 000 fish (0 age 2 g and 1^+ 50 - 70 g) escaped from a freshwater hatchery. Electrofishing conducted the day after the incident allowed to recover a part of the fish in the vicinity of the hatchery.
Small escapes from the sea cages probably occur regularly but in limited numbers from the present rearing sites : Jaudy estuary, Bay of Brest and Bay of Cherbourg. Only one significant accident was recorded in early 1977 in the Bay of Brest. 6 000 large 2^+ fish (400 g) which had been reared for several months at sea escaped from a teared-off net pen during a storm. Most of the fish stayed in the vicinity of the pens and 4 000 of them were seined in the days following the accident. Small quantities of fish were captured regularly during summer by the sea farm staff by attracting the fish with pellets around the cages, and casual catches by commercial or recreational fishermen occurred within the immediate vicinity (10 km) of the release point.

No record of catches were reported in the rivers of the areas where escapes did occur except in the Jaudy estuary.

Intentional introduction

The first recorded intentional introduction was performed by a sport fishing association in the Sienne river in March of 1977 as part of the restocking program of the river. This limited release was composed of 636 coho yearlings (28 to 35 cm) and 700 Atlantic salmon smolts. Cohos were observed in estuary in which at least 100 were recaptured by the anglers in the ensuing months.

A second and more important intentional release was done in the spring of 1979 by a sport fishing association in Mediterranée when 10 000 0 age smolts (12 - 15 g) were released in the estuary of the Var river.

These two attempts are limited but reveal the interest of legal freshwater angling associations in this species and indicates that some pressure might occur in the next years for more introductions.

Could coho salmon establish in French rivers ?

. The fragmentary observations done at the occasion of the escape in Normandy show that adults did return in their home stream with a fair degree of accuracy, and a probable significant survival rate at sea. Adults successfully spawned in the rivers and produced viable juveniles. The lack of precise observations about the escapes in other rivers, and the apparent absence of recaptures in Leff and Odet must not be taken as a proof of non adaptation to these rivers as :

- no counting trap allows to check the upstream migration,
- no commercial or sport fishery is practiced during the probable homing period which takes place with the first heavy rains in autumn.

However, the examples of other introductions suggest that, without massive and constant releases, the new species will fail to establish durable populations adapted to the new environment. The escapes were probably, to date, too limited or erratic to allow the settlement of permanent runs in Northwestern France.

In spite of the differences with the preferable temperatures of the species, the freshwater environment does not seem to be a real limiting factor for natural expansion of the species. It seems likely that even in wild populations, a non negligeable part of a given stock may reach smolt stage during its first spring.

Moreover, the remaining part of the population, according to hatchery rearing results, would stand the critical summer period without major damage. At the opposite with New Hampshire, whose rivers are very cold in winter, the mild temperatures would be almost ideal for the species, allowing a rapid growth and probably an early downstream migration of large yearling smolts.

In the other hand, the marine environment might be more selective or adverse for coho salmon. The species is generally quoted as more coastal than other anadromous fish, including Atlantic salmon, but no one can affirm that juveniles, freely migrating downstream at the optimum stage of smoltification, would stay in the coastal area in spite of unfavourable water temperatures in summer. This fact will result from a balance between environment preferenda and food availability. In case of escape from sea rearing structures, one may reasonally think that cohos would behave like delayed release smolts (MAHNKEN and JOYNER, 1973) and have a more sedentary behavior providing that sufficient food is available, even if environmental conditions are not totally satisfactory. The first observations, realised on escapes from sea pens in the Bay of Brest, tend to confirm this hypothesis.
The major problem, as described for Connecticut introductions by JOYNER (1973) would probably be the mismatch of sea surface temperatures and precise timing of upstream migration :

- if confined to warm coastal waters following a delayed release, would adults have a normal sexual maturation process ? (HARACHE et al, 1979).

- if migrating offshore in colder waters, would they return to their home streams in spite of a thermal front standing in the coastal area till late October or early November ?

One must recall that for intensive rearing purposes, the early spawning stocks present the best advantages for furnishing 0 age smolts, and that all escapes to date originated from early broods. For the specific case discussed , it appears likely that late run fish would have the best chances to adapt to the French coastal environment for their ultimate homing migration.

Possible consequences of establishement of coho salmon in France

Compétition with local species

In case of a return of large numbers of coho salmon adults in a stream sustaining a population of Atlantic salmon and sea-trout, the lack of precise scientific evidences, obliges to a speculative discussion.
The spawning requirements of coho and Atlantic salmon seems to be fairly close, even if the first one seems able to colonize smaller streams than the later one. Anyhow, it is possible that the spawning areas, if not identical may be

partially the same. One of the first facts conditionning interspecific competition is the date of spawning.

- will coho spawn first, and have its nests partially destroyed by Atlantic salmon ? In this case, cohos emerging earlier will select the best habitat.

- will Atlantic salmon spawn and emerge from gravel before coho ?

It is difficult to give an objective answer to that question as it depends upon the interactions between the stocks genotype and the possible adverse environmental factors cited above.

GIBSON (1977), studying the behavioural interactions between juveniles of coho almon, Atlantic salmon dans brook trout (Salvelinus fontinalis) in an experimental stream showed that : "coho distributions were different when observed alone than when with either brook trout or salmon parr, but coho had little effect on the distribution of either of the other two species. Interspecific displacements of coho by brook trout and Atlantic salmon parrs were greater than displacements by cohos of the other two species".
The displacement of cohos by other species become more important at the higher temperatures tested (20°C) ... "Salmon parrs appear better adapted to the fast water environment than coho, which are better adapted to the pool environment ... and salmon parrs held station closer to the substrate than coho".
The author concludes that "the two species would probably be ecologically compatible".

These preliminary observations seem to indicate some differences in the ecological niches occupied by each species, ant that coho salmon would have few chances to displace Atlantic salmon juveniles.
However, the faster growth of coho salmon might influence the basic mechanisms described by GIBSON.

Disease factors

Coho salmon was chosen by CNEXO for various reasons expressed earlier, but also because of its favourable "disease resistance profile".
The species is resistant to all viruses, known to date, to affect salmonids, especially Viral Hemorrhagic Scepticemia and its North american form Infectious Hemotopoïetic Necrosis.

Coho salmon seems to be more resistant to bacterial diseases such as furonculosis (Aeromonas salmonicida) and vibriosis (Vibrio anguillarum), than rainbow trout and Atlantic salmon. However, coho is very sensible to bacterial kidney disease (Corynebacterium sp.).
The disease, reported in Scotland in Atlantic salmon (SMITH, 1964) and more recently in sea farms rearing rainbow trout, is common in North America and affects all species of salmonids.
The bacterium was not found during the two first years of coho salmon rearing in France, but was reported in a hatchery rearing cohos by de KINKELIN (1974), then in sea water farms of Brittany (VIGNEULLE et al, 1977). According to MUNRO (1979) : "Bacterial kidney disease of salmon is the only identified disease which might have been introduced with eggs imports, but even here, there is insufficient proof of the origin of the KD bacterium".
The possibility of contamination through infected eggs have been established recently, and all the ova introduced to France since 1977 (included) were certified to be treated with erythromycin at water hardening (COLE, 1977), which is claimed to prevent KD transmission.

CONCLUSION

Coho salmon represents a good opportunity for coastal salmon aquaculture in France, and will probably allow the development of a small industry in the near future. This means that escapes already occurred and will most certainly continue in the future. They concern usually small numbers of fish but the risk of a major escape cannot be overlooked.
Objectively facing the unprobable eventuality that sporadic and limited escapes would allow coho salmon to build large self sustaining runs in French rivers, one may assess that commercial fishermen, the majority of anglers, lots of potential candidates for recreational fishery would probably encourage the development of this new resource.

The absence of Atlantic salmon lobby (less than 3 000 catches in 1979 for all rivers in France) would make difficult without serious reasons to obtain the eradication of coho stocks if the new resource was providing more resources than disagreements.

Anyhow, we feel that some of the questions arised in this paper should encourage more specific scientific investigation about the possible consequences of coho salmon introduction in France, including studies of the competition with native species in fresh water and of the marine migrations along the French coasts. Moreover, some recent findings in ethology or physiology may bring rapidly some new "tools" which could make coho salmon aquaculture safer. These technics could include the creation of monosex populations or systematic olfactive imprinting with chemical scents to increase the accuracy of the homing to the escape point.

At last, if sufficient scientific evidence was prooving in the future that coho salmon was an indesirable species in European waters, and even if some successful runs had settled, we may be reasonably confident that an adapted eradication policy would make wild cohos disappear fairly rapidly from French rivers.

The contrary would be most surprising as all anadromous species are persistantly endangered by human interventions on their river habitat, and subsist only in case of careful protection and management.

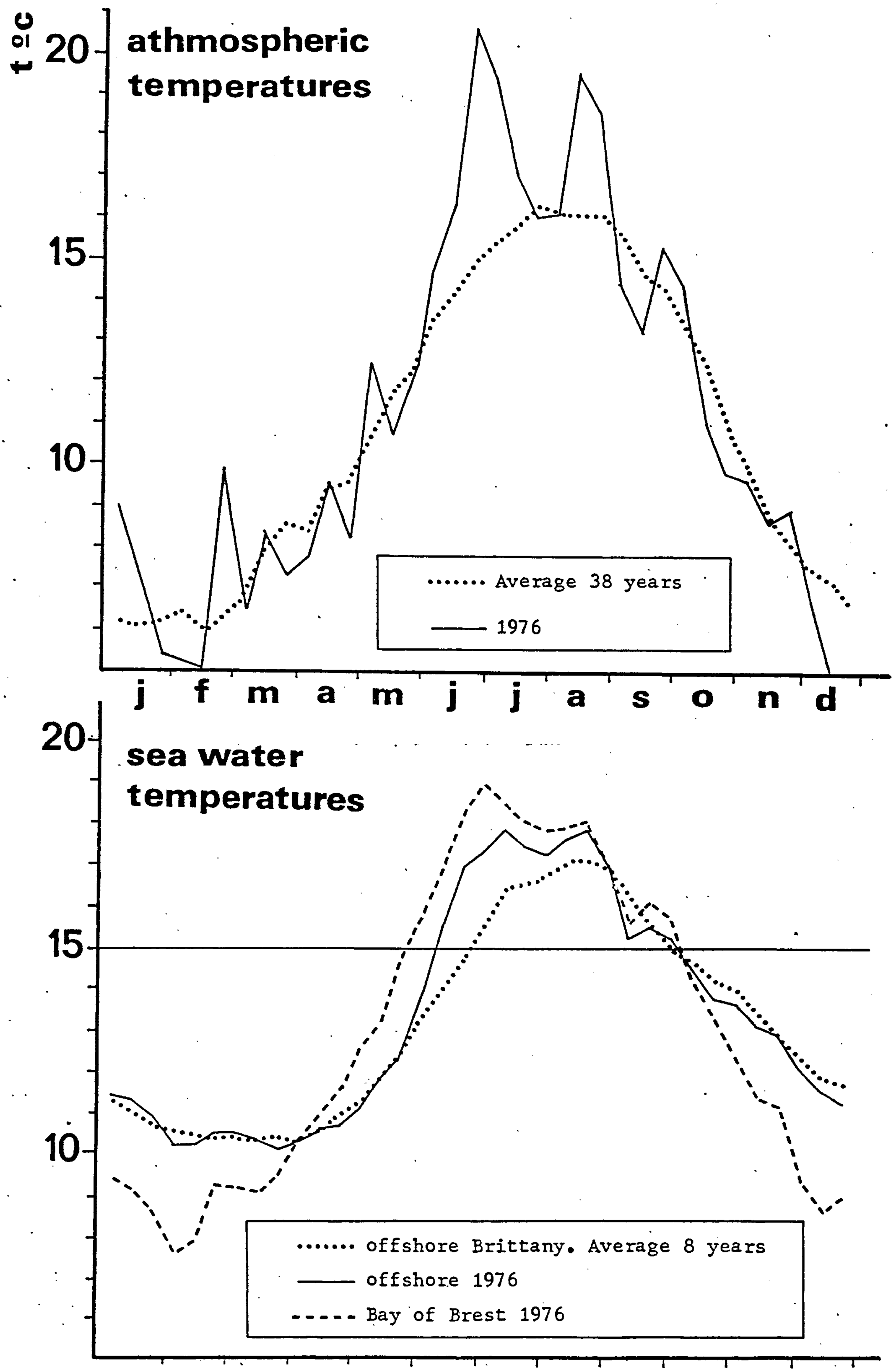

Fig. 1 - Temperatures in Brittany in 1976 (from AGUER, 1979)

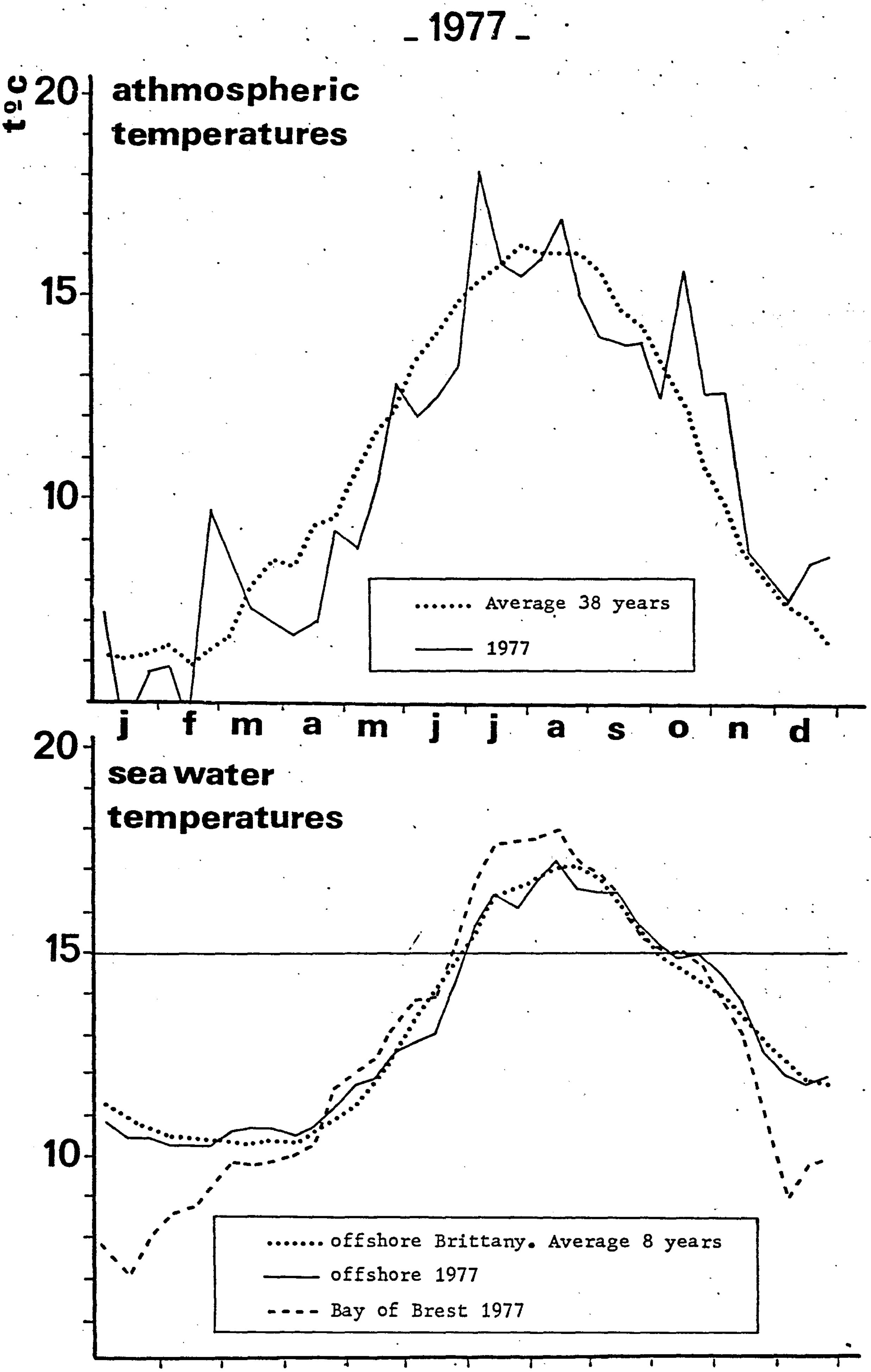

Fig. 2 - Temperatures in Brittany in 1977 (from AGUER, 1979)

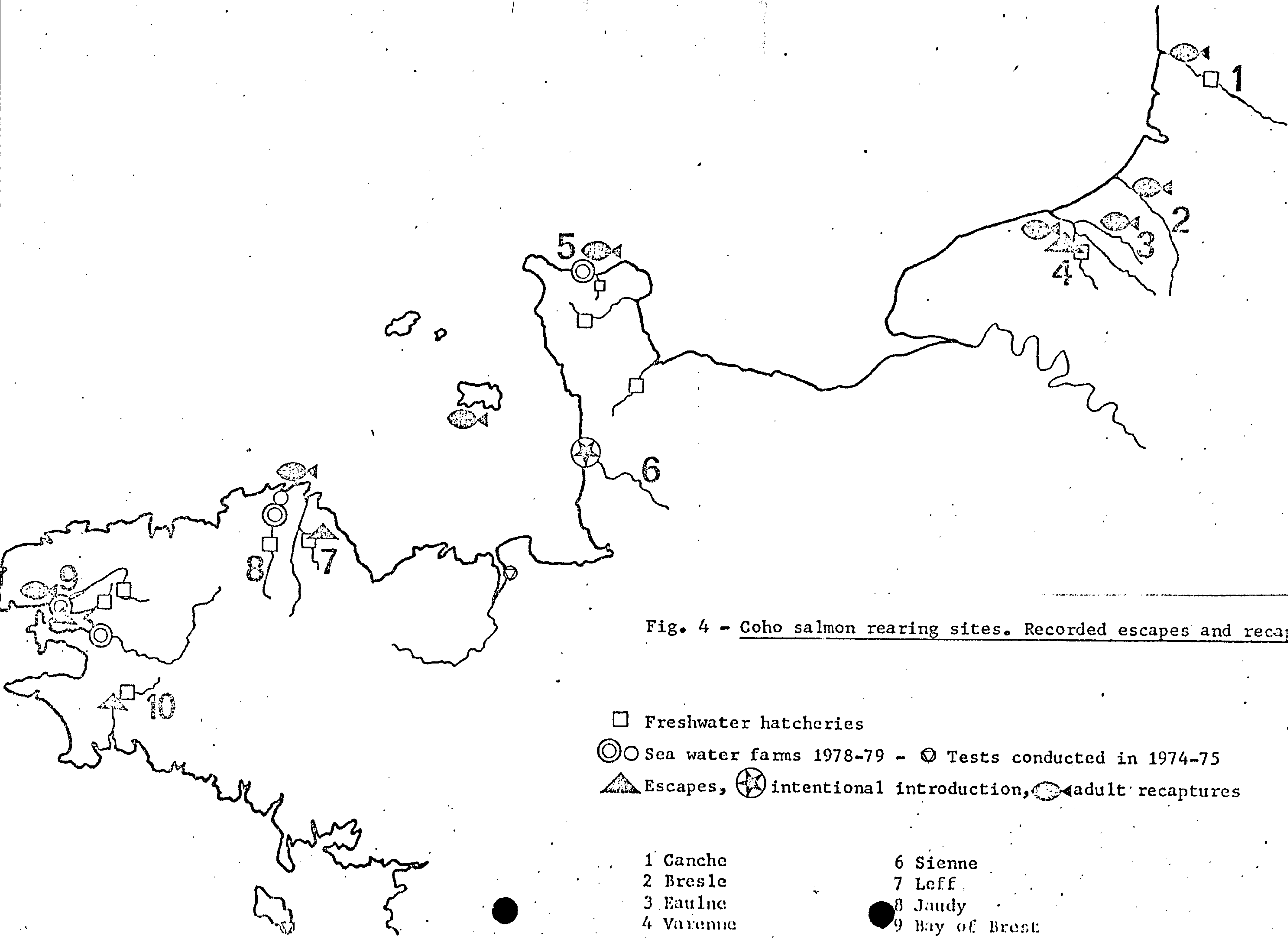

Fig. 4 - Coho salmon rearing sites. Recorded escapes and recaptures.

□ Freshwater hatcheries

◎○ Sea water farms 1978-79 - ⊽ Tests conducted in 1974-75

▲ Escapes, ✪ intentional introduction, adult recaptures

1 Canche	6 Sienne
2 Bresle	7 Leff
3 Eaulne	8 Jaudy
4 Varenne	9 Bay of Brest
5 Bay of Cherbourg	10 Odet

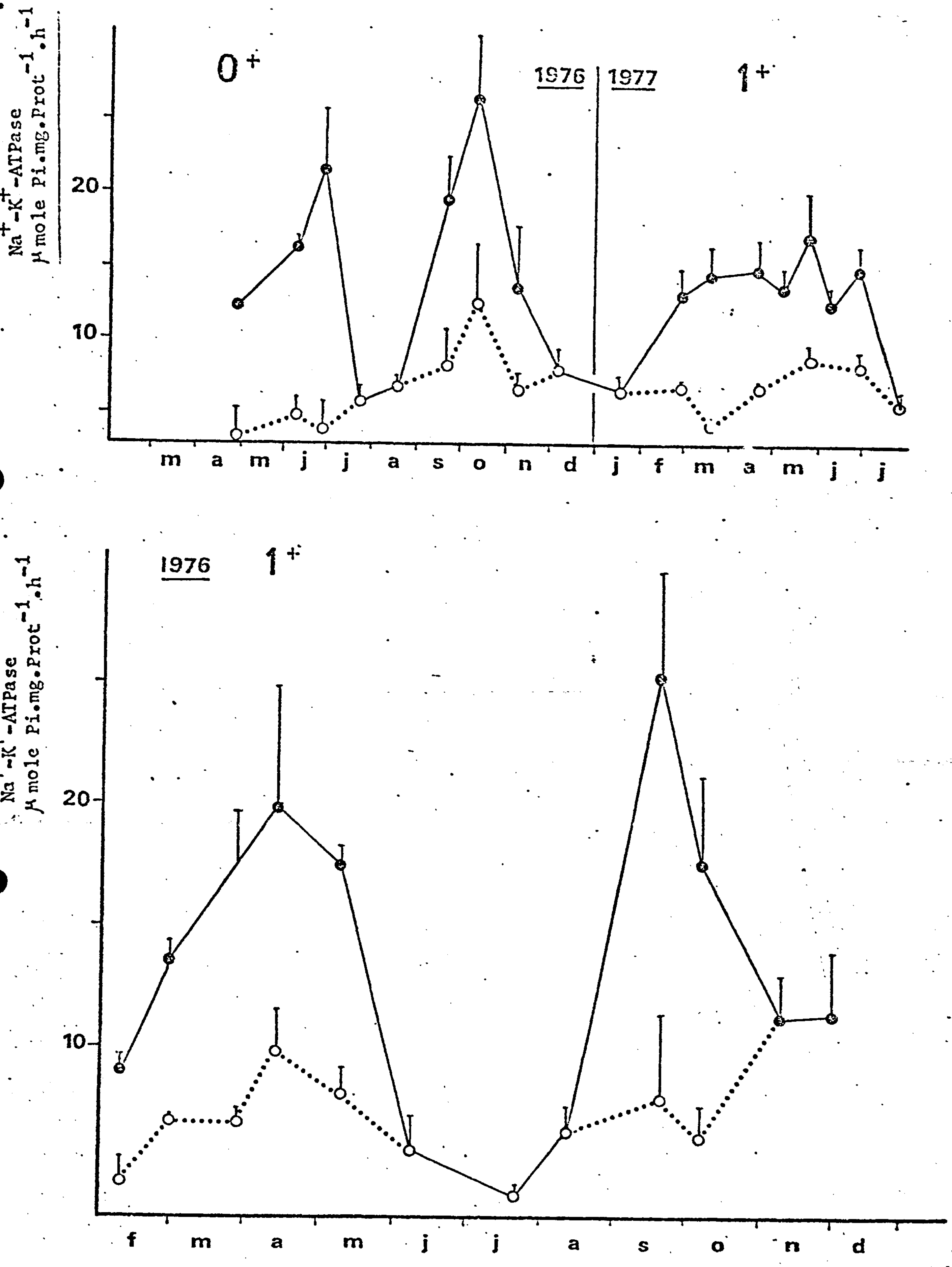

Fig. 3 - Gill Na^+-K^+-ATPase activities in 0 age and yearling coho salmon (from BOEUF, 1979)

- heavy line : cyclic activity in larger fish
- dotted line : low activity in smaller fish.

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