A review of plaice (*Pleuronectes platessa*) transplantation trials in Denmark 1891–1990

Erik Hoffmann

Transplantation of young plaice (*Pleuronectes platessa*) in Denmark started back in the last century. The first published data are from 1891. Experiments were initiated by local fishermen and sponsored by the government. Large quantities of small plaice (16–19 cm) were caught, either in the western part of the estuarine fjord Limfjorden close to the North Sea or in the coastal waters of the North Sea, and transplanted to the inner parts of the fjord and to water bodies between the Danish islands in the southern Kattegat. In a few cases, transplantations of plaice to the central North Sea (Dogger Bank) were also carried out. The idea was to enhance either the local stocks or just the catch. The latter was the case for the Limfjord area, where the great majority of the transplantations were carried out. The work started in 1891 and continued for more than sixty years, during which time about 6000 t were transplanted. The work stopped in 1958 due to the lack of financial support from the government. Up to then the transplantations had been the topic of long economic and political discussion. The overall conclusion concerning the economics of the matter was that no net gain was actually being obtained by the transplantations except in certain areas in Limfjord. In 1984, some minor experiments initiated by the Fishermen’s Association were again started up in Limfjord. The findings of this work were that the plaice stayed in the fjord and that the growth rate was satisfactory. In 1988, a semi-commercial transplantation programme was initiated and 14,000 plaice were transplanted to Limfjord. In 1989, the programme was expanded, 132,000 being transplanted to Limfjord and 30,000 to other water bodies in Denmark. This new work also included turbot (*Scophthalmus maximus*), eels (*Anguilla anguilla*), whitefish (*Coregonus* sp.), rainbow trout (*Salmo gairdneri*), reared in captivity, and cod (*Gadus morhua*), caught in the wild. The government is granting this new work Dkr 1 mill. in 1990. The final question is, of course, whether or not such transplantations of plaice and other marine species should be carried out. The conclusions have to be drawn on both an economic and ecological basis. The present paper summarizes experiences from transplantation programmes and attempts to provide suggestions for the future work.

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General introduction

In the late 1880s, the idea of transplanting marine fish was born among Danish fishermen and fishmongers. The idea was the same as the one the gardener has: to move individuals from overcrowded areas where there is thought to be a deficit of food to areas with a surplus of food and space. The first results reported were for the years 1891 and 1892 (Drechel, 1893) and the experiments were carried out in Limfjord. The first transplantation included 80,000 plaice, all caught in the western part of the fjord close to the North Sea (Fig. 1).

Today, plaice and cod from the wild stock and salmon, trout, whitefish (*Coregonidae*), turbot, and eel reared in captivity are released into the sea. This latter enterprise should more correctly be named “sea ranching” and, therefore, not discussed in the present paper. But for both activities many of the problems and their solutions are the same.

The background for the early transplantation was that the local fishermen had observed that large numbers of small plaice were present in the western part of the fjord, close to the entrance from the North Sea, whereas only comparatively few were present in the central part of the fjord. At that time little was known about the migration and spawning habits of plaice, but it was widespread opinion among fishermen that the plaice did not spawn in the fjord but immigrated from the North Sea. This was later shown to be the case by the famous
Danish biologist, C. G. Joh. Petersen (Petersen, 1986). Petersen followed and supported the transplantations in the early years and it was due to his personal contribution that a paragraph in the Danish Fisheries Law of 1907 claims that the State should fund the transplantation programme by Dkr 20,000 (US $3000) annually. In 1917 this sum was increased to Dkr 30,000.

In the years up to 1957, a total 60641 of approximately 80 million individuals were transplanted to Limfjord (Bagge, 1970). In 1928, transplantations to the inner Danish waters in the southern Kattegat; these programmes are described by Blegvad (1935). Later, in 1932, the transplantations were carried out in the North Sea from the Horns Reef area to Dogger Bank (Tånìg, 1952; Ursin, 1952). This was, in fact, not a new business, as Garstang reported as early as 1905 on English plaice transplantation programmes to the Dogger Bank (Garstang, 1905). Blegvad (1933) reviewed the period 1929–1932 and included valuable historical conclusions based on the work carried out in the whole period 1891–1932. Tånìg (1952) gave a comprehensive review of plaice transplantations up to that year and included remarks on the yields achieved. At that time, enthusiasm for the idea of transplantation had cooled down a little but Tånìg still recommended the transplantations in Limfjord, although he completed his paper with the following few words of warning: “It is of fundamental importance in all transplantation work that the expenses of fishing and transport should always be kept much less than the value of the yield that the transplanted fish can give to the fishery” (!) (see also Peterman, this volume).

After a period with no transplantations the experiments started again in 1984 but only to the “special broads” already mentioned in 1928 and reviewed by Kirkegaard in 1955. The work was initiated by the Fishermen’s Association and the local counties and some results were given by Hoffmann and Degel (1987). The work was intensified in 1988 and some comments on and the results are given below.

It should be noted that also other countries took up the idea of the transplantation of plaice. In Sweden, experiments were carried out as early as 1902 (Trybom, 1901–1904). In the UK, Garstang (1905) gave the first information and, later, Carruthers (1924) described English transplantation and marking experiments in the North Sea. Information on Norwegian transplantations of Danish plaice to the Oslo fjord is given by Kolstad (1953). In Germany, transplantations were carried out with plaice from the North Sea being moved to the Baltic; these experiments are treated by Henking (1925) and, later, some comments and conclusions were given by Meyer (1952).

Material and methods

Brief comments are given here on the different methods used in the Danish transplantation programmes. The period is divided into two: 1891–1957 and 1984–1990.

1891–1957

The small plaice were caught mostly in the early spring (from February to April) in the western part of Limfjord (Nissum Broad), but also just outside the entrance to the fjord and at Horns Reef (Fig. 1). The gear used was Danish seine and fishing was performed using small well-boats (8–12 tons). The plaice were collected using
larger well-cutters (20–50 tons) and when these were loaded with 2500 to 3500 kg they departed for the localities where the fish were released. This method implied that the fish were handled several times before transplantation was completed, and sometimes resulted in high mortality. The mortality problem was discussed fully by Bagge (1970). Plaice caught at Horns Reef were taken to the Danish harbour of Esbjerg and unloaded to floating well boxes for 2–4 days to ensure that stomachs and intestines could be emptied; this way to prevent the sharp edges of bivalve shells causing internal injuries. Weak and dead plaice were discarded from the well boxes. Later, the plaice were loaded onto lorries and taken across Jutland to be unloaded again to larger well-boats which sailed to the release localities (Fig. 2). This long procedure placed severe strain on the small plaice and often very high mortalities were observed (Blegvad, 1934).

The plaice used for transplantation were all undersized fish (<26–27 cm), generally between 10 and 26 cm, with mean lengths in the early years of between 16 and 19 cm. It was later decided that the plaice should be larger than 18 cm at the time of transplantation due to the fact that the smaller fish seemed to suffer more from the moving procedure. The mean lengths in the period 1952–1957 varied between 17.8 cm and 21.6 cm, with corresponding mean weights of 67 and 110 gram (Bagge, 1970).

In order to follow the fate of the transplanted plaice several marking and tagging programmes were established. In the period 1895–1952 the Petersen disc was used. However, this type of tag appeared inadequate in areas with much net fishery, as the tag had a tendency to catch in the meshes; therefore, some new types were used. More details have been given by Bagge (1970).

1984–1990

When the new transplantation programme was started in 1984 it was decided that mortality during the moving period had to be reduced. Moreover, tagging procedures had to be quicker without giving higher tagging mortalities. The size of the plaice transplanted should be smaller and the seasons for transplantation should be late autumn and early spring.

The fishing for plaice was carried out with a small meshed trawl or Danish seine. The trawl hauls were of only 15 to 20 min duration in order to avoid damage to the plaice. After capture the small plaice were immediately transferred to containers onboard the ship. These containers were supplied with oxygen and the water was slowly renewed during transportation. The boat sailed to the release positions when stocked with small plaice. With this method excessive handling was avoided (Hoffmann and Degel, 1987). The size of the transplanted plaice in the period 1984–1986 varied between 16.6 cm and 20.8 cm (Hoffmann and Degel, 1987). The size distribution of the plaice in the 1988–1990 transplantations is of the same magnitude as earlier (Paulsen, pers. comm.)

Tagging was carried out with red Floy-tags type FD-67 using a tagging gun. It was possible to tag between 250 and 300 fish per hour. A reward of Dkr 20 (US$ 3) was given for any information on tagged plaice (Hoffmann and Degel, 1987). No results from the 1988–1990 taggings have yet been published.

Results

It is not possible to present the results from all the transplantations carried out in the period 1891 to 1990.
in the present paper, but some general conclusions can be drawn. The most important points in all transplantation work are the following: (1) Transplantation mortality; (2) natural mortality and fishing mortality of undersized fish; (3) emigration of transplanted fish; (4) growth of transplanted fish; (5) carrying capacity of the transplantation area; (6) yield.

Transplantation mortality

Transplantation mortality is of vital importance for the success of transplantation. It was understood early that careful handling and low temperatures gave the best results. Water temperatures above 8°C to 10°C gave low recapture rates and the experiments with transplantations including several handlings (e.g. the transplantations to the inner Danish waters) sometimes gave very low recaptures corresponding to a transplantation mortality as high as 80%. It was shown by Bagge (1970) that the amount of lactic acid in the blood following severe activity was increased with increasing temperature. Accumulation of lactic acid in the blood is lethal for plaice.

Another factor affecting the survival is the size of the fish at transplantation. Small plaice (<10-12 cm) seem to tolerate the moving process less well than larger ones (Bagge, 1970). However, it has to be remembered that transplantation mortality is difficult to separate from tagging mortality, so this statement may be somewhat biased. In the experiments up to 1957, the Petersen disc tag was used. This tag is rather big and clumsy and not suitable for smaller fish. Later, in 1984-1987 the Floy tag was used and with this no differences in recapture percentage were found for plaice between 12 and 28 cm (Hoffmann and Degel, 1987).

Natural and fishing mortality

The natural and fishing mortalities of the undersized transplanted fish have a negative effect on the yield. Predation has to be avoided. In the Danish transplantations, predation on small plaice has never been reported. Fishing mortality for undersized transplanted fish has had some effect in Denmark and different precautions (e.g. closed fishing periods) have been taken to reduce this (Bagge, 1970).

Emigration

It is very important that emigration rates of transplanted fish are small if the goal of the transplantations is to be achieved. For the Limfjord area it has been shown that only very few plaice emigrate in the first year after transplantation. On the other hand, it has also been shown that only very few larger and older fish were ever caught in the fjord. This indicates that the plaice not caught in the first or second year after transplantation sooner or later try to emigrate to the North Sea for spawning (Bagge, 1970). For the plaice transplanted to the Belt Sea, Blegvad (1933) states "... that on the whole the plaice remain near the localities where they have been liberated". In the experiments in 1984-1987 only 3% of the recaptured plaice were caught in the North Sea (Hoffmann and Degel, 1987).

Growth

One of the main reasons for starting up the transplantations was the great amount of suitable "first class fish food" found in Limfjord (Blegvad, 1928). It was shown that the transplanted plaice grew faster than the North Sea plaice and in the Belt Sea the transplanted plaice had a higher growth rate than the local stock (Blegvad, 1933). In the period 1952 to 1987, the growth rate seemed to be of the same magnitude as the growth rate for the North Sea stock (Bagge, 1970; Hoffmann and Degel, 1987).

Carrying capacity of the transplantation area

In none of the Danish transplantation programmes have there been special efforts made to determine the carrying capacity of the transplantation area. The scientists working in the Limfjord have considered this concept but no quantitative estimates have been made. For the Belt Sea the viewpoint was that the transplanted plaice should take the place of the decreasing local stock and, in that way, be a natural part of the community. One of the problems in these areas was that other flatfishes (flounder and dab) and cod were present and therefore potential competitors to the plaice. No comments on this subject are found in the literature.

To find the carrying capacity of a transplantation area, one has to develop ecosystem models including the different elements in the food chains. This has never been carried out on a quantitative basis and it is only recently that such total models have been developed (see Masfjorden cod papers, this volume).

Yield

The ultimate answer concerning the value of transplantations is of course their yield. In all Danish transplantations, the main goal has been to give the local fishermen larger catches and, for the period 1891 to 1952, this yield was simply calculated as the value of recaptures minus the cost of transplantations. No attention was paid to the possible effect on the local catch in the area where the small plaice for transplantation were caught.

Many calculations have been carried out and the results differ from area to area. For Limfjord as a whole, the total yields in the early years were always positive. Tåning (1952) notes that the value of the yield to the
Table 1. Yield per tonne of transplanted plaice in Limfjord (Thisted and Visby Broads only).

<table>
<thead>
<tr>
<th>Tonnes transplanted per year</th>
<th>Yield per tonne transplanted</th>
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<tbody>
<tr>
<td>1901–1907</td>
<td>10</td>
</tr>
<tr>
<td>1908–1916</td>
<td>51</td>
</tr>
<tr>
<td>1918–1927</td>
<td>26</td>
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<tr>
<td>1928–1934</td>
<td>35</td>
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<tr>
<td>1935–1940</td>
<td>44</td>
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<tr>
<td>1941–1947</td>
<td>26</td>
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<tr>
<td>1948–1951</td>
<td>47</td>
</tr>
<tr>
<td>1952–1957</td>
<td>90</td>
</tr>
</tbody>
</table>

From Johansen (1928), Kirkegaard (1955), and Bagge (1970).

The yields per tonne transplanted to the “special broads” in Limfjord (Thisted and Visby) have been calculated for the period 1901 to 1957 (Table 1). It can be seen from the table that the yield per tonne of transplanted plaice has varied during the years from 1.1 t catch to 3.5 t catch per tonnes transplanted plaice. The difference between the price of plaice for transplantation and the market price of plaice has changed too (see later).

The yields for the Belt Sea were very promising to begin with. For 1931, the total cost of the transplantation was Dkr 40,000, while the total yield of the transplantation was Dkr 125,000 (Blegvad, 1933). In the years after World War II, the transplantations were uneconomic mostly due to the fact that the price for small plaice to be transplanted went up without a similar increase in the market price of plaice for consumption. In 1928, the price for fish for transplantation was only 13% of the market price. In 1957, this percentage had changed to about 25% (Bagge, 1970). The support from the government stopped in 1956 after a long and heated debate. Two years earlier, Kirkegaard (1955) published a paper dealing with the economics of the transplantations to “the special broads” in Limfjord (Thisted and Visby) and his conclusion was “Transplantations to the broads may safely be considerably increased…” Evidently, nobody took notice of this statement.

Bagge (1970) discussed the definition of the yield of transplantations and introduced what he called the real economic yield. This he defined as the difference between the economic net yield and the economic yield of plaice if not transplanted. For Limfjord as a whole, he finds that the economic yield will be of about the same size whether or not the plaice are transplanted (Bagge, 1970).

In spite of this statement transplantations started again in 1984. Once again the transplantation area was the “special broads” mentioned by Johansen (1928) and recommended by Kirkegaard (1955). The results from the transplantations in 1984–1987 are described by Hoffmann and Degel (1987). In 1988, the work was expanded and a total of 14,000 plaice were moved of which 1200 were tagged. In 1989, the number transplanted to Limfjord was 132,000, of which 6200 were tagged. The amounts to the southern Kattegat were 30,000 with 2300 tagged. No data on recaptures and yields from this new work have been published.

To complete the transplantation story in Limfjord, it has to be mentioned that the work carried out today also includes turbot (Scopthalmus maximus) and cod (Gadus morhua). The turbot are reared in the laboratory and released at a size of about 16 to 20 cm. The number released in 1989 was 5600. The cod are caught in the North Sea just outside the entrance to the Limfjord (Paulsen, pers. comm.). The government has sponsored these new experiments in 1989 with Dkr 700,000 and in 1990 with Dkr 1 mill.

Discussion and conclusions

Transplantations of marine fish in Denmark started one hundred years ago and are still being carried out today. Plaice and cod from the wild stock and salmon, trout, whitefish, turbot, and eel reared in captivity are released into the sea. This latter enterprise should more correctly be named “sea ranching” and, therefore, not the subject of discussion in the present paper. But for both activities many of the problems and their solutions are the same.

Ownership

In Danish transplantations, a serious problem has been ownership of the small plaice to be transplanted. In the western part of Limfjord, where the small plaice for transplantation were caught, the local fishermen argued that these fish belonged to them and, if they were moved, then the local catch would decrease later on. Actually, the problem was never resolved and even today the discussion goes on.

Bagge (1970) discussed this and estimated the yield of the plaice if not transplanted and subtracted it from the yield of the transplanted plaice in order to find the real economic yield.

When it comes to the catch of the fish transplanted, the discussion of ownership flares up again. Today, both commercial and amateur fishermen and sports anglers catch the transplanted plaice. Much discussion goes on between the different groups as to who has the right to fish but, fortunately, no serious problems have developed while the government has been paying for the transplantations.

For trout, salmon, whitefish, and eel other agencies also pay for the stocking programmes. The commercial fishermen pay to a salmon fund and to an eel fund and...
local associations collect money for trout and whitefish stocking programmes. Many of the programmes are freshwater projects where it is possible to supervise the fishing rights but, in marine waters, there have been many problems on how to share the benefits of the stocking programmes. In the Danish Act of Fisheries, a new paragraph from 1989 concerning amateur fishermen provides that the great majority of the money paid for fishing licences has to be used for stocking purposes. The main idea is that if everybody contributes to the common good problems will not arise.

Stock or catch enhancement?

In transplantation and sea-ranching programmes, the term stock enhancement is normally used. This indicates that the activities carried out are supposed to have a long-term effect on the stock in the shape of for example new spawners and new genetic material. However, the situation is actually not so. Usually, the fact is that the activities can be defined as catch enhancement. For the Limfjord plaice and for many of the sea-ranching programmes, i.e. the salmon in the Baltic, catch enhancement is the essential part. The transplantations of plaice to the Belt Sea in Denmark were supposed to be some sort of stock enhancement because the local spawning stock had decreased and it was expected that the transplanted North Sea plaice could give this vanishing stock "new blood". Today, some local fishermen in the Belt Sea still claim that they can point out relatives of the North Sea plaice transplanted more than fifty years ago (!).

Future stocking programmes

New possibilities for Danish restocking programmes have arisen in recent years. First of all because of the support from the government but also based on a growing understanding among fishermen and the population as a whole. But before starting up too many programmes, the following points have to be considered - points which are also applicable outside Denmark. Do we want: (1) simple catch enhancement; (2) stock enhancement; or (3) introduction of new species. When these questions are answered, we have to consider the carrying capacity of the stocking area. As mentioned above, no quantitative models are able to give detailed knowledge on this point. The result is that in many cases the scientists have to feel their way. If new species are introduced the impact on local species and the environment have to be seriously considered (see also Anon., 1982).

Another important question is finding the optimum size of the fish to be stocked and the method of stocking. This indicates - except for new species - that it is necessary to find the limiting factor for the propagation of the stock to be enhanced. For the Baltic salmon, the limiting factor was the destruction of the spawning grounds and the salmon's possibilities to reach the spawning ground due to the building of hydroelectric power plants and other human interferences. The solution was to release smolts in the lower parts of the rivers or directly in the sea. For Limfjord, the limiting factor for the plaice was the distance from the North Sea to the inner parts of the fjord. The solution was to catch and move the small plaice. Strictly speaking, the size of the plaice could have been much smaller because of the higher growth potential of smaller fish and the released fish could as well have been laboratory reared. However, small plaice could not stand the transportation and the laboratory rearing technique was not developed.

The author believes that sea-ranching programmes will play a more and more active role in fisheries management. Transplantations in the old-fashioned way should only be carried out in restricted areas and be replaced by releases of fish reared in captivity. The interaction from the released fish will become of great importance in future assessment work and new ideas such as the possibility of wiping out entire, unwanted populations to make room for commercially important species have to be considered.

References

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