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INFLUX OF ATLANTIC WATER AND FEEDING MIGRATION OF HORSE MACKEREL

By

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Abstract

The Norwegian fishery for horse mackerel in the Norwegian economical zone is unregulated and thereby reflecting the availability of horse mackerel in these areas. The Norwegian fishery is exploiting western horse mackerel. The availability of horse mackerel for this fleet is depending on extensive migration of western horse mackerel. The Norwegian catches have increased significantly since 1987 and the catches for the period 1982-1997 are compared with the modelled influx of Atlantic water to the northern part of the North Sea. This modelled influx correlates strongly with the fluctuations in the Norwegian horse mackerel fishery during this period.

The fishery and migration of horse mackerel

Norway has in later years been the main fishing nation for horse mackerel in the North Sea and Norwegian Sea. This fishery is mainly carried out in the Norwegian economical zone of the northern part of the North Sea but also to a smaller degree in the southern part of the Norwegian Sea in the second half of the year, particularly in October. The fishing area is relatively small usually between 58° - 63° north and between 2° east and the Norwegian coastline. This fishery is considered to exploit the western stock (Anon., 1990, 1991). The fishery is carried out by Norwegian purse seiners. This fleet adapts its effort in this fishery according to the actual availability of horse mackerel in the Norwegian economical zone. This means in years with low availability of horse mackerel for the purse seiners they will leave this fishery. The Norwegian fishery is not regulated within the Norwegian zone and is therefore considered to reflect the availability and abundance of horse mackerel in this area during the autumn.

Based on results from egg surveys and the spatial and temporal distribution of the fishery ICES are considering the horse mackerel in the North East Atlantic area as separated into three management units (stocks); southern-, western-, and North Sea horse mackerel (Anon., 1990, Anon.,1996a). They are named after their spawning areas. The western horse mackerel are spawning west and south west of Ireland. It is assumed that western horse mackerel at least since the early 1980s has adopted the same migration pattern as western and southern mackerel (Anon., 1990, 1991, 1996b, SEFOS, 1997). After spawning (late July) in the area south west and west of Ireland the fish migrate northwards to the Norwegian Sea and North Sea. It seems that the horse mackerel enter this area later than mackerel and also leave the area earlier. The main Norwegian fishery for horse mackerel is carried out in October, while the mackerel is available in considerable quantities in the same area during the third-, fourth- and some years also in the first part of the first quarter of the following year before they migrate back to the spawning area. This migration pattern for western mackerel is confirmed by Norwegian tagging experiments since 1969 (Bakken and Westgård, 1986, Iversen and Skagen, 1989) and for southern mackerel by Spanish tagging experiments in 1994 (Uriarte, 1995). In the later years Spain has tagged horse mackerel, but so far no tags have been recovered.

The Norwegian fishery for horse mackerel in the Norwegian economical zone was quite small until 1987 when the catches increased to 15 000 t and further to a maximum of 127 000 t in 1990 (Figure 1). After that the catches declined by 60 % in 1991 and then increased in 1992 and in1993 to the same level as in 1990. Since then the catches dropped to about 95 000 t in 1994 and 1995, to15 000 t in 1996 and increased to 46 000 t in 1997. Little is known about the age composition of the Norwegian catches before 1991. However, based on length frequencies in the catches, and Dutch age readings, it seems that the extremely rich 1982 year class have dominated the Norwegian catches since 1987. Only fish older than five years seems to undertake the long journey to the waters fished by Norway. Surveys in the Norwegian Sea have demonstrated that the largest horse mackerel are migrating the longest distance (Holst and Iversen, 1992). The 1982 year class has also dominated the catches of western horse mackerel in other areas since 1984 (Anon., 1997). The total catches of western horse mackerel are known for the period 1982-1996 (Anon., 1998) and increased from about 40 000 t in 1982 to 510 000 t in 1995 (Figure 2) after that the catches dropped to about 400 000 t in 1996. The total international catches for western horse mackerel in 1997 seems to be at the same level as in 1996 (Iversen pers. com.). Particular since 1993 it seems that horse mackerel was relatively more available for fishing fleets working in the western area than for the Norwegian fleet.

Factors trigging the migration

The migration is undertaken for feeding purposes. The changes in the fishery in the Norwegian fishing area and thereby changes in migration might be explained by at least two factors:

1. Variations in stock size

2. Changes in hydrographical conditions affecting the migration and catchability directly or indirectly by affecting the feeding condition

The ICES Working Group has estimated the spawning stock biomass (SSB) for the period 1982-1997 by the ADAPT analysis (Anon., 1998) (Figure 3). The spawning stock has been measured every third years during the western mackerel and horse mackerel surveys (Anon., 1996a). Particularly during the period previous 1992 the ADAPT based SSB estimates are overestimated considerably compared with the estimates based on the egg surveys. The ADAPT analysis is carried out particularly to calculate the development of the SSB after the last eggsurvey in 1995. The spawning stock has declined since 1988 because no new strong year classes have been observed to recruit the stock since the very rich 1982 year class. It is impossible to tell if the size of SSB is the only or main factor trigging the migration to the North Sea and Norwegian Sea. Neither is there so far much knowledge of what minimum level the stock size has to be for trigging this. According to the egg survey based SSB estimates (Figure 3) it seems that the SSB has to be larger than the level estimated in 1986, i.e. 750 000 t before migration is trigged. The very numerous 1982 year class was probably previous 1987 individually to small to undertake that long migration.

Since the horse mackerel caught by the Norwegian fleet is migrating into their fishing areas from the western spawning area the availability of fish for this fleet might be linked to the inflow of Atlantic water. This has been estimated by the NORWegian ECOlogical Model system (NORWECOM).

The model design

The NORWECOM (Skogen 1993, Skogen et al., 1995) is a coupled physical, chemical, biological model system applied to study primary production and dispersion of particles (fish larvae and pollution). The main weakness of 3-D modelling activities claiming to simulate nature is the lack of comparison with adequate real data. Therefore the extensive SKAGEX data set (Danielssen et al., 1991, Danielssen et al., 1997, Ostrowski, 1994) has been used to validate (Dee, 1994) the model (Svendsen et al., 1996, Skogen et al., 1997). The model has also been used to investigate long-term residual transports in the North Sea together with two other models (Smith et al., 1998), and taken part in several models to model intercomparison studies (Røed et al., 1989, Gustafsson and Jønsson, 1995, Proctor et al., 1997).

The circulation model is based on the wind and density driven primitive equation Princeton Ocean Model (Blumberg and Mellor, 1980, Mellor, 1996). In the present study a 20 x 20 km horizontal grid covering the whole shelf area from Portugal to Norway, including the North Sea, has been used (Figure 4). In the vertical the model uses12 sigma layers.

The forcing variables are six-hourly hindcast atmospheric pressure fields provided by the Norwegian Meteorological Institute (DNMI) (Eide et al., 1985, Reistad and Iden, 1995), 6-hourly wind stress (translated from the pressure fields by assuming neutral air-sea stability), four tidal constituents and freshwater runoff. To absorb inconsistencies between forced boundary conditions and model results, a 7 gridcell "Flow Relaxation Scheme" (FRS) zone is used around the open boundaries (Martinsen and Engdahl, 1987). In the lack of data on the surface heat fluxes, a "relaxation towards climatology" method was used (Cox and Bryan, 1984). During calm wind conditions, the surface temperature field will adjust to the climatological values after about 10 days (Oey and Chen, 1991). The net evaporation precipitation flux is set to zero.

The model runs

The model is initiated from monthly climatologies (Levitus, 1982; Martinsen et al., 1992) for December. Each run has started on December 15, and after a two week spin-up time, model results has been stored as daily values (25 hourly means) from January 1. In Figure 5, the mean (1976-1997) modelled residual currents for winter (January, February and March) at 10 m depth are given. Based on the 25 hourly mean current fields, average (daily) transports into the North Sea through an east-west section going from Norway to the Orkneys (along 59°17' N) has been computed. From these daily values, monthly transports are estimated for each of the modelled years (1976-1997). The winter volume flux is defined as the mean of the January, February and March fluxes.

Conclusion

The estimated fluxes and catches of mackerel since 1976 are shown in Figure 6. In the period of significant Norwegian catches (1987-1997) the catch level are strongly related to the influx level. It therefore seems that when the western horse mackerel stock is migrating, the amount of fish entering the Norwegian area are closely correlated to the influx of Atlantic water (Figure 7). This correlation might be used for predictive purposes. For 1997 the model predicted an increase in the catch from 15 000 t in 1996 to about 70 000 t (Iversen et al., 1997) which corresponded with the actual catch of 46 000 t. Given that the stock size in 1998 is still above the level trigging significant migration to the North Sea and Norwegian Sea, a modelled influx this winter of about 2.11 Sverdrup predicts a Norwegian catch of about 30 000 t during the coming season. Standard error of the predicted catches are calculated by SYSTAT to be 24 000 t.

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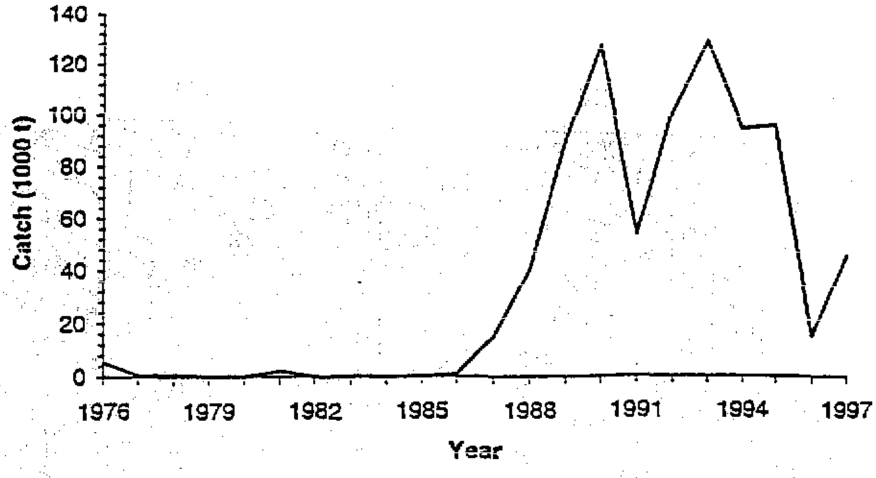

Fig. 1 Norwegian catches of horse mackerel during the period 1976-1997

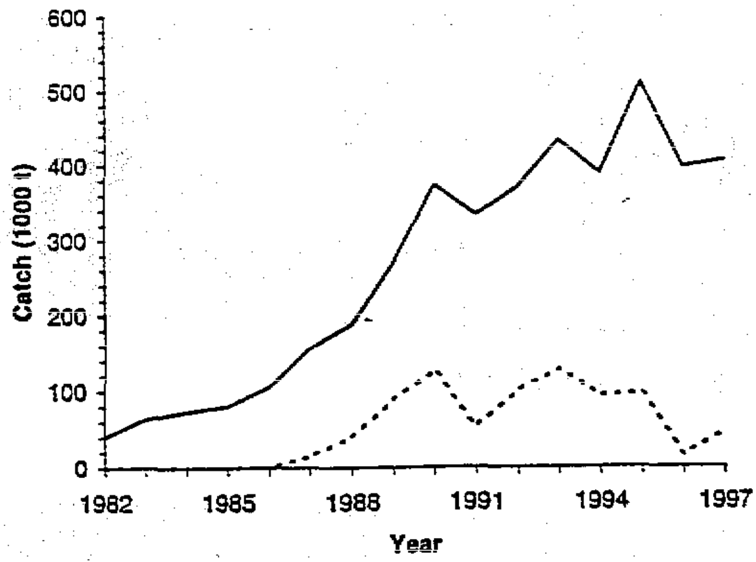

Fig. 2 The Norwegian catches (dotted line) compared with the total catches of western horse mackerel since 1982.

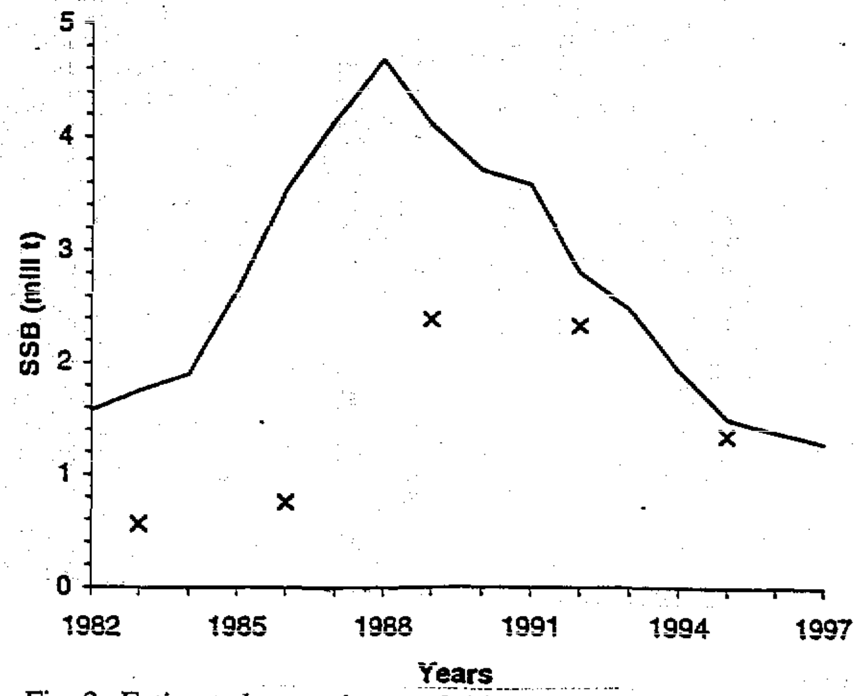

Fig. 3 Estimated spawning stock biomass (SSB) by the egg production method (x) and by the ADAPT analysis (line) of western horse mackerel, 1982-1997, (Anon., 1996a, 1998).

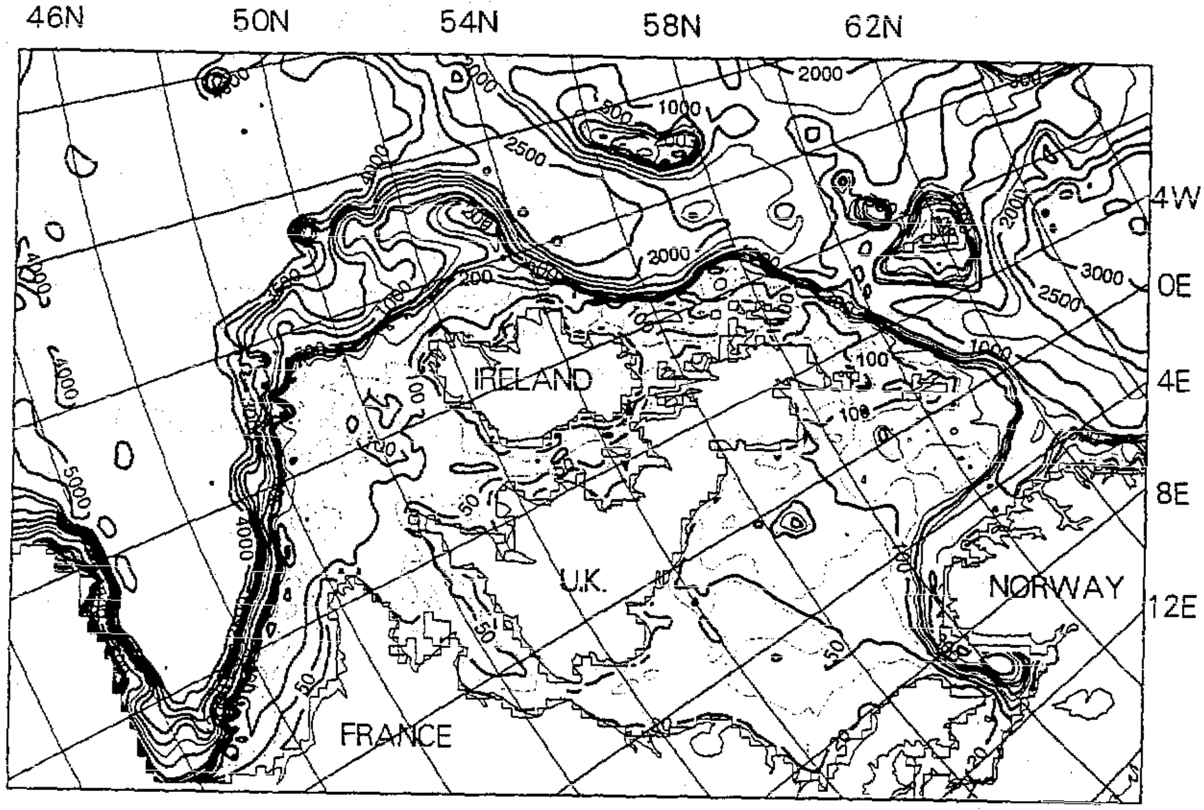

Fig. 4 Bottom topography in the modelled area.

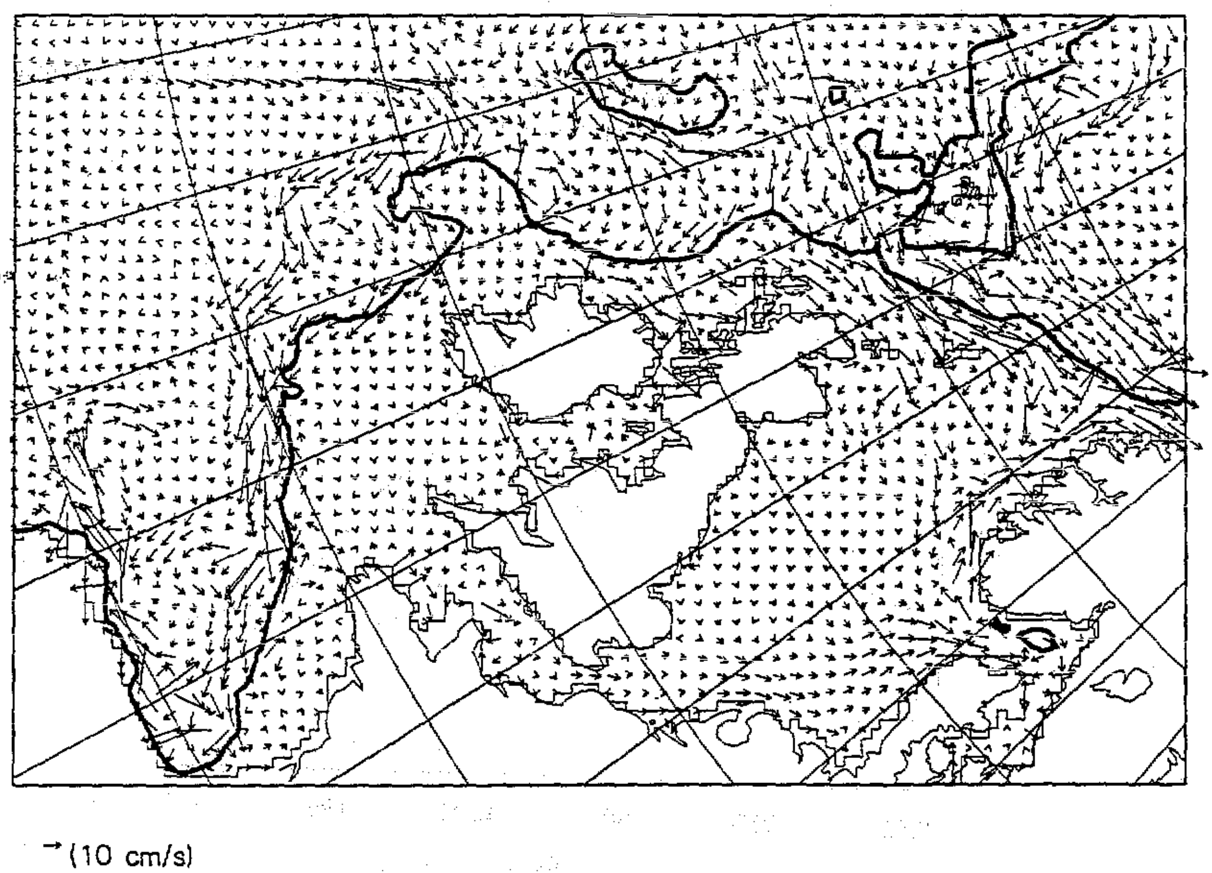

Fig. 5 Modelled mean flow field for January, February and March at 10 m depth. The solid line is the 500 m depth contour.

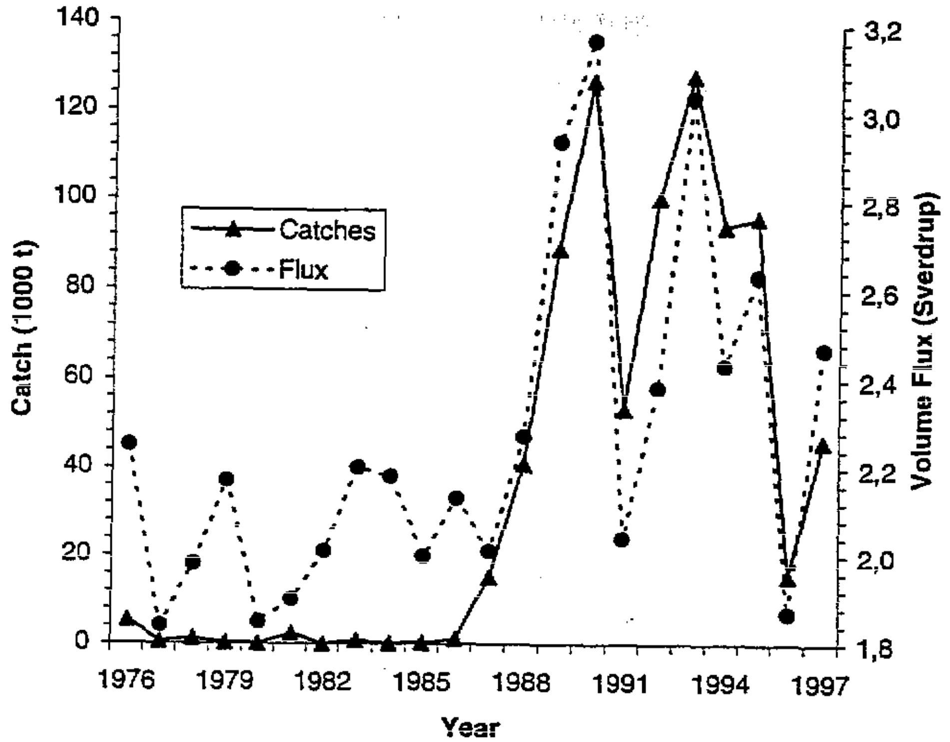

Fig. 6 Norwegian horse mackerel catches and winter volume fluxes for the period 1976-1997.

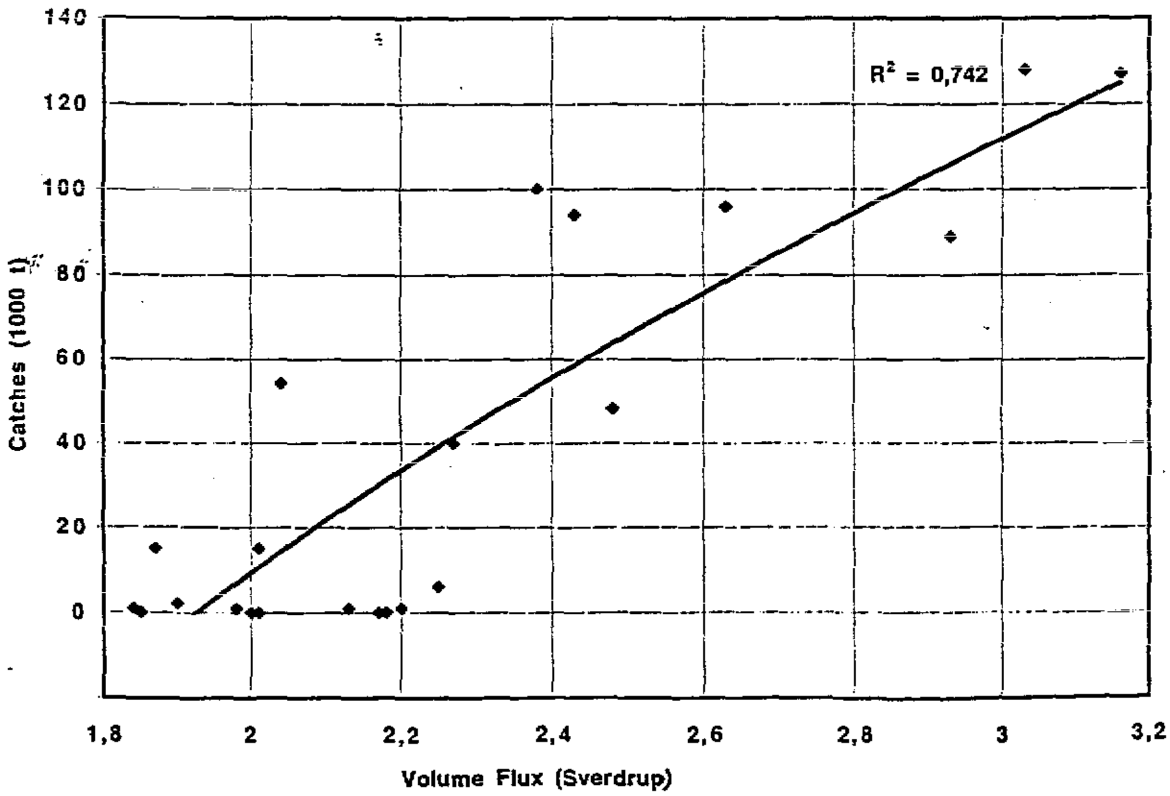

Fig. 7 Norwegian horsemackerel catches versus winter volume fluxes 1976-1997.