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The impact of technological progress on fishing effort

Final report

Lot 10 - Call for tenders Nº XIV-C-1/99/02

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Summary

The subject of this study is related to the Multi-Annual Guidance Programmes (MAGPs), specifying target sizes for various fleet segments in terms of aggregate engine power (kW) and tonnage (GT). Technological progress may make vessels more efficient, leading to higher catching capacity per kW or per GT and thus undermining the MAGPs. Therefore the main objective of the study is: *'... to quantify increases in fishing effort attributable to technological progress'*.

To focus only on this objective would imply a too narrow concept of technological progress in the fishing sector. Technological progress is connected with the introduction and adoption of innovations in a broad range of fields not all affecting fishing effort.

In view of this, the study began with a classification of technological progress, including two aspects: a) the motives for the vessel owners to implement technological improvements; b) the different kinds of technological progress such as innovations in vessel design and lay out, gear and equipment; organisational innovations were also included.

Technological progress in four fisheries was studied: the Dutch beam trawl fishery for flatfish, the Danish trawl fishery for cod in the Baltic Sea, the Scottish pelagic fishery and the Gulf of Lions trawl fishery.

A qualitative analysis combined a general description of the fishery with an application of the classification and the results of interviews with vessel owners and suppliers on the character, motives, effects and timing of the adoption of technical innovations. Following the qualitative analysis, a statistical analysis was undertaken to investigate factors influencing technological progress and to assess the effects of technological progress on productivity and thus on effective fishing effort (= mortality).

Dutch beam trawl fishery for flatfish

The qualitative analysis arrives at a variety of factors that have had a negative effect on the fishing power of beam trawlers in relation to their main characteristics, tonnage and main engine power. To mention are: the shift to large beamers, the change in tonnage measurement system, the technical measures increasing the minimum mesh size and decreasing the allowed beam length and, probably most important, the stricter control and enforcement of ITQs of plaice and sole.

Innovations in the beam trawl fishery were mainly directed at improving working conditions and safety, better product quality and cost reductions. Only a few instances could be found where innovations were primarily directed at improving catching performance. The most important of these were improvements in boat design and propeller efficiency increasing the pulling power of both modern Eurocutters and 2000-HP beam trawlers.

A time series analysis of catches per unit of effort (kW-days) indicates a continuous downward trend of mortality per unit of physical effort for plaice. For sole this ratio is go-

ing down steeply during the eighties and rising again less steeply during the nineties. The latter may be resulting from technological progress, but other factors may be involved as well.

Econometric analysis, involving the estimation of a production function, shows annual increases of productivity due to disembodied technical change (= external shift forces) of 1.5 to 2% during the eighties, rapidly dropping to around zero change after 1990. The resulting total change in productivity since '83 was 18% in '93 and increased no further since. The drop coincides with the implementation of stricter control and enforcement of ITQs.

The results of the CPUE/stock ratio time series and the econometric analysis are contradictory. The econometric analysis is not completely conclusive, as it had to be based on revenues and not on landings/catches, with unclear effects of price fluctuations. However, it appears fairly certain that technological progress has had very little impact on the effective beam trawling effort during the last decade of the 20th century. This seems to be primarily due to the progressively achieved full compliance with the ITQ system for plaice and sole.

Danish cod trawl fishery in the Baltic Sea

A multi-gear fleet exploits the Baltic cod fishery, although trawling vessels have been the dominant vessel type. The trawling fleet is ageing (average age over 30) with the majority of vessels having retained their original wooden hull configurations. The cod fishery is most concentrated during the winter months, with some vessels entering other fisheries and areas during other parts of the year.

The statistical analysis clearly indicates that capital investments have contributed substantively to output production. This effect has been most prominent during the 1987-93 period. There seems to be a clear downward trend in the contribution of technological progress to output since 1993, except perhaps 1996-97, at least in part due to the reduction in exhibited investments. This evolution is in line with the general trend of the fishery that has seen a decline in cod stocks and overall production. The analysis seems to support the qualitative information from interviews that indicate that fishers have had few incentives to invest in new technologies during the latter half of the 1990's. The findings also seem to indicate that the vessels have been less efficient in the latter period, enjoying less success than during the period when the fishery was highly profitable.

It is acknowledged that the statistical analysis undertaken has resulted in a comprehensive list of findings on the fleet and vessel level, in terms of production and performance indicators as well as their relationship with technological progress. It is currently outside the scope of this report to review all these findings. Furthermore, although technological progress is often tied to the idea of increasing production, it is evident that some capital investments also aim to reduce operating costs, improve safety and working conditions, and help to diversify fishing strategies. These are obviously more difficult to quantify here, although an extended analysis that incorporates cost and earning data would provide a sufficient basis for analysing potential changes in the cost structure of vessel operations.

The findings of this report suggest that technological progress undermines reductions in fishing effort under MAGPs. The overall contribution of technological progress has been 1.8% per annum, largely driven by high values of technological progress during the 1987-93 sub-period. However, the difference observed during the 1987-93 and 1994-99 sub-periods implies that progress has stagnated significantly and currently has a limited impact on fishing effort. This is an important finding that must be considered when adopting a management strategy. It is clearly apparent that resource availability and quota ration restrictions have influenced fisher strategies and investment behaviour, and will also restrict the possible output of each vessel. This trend can be expected to continue. Therefore, a significant contribution of technological progress to increased production in the future would not be expected, unless cod stocks recover to the levels of the 1980's or an appreciable restructuring of the fleet occurs.

Scottish pelagic fisheries

In the case of the Scottish pelagic sector, the perception is that capacity has increased substantially with a significant change in vessel structures. The fear is that irrespective of the fact that fleet rationalisation has taken place through licence aggregations and a reduction in the number of small scale pelagic vessels targeting herring and mackerel, the reduction in the nominal size of the fleet segment has not lead to the desired equivalent reduction in fishing mortality. However, fishing mortality has remained remarkably stable in the last decade and a half whilst the technological inputs on a boat by boat basis have increased substantially through a number of innovations.

There is little evidence from within the Scottish pelagic fishery that technical progress undermines MAGPs. It is also incorrect to assume that technical advancement will inevitably lead to an increase in output.

Technical change will achieve cost savings. This will in turn increase the level of investment within the fleet but production constraints (i.e. transferable quotas and licence aggregation penalties) provide a facility to ensure that catch will be kept within manageable limits.

Technical creep or technical change is not necessarily responsible for reducing effort. It simply indicates that a higher level of landings is possible given the same level of effort and other factors. It would, however, allow fishermen the ability to reduce effort with no change in catch or to maintain the same level of catch with a reduction in effort - which would also yield cost savings. Both of these factors have taken place in the fishery. Such a finding would suggest that the quota constraints allied by the ability to transfer quota between the vessels are sufficient to constrain output.

It is widely recognised that vessel size and engine power are key variables in the fishery. Existing data on vessel size is presently inaccurate for a large number of the 11 super trawlers. This issue needs to be rectified. As a result, nominal engine power is no longer a reliable indicator of fishing capacity. It is recommended that a new series to be used as the basis for MAGP be put into place rapidly.

As the statistical analysis makes clear, size and power are not the only elements determining fishing performance. In fact, increases in size and power should not necessarily be interpreted as increasing output. There are other reasons why these variables increase -

range, safety and fish storage. A movement to larger vessels in this fishery is inevitable given the requirement to steam to more distant market outlets.

Other variables are clearly important. The statistical analysis within this report has failed to identify most of these simply because the fishery has been unregulated for so long. A further review will therefore have to be undertaken at some stage against the background of behaviour in a regulated fishery.

It is also important not to seek to attempt to apply a global estimate of technical creep for a sector with many different components. The analysis of the Scottish fleet has revealed three sub sets of vessels. A broader examination of other vessels from the other European fleets, for example freezer trawlers, could reveal markedly different results.

The ultimate objective of the MAGPs is to reduce fishing capacity to bring it into line with the catches available on a sustainable basis. A legitimately managed fishery with the facility to trade quota results in some technical efficiency but for the purpose of achieving cost savings. As profitability increases, the vessels will find themselves either competing for more quota or reducing the time spent at sea. An alternative scenario might be for some vessels to seek to find other fisheries (e.g. Irish and Dutch pelagic vessels operating off Mauritania). The enhancement in prices has increased the pace of change amongst the fleet and if sustained will lead to fewer vessels in the fishery.

On the basis of the above experience, fishery managers should seek to explore the impact that ITQs would have on other fisheries. If technical creep is leading to an increase in output, then a quota trading environment could be an adequate means of controlling fishing effort.

Gulf of Lions trawl fishery

A major difficulty for fishery management in the Mediterranean is the method used to evaluate fishing effort based on tonnage (GRT) and engine power (kW). Two factors must be mentioned.

The statistical analysis carried out in this study supports the view that technical progress undermines MAGPs. The best estimate of the extent to which this occurs is of 1.07% per annum over the whole period 1985 to 1999, rising to 1.49% per annum if only the most recent sub-period of 1994 to 1999 is considered. These figures must be considered as tentative. They are average figures which mask considerable variability between vessels and between years. It has not been possible within the confines of this relatively short study and within the confines of data availability to provide more accurate estimates. It is suggested that a fuller study of the French Mediterranean trawl fishery is required in order to determine more accurately the appropriate correction to use in MAGPs in order to allow for technical progress.

Input substitution has clearly occurred with inputs other than engine power being used to increase the traction power of vessels, and inputs other than traction power being used to increase the fishing performance of vessels. The problem of input substitution is a well-known problem of effort-based management, and it certainly seems to be an important phenomenon in the Mediterranean trawl fishery.

Data problems
Notwithstanding the discussion above, it is widely recognised that engine power is a key variable in the fishery. But the data concerning it are unreliable. As a result, nominal engine power is no longer a reliable indicator of fishing capacity. It is recommended that a new series to be used as the basis for MAGP be put into place rapidly. In developing this series, two considerations need to be borne in mind.

The series needs to integrate as many elements as possible determining the traction power of the vessel. A proposition has long been made (ISTPM, 1974) for the use of bollard pull (traction à point fixe). Although there will inevitably be some input substitution associated with this measure, on the whole it provides a much better indicator of the fishing power of vessels than engine power and appears much more difficult to circumvent. It integrates most of the different inputs used on the vessel to provide traction for the trawl. A new series would be relatively easy to institute.

As the statistical analysis makes clear, traction power is not the only element determining fishing performance, even in a trawl fishery (and even less so in other kinds of fishing). Insofar as possible therefore there is a need to develop a series that incorporates the impact of other inputs, such as electronic equipment.

Fishery management strategy
The ultimate objective of the MAGPs is to reduce fishing capacity to bring it into line with the catches available on a sustainable basis. Three observations may be made.

The current segmentation in the French Mediterranean trawl fishery appears too broad to allow this goal to be achieved. There is no mechanism to prevent large changes in capacity between target species in accordance with relative profitability (which will depend on resource abundance and prices amongst other things). It is recommended therefore that the issue of appropriate segmentation should be re-considered in the fishery.

Related to the above point, the current strategy is to try to reduce fishing pressure in particular on demersal species. Part of the strategy is to encourage trawlers to target small pelagics, partly through public support towards modernisation of the fleet: the idea being that fishers will be able to fish stocks of small pelagics located further offshore than the main demersal stocks. But since the current licensing system allows fishers to change target species within a single trip (if they so wish) there is no way to ensure that the impact of modernisation is not ultimately increased pressure on demersal stocks, particularly in situations where the market for small pelagics becomes unfavourable. It is suggested therefore that the appropriate definition of management units should be re-considered at the same time as the issue of segmentation.

This study demonstrates the importance of keeping fisher behaviour in mind in designing fishery management measures. The economic, and other, factors which determine such behaviour as generally poorly understood and yet they play a key role in determining the success or failure of management measures, including measures such as MAGPs. In the French Mediterranean, part of the management strategy is to encourage, using subsidies, fishers to invest in larger vessels so that they will target pelagic species further offshore. The expectation is that this will reduce pressure on demersal stocks found closer inshore. In a situation where the factors that determine fisher behaviour, including location choice and target species, are not well understood, this strategy runs certain clear risks, particularly given the current segmentation and licensing arrangements.

Conclusions

The results obtained differ quite substantially from one case study to another and sometimes even within the fleet segments studied. If in the MAGPs allowance should be made for technical progress, applying a standard correction factor (be it 2% per annum or any other figure) does not seem to be a valid option. It appears that segment by segment adjustments would have to be made and such adjustments will have to be verified over time and, where necessary, modified. This would add another complicated cycle of research and assessment to the EU fisheries management decision making process for a fairly marginal effect. Moreover, the case studies illustrate that well enforced quotas can effectively curb the impact of technical progress.

The study identifies two main sets of factors that give rise to differing results. First, there are many motivations for technical progress; second, the impacts of technical progress differ from situation to situation.

The hypothesis underlying the use of an 'MAGP-correction factor' is that technical progress affects the quantity of fish caught. However, the principal economic reason for technical progress is to increase profitability. Increasing the quantity caught is only one way to increase profitability. As the various case-studies make clear, profits may also be increased by selling the same (or even a lesser) quantity for a higher price (hence the emphasis on markets and quality in the case, for instance, of Scottish and Mediterranean pelagic trawlers). Similarly, profits may be increased by fishing the same quantity at lower cost (as appears to be the primary motivation for technical progress in the case of Dutch beam trawlers).

There may also be non-economic factors explaining investment in technical progress, in particular desires for safety or generally-improved working conditions.

Depending on the motives for technical progress, the implications for fishery management and for MAGPs in particular may be quite different. This conclusion highlights the need for an understanding of the economic behaviour of fishers.

The major factor determining the impact of technical progress is the nature of the fishery management system. Where economically-based management systems have been implemented, particularly individual transferable quotas, technical progress appears to have little effect on catch (as predicted by economic theory). The consequence is that the extent to which technical progress appears to have undermined MAGPs differs significantly from case study to case study and over time. Hence in the case of the Netherlands and Scotland where ITQs appear to work now quite effectively, there appears to be no evidence of MAGPs being undermined. In the Baltic, the situation has changed over the period from one where there was quite a substantial impact to one where there is only a negligible one. Only in the case of the Mediterranean, where fishery management remains effort-based, does input substitution (through technical progress) appear to undermine the MAGP.

The conclusion is therefore that in deciding on MAGP targets and whether to correct for technical creep, there is a need to take into account the nature of the management system in the fishery concerned.

1. Introduction

This report results from the Call for tenders n° XIV-C-1/99/02 'Studies and support services related to the Common Fisheries Policy' of 6 August 1999, specifically Lot 10 of this call: 'The impact of technological progress on fishing effort'.

The subject of this study is related to the Multi-Annual Guidance Programmes (MAGPs). These Programmes specify target sizes for various fleet segments in terms of aggregate engine power (kW) and tonnage (GT). The reduction sought in each segment is based on the desired reduction in fishing effort, which is expected to lead to a similar reduction in fishing mortality.

Technological progress may make vessels more efficient, leading (ceteris paribus) to higher catching capacity per kW or per GT. In the considerations going with the third MAGP for the period 1993 to 1996, the increase from this kind of efficiency has been assumed to be 2% annually. The tender document mentioned specifically that *'new vessels are more efficient than old ones as a result of technological progress'*. Therefore the reduction in the nominal size of the fleet will not lead to the desired equivalent reduction in fishing mortality. In view of this problem, the main objective of the study has been defined as *'... to quantify increases in fishing effort attributable to technological progress'*.

Quantification of the effect of technological progress on fishing effort is hampered by bias from other variables such as the ability of the skipper and the crew and also by uncertainties in the measurement of technological change.

Moreover, to focus only on this objective would imply a too narrow concept of technological progress in the fishing sector. Technological progress is connected with the introduction and adoption of innovations, and in fisheries this also occurs for a variety of reasons in a broad range of fields without affecting the fishing effort:

- vessel owners may implement new technologies for safety reasons or to improve the working conditions for the crew;
- innovations may be adopted because of changes in market conditions or to improve fish quality;
- investments may be induced by a higher cost efficiency so that the same quantity can be caught with less cost;
- regulations may lead to technological changes affecting the fishing effort negatively, such as mesh size rules and other gear restrictions;
- fishing rights may effectively prevent that technological progress has a higher impact on fishing effort. This can be the case with individual transferable quota (ITQs) where vessel owners have to acquire additional quota rights if they implement innovations that increase the productivity of the vessel.

In view of these considerations, the study began with a classification of technological progress, focussing on two aspects: a) the motives for vessel owners to implement technological improvements; b) the different kinds of technological progress such as innovations in vessel design and lay out, gear and equipment; organisational innovations were also included. Annex 1 presents this classification of technological progress.

Technological progress in four fisheries was studied: the Dutch beam trawl fishery for flatfish, the Danish trawl fishery for cod in the Baltic, the Scottish pelagic fishery and the trawl fishery in the Gulf of Lions from the port of Sète.

Vessel owners and suppliers for each of those fisheries were interviewed to obtain insights into the kinds of technological progress that have been implemented, the reasons for doing this and the year(s) of innovation. A 'Standard questionnaire' for the interviews is included in annex 2.

Following the qualitative analysis of each of the fisheries studied, a statistical analysis was undertaken to investigate factors influencing technological progress and to assess the effects of technological progress on productivity and thus on effective fishing effort (= mortality). In undertaking the statistical analyses, the study team was assisted by James E. Kirkley of the Virginia Institute of Marine Science, an expert in the field of fisheries econometrics, particularly on the measurement of fishing capacity [1], and Catherine Morrison-Paul of the University of California, an authority on economic capacity. But the study partners are, of course, responsible for the conclusions drawn from these analyses.

The methodology applied for all cases was an econometric one, implying the estimation of a production function (basically a multiple regression analysis). For a varying set of boats over a range of years, production was explained by variables on capital, effort, fish stock, changes of equipment and time. The impact of technological progress was assessed by measuring the shifts in productivity over time. As an extra, a stochastic production frontier analysis was done, generally leading to similar results. The methodology has been described most extensively for the Gulf of Lions case (Annex 6), the first case that was analysed.

The results of the case studies have been summarised in chapter 2 'Results'. Full reports of each case study are presented in annexes 3 to 6. Chapter 3 discusses the results of the case studies and presents conclusions for the full study.

[1] James Kirkley is (co-)author of 5 out of the 26 background documents for the FAO Technical Consultation on the Measurement of Fishing Capacity in Mexico City, 29 November - 3 December 1999 (FAO Fisheries Report No. 615, Rome, 2000).

2. Results

2.1 Dutch beam trawl fishery

2.1.1 Description of the Dutch beam trawl fishery and qualitative analysis

2.1.1.1 Fleet, performance, dynamics

The beam trawl fishery for flatfish is one of the largest fisheries of the North Sea, with annual landings of about 130,000 tons and a turnover of around € 400 million. The Dutch beam trawl fishery represents some 60% of this fishery in terms of landing value and takes some 80% of total North Sea sole catch and 50% of North Sea plaice. The fleet by the end of 1998 consisted of 204 vessels with a total engine power of 273,590 kW and total tonnage of 71,405 GT.

The Dutch beam trawlers belong to two MAGP segments, the smaller ones to the segment of Eurocutters (up to 221 kW) and the bigger ones to the >221 kW segment. The number of vessels in these two segments was 43 and 161 respectively by the end of 1998.

The target species of the fishery are sole and plaice with important by-catches of turbot, brill, dab, flounder, cod and whiting. Because of the weekly trip pattern the annual number of days at sea for the beamers is 240 at maximum.

Individual transferable quota (ITQs) for sole and plaice limit the catches effectively, in particular since the introduction in 1993 of the co-management PO-groups. Since 1985, horsepower licences restrict the capacity of the beam trawling fleet and Gross Tonnage (GT) restrictions were implemented in 1998 to comply with the MAGP IV targets. The effort is regulated by days-at-sea limitations, with the annual number of days allocated on the basis of the ITQs and engine power.

The economic performance of the beam trawl fleet has been rather good since 1991. In 1998 the total profit increased to almost € 15 million but the situation has worsened in the second half of 1999 due to the drastic increase of the fuel price.

The fishery was at a lower level in 1998 than in 1983 in terms of boat number, total capacity (kW) and volume of catches. The number of vessels and the catches have declined the most (by 30-35%) in this period.

There has been a tendency towards bigger beam trawlers, which has had a decreasing effect on productivity. This is because the production per unit of effort - measured in kW-days - diminishes when the engine power of a beamer increases. Although the total engine power of the beam trawler fleet was at nearly the same level in 1998 as in 1983, the impact on the fish stocks was in fact less because of this lower productivity.

2.1.1.2 Technological change

The general layout of beam trawlers has basically not changed since the early seventies and also the engines of the vessels remained essentially the same. There are indications that the modern Eurocutters and 2000-HP beamers have a relatively high fishing power, which can, at least partly, be explained by the fact that all power is reserved for propulsion. The improved design of the propulsive system as a whole has also contributed to a higher fishing power because of the resulting increase of pulling power. Some innovations in the field of navigational equipment can be assumed to have had a positive effect on fishing performance. Gear innovations were mostly directed at avoiding unwanted by-catches and reduction of wear and tear, but some have raised the catching performance.

A comparison between 'old' and 'new' 2000-HP beamers points out that the new ones perform 15-18% better on a per kW-day basis than the older vessels. But this may also be attributed to better skippers and crew. If on the other hand gross tonnage is used as a proxy for fishing power the outcome is the opposite: the older boats perform about 18% better per GT per day at sea.

The technique of beam trawling has not changed essentially in the past couple of decades. Regulations prescribing bigger mesh sizes and the maximisation of the beam length have affected the catches negatively, probably in excess of positive effects of technological progress.

The operational management of the firms in the beam trawl sector has changed importantly because of the ITQs and the security of these that is guaranteed by the co-management groups. This has consequences for productivity improvements, since these would require acquisition of extra ITQs or, alternatively, reduction of the number of days at sea.

2.1.2 Statistical analysis

2.1.2.1 Catch per unit effort to stock ratios

Technological progress is expected to bring about increases in fishing mortality rates. Such increases should become apparent in an increasing ratio of CPUE to stock biomass, a proxy for the mortality brought about by a unit of physical effort (in kW-days at sea). For both target species these ratios were estimated from a combination of time series of beam trawling effort in kW-days, landings of plaice and sole and stock biomass.

It appears that the CPUE to stock ratio of plaice for the Dutch beam trawling fleet has declined since 1983 by about one third. For sole, the ratio of CPUE to stock size dropped to about half the '83 level in 1989, but it more or less recovered half that loss again during the nineties.

The downward moves for both species may well be a result of the reduction in productivity connected with the structural change in the beam trawler fleet towards bigger boats. The change in trend of the sole ratio coincides with the recruitment of the strong '87 year-class that marked the return of the inclination of the fleet towards sole, after a period when the accent was more on plaice. The rising trend is an indication of improving catching efficiency that could be connected with technological progress. Another explanation may be the ongoing specialisation on sole, as plaice quotas have been reduced considerably during the nineties.

2.1.2.2 Econometric analysis

From the database on the LEI costs and earnings panel over the period 1983-1998 a set of data was selected on 52 boats, spending at least 80% of their time on beam trawling. These boats were in the panel for at least half the period or commissioned during the last eight years and still in the panel. Per MAGP segment, the boats of the resulting sample are on average slightly more powerful and bigger and younger than the average beam trawler in the fleet by the end of 1998, but their engines are marginally older. The sample is fairly representative for the large beamers; for the Eurocutters it is chiefly representative for the modern, big and powerful boats, as the boats with more mixed fisheries were excluded.

The data included in the set comprised capacity indicators tonnage, engine power, length and year built of hull and engine, and activity measures days at sea and months active. Crew size, fuel consumption, propeller characteristics and change of ownership were added as potential extra indicators of fishing power. For the result of fishing effort, annual revenues and landings in total as well as for plaice and sole separately were included. Regrettably, landing volumes for the individual boats were only occasionally recorded during the eighties and the same goes for revenues of plaice and sole. In fact, only for total revenues full time series are available.

In addition to these per boat data, a set of general data per year was composed of biomasses of plaice and sole, inflation index and fishery management measures like mesh size increases, beam length restrictions, introduction of plaice box, etc.

The econometric analysis implied the estimation of a log-linear Cobb-Douglas production function. On the basis of preliminary investigations most of the 'additional' variables were skipped, as they appeared to make no significant contribution or were not available throughout the data set. Eventually the function was composed of total revenues (corrected for inflation) as dependent variable; tonnage, engine power and length as 'capital' variables; crew size, days at sea and plaice and sole biomass as 'effort' and stock variables; and time as a variable to catch the 'disembodied' technical change drivers or other factors beyond the control of the vessel operator. In addition, cross terms for plaice stock with days at sea and sole stock with crew size, and for time with stocks of plaice and sole, tonnage and engine power were included. Finally, change of ownership was included, together with dummy variables for 48 of the 52 boats. No specific technical change variables were included to add to the explanation of the 'embodied' technical change.

(As an alternative, a Stochastic Production Frontier Analysis was done with the same set of variables. The results were very much in line with those of the Cobb-Douglas approach and it therefore has been left out of further consideration.)

The estimated parameters of the production function show some interesting effects. The most relevant for our study are that tonnage has a negative effect on production (= revenue) directly as well as over time, and that engine power has a similar but week direct effect that is overruled by the strongly positive effect of power over time. Generally the differences in productivity between boats, taking all other factors into account, are relatively small (between -1 and +1 %) except for four modern Eurocutters that do about 2%

better than could be expected on average. Remarkably, there appears to be no relation between the year beam trawlers were commissioned and their performance.

Of the two components of technical change, the 'embodied' technical change (related to changes in capital factors and the adoption of new equipment) is negligibly small, so virtually all impact is incorporated in the 'disembodied' technical change. This can be driven by anything not represented in the model, so a more appropriate indication is 'the impact of external shift forces over time'.

The disembodied technical change for the Dutch beam trawlers was on average 0.8% per year over the whole period considered, but the level changed considerably over time. During the eighties it was gradually rising from 1.5% to 2% from year to year, but it started to drop steeply in 1990 to less than 0.5% after '93 and even slightly negative (but statistically not significantly differing from 0) values over the last three years. Cumulated over the years, productivity of the beam trawlers increased by about 18% since 1983 as a result of the 'external shift forces' over the first ten years and remained at that level since.

The drop in disembodied technical change coincides fairly well with the introduction of a much stricter regime of control and enforcement of ITQs, culminating in a situation of full compliance after the implementation of the system of co-management PO-groups. The rapidly improving fishing situation for sole, with the advent of a very strong year-class, may have contributed to this. Rather unexpectedly, no effect of the mesh size increase or the beam length reduction is discernible. The fishermen may have found ways to compensate for these measures immediately, or price changes may obscure the effects.

On a per boat basis, similar shifts of the impact of disembodied technical change over time are apparent. It is interesting to note that older boats seem to have a slightly higher rate of technical change than more modern ones. The overall negative average change since 1993 comes mainly on account of the boats entering the fishery since 1990.

The results of the CPUE/stock size ratio analysis and the econometric analysis seem to be contradictory. The former shows an overall downward trend when the latter still shows a significant increase in productivity, and exactly when the econometric analysis starts to drop the CPUE to stock ratio for sole begins to rise. Several important factors may contribute to this contradiction. Firstly, the CPUE is based on engine power only, whereas the production function includes power as well as tonnage (plus length), with contrasting effects as indicated above.

Secondly, the results of the econometric analysis may be biased by price effects. Plaice and sole contribute roughly 80% to total revenues of beam trawlers, but the partition between the species has shifted considerably. The accent was on plaice mainly during the eighties, but rapidly switched to sole in 1990. In view of the large price and volume differences between the species and the relatively high price elasticity of sole, strong price influences can be expected. A Fisher price index calculated for the combination of both target species indeed shows strong fluctuations. To assess the impact of this on the results of the econometric analysis would require further study.

2.1.3 Conclusions

The qualitative analysis arrives at a variety of factors that have had a negative effect on the fishing power of beam trawlers in relation to their main characteristics, tonnage and main engine power. To mention are: the shift to large beamers, the change in tonnage measurement system, the technical measures increasing the minimum mesh size and decreasing the allowed beam length and, probably most important, the stricter control and enforcement of ITQs of plaice and sole.

Innovations in the beam trawl fishery were mainly directed at improving working conditions and safety, better product quality and cost reductions. Only a few instances could be found where innovations were primarily directed at improving catching performance. The most important of these were improvements in boat design and propeller efficiency increasing the pulling power of both modern Eurocutters and 2000-HP beam trawlers.

A time series analysis of catches per unit of effort (kW-days) indicates a continuous downward trend of mortality per unit of physical effort for plaice. For sole this ratio is going down steeply during the eighties and rising again less steeply during the nineties. The latter may be resulting from technological progress, but other factors may be involved as well.

Econometric analysis, involving the estimation of a production function, shows annual increases of productivity due to disembodied technical change (= external shift forces) of 1.5 to 2% during the eighties, rapidly dropping to around zero change after 1990. The resulting total change in productivity since '83 was 18% in '93 and increased no further since. The drop coincides with the implementation of stricter control and enforcement of ITQs.

The results of the CPUE/stock ratio time series and the econometric analysis are contradictory. The econometric analysis is not completely conclusive, as it had to be based on revenues and not on landings/catches, with unclear effects of price fluctuations. However, it appears fairly certain that technological progress has had very little impact on the effective beam trawling effort during the last decade of the 20th century. This seems to be primarily due to the progressively achieved full compliance with the ITQ system for plaice and sole.

2.2 Danish trawl fishery in the Baltic

2.2.1 Description of the Baltic cod trawling fleet and qualitative analysis

The Baltic cod fishery has historically been the most valuable commercial fishery in Denmark. The cod is divided into two defined stocks, Eastern and Western Baltic, based on genotypic and phenotypic characteristics. The stocks have fluctuated greatly over the last two decades with the cod fishery seeing a significant reduction in total allowable catches and subsequent landings in 1993-94. The reasons for this decline have been increased fishing mortality and lowered spawning stock biomass in preceding years. Concerns over environmental changes such as rising water temperatures, and salinity and oxygen fluctuations may also explain some of this decline.

A multi-gear fleet exploits the Baltic cod fishery, although trawling vessels have been the dominant vessel type. Trawling vessels have traditionally been of a very mobile nature, with homeports ranging from Bornholm, the Sound and Belts region, and Jutland,

and exhibit great flexibility in terms of fishing strategy, depending on time of year, stock abundance etc. The trawling fleet is ageing (average age over 30) with the majority of vessels having retained their original wooden hull configurations. The cod fishery is most concentrated during the winter months, with some vessels entering other fisheries and areas during other parts of the year.

The main technological and regulatory developments that have influenced the trawling fleet over the 1987-99 period are examined below. There has been no specific time frame for many of the individual developments although it is noticeable that most prominent developments took place before the analysed period, during the 1970's to mid-1980's.

Interviews and literature reviews helped to identify and qualify the most important factors that have affected the performance of individual vessels during the 1987-99 period. The general consensus was that the factor that by far had had the biggest impact on performance, and indeed affected a fisher's incentive to invest in new technologies, was the stock development and management regulations (including quota rations and mesh size restrictions). Furthermore, the general opinion was that the modernisation of the fleet during the period has helped to improve working conditions and safety, whilst reducing operating costs. Investments in technologies to increase production and improve fish quality have been less extensive.

The extent of the development of the cod trawling fleet over the 1987-99 period has been rather limited in comparison to other capital-intensive fisheries in Europe. Incentives to invest have been lacking due to stringent quota (ration) regulations, perceptions of stock uncertainty and poor returns of capital, and strict national capacity restrictions. The existence of ration regulations seems to have specifically stemmed fishers' attempts to increase production and improve competitiveness. Observed technological progress and capital investments have largely concerned structural renovations and maintenance, layout conversions, purchasing of new engines, and general updating of electronics and fishing gears. No specific innovations have been singled out as having had a significant impact on fishing effort. The overriding perception of people involved in the cod fishery is that quota regulations have played the major part in determining fleet investment and production.

2.2.2 Statistical analysis

A statistical analysis of a trawling sub-fleet for the period 1987-99 was undertaken in an attempt to measure the extent to which technological progress has had an impact on fishing effort.

The Directorate of Fisheries databases (vessel register, sales records and logbooks) have provided reliable data for the analysis and have been supplemented by interviews with scientists and fishing industry participants. Due to the flexible nature and seasonal fishing strategies of Baltic vessels, a sub-fleet consisting of 23 trawlers with historical catches of cod in February was used.

Each of the trawling vessels in the sub-fleet over the 1987-99 period, based on Directorate of Fisheries data, has registered February cod landings from ICES area III bcd for each of the given years and is registered as a trawling vessel in MAGP category 4B3.

At least 97% of average February fish landings (volume) of each vessel are from the Baltic Sea, with cod comprising at least two-thirds of these landings. In value terms, February cod landings of each vessel constitute over 75% of landing values. Furthermore, almost 85% of average annual fish landings of each vessel are from the Baltic Sea, with cod representing 50% of annual landing values. The sub-fleet vessels have homeports on Bornholm and in the Sound and Belts regions.

The vessels are all trawlers and all but one are constructed of wooden hulls. In 1999, the vessels of the sub-fleet are between 80-370 kW, 9-74 GT, 9.70-20.00m LOA (length overall), and 14-81 years old. The majority of vessels has used demersal trawls as their main fishing gear, with pelagic trawl and gillnets having been used to a lesser extent. Some vessels have also adopted pair trawling as a means to exploit the fishery.

The principal conclusions of the statistical analysis are outlined below.

Technological change - fleet level

- Technological change for the entire fleet during 1987-99 was 1.8% per annum. Split into two sub-periods, there was an average annual change of 2.8% during 1987-93 and a 0.08% change during 1994-99.
- Technological change for the fleet was fully captured by embodied technological change (capital investments and insurance values) and, hence, disembodied technological change (external time trend factors) was regarded insignificant.
- Capital investment was the main contributor to technological change during 1987-99, explaining 1.6% out of the 1.8% change per annum.
- Capital investments contributed to over 2.5% annual growth in output production during 1988-92, with a maximum growth of over 9% in 1990-91. Except significant growth in 1996-97, the general growth trend stagnated and even included a growth reduction of 2.3% in 1994-95.
- The impact of layout conversions seemed to drive the overall capital investment contribution, especially during the 1989-93 period. The engine power variables showed small contributions to output production, whereas capital investments in GT and LOA seemingly diminished output, potentially due to the effect of management regulation.
- The analysis suggests that the value captured in the insurance value estimate is representative of technological advancements that have had an important contribution to technological change.
- Insurance values have increased their importance in explaining technological change during 1994-99 with the largest positive impact occurring in 1994-95 at 1.5%.

Technological change - vessel level

- Embodied technological change of vessels varied from all-positive average contributions, to no exhibited improvements, to those with only negative impacts.
- For example, two vessels showed clear positive effects of technological innovations of 11% and 7% per annum. Another vessel showed no technological progress over the entire period, whereas a further vessel seemed to have experienced technological regress of about 2% per annum in terms of effective output production.

Fleet production

- The average annual change in output for the fleet was negative, at nearly 3% per annum. The spawning stock biomass (SSB) declined at a similar rate. Both the effort variables (days at sea and landing declarations) increased significantly, suggesting that productivity (output per unit input) declined over the period.
- The number of days at sea appeared to affect output in a negative direction. Holding all other arguments of the function constant, 1% more days resulted in 3.5% less catch. This would imply that greater effort did not necessarily result in greater production. However, potential under-reporting due to management regulations may have had an impact on this relationship.
- An increase in SSB contributed significantly to output, with a 1% increase in SSB resulting in a 0.58% increase in output.

Performance indicators

- Given all other measured characteristics of production, two vessels were higher-than-average producers (averaging 1.5% greater production). One vessel produced more than 2% below average.
- The type of gear affected output significantly, with demersal pair trawling in particular exhibiting significantly higher output. Gillnetting, however, showed significantly lower output on average.
- The results indicate that the technical efficiency of the entire fleet was low, with a reduction in efficiency taking place during the 1994-99 period, compared to the preceding sub-period.

The results seem to support the general evolution of the cod fishery in the Baltic region. The fleet has seen an overall decline in production, a trend that closely follows the decline of the spawning stock biomass. Technological progress has been in the magnitude of 1.8% per annum during 1987-99, although this average somewhat simplifies the evolution. The analysis clearly shows that during the latter part of the 1980's and early 1990's, the fleet enjoyed a period of technological improvements mainly through capital investments, contributing to overall production growth. Following the stock decline in 1993-94, and a consequential reduction in quotas, the fleet seemed to experience stagnation in technological progress, with only a 0.08% annual change during 1994-99 compared to 2.8% in the 1987-93 sub-period. A reduction in overall efficiency of the fleet also seemed to be evident in the latter half of the 1990's. Furthermore, the analysis indicates that vessels have performed differently and have contributed to overall technological progress to various extents (some of which have had a significant negative impact on overall progress).

The analysis has experienced a range of data and modelling obstacles that may have influenced the results, and hence, these results should only be viewed as suggestive rather than precise results.

It is clear that selecting 23 vessels out of a large mobile fleet may give rise to skewed results if one uses the results as an overall indicator for the whole fleet exploiting Baltic cod. The analysis has shown significant variance of technological progress and performance between vessels. Furthermore, the vessel data included in the analysis only comprise landings of cod and other fish in the month of February of each year. Hence, the highly flexible and mobile nature of the fleet may lead to the analysis not taking changing fishing strategies into account. It is possible that conditions of weather, the environment, fish stocks, and markets have played an important role in determining these strategies. Furthermore, the analysis has not distinguished cod landings from other fish landings due to modelling specifications, and so overall landings may have been over- or under-estimated in the model. Misreporting of days at sea and landings may also have been a potential problem.

A further restriction is that simply concentrating on the cod fishery in one month does not account for potential capital investments that are aimed towards other fisheries in other time periods and/or fishing areas. This highlights the general problem one faces when analysing a fleet segment that is able to move between fisheries, areas, and species within a given year. Nevertheless, the analysis is believed to convey a relatively good indicator of the technological progress of the Baltic cod trawling fleet, as the chosen vessels in the sub-fleet have a significant and dominating track record of cod landings during the 1987-99 period.

2.2.3 Conclusions and recommendations

The statistical analysis clearly indicates that capital investments have contributed substantively to output production. This effect has been most prominent during the 1987-93 period. There seems to be a clear downward trend in the contribution of technological progress to output since 1993, except perhaps 1996-97, at least in part due to the reduction in exhibited investments. This evolution is in line with the general trend of the fishery that has seen a decline in cod stocks and overall production. The analysis seems to support the qualitative information from interviews that indicate that fishers have had few incentives to invest in new technologies during the latter half of the 1990's. The findings also seem to indicate that the vessels have been less efficient in the latter period, enjoying less success than during the period when the fishery was highly profitable.

It is acknowledged that the statistical analysis undertaken has resulted in a comprehensive list of findings on the fleet and vessel level, in terms of production and performance indicators as well as their relationship with technological progress. It is currently outside the scope of this report to review all these findings. Furthermore, although technological progress is often tied to the idea of increasing production, it is evident that some capital investments also aim to reduce operating costs, improve safety and working conditions, and help to diversify fishing strategies. These are obviously more difficult to quantify here, although an extended analysis that incorporates cost and earning data would provide a sufficient basis for analysing potential changes in the cost structure of vessel operations.

The findings of this report suggest that technological progress undermines reductions in fishing effort under MAGPs. The overall contribution of technological progress has been 1.8% per annum, largely driven by high values of technological progress during the 1987-93 sub-period. However, the difference observed during the 1987-93 and 1994-99 sub-periods implies that progress has stagnated significantly and currently has a limited impact on fishing effort. This is an important finding that must be considered when adopting a management strategy. It is clearly apparent that resource availability and quota ration restrictions have influenced fisher strategies and investment behaviour, and will also restrict the possible output of each vessel. This trend can be expected to continue. Therefore, a significant contribution of technological progress to increased production in the future would not be expected, unless cod stocks recover to the levels of the 1980's or an appreciable restructuring of the fleet occurs.

2.3 Scottish pelagic fisheries

2.3.1 Introduction

In the case of the Scottish pelagic sector, the perception is that capacity has increased substantially with a significant change in vessel structures. The fear is that irrespective of the fact that fleet rationalisation has taken place through licence aggregations and a reduction in the number of small scale pelagic vessels targeting herring and mackerel, the reduction in the nominal size of the fleet segment has not lead to the desired equivalent reduction in fishing mortality.

However, in contrast, fishing mortality has remained remarkably stable in the last decade and a half whilst the technological inputs on a boat by boat basis have increased substantially through a number of innovations. Initially, technological change facilitated substantial over quota catches. However, the pelagic fleet has rationalised as a result of a more restrictive licensing regime and trading in quotas between vessels. Moreover, the nature of pelagic fishing has become more seasonal as a result of market constraints (maximisation of product quality when the fish's oil content is at a premium). This has meant that over the evolution of the last 3 to 4 years, output has remained remarkably stable. New technology has been added on a progressive basis largely to reduce the cost of production. Technical creep has taken place but has led to reduction in fishing time and a greater selection in catch. The radical improvement in the market, caused in part by the decline in surplus production has been a crucial factor in this development.

2.3.2 Description of the Scottish pelagic fleet and qualitative analysis

The aim of this section is to characterise the activity of Scottish pelagic fleet.

Because of difficulties in the reliability of data, the authors have had to resort to extracting primary data from fishers. This has in effect revealed substantive differences from official catch records.

From interviews with fishers, gear suppliers and other experts, three groups of fishing vessels were identified. Detailed data covering the period 1984 to 1999 were collected for a sample of 18 vessels in order to identify and analyse the impact of technology in the three groups. Key differences were detected in respect to the innovations applied to specific groups, the timing of the innovations and the outputs (catches).

The catch is almost exclusively confined to two species groups, herring and mackerel. For each vessel, the catch is evenly split between the two species. As a result of the evolution of time, an increasing proportion (over half) of the catch is concentrated into a third of the fleet (11 vessels in total). This group is known as the super trawlers. There are two other groups: pair trawlers (5 in number), a group largely in decline, accounting for about 5% of the total catch; and purse seiners/pelagic trawlers (20 vessels) accounting for the balance.

The different groups of vessels have established similar patterns of change in technological progress. The exception to this being the pelagic trawlers. The impressions of skippers of these vessels as to the benefits of new technology were somewhat at odds with the rest of the fleet. Moreover, some of the groups are more likely to be influenced by specific innovations than others.

The Super trawlers

These vessels have much greater carrying capacities, although it is their power as much as their size that distinguishes them from the other groups of vessels (Typically 6-8,000kW, ranging in length from 50-75m and 1,100-2,300 GTs). The first of these vessels was built in 1995, and was quickly followed by several others. Although several of these vessels retain pursing licences and capabilities, it is rare for any of these vessels to use any method other than trawling. These vessels account for 54 % of the total landings and 55 and 51% of the total kW and GT respectively.

The owners of the first super trawlers tended to be skippers with a history of innovation, and a willingness to try out new technology. They highlight size and power as being two key areas of technological advance. However, whilst size has increased, effort and catches have only increased marginally, much of the increase being accommodated by the purchase of additional quota. Fish finding equipment and trawl design are also seen as key distinguishing features which have changed. Finally, chilling equipment is seen as being highly influential.

The Purse Seiners

These vessels comprise a larger group, with relatively low power for their size. (Typically 50 m in length, with power in the range of 1,600-2,400 kW averaging 1,500 kW and GT range of 640-2,240, averaging 713 GTs. Typically these vessels were built in the 1980's as purse seiners, although the majority are now working as pelagic trawlers. A small number of the 20 or so currently fishing in the fleet retain pursing capabilities, although they are increasingly reliant on trawling, in all but a few special circumstances. These vessels currently account for 44% of the fleet in respect to landings and 39 and 47% in respect to kW and GT respectively.

As with the super trawlers, net design and vessel size are key factors. Chilling equipment is also seen as hugely influential along with net sounders. These vessels have benefited both in terms of advances in trawl and purse seine technology.

Pair trawlers

The group of pair trawlers between 30-40 m represents the older class of lower powered vessel, with a range of engine size between 560-1,120 kW and a range of 275-387 GT.

These average 884 kW and 347 GT. This group of vessels accounts for 6 and 5% of pelagic kW and GT (1998) respectively.

In the early 1980's this class of vessel dominated the pelagic sector in terms of numbers, if not in proportion of landings, accounting for 50% of the total. Current dependence is now judged to be as low as 5%.

These vessels cite advancement in gear design, chilling, deck machinery and electronics as key areas of advancement.

2.3.3 Statistical analysis

A statistical analysis of Scottish pelagic fleet was undertaken in an attempt to measure the extent to which technical progress may undermine controls on kW and GT.

The principal conclusions of the statistical analysis are that:

- the overall rate of technical change between 1986 and 1998 was 0.38% per year. This represents 3.03% during the course of the combined MAGPs. On balance, productivity appears to be increasing at an increasing rate over this time period, but little impact can be directly attributed to technological innovations;
- it is difficult to identify specific technological innovations which have directly caused technical creep. The only technical variable that appeared to be significantly related to output was hydraulics. This is somewhat at variance with the qualitative data, which suggests that vessel size power, kort nozzles, bow thrusters, net design and chilling facilities were all significant;
- the key problem is that the link between technological advancement and *output* is difficult to identify when the vessels have historically caught well above quota. The data suggests that there has been no upward shift in the relationship between landings and inputs (i.e. landings did not increase for a given level of effort);
- this would imply that technology was being added mostly to reduce the cost of production;
- the fact that output and effort have fallen, but output less so, indicates a downward shift in the production function (function relating landings to all inputs) and likely a shift or rotation of that function. The fact that such shifts have occurred implies some technical change. It is possible that the production function shifted up, but the level of effort was decreased. In this case, we could have a small reduction in landings accompanied by a larger reduction in fishing effort;
- the production model however also shifted up - positive technical change. There also may have been gains in technical efficiency relative to the new production strategy;
- the disembodied technical change from the frontier is difficult to comprehend. This measure represents gains or shift in production associated with factors beyond the control of the vessel owner or operator (e.g. a relaxation of quota; or more quota acquired through purchase). The changes relative to purchasing quota and landing illegally would be reflected in the disembodied technical change.

It would appear that technical advancement is taking place with great regularity. However, this has not led to an increase in output. It has led to an increase in the resource use efficiency. Though all the vessels have the capacity to significantly increase their catches, the ability to do this is restricted by limited season influenced largely by the market constraints.

The vessel owners may also invest in technical progress for many other reasons. Although the primary reason is to increase productivity, such investment may also occur for reasons such as increased safety, improved working conditions, and improved product handling.

2.3.4 Conclusions and recommendations

Fishing effort

There is little evidence from within the Scottish pelagic fishery that technical progress undermines MAGPs.

It is also incorrect to assume that technical advancement will inevitably lead to an increase in output.

Technical change will achieve cost savings. This will in turn increase the level of investment within the fleet but production constraints (i.e. transferable quotas and licence aggregation penalties) provide a facility to ensure that catch will be kept within manageable limits.

Technical creep or technical change is not necessarily responsible for reducing effort. It simply indicates that a higher level of landings is possible given the same level of effort and other factors. It would, however, allow fishermen the ability to reduce effort with no change in catch or to maintain the same level of catch with a reduction in effort - which would also yield cost savings. Both of these factors have taken place in the fishery. Such a finding would suggest that the quota constraints allied by the ability to transfer quota between the vessels are sufficient to constrain output.

Data problems

It is widely recognised that vessel size and engine power are key variables in the fishery. Existing data on vessel size is presently inaccurate for a large number of the 11 super trawlers. This issue needs to be rectified. As a result, nominal engine power is no longer a reliable indicator of fishing capacity. It is recommended that a new series to be used as the basis for MAGP be put into place rapidly.

As the statistical analysis makes clear, size and power are not the only elements determining fishing performance. In fact, increases in size and power should not necessarily be interpreted as increasing output. There are other reasons why these variables increase - range, safety and fish storage. A movement to larger vessels in this fishery is inevitable given the requirement to steam to more distant market outlets.

Other variables are clearly important. The statistical analysis within this report has failed to identify most of these simply because the fishery has been unregulated for so long. A further review will therefore have to be undertaken at some stage against the background of behaviour in a regulated fishery.

It is also important not to seek to attempt to apply a global estimate of technical creep for a sector with many different components. The analysis of the Scottish fleet has revealed three sub sets of vessels. A broader examination of other vessels from the other European fleets, for example freezer trawlers, could reveal markedly different results.

Fishery management strategy

The ultimate objective of the MAGPs is to reduce fishing capacity to bring it into line with the catches available on a sustainable basis.

A legitimately managed fishery with the facility to trade quota results in some technical efficiency but for the purpose of achieving cost savings. As profitability increases, the vessels will find themselves either competing for more quota or reducing the time spent at sea. An alternative scenario might be for some vessels to seek to find other fisheries (e.g. Irish and Dutch pelagic vessels operating off Mauritania). The enhancement in prices has increased the pace of change amongst the fleet and if sustained will lead to fewer vessels in the fishery.

On the basis of the above experience, fishery managers should seek to explore the impact that ITQs would have on other fisheries. If technical creep is leading to an increase in output, then a quota trading environment could be an adequate means of controlling fishing effort.

2.4 Gulf of Lions trawl fishery

2.4.1 Description of the Sète trawl fleet and qualitative analysis

The activity of Sète trawlers and the conditions under which they operate was characterised so as to lay the basis for the quantitative statistical analysis.

In order to do this, data on the amounts landed by the trawlers were supplemented with data obtained from interviews with fishers, suppliers and fishery managers.

2.4.1.1 Fishing strategies

From interviews with fishers, fishery managers and other experts, three broad fishing strategies were identified. Detailed data covering the period 1984 to 1999 were collected for a sample of 20 trawlers in order to analyse fishing activity on the basis of these different strategies.

The considerable differences in catch rates observed between groups of vessels may be explained largely by the different fishing strategies. The quantities landed are strongly related to the target species groups. For instance, small pelagics account for over 60% of the catch of trawlers landing, on average, over 300 tons per annum. On the other hand, demersals represent over 80% of the catch of trawlers fishing less than 150 tons per annum on average.

Correlating the annual average landings (all species combined) of each vessel with the average proportion of small pelagics allows the identification of three distinctive fishing strategies. These strategies were then evaluated in terms of the human and technical inputs used. This gave the following three groups:

Group A. Relatively homogeneous trawlers, landing on average less than 500 kg. per day to the fish auction and targeting almost exclusively demersal species. The average trawler in this group was built in 1964 and measures around 20 metres for 39 GRT. It is not equipped to fish for small pelagics and is one of the last to install new equipment.

Group B. Trawlers in this group are much more heterogeneous, particularly with respect to the composition of their catches. Average daily catch is between 750 and 1,250 kg. Taking the period as a whole, the group mainly targets demersal species but there have been periods when they have targeted small pelagics, especially anchovy, mainly from 1988 to 1990 and again from 1992 to 1994.

Vessels in this group are equipped so as to allow changes in strategy. As a result, unlike those in group A, they have the capacity and gear needed to fish small pelagics. Overall, they have similar characteristics to vessels in group C, which specialise in small pelagics. The average trawler in group B was built at the beginning of the 1980s. It measures 25 metres for 75 GRT, and changes engine every 5 or 6 years. From the beginning it has been equipped with a variable pitch propeller over which a Kort nozzle was installed in the early 1990s. The vessel quickly adopts innovations concerning electronic equipment.

Group C. Vessels in group C are relatively homogeneous in terms of their catches. These are vessels that have specialised over the period in small pelagics (sardine and anchovy). As a result, the quantities landed are greater, averaging 1,800 kg per day.

The skipper of an average vessel from group C considers that fishing for demersal species is less profitable; the greater quantities of small pelagics compensate for the difficulties concerning their price. However, if the market situation worsens, as has been the case for sardine for the last two years, some of the vessel's activity is switched towards demersal species.

The average technical characteristics are very similar to those of group B, except that the hull is plastic. These trawlers also change their engines on average every 6 years, and are equipped with variable pitch propellers on which Kort nozzles were fitted in the early 1990s. They are the swiftest to adopt technical innovations.

2.4.1.2 Fleet dynamics

It is expected that the physical characteristics of the trawl net (size, equipment) will be an important determinant of the fishing power of a trawler. But the characteristics of the trawl depend principally on the towing power that the trawler has available.

Hence, true towing power is a fundamental factor when considering improvements in catch rates of the vessels. This power is in turn closely related to the nominal power of the engine and to the various systems used to increase propeller force (variable pitch propellers, nozzles, supercharging of the engine).

On the other hand, it is expected that the use of electronic equipment leads principally to changes in working practices but does not necessarily impact directly on catch rates. The use of such equipment may also lead to important improvements in safety.

In fact, some experts feel that the race to install electronic equipment in the 1990s is mostly the result of imitative behaviour encouraged by a regional policy of subsidising such investments.

Moreover, the activities of trawlers appear to have been strongly constrained over the period by market conditions for small pelagics. Such conditions are the main determinant of fishing strategy. In order to assure their sales revenue, trawler owners and the Producer Organisation SA.THO.AN have increased their efforts towards improving fish quality.

Although this policy appears to be paying off according to fishers who were interviewed, other experts emphasise that there remains an important gap between what has been and what could be achieved. The study 'Adéquation de la flottille méditerranéenne à la ressource et aux marchés' (IFREMER, CEPRALMAR, 1996) concludes that there is scope to improve processing and packaging practices on-board by increasing the mechanisation of some on-board activities and by transferring some others onshore.

2.4.2 Statistical analysis

A statistical analysis of Sète trawlers was undertaken in an attempt to measure the extent to which technical progress may undermine controls on kW and GT.

The principal conclusions of the statistical analysis are that:

- there was technical progress at a relatively low but increasing rate in the fishery over the period 1985 to 1999. The analysis suggests that it was at a rate, on average, 1.07% per annum over the entire period. Breaking the period into two sub-periods suggests that the rate of technical progress increased from 0.7% per annum on average over the sub-period from 1985 to 1993 to 1.5% per annum on average over the sub-period 1994 to 1999;
- the impact of capital components such as vessel size, hull material, number of engine changes was almost constant over the total period, accounting for technical progress of some 0.45% per annum during both sub-periods;
- it is the impact of components (such as GPS, route tracers, sonar, netsondes etc.) defining the technology base of the vessels that has increased markedly over time. During the first sub-period, such components accounted for technical progress of only 0.27% per annum whereas in the second sub-period this increased to over 1% per annum. This result is most interesting. It contradicts the expectations expressed above. It appears that even if such equipment were initially installed in a process wherein fishers emulated their peers, they have relatively quickly learnt to use the equipment effectively;
- however, the analysis also suggests that the impact of technical progress has been offset by factors outside the control of vessel operators. Most probably such factors relate to the state of the stocks. It also appears that vessels were relatively inefficient and did not operate at the optimal scale of production. The impact of these external factors was to decrease the technical efficiency of the vessels (as a group) by 3.16% per annum;

- the effect of the technical progress observed at the vessel level has therefore only been to partially offset the decline due to external factors. The net effect has been an annual average decline in efficiency of 2.09%.

Overall there is evidence that input substitution has occurred with fishers investing in uncontrolled inputs (such as nozzles, sonar and so on) to compensate for the restrictions on controlled inputs.

However, these results must be considered as suggestive rather than precise. Significant problems hamper the statistical analysis of technical change in the French Mediterranean trawl fisheries.

First, the fishery management system allows vessels to switch target species. Although not all vessels do so, a significant number switch their target species from demersal to pelagic and vice versa, according principally to the price of pelagic species on the Spanish and Italian markets. As a result of this behaviour, it is impossible with currently-available data to know how much of the fleet's capacity has been targeted at one or other species group during any given time period. Effort and CPUE indices had therefore to be constructed in terms of the overall vessel activity (in terms of total days fished during the year). This makes the analysis and the interpretation of the results difficult.

Second, vessel owners may invest in technical progress for many reasons. Although the primary reason is to increase productivity, such investment may also occur for reasons such as increased safety, improved working conditions, and more choice in fishing areas and species. As discussed above, there may also be an element of emulation where fishers invest in more powerful vessels and more sophisticated gear because this is what other fishers are doing. In such cases, the results in terms of output may be less than otherwise expected.

Third, direct observations of fishing mortality are not available. Catch was therefore used as a proxy for mortality and lagged CPUE as a proxy for stock size. Neither of these proxies is ideal. It is possible therefore that the analysis suffers from an important missing variable problem.

Fourth, engine power is widely recognised by fishers as a key variable. Unfortunately data on engine power are unreliable. An attempt was made to compensate for this by using years when engines were changed but this did not give satisfactory results.

Fifth, data were collected from fishers for the period 1985-1999. Inevitably, their memory of events in the 1980s was not as good as that for the 1990s. This may be one factor explaining the apparently lower level of technical progress in the 1980s compared to the 1990s.

2.4.3 Conclusions and recommendations

Fishing effort

A major difficulty for fishery management in the Mediterranean is the method used to evaluate fishing effort based on tonnage (GRT) and engine power (kW). Two factors must be mentioned.

First, the statistical analysis carried out in this study supports the view that technical progress undermines MAGPs. The best estimate of the extent to which this occurs is of 1.07% per annum over the whole period 1985 to 1999, rising to 1.49% per annum if only the most recent sub-period of 1994 to 1999 is considered. These figures must be considered as tentative. They are average figures which mask considerable variability between vessels and between years. It has not been possible within the confines of this relatively short study and within the confines of data availability to provide more accurate estimates. It is suggested that a fuller study of the French Mediterranean trawl fishery is required in order to determine more accurately the appropriate correction to use in MAGPs in order to allow for technical progress.

Second, input substitution has clearly occurred with inputs other than engine power being used to increase the traction power of vessels, and inputs other than traction power being used to increase the fishing performance of vessels. The problem of input substitution is a well-known problem of effort-based management, and it certainly seems to be an important phenomenon in the Mediterranean trawl fishery.

Data problems

Notwithstanding the discussion above, it is widely recognised that engine power is a key variable in the fishery. But the data concerning it are unreliable. As a result, nominal engine power is no longer a reliable indicator of fishing capacity. It is recommended that a new series to be used as the basis for MAGP be put into place rapidly. In developing this series, two considerations need to be borne in mind.

First, the series needs to integrate as many elements as possible determining the traction power of the vessel. A proposition has long been made (ISTPM, 1974) for the use of bollard pull (traction à point fixe). Although there will inevitably be some input substitution associated with this measure, on the whole it provides a much better indicator of the fishing power of vessels than engine power and appears much more difficult to circumvent. It integrates most of the different inputs used on the vessel to provide traction for the trawl. A new series would be relatively easy to institute.

Second, as the statistical analysis makes clear, traction power is not the only element determining fishing performance, even in a trawl fishery (and even less so in other kinds of fishing). Insofar as possible therefore there is a need to develop a series that incorporates the impact of other inputs, such as electronic equipment.

Fishery management strategy

The ultimate objective of the MAGPs is to reduce fishing capacity to bring it into line with the catches available on a sustainable basis. Three observations may be made.

First, the current segmentation in the French Mediterranean trawl fishery appears too broad to allow this goal to be achieved. There is no mechanism to prevent large changes in capacity between target species in accordance with relative profitability (which will depend on resource abundance and prices amongst other things). It is recommended therefore that the issue of appropriate segmentation should be re-considered in the fishery.

Second, and related to the above point, the current strategy is to try to reduce fishing pressure in particular on demersal species. Part of the strategy is to encourage trawlers to target small pelagics, partly through public support towards modernisation of the fleet: the idea being that fishers will be able to fish stocks of small pelagics located further offshore than the main demersal stocks. But since the current licensing system allows fishers to change target species within a single trip (if they so wish) there is no way to ensure that the impact of modernisation is not ultimately increased pressure on demersal stocks, particularly in situations where the market for small pelagics becomes unfavourable. It is suggested therefore that the appropriate definition of management units should be reconsidered at the same time as the issue of segmentation.

Third, this study demonstrates the importance of keeping fisher behaviour in mind in designing fishery management measures. The economic, and other, factors which determine such behaviour are generally poorly understood and yet they play a key role in determining the success or failure of management measures, including measures such as MAGPs. In the French Mediterranean, part of the management strategy is to encourage, using subsidies, fishers to invest in larger vessels so that they will target pelagic species further offshore. The expectation is that this will reduce pressure on demersal stocks found closer inshore. In a situation where the factors that determine fisher behaviour, including location choice and target species, are not well understood, this strategy runs certain clear risks, particularly given the current segmentation and licensing arrangements.

3. Discussion and conclusions

The case studies presented show a number of common features and some significant differences. In this section we will discuss these briefly in order to arrive at some common conclusions.

A common feature, that was implied in the project plan, is that all cases concern trawl fisheries. Only the Danish Baltic trawling case mentions gill netting as an alternative activity of some boats. Of course, the MAGP capacity measures tonnage and power are probably most relevant for trawlers, or, the other way around, they are probably less relevant or possibly completely irrelevant for other fishing methods. For the former, ship and particularly engine are essential elements for the fishing technique, for the latter the ship just provides for a working platform and the engine just serves to move this to the desired working locations. This suggests that it is easier for such fisheries to get around MAGP restrictions by gear developments or other technical innovations than for trawlers. The impact of this, however, will be relatively small in view of the modest role these fisheries have in the European Union.

All cases had to deal with more or less serious data problems. For the Dutch case, a fairly complete and useful set of data could be derived from an existing database. Regrettably, records of landed quantities in total and by target species by boat were virtually non-existent during the 1980's. This proved to be a serious bias for the statistical analysis. For the Danish case, the fishery chosen as such made for some 'data and modelling obstacles', as it is performed by a large, mobile fleet that is regularly switching grounds and partly also fishing methods. A dataset of 23 boats for one month was chosen to represent the Baltic cod fishery for the statistical analysis. The results of the analysis may, however, not be representative for the full fleet and its activities.

The studies of the Scottish pelagic fishery as well as the trawl fishery from Sète encountered serious discrepancies between officially recorded and actually installed engine power of boats. In the Scottish case this problem was augmented by the inaccuracy of landings data due to landings of over quota fish. To arrive at a useful set of data, they had to be collected through the interviews and could not cover all years of the period considered. In the French case, replacement dates of engines were tried as a proxy, but with little success.

In undertaking the statistical analysis of the case studies, a standard approach based on a rigorous use of economic theory was employed so far as possible. However, as the case study discussions make clear, the approach had to be tuned to each fishery, in particular in response to data constraints. The conclusion emerges as to the need for standardised European economic data sets if the effect of the Common Fisheries Policy is to be analysed on a common basis at a European level.

The results obtained differ quite substantially from one case study to another and sometimes even within the fleet segments studied. If in the MAGPs allowance should be made for technical progress, applying a standard correction factor (be it 2% per annum or any other figure) does not seem to be a valid option. It appears that segment by segment adjustments would have to be made and such adjustments will have to be verified over time and, where necessary, modified. This would add another complicated cycle of research and assessment to the EU fisheries management decision making process for a fairly marginal effect. Moreover, the case studies illustrate that well enforced quotas can effectively curb the impact of technological progress.

The study identifies two main sets of factors that give rise to differing results. First, there are many motivations for technical progress; second, the impacts of technical progress differ from situation to situation.

The hypothesis underlying the use of an 'MAGP-correction factor' is that technical progress affects the quantity of fish caught. However, the principal economic reason for technical progress is to increase profitability. Increasing the quantity caught is only one way to increase profitability. As the various case-studies make clear, profits may also be increased by selling the same (or even a lesser) quantity for a higher price (hence the emphasis on markets and quality in the case, for instance, of Scottish and Mediterranean pelagic trawlers). Similarly, profits may be increased by fishing the same quantity at lower cost (as appears to be the primary motivation for technical progress in the case of Dutch beam trawlers).

There may also be non-economic factors explaining investment in technical progress, in particular desires for safety or generally-improved working conditions.

Depending on the motives for technical progress, the implications for fishery management and for MAGPs in particular may be quite different. This conclusion highlights the need for an understanding of the economic behaviour of fishers.

The major factor determining the impact of technical progress is the nature of the fishery management system. Where economically-based management systems have been implemented, particularly individual transferable quotas, technical progress appears to have little effect on catch (as predicted by economic theory). The consequence is that the extent to which technical progress appears to have undermined MAGPs differs significantly from case study to case study and over time. Hence in the case of the Netherlands and Scotland where ITQs appear to work now quite effectively, there appears to be no evidence of MAGPs being undermined. In the Baltic, the situation has changed over the period from one where there was quite a substantial impact to one where there is only a negligible one. Only in the case of the Mediterranean, where fishery management remains effort-based, does input substitution (through technical progress) appear to undermine the MAGP.

The conclusion is therefore that in deciding on MAGP targets and whether to correct for technical creep, there is a need to take into account the nature of the management system in the fishery concerned.

Annex 1 Classification of technological progress

Before going into technological progress in the various case study fisheries and trying to measure its effects on fishing effort, we first have to get a better understanding and a clearer picture of what lies behind and brings about technological progress.

Technological progress is connected in economic literature with increases in productivity that can be expressed either in physical terms (units produced by units of input) or in economic terms (produced value by value of inputs). It is often seen as an autonomous factor that leads to an increase of production over time, apart from changes in common production factors, like capital and labour, or in the instance of fisheries, fishing capacity expressed e.g. in engine power and gross tonnage. As such, technological progress is an umbrella term for the more or less continuous introduction and adoption of innovations in all components of the production process. Although from the outside it may appear to be rather amorphous and non-transparent, the process is basically the result of decisions and actions taken by individual firms.

For a better understanding, it therefore seems appropriate to start with looking into the motives for these decisions. Then a more detailed look should be taken at the kind of innovations that were being adopted over the last couple of decades, together with the possible effects they may have had with regard to the various motives. Finally, it should be established to what extent the various identified innovations have actually affected fishing effort (mortality) and fish stocks.

In general, the motives why certain innovations are adopted by fishing companies can be divided into the following five:

a. to increase physical productivity;
b. to reduce costs (including taxes);
c. to improve the quality of the product;
d. to increase the operating capability of the vessel;
e. to improve safety and working conditions.

Seeing fishing as an economic activity, the motives of fishermen in general are connected with the objectives of increase and continuity of the income(s) generated. Fishermen, like all human beings, are not purely economically driven and acting, however. The adoption of innovations may very well be induced by other than economic motives, making the process of technological progress more erratic than we would like it to be (Dixon et al., 1997).

When we look into the possible impact on effort and stocks of the motives summed up above, clearly only an increase in physical productivity has a direct raising effect on real fishing effort (mortality). A reduction of costs can have an indirect raising effect, as fishing can continue at lower catch rates, but not necessarily. Quality improvement, resulting in higher prices, rather tends to reduce fishing effort, as smaller volumes suffice to provide for adequate incomes. Wider operating capabilities of the vessel may work out various ways: if it means a greater radius of action, fishing effort may go up; if it means a potential to diversify, it may result in a reduction of effort on the (old) target species. Improvements in safety and working conditions may increase the endurance of the crew and thus bring about a variety of changes in performance, like: better crew performance, continued fishing in adverse conditions, longer trips; but the effects may as well be restricted to a better life for the fishermen.

The concept of technological progress by its name appears to indicate changes in technology only, but that would be a too limited approach. The general view as given above implies more, as all increases in productivity, apart from those ensuing from changes in well defined production factors, are allocated to this 'technological progress'. Certainly from an economic point of view, changes in productivity may very well result from other factors than technological ones, e.g. changes in regulations or in market conditions. For our purpose, we will call these 'organisational' or 'institutional' factors and include them as one of the main fields of innovation in our considerations.

In fisheries then the following main fields of innovation can be distinguished:

- hull;
- engine (room);
- electronic equipment;
- fishing gear;
- processing and storage;
- crew accommodation;
- 'organisation'.

These fields are explained in more detail in the next paragraphs [1].

Hull

Size

An internationally applied measure for indicating the size of a vessel is gross tonnage, a measure of hull volume, assessed according to internationally agreed rules. Before 1983, the gross tonnage of sea going vessels was measured according to the Oslo Convention of 1947. From 1983 onwards, new vessels were measured according to the London Convention of 1969 and older ones were gradually re-measured. The same applies to sea-going fishing boats, as just one of the categories of sea going vessels.

The old and the new system have a rather different approach to measuring hull volume. The results of the old method could be (and were actively) manipulated by favourable positioning of structural elements and the introduction of (administratively) non-watertight rooms. The new method is a more objective one, measuring total hull volume and including other rooms that serve the purpose of the vessel, but even this system is not completely unambiguous (De Wilde, 1992, 1998). Adjustment factors for the results of new measurement, depending on vessel size, have been introduced to make both systems compatible. The same factors are used for all vessel types, so not surprisingly they do not work particularly well for fishing boats. For Dutch beam trawlers e.g., it appears that gross

[1] Many of the issues brought up in the following are discussed in Anon., 1989.

tonnage by the old method expressed in GRT was roughly 15% smaller than that by the new method in GT (De Wilde, 1992).

Gross tonnage serves also as one of the main fishing capacity indicators in MAGPs. The European Commission has required the Member States to re-measure all fishing boats before the end of 1996, in order to have a clean start of MAGP IV. However, no allowance was made for possible differences in tonnage (= capacity) resulting from the change of measurement system. The Dutch example (that has to be re-assessed more thoroughly) shows that these differences can be considerable, even in the same order of magnitude as the reductions required under MAGP III.

Larger boats are in general more seaworthy, and thus safer, and offer a more stable platform than smaller boats. This enables fishermen to operate in worse conditions than with a small boat, to the extent that large boats rarely have to stop fishing or stay in port because of bad weather.

In addition, but also as a consequence, big boats have a large radius of action. This is now mainly limited by the trip duration and steaming speed. The latter is basically limited by length ($V_{hull} = 1.25 * \sqrt{L}$; where Vhull is maximum hull speed in m/sec and L is waterline length).

This does not mean that catches per day (at sea) increase more than proportionally with boat size; the contrary may well be the case, reflecting less than constant returns to scale. Even on an annual basis, catches and revenues may increase less than proportionally with size (= GT).

Shape

The shape of the hull generally determines the hydrostatic and hydrodynamic characteristics (stability, resistance, motion in a seaway) of a vessel. Most fishing boats have conventional displacement type hulls, but some are of lightweight construction and, in combination with the right shape and engine power, have planing capability. This results in a wider radius of action over the same time span.

A conspicuous change in boat shape has been the introduction of bulbous bows. Usually these appendages are intended to reduce resistance under certain loading conditions. For fishing boats with highly variable loading conditions, the real purpose is more in the field of sea keeping, boat handling and trim (also, it provides a good room for a bow thruster).

Another eye catching change of shape is the switch from canoe sterns to flat counters, often in combination with a switch from side trawling to stern trawling. Possible changes in fishing performance will have more to do with that switch than with the changed shape.

Construction

Changes in construction material may influence fishing boat performance. Above already reference was made to lightweight construction, possibly resulting in high boat speed. Another aspect is the demand for maintenance that can be related to the way of construction and the materials used, influencing the available operational time.

Layout
In many fisheries, a switch from side trawling to stern trawling can be observed, usually implying a movement of the wheelhouse and crew accommodation forward and of the working deck aft. This change of layout can also be observed in non-trawling fisheries, where apparently the better working deck (less exposed, more space, less motion) is found more important than the less comfortable crew quarters and steering position and the often longer propeller shaft.

Engine (room)

Type
The standard type of engine installed in fishing boats is the diesel. These are subdivided into low speed (up to 500 PM), medium speed (500-1,500 RPM) and high speed (more than 1,500 RPM) engines, naturally aspired or turbo-charged to various degrees, with or without intermediate cooling. The latter appliances serve to improve the efficiency of the engine, increasing its power by size ratio and (slightly) lowering the specific fuel consumption (g/kW/hr). Modern diesel engines of a certain size (cylinder volume) can deliver a wide range of powers, depending on their tuning. As a consequence, engines delivered by the manufacturer at a certain rating basically can be tuned rather easily to a higher power. For structural, safety and reliability reasons the vital parts of the engines are blocked and/or sealed to prevent such meddling with the tuning.

Power
Main engine power is the other indicator of fishing fleet capacity in MAGPs. It is considered to be one of the main parameters for fishing power, particularly in trawling. As a consequence, it is rather susceptible to measurement and registration problems, especially when general or license limitations are in force. In some instances, fishing boats can deploy considerably more main engine power than according to the registers and it can be quite difficult to prove the extent of overshooting the registered power. Of course, the actual fishing power of such boats is larger than the official registers suggest (De Wilde, 1998).

In general, the fishing power of vessels is not necessarily linearly proportional to main engine power. Usually, boats of twice the engine power are not able to catch twice as much in the same fishery.

Configuration
Mechanised boats started with having only one engine, providing all the necessary power for propulsion as well as auxiliary services, like driving the winch and generating electricity. With the increase in size and complexity of fishing boats and their systems, ever more auxiliary power was required and special auxiliary engines became installed to provide for this. In most cases, the main engine, driving the propeller through a reduction gear box, still provides some auxiliary power by generators or hydraulic pumps coupled to the gear box or more directly to the engine through a 'power take off'. Studies on power requirements during fishing trips have shown that this practice can improve the loading conditions of main engines and by that their efficiency and their life span (Blom, 1986, 1989).

In situations where engine power limits are in force, it can be attractive to use the main engine exclusively for propulsion purposes, particularly where net pulling power is decisive for fishing power. As a result, a certain main engine power can represent a fairly wide range of fishing powers, depending on the extent to which auxiliary power is taken off.

Propeller

The design and characteristics of the propeller are a decisive factor in the efficiency of the propulsive system and therefore for the fishing power, particularly in the case of trawling. Propellers can be designed for high pulling power at low speed or for efficient propulsion at (high) free running speed or situations/compromises in between. Adjustable pitch propellers provide a possibility to be (nearly) optimal in both situations. Variable pitch propellers allow adjusting the propeller to a wide range of loading. Both go at the cost of a small loss in efficiency, but a more important argument for not applying such propellers in some fisheries is the increased complexity, making them more vulnerable in rough conditions.

Another device for getting good performance of the same propeller/engine combination at pulling (trawling) as well as sailing speed is a multiple reduction gear box (Chardome, 1960).

A technical innovation that has substantially increased the pulling - and thus the fishing - power of trawlers is the Kort nozzle (a short venturi nozzle encircling the propeller with a narrow margin). A well-designed nozzle can increase the pulling force at a certain engine power by more than 30% (Chardome and Roscher, 1960). That represents a considerable impact on the fishing power of trawlers. In addition, a nozzle makes the propulsion system less sensitive for variations in loading and because of that may also have a positive effect on fishing power in other types of fishery.

The combination of propeller diameter and number of revolutions at a certain engine power is decisive for its efficiency. Large diameter, slow turning propellers are more efficient than small, fast turning ones. This can make tens of percents of difference in performance.

Auxiliary power

As was mentioned above, the increase in size and complexity of fishing boats has brought about an increasing demand for auxiliary power, be it electrical or hydraulic. Nowadays some vessels have auxiliary engines installed with an aggregate power that is close to, or even in excess of that of the main engine. Of course, this auxiliary power contributes more or less indirectly to the performance of the fishing boats, by driving winches and net haulers and by providing the energy for cooling or freezing catches, refrigerating holds, making ice etc., apart from smaller consumers like lighting, cooking and electronics.

Electronic equipment

The introduction and application of electronic equipment in fisheries has been the field of innovation in the second half of the twentieth century that has most quickened the imagination of fishermen as well as onlookers. Most of the major developments took place before the inception of the CFP and the use of fairly advanced electronics was common practice in all fishing fleets around 1980. Three main types of electronic equipment can be distinguished: fish finding, navigation and communication. These will be discussed below, with special attention to relevant developments over the last two decades. In addition to that attention is given to the minor field of monitoring of ship and gear functioning and to the integration of various equipment and functions.

Fish finding

Electronic fish finding equipment mainly consists of echo sounders and sonar of various designs. Echo sounders are commonly used in both demersal and pelagic fisheries. They can give an indication of the occurrence of fish right below the vessel and of their density and their position in the water column; sometimes also size and type of fish can be detected. The skill of the operator is rather important for tuning the equipment and interpreting the signals received. While the basics of the technique were fairly well mastered before 1980, developments since were particularly directed at ease of handling and interpretation. An important feature to that end was the introduction of coloured CRT screens, in combination with memory capacity, that now have virtually completely replaced the old black and white CRTs and writing sounders. Instead of variations in intensity of black and grey indicating the strength and character of echoes received, more easily distinguished colours now do the job. One of the important functions of echo sounders is also to detect the quality and, of course, the depth of the bottom and as such serves more as a navigational aid.

Sonar enables the fisherman to look around under water in search for fish or obstacles like wrecks or pinnacles etc. Here the development has been similar to that of echo sounding. Interpretation of sonar images is even more difficult than those of echo sounders, as they represent distance, height and direction. Over the last decades, progress was particularly made in making sonar more easy to interpret, by transforming the echoes into (apparently) three dimensional images. The equipment is particularly useful for pelagic fisheries, but also frequently used by wreck fishers (with gill nets), serving navigational purposes more than for fish finding in that case. As it is relatively expensive, it is little used by demersal trawlers, although they might profit from the possibility to detect wrecks and other hazards for their gear ahead.

A quite new development in fish finding technology is remote sensing with satellites, e.g. detecting changes in water temperature or salinity that may bring about concentrations of food and therefore of fish. This technology will be mainly interesting for pelagic fisheries, in particular tuna fishing. It is still in it's infancy and is little applied yet.

The developments in fish finders over the last decades will have raised the catching power of fishing boats to some, probably limited, extent. Certainly, the impact of the earlier introduction and developments has been much larger.

Navigation

Electr(on)ic aids are available for virtually all aspects of navigation (although their application is sometimes limited to the larger vessels). The course can be indicated by a gyrocompass instead of the traditional magnetic one; the speed is usually measured electronically; for knowing the depth under the keel there is the echo sounder; for looking out in poor visibility, the use of radar is even compulsory; for steering, practically all boats have an auto-pilot; finding your position used to be done with Loran or Decca, systems made obsolete during the nineties by the availability of the Global Positioning System GPS; keeping track of your movements and recording the exact position of wrecks and other obstacles can be done on an electronic chart (but paper back ups still are officially required).

All these aids and equipment have made life a lot easier for seamen in general, but most of them were widely used before 1980. Similar to those of fish finding equipment, the developments in this field over the last two decades mostly served to improve the performance and ease of handling the equipment and therefore have probably little contributed to an increase of catching power of fishing boats.

There is at least one exception, however: that of the - initially restricted ('selective'), but since early 2000 full - availability of GPS (the originally US military satellite navigation system) to the general public. In many fisheries it is quite important to know where you are fishing (or sailing) and even more important to be able to return to that same position, e.g. to return to a good fishery, or to avoid underwater obstacles, etc. The present full availability of GPS has made this possible within a boat length (roughly 10 m). Already the selective availability of GPS was a considerable improvement on the often volatile performance of Loran and Decca, that are sensitive to atmospheric conditions and require quite a bit of skill and experience for a correct interpretation. (In some areas, Differential GPS was available, where a ground station, having a fixed position, was used to correct for the aberrations in the indicated position.)

Communication

Apart from the usual navigational, safety and social reasons, electronic communication equipment on board of fishing vessels is also used as a means to find out how fellow fishermen are doing and where they are; thus as a kind of spying device. Radio transmitters and particularly VHFs have been installed on fishing boats from the moment they were on the market. It is not uncommon to have a variety of VHFs installed to serve various functions. A virtual arms race has been going on in means to keep confidential information secret and means to get access to it.

Again, the giant steps in this field were made long before the start of the CFP and developments since were mostly improvements in quality and ease of handling, including compulsory adaptations and innovations to comply with IMO safety regulations (e.g. the recent requirement of GMDSS). An innovation of the last two decades that has been a important step forward in communications, is the use of satellites as relay stations or satellite communication ('satcom'). This is specially interesting for ship to shore communication and rather expensive, so it's application in fisheries until now is restricted to larger, mostly company owned vessels.

The impact of the innovations in communication equipment over the last two decades on the catching power of fishing boats has probably been rather small.

Monitoring and integration

The development of electronics in combination with developments in other fields of technology have seen to it that the functioning of a variety of machinery, equipment and gear can nowadays be monitored remotely from gauges and digital displays and be recorded if required. As a result, unmanned engine rooms are allowed even for relatively large fishing vessels and engine powers, the position and performance of nets can be followed on CRT screens, and the amount of fish in the codend 'counted'.

The general digitalisation of electronics and measuring gauges, in combination with the huge increase in electronic computing power and speed over the last decade, has enabled an integration of various functions of different navigational, fish finding or monitoring equipment. One, more general, example is the connection, or complete integration, of auto-pilot, GPS and electronic map for programming a route to be sailed and plotting it's eventual course. Another, specifically for fishing, is the combination of information from fish finders (sonar), net monitoring equipment, auto-pilot and positioning device (Loran, GPS) into an integrated and (semi-)automated fishing system. Such sophisticated and rather expensive systems are interesting only for fisheries on schooling fish of relatively high densities and are not widely applied. Where applied, however, they may have a significant impact on the catching power of the boats concerned.

More in general, monitoring devices and integration of functions have served mainly for making life easier for the fishermen, saving labour, often resulting in reductions of crew size.

Fishing gear

In the stricter sense, fishing gear is composed of nets (or hooks) and warps, ropes or lines; that is the gear that is put into the water to catch the fish. For our purpose, we will include the on board equipment for handling the gear, like winches, haulers and drums.

Nets

The introduction of synthetic fibres in the fifties and sixties into fisheries has had an enormous impact on the handling characteristics and efficiency of fishing gears. Application of these fibres was common practice in all fisheries in the seventies, but the development of ever stronger and tougher fibres continued. During the period under consideration, since 1980, a new generation of high tensile fibres became available, allowing net designers to develop ever more sophisticated constructions, using combinations of materials for optimal strength, wear resistance, catching performance and ease of handling.

New, stronger materials and more sophisticated constructions allowed towing of larger nets or at higher speeds with the available pulling power. The lower resistance was realised not only by the possibility of using thinner yarns, but also by applying larger mesh sizes in the front and belly of the net, or even by substituting the meshes by longitudinal lines. Such constructions have in some instances contributed to the selectivity of the gear. The main effect, however, was to make them more efficient, catching more fish with the same effort. In some fisheries, this may have had a considerable impact on the catching power of the boats, others may have profited less, but still notably.

Warps, ropes, lines

Trawling warps and seining ropes, partly or completely made of steel, have not experienced any significant development over the last two decades, and whatever development there was, was mainly directed at improving wear resistance and durability. For the variety of (auxiliary) lines used, the same range of synthetic fibres is used as for nets, but the impact of the new, stronger fibres on the catching performance will be less than with the nets.

Winches, haulers and drums

Electrically or hydraulically driven winches, line and net haulers and net drums were common practice long before the inception of the CFP. Developments since then have been gradual and directed at improved performance, operational reliability and safety. Remote control and replacement of warping heads by extra drums in the main winch are features growing gradually more common. Where higher speeds of setting and hauling the gear have been realised, this has had a certain impact on the catching power of the boats concerned.

Processing and storage

The on board processing, preservation and storage of the catch is a field of innovation that has no direct relation to the catching power of vessels, but on the other hand can have a significant impact on their earning power. Market demands for higher quality - with minimum requirements for hygienic on board handling and storage of fish laid down in EU legislation (Council Directive 92/48/EEC, 1992) - and considerations and requirements of labour saving and improved working conditions have brought about a lot of development in this field during the CFP era.

Of course, sorting and grading, gutting, heading and filleting, chilling, freezing and packaging equipment and cold storage were all there before 1980, but the application was mainly restricted to the larger boats, with full factory freezer trawlers as the top segment. Partly under the influence of the EC support programmes for the improvement of fishing vessels, many of these implements gradually were adopted by the smaller boats in the fleets. Sorting equipment, gutting machines, ice makers, plastic boxes and chilled fish holds have become normal, at least on boats making trips of more than one day.

Innovations in on board storage and processing have basically not led to an increase of catching power, and it can even be argued in some cases that by putting quality above quantity, the fishing mortality brought about by a fleet has been reduced.

Crew accommodation

Crew comfort can affect their performance positively and as a consequence that of the boat. It might also work in the way that boats with more comfortable quarters attract better crew. Anyway, improvements in crew comfort - better location, more separate cabins, lower noise levels - may have raised the fishing mortality of boats of a certain size and engine power.

Apart from an autonomous urge to improve the comfort of the crew, stricter and more explicit national and European regulations on labour conditions and crew safety aboard fishing vessels have induced such improvements (e.g. Council Directive 93/103/EC, 1989). They are particularly realised on larger boats, making longer than day trips; for day fishing boats there is generally rather little room for improvements of this kind.

Organisation

The institutional and organisational environment and set up of a fishery can have a significant influence on the physical and economic performance of the boats involved.

Management of the firm
Family owned boats, skippered and crewed by family members generally perform better than company owned boats with hired skippers and crews. Share fishermen bearing the full catching risk will perform better than fishermen having a partly fixed or minimum wage. A general switch of boat ownership from families to companies may result in a reduction of catching performance. On the other hand, a development from a small scale, livelihood type of fishery towards more businesslike family enterprises can have a positive effect on the fishing results. Such aspects should also be taken into account when looking at changes in physical performance of the fleets.

Markets
Changes in the market conditions can also affect the performance of fishing fleets. A field of significant change is the development and expansion of the European Community/Union, opening new marketing opportunities, but also bringing fresh and more fierce competition. Species that used to be insignificant and mostly discarded, may now find a good demand and make a considerable contribution to the earnings. Formerly important species can have become of minor interest. Another field of change is the retail market where large supermarket chains are increasingly including fish in their range of products, sometimes pushing out the small specialised retail shops. This is also bringing about changes in market organisation earlier in the chain, e.g. direct selling of fish on landing to supermarket chain suppliers, instead of through auctions, in order to fulfil the special demands for quantity and quality. Such demands may result in complete changes of fishing patterns and catch compositions. This 'chain reversal', where demand is pulling the activities in the chain, instead of supply pushing them as it used to be, is still in an early stage of development, but it is expanding rapidly. Even without this, the constant upward push for better quality from the market has seen to it that in some fisheries volume became subordinate to quality, as higher prices more than compensated for reduced catches because of better quality care.

Fisheries management
Last, but certainly not least, fishery management measures for stock conservation, like quota and effort restrictions, have had an undeniable impact on the performance of most of the European fishing fleets. In many instances this impact has been negative, as restrictions forced boats to under-perform, by limiting their allowed catch of target species, or by reducing their level of activity, or both together. Such restrictions have been there practically throughout the period under consideration and it may not be possible to find a situation of unlimited, full performance, fishing for some of the fisheries. On the other hand, sometimes improvements in performance were observed in relation to restrictions, e.g. when effort restrictions in the fishery for roundfish did not result in lower fishing mortality rates in the UK.

Transferable fishing rights allocated to individual firms in some fisheries have acquired considerable value, making general compliance a desirable feature. This may lead to distinct changes in fishing strategy, e.g. leaving prolific grounds to prevent early exhaustion of the quota and looking for good by-catches instead; or catching the quota as efficiently as possible and seeing to it that the fish arrives in prime condition at the best market. Such changes in strategy may have a short run effect on fishing effort but on an annual basis they do not affect fishing mortality.

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Annex 2 Standard questionnaire

Introduction

This questionnaire serves to provide a common framework for the interviews with boat owners, skippers, designers, shipbuilders, engineers, suppliers of electronics and gear etc. Basically it is supposed to contain the basic questions we have on our subject: what, why, when, to what effect? It is not comprehensive with respect to the included items and is open to supplementation. It is also not comprehensive in the sense that the interviews could be restricted to these questions. The purpose of the interviews is to support and improve our understanding of how the adoption of innovations and the ensuing 'technological progress' work. Therefore we should go more deeply into the matter with our interviewees whenever possible.

General

1. Type of interviewee:
   - Boat owner
   - Skipper
   - Designer
   - Shipbuilder
   - Engineer
   - Electronics supplier
   - Nets and gear supplier
   - Other: ....

As to 'What?'

2.a Can you select *six* items from the following list of technical and 'organisational' innovations that have most enhanced the performance of (your) fishing boat(s) over the last 20 years?
For Owners and Skippers: These may have been included in 'new' boats commissioned in the period considered.

2.b Can you describe the innovation more precisely?

2.c And can you rank them? (1 = most important; 6 = least important)

Main field	innovation	more specifically	rank
Hull	Size		
	Shape		
	Construction		
	Lay out		
	Other		
Engine (room)	Type	(speed, turbo, etc.)	
	Power		
	Configuration	(pto's/separate aux.)	
	Kort nozzle		
	Prop. diameter & RPM		
	Auxiliary power		
	Other		
Electronics	Fish finding		
	Navigation		
	Communication		
	Other		
Fishing Gear	Winches & haulers		
	Lines & warps		
	Boards & beams		
	Nets: -Type		
	- Size		
	- Material		
	- Construction		
	Other		

Processing & Storage	Sorting & grading		
	Gutting, filleting		
	Chilling, freezing		
	Packaging, storing		
	Other		
Crew accommo-dation	Location		
	Partitioning		
	Other		
'Organisation'	Company type		
	Type of fishery		
	Marketing		
	Quota regulations		
	Other		

As to 'Why?'

3. Can you indicate for these six most important innovations for which of the following reasons you adopted them / they were adopted?

f. to increase physical productivity
g. to decrease operating costs (including taxes)
h. to improve quality of the product
i. to increase the operating capability of the vessel
j. to improve safety and working conditions

Innovation	Reason(s)	Explanation
1		
2		
3		
4		
5		
6		

As to 'When?'

4. When/over what time span were these innovations adopted?

Innovation	Time span	Comments
1		
2		
3		
4		
5		
6		

5.a Was your company one of the front runners in adopting these innovations, or
b did you wait until the competition had sorted out the teething problems?

As to 'To what effect?'

6. Can you give an estimate of the relative improvements (percentages) in productivity, costs and prices ensuing from the relevant most important innovations as expected and realised?

	% Expected	% Realised	Comments
Increase in catches per day of target species			
Increases in selectivity (i.e less catch but more marketable)			
Increase in annual catches of target species			
Increase of prices of target species			
Increase of gross revenues			
Decrease of operating costs			
Decrease of total costs (including taxes)			

7. Have you experienced or noticed any technological or organisational changes over the last two decades that have had a negative effect on productivity (apart from occasional reductions in TACs and quotas)?