THE BENEFIT OF HINDSIGHT; AN EVALUATION OF NORTH SEA HERRING MANAGEMENT PLANS FROM 1995 TO THE PRESENT.

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ABSTRACT

In 1995 North Sea herring was estimated to have declined from previous high of around 1.5 million to 400,000 tonnes, the point at which significant reduction in recruitment had previously been observed. The response to this was to cut the fishery by reducing the human consumption TAC by 50% and reduce the catches of juvenile herring for reduction even further. In addition the European Commission proposed a management plan to be followed. Since then this management plan has been revised twice. Elements of these plans have included target fishing mortality, 15% constraints on inter-annual change in TAC, nevertheless due to other clauses the management has resulted in an increase and a subsequent decrease of 50% in TAC during the last 15 years. We assess potential economic impacts under alternative management scenarios and discuss the lessons that can be learned for the design of management plans. The analysis includes the simulation of different strategies, including the impact of stock dynamics, and uncertainties in the estimation. In addition, the impact on the UK economy of the fluctuation in the TAC, in terms of value, employment, will be assessed.

Keywords: herring, management plan, economic impact

INTRODUCTION

Currently, the European Commission is developing policy changes for multi-annual fishery plans. One of the aspects of this is the legal requirement to evaluate the past performance of existing multi-annual plans. The CFP requires sustainability of environmental, economic, and social aspects of fisheries. One of the main objectives for sustainable economic performance is achieving MEY, to be monitored using data on profits and Gross Value Added (GVA), while the basis for the evaluation of social outcomes focuses on the potential for employment. Here we have chosen to evaluate the North Sea herring fishery which has operated with a multi-annual management plan since 1997.

For hundreds of years, the North Sea herring (Clupea harengus) had been an important source of economic wealth and food in Europe. During the 14th–16th centuries the North Sea herring contributed to the development of the Hanseatic League. Historical detail for the period 1600–1860 is provided by Poulsen (2006), who concludes that, although the fisheries met periods of hardship, they have had a negligible impact on the stock. However, by the 1950s, the North Sea herring fisheries had expanded to a level at which they were having a major impact on the stock. Between 1960 and 1978 the stock declined to around 2% of its earlier biomass (Fig 1) (Dickie-Collas et al 2010). After reviewing management actions from 1964 to 1978, Saville and Bailey (1980) concluded that overfishing had been the major cause of extreme stock depletion. The stock recovered through the 1980s and declined again in the early 1990s, and again high fishing mortality (F) was the major cause. In 1996 management action was taken and a management plan was put in place as an EU/Norway agreement and resulted in a formal regulation in 1997. By 2003 the stock had recovered without the need for the closure of the fishery that was needed in the 1970s. These two periods of management are compared in Simmonds (2007). The stock has been managed through TACs since the mid 1970s, first under NEACF management and later under EU/Norway agreements. Management advice on the catch options has been supplied annually by ICES (eg. ICES 2008). This advice is based on the ICES Herring Assessment Working Group HAWG (ICES 2010). The ICES catch advice is derived from an assessment using the Integrated Catch at Age (ICA) assessment method (Patterson and Melvin1996). The assessment is a separable model based on estimated catches and research vessel surveys. The performance of the model has been reviewed by Simmonds (2009) who concluded it provided one of the more reliable assessments used by ICES for advice.

During the periods of management under plans, from 1995 onwards the TACs and catches have not fluctuated as much as in the 1970s but still experienced substantial changes (Figure 1), a decline of 60% from 600 000t to 200 000, and increases of 2.5 times to 650 000t and a further decline by 75% to 170 000t.

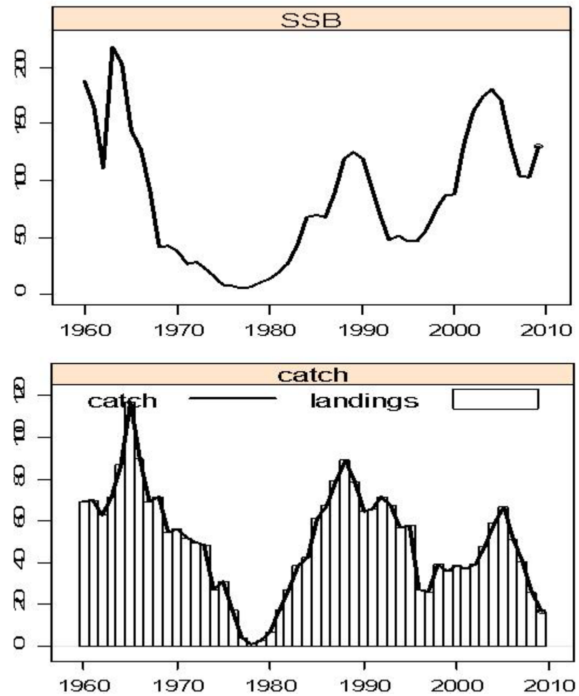

Figure 1. Spawning Stock Biomass of North Sea herring 1960 to 2010 (ICES 2010)

To date a number of empirical studies focusing on North Sea Herring have taken a bio-economic approach to estimate optimal management conditions and resource rents under alternative management regimes (see Bjorndal et al. (2010), Nostbakken (2008), Bjorndal & Nostbakken (2003)). In particular, Bjorndal et al (2010) suggest that current rents for the North Sea herring fishery are negative, while substantial economic gains could be achieved with optimal management.

Our approach is different in the sense that we do not attempt to estimate optimal resource rent or follow the more traditional bio-economic modeling route. Here we compare and contrast the socio-economic consequences of alternative simulated management strategies for North Sea Herring, using a biological model coupled to an economic evaluation using existing input-output multipliers (Fraser of Allendar Institute 2007) for the UK pelagic sector. This approach was chosen because not only are the potential value gains of the fishery itself identified, but also the likely socio-economic impacts on the UK economy and workforce as a whole are quantified by incorporating employment, output and value added multipliers to changes in landings that would have taken place under the alternative management scenarios.

METHODS

Biological and management model

The stock was simulated using the computer program environment FLR specifically developed for biological simulation (Kell et al 2007). The economic components were carried out using Excel.The basic form of the simulation system is shown in Figure 2. The stock is simulated using a standard age based fisheries model (Equ 1). The simulation mimics the management system used in recent years to give the catch advice: ICES assembles the data annually in March each year using catch data up to 31 December from the year before. This data is combined with four surveys; two trawl surveys on ages 0 (years 1992-2010) and 1-5 (years 1984-2010) respectively; an acoustic survey on ages 2-9 (years 1989-2009) and larvae survey (years 1973-2009) which is used to estimate the SSB that produces the larvae. Survey errors at age *a* in year *y* were estimated from the survey observations and the 2010 stock assessment as the log residuals ε_{ays}. Varying relative catch at age is estimated in the early years (1992-2004) as variability in $F_{ay}/Fbar_y$ at age in the assessment and in recent years (2005-2009) as catch residuals in the separable model in the assessment

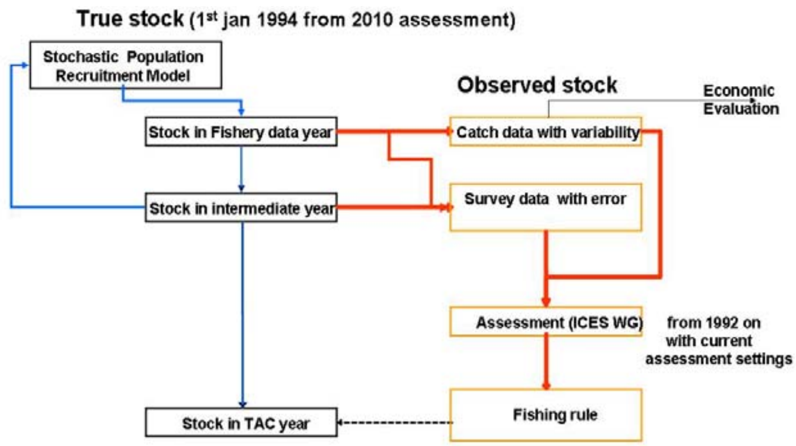

Figure 2. Biological and management components of the simulation based on routines in FLR. Stock components in blue observation and decision components in red. Economic evaluation is based on catches.

$$\begin{pmatrix} N0 \\ N1 \\ \vdots \\ N9+ \end{pmatrix}_{t+1} = \begin{pmatrix} \exp(\log(A*SSB*\exp(-B*SSB))+\varepsilon_y) & & & & & \\ \varphi_a \cdots & & & & & \\ \cdots\ \varphi & & & & & \\ & \varphi & & & & \\ & & \varphi & & & \\ & & & \varphi & & \\ & & & \cdots & \varphi & \varphi \end{pmatrix} \begin{pmatrix} N0 \\ N1 \\ \vdots \\ N9+ \end{pmatrix}_{t} \quad \text{(Ricker 1957)} \qquad \text{Equ 1}$$

$\Phi_a = F_a + M_a$ (Age dependent Fishing and Natural mortalities)

The recruitment (*N0*) is generated assuming a Ricker stock recruit (S/R) relationship (Ricker 1957) in which the recruitment depends on a function of SSB and a deviation ε_y that is used to simulate the environmental variability independent on stock size. The choice of the Ricker function is based on statistical fit criteria, the good fit at high SSB that justifies the depensatory function can be seen in Figure 3.

The S/R relationship was based on a maximum likelihood fit assuming log deviations (Equ 1). The years chosen for the fit were those from the ICES assessment 1978 to 2009. This covers the period of the simulated management but allows a plausibly extended range of SSB for the stock. The choice of years is discussed in Nash et al (2009). The deviations from the model were retained to act as environmental influences acting independently from stock size. The deviations were with the simulated SSB and used in the years they originally occurred. This introduces a small dependence of recruitment on management through the SSB but maintained the large environmental effects assumed to be independent of stock or fishery (see below).

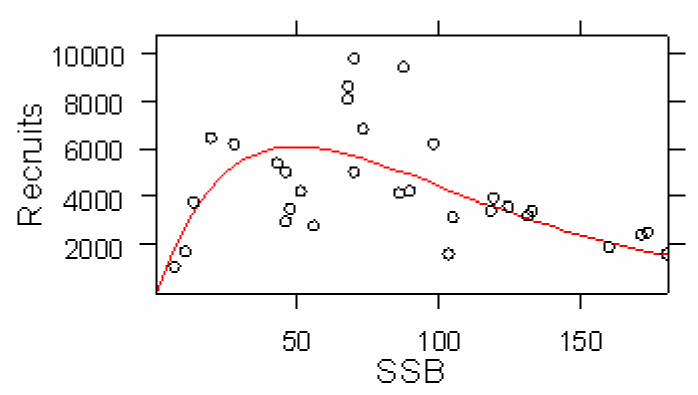

Figure 3 Fitted Ricker Stock Recruit relationship to years 1978 – 2009 SSB and R rescaled by 10000 to allow fitting.

Simulated surveys are generated from the simulated *N*, the fitted *Q* and including errors in year *y* and age *a* which are estimated as:-

$$N_{ays} = Q_{as} N_{ay} * \exp(\varepsilon_{azs}) \qquad \text{Equ 3}$$

The year index of the error term z can be drawn (several times) at random for a stochastic evaluation to check sensitivity of management to errors or made equal to the original year to mimic the exact errors experienced. For the evaluations presented here this second option is chosen.

The assessment procedure used in the simulations followed the ICES assessment procedures using the data and weighting described in the ICES assessment report (ICES 2010). The survey time series were slightly modified, from those used by ICES in the annual assessments, to those used in Simmonds (2009) when carrying out a long retrospective analysis. The acoustic survey has the estimates of age 1 removed as they only available since 1996, the age 0 trawl survey was extended back from 1992 to 1989 by use of earlier non standardized values rescaled to have the same coefficient of proportionality *Q* of the later values. This arrangement allowed the first assessment to be performed using 1960-1992 catch data as if assessment year was 1993 and the catch advice year was 1994.

Economic methods

First it is important to note that in this analysis we are looking at the impact of changes in landings by the UK pelagic fleet into the UK. This is because Input-Output multipliers on fishing are currently only available for the UK. Further work is required to extend this analysis to all countries and fleets involved in North Sea herring. The economic outcomes for the UK under each management scenario are estimated in three stages.

1) Determination of volume of catch in tonnes landed in to the UK. Historically the UK pelagic fleet can choose to land in a number of markets. The proportion of herring landed in UK is estimated from UK official statistics and assumed to be consistent under different scenarios (see below)
2) The price paid per tonne for herring in UK is obtained from UK official statistics. Corrected for inflation (Equ 4) to 2008 prices using the UK retail price index I_y. The price for the different scenarios is obtained by assuming and applying a price elasticity factor to estimate value of

landings for the scenarios with different landings. For every 1% increase in herring landings volume, price decreases by 0.44% (Nielsen, Smit & Guillen 2008). This factor is first removed from the original series of UK prices to give an elasticity free series. Then reapplied (Equ 4) with the changes that occur in the different scenarios. P_{yx} is calculated from the original prices P_{yo} with the change in weight of landings in the original scenario $\Delta W_{y,y-1,o}$ and the new scenario $\Delta W_{y,y-1,x}$.

$$P_{yx} = P_{yo} * I_{2008} / I_y + 0.0.044(\Delta W_{y,y-1,x} - \Delta W_{y,y-1,o}) \qquad \text{Equ 4}$$

3) Input-Output (I-O) multiplier factors for the UK were taken from a study commissioned by Seafish and undertaken by the Fraser Allander Institute (2007). The multipliers are used to quantify the importance of the catching and processing sectors to the overall economy, which is always greater than the sales value. The impact of changes in the economic output of the sea fishing sector initiates a multiplier process that further affects output and activity in other sectors (the direct impact). These changes in output change the demand for intermediate inputs (indirect impact) plus changes in consumption demand as employment and household incomes adjust (induced impact). UK pelagic type II multipliers (incorporating direct, indirect and induced impacts) for 1 million increase or decrease in UK pelagic landings value of the UK fleet are:-

Output = M£6.98
Gross Value Added = M£3.42
Employment = 81 FTEs

Scenarios

Five main management scenarios are selected to illustrate the issues. It is not intended that these form a full management strategy evaluation, rather they investigate the main issues for managers. All of these were run from an assessment in 1993, then implementing catch advice in 1994 (the first management year). The following year (1994 in the first case) recruitment was estimated from the SSB in that year using the S/R model with the year deviation ε_y to simulate environmental influences. The fishery was simulated as removals at age using the same age structure observed for that year. New survey indices were generated from the simulated stock. Then a new assessment was carried out and the next years catch advice was obtained (1995). This was repeated up to 2009, with economic evaluation available until 2008. The purpose of the five chosen scenarios is to illustrate the economic differences between what happened if (1) the original observed management from 1994 had occurred, (2) the basic F target rule had been followed without error, (3) a constant unchanging TAC (chosen so simulated SSB in 2010 = observed SSB in 2010). This was to test the outcomes of the most consistent supply of herring possible; not as a realistic proposition but to evaluate the difference in economic outcome between fixed and variable supplies. Two constrained methods (4 and 5) are realistic as they incorporate errors and management decisions. They are designed to give a realizably consistent TAC that would be possible in the presence of biological fluctuation and measurement error. The five scenarios are summarized as:-

- 1) Original catches (Original)
- 2) Fishing mortality (F0.25,0.12) implemented without error (F adult = 0.25, F juvenile = 0.12)
- 3) Constant catch (CC 420) of 420 000t per year (to give same SSB as observed in 2010)
- TAC set following the F rule above but TAC constrained to be constant unless estimated F (including measurement error) departs from the rule by a defined percentage, in which case TAC is changed by that percentage
    - 4) 10% constraint (10%)
    - 5) 15% constraint (15%)

RESULTS

Changes in stock

The changes in the recruitment, mean Fishing Mortality ages 2-6 (F), spawning stock (SSB) and landings are shown for each of the 5 different scenarios are shown in Figure 4.

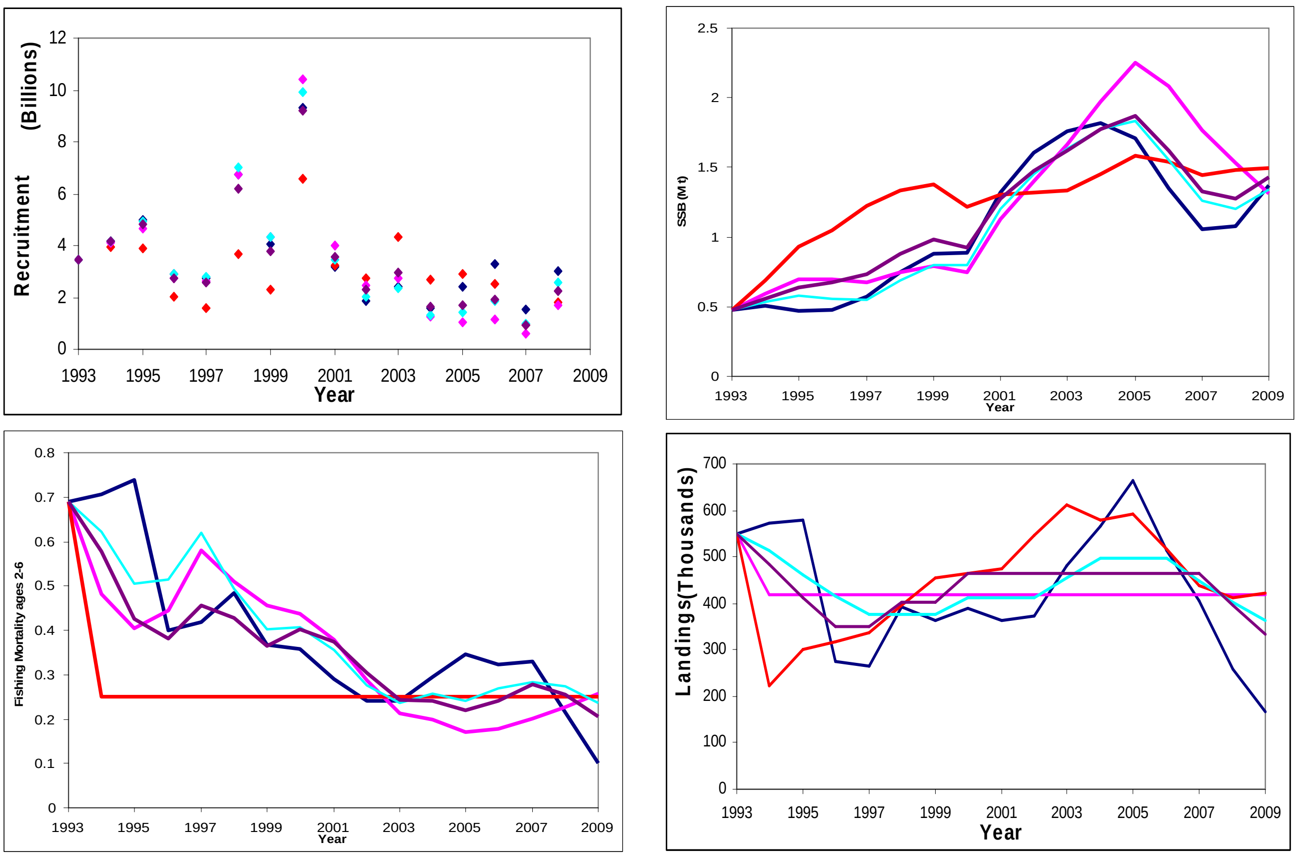

Figure 4 1993 to 2009 changes in Recruitment , SSB, mean Fishing Mortality ages 2-6 (F) and total landings for North Sea herring under the 5 different scenarios: 1) Original management; 2) F management without error; 3) constant catch of 420 000t in all years. 4) F constraint with constant catch unless target catch deviates by up to 10% or 5) 15%.

1) Original — 2) F 0.25,0.12 — Con Catch 420 — F 10% y-y limit — F 15% y-y limit

Figure 4 shows that while there are differences in trajectories among scenarios, all give similar SSB in 2009. While recruitment is dominated by the deviations that are assumed to be environmentally dependent it is possible to see the potential impact of SSB implied by the Ricker function, 1998, 2000, 2005 and 2006 show the greatest sensitivity to biomass. The original scenario has the widest range fishing mortality due to fluctuation of both measurement error but also compliance. The constant catch scenarios gives the widest range of biomass; the highest biomass achieved in 2005 is around 15% higher than any other scenario but is needed to maintain catches during the last 3 years. This scenario is not a practically realizable scenario, rather, it is included to investigate the economic circumstance of stable fish supplies. The two percentage constrained scenarios are chosen to try to give stability with realistic responses. These scenarios deliver variability at around 1/3 of that observed originally. The unconstrained F strategy has twice the variability of these constrained approaches. Except for the constant F version (2) all strategies take time to reduce F reaching the target by about 2000 as a good recruiting year-class from 1998 enters the population and fishery. So the response of the population is dominated by the available recruitment only more minor difference depend on management.

Economic outcomes

The economic outcomes are presented first as the price and value of landings for the five scenarios 1993 to 2008 (Figure 5). Price changes throughout the period, there is a period of greater stability 1993 to 2000, with a sharp change in 2001 and a generally more volatile period 2001 to 2008 with a high mean. The value of landings is most variable in the original scenario, However, even constant catch scenario delivers variable landings value due to the considerable price variability.

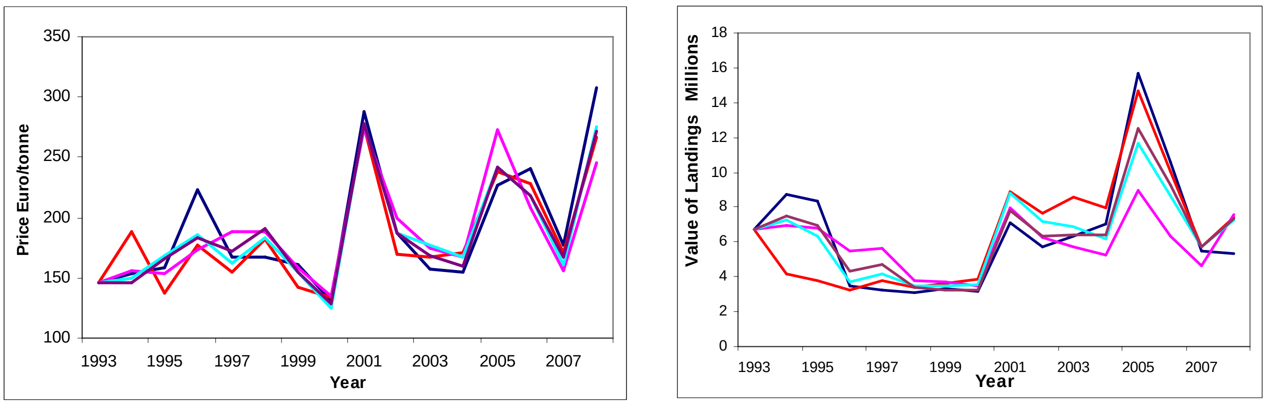

Figure 5 Prices and Value of UK landings (Euro) 1993 to 2008 corrected for inflation under different scenarios (see text for scenario descriptions).

1) Original 2) F 0.25,0.12 Con Catch 420 F 10% y-y limit F 15% y-y limit

The changes in landings value is translated to changes in UK employment, GVA (Figure 6). The different scenarios are compared with the original (Figure 7). All of the more stable scenarios have lower landed value overall (Table 1). However, the net economic impact for the period are all negative for the period however the reduction is lower under the more stable scenarios (Table 1, Figure 7)).

Table 1. Summary of economic outcomes.

	Original	F adult 0.25	Con Catch 420	15 % y-y	10 % y-y
Total landed value	95.7	94.0	88.7	93.3	94.3
Net change in landed value	-4.3	-2.6	-2.5	-2.7	-2.7
Net change in GVA	-30.0	-18.3	-17.6	-19.0	-18.7
Net change in employment	-349	-213	-204	-220	-217

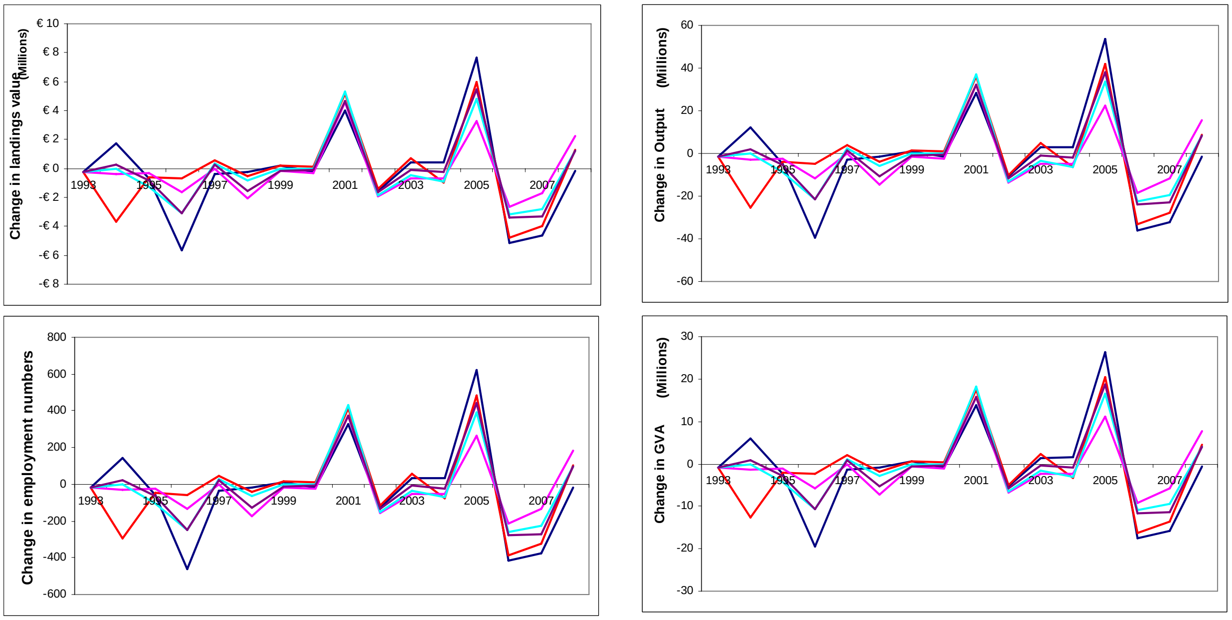

Figure 6 Year on year changes in landed value and resulting changes in Output, GVA and Employment
1) Original 2) F 0.25,0.12 Con Catch 420 F 10% y-y limit F 15% y-y limit

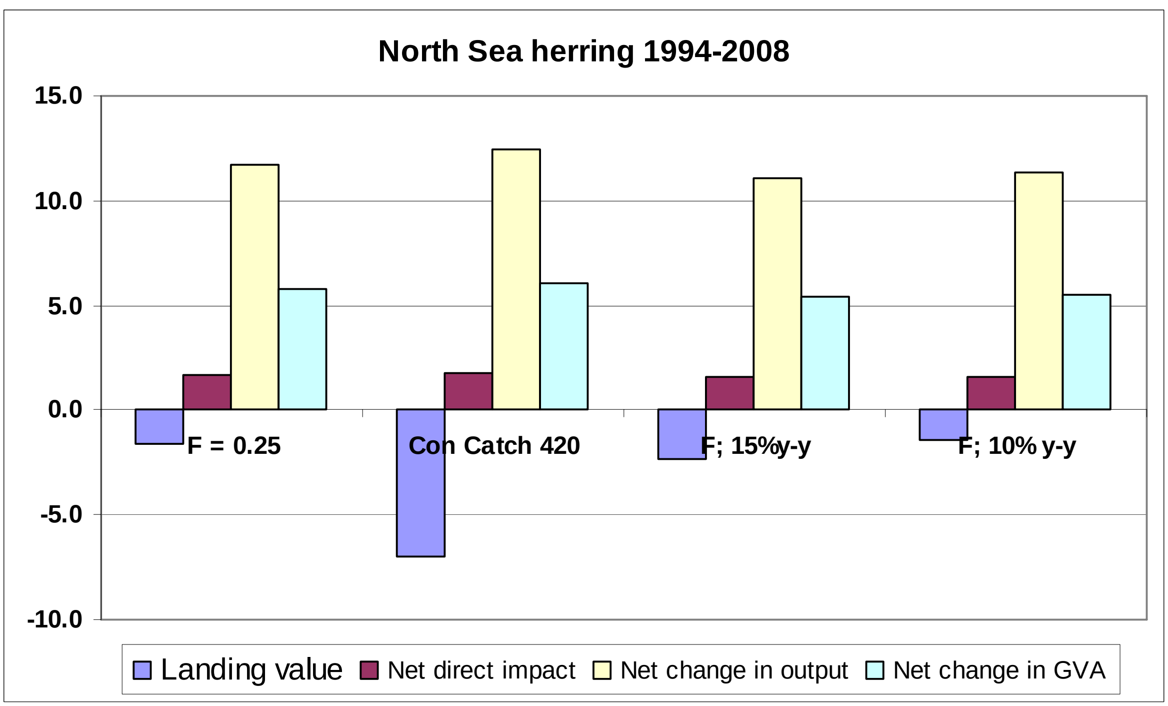

Figure 7 Relative changes in total landed value and the resulting changes in total net direct impact, net change in output and net change in GVA for the four alternative scenarios compared with the original management.

DISCUSSION & CONCLUSIONS

Taken in isolation, the rise in price in 2001 might be thought alarming. During the earlier years the first sale price of herring was relatively low at around 18p per kilo, representing a low price relative to the processed product. The opportunity for fishers to obtain higher prices was available by landing into non UK ports where prices were higher but also more variable (UK statistics). Bjorndal (2010) acknowledges the variation in herring price, which is sold on an international market along with Norwegian spring spawning and Icelandic herring. North Sea herring is a small part in comparison to the total, so in this context the changes that independent of the supply of North Sea herring are plausible.

The value of landings derived under the original management setup is higher than all the other scenarios tested. However, despite the fact that the other management plans resulted in lower total landings values over the period, better socio-economic outcomes were observed in terms of net output, employment and value added in the UK economy relative to the original case. Lower variability in landings results in lower variability in employment and, in this case, higher final numbers employed at the end of the period relative to the original case. External factors influence the North Sea herring price to an extent that even with smoother landings volumes the value of landing varies considerable from one year to the next. The socio-economic impact of changes in the value of fish landings as expressed through net output, employment and GVA on all sectors of the economy are always greater than the impact on the catching sector alone. Controlling variability in landings is a viable proposition; the 10 and 15% constraints give much lower variability in landings at 1/3 of the original variability. The evaluations suggest that there is potential for fairly substantial movement of catch from one year to the next, provided exploitation levels are near Fmsy. But this implies either borrowing against the future or banking surplus from the past and implies a discipline in the behaviour of fishers and managers as well as sufficient resource levels in the stock to allow this.

REFERENCES

Bjørndal, T. (1987). "Production Economics and Optimal Stock Size in a North Atlantic Fishery". Scandinavian Journal of Economics 89: 145-164.

Bjørndal, T. (1988). "The Optimal Management of North Sea Herring". Journal of Environmental Economics and Management 15: 9-29.

Bjørndal, T. and Conrad, J.M. (1987). "The Dynamics of an Open Access Fishery". Canadian Journal of Economics 20: 74-85.

Bjørndal, T. and Lindroos, M. (2004). “International Management of North Sea Herring”. Environmental and Resource Economics 29: 83-96.

Buhl-Mortensen, L., and Toresen, R. 2001. Fisheries management in a sea of uncertainty: the role and responsibility of scientists in attaining a precautionary approach. International Journal of Sustainable Development, 4: 245–264.

Christensen, S., and Lassen, H. 2004. The economic impact of the ACFM catch options for the Danish North Sea herring and industrial fisheries in 1999. Fisheries Research, 68: 21–35.

Dickey-Collas, M., Nash, R. D. M., Brunel, T., van Damme, C. J. G., Marshall, C. T., Payne, M. R., Corten, A., Geffen, A. J., Peck, M. A., Hatfield, E. M. C., Hintzen, N. T., Enberg, K., Kell, L. T., and Simmonds, E. J. 2010. Lessons learned from stock collapse and recovery of North Sea herring: a review. – ICES Journal of Marine Science, 67: 000–000.

Fraser Allander Institute, prepared for Seafish (2007) The economic impacts of the UK sea fishing and fish processing sectors: an Input-Output analysis

ICES 2008 ICES ADVICE 2008 Books 6 North Sea Report of the ICES Advisory Committee.

ICES 2010. Report of the Herring Assessment Working Group for the Area South of 62°N, 15–23 March 2010 (ICES CM 2010/ACOM:06).

Kell L.T. Mosqueira I., Grosjean P., Fromentin J-M., Garcia D., Hillary R., Jardim E., Mardle S., Pastoors M. A., Poos J. J., Scott F. and Scott R. D. 2007 FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science; 64 640-646

Nash, R. D. M., Dickey-Collas, M., and Kell, L. T. 2009a. Stock and recruitment in North Sea herring (Clupea harengus); compensation and depensation in the population dynamics. Fisheries Research, 95: 88–97.

Nielsen, M., Smit, J., Guillen, J 2009. ”Market integration of fish in Europe”. Journal of Agriculture economics, Vol 60, No. 2, 367-385.

Patterson, K. R., and Melvin, G. D. 1996. Integrated Catch at Age Analysis, version 1.2. Scottish Fisheries Research Report, 58. 60 pp.

Patterson, K. R., Skagen, D., Pastoors, M., and Lassen, H. 1997. Harvest Control Rules for North Sea herring. Working Document for the ICES ACFM November Meeting 1997.

Poulsen, B. 2006. Historical exploitation of North Sea herring stocks an environmental history of the Dutch herring fisheries, c. 1600–1860. PhD thesis, Centre for Maritime and Regional Studies, Department of History and Civilization, University of SouthernDenmark.

Ricker, W. 1954. Stock and recruitment. Journal of Fisheries Research Board of Canada. 11: 559–623

Saville, A., and Bailey, R. S. 1980. The assessment and management of the herring stocks in the North Sea and to the west of Scotland.ICES Marine Science Symposia, 177: 112–142.

Simmonds, E. J. 2007. Comparison of two periods of North Sea herring stock management: success, failure, and monetary value. ICES Journal of Marine Science, 64: 686–692.

Simmonds, E. J. 2009. Evaluation of the quality of the North Sea herring assessment. ICES Journal of Marine Science, 66: 1814–1822.