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THE ICES STOCK EVALUATION COURSE: AN EXPERIMENT IN REPLICATE ASSESSMENTS

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INTRODUCTION

The Stock Evaluation Course held at the Fisheries Laboratory, Lowestoft, 16-25 November 1976, was devoted to syndicate exercises to simulate the problems encountered in practical working group experience. Typically these included incomplete catch statistics, inadequate sampling, fishing effort data of dubious value together with fundamental biological imponderables concerning, for example, stock identity and levels of exploitation. These problems were represented in a series of fictitious stock simulations. Though recognized as potential sources of error in stock assessment their relative importance and indeed the total potential error in an assessment is extremely difficult to measure. The replicate assessments carried out independently by each syndicate during the course gave an opportunity to illustrate the likely range of interpretation of a given set of data. The summary of results below record the 'flavour' of the course and the range of assessments as a cautionary note to all engaged in this aspect of management. We believe this will be of interest and to that extent all the course participants (Appendix 1) have contributed to this paper.

THE COURSE

The course followed the flow chart logic of assessments as they are usually conducted within ICES and ICNAF Working Groups for stocks where the age structure of the stock and catches are available. This logic is set out in Figure 1 but generalised production models were also open for use by syndicates as they wished. The separate phases of an assessment were introduced and explored through lectures staged to keep pace with the development of the syndicate exercises, the results being drawn together at the end. The course also included discussions of the long term importance of biological interaction (led by Prof Hempel and Dr Ursin) and on the importance of economic considerations (Mr Curr, UK, White Fish Authority Operations Research and Mr Holden, Lowestoft), so as to introduce some of the wider aspects of assessments which cannot yet be formally introduced into the computational procedures.

The syndicate exercises concerned eight species, each fished by two countries. In four species - the flaice (*Flaccidia flatarca*), the common scod (*Gadus gomorrohe*), the ballock (*Cryptogadus sphaeroides*) and the sprattl (*Scomber skimper*) - age composition data could be constructed, but the other four - the greater quark, capout, sargentain and skwelioreps - presented different problems of complex biology or almost total lack of data. The syndicates were asked to prepare assessments and management advice for each of these eight species. People interested in the second group should consult course participants for further detail: the results below concern only the first four where some sensible comparisons between syndicate assessments were possible.

The main characteristics of the four principal stocks were as follows:

a Flaice - a stable fishery over a long term period with straightforward data containing all the requisite catch and effort statistics and biological samples. A comprehensive age composition could be constructed and analyzed by conventional techniques and confirmed using the fishing effort data. Recruitment was independent of stock size.

b Ballock - followed the flaice in broad principle but was drawn from two separate stocks without clear evidence of a distinction. Syndicates had to decide on the grouping and at the same time accommodate wide variations in recruitment between the two stocks and over time. There was no stock/recruitment relationship.

c Scod - maintained the dilemma created by stock separation problems but did incorporate a well-behaved Ricker-type stock recruitment relationship.

d Sprattl - introduced all the extreme difficulties of a pelagic species fished for industrial and human consumption purposes at different phases of the life history, with rapid fluctuation in the fishery and its partial recruitment pattern, meaningless fishing effort data, a high level of natural mortality and an ill-conditioned stock recruitment relationship.

THE ASSESSMENTS

The length and age sampling data were incomplete for all species and required syndicates to select samples which were most appropriate to the catches in the most recent year of fishing even though they might be from different countries or from adjacent fishing areas. The syndicates adopted a range of options but produced very consistent estimates of the age composition of the total catch of each species. Likewise the estimates of growth and average weight at age were treated in slightly different ways but their influence on the final assessments was marginal compared to the recurring principle problems of:

a the level of natural mortality;

b the terminal fishing mortality and exploitation pattern;

c the prospective recruitment in the immediate future.

Tables 1A to D compare the syndicate estimates of natural mortality, terminal F and exploitation pattern with the simulation data. These are crucial determinants of current stock size which are certain to influence estimates of prospective yield, also the mortality appropriate to a management objective and possibly even the direction in which mortality should be regulated to achieve that objective.

The syndicate results for flaice were generally low, lower than the actual for ballock and scod they were reasonably consistent with the actual but for sprattl they showed some quite remarkable discrepancies, though this was not entirely unexpected in view of the programmed difficulties. The variation was generated by a combination of factors but primarily the initial choice of M which, if wrong, led to inconsistent trends in stock size in trial cohort analyses, and hence poor estimates of F and F/F + M which were particularly important where F was low.

The estimates of natural mortality were not in all cases valid. Several syndicates were discouraged by the lack of resolution in the fishing effort data and reverted to the Pope Query Symbol method which happened to correspond tolerably well with some of the simulations. The estimates for sprattl give some indication of the scope for discrepancy in the absence of this guideline and it is as well to remember that there is no foundation to the Query Symbol approach.

Table 2 summarizes the outcome of the assessments and the recommended TAC in respect of the chosen objective. This was invariably to achieve the level of fishing associated with the maximum yield or MSY per recruit, though syndicates adopted different strategies according to their assessment of the present state of the stock and exploitation in relation to the goal. Most of the assessments of ballock and scod were close to the simulated target subject to the same objective and so too were the completed sprattl assessments, bearing in mind the strategy adopted by the syndicates and the severity of management they were prepared to recommend. The flaice assessments showed more variability, although this was the least complex situation. The reason lay in over-estimation of natural mortality and ~~its~~ its consequent effects on identification of the correct objective, which became compounded in deciding future management to reach the wrong objective. To this must be added uncertainty over future recruitment, though in the two syndicates where this resulted in grossly anomalous yield projections they had realised the need to review their assessment before offering any advice.

CONCLUSIONS

In some quarters there has been a hint that because the basic assessment data are subject to unspecified errors, and because several parameters are difficult to estimate explicitly, then the assessments themselves will be grossly unreliable. Indeed there is a danger this attitude will influence the people whom scientists advise. There are uncertainties, and there is a danger that Working Groups will become conditioned to a set approach and interpretation of their data, but in our view the developing climate of opinion amongst some scientists does less than justice to their own judgement. The results of this little experiment show that, despite the problems, the careful sifting of available data and deductive judgement within each syndicate did lead to a sound appraisal of the state of each stock. In real situations this can be reinforced by the annual review procedure, especially if this involves thought and an in-depth study of new data and of the established approach of a group that has worked together for some time. This will detect a stock responding in a way that has not been anticipated and so allow the accuracy of an assessment to be improved. The experiment showed the initial assessments can be quite good and the reality of annual review adds an iterative procedure over time. An actual example of this process can be drawn from the estimates of terminal F in a series of six assessments of Arcto-Norwegian cod in the period 1966-1973. These are summarized in Table 3 giving, in A the estimate of terminal F in the year of each assessment and in B the retrospective estimates of F in those years based on the most recent figures (1976) which, through convergence of the serial estimates of F in cohort analysis, will provide good estimates of F to compare with the initial figure. Table 3C gives the discrepancy between the two. The average discrepancies by age group as a percentage of actual F per age group are:

Age group	% error	Age group	% error
3	+ 125	7	+ 46
4	+ 91	8	+ 12
5	+ 60	9	- 3
6	+ 55	10	+ 18

These reflect the great difficulty in judging the fishing mortality on partially recruited age groups and hence in judging recent recruitment. They reflect also the scientists' dictum - when in doubt be pessimistic. The average discrepancy by years over all age groups as a percentage of actual F is:-

Years	% error	Years	% error
1966	+ 47	1971	+ 10
1968	+ 63	1972	+ 2
1970	+ 27	1973	+ 18

These show the same pessimism but a steady improvement. It also explains the common experience that fisheries tend to perform better than scientists anticipate but it lends confidence to the view that assessments can reach a workable level of accuracy despite the wealth of imperfection implied by statistical criteria. Scientists should not disregard the value of their own judgement simply because it cannot be allocated confidence limits, but they must remain wary of the difficulties and use each opportunity to discuss their stocks to the full and reappraise their own habits of thought in respect of it.

TABLE 1A   Terminal F values + value of M - flaice

	Actual	Syndicate number					
		1	2	3	4	5	6
M	.1	.16	.2	.2	.28	.24	.2
1							
2							
3	.08	.036	.05	.02	.03	.046	.08
4	.22	.096	.15	.1	.07	.122	.19
5	.32	.14	.2	.1	.10	.156	.3
6	.32	.14	.2	.1	.10	.156	.3
7	.32	.14	.2	.1	.12	.156	.3
8	.32	.14	.2	.1	.13	.156	.3
9	.32	.14	.2	.1	.15	.156	.3
10	.32	.14	.2	.1	.19	.156	.3
11	.32	.14	.2	.1	.19	.156	.3

TABLE 1B F values + value of M - ballock

	Actual	Syndicate number						
		1	2	3	4	5		6
						Area 1	Area 2	
M	.2	.2	.3	.2	.2 + .4	.16	.29	
1	.04	.055	.05	.06	.06	.06	.11	
2	.58	.59	.45	.67	.62	.61	.32	
3	.56	.56	.45	.68	.62	.675	.33	
4	.69	.74	.73	.83	.79	.959	.5	
5	.84	.74	.85	.95	.92	1.16	.67	
6	.99	.74	.85	.98	.90	.551	.78	
7	1.09	.74	.85	.98	.76	.551	.65	
8	.75	.74	.85	.98	.71	.89	.65	

TABLE 1C Terminal F values + value of M - scod

	Actual	1	2	3	4	5	6
M	.3	.2	.25	.25	.2	.25	
1	0	0	0	0	0	0	
2	.06	.05	.08	.05	.04	.07	
3	.30	.33	.45	.3	.33	.43	
4	.59	.54	.85	.6	.56	.88	
5	.57	.54	.75	.5	.47	.78	
6	.72	.54	.75	.5	.48	.82	
7	.82	.54	.75	.5	.49	.91	
8	.87	.54	.75	.4	.42	.85	
9	.70	.54	.75	.3	.3	.85	

TABLE 1D Terminal F values + value of M - Bight of Pixyland - sprattl

	Actual	Syndicate number					
		1	2	3	4	5	6
M	.6		1.0	.6	.6	1.5	
1	.67		.65	1.3	.9	.9	
2	1.35		0.9	1.5	1.6	.9	
3	1.42		1.5	2.4	2.2	.9	
4	1.43		1.5	2.4	2.2	.9	
5	2.12		1.5	2.4	2.2	.9	
6							

TABLE 2 Summary of assessments and TACs to achieve F_{max}

Species	Assessment	M	Terminal F (selected age range)	Y/R	F_{max} Y/R with S/R	F objective	TAC (000 t)
PLAICE	Actual	0.1	0.3	0.3		0.3	356
	1	0.2	0.3	0.6		0.2	300
	2	0.2	0.2	0.8		0.4	600
	3	0.28	0.2	0.3		0.3	440
	4	0.2	0.1	0.6-0.8		0.6	2000
	5	0.24	0.16			0.5	1000
BALLOCK	Actual	0.2	0.92	0.6		0.6	300
	1	0.2	0.74	0.5		0.5	273
	2	0.3	0.85	(1.45)?		0.75	356
	3	0.2	0.97				
	4	0.3	0.82	0.6		0.4	
	5	0.2	0.79			0.3	250
	6	0.3	0.69				
SCOD	Actual	0.3	0.71		0.6	0.6	456
	1	0.2	0.54		0.55		
	2	0.25	0.75		0.65	0.6	465
	3	0.25	0.47				
	4	0.2	0.45			0.35	440
	5	0.25	0.85		0.50	0.25	220
SPRATTL (Bight of Pixyland)	Actual	0.6	1.4	∞	0.7	$F_{0.1}$ 0.7 0	49 ZERO
(Fairyland coast)		0.6	0.93	∞	0.7	$F_{0.1}$ 0.7 0	222 ZERO
	1	0.6	1.5 +	'1.75'	0.9	0.7	228
	2	1.0					
	3	1.2	0.9				ZERO (or token exploitation midwater trawl fishery)

TABLE 3 Arcto-Norwegian cod: comparison of sequential best estimates of F (1966-1973) with 1976 analysis

		1966	1968	1970	1971	1972	1973	Average
A								
Initial estimate of year made in Year n + 1	3	.02	.06	.06	.15	.06	.20	
	4	.14	.25	.17	.30	.22	.20	
	5	.46	.52	.28	.45	.32	.35	
	6	.45	.71	.56	.50	.38	.45	
	7	.39	.69	.73	.50	.50	.60	
	8	.60	.74	.90	.50	.63	.65	
	9	.81	.85	1.12	.50	.63	.65	
	10	1.13	1.12	1.12	.50	.63	.65	
B								
1976 estimate	3	.03	.02	.03	.01	.03	.13	.04
	4	.08	.16	.10	.07	.12	.14	.11
	5	.16	.34	.31	.18	.22	.26	.25
	6	.31	.40	.47	.20	.31	.30	.33
	7	.40	.35	.54	.43	.28	.34	.39
	8	.49	.46	.73	.73	.55	.62	.60
	9	.60	.68	.85	.80	.96	.79	.78
	10	.63	.64	.86	.69	.97	.58	.73
C	Average	.34	.38	.49	.39	.43	.40	
Discrepancy	3	- .01	+ .04	+ .03	+ .14	+ .03	+ .07	+ .05
	4	+ .06	+ .09	+ .07	+ .23	+ .10	+ .06	+ .10
	5	+ .30	+ .18	- .03	+ .27	+ .10	+ .09	+ .15
	6	+ .14	+ .31	+ .09	+ .30	+ .07	+ .15	+ .18
	7	- .01	+ .34	+ .19	+ .07	+ .22	+ .26	+ .18
	8	+ .11	+ .28	+ .17	- .23	+ .08	+ .03	+ .07
	9	+ .21	+ .17	+ .27	- .30	- .33	- .14	- .02
	10	+ .50	+ .48	+ .26	- .19	- .34	+ .07	+ .13
	Average	+ .16	+ .24	+ .13	+ .04	- .01	+ .07	

APPENDIX: COURSE PARTICIPANTS

Canada	Campbell, Humphries, Stasko, Wells
Denmark	Jensen, Lokkegaard
Egypt	Mohamed
Finland	Parmanne
France	Gueguen, Maucorps
FRG	Kock, Pommeranz, Schöne, Weber
Iceland	Fridgeirsson, Palsson, Skuladottir
Ireland	Griffiths
Italy	Levi
Morocco	Rani
Netherlands	Becker, Corten
Norway	Dommases, Giskeødegard, Gjøsaeter, Jakobsen, Ugland
Poland	Janusz, Paciorkowski
Sweden	Sjöstrand
Spain	Fuertes, Macpherson
UK England	Bennett, Curr, Houghton, Macer, Wood
Scotland	Chapman, Shelton

Figure 1. Flow chart of a stock assessment procedure