Consistency of Stock Assessment and Evaluation of Fisheries Management for European Fish Stocks, 1983-1995

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Abstract

This paper looks at the actual catches of eight European demersal fish stocks back to 1983 in reference to the annual assessment and recommendations issued by the European Community management system. We used all estimates obtained at all steps of the process (catch data for any year *n*, VPA assessment, TACs for any (*n*+1) year, and respective actual catches). From this, we calculated ratios linking expected and actual values of demographic parameters of stocks. These ratios highlight discrepancies along the TAC setting process and their induced outcomes for exploitation and management. The scientific diagnoses obviously are pessimistic for saithe in West Scotland but not always pessimistic enough given the actual state of the stocks. Conversely, for whiting, the assessment and recommendations lead to an optimistic diagnosis but not optimistic enough. Additive uncertainty together with too much trust in sophistication of assessment methods, associated with bargaining along the whole process, may explain a low performance of the management system of some European fish stocks.

Introduction

During recent decades, the scientific assessments and the management framework that was set up within the European Union were unable to stop the decline of most fish stocks. Today, many stocks are overexploited, sometimes very heavily, in spite of technical measures taken for many years such as total allowable catches (TACs) and quotas (Biais 1993). By scrutinizing the history of the decision-making process, it seems possible to identify some reasons for this failure, to improve the assessment process, and to design more efficient management tools.

Northeastern Atlantic fish stocks are exploited by European Community fishing fleets. Many stocks are scientifically assessed on an annual basis by working groups of the ICES (International Council for the Exploration of the Sea). The assessment stage leads to management recommendations that are converted into TACs and fishing quotas through a complex process, which was described by Gueguen (1988). Our working assumption is that part of failure may come from this long and complicated process. Then, by using a retrospective analysis applied to some stocks exploited by Brittany fleets from 1983 to 1994, this paper evaluates the reliability of diagnoses issued from the ICES assessment groups, the discrepancies between proposed management recommendations, the adopted levels, and the recommendations that were implemented. The subsequent impact of actual catches on the stocks is also considered.

Material and Methods

Status of the Fish Stocks

High-seas French fleets based in Southern Brittany (Lorient, Concarneau, Guilvinec, Douarnenez, and Audierne) are composed of about 350 trawlers (artisanal, semi-industrial, and industrial) based in different harbors. They mainly exploit West Scotland zones (industrial trawlers from Lorient and semi-industrial from Concarneau), the Celtic Sea zone (semi-industrial from Lorient and artisanal fleet from Concarneau), and Bay of Biscaye (artisanal fleet). A fishing vessel is defined as a high-seas vessel if it makes more than one 96-hour fishing trip during a given year.

All quoted data come from Maguer (1996) and were extracted from databases held by the Administrative Center of Marine Affairs at St. Malo, France, and by IFREMER (Fishery Laboratory located at Lorient, France). As assessment refers to stock concept which associates a species with an ICES area, some species may include two distinct stocks. Thus, of the ten main species exploited by high-seas fishing fleets from southern Brittany, only eight are under scrutiny of the ICES and managed under TACs; this corresponds to nine stocks. Monkfish stocks *(Lophius piscatorius* and *L. budegassa)* are not considered in this paper because of their low level catch within West Scotland zone.

As a whole, catches of species under TACs decreased by a factor of two. During the mid-1980s, the total catch of the main eight species was about 100,000 metric tons from a total of 150,000 t caught by those fleets. Since 1989, overfishing and the decline of the industrial fishery led to a very severe depression in catch and spawning stock biomass. In 1994, they represent only 50,000 t (Fig. 1a). Similar patterns are observed for

Table 1. The eight main stocks exploited by high-seas fishing fleet based in Southern Brittany, under annual ICES working groups assessment.

Species	Name	Geographical zone	ICES zones	Stock level in 1995
Saithe	*Pollachius virens*	West Scotland	VI	Overexploited and biomass lower than MBAL
Cod	*Gadus morhua*	West Scotland	VIa	Overexploited and biomass lower than MBAL
Cod	*Gadus morhua*	Celtic Sea	VIIfgh	Overexploited and biomass close to MBAL
Hake	*Merluccius merluccius*	North Atlantic	IIIa IV VI VII VIIIab	Overexploited and biomass lower than MBAL
Whiting	*Merlangius merlangus*	Celtic Sea	VIIbk	Growth overfishing
Megrim	*Lepidorhombus* sp.	Celtic Sea and Bay of Biscaye	VIIbk + VIIIab	Growth overfishing
Norway lobster	*Nephrops norvegicus*	Celtic Sea and Bay of Biscaye	VIIIab	Growth overfishing (evaluation in 1992)
Haddock	*Melanogrammus aeglefinus*	West Scotland	VIa	Growth overfishing

The status level of exploitation is given for 1995 (from ICES 1996).

their relative spawning stock biomass which suggest a decline of some stocks (hake, saithe, and haddock) for the considered area. All these stocks are currently considered overexploited (Table 1) and three of them display biomass levels lower than the minimum considered under a precautionary approach (ICES 1996).

The MBAL (Minimum Biological Acceptable Level) is a critical empirical threshold which defines a precautionary approach. MBALs aim at avoiding overexploitation on recruitment by conserving a minimum biomass and spawning stock biomass to allow the stock to perpetuate in the long term. MBALs are estimated by referring to a fishing mortality, F_{high}, which corresponds to the mortality level inducing the decline of the biomass from one brood year to the next one for 90% of chance, if applied for the previous years (i.e., when the spawning biomass and recruitment would have been known).

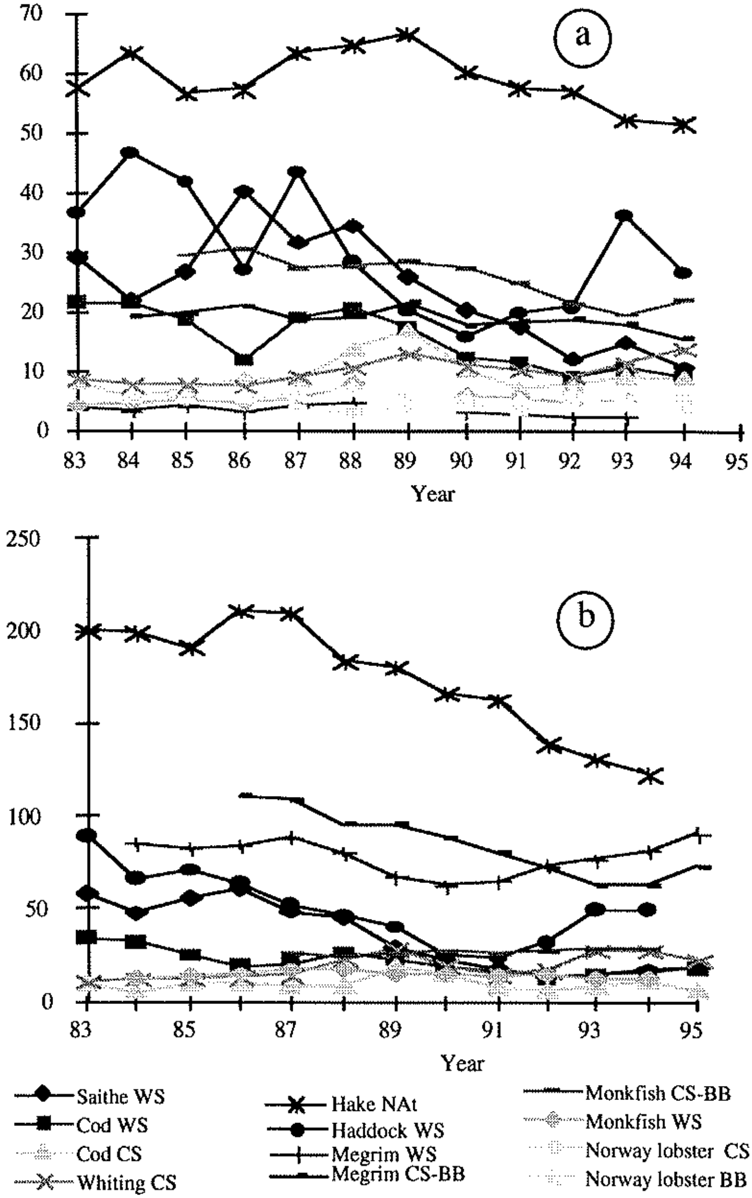

Figure 1. Evolution of (a) catches and (b) spawning stock biomass (in thousand metric tons) of the top eight species (12 ICES stocks) exploited within four ICES zones by high-seas fishing fleets based in Southern Brittany from 1983 to 1994. WS: West Scotland; CS: Celtic Sea; Nat: North Atlantic; BB: Bay of Biscaye.

A Backward Analysis of the Reliability of Diagnoses

Virtual population analysis (VPA) constitutes the basic tool used by the ICES working groups to elaborate their diagnoses. For any stock, this method leads to the estimation of fishing mortalities *F*, the biomass *B*, the spawning stock biomass *SSB*, and the recruitment *R*. For each year *n*, this evaluation applies for all years before up to (n–1). Because of the mathematical convergent properties of the VPA, the results can be considered more reliable for old data and more uncertain for recent data (Pope and Shepherd 1985). Results of the most recent period are also used to predict future catches. These results are subsequently used as input variables into simulation processes which constitute the basis of the management recommendations issued by the ACFM (Advisory Committee on Fishery Management). The crucial importance of recent year estimates to future predictions explains why the calibration process of VPA needs scrutiny. Calibration aims at refining the reliability of diagnoses after considering fishing effort data. However, this reliability can be appreciated only afterward.

Uncertainty of recent years' estimates remain a basic drawback of the VPAs. But for any past year, this is the most recent estimate that can be considered as the most probable value. Based on this background, we estimated the reliability of the scientific diagnoses with a retrospective analysis. As a convention in this paper, the parameters calculated in 1995 for the entire assessment period (back to 1983) served as the reference, and are considered as the "actual" values. Then, we compared estimates of fishing mortality (*F*), spawning stock biomass (*SSB*), and recruitment (*R*) made in each year prior to 1995 with estimates of the same parameters made using 1995 data (F^*, SSB^*, and R^*). The reliability for year *n* was estimated with three ratios of prior year estimates: the fishing mortality (average on main exploited age groups), the spawning stock biomass and the recruitment, which for year n–1 are noted as F_{n-1}, SSB_{n-1}, and R_{n-1}.

Given the estimate made in 1995 concerning any (n–1): F^*_{n-1}, SSB^*_{n-1}, R^*_{n-1}, the reliability of the diagnosis made the year *n* is appraised by calculating three ratios:

$$\frac{F_{n-1}}{F^*_{n-1}},\ \frac{SSB_{n-1}}{SSB^*_{n-1}},\ \text{and}\ \frac{R_{n-1}}{R^*_{n-1}}$$

If greater than 1, each parameter is overestimated; if less than 1, it is underestimated.

From the Diagnosis to the Management Decisions and Implementation

The annual estimations by ICES working groups are followed by simulations which give, for some fishing mortality values, the expected catch and biomass for the next years. Hence, a fishing mortality is recommended for the following year (n+1). In principle, this is the mortality that would allow the spawning stock to rebuild or at least to stop a declining trend. In order to reply to the European Commission's request, whose management system mainly lies on catch allocations, the proposed recommendation issued by the ACFM, implicitly and often explicitly, lies on defining a catch volume based on the "desired mortality." These scientific recommendations are noted: F^r_{n+1}, SSB^r_{n+1}, and R^r_{n+1}.

From the recommendations, the European Commission's Fishing Office (DG-XIV) sets up a TAC proposal. This proposal is conveyed to the Council of European Union through a complex administrative process in which various commissions are involved to consider social, economic, and political issues. Then, for the following year, the council adopts a TAC, so-called "approved TAC" noted as: TAC_{n+1}. We quantified the discrepancy between the scientific recommendation and the political choice by calculating the ratio:

$$\frac{TAC_{n+1}}{Y^r_{n+1}}$$

A ratio greater than 1 means the "approved TAC" exceeds the scientific recommendation

The implemented management measures can be more or less abided by, which leads to a discrepancy between actual catches (or landings) and the approved TACs. The catches made during the year n+1 are estimated by the working groups during the subsequent years. In particular, for the 1995 assessment, we have catch estimations for every year from 1983 to 1994. We calculated two ratios:

$$\frac{Y^*_{n+1}}{TAC_{n+1}}$$

which measures the lag between the management "approved TAC" by the Council and the "actual catch." A ratio greater than 1 means the TAC was exceeded, and:

$$\frac{Y^*_{n+1}}{Y^r_{n+1}}$$

which measures the lag between the initial scientific recommendation and the actual catch. A ratio greater than 1 means the recommendation was exceeded. Finally, we translated the catch into fishing mortality. This mortality also implies a given level of the surviving spawning stock biomass.

Table 2. Mean ratios (period 1983-1993) between estimated and actual values (*) of fishing mortality (*F*), spawning stock biomass (SSB) and recruitment for eight fish stocks in four ICES zones

Stock	Geographic zone	$\frac{F_{n-1}}{F^*_{n-1}}$	$\frac{SSB_{n-1}}{SSB^*_{n-1}}$	$\frac{R_{n-1}}{R^*_{n-1}}$
Saithe	West Scotland	0.88	1.18	1.45
Cod	West Scotland	0.88	1.06	1.37
Cod	Celtic Sea	0.92	0.81	0.81
Hake	North Atlantic	0.99	1.52	1.22
Whiting	Celtic Sea	1.33	0.65	0.64
Megrim	Celtic Sea and Bay of Biscaye	0.69	1.26	0.98
Norway lobster	Bay of Biscaye	1.43	0.87	0.97
Haddock	West Scotland	1.20	0.90	0.88

So, we compared the impact of actual catches on the stock with the recommended effect by calculating the two ratios:

$$\frac{F^*_{n+1}}{F^r_{n+1}}, \text{ and } \frac{SSB^*_{n+1}}{SSB^r_{n+1}}$$

These ratios account for the efficiency of the scientific work about limiting fishing pressure and preserving spawning potential. The closer to the value 1 they are, the closer to the biologist's advice the fishing practices are.

Results

Reliability of Diagnoses

The ratios between estimated fishing mortality and "actual" mortality range from 0.6 to 1.8, carrying errors through the whole process. Errors may sometimes be very important in estimates (Table 2 and Fig. 2). On average, for the considered period, the mortality is overestimated for three among nine stocks: the Norway lobster in Bay of Biscaye (but too few years are available for this species), haddock in West Scotland, and whiting in the Celtic Sea. In the three cases, they are considered as "moderately overexploited," but with a biomass greater than precautionary thresholds.

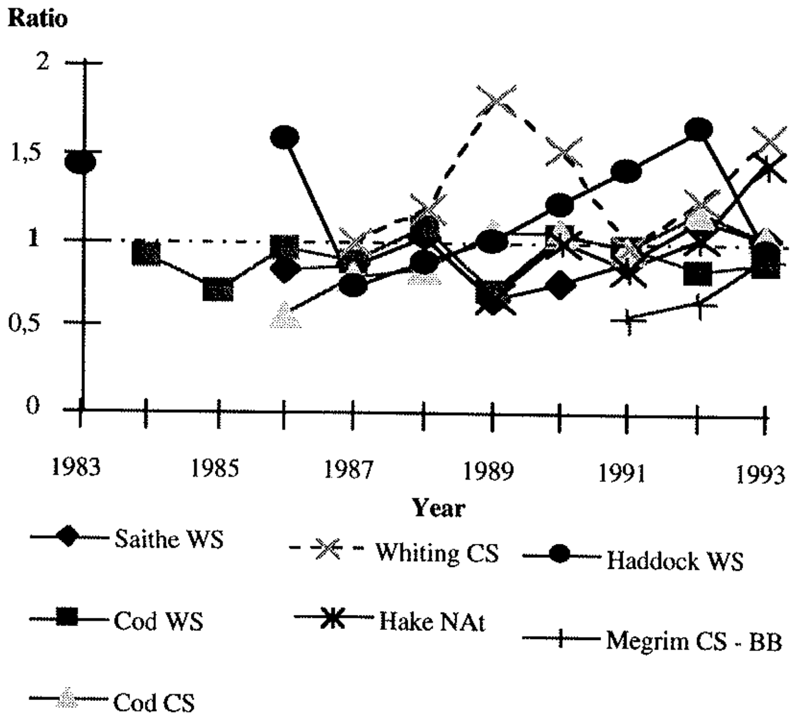

Figure 2. Evolution of ratios between estimated and actual annual fishing mortality values from 1983 to 1993 for ICES stocks exploited within four ICES zones. WS: West Scotland; CS: Celtic sea; Nat: North Atlantic; BB: Bay of Biscaye.

For most cases, however, the fishing mortality is underestimated. This is particularly true for the three stocks that are considered as heavily exploited (i.e., biomass lower than MBAL): hake in North Atlantic, saithe and cod in West Scotland. To sum up, diagnoses tend to underestimate the seriousness of the most critical situations. Moreover, this underestimation seems especially pronounced when fishing mortality is growing. For instance, this is the case for saithe in 1989 and for cod in the Celtic Sea in 1986.

Regarding the spawning stock biomass and recruitment, the ratios between estimated and actual values range from 0.4 to 2.4. The average values for the period strengthen the above results and lead to opposite situations:

- For the most exploited stocks such as saithe and cod in West Scotland, the diagnoses got more pessimistic as the stock declined. But

Table 3. Average ratios (1983-93) between recommended yield (Y^r), approved catches (TAC), and actual catches (Y^*) for nine fish stocks in four ICES zones.

Stock	Geographic zone	$\frac{TAC_{n+1}}{Y^r_{n+1}}$	$\frac{Y^*_{n+1}}{TAC_{n+1}}$	$\frac{Y^*_{n+1}}{Y^r_{n+1}}$
Saithe	West Scotland	1.37	0.95	1.24
Cod	West Scotland	1.17	0.78	0.90
Cod	Celtic sea	3.27	0.50	1.53
Hake	North Atlantic	1.25	0.94	1.31
Whiting	Celtic Sea	2.83	0.47	1.34
Megrim	Celtic Sea and Bay of Biscaye	1.03	0.98	0.80
Norway lobster	Bay Biscaye	1.04	0.77	–
Norway lobster	Celtic sea	1.19	0.18	0.25
Haddock	West Scotland	1.50	0.65	0.95

because the fishing mortality was steadily underestimated, whereas the spawning stock and recruitment were overestimated, the diagnoses remained not pessimistic enough.

- Conversely, the whiting stock in the Celtic Sea seems in a much better situation: the catches grew while mortality dropped. Here, the mortality remained overestimated whereas the spawning biomass and the recruitment were underestimated. The diagnoses became more and more optimistic, but not enough given the actual state of the stocks.

From the Recommended Catch to the Actual Catch

Through all the cases studied in this paper, the approved catches by the Council of Europe are higher than the scientific recommendations (Table 3 and Fig. 3). For the cod and the whiting in the Celtic Sea, the approved TACs reach about three times the recommendations (!). Such a result is misleading insofar as the recommendation deals with the only Celtic Sea zone (ICES zone VIIfgh), whereas the TACs concern a much wider area (ICES zone VII as a whole). Such a gap illustrates a lag between the assessment and the management stage which are set up for different spatial scales. The situation is different when they apply to the same zone, as the gaps between scientific recommendations and approved TACs often remain narrow; this is the case for the Norway lobster and the monkfish.

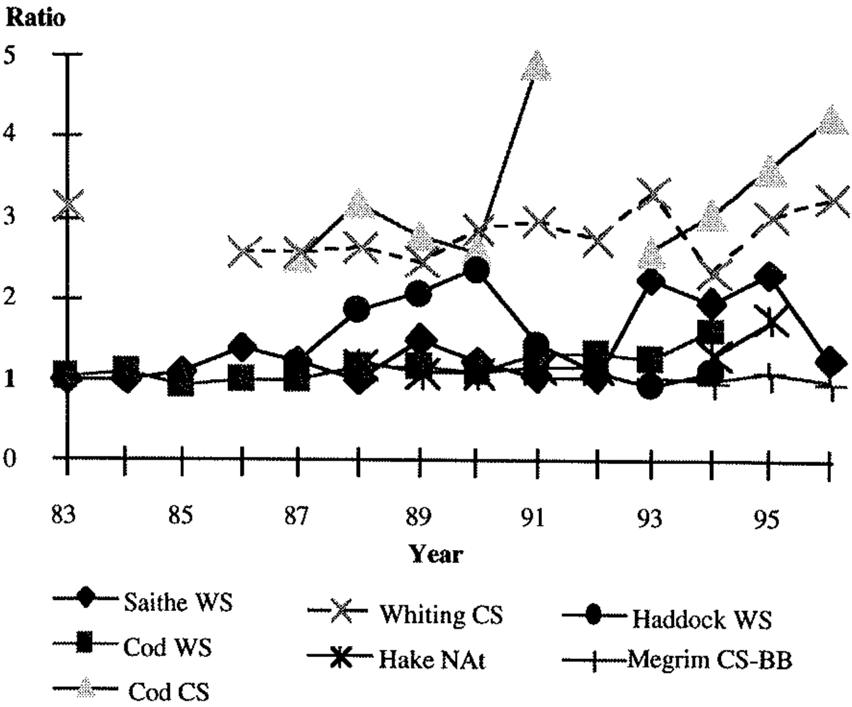

Figure 3. Evolution of ratios between annual recommended yields and approved catch for ICES stocks within four ICES zones from 1983 to 1996. WS: West Scotland; CS: Celtic sea; Nat: North Atlantic; BB: Bay of Biscaye.

However, wide gaps can be observed systematically when the working groups tend to recommend drastic decreasing catches for depleted stocks. This is the case for West Scotland stocks: haddock through years 1987-1990, saithe and cod through 1993-1995. Even when the approved catches are diminishing, they still exceed the values recommended by the ACFM. In other words, the political decisions follow rather well the biologists' recommendations but with a longer delay as the recommendations involve difficult choices. The ratios of actual catches vs. the "approved catches" are systematically lower than 1: i.e., quotas were never reached during the investigated 10-year period. Thus, for the studied stocks, the catch level was limited by fish availability, not by quotas; this is particularly obvious when the TACs exceed the scientific recommendations for cod and whiting in the Celtic Sea; the actual status of the stock (potential harvestable biomass) counterbalances the excessive optimism of the political decision. We see this pattern when TACs are close to recommendations (e.g., cod in West Scotland). In the latter case, the desirable regulation of

Table 4. Average ratios (1983-1993) between actual (*) and recommended values of fishing mortality (*F*) and spawning stock biomass (*SSB*) for fish stocks in four ICES zones.

Stock	Geographic zone	$\frac{F^*_{n+1}}{F^r_{n+1}}$	$\frac{SSB^*_{n+1}}{SSB^r_{n+1}}$
Saithe	West Scotland	1.60	0.78
Cod	West Scotland	1.44	0.71
Cod	Celtic Sea	1.37	1.21
Hake	North Atlantic	1.03	1.19
Whiting	Celtic Sea	0.83	2.39
Megrim	Celtic Sea and Bay of Biscaye	0.80	0.71
Haddock	West Scotland	1.07	1.28

catches seems to depend more on the weakness of the potential biomass than on wise political decisions with respect to scientific diagnoses. Finally, in many cases, the observed catch is greater than the recommendation. This pattern can be seen for overexploited stocks (saithe and hake) as well as for the stock of whiting in the Celtic Sea which might support more exploitation.

From the Real Catch to the Impact on the Stock

Because most of the actual catches were higher than the scientific recommendations, they were translated into a fishing mortality often higher than the initially recommended mortality (Table 4). The resulting spawning stock biomass became lower than the expected level. This situation can be observed for two of the most exploited stocks: saithe and cod in West Scotland. The too optimistic diagnoses were associated with failures in reaching the initially recommended objectives, which may have induced higher risks for the stocks to decline. Inversely, the less overexploited stock, whiting in the Celtic Sea, had lower mortality levels and higher spawning biomasses than the recommended levels. But if the actual catches were higher than the recommendations (as estimated in Table 3), they induced mortalities lower than expected because the initial diagnosis was too pessimistic. In short, the recommendation seems to have been too restrictive. In part, reducing the recommendation is warranted in this case. Indeed, catch limits of whiting in the Celtic Sea are proposed in order to protect the more fragile cod stock which is exploited together with whiting (ICES 1996).

Discussion and Conclusion

The lag between scientific evaluations and the real status of stocks are often addressed by assessment groups themselves (ICES 1996, 1997), as well as by specific studies on some stocks (e.g., Ould El Kettab 1993, for gadoids in the Celtic Sea). Our paper shows that the evaluations are delayed from the real status of a stock, and much more when changes in stock status are fast. They lead to overlay optimistic diagnoses in the most degraded situations. Moreover, the adopted TACs, often higher than biologists' recommendations, do not constrain the fishers enough and do not lead to expected lower mortalities.

For increasing overexploitation, the entire process from the assessment step to the catch step is questionable. Saithe and cod in West Scotland illustrate those situations. Neither the evaluation, nor the implemented management rules were able to prevent the declining of stocks from 1983 to 1992. Conversely, this degradation of the available resource can also explain the economic difficulties that the industrial fishing fleet from south Brittany is facing. Since the late 1980s, these difficulties have induced a strong decline in the industrial fishery. The related drop in fishing effort led to lower mortalities which we have noticed since 1990 for saithe and 1992 for cod. Recently the stock of saithe seems to be recovering with very recent increasing biomasses (ICES 1997). We may wonder if economic regulations, mainly declining rents for fishing companies, played a role over biological and statutory regulations by decreasing targeting on such depleted stocks. The successive lags that occur through the chain "assessment-decision-implementation-impact" have consequences on the stocks and decision makers must realize they have some responsibilities not to be minimized.

Exceeding the recommended catches can only partially explain the too high fishing mortality values. For instance, the actual fishing mortality for saithe was 60% higher than the recommended level whereas the excess was only 24% for catches. For cod in West Scotland, the recommended mortality was exceeded by 44% while the catches were 10% lower than recommendations. These differences may be linked to uncertainty of the diagnosis, in particular during the VPA stage. In both cases, the uncertainty led to an underestimation of past mortalities, and to an overestimation of available biomasses. Hence, even a strict implementation of scientific recommendations would not have induced the expected drop in mortalities. On the contrary, most of the biomass of cod and whiting in the Celtic Sea seem underestimated. When recommendations for catches were highly exceeded (+53% and +34% respectively), the effect on the related mortalities were slightly higher for cod (+37%) or lower than recommended for whiting (–17%).

The efficiency of scientific recommendations, to reduce fishing effort and conserve stock biomass, appears to depend as much on the reliability of stock assessments as on the way the administrative and political powers interpret them. The reliability of the scientific diagnosis relies on the VPA; however, we know that this method cannot be used to reliably estimate the actual status of stocks for recent years (Laurec and Shepherd 1983). This drawback is well acknowledged by scientists involved in assessment tasks (Ulltang 1977, Sampson 1988, ICES 1991). From this point of view, our analysis emphasizes that even the most powerful methods, as the ones used by ICES experts, cannot solve this difficulty. There has been much progress in the recent past to improve VPA methods (Sinclair et al. 1991, Angel et al. 1994). The growing sophistication of processes and software for VPAs (including statistical optimization processes of calibration, shrinkage, and others) were supposed to increase the reliability of estimations. So far, this improvement still remains to be demonstrated. Nevertheless, we wonder whether the more complex statistical processes do not lead scientists in charge of assessment to be set aside from the full methodological mastering of the evaluation. In spite of a rigorous procedure, there is a high risk that computing power may mask an oversimplification of some underlying assumptions, by minimizing the necessary critical analysis of methods and results. As an example, and without saying it could be the only or main causes of errors in evaluations, we suggest three methodological issues to address:

i. The commonly used calibration method known as XSA (eXtented Survivor Analysis, Darby and Flatman 1993, Laurec 1993) relies on the assumption that catchability for each age should be constant over the years; even if this assumption is routinely analyzed, we can sometimes wonder about its potential impacts, notably when fast changes in biomass induce changes in fishing strategies, and consequently in fishing power of vessels (Biseau 1996, Millischer and Gascuel 1997).

ii. The estimated fishing mortalities for the past year (n–1) and exploitation diagrams which are deduced for the last three years (from n–3 to n–1), are often used in the simulation process for the ongoing year n and the following year (n+1); which leads to the recommendation of catches. Of course, this process can contribute to all observed lags when the fishing effort gets higher.

iii. The impact of recruitment input for forecasting can also be important for some stocks. As an example, for whiting in the Celtic Sea, almost 40% of catches and more than 50% of spawning stock biomass that are predicted come from the recruitment input value.

Obviously, the prediction is the most uncertain operation. As a whole, the diagnoses on the past are very reliable; the deviations from reality are the most sensitive for the most recent years and often do not question the main stock trend. These deviations seem magnified through the prediction process the recommendation is based on. Of course, our paper does not aim at condemning the scientific assessment. Instead, we emphasize the major scientist's responsibility, the importance of the reliability of diagnoses, and the need for critical analyses given that sophisticated methods are not sufficiently reliable. This major issue has been raised by scientists Cadrin and Vaughan (1997) for the Atlantic menhaden and Starr et al. (1998), who ask for a more cooperative approach among players within the whole management process from revisited scientific assessments.

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References

Angel, J.R., D.L. Burke, R.N. O'Boyle, F.G. Peacock, M. Sinclair, and K.C.Y.T. Zwanenburg. 1994. Report of the workshop on Scotia-Fundy groundfish management from 1977 to 1993. Can. Tech. Rep. Fish. Aquat. Sci. 1979. 81 pp.

Biais, G. 1993. La gestion de pêches par contingentement des captures dans le nord-ouest de l'Europe. In: D. Gascuel, J.-L. Durand, and A. Fonteneau (eds.), Les recherches françaises en évaluation quantitative et modélisation des ressources et des systèmes halieutiques. Premier Forum Halieumétrique, ORSTOM éditions, Paris, pp. 309-320.

Biseau, A. 1996. Definition of directed fishing effort, and its impact on CPUE trends: The case of the French demersal fishery of the west coast of Scotland. ICES C.M. 1996/G:17.

Cadrin, S.X., and D.S. Vaughan. 1997. Retrospective analysis of virtual population estimates for Atlantic menhaden stock assessment. Fish. Bull. U.S. 95(3):445-455.

Darby, C.C., and S. Flatman. 1993. Virtual population analysis: XSA user guide. MAFF [Ministry of Agriculture, Food and Fisheries] Directorate of Fisheries Research Ed., Lowestoft. 47 pp. Unpublished.

Gueguen, J. 1988. Les quotas, qui décide quoi? Equinoxe 19:4-9.

ICES. 1991. The working group on methods of fish stock assessments. ICES C.M. 1991/Assess: 25 Sess:S.

ICES. 1996. Report of the ICES Advisory Committee on Fishery Management 1995, 214, Part 1, 368 pp. and Part 2, 355 pp.

ICES. 1997. Report of the ICES Advisory Committee on Fishery Management 1996. 216 pp.

Laurec, A. 1993. Etalonnage de l'analyse des cohortes en halieutique. In: D. Lebreton and B. Asselain (eds.), Biométrie et environnement. Masson, Paris, p. 332.

Laurec, A., and J.G. Shepherd. 1983. On the analysis of catch and effort data. J. Cons. Cons. Int. Explor. Mer 41:81-84.

Maguer, C. 1996. De l'évaluation des stocks à l'activité des flottilles: Étude des flottilles hauturières de Bretagne Sud. Mémoire DAA Halieutique de l'ENSA-Rennes. 48 pp.

Millischer, L., and D. Gascuel. 1997. Estimation des puissances de pêche des navires: Étude des flottilles industrielles de Bretagne sud. 3e Forum Halieumétrique, Montpellier, 1-3 Juil 1997. 12 pp.

Ould El Kettab, M. 1993. La pêcherie de Gadidés de mer Celtique: Description, analyse de l'exploitation et évaluation des stocks. Tentative de gestion par un modèle économique. Ph.D. thesis, Université de Bretagne Occidentale, Brest. 207 pp.

Pope, J.G., and J.G. Shepherd. 1985. A comparison of the performance of various methods for tunings VPAs using effort data. J. Cons. Cons. Int. Explor. Mer 42:129-151.

Sampson, D.B. 1988. The stability of virtual population analysis cohort size estimates. J. Cons. Cons. Int. Explor. Mer 44:135-142.

Sinclair, A., D. Gascon, R. O'Boyle, D. Rivard, and S. Gavaris. 1991. Consistency of some northwest Atlantic groundfish stock assessments. NAFO Sci. Counc. Stud. 16:59-77.

Starr, P., J.H. Annala, and R. Hilborn. 1998. Contested stock assessment: Two case studies. Can. J. Fish. Aquat. Sci. 55:529-537.

Ulltang, O. 1977. Sources of errors in and limitations of virtual population analysis (cohort analysis). J. Cons. Cons. Int. Explor. Mer 37:249-260.