THE EFFECTS OF IUU FISHING (UNREPORTED CATCHES) ON STOCK ASSESSMENTS, PREDICTIONS AND MANAGEMENT ADVICE

by

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Introduction

The term illegal, unregulated, unreported (IUU) fishing reflects activities in direct conflict with the basic playing rules required for a managed fishery. When there is evidence that such activities take place the obvious management advice is to bring the fisheries in order. This might appear rather trivial, however, when discussing technical details on how unreported catch data influence the assessment results, this should be kept in mind; -A precise quantitative advice on regulations is not very helpful in cases when the fisheries do not follow the rules.

From an assessment point of view the main problem with IUU fishing is that catches are unreported. Unreported catch is therefore the main focus for this document. Unreported catch is by its nature very difficult to quantify. Even their magnitude relative to the reported catch is very difficult to judge. It is therefore impossible to properly quantify the associated errors in stock assessment and predictions. The error will depend both of the magnitude of such catches, their time trend relative to the time trend of the official catch, the amount and precision of fishery-independent data, and the assessment method used. Here we will describe some generic cases illustrated by a couple of examples. In all cases it is assumed that no attempt has been made to take account of unreported catches.

The general rule is that in the assessment unreported catches primarily leads to underestimation of the absolute size of the stock, while in the predictions such catches typically increases fishing mortality and reduces stock size. The latter may not always be true in relative terms. A fixed proportion of unreported catch could be hidden both in assessment and predictions, so that the prediction and advice for the legal part of the fishery still might be reasonable although the real catch and stock size is underestimated. In absolute terms, however, it is always true that any additional removal from the stock reduces the future stock size and catches.

<u>How unreported fishing affects the true stock. The cost of rebuilding (repairing)</u>

A typical goal for fishery management is to keep the stock sufficiently large to ensure its productivity. A common strategy for achieving this is to aim for a fairly constant fishing mortality (a target F). This is wise because periods with increased fishing mortality usually lead to increased growth overfishing (the fish is not allowed to survive sufficiently long to utilise its growth potential). If the management strategy is to fish at a constant fishing mortality, then additional unreported catches leads to overfishing of quotas. This will reduce the stock compared to the management goal, and future catches have to be reduced to repair the damage. Typically the time required for repairing is much longer than the duration of the overfishing period. This is illustrated by a simple example in Table 1. This shows the number of years each year-class in the stock has experienced overfishing, when the overfishing took place over a 4-year period (2103-2106). The first year after the overfishing period all fish older than recruitment age plus 4 belong to year-classes that have experienced 4 years overfishing, while the younger age groups have experienced less. For each year passing on the affected part of the stock gets one year older. Recruitment age is 3, which means that the overfishing does not affect age 2 or younger. The 2103 year-class (age 3 in 2106) is thus the latest one affected. This year-class reach age 12 in 2115. Thus in the 10th year after the overfishing took place one might consider the stock fairly well repaired, although some effect will endure in the plus group (13+) for a few more years.

Table 2 is a calculated example similar to Table 1, illustrating the consequences for stock numbers, catch and spawning stock. The recruitment is assumed constant. Before the overfishing period the stock is in equilibrium at a fishing mortality, F=0.4. During the 4 years of overfishing F=0.6. It is seen that after returning to the previous F=0.4 it takes about 10 years to obtain the original stock numbers, catch and spawning stock. If recruitment had dropped due to the decrease in spawning stock (recruitment overfishing), the rebuilding period of the spawning stock, plus the 3 year delay between birth and recruitment had to be added to those 10 years before equilibrium had been obtained.

It is observed in Table 2 that compared to the equilibrium situation the catches were high in the overfishing period and low in the rebuilding period. The average over the whole non-equilibrium period is slightly less than at equilibrium. This reduction is caused by increased growth overfishing in the overfishing period. If recruitment had dropped there would be an additional loss in average catch (caused by recruitment overfishing).

How would overfishing affect Noth-East Arcic cod?

Table 2 is based on cod data and could be a reasonable illustration for that stock if it has been in equilibrium at F=0.4. This has never been the case in the quantified history of the stock. In the 8 year period 1994-2001 F varied between 0.7 and 1.0. The existing management rule aiming at F around 0.4 was first time applied for setting the TAC for 2004. The message from Table 2 is that it requires at least 10 years to obtain the full benefit of the new strategy. The indicated unreported fishing for the years 2002-2004 have reduced the starting point and delayed the process. It has been expected that the new strategy would result in a gradual increase in stock size and TAC, instead stock size and TAC-advice have levelled off due to the unreported catches.

<u>How does unreported catches influence assessment results?</u>

VPA-type assessments (like xsa) is still the most common tool in ICES working groups. This method is basically a bookkeeping of historic catches by year-class. Some years prior to the latest data year the stock consisted of year-classes that has later died out (by fishing and natural mortality). This is technically referred to as the converged part of the vpa. For this part of the time series the stock is fully described by the catches and the (assumed) natural mortality. For the later years in the analysis (the un-converged part) the stock size is fitted both to catches and to the survey data, by using the experienced relationship between the survey and vpa. This fitting is an iterative process referred to as “tuning”.

Other models used in ICES (ICA, Fleksibest (Gadget), Amci) allows for some uncertainty in catch data. Errors in catch data may therefore have different effects on the results of such models, but the main effects of large underreporting are considered to be similar. The following considerations refers to vpa-type assessments.

Unreported catches will in the converged period cause the stock size to be underestimated by roughly the same extent as the catches are underreported. For the un-converged years the effects will depend on the time development of unreported catches.

If unreported catches represent a constant fraction of the total catch over the whole time series, the effect for the un-converged period will be the same as in the converged. If this goes on in the future, the predictions will be confirmed by future assessments. The advices may work ok, even though they are biased to the same extent as the reported catches.

If unreported catch is increasing relative to the official catch, the assessment will (in relative terms) give an overoptimistic stock development in the un-converged part and in the predictions. Future assessments will then show downward revisions of stock size. Advice for reduced fishing may then come too late and rebuilding might become painful.

If unreported catch is decreasing relative to official catch, the assessment will (in relative terms) give a too pessimistic stock development in the un-converged part and in the predictions. Future assessments will then show upward revisions of stock size. Advice for increased fishing may then come later than necessary, but in the meantime the stock has got a chance to increase its production, thereby paying back with high interest.

The above considerations refer to stock size. For the un-converged period and the predictions the conclusions are similar if we consider fishing mortality. For the converged period unreported catches tend to have considerably less impact on F than on stock size. F is a measure of how fast a year-class disappears in the catches, and this is reflected in the annual age sampling, either the total catch is known or not.

Example 1, related to North-East Arctic cod

True catch at age and true stock number at age for each year in the period 1965-2004 are assumed. Then 5 different time series of unreported fishing is assumed. In each of these series this leads to a the reported catch at age that makes up a certain proportion of the true catch at age (same proportion for all ages at the same year).

Case 1: Constant underreporting from 1978
reported catch= true catch in 1965-1977
reported catch= 0.7*true catch in 1978-2004
Case 2: Constant underreporting from 1990
reported catch= true catch in 1965-1989
reported catch= 0.7*true catch in 1990-2004

Case 3: Decreasing underreporting from 1990
reported catch= true catch in 1965-1989
reported catch= 0.7*true catch in 1990, increasing linearly to 1.0*true catch in 2004
Case 4: Increasing underreporting from 1990
reported catch= true catch in 1965-1989
reported catch= 1.0*true catch in 1990, decreasing linearly to 0.7*true catch in 2004
Case 5: Periods of constant and periods of variable underreporting
reported catch= true catch in 1965-1977
reported catch= 0.7*true catch in 1978-2004, except for higher proportions in two periods.

The catch at age matrix corresponding to each of these cases was calculated and a survey series identical to the true stock in the period 1985-2004 was assumed.
Each of these catch at age matrices was then tuned with this “ideal” survey by using a simple vpa-tuning (Laurec-Sheperd, without shrinkage or time weighting). The reason for using an ideal survey and the simple tuning method is that we want to isolate the effects caused by the bias in catch data. Shrinkage, time weighting and noise from survey data could confound some of the effects caused by biased catches.

The results are shown in Figures 1-5. Each Figure has 6 panels; time series of reported catch compared to true catch, the ratio between those, the fishing mortality (F), total stock biomass (TSB) compared to the one corresponding to true catch, spawning stock biomass (SSB) compared to the one corresponding to true catch, and finally the ratios between estimated and true values (relative error) of TSB, SSB and F. Since the survey in these cases equals true stock, the relative error of TSB also show how the survey relate to the assessed stock. The term survey catchability is here inverse to the relative error of TSB.

Case 1: Constant underreporting from 1978
The period with 30% underreporting of catches has 30% underestimation of stock size, with a transition period starting about 5 years before the underreporting starts. Fs are unchanged except for some overestimation in the transition period.

Case 2: Constant underreporting from 1990
Similar to case 1, except for the most recent years, when F is slightly underestimated and stock size is overestimated compared to the first part of the underreporting period (relative error increases), thus giving an overoptimistic view of the most recent relative stock development (but still nearly 30% underestimation in absolute terms). The difference between case 1 and 2 is that in case 2 the underreporting starts within the 20 year survey series. These effects would be stronger if the underreporting shift occurred closer to the most recent year in the analysis.

Case 3: Decreasing underreporting from 1990
Here there is first a sudden shift from zero to 30% underreporting, then a gradual development back to zero. Up to about 2000 (within the fairly converged part of the vpa) the bias in stock size decreases parallel to the decrease in underreporting, while later, when the results is mainly driven by the survey, underestimation of stock and overestimation of F increases again. The result is in relative terms a too pessimistic view of the most recent stock development.

Case 4: Increasing underreporting from 1990
This is opposite to case 3. Up to about 2000 (the fairly converged period) stock size gets gradually more underestimated as underreporting increases, while later turning to less underestimation of stock size. The F in the two latest years is underestimated. In total this gives a too optimistic view of the recent stock situation.

Case 5: Periods of constant and periods of variable underreporting
Since there is a decreased underreporting in the most recent years, the view the most recent stock situation is a bit too pessimistic, similar to case 3. This case involves more variability in underreporting compared to the other cases, and gives larger errors in F.

General remarks on example 1

These analyses are based on manipulated data for the North-East Arctic cod stock. Official catch of cod correspond to case 1. “True catch” and the corresponding “true stock” are constructed so that for the period 1978-2004 the reported catch is 70% of true catch, while there is no underreporting prior to 1978. The catch used in the AFWG assessment (ICES 2005a) corresponds to case 5. It should be noticed that the “true” values of catches and stock used here only serve as an example. The working group values are still considered to be the best estimates.

In view of the large amount of underreporting assumed the errors shown by these simulations may appear small, especially compared to historical revisions experienced in the assessment of this stock. More year to year variability in underreporting, more survey uncertainty, and underreporting focused on certain age groups would all tend to enlarge the errors. Here the main purpose is to illustrate the direction of the error for the last assessment year in the various cases. One general pattern illustrated by these cases is that the largest errors occur when there in the recent period are large changes in the proportion reported.

The analysis was done with a simple vpa without shrinkage or time weighting. An analysis based on the same true catch (cases 1-5) has also been made by using xsa with the exact working-group-settings. This gives similar directions of the errors except for case 4 where the F shrinkage in the xsa compensates for the tendency of underestimating F. This happens because F is falling. If this occurred in a situation when F was increasing such shrinkage would exaggerate the tendency to underestimate F.

The error in the predictions corresponding to cases 1-5 will be in the same direction as the error in the last assessment year. The magnitude of the prediction error tends to be larger than the assessment error, and this tendency increases with increasing true F.

<u>Example 2, North Sea Cod</u>

For this stock discards and unreported landings have been considered to be a problem. In the years when TAC was considerably reduced there are indications that the proportion of the real catch reported has decreased.

In the 2004 assessment (ICES 2005b) the working group made attempts to estimate the catches needed to explain the relative stock changes observed in the surveys (ICES, 2005). Figure 6 shows the estimated catches (with percentiles indicating the uncertainties) compared to reported catch. The estimated “true” catch in 2003 was more than twice the reported. Figure 7 shows the corresponding F-values, and again it is observed that in the converged series the Fs do not change radically, while in the un-converged years the adjusted Fs are higher than those based on reported catch. The adjustments of stock biomass tend to follow the adjustments of catches.

Figures 8 and 9 show a retrospective analysis, indicating the magnitude of annual assessment revisions that would have been the result of using the new assessment approach for the earlier time series. This seems very promising and is in great contrast to Figure 12 showing the real revisions between assessments made historically (based on reported catches). During the last decade there has been a nearly continuous downward revision of stock size and upward revision of F-values.

References

ICES 2004. Report of the ICES Advisory Committee on Fishery Management and Advisory Committee on Ecosystems, 2004. ICES ADVICE, Vol 1, no 2.

ICES 2005a. Report of the Arctic Fisheries Working Group. ICES CM 2005/ACFM:20, 19-28 April 2005, Murmansk, Russia.

ICES 2005b. Report on the Assessment of Demersal Stocks in the North Sea and Skagerrak ICES CM 2004/ACFM:07, 7-16 september 2004, Bergen, Norway.

Table 1. Number of years each year-class has experienced overfishing through its life, when the overfishing occured over the years 2103-2106. Year-classes are followed along diagonals from left downward to the right. 13+ is age 13 and older

	Age										
Year	3	4	5	6	7	8	9	10	11	12	13+
2101	0	0	0	0	0	0	0	0	0	0	0
2102	0	0	0	0	0	0	0	0	0	0	0
2103	1	1	1	1	1	1	1	1	1	1	1
2104	1	2	2	2	2	2	2	2	2	2	2
2105	1	2	3	3	3	3	3	3	3	3	3
2106	1	2	3	4	4	4	4	4	4	4	4
2107	0	1	2	3	4	4	4	4	4	4	4
2108	0	0	1	2	3	4	4	4	4	4	4
2109	0	0	0	1	2	3	4	4	4	4	4
2110	0	0	0	0	1	2	3	4	4	4	4
2111	0	0	0	0	0	1	2	3	4	4	4
2112	0	0	0	0	0	0	1	2	3	4	4
2113	0	0	0	0	0	0	0	1	2	3	4
2114	0	0	0	0	0	0	0	0	1	2	4
2115	0	0	0	0	0	0	0	0	0	1	4
2116	0	0	0	0	0	0	0	0	0	0	4
2117	0	0	0	0	0	0	0	0	0	0	4
2118	0	0	0	0	0	0	0	0	0	0	4

Table 2. A calculated example corresponding to table 1. Number at age in millions, Catch and spawning stock biomass (SSB) in thousand tonnes. Recruitment at age 3 is equal for all years. Before overfishing starts the stock is in equilibrium at a stable fishing mortality, F=0.4. In the overfishing period (2103-2106) F=0.6. After this period F returns to 0.4, and the stock approaches equilibrium about 10 years later. The shadowed area is the effected part of the stock, corresponding to non-zero values in Table 1

	Age											Catch	SSB
Year	3	4	5	6	7	8	9	10	11	12	13+	‘000 T	‘000 T
2101	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.3	714	1337
2102	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.3	714	1337
2103	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.3	983	1337
2104	600	431	308	195	110	58	28.1	13.9	6.6	3.0	2.4	842	1098
2105	600	431	307	188	100	50	23.0	10.9	5.2	2.3	1.8	757	944
2106	600	431	307	187	97	45	19.8	8.9	4.1	1.8	1.4	710	853
2107	600	431	307	187	97	44	18.0	7.7	3.3	1.4	1.1	496	805
2108	600	433	317	206	113	53	22.1	8.9	3.7	1.6	1.1	560	937
2109	600	433	319	213	124	62	26.9	11.0	4.3	1.7	1.2	613	1062
2110	600	433	319	214	128	68	31.3	13.4	5.3	2.0	1.3	652	1163
2111	600	433	319	214	129	70	34.4	15.6	6.5	2.5	1.5	678	1236
2112	600	433	319	214	129	71	35.6	17.1	7.6	3.0	1.8	695	1282
2113	600	433	319	214	129	71	35.8	17.7	8.3	3.5	2.2	704	1310
2114	600	433	319	214	129	71	35.8	17.8	8.6	3.9	2.5	709	1324
2115	600	433	319	214	129	71	35.8	17.8	8.6	4.0	2.9	712	1331
2116	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.1	713	1334
2117	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.2	714	1337
2118	600	433	319	214	129	71	35.8	17.8	8.6	4.0	3.2	714	1337
Average 2103-2116												702	1144

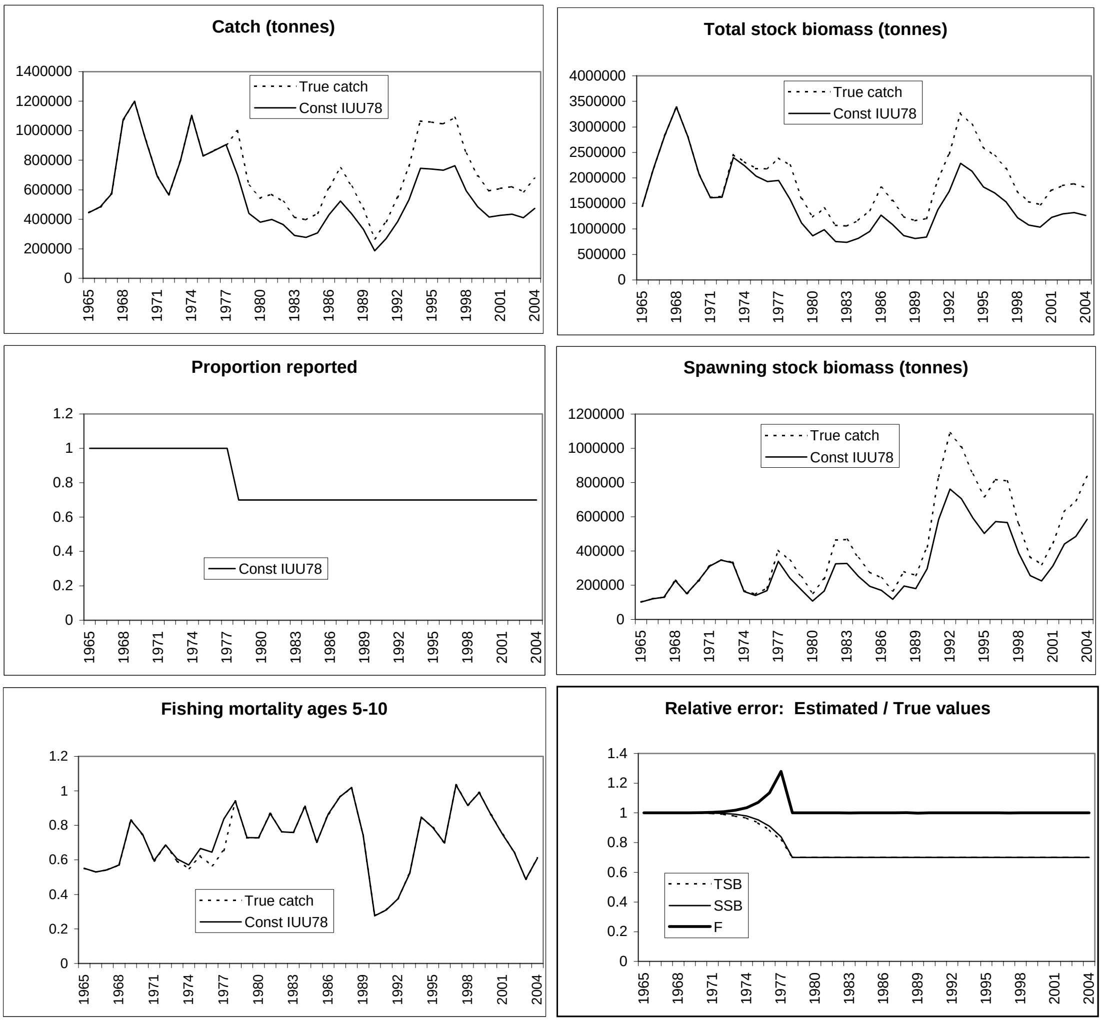

Figure 1. Constant underreporting from 1978. Left panels: Upper; Reported catch (full line) and true catch (broken line). Middle; proportion of the catch reported. Lower; Estimated F (full line) and true F (broken line). Right panels: Upper; Estimated total biomass (full line) and true total biomass (broken line). Middle: Estimated spawning biomass (full line) and true spawning biomass (broken line). Bottom; Relative error of F (thick line), total biomass (broken line) and spawning biomass (thin line)

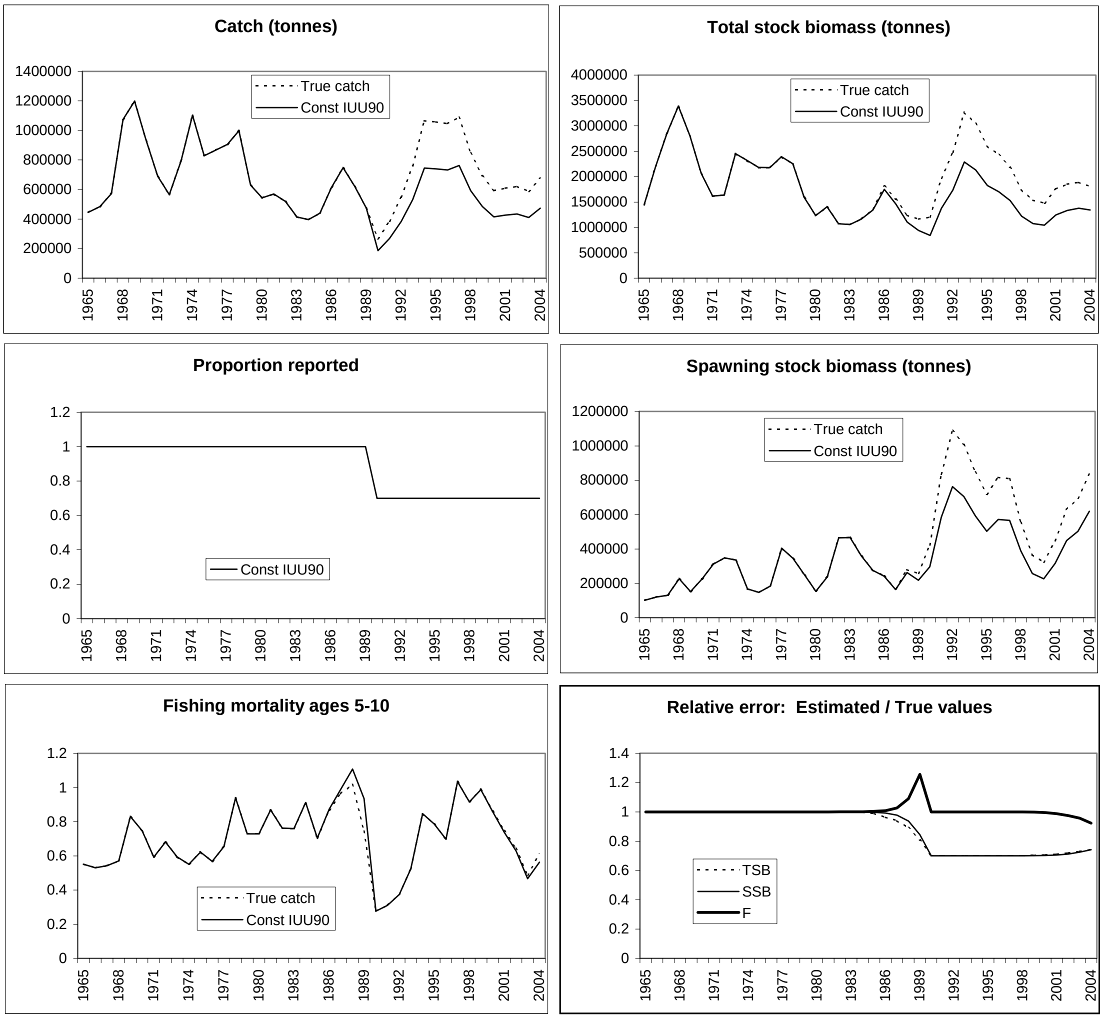

Figure 2. Constant underreporting from 1990. Left panels: Upper; Reported catch (full line) and true catch (broken line). Middle; proportion of the catch reported. Lower; Estimated F (full line) and true F (broken line). Right panels: Upper; Estimated total biomass (full line) and true total biomass (broken line). Middle: Estimated spawning biomass (full line) and true spawning biomass (broken line). Bottom; Relative error of F (thick line), total biomass (broken line) and spawning biomass (thin line)

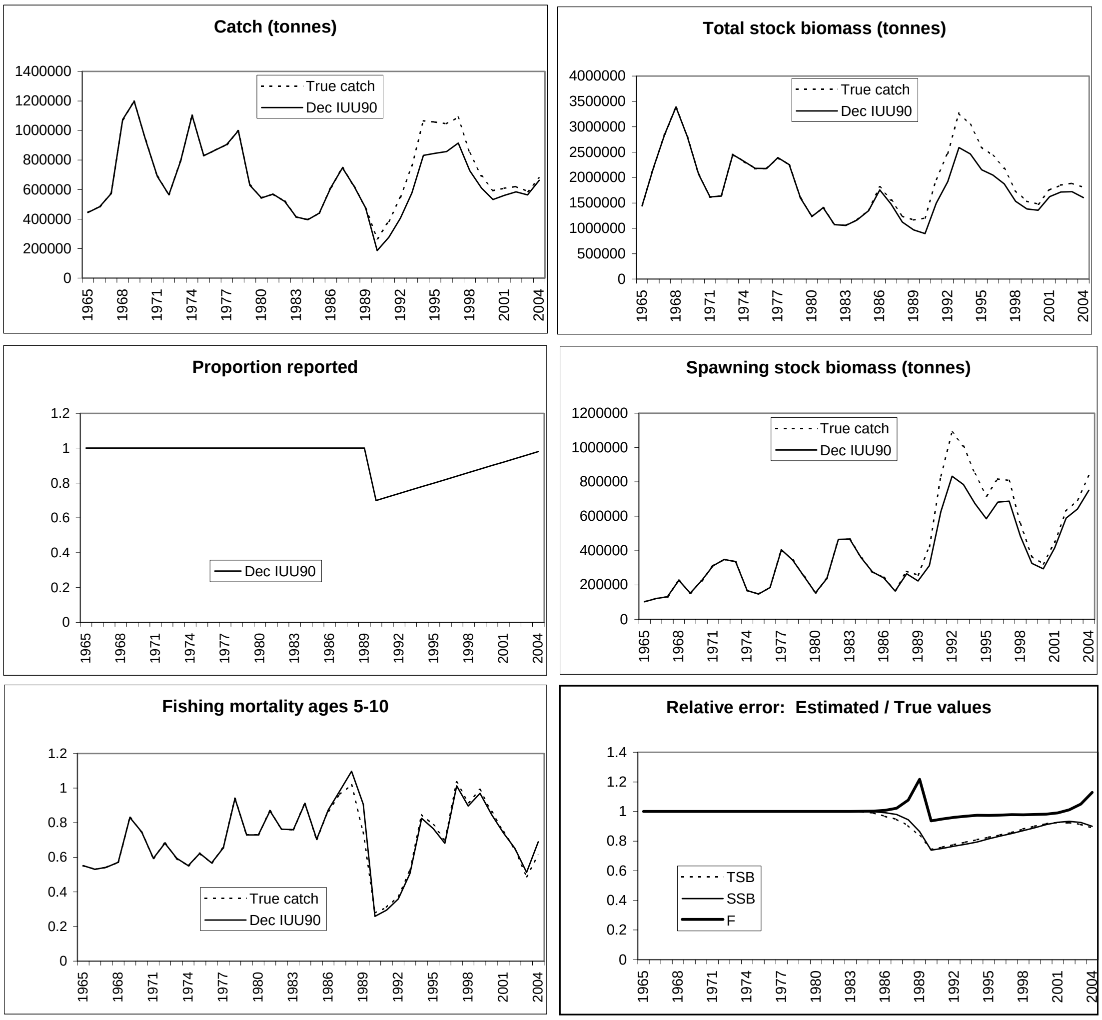

Figure 3. Decreasing underreporting from 1990. Left panels: Upper; Reported catch (full line) and true catch (broken line). Middle; proportion of the catch reported. Lower; Estimated F (full line) and true F (broken line). Right panels: Upper; Estimated total biomass (full line) and true total biomass (broken line). Middle: Estimated spawning biomass (full line) and true spawning biomass (broken line). Bottom; Relative error of F (thick line), total biomass (broken line) and spawning biomass (thin line)

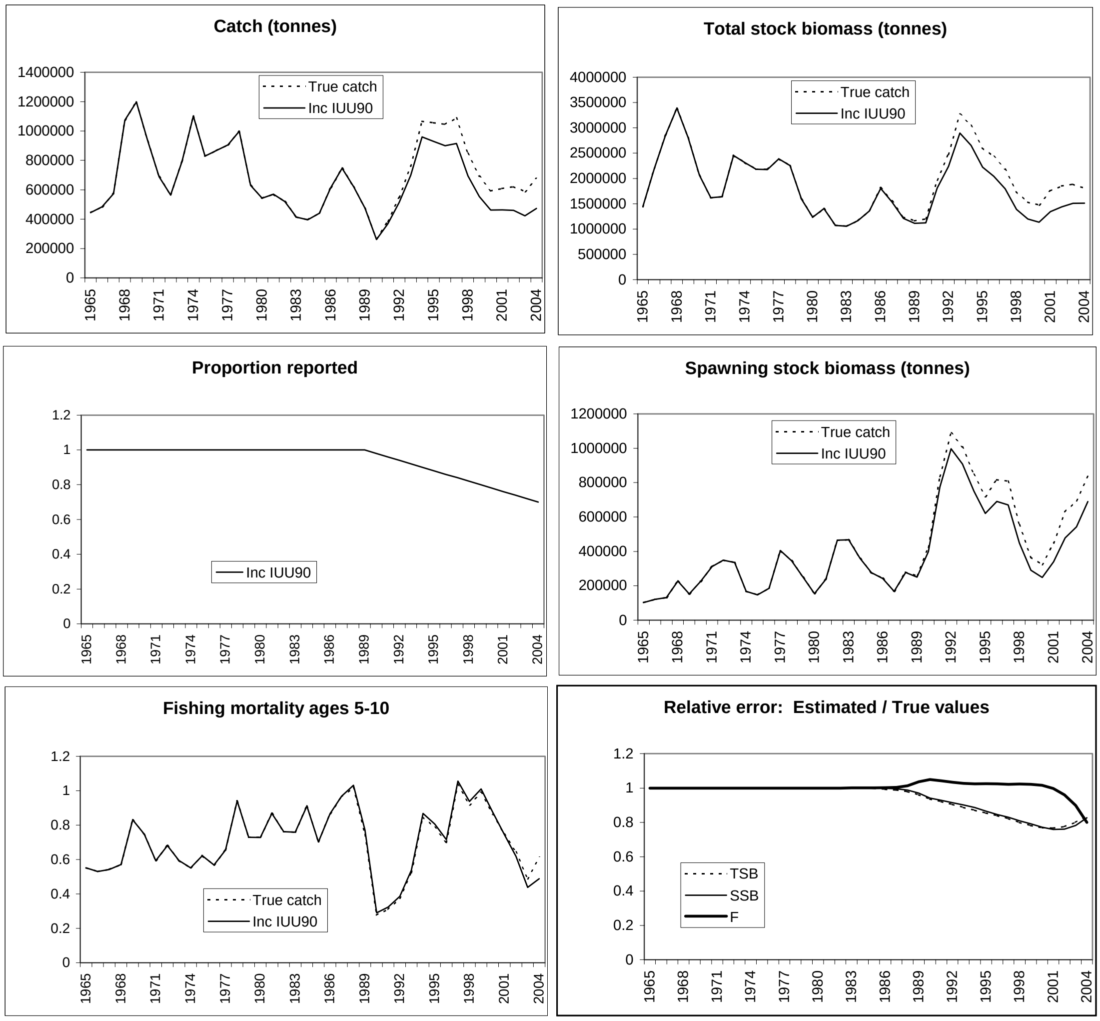

Figure 4. Increasing underreporting from 1990. Left panels: Upper; Reported catch (full line) and true catch (broken line). Middle; proportion of the catch reported. Lower; Estimated F (full line) and true F (broken line). Right panels: Upper; Estimated total biomass (full line) and true total biomass (broken line). Middle: Estimated spawning biomass (full line) and true spawning biomass (broken line). Bottom; Relative error of F (thick line), total biomass (broken line) and spawning biomass (thin line)

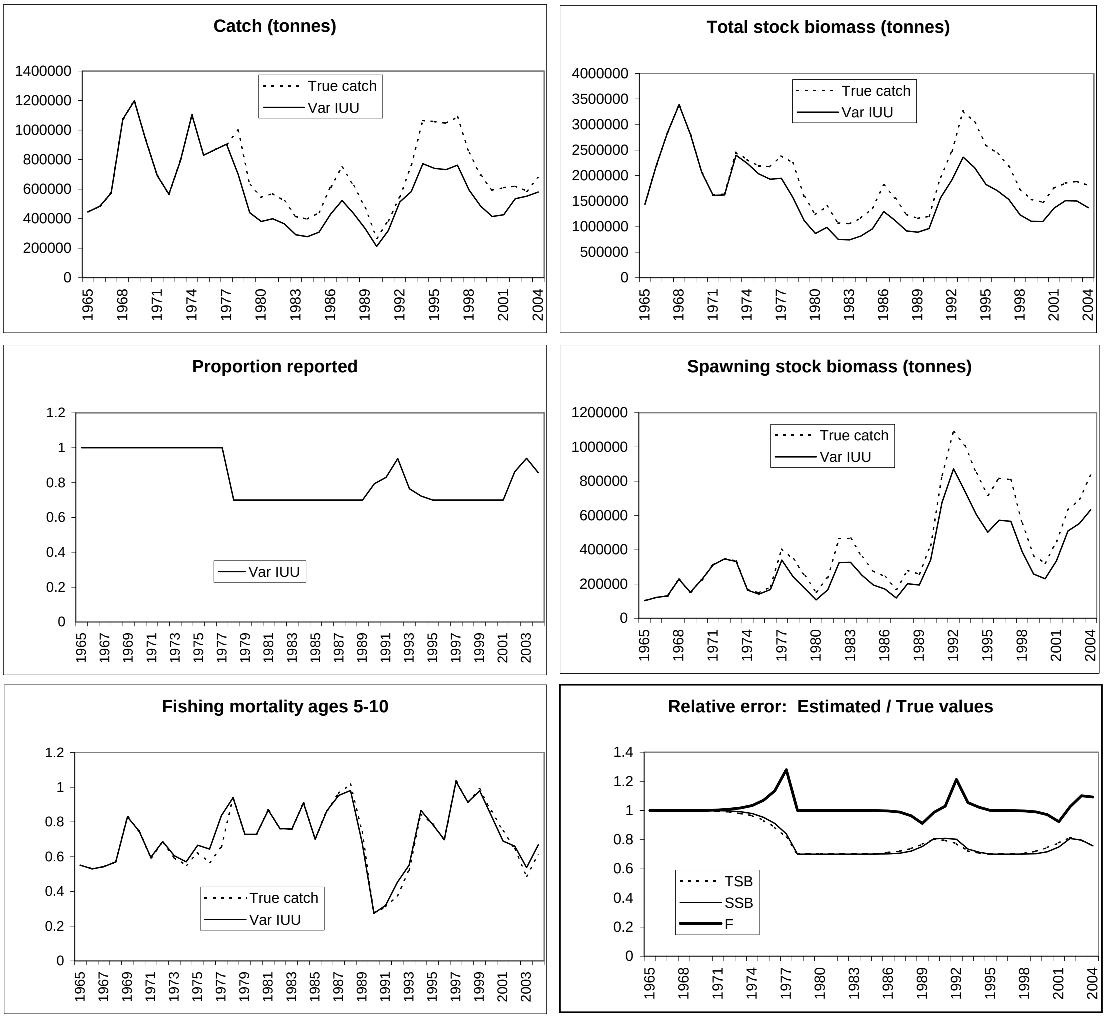

Figure 5. Variable underreporting from 1978. Left panels: Upper; Reported catch (full line) and true catch (broken line). Middle; proportion of the catch reported. Lower; Estimated F (full line) and true F (broken line). Right panels: Upper; Estimated total biomass (full line) and true total biomass (broken line). Middle: Estimated spawning biomass (full line) and true spawning biomass (broken line). Bottom; Relative error of F (thick line), total biomass (broken line) and spawning biomass (thin line)

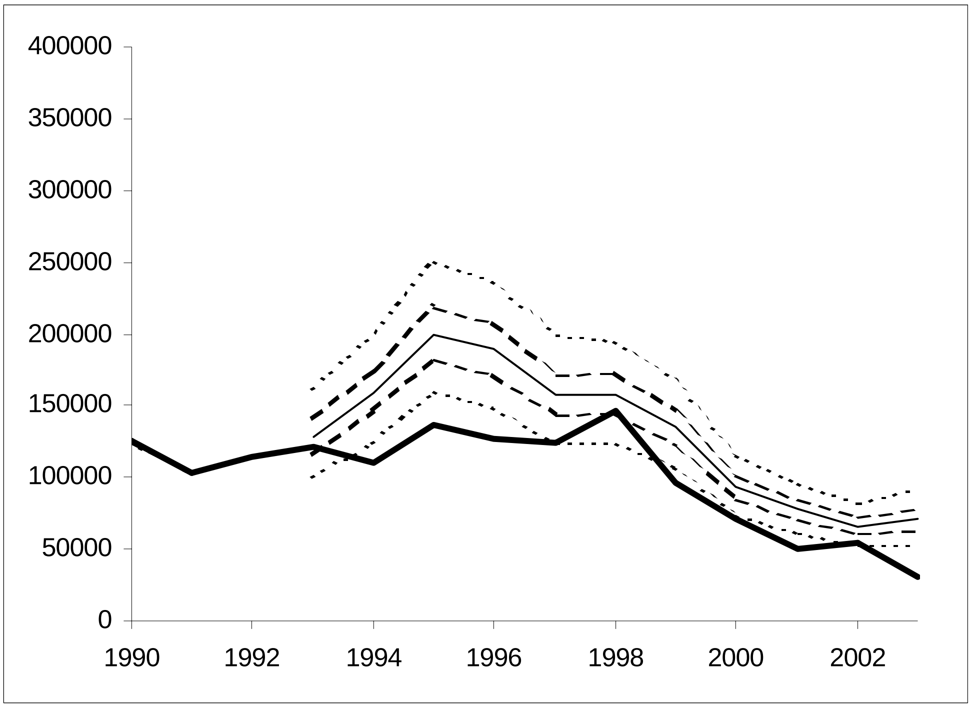

Figure 6. North Sea cod catches (Tonnes). The percentiles (5,25,50,75,95) of estimated “true” catch. The solid line represents the reported catch (Figure 3.4.7.5 in ICES 2005b)

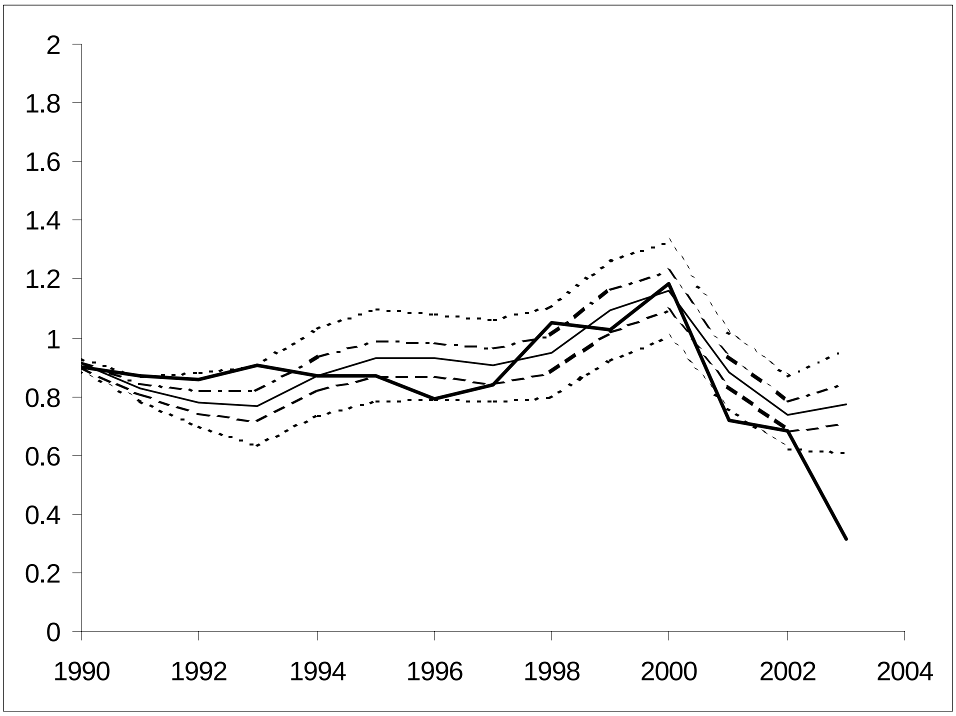

Figure 7. North Sea cod fishing mortality. The percentiles (5,25,50,75,95) of fishing mortality based on estimated catch. The solid line represents fishing mortality based on reported catch (Figure 3.4.7.6 in ICES 2005b)

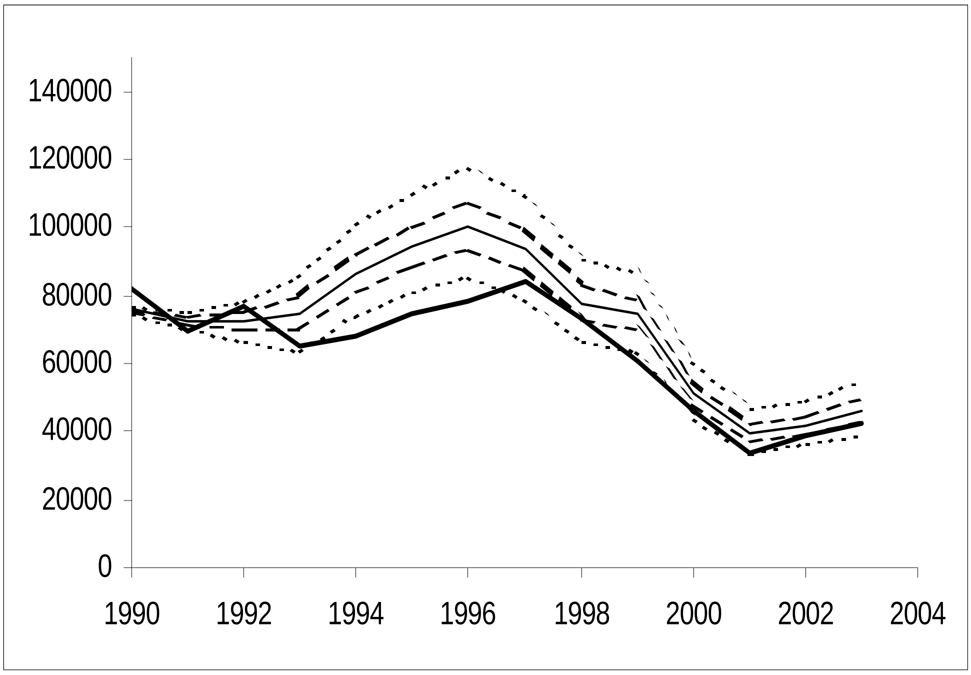

Figure 8. North Sea cod spawning stock biomass (Tonnes): The percentiles (5,25,50,75,95) of the SSB based on estimated catch. The solid line represents the SSB based on reported catch. (Figure 3.4.7.7 in ICES 2005b)

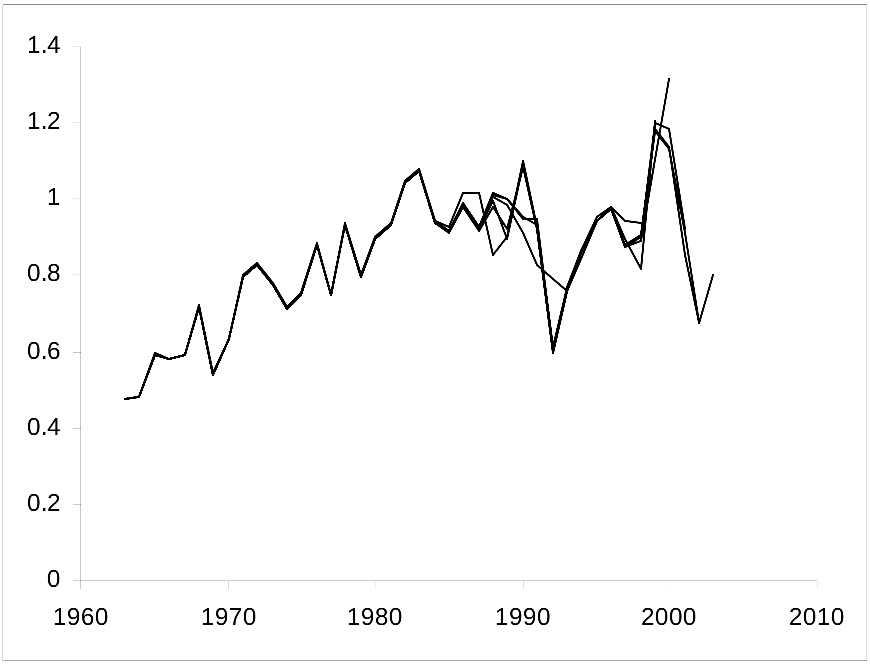

Figure 9. North Sea cod: Retrospective series of average fishing mortality as estimated using the new assessment approach. (Figure 3.4.7.13 in ICES 2005b)

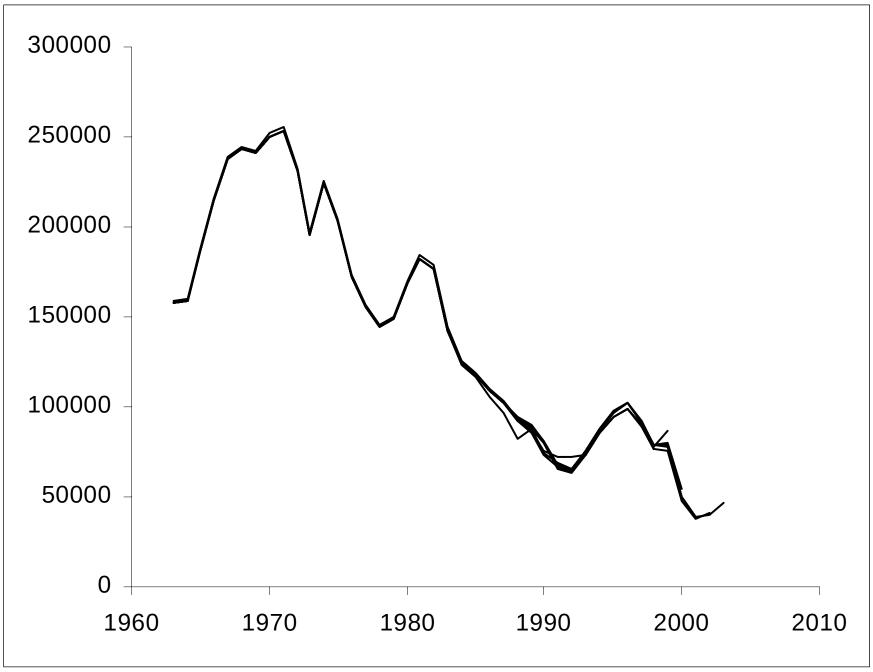

Figure 10. North Sea cod: Retrospective series of spawning stock biomass (Tonnes) as estimated using the new assessment approach. (Figure 3.4.7.14 in ICES 2005b)

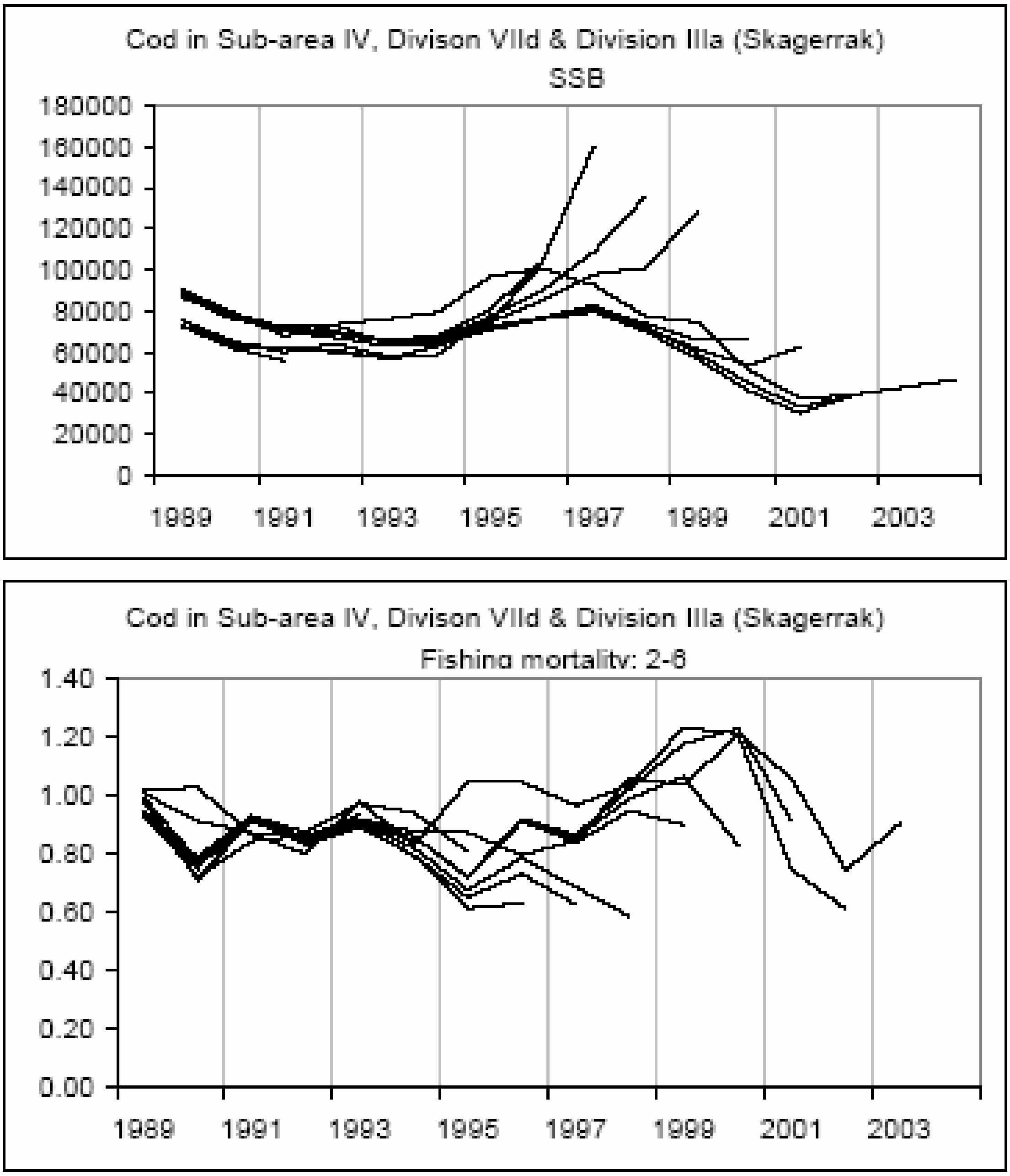

Figure 11. Retrospective plots of the Working Group assessments of North Sea cod, based on reported catches. From ICES 2004