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Proceedings of the Newfoundland Regional Advisory Process of the 3Ps Groundfish Stocks : Cod, American Plaice, Witch Flounder and Pollock.

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ABSTRACT

This document records discussions during the Regional Advisory process meetings for Newfoundland groundfish stocks, specifically cod, American plaice, witch flounder and pollock in 3Ps. The scientific peer review took place at the Airport Inn in St. John's in October 1999.

RÉSUMÉ

Le présent document offre un compte rendu des délibérations tenues durant les rencontres du Processus consultatif régional sur les stocks de poisson de fond de Terre-Neuve, notamment la morue, la plie canadienne, la plie grise et la goberge dans la 3Ps. L'examen scientifique par les pairs a eu lieu au Airport Inn à St. John's en octobre 1999.

Document Summaries and Related Discussions

Oceanographic Conditions

W.P. 99/2.1 Oceanographic Conditions in NAFO Subdivisions 3Pn and 3Ps during 1999 with comparisons to the long-term (1961-1990) average. - Eugene Colbourne.

Summary

Oceanographic data from NAFO subdivisions 3Pn and 3Ps during 1999 are examined and compared to the long-term (1961-1990) average. The data are presented in several ways, as vertical transects across the major banks and channels, horizontal bottom maps, time series of areal extent of bottom water in selected temperature and salinity ranges and as time-series of temperature anomalies at standard depths. Time series of temperature anomalies in the 3Ps St. Pierre Bank area show anomalous cold periods in the mid-1970s and since the mid-1980s, similar to conditions on the continental shelf along the East Coast of Newfoundland. The most recent cold period, which started around 1984, continued to the early 1990s with temperatures up to 1^{o}C below average over all depths and up to 2^{o}C below the warmer temperatures of the late 1970s and early 1980s in the surface layers. Temperatures in deeper water off the banks show no significant trends. Since 1991, temperatures have moderated in some areas from the lows experienced from the mid-1980s and early 1990s but negative temperature anomalies continued over large areas of the banks into the spring of 1995. During 1996 temperatures started to moderate, decreased again during the spring of 1997 and returned to more normal values during 1998. Temperatures during 1999 continued to warm and were above normal over most of the water column and near bottom. An analysis of the areal extent of subzero oC bottom water covering the banks shows a dramatic increase since the mid-1980s, very low values in 1998 and a complete disappearance in 1999. The areal extent of bottom water with temperatures above 1^{o}C on the banks was about 50% of the total area during 1998 the first significant amount since 1984 and it increased further to about 70% during 1999. The salinity data clearly shows a change in water mass characteristics during the last 2 years, compared to conditions that prevailed during the first half of the 1990s. The areal extent of the relatively saltier water (> 32.5) on the banks increased by approximately 40% during this time, indicative of a shift from the cold-fresh conditions of the late 1980s and first half of the 1990s on the Newfoundland Continental Shelf to warmer-saltier conditions.

Discussion

Are anomalies on the order of 1 C unusual? Yes. It might be useful to express anomalies in tems of the fraction of time one would expect them to be exceeded rather than by their absolute amounts. It would be useful to have more oceanographic data pertaining to inshore areas. One possible source is the sentinel fishery and there are plans to include these data in subsequent years. Water temperatures in 3Ps appeared to be more weakly

related with the North Atlantic Oscillation than are areas further north. The most recent warming in 3Ps started in 1998, compared to 1996 for Station 27. Will the temperature data be used in the stock assessments? Not in a quantitative way; although it might be important for interpreting results from research surveys and the commercial fishery. The time of the surveys was variable and probably a more likely cause for any survey inconsistencies. It may be useful to investigate the relationship of the 3Ps oceanographic data to that from other larger areas, such as the northeast Atlantic.

3Ps Cod

W.P. 99/8 An assessment of the cod stock in NAFO Subdivision 3Ps. Section 8. Size, weight and condition-at-age. - G.R.Lilly.

Summary

Mean lengths-at-age varied over time. For the period 1972-1999, peak length-at-age occurred in the mid-1970s for young ages and progressively later to 1980 for older ages. From the mid-1980s to the late 1990s, length-at-age and weight-at-age varied with no trend (younger ages) or declined (older ages). There appears to have been some increase in recent years.

Both gutted condition and liver index declined from 1992 to 1993 and have remained low to 1999. This decline is attributed to the change in timing of the surveys from February to April, resulting in the sampling moving to a lower point in the cod's seasonal condition cycle. There is no evidence that either gutted condition or liver index has been unusually low in recent years.

Discussion

Only lengths and weights from the commercial fishery are used in stock assessment models. These might be biased (e.g. only the largest of young fish would be caught). Weight and length at age information obtained from survey sampling might be less biased; however, surveys were conducted at only one time of the year and consequently data were not available to determine if seasonal cycles occur; and sample sizes are smaller. *It was recommended that this issue be studied further*. Estimates of survey weights at age for older ages are quite variable and consequently could have considerable impact if used to determine SSB. *It was recommended that modelling of the data be considered to effect some smoothing of the estimates.* Weights at age can change quickly, as evidenced by observed changes in size of captive cod. It was also the fishermen's experience that perceived changes in fish condition could occur rapidly because of the movement into or out of an area of a subgroup of cod from the larger population. Differences in selectivities of fishing gears could also affect weight at age estimates if the gear compositions in the fishery were changed. Analysis of information from the sentinel

fishery might be useful to answer some of these questions, although the impact of temporal differences in the data sets remains an issue .

W.P. 99/4. An assesssment of the cod stock in NAFO Subdivision 3Ps. Section 4: Science Logbooks - E. Murphy and P. Shelton.

Summary

A new science logbook was introduced to record catch and effort data for vessels less than 35 ft in 1997. The purpose of this logbook is for scientific stock assessments and not for quota monitoring or other controls on the fishery. Previously only purchase slip records were available for these size vessels, containing limited information on catch and no information on effort. Catch rates have the potential to provide a relative index of temporal and spatial patterns of fish density, which may relate in some way to the overall biomass of the stock. At this stage, with only three years data for 3Ps, the emphasis is on descriptive studies rather than modelling.

Although it is too early to try and obtain an index of stock size from the catch rate data, there are several temporal and spatial patterns that appear to be consistent across space and time and which should therefore be interpretable. The apparent decreasing trend in gillnet catch rates in 3Psa and 3Psb, the decreasing trend in linetrawl catch rates in 3Psa as well a the low catch rates in the current year in 3Psc may be cause for concern. An attempt should be made to relate these observations to the estimated abundance of fish in the size categories selected by these gears.

Discussion

Catch rates in some areas (e.g. Placentia Bay) might be influenced by the imposed management plans. Some areas had an open fishery while others operated under an individual quota (I.Q.) system. It is important to know how fisheries are being conducted when interpreting their catch rates. What is the relationship of the inshore effort data to the total stock? This is not known and it is difficult to determine spatial and temporal patterns. These patterns need to be modelled. These inshore catch rates were not disaggregated and sampling was not sufficient to indicate small scale differences which appear to be real.

W.P. 99/5.1 1999 Sentinel survey in NAFO Subdivision 3Ps. R. Stead, D. Maddock Parsons

Summary

In 1999 Sentinel Surveys in NAFO Subdivision 3Ps continue to produce the time series of inshore biological and catch/effort data collected by trained fish harvesters. There are

16 active sites in 3Ps, using predominately gill nets in Unit Area 3PsC (Placentia Bay) and line trawls in Unit Areas 3PsA and 3PsB (Fortune Bay and west). Fishing times have been reduced to a minimum of 6 weeks in 1999 as opposed to 12 weeks from 1996 - 1998. Catch rates from both gears have been relatively low in those areas that have a spring/summer fishery. However, most fishing takes place in the fall/early winter and no results are available to date.

Discussion

In 1999 there were smaller and fewer cod in the sentinel surveys than in 1998. However, when all surveys are complete and data included results were expected to be more comparable with previous years with respect to quantity and size. Catch rates were expected to show an increase with the inclusion of fall data as this has been the period of best catch rates in the past. Because of the larger commercial fishery in 1999, some difficulties in occupying previously used control or experimental fishing sites were experienced. Differences in the weekly patterns of catch in 1999 were questioned and it was suggested that there might be a relationship with environmental conditions. This could not be confirmed but was considered an issue requiring further attention. Fishermen reported that water was warmer in 1999 than previous years and that cod were more likely to be found in deeper water. Although environmental data would not be incorporated into the formal assessment it was concluded that the effect was most likely on distribution and catchability. Data from an acoustic survey also indicated that the 1999 cod distribution was different than that observed in the previous four surveys. Will this environmental effect influence our ability to use the sentinel data as an abundance index in the future? It was considered that the index could be useful with the possibility of removing any known effects. Any potentially useful indices should be tried out in an assessment before deciding on their usefulness. There was a suggestion that the sentinel fishery as currently being conducted may not produce a useful time series.

W.P. 99/5.2 An age disaggregated index from the sentinel program for cod in NAFO Subdivision 3Ps. Don Stansbury.

Summary

Discussion

The use of modal age groups to assign ages to non-aged fish overestimates strong year classes. The narrow range of selectivities of gillnet might also have an effect on the age structure obtained. The age structure was not weighted by the selectivities of the gears, which might restrict age by age comparisons but not year-class comparisons. The problem of strong year effects was noted . Inconsistencies between the results from this paper (1995 and 1996 similar) and other papers (1995 lower than 1996) were related to the influence of the model used (multiplicative) which removes some of the temporal and

spatial effects. Although the model tries to remove site variability, it was felt that it might be useful to identify areal (community) effects. It was decided that the index should be used in SPA calibrations on a trial basis, to permit some evaluation.

W.P. 99/13. Comments on the population age structure of 3Ps cod. George H. Winters.

Summary

Two approaches were used to provide alternative estimates of recent recruitment trends and recruit to adult ratios for comparison with estimates of these population statistics from the 1999 assessment. The two approaches (salinity model and RV indices) indicated that the older age groups have been underestimated by the 1999 QLSPA assessment. These two sources are somewhat in disagreement with respect to the most recent year-classes (1994-96) with the salinity model indicating that these year-classes had been overestimated by the QLSPA. A comparison of predicted and observed age compositions for the 1999 fishery as well as new information from the 1999 RV will be useful in resolving this issue.

Discussion

The survey catchabilities were assumed to be the same over time and age and it might be more appropriate to weight the RV by its catchabilities. Can the salinity series be used as a tuning series? A previously determined relationship between salinity and recruitment for 2J3KL became weaker with additional years of data; it was not known if a similar analysis had been done for 3Ps cod. There was no strong support for similar re-analysis to be conducted for presentation at this meeting but *it was recommended that such analysis be conducted in the future to determine if the relationship exists.*

W.P. 99/3.7 An assessment of the cod stock in NAFO Subdivision 3Ps: catch, catch-at-age and RV trawl surveys. E.F. Murphy.

Summary

Discussion

Landings reported from the commercial cod fishery in 3Ps during 1999 were less than 50% of the TAC at time that this documentation was produced. A fisherman at the meeting indicated that all of his IQ remained to be caught but he anticipated that he wouldn't have trouble during the remaining time as this was traditionally a time of good catch rates in his area. He also expected that about 85 to 90% of the total remaining TAC would be caught with the shortfall occurring only because of an anticipated lack of effort by some fishermen. The actual catch could be somewhat larger because any discard

information would not be included in current estimates. There has been no formal analysis of a possible relationship between cod distribution and water temperature.

Biomass and abundance estimates for 1995 appeared to be outliers relative to surrounding years: should they be removed from the analysis? There is no reason to remove them on the grounds of possible instrumental error. If they are to be removed for being unexpectedly high, then other surveys that missed such real concentrations should be corrected for being unexpectedly low. Similarly large data points had been removed in the assessment of 4T cod although in this case it had little effect on SPA. The 1995 survey will not be excluded from this year's analyses.

W.P. 99/6 Movements of cod and relative selectivity of gear types from tagging experiments in NAFO Subdiv.3Ps during 1998-99. John Brattey and Noel Cadigan.

Summary

The Strategic project on inshore/offshore cod was continued during 1999 with an additional 6,162 tagged fish released in 3Ps during 1999 (2272 in the offshore, 3990 in the offshore). The design was the same as in 1997 and 1998 with single, double, and high-reward tags applied, and tagging was conducted on spawning and post-spawning aggregations in the following areas: Halibut Channel (3Psh), Burgeo Bank-Hermitage Channel (3Psd), Fortune Bay (3Psb), and Placentia Bay (3Psc). Up to Oct 8th, a total of 161 of these tagged cod had been reported as recaptured, along with 343 from the 1998 releases (N=9941), and 154 from the 1997 releases (N=6029). No quantitative analyses of the data was attempted (exploitation rate or migration model) because the fishery was still in progress and it was not known what fraction of recaptures had been sent in by fishers. Information on the spatial distribution of recaptures was presented. Recaptures from the Halibut Channel releases were consistent with those seen in 1998 and showed an inshore migration of a portion of this stock component to Placentia Bay and southern 3L. The 1999 tagging in the Burgeo Bank area gave several inshore recaptures in 3Ps, but none in 3Pn-4R in spite of landings of approximately 6,800 t. In contrast, tagging in the Burgeo Bank area in 1998 gave several recaptures in 3Ps and in 3Pn-4R in both 1998 and 1999. Cod tagged in Fortune Bay were recaptured mostly within the stock area within Fortune Bay itself, or eastward into Placentia Bay. Cod tagged in Placentia Bay in 1998 and 1999 gave many recaptures within Placentia Bay itself as well as several from southern 3L; a few of the 1998 releases were recaptured in northern 3L and 3K during 1999. Relative selectivities of various gear types on 1 cm length-classes over the size range 45-90 cm were also computed given that a known number at length were released and gear types were available for most recaptures. Most of the recaptures came from gill-nets and these showed a strongly domed selectivity with a mode at around 70 cm. Hand-line and line-trawl showed progressively increasing selectivity with length; traps showed a mode at around 50 cm which declined with further increase in length. Comparison of the gill net selectivity curve from 1997-99 data with that from 1997-1998 showed a shift of the mode

to the right, rather than the left as would be expected; this suggests that fishers may have increased the mesh size of their gill nets in the 1999 fishery.

Discussion

Recapture plots are difficult to evaluate because they are not weighted by effort. There were fewer recoveries in 3L than in 3Ps, but the effort was lower. Conversion of selectivity at length to age was considered desirable but probably not feasible because of the wide range of lengths associated with each age especially for the older age groups. The use of a calculated annual selectivity at age would be more appropriate in SPA than the assumed selectivity pattern that is presently used. The calculated selectivities would be for Placentia Bay cod only and represent sizes not available to all gears. The issue involves both selectivity and availability.

A comparison of the gillnet selectivities for the 1997-98 and 1997-99 [sic] periods indicated a shift towards larger fish in the second period. This would suggest that the gillnet selectivity for 1999 might be higher than that suggested in the analysis. This may be because larger mesh sizes were used to increase fish size for quality and price considerations.

W.P. 99/9. Update on age at maturity and spawning of cod in NAFO Subdiv. 3Ps . John Brattey.

Summary:

Age at 50% maturity for females collected during annual spring DFO research vessel surveys from 1978-1999 was calculated. The estimated age at 50% maturity dropped dramatically from a high of 7.2 years during 1988 to a low of 4.64 during with males showing a similar trend over time.. Maturities at age have been highly variable over the past 5yrs, but have not shown a continuation of the rapid decline seen during 1988 to 1994. Nonetheless, the age at maturity remains low and this has a substantial effect on spawner biomass production by the 3Ps cod stock. To project the maturities for 3Ps cod to 2000 and 2001, the estimated proportion mature at age was computed in the standard manner for each of the previous four years (1995-1998 inclusive), then the model was again fitted to these estimates (i.e there would be four estimates for each age class) to get new estimates comparable to average maturation for the recent period. These values were used for both 2000 and 2001 in projections of mature spawner biomass. Maturities of cod sampled in three sub-areas of NAFO subdivision 3Ps during winter/spring research vessel bottom-trawl surveys from 1983-1999 were also determined. The three sub-areas show a consistent pattern of maturity stages across most of the time series, with maturing fish dominating in most years. The switch in timing from February to April clearly results in an increase in the proportions of spawning fish and a reduction or disappearance of fish that are spent from the previous year. When surveys were conducted in April, spawning and spent fish were found in each area; within any one year the proportion of spawning and spent fish tended to vary among sub-areas, but generally about 15-50% of the mature fish sampled were spawning or recently spent. The results from the 1999 survey show no

dramatic changes from recent years. The results also show that a substantial portion of the mature cod sampled in the Burgeo area in the April surveys are spawning and by definition belong to the 3Ps stock; most of the remaining adult fish are maturing to spawn later in the same year and their stock affinities remain unclear. Maturities of cod sampled during the survey were also compared to those of cod collected during tagging trips (inshore and offshore) during 1998 and 1999 (Fig. 4). The offshore tagging trips were conducted about 2-4 weeks before the survey. The most notable finding was the higher proportions of spawning and spent fish in the Burgeo and Halibut Channel areas during tagging compared to during the survey, even though the surveys were conducted later. In most areas, there was generally higher proportions of spawning and spent fish in 1999 compared to 1998, suggesting that spawning occurred earlier in 1999.

Discussion:

It is difficult to determine gonad maturity stages in the field, particularly that described as 'previously spent'. The proportion of this stage has increased in 1999 in the Halibut Channel area and the implications were that a substantial number of cod might not spawn in that year. The accurate determination of this stage should be verified using histological techniques.

There are seasonal changes in maturity as well as dramatic changes over years. It is important to know if these are real changes. Some of the variation could be the result of spillover from adjacent stocks with different maturity rates; but there was no evidence to support this and adjacent stocks have shown a similar trend in maturity rates over the same years.

No particular specific or consistent spawning areas could be identified. Large spawning aggregations have been found in areas of Placentia Bay but not consistently over the years. No information was available to indicate whether spawning areas exist in offshore areas. This issue was considered important should closures be considered for protection of spawning areas. Observations by fishermen indicate that spawning occurs over a long period (March to August) in Placentia Bay.

Reproductive potential has changed over the years because the age at maturity has declined substantially. In this regard it was suggested that egg production data should be considered as an alternative to SSB. The issue of sex ratios was addressed as potentially important in determining SSB. It is assumed that the existing sex ratio is 50:50. The past decision to use the female maturity ogives [*sic*] was arbitrary and it was recognized that egg production estimates might be useful. Fecundity information is not currently available. The possibility of temporal trends in fecundity might also be an issue.

W.P. 99/8.1 An assessment of the cod stock in NAFO Subdivision 3Ps: Commercial weights at age. G. Lilly.

Summary

The time-series of commercial weights-at-age was presented. There is no update to 1999 because the fishery has not been completed.

Estimation of population biomass at the beginning of the year requires an estimate of the mean weight-at-age at that time. In recent assessments the January 1 weights-at-age were estimated from the commercial weights-at-age. There are several potential problems with this approach. For example, there have been changes in the proportion of the total catch taken by each gear type as well as changes in the temporal and spatial pattern of fishing. In response to a request for additional exploration of the relative merits of commercial weights-at-age and research vessel weights-at-age, an earlier preliminary comparison between the two was presented.

The research vessel weights-at-age are not without problems. They have been highly variable over time and include some strong year effects. In addition, they come from surveys that were conducted 2 - 6 months after January 1. In the absence of information on seasonal changes in weights-at-age, it was assumed (with little support) that fish length does not change during the first 6 months of the year, and that changes in weight at length (condition) after January 1 could be overcome by applying to the lengths a weight-length relationship derived from sampling as close as possible to January 1. A weight-length relationship was calculated from samples collected during the February surveys in 1988-1991. Mean weights-at-age were then calculated from these estimated weights.

A visual comparison between the commercial and research estimates of January 1 weights-at-age showed that on average over the period 1977-1997 the estimates from research sampling were lower than estimates from commercial sampling at ages 3 and 4 and higher than the commercial estimates at older ages. When temporal changes in the two series were compared on an age by age basis, it was clear that the research values were more variable and that there was no consistent relationship between the two series.

It was recommended that modelling of the research weights-at-age be explored, with the goals of clarifying the temporal changes in growth rate and providing more appropriate January 1 weights-at-age to be used in reconstruction of population biomass.

Discussion

Weight-at-age currently used to compute population biomass in assessment models is estimated from the commercial fisheries. It was suggested that the RV weights at age had potential for use in assessment purposes, after modelling of the raw data to deal with the problems of small samples collected at only one time of year. *It was recommended that all the data relevant to catch-at-age be examined to determine the appropriateness of using either the commercial or RV data.*

Sequential Population Analyses

W.P. 99/10.2. An assessment of the cod stock in NAFO Subdivision 3Ps using the ADAPT Framework. Don Stansbury.
W.P. 99/10.3. Overview of QLSPA, Oct 99 RAP. Noel Cadigan.
W.P. 99/10.4 A preliminary Extended Survivors Analysis assessment of the 3Ps cod stock. C.D.Darby.
W.P. 99/10.5 Preliminary assessment of 3Ps cod using ICA. Mike Armstrong.
W.P 99/10.6 3Ps cod: medium term projections based on ICA. Mike Armstrong
W.P. 99/10.25 A comparison of the preliminary assessments of the 3Ps cod stock using ADAPT, QLSPA and XSA. N. Cadigan, C.D. Darby, J.C. Mahé and D. Stansbury.

This assessment was performed only 7 months after the previous one. There was little new information: one new survey, and incomplete (probably unrepresentative) catches from the ongoing fishery. It was therefore decided to invest much of the effort of the meeting in comparing different methods of sequential populations analysis on the available data sets. It has not been possible to reconstruct all of the discussions on this topic, or all of the reasons why the meeting settled on certain choices. It is useful to organize the proceedings and discussion around three broad questions (subordinating chronology to logical flow): What is the deterministic structure of the model? What is the random structure and what data are considered when choosing model parameters? What outputs from the model are useful to decision makers?

The overall sequence of events: first all four candidate methods (QLSPA, ADAPT, XSA, ICA) were run making assumptions that were, to the extent possible, the same (the 'identical' runs). Then each model was run with the assumptions that its custodian felt were the most appropriate (the 'preferred' runs). Effects of combining different parts of the RVs series, and including a sentinel index, were investigated. A single model, QLSPA, was chosen as the preferred one for this assessment, and a preferred run was agreed upon. Some biological and management reference points were chosen—both management targets and levels that should trigger conservation actions or at least concern—and the probability of being on the wrong side of them was computed. In general, the predictions and risks computed with different models were comparable; the major differences among runs were due to differences either in the deterministic model applied or in the degree to which different data series were combined.

A first step was to compare SPA results obtained using the ADAPTive framework (Gavaris 1988), XSA (Darby and Flatman 1994), a quasi-likelihood approach (QLSPA, Cadigan 1998) and Integrated Catch-at-Age Analysis (ICA, Paterson 1996) on the cod stock in NAFO subdivision 3Ps. The assessment structure from the zonal assessment in March 1999 was used in all runs, to the extent possible with each model, to try to confirm that the models produce similar results from similar assumptions.

Deterministic model structure

Terminal populations were estimated at each age in the final year and at the oldest age in the years 1994-1999.

$N_{a,y}$ where a = 2 to 14 y = 1999.42 (May) and i = 14 for t = 1994-98.

For the ICA run only population numbers in the terminal year were estimated.

Catchabilities at each age and survey were estimated independently.

$K1_a$ where a = 3 to 12 for the Canadian Research Vessel survey winter

$K2_a$ where a = 2 to 12 for the Canadian Research Vessel survey spring.

For the ICA run a = 3 to 12

The following structure was imposed for the ADAPT, QLSPA and XSA runs:
natural mortality is 0.2 /year; fishing mortality on the oldest age (14) is half the average F for age 11-13 for 1959-93; no 'plus' age class; negligible error in the catch numbers at age.

ICA differed from the other 3 runs in many respects. Catches at age are assumed to be measured with error. A separable (year and age effects) model for fishing mortality is fitted over a recent period of years (different separable models may be fitted to two time periods at the expense of estimating additional parameters). Correlated errors across ages may be specified for age-disaggregated indices (but not for the commercial catches). Preliminary ICA runs indicated that the model would not work with age class 2 included (a catch of 1 thousand fish was assumed at age 2 for each year to avoid zero catches, and the age 2 index for spring surveys 1996 – 99 was included in survey file). The files were amended to remove age class 2. Zero catches at other ages were replaced by 1000 [kilograms?]. Age class 14 in the commercial catch numbers file had to be treated as a plus group as ICA assumes that the final age class in the file is a plus group. The program is not able to deal with a partial year's catches (as in 1999), and was run using catches up to and including 1998. The inclusion of survey data for 1999 allows the model to project population numbers to the end of 1999 assuming status quo fishing mortality.

All four methods gave equal weighting to the surveys at age and the indices are proportional to population numbers.

All of the programs perform a non-linear minimisation of an objective function. The function for ICA is

$$\sum_{a,y} w_{a,y}(\ln(C_{a,y}) - \ln(C'_{a,y}))^2 + \sum_{a,A} w_{a,A}(\ln(I_{a,y,A}) - \ln(I'_{a,y,A}))^2$$

where $C_{a,y}$ are the observed numbers caught at age *a* in year *y* in the commercial fishery; and $I_{a,y,A}$ are the indices of population numbers at age *a*, year *y*, survey *A*. Variables with apostrophe are the model estimates from specified catchability model, and the *w* are weighting factors entered manually or recalculated iteratively. ADAPT minimizes the second term in the ICA formulation above for the survey indices but assumes no error in the catch. The objective function for QL is

$$\sum_{a,y,A}(I_{a,y,A} / I'_{a,y,A}) - \ln(I_{a,y,A} / I'_{a,y,A}) - 1$$

The function that XSA minimizes is harder to discern, but is implicit in the steps taken to iterate to a solution (= minimum value). Beginning of the year population numbers are obtained from the catchability model. They are projected forward to the final age of each cohort using fishing and natural mortalities(estimated and assumed respectively). A weighted average of the survivors provides new estimates of terminal numbers.

ADAPT, ICA and XSA assume error is independent, lognormally distributed with constant CV; QLSPA allows the CV to vary with age.

Data

Catch numbers at age $C_{a,y}$ where a = 2 to 14 and y = 1959 to 1999.42. No plus group. Zero catch assumed for age 2. Catch data for 1999 is preliminary catch up to May 1999.
Two series of Canadian Research Vessel indices: (Campelen or Campelen-equivalent)

$RV1_{a,y}$ where a = 3 to 12, y = 1985 to 1993, winter without Burgeo Bank strata

$RV2_{a,y}$ where a = 2 to 12, y = 1983-84, 1993 to 99, spring

Maturity, stock and catch weights at age from the March 1999 assessment (CSAS 99/36) with the addition of the data for 1999.

Excerpts from Chris Darby's manual:

10.1 Description of the method

The XSA algorithm performs:

1) A Cohort analysis of the total catch-at-age data to produce estimates of population abundance-at-age, and total fishing mortalities.

2) Adjustment of the CPUE values for the period of fishing defined using the alpha and beta parameters in the fleet tuning file, into CPUE values that would have been recorded if the fleet had fished only at the beginning of the year. The adjusted values are directly comparable with the population abundances at the beginning of the year.

3) Calculation of fleet-based estimates of population abundance-at-age from the adjusted CPUE values and fleet catchabilities. Fleet catchabilities-at-age are assumed to be constant with respect to time (for ages considered to be 'recruited'), or dependent on year class abundance (for ages to be treated as 'recruits') within the model described by Shepherd (1993) and implemented in the program RCT3 (previously RCRTINX2) described by Darby and Shepherd (in prep.).

4) Calculation of a least squares estimate (weighted mean) of the terminal population (survivors at the end of the final assessment year) for each cohort in the tuning range using the fleet-derived estimates of population abundance-at-age. These terminal populations are used to initiate the Cohort analysis in the next iteration.

The process iterates until the convergence criteria described for ad hoc tuning are achieved. Various options are available for catchability analysis, time series weighting and shrinkage of the weighted estimates.

Results

There is close agreement between methods if they are set up with equivalent structure.

Discussion

The assumption of separable fishing mortality in ICA was challenged given the gear changes that have occurred during the history of the fishery.

Does removing Burgeo tows lead to an underestimate of the stock? No, because we are considering an index that is an average over sets, not a total.

Because the 1998 spring survey had found higher-than-average numbers of young fish, and the most recent survey was more in line with previous years', this extra survey was quite influential for estimates of recent recruitment.

The age range to be used in the comparison modelling runs was questioned. The use of all ages was recommended. It was pointed out that the catch-at-age data had missing points for some ages and that it was necessary to be sure that there were catch and survey estimates for all years otherwise there would be population estimates based on an assumed M. Arguments for the inclusion or exclusion of young and old fish was considered a question of Q values. There was a question of using different Q values when dealing with data from the Engels or Campelen survey trawls. However it was questioned whether there was evidence for the existence of different Q's for the Campelen.

Subsequent Investigations

The changes from the 'identical' run for each 'preferred' model run were .... For example, the assumption about F[14]/F[11-13] which was set equal to 0.5 in the preliminary runs, and in general in XSA, was estimated as a parameter in the preferred run of QLSPA. The estimated value was 0.412.

In discussions of the preliminary runs, two major data issues arose. (1) Is it appropriate to use the spring surveys of 1983 and 1984 to calibrate the 1993-1999 spring survey series? Arguments for splitting the spring series: that's what ICES would do when the first part was so old; the vessel and (for the most part) gear were different. Arguments for not splitting it: the old part of the series is useful for pinning down values that would otherwise be floating in just the unfinished cohorts; there is no intrinsic reason to consider them as different; they didn't seem to be different for flatfish. (2) Should we use the sentinel index presented in WP5.2, and what effect would it have? Arguments for adding the sentinel index: it has been computed so why not see what difference it makes; the tuning methods include self-weighting that can downweight it if this appears appropriate. Arguments for not adding it: the nature of the sentinel program has changed and will continue to change, as the time available is altered and as sentinel fishermen devote a larger part of their time and effort to commercial fishing and commercial sites interfere with sentinel sites - so there is no intrinsic reason to think that the sentinel series is a series of the same measurement in many years. A set of 4 further runs was made, in which each investigator used his preferred set of model assumptions: with and without adding the sentinel index; with and without the spring survey split into two parts: 1983-84 and 1994-99.

There was a major effect of combining the two parts of the spring series: estimates of current numbers at each age were about 3 times as high as when they were kept separate. The effect on confidence intervals was small: the 97.5% level for ages that are largely recruited is typically 4 times the 2.5% level in both instances. The numbers when the series were considered as separate were so low as to be outside the range indicated by ancillary data like the GEAC surveys and tagging survival estimates (also acoustic estimates; but they were less trusted because of target-strength worries). Then runs were made in which the whole RV series was considered as a single series (same catchability, with and without equal variance assumed for the winter and spring parts). This was based on the observation that the Qs for the two series were similar, rather than on any intrinsic grounds for asserting that the two series were the same. In fact it was stated by some that the Qs were importantly different for older fish.

An attempt was made to estimate the ratio of F[14] to F[11-13] for the fisheries during the 1980-90 period using average catch by gear and selectivity patterns by gear and by 1 cm length as obtained from tagging data. Earlier length at age data were used to convert the length data to ages and selectivity at age was plotted by smoothing the distribution. Selectivity at individual ages (ages 8-12) were read from the fitted curve. The PR obtained was described as mostly flat. This estimate was then used in QLSPA.
The model output indicated year and age effects in the survey residuals suggesting that the model didn’t match with the survey. There were anomalies in the F matrix produced, in that PR’s appeared to be flat prior to the moratorium (1993) but domed since that time. The dome pattern produced for the recent years appeared to be distorted by the input flat PR and was causing the massive model mis-specification. It was decided to reject the presented model run. It was suggested that the model could be run including ages to 12 to

avoid problems of inputting PR for the oldest ages where there was no estimate from the tagging data. However, it was noted that the older ages were present in the surveys and should be included in the analysis.

The weightings incorporated into the models were considered important with regard to their impact on assessment outcome and the effect on risk. Self weighting models (XSA, QLSPA) may not provide reliable estimates for young ages. The models assigned high weights to sentinel gillnet indices for young fish; these were felt to be an accidental feature of the data, and not to indicate real high accuracy. The sentinel indices for young fish were therefore dropped.

The accepted SPA

It was noticed that, when Burgeo strata were not included in the winter index, statistical tests could not detect a difference between the Qs of winter and spring indices (although they could if 1983-84 was deleted from the spring series). The similarity was less at the oldest ages. It was objected that similarities in Q were not necessarily a good reason to amalgamate two series which we knew differed in important respects; amalgamating based solely on a failure to detect a difference might lead to a spurious increase in precision. Nonetheless, it was decided to perform a run of QLSPA with a single RV series (a single Q for each age, although the associated variance was still allowed to differ between the winter and spring series; it was suggested that the option of separate variances be deleted.) QLSPA was chosen as the method for the accepted run because its custodian works in St. John's and so subsequent investigations will be most easy; and investigations during the meeting had revealed no huge differences between tuning methods and no reason to prefer one over another.

General problems with all SPAs.

Low Fs in recent years, especially the years of the moratorium, make calibration difficult. The survey is unusually noisy: standard errors around 1 are common. Changes in survey practice make it difficult to construct a single long series we have confidence in.

The results are very sensitive to the assumption that there is a constant arithmetic relationship among fishing mortalities on old fish of different ages, and to the value chosen for this relationship. A trial run of QLSPA was made in which F[14] was computed from another data set (selectivity from recaptures of tagged fish) but it was rejected on the grounds of .... Assuming a dome-shaped partial recruitment to the fishery is not conservative: it is assuming there exist a lot of old fish that you can’t catch. Symmetric aging errors will appear to create more old fish by accident; but aging errors in old fish are not symmetric - reportedly they tend to age on the young side. Thus the error pattern can create a dome that isn’t really there.

A retrospective analysis was performed with the preferred QLSPA run. It showed no retrospective pattern (unlike analyses in previous years.) It also showed no 'converged' part of the SPA; so, perhaps it is not fully understood.

Reference points

One limit reference point considered, proposed by Serebryakov, is the intersection on the stock-recruit scatterplot of the straight line through the origin which 90% of the points fell to the right of, with the horizontal straight line that 90% of the points fell below. But this was deprecated as depending on the history or the stock and therefore not being a 'biological' reference point. Another candidate was 20% of virgin biomass - if that were known. The target or management reference points chosen were $F_{0.1}$ and a spawning biomass at least as large as the previous year's; the limit reference points that should trigger conservation measures were chosen to be F_{loss}, the F that the stock can sustain at its lowest observed biomass (which again depends on the history of the fishery), and the spawning biomass that can be expected to produce a recruitment only half of that expected at the optimal biomass for recruitment.

Probabilities were estimated using both QLSPA and the Lowestoft assessment package built around but not dependent on XSA.

The risks assessed did not include the possibility that the natural mortality was not 0.2, or the risk that it will not be in future, or that fishing deaths will exceed the stated quota, or of the pattern of fishing by age will be different from that assumed in the analysis.

It might be necessary to provide the different risk calculations from the models. The degree of uncertainty related to the sensitivity to biological parameters should be highlighted.

In addition to formal risk analysis, it is important to point out that recruitment in recent years has been poor and will have an adverse affect on the stock in the future years, and that older age groups are predominant in the stock.

W.P. 99/14. The impact of at-sea discarding on tuned virtual population analysis I: an empirical study. Harshana Rajakaruna and Yong Chen.

In many fisheries a significant proportion of catch is often discarded at sea and almost all fish die after being discarded. Yet discarded catch has usually been ignored when accounting for true catch in estimating stock parameters using virtual population analysis (VPA). Such an analysis may produce biased estimation of stock parameters and subsequently result in the mismanagement of the fish stocks. In this study we examine biases resulting from excluding discarded catch from tuned VPA, using a simulation approach, in estimating fish stock size and fishing mortality in various fisheries. The fisheries are characterized as inclining, declining, and stable fisheries by the temporal trend in the integral of averages of landed catch of age classes between complete and incomplete cohorts. Excluding discarded catch from tuned VPA more likely results in overestimating the current stock size in inclining fisheries, while underestimating that in both declining and stable fisheries. The association between temporal trends in discarded catch and the direction of bias was examined. The bias in the current stock size as a percentage of unbiased stock size tends to be high both in inclining and declining fisheries. The bias in fishing mortality tends to be insignificant in all types of fisheries. Excluding discarded catch from tuned VPA in inclining fisheries may lead to overexploitation of the fish stock due to the high likelihood of overestimating the current stock size in such fisheries. However, in declining fisheries, it may be more likely to adapt a risk averting management policy due to the high likelihood of underestimating the current stock size.

W.P. 99/15. The impact of at-sea discarding on tuned virtual population analysis II: an analytical study. Harshana Rajakaruna and Yong Chen.

Excluding discarded catch from tuned virtual population analysis (VPA) results in biased estimation of stock size. The bias is always negative (i.e. under-estimating stock sizes) in complete cohorts in fisheries while either negative or positive (i.e. over-estimating stock size) in incomplete cohorts. This result in underestimating the stock size aggregated over the ages, in early years, while either underestimating or overestimating that in later years. Preceding simulation study showed that the direction of the bias in the current year is determined by the temporal trends in discarded and landed catch. This paper examines the methodological basis of the direction of biases analytically. Evidence for the basis of the argument and prediction of the direction of biases in the analysis that was not explained completely by the preceding paper is presented. Fundamentally, the direction of bias in the current year is decided by an inequality of ratios that consists of the temporal trends in both landed and discarded catch. Positive bias is also conditioned by the fact that discarded catch is relatively high in younger ages, and drops to negligible quantities towards the older ages within few age classes. The assumption in tuned VPA that catchability coefficient is a constant for each age class, may be a reason that the current stock size could be positively biased. Analytical results strongly support the empirical and

simulation results. This micro analytical model could be developed into an advanced macro model to analyze complex systems compartmentally with more precision.

Discussion of 14 and 15

There were questions relative to the appropriateness of reversing the order of catches and survey indices. It was claimed that the usefulness of the analysis could be in explaining the reason for abrupt stock declines as had occurred for northern cod. It was concluded that the main message was the emphasis of the effect on assessments of not including data on discards and misreported catch. More information is needed on the age structure of discards.

3Ps American plaice and 3Ps Witch flounder

Res Doc. 99/59. American Plaice and Witch flounder catch results from surveys in NAFO Division 3Ps. John McClintock.

Summary

To enhance the fisheries research database in NAFO Subdivision 3Ps, the Groundfish Enterprise Allocation Council (GEAC) has funded surveys during fall 1997 and fall 1998 directed at cod and flatfish. The continuing intent is to create a series of annual fall surveys in 3Ps to complement current resource assessment activities carried out by the Department of Fisheries and Oceans (DFO). GEAC funded and performed the surveys with scientific guidance from DFO in the design and execution of a stratified random survey and the associated sampling. The data collected during these surveys have been subsequently analysed on behalf of GEAC for the express intent of providing this information to DFO, for their databases and their assessment work. One trip to perform the 1998 survey was carried out from 30 November to 11 December 1998. During the trip, set details and length frequencies were logged in the DFO FFS system and American plaice and Witch flounder otoliths were collected for subsequent aging. Plaice and witch catch statistics, length and age distribution, and stratified analysis estimates of abundance and biomass, including age distribution estimates, are presented.

Discussion

Ages may have been overestimated by one year, based on some previous information on the strength of the 1989 year class. Comparisons of age readings with DFO readers had not been possible as DFO aging of witch from this stock had been curtailed for several years due to the lack of sufficient staff.

W.P. 99/20 An assessment of American plaice in Subdivision 3Ps. M.J. Morgan, W.B. Brodie, S.J. Walsh and Don Power.

Summary

The last full assessment of this stock was in 1995. Catches from this stock were highest from 1968 to 1973, exceeding 12,000 t on three occasions in this period. Catches by foreign vessels peaked at about 8800 t in 1968, due mainly to the USSR catch, and have not exceeded 800 t since 1973. Since 1977 only Canada and France have been involved in this fishery. Catches averaged just under 4000 t during the 1980's but rapidly declined after 1991. The fishery for 3Ps American plaice has been under moratorium since September 1993. There has been no directed fishing since that time and catch has not exceeded 500 t. The catch in 1998 was 423 t and the catch to date in 1999 is 475 t.

Few samples of commercial catch exist since 1993. A number of comparison were done to determine if the fishery since that time was sufficiently similar to the previous time period to apply the historic age composition to the catch from 1993-98. There were found to be major changes in the commercial fisheries and the resulting length compositions taken from these fisheries on this stock during the 1990's. There has been a substantial truncation of the length distribution since the early to mid 1990's, and length frequencies since then have usually been comprised of about 90% females. Thus it is not advisable to apply historic length and age compositions to the recent catch data.

Analyses of research vessel data from 1972-99 were presented. Both biomass and abundance were variable from 1973-83 with perhaps a slight increasing trend. From the mid 1980's to 1990 there was a large decline in the indices. Since 1992 stock size has been very low. There has been a slight increase since 1993 in both biomass and abundance indices but current biomass is only 16% and abundance 21% of the 1983-87 average. Abundance at all ages has declined.

Estimates of total mortality (Z) from the Campelen or equivalent survey data were calculated for ages 2 to 17. For most ages mortality increased until the early to mid 1990's before declining in recent years. The average Z on ages 6-13 in 1994-95 was –1.0, despite very low catches.

Mean weight and length at age both showed a significant increasing trend over the time period. There has been little change in age at 50% maturity but a significant decline in length at 50% maturity.

Female spawning stock biomass (SSB) was calculated using survey data from 1983 to 1998. Estimates of maturity and mean weight at age were used, along with female abundance at age. Before 1990 individual weights were not available and a length-weight relationship used in the conversion of biomass for that period was applied to mean length at age to produce mean weight at age. SSB calculated in a similar fashion for the Engel data was taken from the last assessment. SSB showed an increase from the mid 1970's to

mid 1980's followed by a precipitous decline. This rapid decline is seen in both the original Engel and the Campelen equivalent time series. Since 1993, SSB calculated from the Campelen series has been only 15% of the 1986-87 average. The 1998 index of female SSB is 7,000 t.

Cohort strengths were estimated using a general linear model. For the Engel time series this model gave a significant fit to the data and there was a significant cohort effect. For the Campelen time series there was also a significant fit of the model to the data but there was no significant cohort effect. The Engel time series shows no good year classes from 1980-92. The largest year classes were 1977 and 1978. The Campelen time series also shows the 1978 year class to be above average and also indicates that the 1994 year class may be stronger than average. Consistent with the Engel series, there was no sign of good recruitment from 1980-92. These two sets of relative cohort strength were plotted against their respective indices of SSB. Both series indicate that some of the best year classes arise from some of the lowest SSBs.

As a proxy for the exploitation rate on this stock, the ratio of catch to biomass from spring RV surveys was examined from Campelen data from 1983 to 1998. Catch/biomass ratio increased steadily through the 1980's reaching a peak of 0.31 in 1990. Since 1994 the C/B ratio has been less than 0.05, reflecting the low catch levels.

Discussion

Survey to biomass ratio value for 1990 was much larger than the rest and most likely an artifact or year effect. The mean length at maturity and life span were said to be negatively correlated suggesting that the population might be reproductively stressed and not accumulating biomass. The commercial fishery is not catching older plaice as in the past. As mortality increased maturity rate declined. The causes of these changes are not known but are probably interwoven.

Plaice stocks in 2J3K and 3NO have shown similar trends in maturity and a decline in abundance. The latter was not related well to exploitation.

Plaice have moved to deeper water. An age 12 mean size anomaly may have occurred because plaice moved to deeper, and warmer water, especially in the Halibut Channel area where growth rates are faster. The change may have been the result of a sampling problem causing a perceived change. If within the stock there are smaller groups growing at different rates then growth rates can appear to change if the relative contribution of the different groups changes.

W.P. 99/22 Surplus production analysis of St Pierre Bank American plaice (NAFO Divs. 3ps). Stephen J. Walsh.

Summary

A non-equilibrium surplus production model (ASPIC) was applied to catch, effort and survey biomass indices of St. Pierre bank American plaice (NAFO Subdiv. 3Ps). Various configurations of the data were tested with the model.

Discussion

It might be useful to look at the ecology of the input to the model. The environment has a carrying capacity for the sum of many fish species, not just plaice. Thus the quadratic loss term is not just proportional to plaice abundance.

The model relates present conditions to the MSY level. The value of *r* (the intrinsic rate of population growth) from most model runs were high considering that plaice is a relatively long lived species. It was noted that the patterns produced over time were driven by the lack of an index in the early part of the catch series. Estimates of B2000 were considerably lower than BMSY. This gave a similar picture to that of the surveys, namely that the plaice population is low.

Most production model configurations indicated that the parameters were strongly correlated. People attending the meeting knew little about the strengths and weaknesses of the model. *It was recommended that advice be sought from those familiar with the model and if possible that a workshop be conducted to determine the utility of the new model.*

If the model were applied to 3NO plaice then the results could be compared with those from a VPA.

W.P. 99/21 Stock status of Witch flounder in NAFO Subdivision 3Ps. W.R.Bowering.

Summary

Landings from this stock over the last 20 years have fluctuated generally between 300t and 1000 t annually but have not exceeded 500t since 1993. Survey stock size indices since 1976 have been highly variable although recent estimates appear to be at the low end of the range. Survey results suggest that the recent biomass levels may be about two thirds of that of the late 1980's and early 1990's when the stock appeared relatively stable at a catch level of 1000t annually. The age and size structure observed in this stock since the early 1980s also appear to have remained stable with little change in growth pattern. Geographic distribution has not changed appreciably since 1983 except during the early to mid 1990's when fish disappeared from the 51-100 fath. depth zone coincident with extremely cold sea bottom water temperatures. Relative mortality rates indicate little change during the past 20 years although there may have been some increase in the mid-

1990s. Data from surveys and recent observations from the commercial fishing industry suggest that witch flounder in Subdiv. 3Ps are found in deeper water than in past years.

Discussion

There were few small witch in the survey length frequency in spite of the use of small-mesh gear. This may reflect poor recruitment since 1996. A comparison of survey length frequencies over the 1983-99 period showed little difference over the whole period with no apparent trend. Thus recruitment was unchanged, and possibly poor, over the whole period. The data did not provide an adequate indication of recruitment levels. With more future years of 'true' Campelen data there should be more confidence in the relative abundance of small witch. Biomass estimates from surveys were variable but suggested that biomass in the 1990's was about 2/3 of levels in the earlier (1980's) years.

It would be useful to have age compositions. Because of insufficient staff, aging of witch samples has not been performed in recent years and remains a low priority.

W.P. 99/23 Surplus production analysis of St. Pierre Bank Witch flounder (NAFO Divs.3Ps) Stephen J.Walsh

Summary

A non-equilibrium surplus production model (ASPIC) was applied to catch, effort and survey biomass indices of St. Pierre bank witch flounder (NAFO Subdiv. 3Ps). Various configurations of the data were tested with the model but the data fitted the models poorly.

Discussion

Analyses were conducted on witch flounder similarly to that for American plaice in a previously presented paper (W.P 99/21). All data configurations fitted the model poorly with no meaningful estimation of parameters. Concerns and recommendations discussed and noted for the American plaice paper were also considered applicable for the present paper.

3Ps Pollock

W.P. 99/24. An update on the status of pollock in NAFO Subdivision 3Ps. E.F.Murphy.

Summary

Discussion

The distribution of pollock in RV surveys was said to be inconsistent in that they appear in some years and not in others and that the distribution had shifted from the Burgeo Bank area in the early years to close to Divs. 3NO in later years. In the past the relationship of 3Ps pollock to the larger stock on the Scotian shelf was questioned. Pollock in 3Ps are still considered a separate stock because mature fish in spawning condition have been found in the area and fishermen have reported (1995) the occurrence of large numbers of small pollock in inshore waters.

It was noted that there appeared to be little of management significance with respect to pollock in 3Ps as they were not consistently abundant. The by-catch limit will be a management issue and there is no basis to provide advice. There was discussion as to the utility of providing any advice when no research is being conducted and there is little data. However it was decided that there was a need to analyze any information available and to identify what resources are lacking and what are needed to answer questions. Abundance appears to have increased in 1999. This needed to be explained relative to availability and fish size. Pollock prefer warmer water and as water temperatures appear to be increasing there is an increased possibility of migration from other areas.

GENERAL COMMENTS

A fisherman at the meeting provided some personal experience information relative to the variable nature of cod catches in the fishery as well as some comments regarding problems associated with the catch limits imposed by management and potential discarding. He fished a trap for the FRCC in 1997 at a time of year when little catch was expected. Although indications were that no fish were in the area (sounder) when the trap was hauled it produced a large catch for the size of trap used. Further fishing showed that the fish stayed in the area for a while. Traps set at the same berth in the following year when the fishery opened obtained no fish.

Over the past two years he fished with the sentinel program on St. Pierre bank using GN and has found cod to be plentiful. The distribution could be spotty as catch rates could be different in places that were only a short distance apart.

He had a concern regarding the management practice of imposing daily cod catch limits and the resulting possibility of increased discarding. It presents a difficulty for fishermen because when nets are set there is no way of knowing what will be caught. If

his daily limit is obtained when only half his nets are hauled, what is he to do with the catch from the remaining nets? Unless he can find a fellow fisherman to take the catch from these nets, his only options are to discard the remaining catch or face penalties if he brings it ashore.

He considered the assessment process was difficult to understand especially when advice changes from year to year without a sound reason. This years advice appears to be down from last year but fisherman continue to report lots of fish on St. Pierre Bank . Some of the information appears to be conflicting and he felt that his (fishermen's) information is not being listened to. He also felt that leaving Burgeo Bank data out of the analyses was not a good idea. He realized the difficulties involved in the assessment process but wanted to point out that he and others had short and long term investments in the cod fishery and emphasized that care is needed when determining the stock status.

A response to his concerns regarding Burgeo Bank data, indicated that the data was being excluded because of potential overlap with the Gulf stock in winter. Although it appeared as though fish were being removed from the stock analysis, the only change was in the abundance index. This would produce less but hopefully better data. The impact of removing could be either positive or negative. Information from the commercial fishery on Burgeo Bank is still included in the assessment.

MANAGEMENT ISSUES

Fisheries Management provided some information relative to quotas in the 1999 fishery. The current TAC of 30,000t covers a period of 15 months and has not yet been taken. Catches in Placentia Bay have so far been low maybe due to a change in management. Quotas in this area were assigned on an individual basis, as opposed to the previous competitive quota, and it appears that fishermen are waiting to catch their quota toward the end of the year when catch rates and prices might be better.

The change from 12 to 15 months as the management period was a concern for the meeting and not well known to those conducting the assessment. If the remaining TAC is carried over to the year 2000 the result could be an error in the risk analysis. *It was recommended that the implications of this TAC period change on the assessment process should be looked at in more detail.*

EXTERNAL REVIEWER'S REPORT

Dr. M. J. Armstrong
Dept. of Agriculture for Northern Ireland

Scientific assessments of the current status of cod, American plaice, witch flounder and pollock stocks in NAFO Subdivision 3Ps were presented at St John's during the week 18 – 22 October 1999. The meeting was open, and was attended by representatives of the fishing industry, Canadian fishery administrators and scientists from DFO, the United Kingdom and France. This review deals firstly with the conduct of the meeting. It then considers the strengths and weaknesses of the actual assessments, based on observations made both during and after the meeting.

Conduct of the meeting

Time-series data on landings, catches at age or length, survey indices, distribution patterns and biological parameters were presented for each stock. Also presented were the results of tagging studies on cod, trends in catch rates from the Sentinel programme and the log book scheme, and spatial and temporal patterns in temperature and salinity. The presentations were detailed and clear, and should have been understandable to all attendees at the meeting. The data series showed that major changes have occurred over time in the environment, the stocks and the fisheries. These include large-scale anomalies in sea temperature, changes in fish distribution, long-term trends in growth and age at maturity, and changes in the mix of gear types in the fishery that will have affected selectivity patterns.

The meeting gave representatives of the fishing industry the opportunity to describe how their own experiences matched the scientific observations. Fishers were also able to comment on how the data from the fisheries may have been affected by fishing practices, fishery regulations or other factors. The close involvement with the fishing industry in the collection of data, the implementation of research (e.g. tagging studies) and in the evaluation of data series is a strength of the DFO assessment process that should be encouraged.

However, it was clear that the presence of fishers or other non-specialists in some technical discussions was not helpful to any of the parties. In particular, the presentation of a variety of results of different Sequential Population Analysis (SPA) models, and the highly technical discussions of these, created considerable confusion to non-specialists. Their conclusion was that fisher's livelihoods could hinge on small changes made to a model at the whim of the scientists. It was not adequately stressed that if a model formulation gives different results, it does not mean that there is additional uncertainty in the state of the stock if there are valid statistical reasons why the model is not appropriate. The potential for non-specialists to misinterpret the SPA results was exacerbated in the present meeting by the inadequate time available for carrying out, interpreting and presenting the different model runs. Working to such short deadlines also increases the

potential for making undetected mistakes. It is strongly recommended that this type of exploratory analysis is carried out prior to the RAP meeting, and that only those model formulations that have been identified as statistically valid are brought to the meeting. The meeting can then focus more clearly on stock trends and analysis of risks.

Cod in Subdivision 3Ps

Quality of assessment data

Sampling of the landings for length and age appears to be good. The fraction of the annual catch measured for length was 4% in 1998, 1% in 1997 and very high at 32% in 1996 when landings were small. The number of cod aged for compilation of age-length keys (ALKs) was about 0.2% of the number landed in 1997 and 1998, and 1% in 1996. For cod stocks around the British Isles, the fraction of the catch sampled for length and age has in recent years been at or below 1.0% and 0.1% of numbers landed. Hence, levels of sampling of 3Ps cod in recent years have exceeded typical levels in European fisheries. The coefficients of variation (CV) of the numbers at age were consequently low for the age classes of 3Ps cod contributing most to the landings (CV < 10% in 1997 and 1998). The 1996 catches at age were estimated with poorer precision (CV = 10 – 20% in the most abundant age classes) despite the high sampling rate. This was probably caused by the smaller number of fish in the ALK in 1996. Precision was relatively poor in the youngest and oldest age classes, a factor to consider if including them in model fitting procedures.

Changes in selectivity patterns, and variations in the contribution of surrounding stocks to the catches, could influence the perceived weights at age in the stock. Modeling of the weight data to provide more consistent stock weights would be a useful exercise and could provide better estimates for short-term forecasts of biomass.

The present system of storing assessment data in flat data files resulted in a very inflexible system for extracting data. It was not possible, for example, to derive a plus group for use in assessment models. This caused a problem in implementing Integrated Catch at Age Analysis (ICA) where the last age in the catch at age matrix is implicitly assumed to be a plus group. Truncation of age vectors at age class 14 also causes biases in estimates of yield per recruit (YPR) and spawning biomass per recruit (SPR) with implications for calculating reference points. At the fishing mortality rates estimated for the 1980s, cod of over 20 years of age were recorded in small numbers in DFO trawl surveys.

The catches at age from 3Ps are likely to include significant quantities of fish from surrounding stocks. For example, mixing of stocks is known to occur on the Burgeo Bank and is a reason why survey strata in this region have been excluded from the DFO winter survey data. Tagging studies also show that 3Ps cod migrate to inshore regions of 3L, and catches of 3Ps cod from this region will not be represented in the 3Ps assessment. Further

sources of error in the catches at age include mis-reporting and discarding (for example, high grading), which are known to have occurred but have not been quantified. Whilst these problems will affect the accuracy of the assessment, they are not unusual in fisheries. The ranges of many European stocks do not correspond well to management boundaries, and mis-reporting and discarding are not always fully quantified. Nonetheless, the assessments of such stocks are able to show declines in abundance or increases in fishing mortality requiring management action.

A major issue with the quality of the cod assessment data is the time series of survey indices. The problems of changes in gear and survey timing, the presence of strong year effects in the data, and the influence of outliers in the station catch-rates are well known to the DFO scientists. There was some discussion concerning the inclusion in the 1995 survey of a single huge catch that contributed 87% to the overall survey index. All assessment models showed strong positive residuals in catchability over many of the age classes in 1995. Some arguments were put forward for keeping the set in the survey index. However, the occurrence of such a large catch only once in the thousands of sets made since the survey series began shows that it was an event of very low probability. The implication is that densities of fish as high as this occur in such small volumes of habitat that they are seldom encountered. Giving the set a weighting of 1/n where n is the number of sets in a stratum is probably not appropriate. One option is to remove the largest and smallest sets from the relevant stratum in 1995. Removal of outliers to improve robustness is an established statistical procedure that should be considered in this case. The collection of acoustic data during trawl surveys could provide valuable information on the spatial extent of high-density patches of cod, as well as the potential bias in swept-area estimates caused by vertical migrations of the fish.

Exploratory assessments

This year, four different assessment models were explored, using Canadian survey data, indices from the Sentinel fishery and total catch at age from inshore and offshore components of the 3Ps stock. The models explored were ADAPT, Quasi-likelihood SPA, XSA and ICA. The previous assessment of 3Ps cod was carried out using QLSPA. The models differ in the assumptions regarding the form of errors in the variables, and the procedures for estimating the model parameters. ICA differs from the other methods in assuming the catches at age to be measured with error, which is a desirable feature for an assessment model. However, a separable fishing mortality pattern must be specified for one or two recent periods.

A full exploration of the four models was not possible in the time available. An initial comparison showed that the different methods gave similar results if given the same input data and assumptions. This implies that the estimation may not be over-sensitive to the assumptions regarding error structure, or to the algorithms used for obtaining a solution. It was clear from each model run that a major source of uncertainty in the assessment came from the survey data. There were large inter-annual variations in catchability, and possible variations in catchability between spring and winter surveys. When the Canadian

winter and spring surveys were input as separate series, the results were highly sensitive to inclusion or exclusion of the 1983 and 1984 spring surveys. Inclusion or exclusion of these two years' data also determined if a significant difference in catchability could be discerned between winter and spring surveys. When all surveys were amalgamated into a single series, there did not appear to be a consistent difference in catchability between the winter and spring data. Subsequent comparisons between models were made with the amalgamated series. This decision should be reviewed as additional years' data become available. Further analysis of the raw survey data to investigate and perhaps reduce the year effects may cast further light on this problem. A decision was made to include the Sentinel fishery indices in the comparative assessments, despite the brevity and variability of the series.

Assessment scientists using each of the models were asked to produce a "preferred" SPA run, configuring their model in the way they considered most appropriate. It became clear that a major issue was how to deal with the change in selectivity patterns associated with the reduction in offshore trawling and the current predominance of gill netting in the fishery. Different assumptions concerning pre- and post-moratorium selectivity patterns at the oldest ages in the fishery, especially the estimation of fishing mortality at ages 11 – 14 in 1993, resulted in large differences in the estimates of absolute biomass and to an extent the trends over time. The structural differences between models in terms of data and constraints were shown to be of far greater importance to the perception of the historical and recent stock dynamics, than the structure of the error distribution. Historical recruitment estimates were comparatively insensitive to assumptions regarding selectivity. Tagging studies were reviewed to give insights into possible selectivity patterns at different times. These studies indicated that the selectivity pattern in recent years, when gill netting contributed a high fraction of the catches, is likely to be more domed than in earlier years when offshore trawling was the predominant method. An attempt was made to constrain QLSPA to give a flat selectivity pattern across the oldest ages in the pre-moratorium period by incorporating a separable fishing mortality function for earlier years. However, the pattern of residuals indicated model mis-specification, and the run was rejected.

The consensus opinion was to adopt a QLSPA structure similar to the one accepted at the Rimouski meeting as the final SPA run. Fishing mortality at age 14 for the period 1959 to 1993 was constrained to be a fraction (estimated to be 0.41) of the average F at ages 11 to 13. (At Rimouski, this fraction was fixed at 0.5 rather than estimated.) Fishing mortality at all ages in 1999, age 14 in 1998 and ages 10 – 13 in 1993 were estimated independently. The latter three parameters were required because of zero catches from these year classes in subsequent years during the moratorium. The precision of the fishing mortality estimates in 1993, 1998 and 1999 were comparatively poor (log standard errors 0.41 to 0.91) indicating that the selectivity pattern and level of exploitation in the most recent period is poorly estimated. This reflects an attempt to estimate selectivity using data from age classes for which both the commercial catch and the surveys have poor-quality estimates due to small sample sizes. (A further problem is that the survey data are given to only one significant figure for many of the older age classes.) Hence, there may

be a loss of robustness if these values are given too much weight within the model when estimating selectivity parameters. There would be considerable merit in examining the comparative robustness of QLSPA, XSA, ICA and ADAPT, and the associated stock predictions and risk analyses, to the errors in variables and changing selectivity patterns typified by this stock.

The diagnostics for the QLSPA run did not indicate any serious model mis-specification (although residuals were noisy), and the run was accepted as the final assessment for 3Ps cod. The estimates imply a substantial decline in F between the age at full selection and the oldest age. In the years prior to 1994, mean F at age 14 was estimated to be only 17% of the mean F at age 7. The estimated domed selectivity pattern in the historical series results in estimates of population numbers declining slowly in the younger ages, more rapidly at intermediate ages, and more slowly again in the older ages. This pattern is not clearly apparent in the survey data, and is not supported by historic tagging data indicating a flatter selectivity pattern. The selectivity curves estimated from recent tagging studies (1997 – 99) indicate that for gill nets, selectivity at a fish length of 90 cm is about 40% of the selectivity at 70cm. As 90 cm is not reached until about 13 years of age, it seems unlikely that F at age on the oldest ages in recent years could be substantially lower than at intermediate ages. As the assessment is so sensitive to assumptions regarding selectivity, this is an important aspect requiring further investigation. It is possible that a model structure in which feasible separable F patterns (taken from tagging studies or surveys which took place before 1993) are imposed for different periods, and catches at age are assumed to have errors, would provide a more robust assessment within the QLSPA framework. A reduction in the oldest true age in the assessment may also be advantageous, to avoid fitting parameters to noisy data. Older fish should be included in a plus group.

Each of the SPA assessment methodologies applied to the stock estimate a high degree of uncertainty associated with the population and fishing mortality estimates in the most recent years. The lack of convergence of the SPA equations due to low fishing mortality during the moratorium, and the low precision of the survey data, mean that the models are effectively under-determined. The absolute level of the biomass of this stock cannot be estimated using the data currently available, and the assessment should be viewed as giving only an index of relative trends in stock size. Research that could produce an absolute measure of stock biomass independent of the historic catch at age data, and with comparatively high precision, would be of considerable value. Although a time series would provide valuable information on stock trends, and a better estimate of the bias in the SPA figures, a single year's estimate would still be valuable. Possible methods include combined acoustic / trawl surveys, tagging studies, egg-production surveys (e.g. the daily fecundity reduction method), or ideally a combination of these.

The process of exploratory assessment runs described above is similar to the procedures in ICES Working Groups, where the sensitivity of SPA models to different input parameters is tested rigorously. Model diagnostics are carefully examined for evidence of model mis-specification, although a full sensitivity test is not carried out every year

unless new data series are added. The investigations carried out at the RAP meeting proved extremely valuable in exploring the behaviour of different SPA models. This type of groundwork should be encouraged in future assessments of the stock until sufficient confidence is gained in the quality and robustness of the assessment, and in the predictions made from it. It is again recommended that this process be carried out at greater leisure prior to the RAP meeting, rather than being done under pressure during the meeting.

Final assessment run

The final assessment run gave point estimates of SSB in 1999 close to the historic high for the 40-year series. It is difficult to compare the precision of the estimates of current population numbers with equivalent SPAs on European stocks, as the latter are assessed by ICES using different methods (mainly XSA for demersal stocks). However, CV estimates of 0.25 to 0.33 on the main age classes from QLSPA were substantially higher than values of less than 0.15 obtained for European stocks with accurate assessments. The comparatively poor precision of the 3Ps assessment comes mainly from weak convergence of the SPA combined with the highly variable catchability of the Canadian trawl survey. Fluctuations in log catchability of + 2.0 were apparent in the series. For ICES assessments, variations in catchability of this magnitude are considered indicative of problems with the tuning data. Most stocks assessed at ICES also have more than one series of relative abundance indices contributing significantly to the assessment.

A retrospective analysis carried out excluding the short Sentinel series and survey indices at age 2, where there are only short time-series of data, did not show a clear retrospective pattern in SSB, F or recruitment.

A comparatively strong 1989 year class is estimated to make up thirty percent of the SSB in 1999, whilst the 1991 year class is estimated to be very weak. Inspection of the estimated fishing mortalities shows that there are year-class effects running diagonally through the matrix, which should be examined in future assessments.

Estimation of recruiting year classes for short-term forecasts

All QLSPA population estimates for 1999 were accepted for short-term forecasts and risk analyses. This includes a large value for age 2 in 1999, although the precision of this estimate is poor. This year class will not have a significant impact on SSB until 2002, but will contribute to landings in 2001. Hence, the deterministic forecast of SSB and yield carried out at the end of the meeting could be over-optimistic. It would be normal practice at ICES to over-write a poor estimate for a recruiting age class using an appropriate mean value, or to calibrate historical SPA estimates against other indices of recruitment, if available.

Biological reference points, and risk analysis.

The historical stock-recruit data for this stock indicate a decline in mean recruitment with declining SSB. A number of biological reference points used for other stocks off Canada and Europe were calculated based on these data. A meta-analysis of stock-recruit data published by Myers suggested that a robust limit reference point for biomass is the SSB giving half the maximum recruitment predicted from a fitted Beverton-Holt stock recruit curve. This reference point was proposed for 3Ps cod. A limit reference point for fishing mortality was proposed as Floss, an estimate of the highest F that could be sustainable at the lowest observed spawning biomass. This was estimated using a smoother fitted to the stock-recruit data rather than from a fitted stock recruit curve. The estimate of Floss was high, due to the influence of some strong year classes at low SSB. However, these strong year classes were formed during the 1970s when there were very different patterns of maturity and growth. It is questionable if reference points calculated from the whole time series are appropriate to the current stock. A further aspect requiring attention is the calculation of reference points from yield per recruit and spawning biomass per recruit, when the cohorts are only allowed to survive to age 14. Cod of over 20 years of age have been represented in the surveys and commercial catches, and must contribute significantly to the stock at low fishing mortality. The analyses should be extended as far as the oldest age observed more than occasionally in the historical series.

It is important that an age range for calculating the reference fishing mortality is established and used consistently over time. The 1998 stock status report used unweighted mean F over ages 7 to 14 whereas the 1999 report gives exploitation rate (in percentages) for an unspecified age-range which appears to be ages 7 to 10. The report then cites a limit F reference point of 1.96, which again has no age range specified. Similarly, F0.1 is mentioned several times, but its value is not stated.

American plaice in Subdivision 3Ps

There was no formal SPA assessment or catch forecast carried out on this stock, as there have been no age determinations from commercial catches since 1993. As with cod in 3Ps, there have been major changes in the stock and fishery over time. Growth rates increased during the 1990s, and length at maturity has declined progressively since the 1970s. Indices of spawning biomass from the DFO trawl surveys were low during the 1970s, increased by more than a factor of six to a peak in 1985, and subsequently declined to a level comparable to the 1970s. The increase in SSB indices in the 1980s followed a substantial reduction in reported commercial landings from up to15,000 t in the 1970s to less than 2,000 t in 1983. Strong year classes may also have been formed in the late 1970s. Landings increased again to around 5,000t in the late 1980s before declining below 1,000 t during the moratorium. There is some indication that total biomass may be increasing slowly at present. Changes in the length composition of American plaice in commercial landings in recent years indicate that the selection pattern may have altered.

The ability to quantify the dynamics of this stock, to establish biological reference points or targets, and to make management decisions in relation to these, will require the age compositions of the commercial catches to be fully updated. A full series of age compositions from the Canadian trawl surveys was available, and an attempt was made to investigate trends in mortality by plotting log catch ratios against time for each age class, with a smoother fitted. These plots were noisy, with no clear trends. A further analysis of the survey data estimated age and cohort effects, and indicated strong year classes in the late 1970s. An alternative approach could be to model age and year effects in mortality assuming a separable pattern of fishing mortality, although some difficulties could be encountered because of changes in selection patterns in recent years.

An application of an age-aggregated production model to reconstruct the historic trends in biomass, and to estimate maximum sustainable yield, was presented at the meeting. The results were difficult to interpret. A possible problem is that a couple of strong year classes may have contributed substantially to the trends over time. The method requires further evaluation.

Despite the uncertainties in the data series and the lack of age data for the commercial catches, there appears to be little doubt that the abundance of this stock remains low. Any recovery is likely to be slow unless strong year classes are formed.

A major concern with this stock, and with other local stocks such as witch, is the reduction in research effort in maintaining important time series of data. For example, the lack of age data from recent commercial catches of American plaice is a source of difficulty in interpreting the dynamics of this stock. DFO scientists have built up extremely valuable data series on longer-term trends in biological processes affecting stock productivity, such as growth and maturity. These data are vital for describing changes in the ecosystem and their potential impact on sustainable fisheries. It is strongly recommended that these data series are maintained.

Witch flounder in Subdivision 3Ps

This stock provides a small by-catch in offshore trawl fisheries. As with American plaice, there are no age data from commercial catches since 1993, and it has not been possible to apply SPA to estimate trends in fishing mortality and stock size or to make forecasts of landings. Age compositions from surveys are also not available since 1993. Survey indices of biomass fluctuated without trend from the mid 1970s to the early 1990s, but subsequent indices appear to be below average. There appear to have been some changes in stock distribution, but without age composition data, it is not possible to fully explore the reasons for the change in abundance. It is clear from distribution maps that the stock probably extends beyond the survey boundary in the Laurentian Channel. Shifts in distribution across this boundary, perhaps related to sea temperatures, would cause year-

effects in the survey data. Again, an analysis of this is impeded by the lack of age data since 1993.

Pollock in Subdivision 3Ps

Pollock in 3Ps appear to be at the northern limit of their range in the NW Atlantic. Data presented at the meeting showed a period of increased commercial catches and survey catches in the 1980s, and it was suggested at the meeting that this coincided with a period of above-average sea temperatures. There is no formal assessment of this stock. Pollock are pelagic fish, and bottom trawl survey indices are generally driven by sporadic catches. Measurement error is consequently high. The frequency of occurrence of pollock catches (i.e. proportion of habitat occupied by the fish) could provide another index of abundance, as catch-rates may bear no relation to local abundance. Acoustic surveys could provide useful data on relative abundance, if the targets could be identified and their length composition estimated. As suggested for cod, recording of acoustic data during bottom trawl surveys could provide valuable additional information on spatial patterns, density distributions, and occurrence of fish above the head-rope of the trawl.

General comments

The DFO Science Branch is faced with considerable problems in assessing these stocks. The recent moratorium on commercial fishing has resulted in substantial changes in fishing patterns during a period when wide fluctuations in sea temperature have affected distribution and, potentially, the catchability of the fish. Large year-effects are apparent in the survey series with errors correlated strongly across age classes. These variations pose considerable challenges for application of sequential population analysis. Stock boundaries overlap, with cod from adjacent stocks occurring seasonally in 3Ps. Tagging studies also show movement of cod into 3L where they are likely to be fished from late spring to fall. Changes in survey methods have introduced additional sources of error to the assessments of all the species. In particular, the survey trawl gear was changed in 1996, requiring large conversion factors to be applied to historic data (e.g. factor of six for 3-year-old cod during the 1980s). The timing of the surveys has also changed, and certain strata have been omitted from the analysis of cod data to reduce the possible effect of stock mixing.

The DFO scientists have tackled these problems on a broad front, and are to be commended on the high quality of their research. They have involved the fishing industry in data collection through the Sentinel fishery and logbook schemes. An extensive tagging programme has yielded important information on movements within and between management areas as well as independent estimates of mortality. Microsatellite DNA studies are yielding additional information on stock structure. A new survey during fall has been initiated in collaboration with DFO. If carried out consistently over time, this survey should yield corroborating information on stock trends for comparison with the

spring survey. In addition to current research, the DFO has also collected long time-series of key biological variables for several stocks, showing substantial changes over time. These time series are crucial for understanding changes in stock productivity in Newfoundland waters, and should be maintained through adequate sampling.

Acknowledgments

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APPENDIX 2: LIST OF WORKING DOCUMENTS

W.P. 2.1. Oceanographic conditions in NAFO Subdivision 3Pn and 3Ps during 1999 with comparisons to the long term (1961-1990) average. E. Colbourne.

W.P. 3.7. An assessment of the cod stock in NAFO Subdivision 3Ps: Catch, catch at age, and Research vessel surveys. E. .Murphy.

W.P. 4. Science logbooks. E. Murphy and P. Shelton.

W.P. 5.1 1999 Sentinel survey in NAFO Subdivision 3Ps. R. Stead and D. .Maddock-Parsons.

W.P. 5.2. An age-disaggregated index from the sentinel program for cod in NAFO Subdivision 3Ps. Don Stansbury.

W.P. 6 Movements of cod and relative selectivity of gear types from tagging experiments in NAFO Subdiv. 3Ps during 1998-1999. John Brattey and Noel Cadigan.

W.P. 8 An assessment of the cod stock in NAFO Subdivision 3Ps.: Size, weight, and condition - at -age. G. Lilly.

W.P. 8.1 An assessment of the cod stock in NAFO Subdivision 3Ps : Commercial weights- at-age. G. Lilly.

W.P. 9. Update on age at maturity and spawning of cod in NAFO Subdiv. 3Ps. John Brattey.

W.P. 10.2 An assessment of the cod stock in NAFO Subdivision 3Ps using the ADAPT Framework. Don Stansbury.

W.P. 10.3 Oveview of QLSPA, Oct 99 RAP. Noel Cadigan

W.P. 10.4 A preliminary Extended Survivors Analysis assessment of the 3Ps cod stock. C.D. Darby

W.P. 10.25. A comparison of the preliminary assessments of the 3Ps cod stock using ADAPT, QLSPA, and XSA. N. Cadigan, C.D. Darby, J.C. Mahe, D. Stansbury.

W.P. 10.5. Preliminary assessment of 3Ps cod using ICA. Mike Armstrong.

W.P. 10.6 3Ps cod: Medium term projections based on ICA. Mike Armstrong

W.P. 13. Comments on the population age structure of 3Ps cod. George H. Winters.

W.P. 14. Impact of at-sea discarding on tuned virtual population analysis I: an empirical study. Harshana Rajakaruna and Yong Chen

W.P. 15. Impact of at-sea discarding on tuned virtual population analysis II: an analytical study. Harshana Rajakaruna and Yong Chen.

W.P. 20. An assessment of American plaice in Subdivision 3Ps. M.J. Morgan, W.B. Brodie, S.J. Walsh, and Don Power.

W.P. 21. Stock status of Witch flounder in NAFO Subdivision 3Ps. W.R. Bowering.

W.P. 22 Surplus production analysis of St. Pierre Bank American plaice (NAFO Div.3Ps) Stephen J. Walsh

W.P. 23 Surplus production analysis of St. Pierre Bank witch flounder (NAFO Div.3Ps). Stephen J. Walsh.

W.P. 24 An update on the status of pollock in NAFO Subdivision 3Ps. E.F.Murphy.

Res Doc. 99/59. American plaice and witch flounder catch results from surveys in NAFO Division 3Ps. Canadian Stock Assessment Secretariat Res. Doc. 99/59. John McClintock

Newfoundland Region

Proceedings of the Newfoundland Regional Advisory Process of the 3Ps Groundfish Stocks: Cod, American Plaice, Witch Flounder, and Pollock October 1999

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