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Synthesis of Information Presented for Georges Bank Yellowtail Flounder Diagnostic Benchmark: Putting the Pieces Together

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ABSTRACT

This diagnostic benchmark is being conducted to address concerns expressed about the performance of the current stock assessment model for Georges Bank yellowtail flounder. It is not a standard benchmark that examines different stock assessment model formulations. Rather, it examines all the information currently available about this stock outside of a stock assessment model framework. A large amount of work has been conducted leading up to this meeting (thanks everyone!). This paper summarizes findings from the working papers grouped into the topics of movement and distribution, life history, missing catch, catchability and biomass, and reference points. I provide a number of TRAC Decision Points that I hope will act as a guide through this large amount of information. Finally, I provide six hypotheses regarding the cause of the poor diagnostic performance of the current stock assessment model along with possible processes for generating catch advice. These hypotheses are put forward to help frame the discussion only, there are many other possible ways to put the pieces together.

Introduction

This Diagnostic Benchmark for Georges Bank yellowtail flounder is something new that has never tried before in the TRAC process. The goal is to explore all sources of data, including those typically not included in stock assessments directly, looking for possible causes of the poor diagnostics in the current VPA for this stock. This exercise has attracted a lot of interest as seen by the 46 working papers totally over 1,000 pages with 105 authors (56 unique authors) representing 10 organizations. I sincerely thank everyone who has participated in this diagnostic benchmark.

The diagnostic issues from the current assessment can be summarized as: Given the large reductions in catch in recent years, why has the population not responded by increasing abundance and expanding its age structure? The relative fishing mortality rate, computed as the catch divided by any of the three bottom trawl surveys, declined substantially in 1995 and has remained low since. In contrast, the total mortality estimated from the age structure of these same surveys (and confirmed with an independent tagging study) indicated a high and relatively constant level throughout the time series, with perhaps an increase in recent years. These conflicting signals result in a strong retrospective pattern in the current VPA for this stock. Splitting the surveys to alias the source of this conflict initially resolved the retrospective pattern, but the retrospective pattern has returned recently. Additionally, splitting the surveys has resulted in abundance estimates from the VPA which are less than some estimates of the population abundance from independent sources. All three bottom trawl surveys have shown a strong declining trend in recent years despite low catches. Thus, issues to consider as diagnostic problems include: trends in abundance over time, the magnitude of the population, the disparity between trends in F and Z, the lack of expansion in the age structure of the population, the spatial concentration of yellowtail, and the retrospective pattern. These issues are the same ones that led to the 2005 benchmark assessment for this stock.

The Term of Reference for this meeting are:

> *1) Summarize all available data for Georges Bank yellowtail flounder which can be used to explore possible causes of the poor diagnostics in the current VPA for this stock.*
>
> *2) Determine which pieces of information are consistent with alternative hypotheses regarding current stock status (e.g., current population is near carrying capacity, current population is near a desired amount, and current population is well below a desired amount).*
>
> *3) If possible, describe how catch advice could be provided based only on the data (e.g. without relying on a stock assessment model). If feasible, identify and estimate appropriate fishing mortality reference points.*

In order to address these TOR, the working papers have been grouped into a number of topics: movement and distribution, life history, missing catch, catchability and biomass, and reference points. This working paper is my attempt to synthesize the information in the working papers developed for this meeting. In doing so, I describe issues that arise from the working papers and have identified a number of issues which I think need to be resolved by the TRAC in order to address the TOR. I denote these as TRAC Decision Points in this paper and hope they will serve as a guide through the large amount of information that has been assembled for this meeting. In the final section of this paper I attempt to put the pieces together for final recommendations under a few alternative hypotheses. These are not the only possibilities and are put forward to help frame discussions. The final decisions will be made after the full deliberations of all the working papers and could differ significantly from any of the ones proposed below.

Movement and Distribution

Movement among the three yellowtail stocks (Cape Cod-Gulf of Maine, Georges Bank, and Southern New England-Mid Atlantic) is low and supports continuing to assess and manage them as separate stocks (WP02; Cadrin, 2010; Goethel et al., 2014). Movement within the Georges Bank stock area is frequent, with off bottom movement detected by depth recorders on tagged yellowtail (WP02) and relatively large distances moved in days (WP24). Seasonal movements have been detected by the change in estimated biomass within portions of Georges Bank, e.g. the scallop access area of Closed Area II (WP20; WP29), as well as the location of bycatch hot spots in the SMAST yellowtail avoidance program for the US scallop fleet (WP03). Differences in prey availability on the bank may be one factor influencing where yellowtail flounder are found on the bank (WP34). Changes in predators or competitors over time were positively related with yellowtail, explained little variability, or occurred in different strata, meaning ecosystem effects do not appear to be driving the distribution of yellowtail (WP43).

One implication of the rapid movement of yellowtail throughout Georges Bank is that population estimates for a portion of the bank will be heavily influenced by how the population is distributed throughout the entire area. This means that changes in distribution could mask changes in abundance if only a portion of the bank is used to estimate the population. Trends over time within a portion of the bank could be due to changes in distribution instead of changes in abundance (WP22).

Yellowtail flounder have been decreasing in recent years on western Scotian Shelf Browns Bank (4X) but increasing in recent years on eastern Scotian Shelf (4VW). This indicates that movement from Georges Bank onto the Scotian Shelf is not a likely explanation for recent declines of yellowtail flounder on Georges Bank (WP41).

TRAC Decision Point: Is movement out of the stock area a likely source of the diagnostic problems for this stock? Is movement or distribution of yellowtail flounder within the Georges Bank area a likely source of the diagnostic problems for this stock?

Life History

Aging of yellowtail has been verified historically (Lux and Nichy, 1969) and recently (WP02) based on the number of growth marks from tagged and recaptured yellowtail. These validations are only up through age 7, which is sufficient for the current assessment which uses a plus group beginning at age 6 (WP05). Aging does not appear to be an issue for Georges Bank yellowtail flounder (WP32).

The current assessment uses M=0.2 based on the probability of seven tagged yellowtail surviving to recapture (Lux, 1969), an observation of a 14 year old yellowtail (Lux and Nichy, 1969), and a regression of total mortality on fishing effort (Brown and Hennemuth, 1971). None of these reasons are particularly strong, but the assumption has been used in all Georges Bank yellowtail flounder stock assessments.

The value of M=0.2 appears to be an underestimate based on a number of analyses conducted for this diagnostic benchmark. The application of four empirical relationships suggest values of M=0.22-0.57 with standard errors of 0.15-0.36 (WP05), although there may be biases in the simple relationship between maximum age and M (WP47). A separate analysis considered five age-independent and two age-dependent estimators of natural mortality and concluded M was likely in the range 0.3-0.5 (WP06). Length-based total mortality estimates from Closed Area II also support increasing the natural mortality rate, with estimates of Z during 1999-2003 of 0.53 and during 2010-2012 of 0.91 (WP07). Based on age-specific catch curves from bottom trawl surveys, male Z is higher than female Z, both have remained high throughout the assessment period, and male Z appears to be increasing in recent years (WP08). A higher natural mortality rate for males than females would be consistent with some of these results, and lends support to increasing the M for a sexes combined assessment because the M=0.2 assumption is derived from old females. This is because if M=0.2 for females and M is greater for males than females, then the sexes combined M must be greater than 0.2. Direct estimation of sex-specific M values also resulted in male M greater than female M (WP05; WP06). Analysis of tagging data suggest much higher values of M, greater than1.0 in Closed Area II and 0.7 for open areas (WP09).

The value of M used in the assessment has a strong influence on the age structure expected under unexploited or fully exploited conditions. The proportional age structure of the yellowtail stocks in this region have not changed over time (WP12), which is consistent with a high and relatively constant total mortality rate (WP08). However, as has been shown in a number of recent stock assessments, the expectation that reducing catch will lead to expanded age structure has not occurred (Legault et al., 2013). For demonstration purposes, equilibrium age structure was computed assuming the most recent fishery selectivity pattern (Legault et al., 2013) and seven different values of M (0.2 to 0.8 in steps of 0.1) when F is set equal to M (Fig. 1). These plots show the decreasing importance of older ages, especially the age 6 plus group, as M increases. The amount and proportion of yield expected from the age 6 plus group when both M and F are low is much greater than when both M and F are high. Thus, increasing the natural mortality rate for Georges Bank yellowtail flounder would help explain why reductions in catch have not resulted in as many old fish as expected from the M=0.2 assumption.

One possible source of an increased M in recent years is an outbreak of the parasitic protozoan *Ichthyophorus sp* which was found in 2.55% of yellowtail flounder examined during the 2012-2014 seasonal bycatch survey (WP31). A time series of prevalence is not currently available to allow estimation of whether a temporal change has occurred or not. Rapid mortality must occur for this protozoan to be causing a major source of yellowtail flounder mortality (WP11).

Simply changing the value of M in the assessment from 0.2 to some larger constant value will help with the issue of absolute magnitude of the population because higher M creates higher SSB in the model (Fig. 2; see Biomass section below), but does not solve the retrospective problem (Fig. 3).

<u>TRAC Decision Point</u>: What natural mortality rate should be used? Should a higher natural mortality rate be used in recent years? How should uncertainty in M be carried through to catch advice?

Condition factor for Georges Bank yellowtail flounder has decreased in recent years (WP30; WP33; Legault et al., 2013; Fig. 4). This is one possible cause for the recent poor recruitment observed in all the surveys and the low larval abundance since 2006 (WP19; WP44).

Missing Catch

A number of analyses were conducted using fishery dependent databases to see if there was any evidence of missing catch in recent years that could explain the retrospective pattern in the Georges Bank yellowtail flounder assessment. Vessel misreporting of stock area fished, the assumption of dealer landings reports as a census, and comparison of dealer and observer landings were all examined and found to not show any strong indication of missing catch in recent years (WP38; WP39; WP40). Overestimation of catch in early years could also explain the retrospective pattern (Legault, 2009) and was suggested to occur in the late 1970s (Brown et al., 1980), but duplicate catch records does not appear to be a source of extra catch in the early years (WP38).

Missing catch could also be caused by increased discarding or illegal landings occurring on unobserved trips. Examination of the magnitude of change required in these factors to explain the amount of missing catch required to fix the retrospective pattern demonstrated these are unlikely sources of the retrospective pattern (WP18).

Mortality related to fishing activity but not seen by on-board observers, such as yellowtail being injured passing through otter trawl meshes, is another possible source of missing catch. Examination of effort trends by US large mesh otter trawls show a declining trend in recent years, meaning this is not a likely cause of the missing catch needed to explain the retrospective pattern (WP18).

TRAC Decision Point: Is missing catch a likely source of the retrospective pattern?

Catchability and Biomass

Catchability can refer to either the ability of a piece of fishing gear to capture fish or to the relationship within a stock assessment model between an index of abundance and a population estimate. These two meanings have different implications. The former relies on physical properties of the fishing gear and individual or schooling fish behavior, while the latter relies on the ability of the stock assessment model to scale the population estimates such that the population dynamics equations result in the best fit to the observed input data. When surveys are expanded to population estimates before being input to the stock assessment model, the two meanings of catchability are often assumed to be interchangeable. This assumption is broken whenever the stock assessment model uses incorrect data, such as catch, parameter values, such as natural mortality, or there are processes occurring in reality that are not fully captured in the stock assessment model, such as spatial heterogeneity. For this reason, indices of abundance have traditionally been used as relative measures and not absolute values. Beginning with GARM III, the use of minimum swept area survey indices allowed the use of catchability estimates to be used as a check on the population estimates from the models. Whenever catchability was greater than 1.0, the model was suspected of underestimating population abundance. Even when the surveys were split to address retrospective patterns, as in the Georges Bank yellowtail flounder assessment, the survey catchabilities were still used as a check on population abundance. The Georges Bank yellowtail flounder assessment has not passed this check since the surveys were split to address the retrospective pattern.

Catchability estimates from a model depend on how the survey catch/tow was expanded to the population estimate. The footprint of a trawl tow depends on whether the door width or wing width is used, with door width resulting in higher expanded population estimates and thus lower model catchability estimates (WP14; WP35). Door width is recommended as the measure of area swept for bottom trawl surveys due to herding of flatfish (WP35).

Estimating catchability of a gear is difficult without direct experiments. Estimation of catchability by relating the catches of different species caught by different gears resulted in too many unknowns without side-by-side tows (WP36). Even more direct comparisons can suffer due to the patchiness of yellowtail flounder (WP37). However, catchability experiments can be done using field experiments. For example, to estimate trawl bridle efficiency multiple tows could be made comparing the standard bridle length to increased bridle lengths or to estimate trawl ground gear efficiency a bag experiment could be done (WP 17). Such direct estimates of gear catchability could be used to expand survey catch/tow to population estimates if the areal expansion is well defined (meaning bottom type effects are correctly modeled).

TRAC Decision Point: Should bottom trawl surveys be used in stock assessment models as relative or absolute estimates of abundance? If absolute, should door width or wing width be used when expanding bottom trawl survey catch/tow to population estimates?

A number of working papers present estimates of population abundance in either biomass or numbers of fish for the whole stock area or a portion of the stock area (Tables 1-2). Many of these estimates are well above the associated values from the VPA despite covering only a portion of the stock area (Figures 5-8). Some working papers have suggested this discrepancy is sufficient to reject the VPA results.

<u>TRAC Decision Point</u>: Should absolute abundance or biomass estimates from survey or other methods be used to reject model results which are lower than the estimates? If so, how should uncertainty in both estimates be considered?

Reference Points

The two working papers in this section both address the potential change in the natural mortality rate for this stock. If the TRAC decides to change the natural mortality rate from its current value of 0.2 for all years and ages to some other constant value for all years and age, then I agree completely with WP26 that the value of Fref used for this stock should be changed. The simplest approach would be to compute both F0.1 and F40% under the new constant M and use those estimates as the starting point for negotiations regarding the new value of Fref because these were the starting points for negotiations when M was 0.2. As noted in WP26, this would result in a higher Fref than the current value of 0.25. If the TRAC decides to use a time series of M values which increase in recent years as a means to address the retrospective pattern, then WP27 notes there is considerable scope for different values of Fref depending on the conceptual approach to dealing with the change in M within the time series. Thus, considerable discussion may be needed within the TRAC regarding reference points if M changes over time.

<u>TRAC Decision Point</u>: Does TRAC recommend that the TMGC renegotiate the value of Fref for this stock? If so, what scientific issues should be considered during renegotiation of Fref?

Putting the Pieces Together

In my opinion, there are not any signals that point towards Georges Bank yellowtail flounder currently being in excellent condition. The declining trends in the three bottom trawl surveys in recent years are quite worrisome, as is the poor recent recruitment seen in these surveys. The lack of old fish mentioned in the current assessment is based on the assumption that M=0.2 and may need to be reconsidered if a higher value of M is set by the TRAC. However, simply changing the value of M from 0.2 to a higher value for all years and ages does not address the retrospective problem. To help frame discussions, I describe below six hypotheses that put the pieces together in different ways along with catch advice possibilities. There are of course many other ways the pieces can be put together, including “mix and match” combinations of these and other hypotheses.

H1: “Noisy surveys” The declining trend observed in all three surveys is just a bad realization of the actual trend due to the noise in the surveys. Despite the relatively low CVs for these surveys (20-40% generally), they exhibited large sudden changes during the late 1960s and early 1970s when stock abundance was almost certainly good. The recent declining trend is just bad luck and might be due to the increased temperature on Georges Bank causing the yellowtail to become even more patchily distributed than they were historically. The difficulty with this hypothesis is that the Canadian fishermen have been unable to find commercial concentrations of yellowtail for the past decade, which would normally indicate a low abundance. The consistency of the three bottom trawl surveys also argues against this hypothesis. Catch advice would be provided by using the Single Series model and ignoring the retrospective pattern. The consequence of this approach would be the bottom trawl surveys finding increased amounts of yellowtail in future years as the bad luck ends and the need to create a yellowtail specific survey that could more accurately track changes in the population.

H2: “Increasing M” The base natural mortality rate for yellowtail is higher than 0.2, say 0.4, and increased in 1995 to say 0.8 and again in 2005 to say 1.2. Two increases are needed to address the original and more recent retrospective patterns. The cause of the recent increase in M is an outbreak of *Ichthyophonus*. This would address the recent retrospective pattern, but the values needed to reduce the retrospective pattern to a reasonable amount would need to be examined. Increasing the natural mortality rate would reduce the issue associated with age structure of the population and could rescale the VPA to be higher than the population estimates from the working papers. Catch advice would be generated from the VPA using this new time series of M and a new Fref. However, if the M continues to increase then the amount of fish available to the fishery could decrease regardless of the value of Fref. The declining surveys and estimates of recruitment would be of great concern. The consequences of this approach would be to implement a large scale study of *Ichthyophonus* to determine its lethality and hopefully identify the infection pathway to reduce or eliminate it.

H3: “Global warming” Conditions on Georges Bank have changed so much that yellowtail have changed their productivity and behavior resulting in skinnier fish that die quicker but are more often off the bottom and less catchable by trawl and dredge gear. The environmental changes could also be impacting the prey of yellowtail causing changes in distribution relative to historic patterns in ways that makes them less available to the bottom trawl surveys, for example by moving to locations that are more difficult to trawl. The consequences of this approach depend on the relative importance of the change in productivity relative to the change in availability to the survey, with more of the former resulting in the “Increasing M” case while more of the latter resulting in the “Noisy Surveys” case.

H4: “Missing Catch” There is a major source of unaccounted fishing mortality that has increased in recent years. This would address the retrospective pattern and might address the scale of the population relative to the estimates from the working papers. To address this hypothesis, catch multipliers could be found in the VPA which remove the retrospective pattern and catch advice generated from this VPA would be reduced to account for the missing catch component. A number of working papers addressed this hypothesis and found no evidence to support it. The consequence of this approach is a large forensic accounting of all yellowtail catches to detect missing catch and gear studies to detect unobserved mortality due to fishing.

H5: “Sexual Dimorphism” The large differences in growth between the sexes result in different M and changes in the appropriate F as the sex ratio changes. The sex ratio of the population is changing causing the sexes combined M to change over time. The problem with this hypothesis is that the difference in M by sex does not appear large enough to create the retrospective pattern. The consequence of this approach would be to create a sex-specific assessment and collect all data in the future by sex. Previous experience with such an approach for fluke found that a sexes aggregated model performs similarly to a sex-specific model if the parameters are set appropriately.

H6: “Space” Closed Area II has had a much bigger impact on the stock than previously realized. There is a large population of yellowtail within the boundaries of CAII, perhaps north of the sea scallop access area, which does not get surveyed sufficiently to contribute to the survey indices and is not available to the fishery. However, these fish are contributing to the actual spawning stock biomass and account for the missing old fish. The recent poor recruitments are due to unlucky environmental conditions that will soon change resulting in large cohorts. The high movement rates seen in tagging studies and seasonal surveys argue against this hypothesis. The consequence of this approach is that the quota could be increased substantially once the strong cohorts are realized because the cryptic fish will remain protected. Additionally, a spatially explicit stock assessment model would need to be created and a survey specific to these areas would need to be started to confirm the presence of these old fish.

In each of the above examples, I have focused on catch advice coming from a VPA or other stock assessment model. This is because of my preference for using a stock assessment model to combine the pieces of information in a statistically rigorous manner to provide quantitative catch advice. This is not the only way that catch advice can be generated. Other approaches include setting catch advice as a specified fraction of the estimated population or changing the quota from year to year depending on signals from surveys. The former could be done by in a number of ways. An empirical catchability coefficient could scale the bottom trawl surveys, the bottom trawl surveys could be forced through an estimate from a separate survey, or a new yellowtail specific survey could be started. The ability to generate the necessary information each year would have to be taken into consideration when deciding among these options. The approach of changing the quota based on yearly surveys would benefit greatly from a management strategy evaluation whereby a number of alternative hypotheses could be used as operating models to ensure robustness.

Literature Cited

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Lux, F.E. and F.E. Nichy. 1969. Growth of yellowtail flounder, *Limanda ferruginea* (Storer), on three New England fishing grounds. ICNAF Research Bulletin 6: 5-25.

Table 1. Biomass estimates (metric tons) from working papers prepared for this meeting. See original working papers for details. The WP24 estimate is from Melgey's thesis.

Source	Area	Gear	Year	Month	Value	Lower_CI	Upper_CI
WP13	GB	HBB	2009	4	18270	10614	34506
WP13	GB	HBB	2010	4	23490	12764	47271
WP13	GB	HBB	2011	4	10850	6029	19169
WP13	GB	HBB	2012	4	15120	5640	34911
WP13	GB	HBB	2013	4	4079	2334	7724
WP13	GB	HBB	2009	10	27570	17394	51790
WP13	GB	HBB	2010	10	9684	5098	19473
WP13	GB	HBB	2011	10	9988	5238	18878
WP13	GB	HBB	2012	10	9254	3802	22840
WP13	GB	HBB	2013	10	3232	1429	7375
WP14	GB	HBB	2010	1	NA	4200	9000
WP14	GB	HBB	2011	1	NA	4200	9000
WP14	GB	HBB	2012	1	NA	4200	9000
WP14	GB	HBB	2010	1	NA	11000	23000
WP14	GB	HBB	2011	1	NA	11000	23000
WP14	GB	HBB	2012	1	NA	11000	23000
WP20	CAIIAA	Scallop dredge	2013	2	2201	NA	NA
WP20	CAIIAA	Scallop dredge	2013	3	787	NA	NA
WP20	CAIIAA	Scallop dredge	2013	5	739	NA	NA
WP20	CAIIAA	Scallop dredge	2013	6	530	NA	NA
WP20	CAIIAA	Scallop dredge	2013	8	1266	NA	NA
WP20	CAIIAA	Scallop dredge	2013	9	3091	NA	NA
WP20	CAIIAA	Scallop dredge	2013	11	2313	NA	NA
WP20	CAIIAA	Scallop dredge	2013	12	971	NA	NA
WP21	CAIIAA	flatfish survey	2013	8	1683	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2005	8	2704	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2007	5	1069	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2008	7	3007	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2011	5	783	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2005	8	4615	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2007	5	3099	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2008	7	3670	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2011	5	901	NA	NA
WP23	GB	flatfish survey	2013	8	NA	4000	10000
WP24	CAIIAA	tagging experiment	2008	6	7600	NA	NA

Table 2. Population abundance estimates (millions of fish) from working papers prepared for this meeting.

Source	Area	Gear	Year	Month	Value	Lower_CI	Upper_CI
WP15	CAIIAA	HabCam	2010	6	5.81	5.21	6.44
WP15	CAIIAA	HabCam	2012	7	1.36	0.87	1.89
WP15	CAIIAA	Scallop dredge	2000	6	35.80	65.90	25.80
WP15	CAIIAA	Scallop dredge	2001	6	25.70	47.30	18.50
WP15	CAIIAA	Scallop dredge	2002	6	21.60	39.70	15.50
WP15	CAIIAA	Scallop dredge	2003	6	24.60	45.40	17.70
WP15	CAIIAA	Scallop dredge	2004	6	13.20	24.30	9.50
WP15	CAIIAA	Scallop dredge	2005	6	15.00	27.50	10.80
WP15	CAIIAA	Scallop dredge	2006	6	32.50	59.80	23.30
WP15	CAIIAA	Scallop dredge	2007	6	28.50	52.40	20.50
WP15	CAIIAA	Scallop dredge	2008	6	25.40	46.80	18.30
WP15	CAIIAA	Scallop dredge	2009	6	15.10	27.70	10.80
WP15	CAIIAA	Scallop dredge	2010	6	15.50	28.50	11.10
WP15	CAIIAA	Scallop dredge	2011	6	5.10	9.30	3.70
WP15	CAIIAA	Scallop dredge	2012	6	6.60	12.20	4.80
WP22	CAIIAA	Scallop dredge, comm	2005	8	5.95	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2007	5	2.91	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2008	7	6.64	NA	NA
WP22	CAIIAA	Scallop dredge, comm	2011	5	1.63	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2005	8	14.87	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2007	5	13.52	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2008	7	9.60	NA	NA
WP22	CAIIAA	Scallop dredge, survey	2011	5	2.48	NA	NA
WP23	GB	flatfish survey	2013	8	NA	11.15	27.86
WP24	CAIIAA	tagging experiment	2008	6	18.00	NA	NA

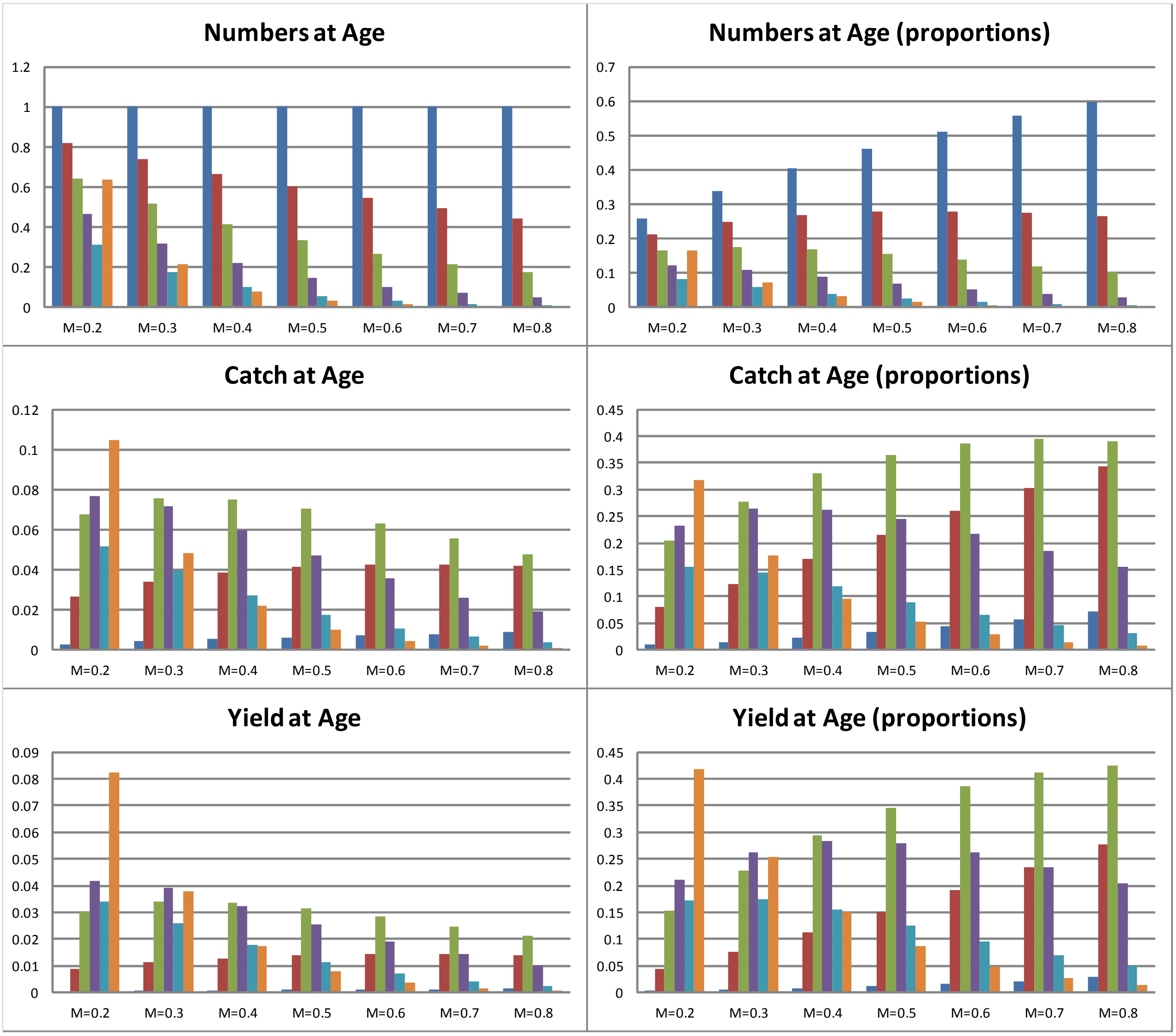

Figure 1. Equilibrium distribution of numbers, catch, and yield at age (left column) and associated values as proportions (right column) when F=M and F at age is the product of F and the recent selectivity pattern. Each bar in each M group represents a different age, from 1 to 6+.

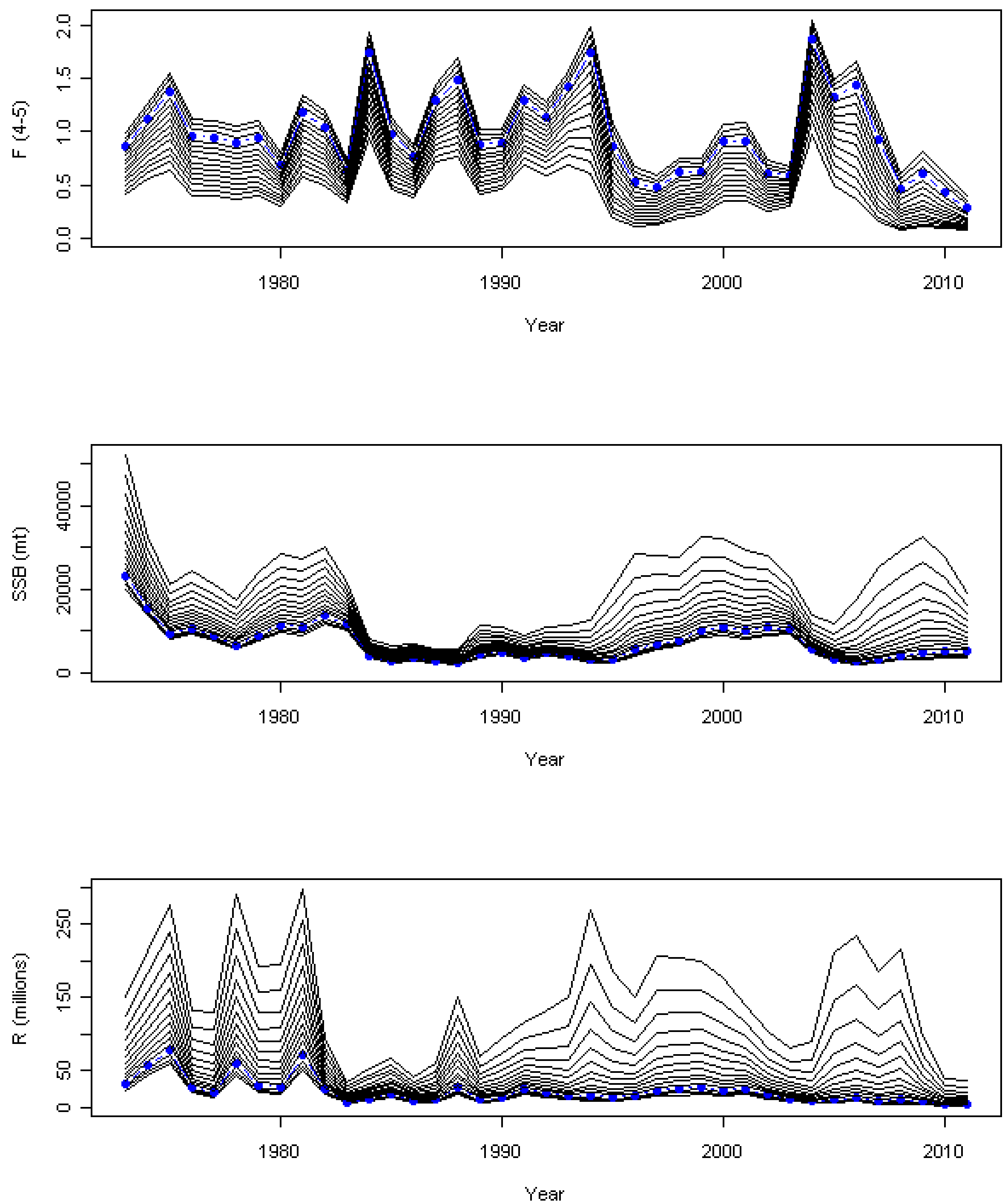

Figure 2. Fishing mortality rate (ages 4-5; top panel), spawning stock biomass (mt; middle panel), and age 1 recruitment (millions of fish; bottom panel) for natural mortality rates ranging from 0.1 to 0.8 in steps of 0.05. The results for M=0.2 are shown as blue dots. (This is Fig. 34 in Legault et al., 2012)

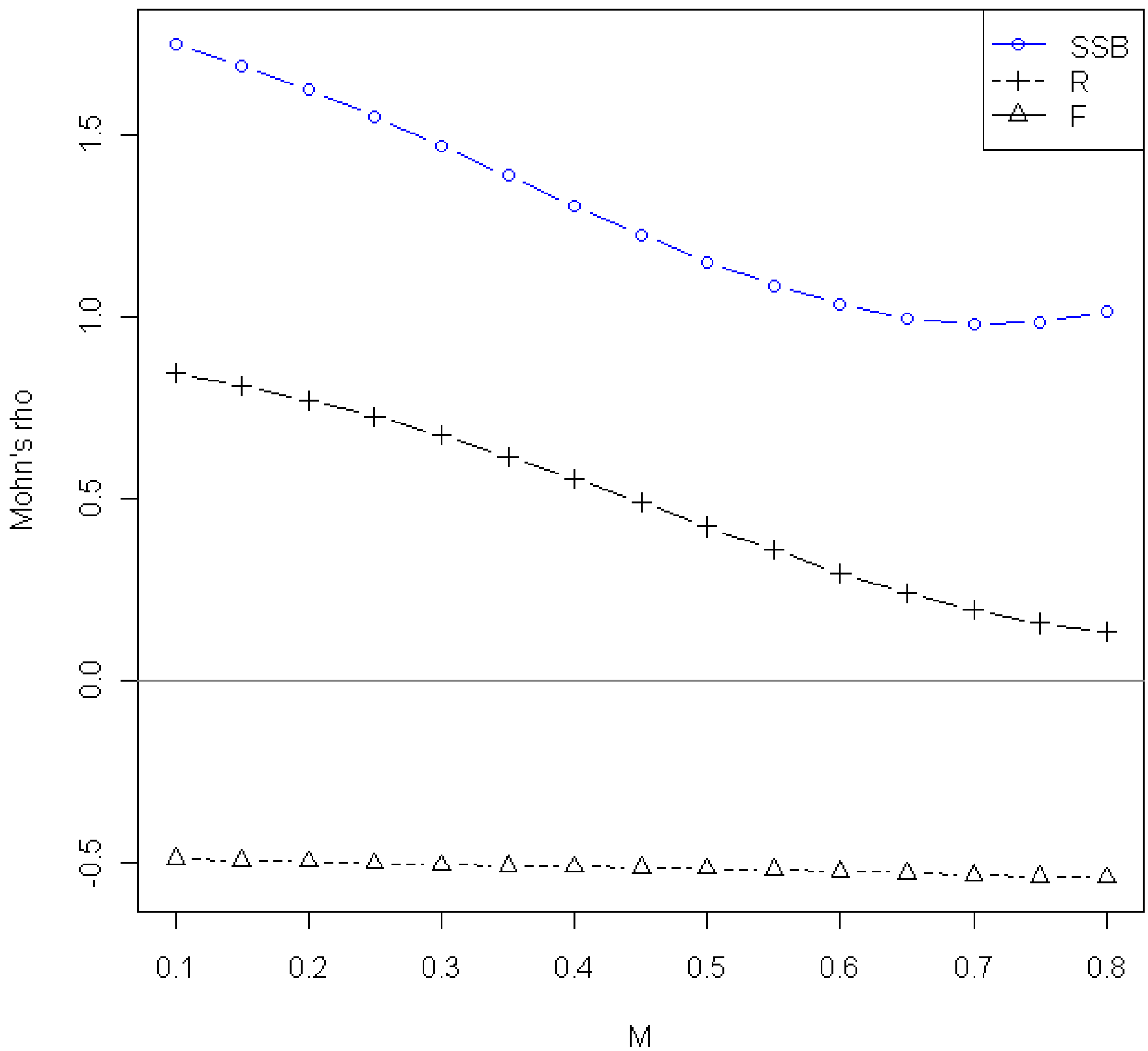

Figure 3. Mohn’s rho for spawning stock biomass, recruitment, and fishing mortality rate for a range of natural mortality values. (This is Fig. 35 in Legault et al., 2012)

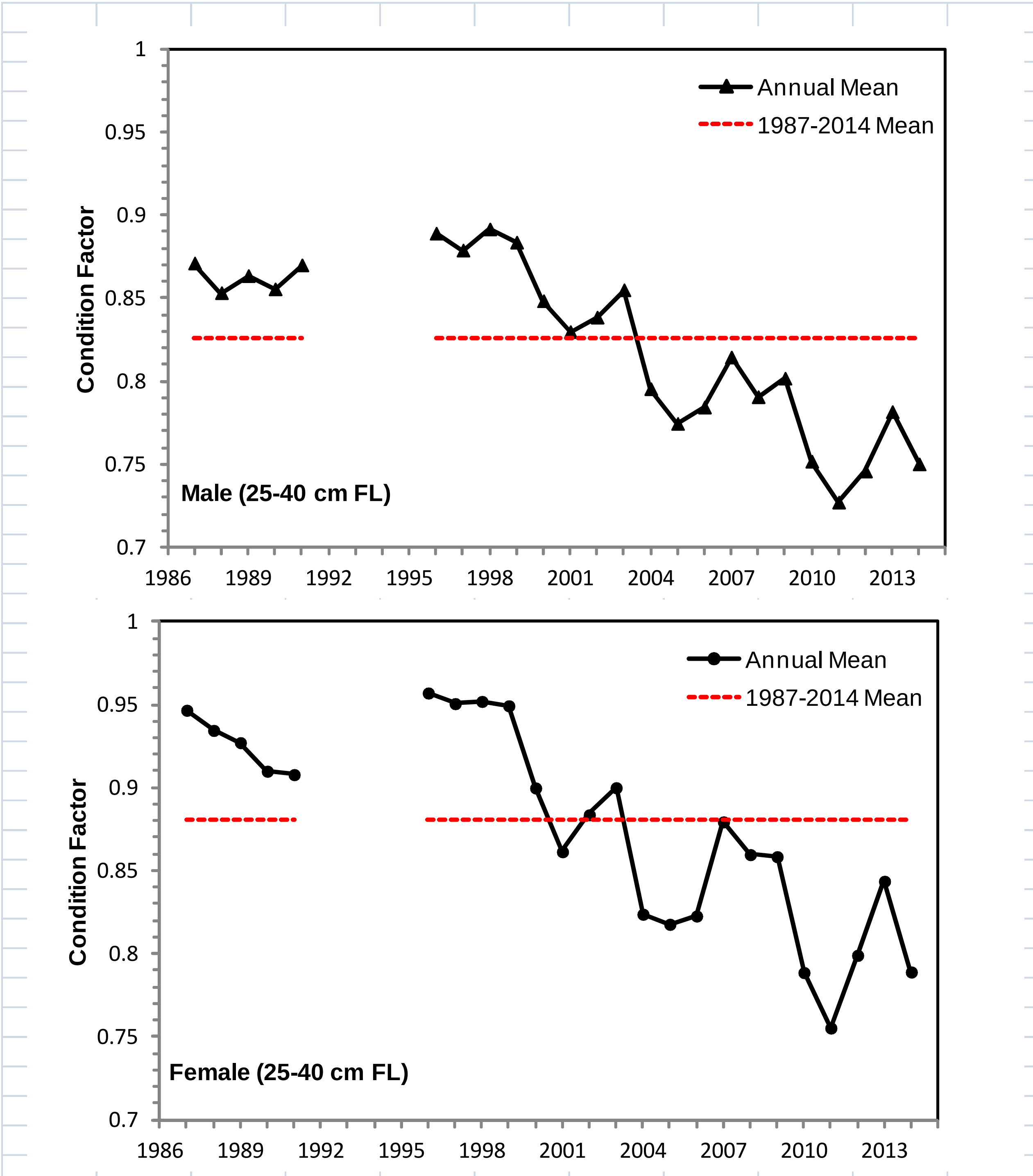

Figure 4. Condition factor from DFO survey updated through 2014.

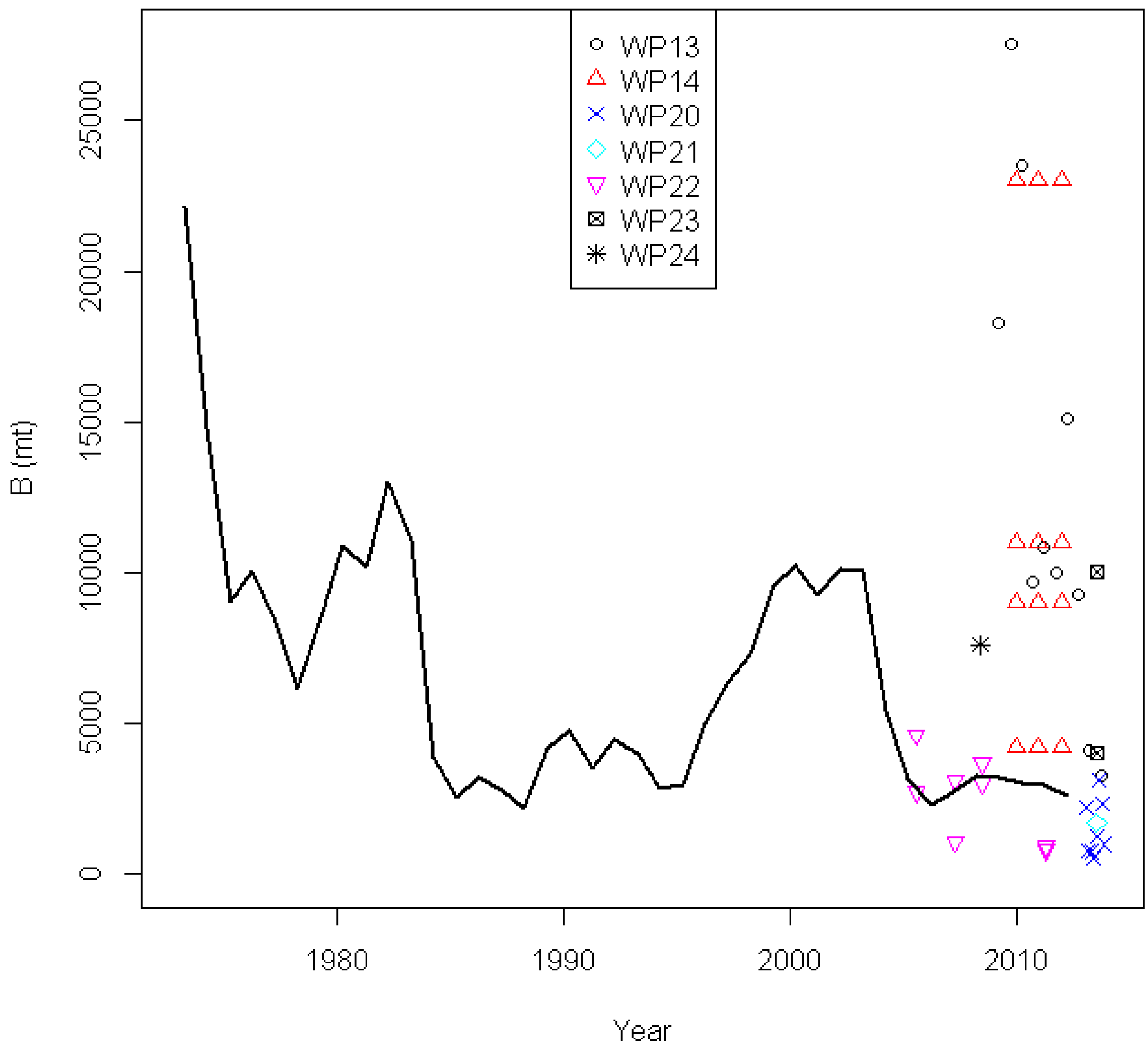

Figure 5. Estimates of biomass (metric tons) from working papers presented at this meeting along with the VPA estimate of spawning stock biomass from the 2013 TRAC (denoted by the solid line).

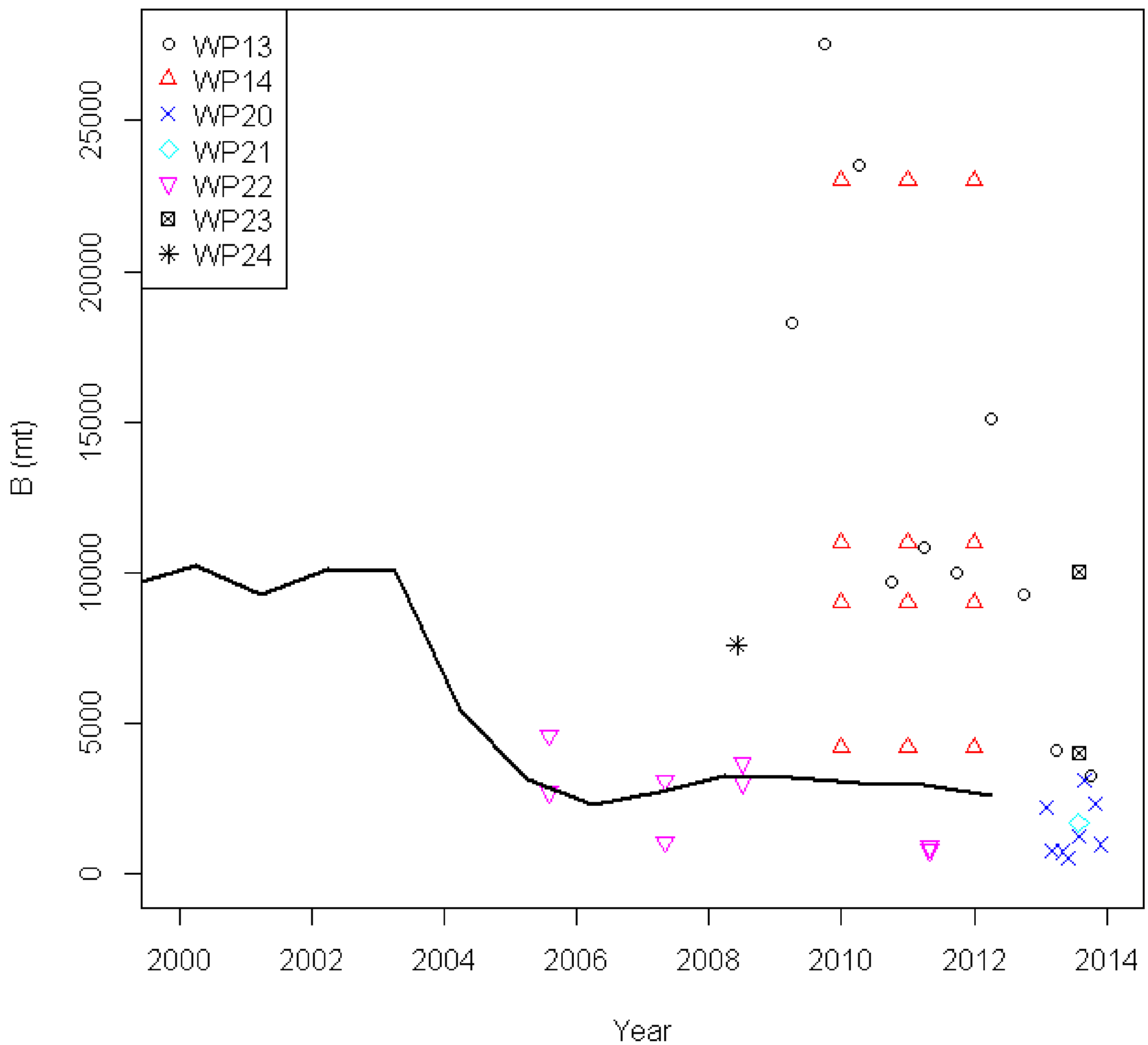

Figure 6. Same as Fig. 5, except only years 2000 onward are shown.

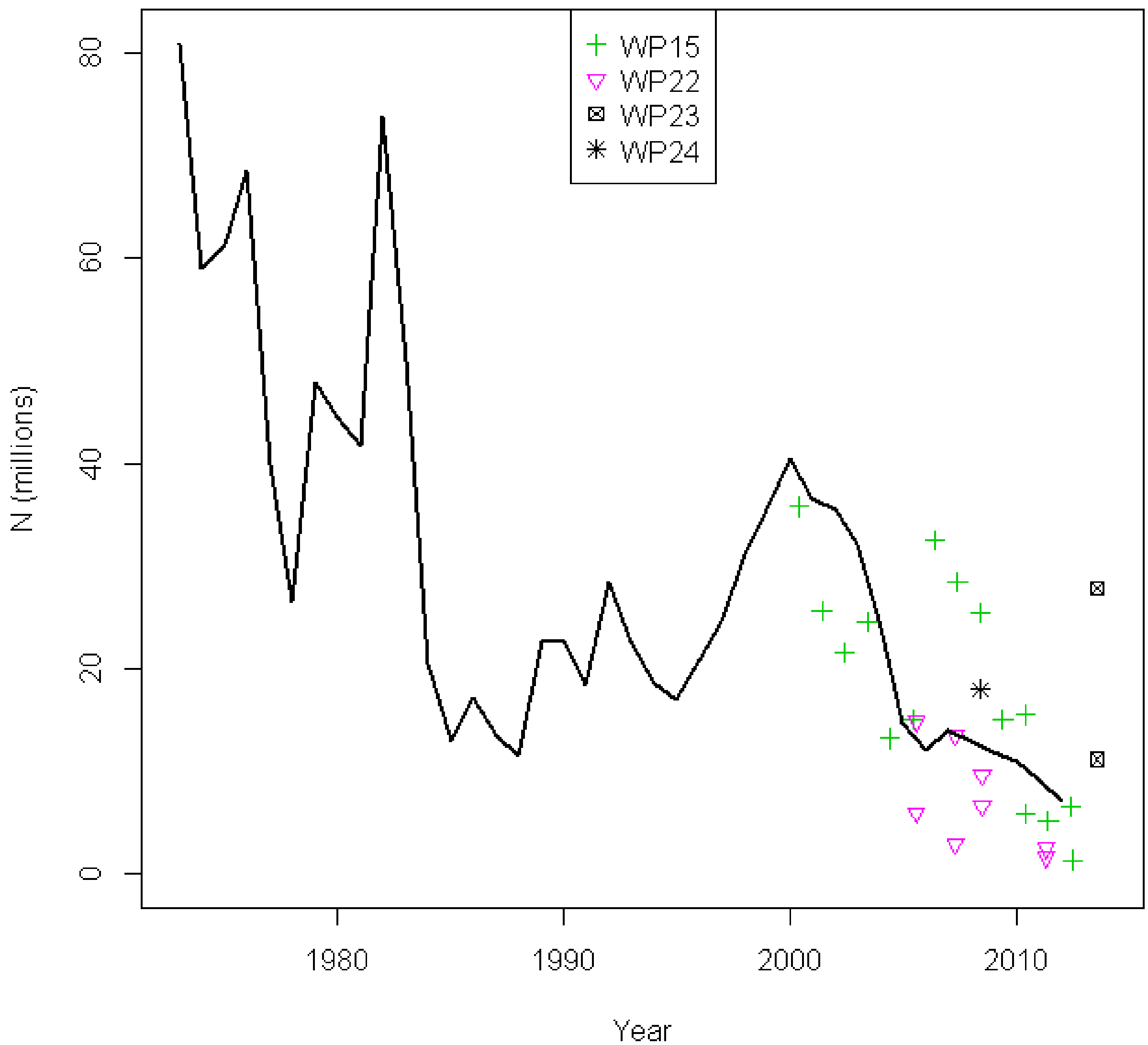

Figure 7. Population abundance estimates (millions of fish) from working papers presented at this meeting along with the VPA estimate of age 2+ abundance from the 2013 TRAC (denoted by the solid line).

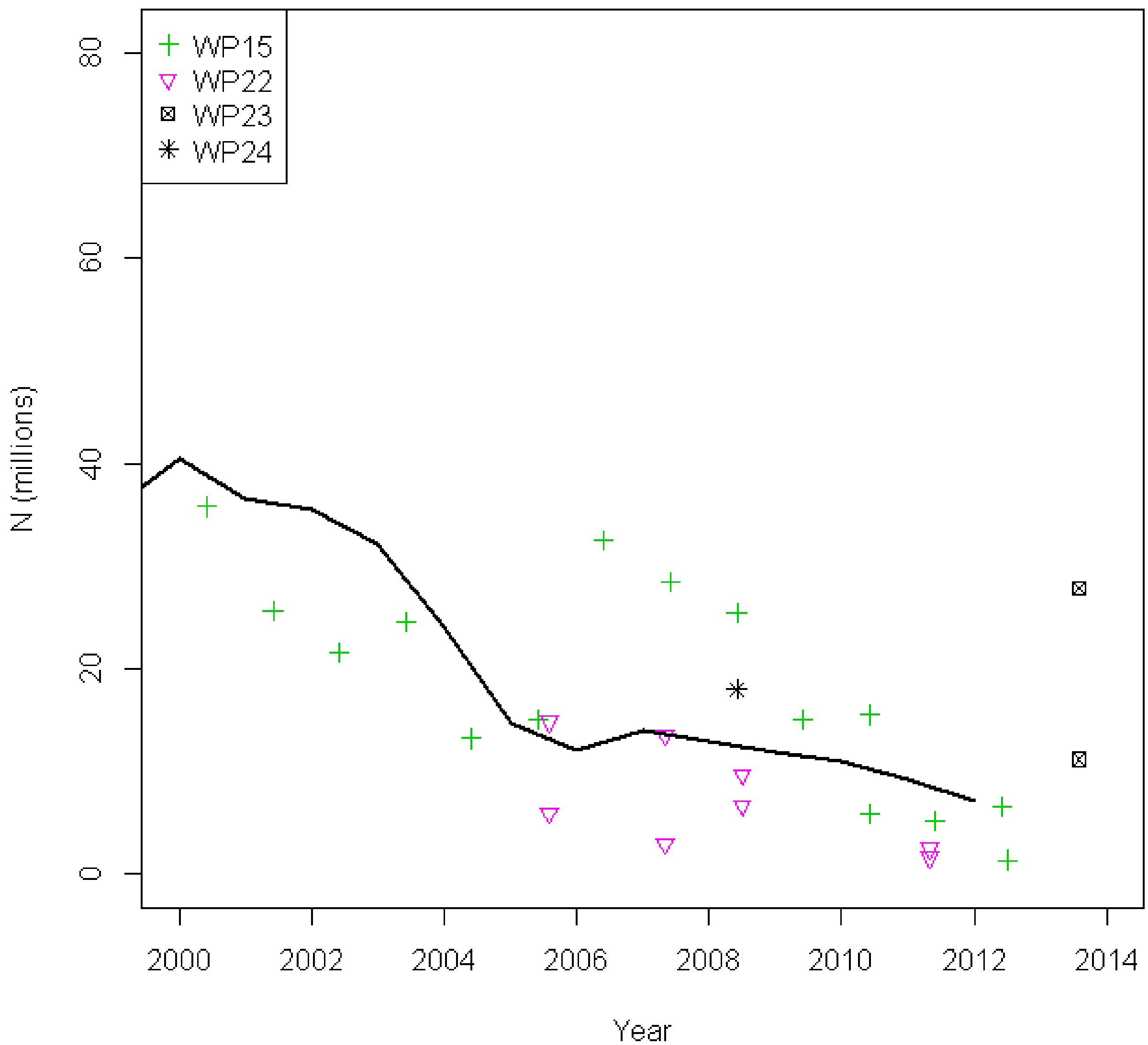

Figure 8. Same as Fig. 7, except only years 2000 onward are shown.