Center for Independent Experts (CIE) Independent Peer Review Report

External Independent Peer Review of the Assessment of the Pacific Cod Stock in the Gulf of Alaska

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Executive Summary

The Gulf of Alaska (GOA) Pacific cod stock assessment has had a large number of alternative models over the years. In 2016, the model was rebuilt from scratch and greatly reduced in complexity from the previous model. Of particular concern is that this stock has experienced a strong decline since 2015, and there is concern that the simpler model may not adequately address the important biological complexities to appropriately manage this stock in the face of climate variability. The Pacific cod fisheries in the Gulf of Alaska is of great economic importance, garnering $103 million ex-vessel value annually (29% of all Gulf of Alaska groundfish fisheries).

A suite of alternative models was prepared by Dr. Steven J. Barbeaux, Alaska Fisheries Science Center (AFSC). These models were presented and reviewed at a meeting during 1-4 May 2018 in Seattle, USA. The review panel consisted of Dr. Jean-Jacques Maguire (Canada), Dr. Henrik Sparholt (Denmark), and Dr. Kevin Stokes (New Zealand). The meeting was chaired by Dr. Grant Thompson, NOAA.

Also presented at the meeting were 1) catch data sampling procedures, 2) scientific trawl and longline surveys, 3) ecosystem conditions, and 4) the system of observer onboard fishing vessels.

The review was in the light of the apparent disappearance of fish between 2015 and 2017 in connection with a “warm blubber” event in the sea area, with special focus on: 1) whether the International Pacific Halibut Commission (IPHC) long line survey data should be included in the stock assessment model, 2) whether Alaska Department of Fish and Game (ADFG) small-mesh trawl survey should be included, 3) the level of complexity in the stock assessment model, 4) data weighting, 5) time variability and appropriate pattern in fishery and survey selectivity patterns, 6) whether environmental indices should be used to model natural mortality in the model, and 7) whether the temperature-catchability relationship for the AFSC surveys were being modeled appropriately.

The review panel recognized the tremendous amount of effort by the staff in preparing the assessment and the excellence of the documentation. The presentations were of the same high quality. The additional analyses requested by the panel during the meeting were done very competently and quickly.

Generally, the collection, compilation and filtering of data were done adequately and to very high standards. The panel welcomed the plans of working more with age determination and re-reading old otoliths, correcting an observed bias in the aging data prior to 2007, as well as improving sampling in the future of age data, with a strong focus on validation and quality control. The panel also welcomed the plans of getting length data on future IPHC surveys.

The IPHC long line survey showed very similar time changes as the assessment of the stock biomass and it covered very adequately the spatial distribution of GOA Pacific cod. Thus, it seems prudent to include this survey in future assessments. The extra cost of sampling length at the survey is likely very small compared to the benefit of such data. This survey is annual and thus can add especially valuable data every second year when the ordinary AFSC trawl survey are not conducted.

The ADFG small-mesh trawl survey is in fact several surveys. They are not covering the entire area of GOA Pacific cod distribution, but the western element seems to cover a sufficiently large part, that it seems worthwhile to explore further the option of including this survey. This survey is annual and thus can add very valuable data in the years when the ordinary AFSC trawl surveys are not conducted. The eastern element of the survey seems to be less useful because it mainly covers fjord areas.

The assessment and projections are based on the SS software as is usual in USA. It is very well done for this assessment. The SS software is very flexible and can be very complex. In this particular implementation, the input file alone was as long as 29 pages. Clearly, it is very demanding to run such a complex model and it needs extreme computer and statistical skills, which luckily were available in this case. The global trend seems to go in the direction of simpler models split into a stepwise approach, where each step can be evaluated separately. This makes the process more transparent and robust, and do not need staff with extreme computer and statistical skills. In this particular case, a future simplification could be to go to a fully age-based model, when sufficient years of age data are available. This way, all the length data could be left out of the modelling, which will be a great simplification and allow for more flexibility in other sometimes more important aspects like annual varying selectivity, variable growth and maturity at age by year, and still be a simpler model. It has been shown numerous times for other stocks that age data contain much more information than length data for fish stock assessment, and the present stock is living in a climate zone with widely different seasons, so age determination should be easy, though care, validation and constant quality control always are needed.

Data weighting is a very important issue especially for SS models with so much length data included as here. The approaches presented were very sensible and it was not obvious that any of them was better than the others. The guidelines given in Francis (2011) were followed and these guidelines are probably the best available at present.

Time variability and pattern in fishery and survey selectivity were elaborated on. The general approach followed was good. It was based on information external to the modelling from historical events in the various fleets and in the surveys. It was regarded as important not to have too much dome shape in the selection pattern, as this will create “paper-fish”, i.e. a large amount of old fish estimated by the model, old fish which have never existed out there in the sea. This was regarded as one of the main reasons that the 2014 and 2015 assessments of the stock estimated large stock sizes in the start of the time series. These were therefore probably an artefact and are now gone in the new assessment.

Environmental indices in terms of sea temperature were considered to be used to model natural mortality. This idea was triggered by the coincidence of the event of a warm period in the sea water in the area simultaneously with the disappearance of fish in the stock, and the observation of low condition of Pacific cod and other animals suffering in the ecosystem. The panel discussed this and noted that the experience of Atlantic cod in relation to starvation and mortality was that cod can live up to two years without eating at all, and that in the Gulf of St. Lawrence the Fulton condition factor was reduced by about 30% before it resulted in mortality. For the present Pacific cod stock the Fulton condition factor was only reduced by a small percentage and not at all for some of the large size groups. Alternative hypotheses were mentioned, like migration out of the area (with a chance that they will come back within the near future—few years), and mortality due to a some kind of disease (there were pictures presented of sick Pacific cod caught in the relevant time period with clear sickness marks of a circular form and of several cm in diameter). Therefore, for the time being it was regarded as most appropriate to just allow M to be estimated separately in two blocks of years 2015-2016 vs the rest of the years. All model runs with this option showed a substantial higher M for 2015-2016 than for the other years, typically a doubling of the M values compared to the other years.

There was a documented relationship between sea temperature and the depth distribution of Pacific cod. Because the AFSC long line survey is not covering the shallow water, this is likely to mean a change in catchability with temperature. Furthermore, the search rate of cod is also likely to be dependent on temperature, because fish are more active the higher the temperature, and thus catchability in long line

surveys might be higher at higher temperatures. Therefore, the temperature-catchability relationship for the AFSC surveys should be part of the model and the way it is suggested (ln(Qy) = ln(meanQ – P *CFSR)) seems appropriate. It adds one parameter to the modelling. Models always improve fits when more parameters are included and even the AIC criteria seems to have a tendency to favor more parameters. Therefore, a very innovative approach was suggested by the assessment team. This is done by resampling the CFSR time series 1000 times without replacement to shuffle time series, having the model refit to resampled time series, and evaluating the distribution of the performance function. In this case, the parameter exceeded initial fit in only 12 of the 1000 iterations (1.2%), and this suggests that the parameter fit to time series improves model performance over just additional parameter fit to random noise. The panel found this approach quite convincing.

Stock definition is an issue for a species moving as much at times as does Pacific cod. It was mentioned that there seems to be some indication that we might have a similar situation as in the Northeast Atlantic cod in the Norwegian and Barents Sea. Here, there is an open sea big stock migrating long distances between feeding areas and spawning areas, and in addition it includes small fjord stocks rather isolated from each other and the from the open sea stock, and only making short migrations. Canada has, for instance, defined such local Pacific cod stocks for the areas just south of GOA Pacific cod stock.

The panel also discussed the stock recruitment model used. With a steepness of 1 it means that recruitment is modelled as a constant. This might be okay historically when the stock has been well above B20%, but now when the stock is around that value this assumption might deserve some attention. The panel was informed that the guidelines in this management area are to use a constant R model unless there are data that allow a proper S-R model to be estimated. This seems from some of the new runs to be close to be the case. There seems to be lower recruitment with lower stock size within the dynamic range in the time series. A Beverton & Holt model or a segmented regression model seem to be the most obvious ones to look at. According to the stomach data there is not much cannibalism, and therefore a Ricker model is not the obvious choice.

The Panel thanked the AFSC staff for its effectiveness in providing new analysis as requested and making the whole review a very positive and constructive process.

Background

The Gulf of Alaska (GOA) Pacific cod stock assessment has had a large number of alternative models over the years. In 2016, the model was rebuilt from scratch and greatly reduced in complexity from the previous model. Of particular concern is that this stock has experienced a strong decline since 2015, and there is concern that the simpler model may not adequately address the important biological complexities to appropriately manage this stock in the face of climate variability. The Pacific cod fisheries in the Gulf of Alaska is of great economic importance, garnering $103 million ex-vessel value annually (29% of all Gulf of Alaska groundfish fisheries).

A suite of alternative models was prepared by Dr. Steven J. Barbeaux, Alaska Fisheries Science Center. (AFSC) These models were presented and reviewed at a meeting during 1-4 May 2018 in Seattle, USA. Also presented at the meeting were 1) catch data sampling procedures, 2) scientific trawl and longline surveys, 3) ecosystem conditions, and 4) the system of observer onboard fishing vessels.

Center for Independent Experts (CIE) reviewers were appointed to serve as panel members and conduct an impartial and independent peer review. The CIE review panel consisted of Dr. Jean-Jacques Maguire (Canada), Dr. Henrik Sparholt (Denmark), and Dr. Kevin Stokes (New Zealand). The meeting was chaired by Dr. Grant Thompson, NOAA.

The review was focused on the apparent disappearance of fish between 2015 and 2017, in connection with a “warm blubber” event in the sea area. Further points in focus were: 1) whether the International Pacific Halibut Commission (IPHC) long line survey data should be included, 2) whether Alaska Department of Fish and Game (ADFG) small-mesh trawl survey should be included, 3) the level of complexity in the stock assessment model, 4) data weighting, 5) time variability and appropriate pattern in fishery and survey selectivity patterns, 6) whether environmental indices should be used to model natural mortality in the model, and 7) whether the temperature-catchability relationship for the AFSC surveys were being modeled appropriately.

The review panel recognized the tremendous amount of effort by the staff in preparing the assessment and excellent documentation. The presentations were of the same high quality. The additional analyses requested by the panel during the meeting were done very competently and quickly.

All relevant documentation was made available on Google Drive two weeks before the meeting. The first two days were spent going through presentations by the data and assessment scientists. The Panel recognized the tremendous amount of effort by scientist staff in preparing the assessment and by fishers, observers, managers, and scientists regarding data filtering. Both the documentation and the presentations were of a very high quality.

The meeting followed the timetable given in Appendix 2, except that the last day of the meeting was held by correspondence. Then the staff could do what it could with all the missing bits and pieces of assignments and it was expected there would only be minor issues that could be dealt with by emails. This turned out to be the case, as no further issues were raised by email following these last assignments.

The panel discussed the assessment materials in the context of the terms of reference provided for this review.

Addressing each term of reference

Terms of Reference (ToR) for the Peer Review Assessment of the Pacific cod stocks in the Gulf of Alaska were:

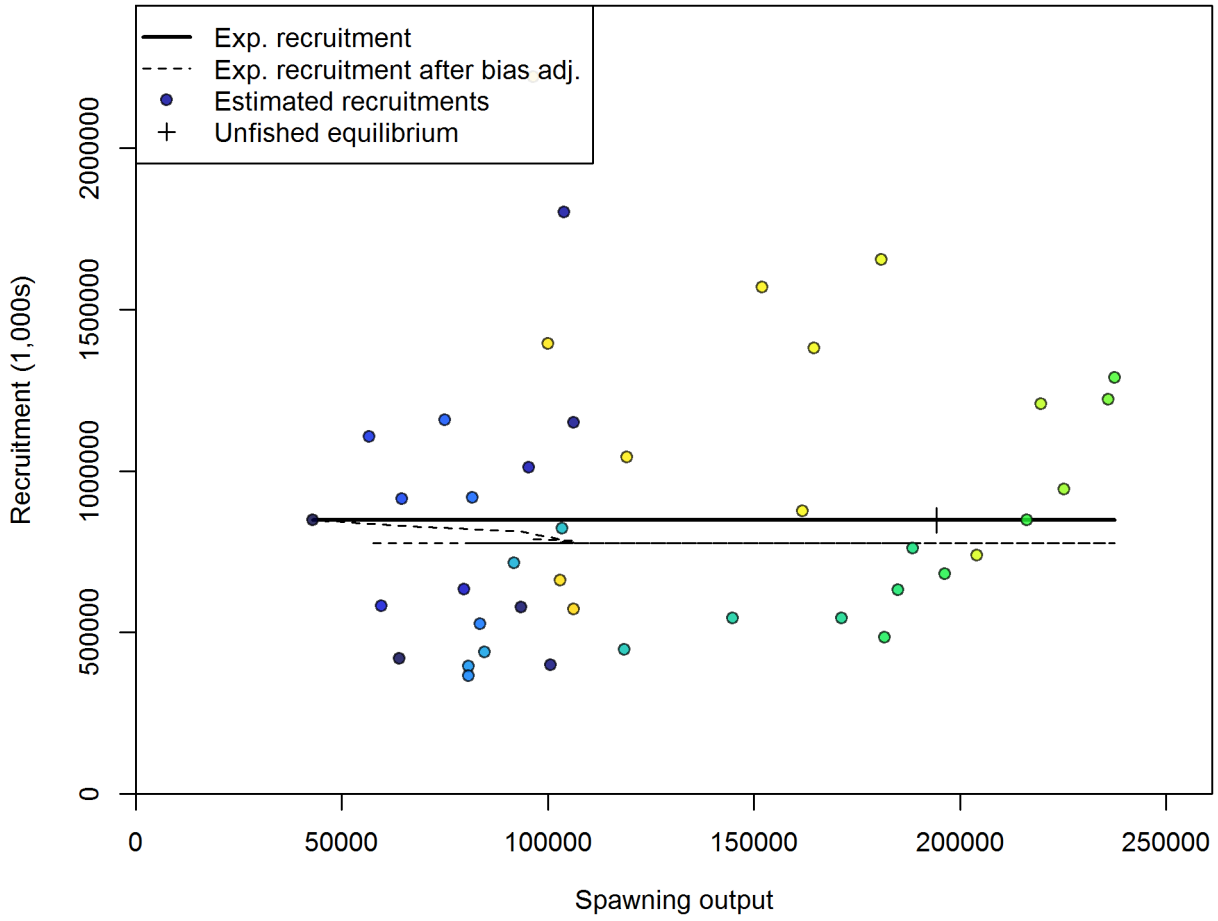
1. Evaluate and provide recommendations on data used in the assessment models. In particular:
a. What are the benefits vs disadvantages of including data from the ADFG small-mesh trawl and the IPHC longline surveys in the assessment?
2. Evaluate and provide recommendations on model structure, assumptions, and estimation procedures. In particular:
a. How would you evaluate the appropriate level of complexity in the stock assessment model given that we have historically used simple and more complex models to manage this stock?
b. What factors should be considered in data weighting and how should we assess the appropriateness of current methods applied for this stock?
c. How can we evaluate the appropriate level of time variability and appropriate pattern (i.e. blocking vs random walk) in fishery and survey selectivity patterns?
3. Evaluate how ecosystem indicators are used in the assessment and provide recommendations how they can be better integrated into model development and stock management.
a. Should environmental indices be used to model natural mortality in the model? Is it appropriate to use a time block for the extremely warm period to adjust natural mortality?
b. Is the temperature-catchability relationship modeled for AFSC surveys being modeled appropriately?

ToR 1. *Evaluate and provide recommendations on data used in the assessment models*

Generally, the data collection, compilation and filtering were done adequately and to very high standards. The panel welcomed the plans of working more with age determination and re-reading old otoliths, correcting an observed bias in data prior to 2007, as well as improving sampling in the future of age data with a strong focus on validation and quality control. The panel also welcomed the plans of getting length data on future IPHC survey. Maybe age data would also be cost effective and worth the while to collect at the IPHC survey, especially in the years of no trawl survey data. See below for further points about age data collection, which typically, at least in the fish stock assessments in the North Atlantic, have been shown repeatedly for many stocks to yield more information relevant for management than length data.

The panel also discussed the stock recruitment model used. With a steepness of 1 it means that recruitment is modelled as a constant with no reduction in recruitment at low stock sizes. This might be okay historically when the stock has been well above B20%, but now when the stock is around that value this assumption might deserve some attention. The panel was informed that the guidelines in this management area is to use a constant R model unless there are data that allow a proper S-R model to be estimated. This seems from some of the new runs to be close to be the case (Figure 1). There seems to be a lower recruitment with lower stock size within the dynamic range in the time series. A Beverton & Holt model or a segmented regression model seem to be the most obvious ones to look at. According to the stomach data there is not much cannibalism, and therefore a Ricker model is not the obvious choice.

Figure 1. *Stock-recruitment curve from the run Model18.09.39NO_AGEPRE2007, probably the most likely refection of the stock dynamics. There seems to be an indication of a relationship with reduced R at low SSBs.*



ToR 1.a *What are the benefits vs disadvantages of including data from the ADFG small-mesh trawl and the IPHC longline surveys in the assessment?*

The ADFG small-mesh trawl survey is in fact several surveys. They are not covering the entire area of the GOA Pacific cod distribution, but the western element seems to cover a sufficiently large part such that it seems worthwhile to explore further the option of including this survey. This survey is annual and thus can add very valuable data in the years where the ordinary AFSC trawl survey is not conducted. However, the eastern element of the survey seems to be less useful, especially because it is mainly covering fjord areas.

The IPHC long line survey showed very similar time changes as the assessment of the stock biomass, and it covered very adequately the spatial distribution of GOA Pacific cod. Thus, it seems prudent to include this survey in future assessments. The extra cost of sampling length of the survey is likely very small compared to the benefit of such data. This survey is annual and thus can add very valuable data, especially every second year, when the ordinary AFSC trawl survey is not conducted. The selectivity in this survey was discussed and the use of 16” hooks, which are quite big, probably means a low catchability of small Pacific

cod. It seems unfortunately difficult to compare with the experience in the East Bering Sea, because here the IPHC is not covering the area well, where small Pacific cod are distributed.

ToR 2. *Evaluate and provide recommendations on model structure, assumptions, and estimation procedures.*

Stock definition is an issue for a species moving so much around at times as Pacific cod. It was mentioned that there seems to be some indication that there might have a similar situation as for the Northeast Atlantic cod in the Norwegian and Barents Seas. Here, there is an open sea big stock migrating long distances between feeding areas and spawning areas, and in addition small fjord stocks rather isolated from each other and from the open sea stock, and only making short migrations. Canada has for instance defined such local Pacific cod stocks for the areas just south of GOA Pacific cod stock.

For the AFSC trawl survey, a catchability of more than 1 was accepted for the most accessible length group of Pacific cod. This can seem a bit strange as normally some fish in the trawling path will escape and avoid being caught. However, on request, the panel was informed that the swept area was calculated based on the net width of the wings and not of the door spread. The door spread is approximately 45 m compared with a 16 m net width of the wings. Thus, herding of fish by the doors and the wires between the doors and the wings mean that a catchability of 1 in fact means that some fish in the trawl path are escaping, so this part of the modelling is probably within realistic bounds.

ToR 2a. *How would you evaluate the appropriate level of complexity in the stock assessment model given that we have historically used simple and more complex models to manage this stock?*

The assessment and projections are based on the SS software as is usual in USA. It is very well done for this assessment. The SS software is very flexible and can be very complex. In this particular implementation, the input file alone was as long as 29 pages. Clearly, it is very demanding to run such a complex model and it needs extreme computer and statistical skills, which luckily were available in this case. The global trend seems to go in the direction of simpler models split into a stepwise approach, where each step can be evaluated separately. This makes the process more transparent and robust, and does not need staff with extreme computer and statistical skills. In this particular case, a future simplification could be to go to a fully age-based model, when sufficient years of age data are available. This way, all the length data could be left out of the modelling, which will be a great simplification and allow for more flexibility in other more important aspects like annual varying selectivity, variable growth and maturity at age by year, and still be a simpler model. It has been shown numerous times that age data contain much more information than length data for fish stock assessment, and here we are in a climate zone with widely different seasons; so age determination should be easy, though care, validation and constant quality control always are needed.

In the present analysis, the geostatistical VAST method on survey data is also very complex and needs extreme computer and statistical skills. We did not go into details and alternative simpler models, but the general experience is that simple methods are almost as good and more robust, so also here there seems to be a possibility for simplification.

ToR 2b. *What factors should be considered in data weighting and how should we assess the appropriateness of current methods applied for this stock?*

Data weighting is a very important issue, especially for SS models with so much length data included - as is the case here. The approaches presented were very sensible and it was not obvious that any of them was better than the others. The guidelines given in Francis (2011) were considered and followed, and these guidelines are probably the best available at present.

ToR 2c. *How can we evaluate the appropriate level of time variability and appropriate pattern (i.e. blocking vs random walk) in fishery and survey selectivity patterns?*

Time variability and patterns in fishery and survey selectivity were elaborated on. The general approach followed was good. It was based on information external to the modelling from historical events in the various fleets and in the survey (see Tables 1 and 2). It was regarded as important not to have too much a "dome shape" in the selection pattern, as this will create "paper-fish", i.e. a large amount of old fish estimated by the model, and old fish which have never existed out there in the sea. This was regarded as one of the main reasons the 2014 and 2015 assessments of the stock estimated large stock sizes in the start of the time series. This probably was an artefact and is now absent in the new assessment.

Table 1. *Events in the fishing fleet for GOA Pacific cod by year. Yellow markings indicate change years in selectivity modelling.*

Year	Event	Block Change by Gear
1865	First commercial delivery of Pacific cod from GOA fisheries	
1976	Magnuson–Stevens Fishery Conservation and Management Act	
1977	Catch time series begins for Trawl and Longline fisheries	
1977	Fishery Length composition time series begins for Trawl	
1978	Fishery Length composition time series begins for Longline	
1987	Catch time series begins for Pot Fishery	
1990	Full "Americanization" of fishery required, all foreign fishers excluded from fishery within US EEZ.	Longline/Trawl
1990	Implementation of a comprehensive domestic observer program	Longline/Trawl
1990	Fishery Length composition time series begins for Pot	
1990	Steller Sea lion classified as Threatened	
1993	Western Stock of Steller Sea lion Critical Habitat designation	
2005-2006	Trawl and longline early fishery closure leaving a very limited B-Season fishery	Longline/Trawl
2013	New observer program deployment method leading to increased coverage of smaller pot vessels	Pot
2017	Substantial cut in the ABC and TAC leading to a change in fishing practices in all gear types	Longline/Trawl
	Longline selectivity blocks 1978-1990 (annual devs),1991-2004,2005-2006,2006-2016,2017	
	Trawl selectivity blocks 1977-1990 (annual devs),1991-2004,2005-2006,2006-2016,2017	
	Pot selectivity blocks 1990 - 2013, 2013-2017	

Table 2. *Events in the AFSC trawl survey for Pacific cod by year.*

Year	Abundance	SD	Note	
1984	320524.5	0.155044	Not Used	Japanese Survey
1987	247020	0.183607	Not Used	Japanese Survey
1990	212131.7	0.205502	Block 1	First domestic survey - development and exploration
1993	225479.8	0.191361	Block 1	
1996	319068	0.21261	Block 2	Change to 15 minute tows
1999	166583.9	0.111689	Block 2	
2001	158424.5	0.178359	Block 2	
2003	159749.4	0.128623	Block 2	
2005	139895	0.205581	Block 2	
2007	192305.8	0.173619	Block 3	Addition of live net mensuration gear using acoustics insuring bottom contact and precise width measurements
2009	573469	0.280651	Block 3	
2011	348034.8	0.175874	Block 3	
2013	337991.8	0.150883	Block 3	
2015	196555.4	0.119472	Block 3	
2017	56199.1	0.116207	Block 3	

ToR 3. *Evaluate how ecosystem indicators are used in the assessment and provide recommendations how they can be better integrated into model development and stock management.*

Natural mortality is modelled as independent of age and length. However, it is normally quite strongly dependent on age and length. The length variable M from the seminal work of Charnov *et al.* (2013) could be considered for input on length-based M in the model. According to Charnov *et al.* (2013) M is related to length by the formula:

$$M = \left(\frac{L}{L_\infty}\right)^{-1.5} \cdot K$$

At the meeting I did the calculations for Pacific cod and this was discussed shortly at the meeting. The length-dependent values of M are given in Table 3.

Length at 50% maturity is 50cm for Pacific cod in GOA, and M at this length is 0.45 according to the table above. This is very close to the M estimated by the various models for Pacific cod presented at this meeting. However, there is a pretty strong change in M by length according to Charnov *et al*. (2013) and it might be fruitful to explore this in future modelling of Pacific cod stock dynamics.

Table 3. *Natural mortality for Pacific cod in GOA by length based on Charnov et al. (2013).*

Length in cm	M per year
10	4.99
15	2.72
20	1.76
25	1.26
30	0.96
35	0.76
40	0.62
45	0.52
50	0.45
55	0.39
60	0.34
65	0.30
70	0.27
75	0.24
80	0.22
85	0.20
90	0.18
95	0.17
100	0.16
105	0.15
110	0.14
115	0.13
120	0.12

ToR 3a. *Should environmental indices be used to model natural mortality in the model? Is it appropriate to use a time block for the extremely warm period to adjust natural mortality?*

Environmental indices in terms of sea temperature were considered to be used to model natural mortality. This idea was triggered by the coincidence of the event of a warm period in the sea water in the area simultaneously with the disappearance of fish in the stock, and the observation of low condition of Pacific cod and other animals suffering in the ecosystem. The panel discussed this at some length and noted that the experience of Atlantic cod in relation to starvation and mortality was that cod can live up to two years without eating at all, and that in the Gulf of St. Lawrence the Fulton condition factor was reduced by about 30% before it resulted in mortality (Figure 2). For Pacific cod, the Fulton condition factor was only reduced by a few percent and not at all for some of the large size groups (Figure 3). It is also clear from Figure 4 that Pacific cod did not starve completely (far from fit) in the period considered, according to the data presented. Alternative hypotheses were mentioned, like migration out of the area (with a chance that they will come back within the future few years), and mortality due to some kind of disease (there were pictures presented of diseased Pacific cod caught in the relevant time period with clear sickness marks of a circular form and of several centimeters in diameter). Therefore, for the time being it was regarded as most

appropriate to just allow M to be estimated separately in two blocks of years (2015-2016) versus the rest of the years. All model runs with this option showed a substantial higher M for 2015-2016 than for the other years, typically a doubling of the M values compared to the other years.

Figure 2. *Condition factor of wild Atlantic cod during the period from June 28 to October 26 in 1958 in Baie-des-Chaleurs and in 1993 in the northern Gulf of Saint Lawrence. Minimum K values in 1993 are omitted for clarity*

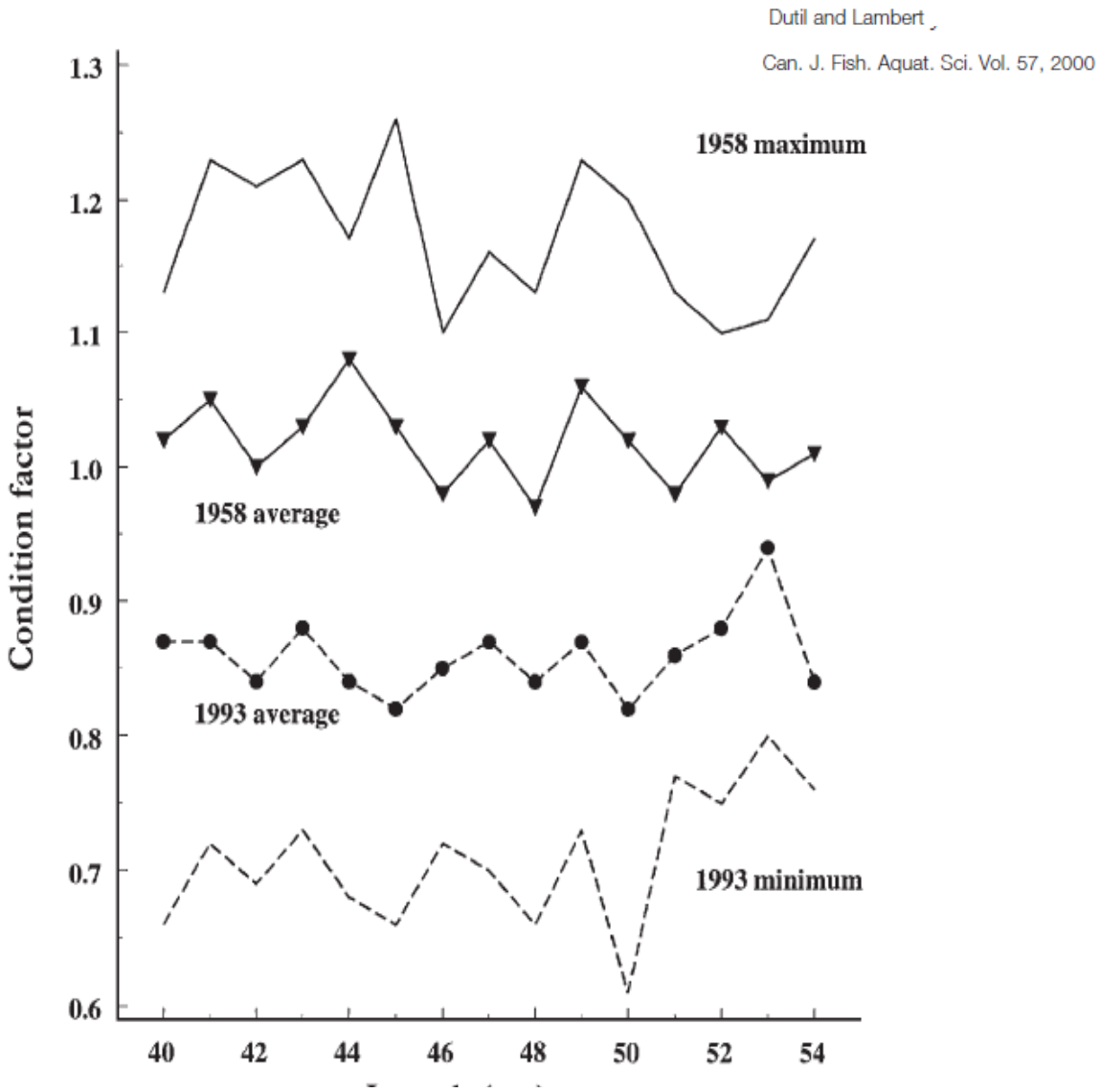


Figure 3. *Pacific cod GOA changes in condition by time*.

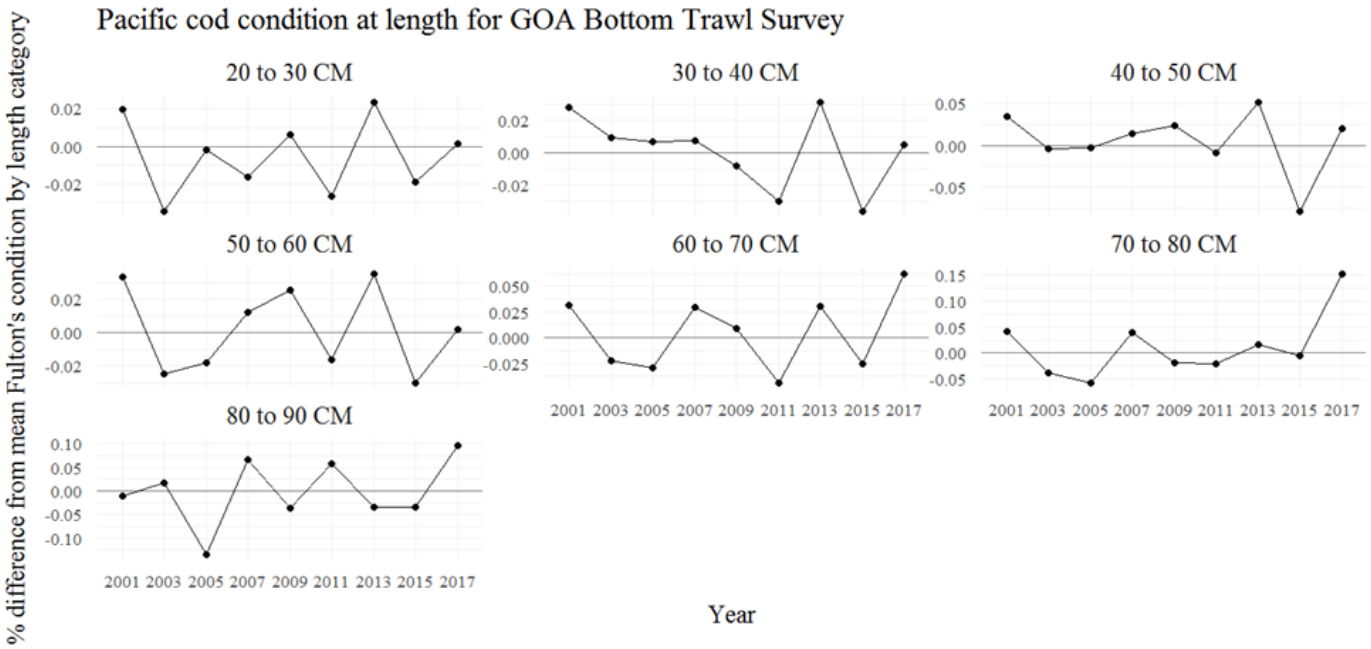
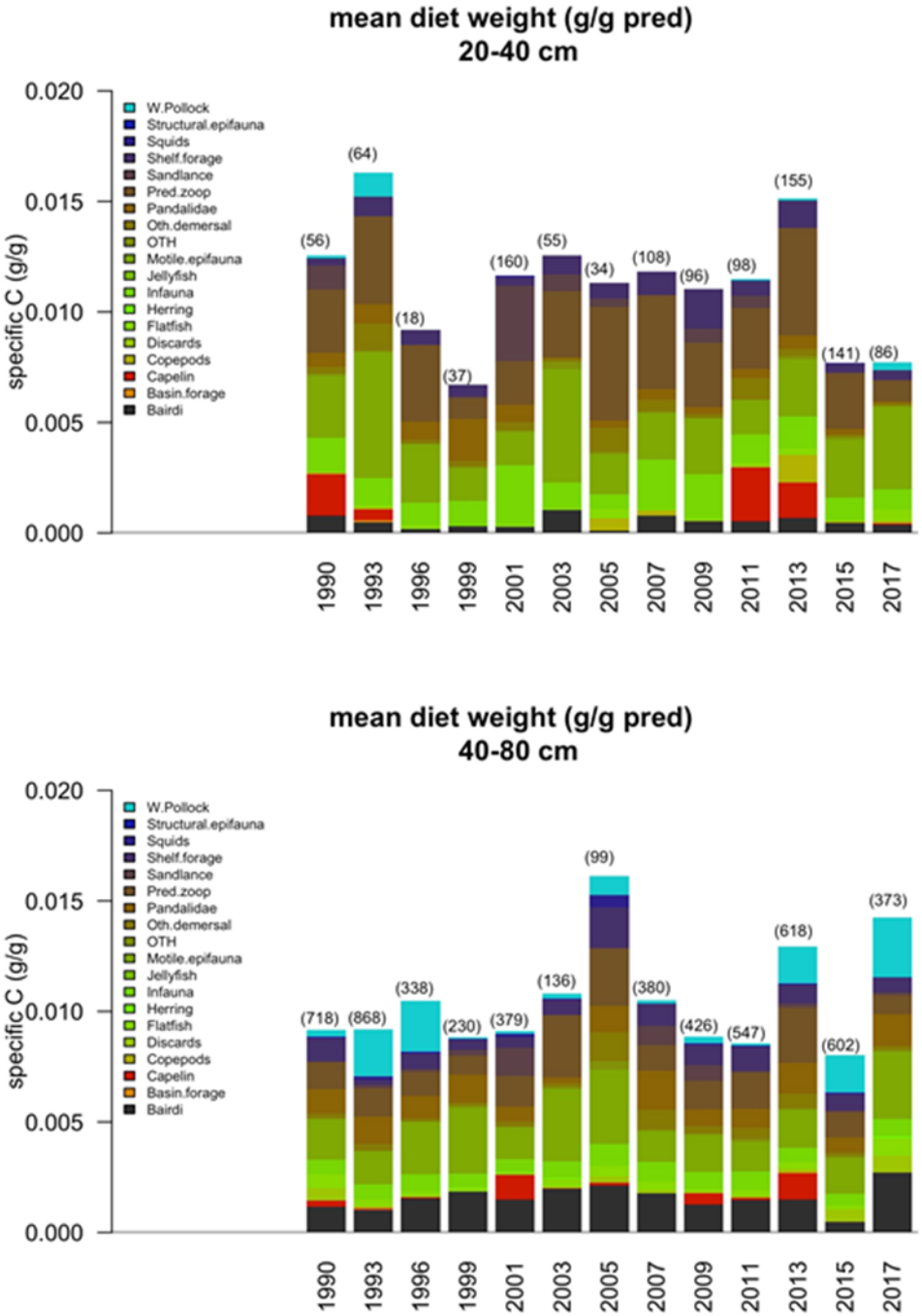


Figure 4. *Pacific cod GOA. Stomach content by two size groups and year.*



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ToR 3b. *Is the temperature-catchability relationship modeled for AFSC surveys being modeled appropriately?*

There is a documented relationship between sea water temperature and the depth distribution of Pacific cod. Because the AFSC long line survey are not covering the shallow water, this is likely to mean a chance in catchability with temperature. Furthermore, the search rate of cod is also likely to be dependent on temperature, because fish are more active the higher the temperature. Therefore, temperature-catchability relationship for the AFSC surveys should be part of the model and the way it is suggested (ln(Qy) = ln(meanQ – P *CFSR)) seems appropriate. It adds one parameter to the modelling. Models always improve fits when more parameters are included and even the AIC criteria seems to have a tendency to favor more parameters. Therefore, a very innovative approach was suggested by the assessment team, namely resampled the CFSR time series 1000 times without replacement to shuffle time series, the model refit to resampled time series, and look at the distribution of the scaling parameter. In this case, the parameter exceeded initial fit in only 12 of the 1000 iterations (1.2%), and this suggests that the parameter fit to time series improves model performance over just additional parameter fit to random noise. The panel found this approach quite convincing. The panel requested elaborations on this approach and this was delivered by the assessment team, after the end of the meeting. I find that these elaborations confirmed the method as being appropriate. After the meeting, I reflected a bit further on this and got the idea that maybe other parameters in the modelling could be tested the same way.

Various assignments

The panel requested a time series of fishing mortality expressed in a metric that is easy to compare with assessments of other stocks in the temperate and boreal climate zone. This was provided as mean F at age for the main ages in the catches, ages 3-8 (Figure 5). The level of F has increased substantially over the years, but seems not to be high compared to other similar stocks in the northern hemisphere.

This way of presenting the F level for the assessment seems to be useful and might be considered for the future.

The ADFG western survey on occasion catches small Pacific cod in large numbers where the AFSC surveys do not and vice versa (Fig 6). Thus, it seems prudent to take this into account if the ADFG western survey data are to be integrated into the modelling. The reason for this variability is probably because the depth distribution of small Pacific cod and the depths surveyed are only partly overlapping, and small shifts in overlap from year to year can mean large changes in the proportion of small Pacific cod caught by the surveys. Down weighting the catch data on small Pacific cod in the surveys when modelling would be sensible.

Figure 5. *Mean F at age for ages 3-8 by year from the assessment.*

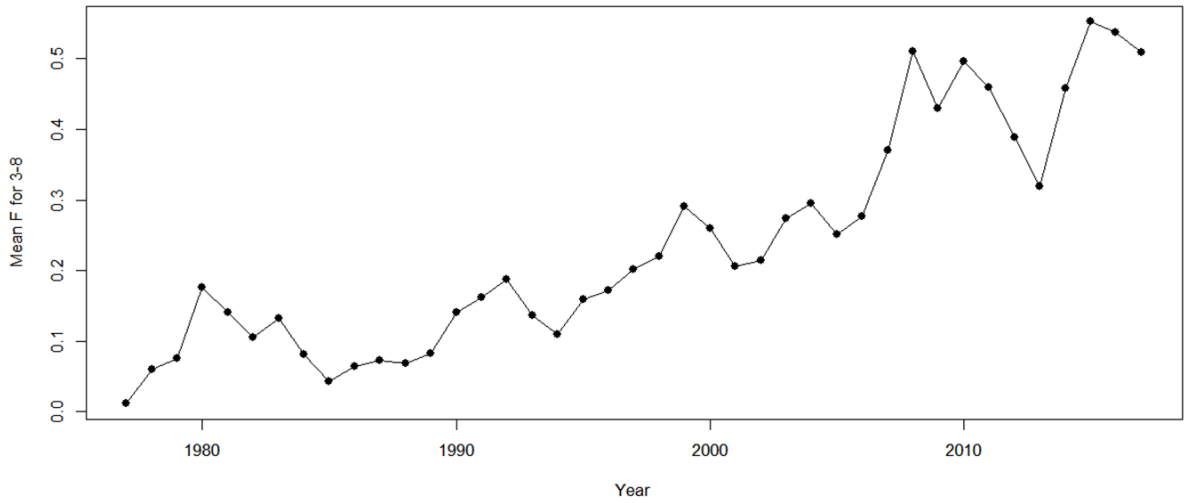
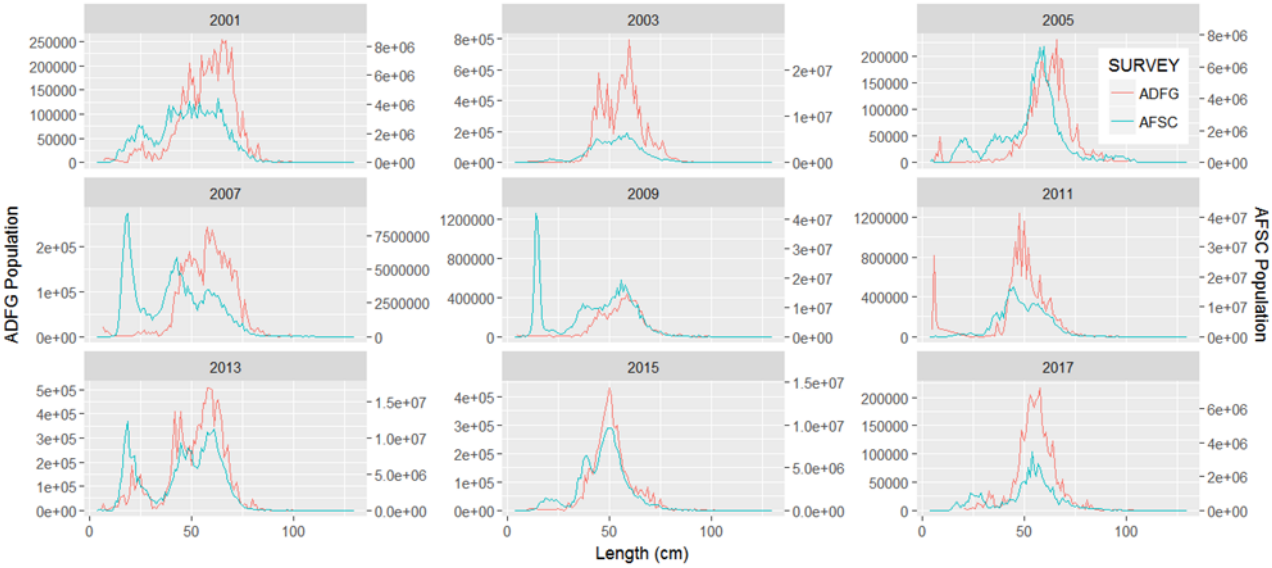


Figure 6. *ADFG Western Large-mesh trawl survey length composition matched with AFSC bottom trawl survey length composition.*



A handful of new model runs were requested and done. The results in terms of performance criteria are shown in Table 4.

Table 4. *Performance metrics for various model runs.*

Label	Model16.0	Model17.09.35	Model17.09.36	Model17.09.37v2	Model18.09.38LM	Model18.09.39NO_AGEPRE2007	Model18.09.40NO_AGE	Model18.09.41_bias	Model18.09.42_biasSTATE
Number of Parameters	83	202	202	203	202	202	202	201	207
AIC	3639.16	3524.12	2774.7	3502.28	3524.12	2742.36	2374.374	4314.9	4917.72
TOTAL_like	1736.58	1560.06	1185.35	1548.14	1560.06	1169.18	985.187	1956.45	2251.86
Survey_like	61.4847	1.00726	2.37867	-3.50705	1.00726	-9.2501	-10.9703	-6.86513	24.4275
Length_comp_like	1104.69	1006.3	643.049	1002.2	1006.3	986.256	980.755	1005.94	1251.62
Age_comp_like	544.726	540.439	533.997	537.674	540.439	190.704	0	947.201	963.18
Parm_priors_like	0	11.6759	9.76094	3.46401	11.6759	2.28509	8.97933	7.44393	13.6833
Recr_Virgin_millions	216.612	531.163	470.604	673.597	531.163	847.751	366.546	399.818	537.581
SR_LN(R0)	12.2859	13.1828	13.0618	13.4204	13.1828	13.6503	12.8119	12.8988	13.1948
SR_BH_steep	1	1	1	1	1	1	1	1	1
Natural Mortality	0.38	0.490292	0.476532	0.75	0.490292	0.539888	0.444227	0.463675	0.48477
Natural Mortality for 2015-2016 Block	NA	0.71416	0.688286	NA	0.71416	1.04587	0.679619	0.654238	0.750296
Natural Mortality Knot Age 1	NA	NA	NA	0.454498	NA	NA	NA	NA	NA
Natural Mortality Knot Age 5	NA	NA	NA	0.494567	NA	NA	NA	NA	NA
Natural Mortality scaling parameter	NA	NA	NA	1.03937	NA	NA	NA	NA	NA
L_at_Amax	113.273	124.064	123.977	126.419	124.064	110.861	102.076	99.816	99.816
VonBert_K	0.12874	0.113425	0.11338	0.110307	0.113425	0.143415	0.168963	0.182506	0.188957
SSB_Virgin_thousand_mt	169.329	177.3805	174.5245	187.5365	161.3825	194.2345	183.813	173.523	198.2405
Bratio_2017	0.400298	0.266542	0.253802	0.250151	0.237174	0.220957	0.245129	0.247745	0.245543
SPRratio_2016	1.09573	0.769416	0.823987	1.00354	0.846562	0.506212	0.802274	0.857974	0.738271
Tuned?	No	No	Francis TA1B Tuned	No	No	No	No	No	No
Data notes	Trawl, longline, and pot fishery composition, and AFSC Trawl survey index< note that these models have been fit with the 2017 data, not what is in the stock assessments. Proportioning of fishery data are per 2017 protocols and addition of 2017 fishery and survey data	Same as Model 16.1	Same as Model 16.1	Same as Model 16.1	Same as Model 16.1	Same as Model 16.1 except no age data pre-2007	Same as Model 16.1 except no age data	Same as Model 16.1	Same as Model 16.1 excepth ADFG Western Large Mesh survey Index and length composition added
Model notes	Fixed M=0.38, Fixed Q=1, Asymtotic selectivity for all but pot fishery	Same as Model 17.09.31 except block on Longline and trawl fishery selectivity for 2005-2006	Same as Model 17.09.35	Same as Model 17.09.35 except annually and age varying M	Model17.09.35 but with L50 instead of M50 for maturity	Same as Model18.09.38 except sd on the M prior was changed from 0.1 to the prior cv of 0.41 for both regular M and Block	Same as Model18.09.39	Same as Model18.09.39 but with aging error and bias added for age Pre-2007	Same as Model18.09.41
General notes on new models						Substantial improvement to index and length composition fits with removal of old ages, suggest some disagreement among data sources. M fit better in this model so I loosened the assumptions on the prior	Similar to Model18.09.39, except only slight improvement with the removal of the 2007 and newwer ages.	Appears to have improved fit to indices, but didn't improve fits to length composition. Would like to try fitting the bias in future models	Adding state data seems to show some disagreement between the state data and other data sources. Recruitment changes a bit, but doesn't really seem to improve the model to include these data.

Because problems were discovered in the age data from before 2007 the model - model18.09No_age pre2007 without age data from before 2007 - was slightly preferred to the other "model18…" models. The performance metrics shown in the table above are also reasonable.

The NMFS review process

The review process worked very well. Documentation and presentations were of a very high quality. Documentation was sent out more than two weeks before the meeting using Google Drive. The meeting was conducted in an efficient, engaged and positive atmosphere. The presentations were done very well.

The guidelines to the reviewers from the CIE secretariat were very clear and to the point. The AFSC informed us that they did not need a summary report, so one was not completed.

The exchange of knowledge between the reviewers and the scientific staff was very fruitful for both parties.

The presentations of all the important aspects relevant for the review were much appreciated. Especially useful and not often done, were the presentations of previous assessments and advice.

I tried hard to think of possible improvements to suggest, but could not come up with any. The NMFS review process have evolved over time and seems now to have reached a very high standard in my opinion.

All in all, a very good process, from the reviewer's perspective, for doing a comprehensive and in-depth review.

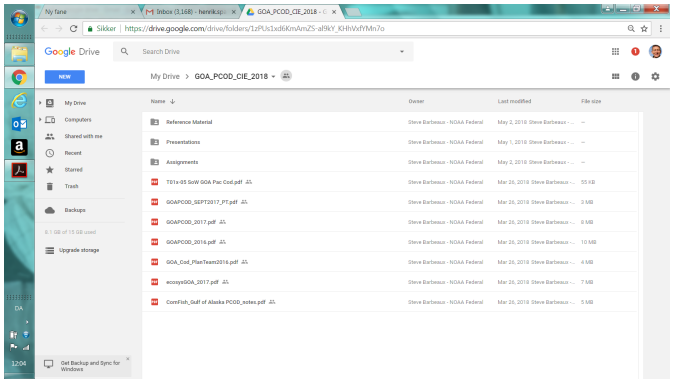
References

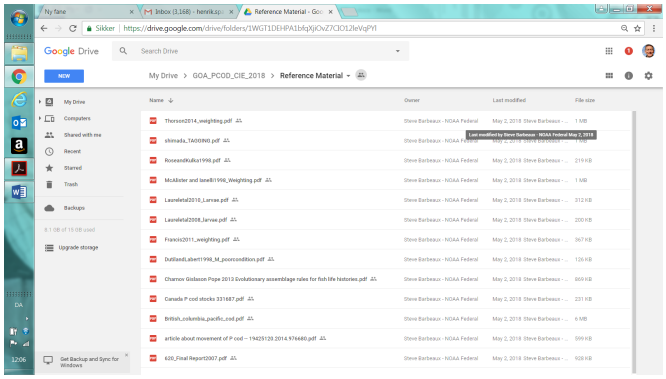
Charnov, E.L., H. Gislason, J.G. Pope. 2013. Evolutionary assembly rules for fish life histories. Fish and Fisheries, **14:** 213-224.

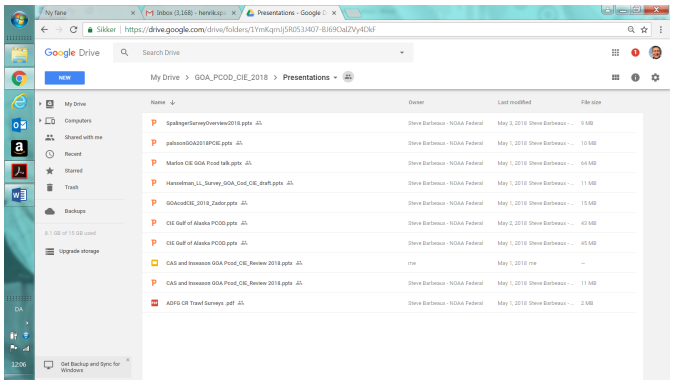
Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. **68**: 1124-1138.

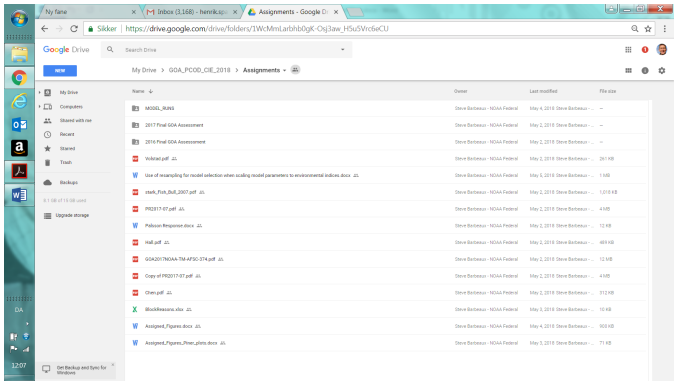
Appendix 1. List of publications provided.

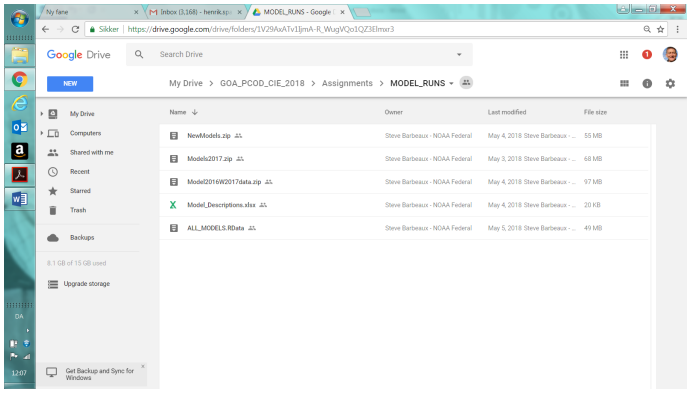
Material were provided at a Google drive as shown below.

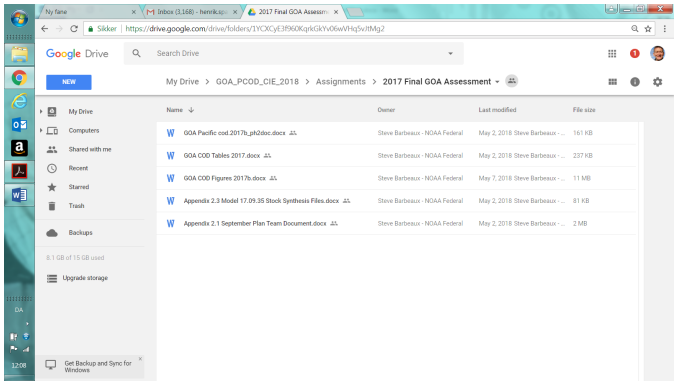


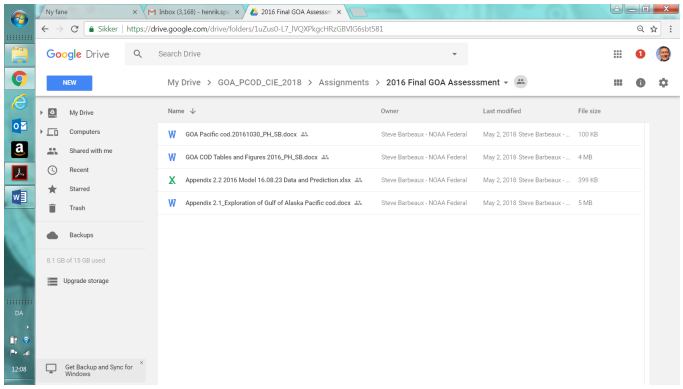












Appendix 2. Statement of work.

Statement of Work

External Independent Peer Review by the Center for Independent Experts

Assessment of the Pacific cod stocks in the Gulf of Alaska

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards[1]. Further information on the Center for Independent Experts (CIE) program may be obtained from www.ciereviews.org.

Scope

The Gulf of Alaska Pacific cod stock assessment has had a large number of alternative models over the years. In 2016, the model was rebuilt from scratch and greatly reduced in complexity from the previous model. Of particular concern is that this stock has experienced a precipitous decline since 2015 and there is concern that the simpler model may not adequately address the important biological complexities to appropriately manage this stock in the face of climate variability. However, review is requested of all aspects of the stock assessment models. The Pacific cod fisheries in the Gulf of Alaska is of great economic importance garnering $103 million ex-vessel value annually (29% of all Gulf of Alaska groundfish fisheries). The individual review reports are to be formatted with content requirements as specified in **Annex 1**. The

[1] http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf

Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements

Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of stock assessment methods in general, and in Stock Synthesis in particular.

Tasks for Reviewers

Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for this peer review.

2016 Assessment of the Pacific cod stock in the Gulf of Alaska (150 p.)
2017 Assessment of the Pacific cod stock in the Gulf of Alaska (144 p.)
2017 Ecosystem Considerations Status of the Gulf of Alaska Marine Ecosystem (215 p.)
Comments on the final 2016 and 2017 Gulf of Alaska (GOA) Pacific cod assessments by the Plan Team and Scientific and Statistical Committee (*SSC*)

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with this SoW and ToRs, and shall not serve in any other role unless specified herein. Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein.

This review meeting will include three main parts: The first will consist of a series of presentations with follow-up questions and discussions by CIE reviewers, and will be chaired by an AFSC scientist or supervisor. The second will consist of real-time model runs and evaluations conducted in an informal workshop setting, and will be chaired jointly by the CIE reviewers. The third, time permitting, will consist of initial report writing by the CIE reviewers, with opportunity for additional questions of the assessment author.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Annex 1**. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in **Annex 2**.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/

http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting scheduled in Seattle, WA during May 1 - 4, 2018.
3) Approximately three weeks after the conclusion of the panel review meeting, each CIE reviewer shall submit an independent peer review report addressed to the CIE. Each CIE report shall be written using the format and content requirements specified in **Annex 1**, and address each ToR in **Annex 2**.

Place of Performance

The place of performance shall be at the contractor's facilities, and Seattle, Washington.

Period of Performance

The period of performance shall be from the time of award through June 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

March 26, 2018	CIE selects and confirms reviewers. Reviewer contact information is sent to the NMFS Project Contact
April 16, 2018	NMFS Project Contact sends the reviewers the pre-review documents
May 1 - 4, 2018	Each reviewer participates and conducts an independent peer review during the panel review meeting
Approximately three weeks later	CIE receives draft reports
Approximately two weeks later	CIE submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:

(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
Steven J. Barbeaux, Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115
Phone: 206-526-4211
Steve.Barbeaux@noaa.gov

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Assessment of the Pacific cod stocks in the Gulf of Alaska

1. Evaluate and provide recommendations on data used in the assessment models. In particular:
    a. What are the benefits vs disadvantages of including data from the ADFG small-mesh trawl and the IPHC longline surveys in the assessment?
2. Evaluate and provide recommendations on model structure, assumptions, and estimation procedures. In particular:
    a. How would you evaluate the appropriate level of complexity in the stock assessment model given that we have historically used simple and more complex models to manage this stock?
    b. What factors should be considered in data weighting and how should we assess the appropriateness of current methods applied for this stock?
    c. How can we evaluate the appropriate level of time variability and appropriate pattern (i.e. blocking vs random walk) in fishery and survey selectivity patterns?
3. Evaluate how ecosystem indicators are used in the assessment and provide recommendations how they can be better integrated into model development and stock management.
    a. Should environmental indices be used to model natural mortality in the model? Is it appropriate to use a time block for the extremely warm period to adjust natural mortality?
    b. Is the temperature-catchability relationship modeled for AFSC surveys being modeled appropriately?

Annex 3: Tentative Agenda

CIE Review of the GOA Pacific cod stock assessment models

Alaska Fisheries Science Center

7600 Sand Point Way NE, Seattle, WA 98115

May 1 - 4, 2018

Building 4; Room 2039

Review panel chair: Grant Thompson, Grant.Thompson@noaa.gov

Senior assessment author: Steven J Barbeaux, Steve.Barbeaux@noaa.gov

Security and check-in: Sandra Lowe, Sandra.Lowe@noaa.gov (206)526-4230

Sessions will run from 9 a.m. to 5 p.m. each day, with time for lunch and morning and afternoon breaks. Discussion will be open to everyone, with priority given to the panel and senior assessment author.

Tuesday, May 1

Preliminaries:

09:00 Introductions and adoption of agenda—Grant Thompson

Data sources (current and potential):

09:10 Overview of data types used in the assessments—Steve

09:20 Catch accounting system and in-season management—AKRO SF Division (via WebEx)

09:50 Observer program—AFSC FMA Division

10:20 Break

10:30 GOA trawl survey—AFSC RACE Division

11:00 AFSC longline survey—AFSC Auke Bay Laboratory (via WebEx)

11:30 IPHC longline survey—IPHC

12:00 Lunch

13:00 ADFG surveys— ADFG (via WebEx)

13:30 GOA Ecosystem assessment—AFSC REFM – Stephani Zador

Assessment models:

14:00 Assessment history—Steve

15:00 Break

15:10 Current assessments—Steve

16:10 Discussion—Everyone

16:40 Assignments for models to be presented on Wednesday—Panel

Wednesday, May 2 and Thursday, May 3

Review of models assigned the previous day—Steve

Discussion, real-time model runs—Everyone

Assignments for models to be presented the following day—Panel

Friday, May 4

Review of models assigned on Thursday—Steve

Discussion, real-time model runs—Everyone

Report writing (time permitting)—Panel

Appendix 3. List of participants.

GOA Pacific cod CIE review

List of presenters:

1. Steve Barbeaux (AFSC)
2. Mary Furuness (NMFS Alaska Region)
3. Marlon Concepcion (AFSC)
4. Wayne Palsson (AFSC)
5. Dana Hanselman (AFSC)
6. Allan Hicks (IPHC)
7. Kally Spalinger (ADFG)
8. Mike Byerly (ADFG)
9. Stephani Zador (AFSC)

List of CIE reviewers:

1. Jean-Jacques Maguire
2. Henrik Sparholt
3. Kevin Stokes

List of other in-person participants

1. Delsa Anderl (AFSC)
2. Jim Armstrong (North Pacific Fishery Management Council)
3. Craig Castelle (AFSC)
4. Anne Hollowed (AFSC)
5. Jim Ianelli (AFSC)
6. Sandi Neidetcher (AFSC)
7. Chad See (Freezer Longline Coalition)
8. Grant Thompson (AFSC)
9. Tom Wilderbuer (AFSC)